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# Preliminary Economic Analysis of Cooling Water Intake Alternatives at Merrimack Station

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# Executive Summary

This report provides an economic assessment of and supplementary information to the analyses prepared by the U.S. Environmental Protection Agency's ("EPA") regarding the cooling water intake requirements in the draft National Pollutant Discharge Elimination System ("NPDES") permit for Merrimack Station.

## A. Overview of EPA Analysis of Best Technology Available (BTA) for Merrimack Station

EPA conducted a site-specific analysis to determine its draft Best Technology Available ("BTA") for Merrimack Station. After determining that converting to closed-cycle using wet cooling towers would generally be the best performing technology and that converting to closed-cycle cooling was an available alternative at Merrimack Station, EPA considered various alternatives to closed-cycle cooling. EPA concluded that alternative screening systems were either infeasible (i.e., "unavailable" or "impracticable") and/or provided uncertain and/or inferior performance. EPA also considered various means of restricting the volume of cooling water withdrawals (e.g., variable speed pumps) but rejected these options because they would involve substantial reductions in Merrimack Station generation.

EPA then selected five closed-cycle variations representing different combinations of closed-cycle cooling for one or both generating units on a year-round or seasonal basis, coupled with a combination of improvements to the existing travelling screen systems. Seasonal use of closed-cycle cooling was included because fish eggs and larvae are generally present in the Hooksett Pool for only five months (April-August).

EPA developed benefit-cost information on the five alternatives. The cost information—including capital costs and variable costs—was used to calculate the private cost to PSNH as well as the social cost of the five alternatives. The present value of the social costs (as of 2010) range from approximately $45 million to $159 million (2010 dollars). EPA's benefit information included information on the entrainment gains (measured in terms of additional fish eggs and larvae) and impingement gains (measured in terms of additional juvenile and adult fish). EPA did not develop estimates of the monetary value of these biological benefits, noting that such an evaluation would be a "nearly insurmountable task" (EPA 2011a, Attachment D, p. 325) and would require "qualified experts" that the EPA does not have on staff (EPA 2011a, Attachment D, p. 327).

Based upon the monetary costs and biological benefits assessments of the options, EPA concluded that the option with seasonal use of closed-cycle cooling at both units was BTA. EPA concluded that for the seasonal use of closed-cycle cooling at both units, "the costs … are neither wholly disproportionate to, nor significantly greater than, the benefits they would produce" (EPA 2011a, Attachment D, p. 338). EPA concluded that the more expensive option with year-around closed-cycle cooling was not warranted "on a cost-benefit basis" given the substantial additional costs and the limited additional biological impingement gains it would provide.

## B. NERA Benefit-Cost Analysis of BTA Alternatives at Merrimack Station

NERA has supplemented the benefit-cost information provided by EPA in two major ways:

1. *Additional fish protection alternatives.* Building upon a recent assessment by Enercon (2012a) and a previous PSNH correspondence with EPA (PSNH, 2009), we have developed benefit-cost information for four additional technologies—Ristroph screens, Multi-Disc screens, cylindrical wedgewire ("CWW") screens and a Gunderboom Marine Life Exclusion System (all with updated fish return systems)—beyond the closed-cycle cooling alternative that EPA chooses as BTA (which would involve seasonal use of cooling towers from April to August along with the addition of Ristroph screens).

2. *Monetary benefit estimates.* We have developed preliminary estimates of the monetary benefits of fish protection alternatives, using the economic valuation techniques recommended by EPA in its *Guidelines for Preparing Economic Analyses* ("*Guidelines*") and in its recent draft proposed rule for site-specific Section 316(b) BTA analyses.

Our benefit-cost estimates thus expand the range of alternatives considered as BTA and deal with the difficulties that EPA identifies in providing monetary benefits estimates. In addition, we use updated information from Enercon on the potential construction costs of the fish protection alternatives.

Table E-1 summarizes our preliminary estimates of the social costs, social benefits and net social costs (i.e., social costs minus social benefits) of the five fish protection alternatives at Merrimack Station. These results indicate that the social costs outweigh the social benefits for all alternatives, with the net costs particularly great for closed-cycle cooling. The social costs in present value terms over the period from 2012 to 2035 range from $1.6 million for Ristroph screens to $99.0 million for cooling towers. In contrast, estimated benefits in present value terms range from $11,000 for the Ristroph screens to $102,000 for cooling towers. Net social costs in present value terms range from $1.6 million for Ristroph screens to $98.9 million for cooling towers. These results can be compared to the status quo alternative, which, by definition, has net costs equal to zero.

**Table E-1. Summary of Present Values of Estimated Net Costs of Alternatives (Thousands 2010$)**

| Alternative | Costs | Benefits | Net Costs |
|---|---:|---:|---:|
| Ristroph Screens | $1,576 | $11 | $1,564 |
| Multi-Disc Screens | $2,624 | $14 | $2,610 |
| CWW Screens | $7,901 | $81 | $7,820 |
| Gunderboom MLES | $17,248 | $82 | $17,166 |
| Cooling Towers | $98,955 | $102 | $98,854 |

Note: All values are in thousands of 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

Two principal conclusions arise from the benefit-cost analysis at Merrimack Station. First, for all five alternatives, the costs are greater than the benefits, resulting in positive net costs and indicating that all five alternatives fail a benefit-cost test. Second, the Ristroph screens have the lowest net costs, making this alternative the most attractive of the five alternatives based upon the benefit-cost results (although due to various uncertainties associated with the costs of installation and operations of the Ristroph and Multi-Disc screens, it is possible that the relative costs of these options could change if a more comprehensive evaluation were undertaken).

Table E-2 provides additional comparisons of the alternatives. The table shows the costs and benefits of each alternative and the incremental costs and incremental benefits for each of the alternatives relative to the alternative with the next lowest net costs. For CWW screens, the cost-benefit ratio is about 98, meaning that for every dollar of social benefit, society would have to pay $98 of costs. For Gunderboom, that ratio is about 211. But the ratio for Gunderboom increases to almost 7,900 based upon the incremental costs and incremental benefits relative to CWW screens ($9,347,055/$1,189=7,859), reflecting the fact that the benefits are virtually the same for the two alternatives but the Gunderboom costs are more than twice the costs of CWW screens.

**Table E-2. Incremental Analysis of Alternatives (Thousands 2010$)**

| Alternative | Costs | Benefits | Net Costs | Cost-Benefit Ratio |
|---|---|---|---|---|
| Ristroph Screens | $1,576 | $11 | $1,564 | 138 |
| Multi-Disc Screens | $2,624 | $14 | $2,610 | 186 |
| *- Incremental to Ristroph Screens* | *$1,048* | *$3* | *$1,046* | *393* |
| CWW Screens | $7,901 | $81 | $7,820 | 98 |
| *- Incremental to Multi-Disc Screens* | *$5,277* | *$66* | *$5,210* | *79* |
| Gunderboom MLES | *$17,248* | *$82* | *$17,166* | 211 |
| *- Incremental to CWW Screens* | *$9,347* | *$1* | *$9,346* | *7,859* |
| Cooling Towers | $98,955 | $102 | $98,854 | 974 |
| *- Incremental to Gunderboom MLES* | *$81,708* | *$20* | *$81,688* | *4,105* |
| *- Incremental to CWW Screens* | *$91,055* | *$21* | *$91,033* | *4,317* |

Note: All values are in thousands of 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Net costs and cost-benefit ratios may differ from differences and quotients of costs and benefits shown in the table because of rounding.
Source: NERA calculations as explained in text

The incremental comparisons for Cooling Towers also are revealing about the full cost-benefit implications of selecting Cooling Towers rather than less expensive alternatives. The cost-benefit ratio for Cooling Towers is very large (974) based upon total costs and benefits. But the ratio increases to roughly 4,100 based upon the incremental costs and incremental benefits of Cooling Towers relative to Gunderboom, and it increases to roughly 4,300 relative to CWW screens. These CWW results mean that for every dollar of additional benefit for Cooling Towers relative to CWW screens, society would pay about $4,300 in costs. Note that this same incremental analysis was used by EPA to conclude that year-around use of Cooling Towers was not warranted relative to seasonal use of Cooling Towers (although the benefits were not expressed in monetary values because—according to EPA—the required expertise to monetize benefits was unavailable).

These results are based upon detailed estimates of social costs and benefits, i.e., the costs and benefits to society if each alternative were implemented at Merrimack Station. We quantify two major types of costs: (1) capital costs for construction and equipment, including the power losses during construction; and (2) operating and maintenance costs, including the power losses during operation. Quantified benefits include the increased recreational catch of various species, including the indirect benefits from reduced losses of forage fish. The cost and benefit estimates are consistent with sound benefit-cost methodologies and the approach set forth in guidelines developed by EPA.

We also consider the implications of non-quantified benefits and costs and evaluate whether their inclusion would be likely to affect the conclusion that each of the five alternatives would result in large net costs. Our sensitivity analyses compared net costs under different assumptions regarding the capacity factor at Merrimack Station (i.e., the percentage of the annual hours that Merrimack would operate) and the discount rate for calculating present values. Using different capacity factors and discount rates modified the calculated net costs but did not change the basic benefit-cost conclusions. We also concluded that the non-quantified benefit and cost categories are unlikely to be large enough to reverse the conclusion that none of the alternatives passes a benefit-cost test. Indeed, we identified several assumptions that would lead to overstated benefits and understated costs. Some unquantified factors, such as the differential costs of installation and debris removal for Ristroph screens relative to Multi-Disc screens, might influence the relative net costs of the screen alternatives.

## C. Implications of NERA Benefit-Cost Analysis of BTA Alternatives at Merrimack

The NERA study evaluates five fish protection alternatives at Merrimack Station. The following is a summary of the benefit-cost results.

§ None of the fish protection alternatives we considered at Merrimack Station passes a social benefit-cost test, because the costs for all five alternatives are substantially greater than the benefits.

§ This conclusion does not change if one considers the factors excluded from the quantitative monetary assessments or the effects of uncertainties regarding future Merrimack capacity factors or the discount rate used to calculate present values.

§ The net costs differ a great deal among the alternatives. The present values of the net costs range from about $1.6 million for Ristroph screens to about $98.9 million for Cooling Towers.

§ The differences in net costs are even greater when the incremental benefits and incremental costs are compared as one considers choosing increasing costly alternatives. Selecting

Cooling Towers as BTA rather than CWW screens would mean that society would be paying about $4,300 in costs for every dollar of additional benefit.

These results lead to the conclusion that the Cooling Tower alternative is not BTA at Merrimack Station based upon the benefit-cost yardsticks used by EPA in the draft permit, because its costs are “wholly disproportionate” and “significantly greater” than its benefits by any reasonable definition of those terms. Of the five alternatives we considered (which does not include the status quo, which has net costs equal to zero by definition), the Ristroph screens alternative has the lowest net costs and are therefore would be the most attractive option for BTA at Merrimack Station based upon the preliminary benefit-cost results (although, as noted above, it would be useful to develop additional information to provide a more complete comparison of the Ristroph and Multi-Disc screen alternatives).

# I. Introduction and Background

This report provides an economic assessment of the U.S. Environmental Protection Agency's ("EPA") analyses regarding the cooling water intake requirements in the National Pollutant Discharge Elimination System ("NPDES") draft permit for Merrimack Station. We focus on developing a complete—though preliminary—benefit-cost analysis of cooling water intake alternatives for Merrimack Station to supplement the information developed by EPA.

This chapter begins with background on Merrimack Station and its cooling water intake structure ("CWIS"). It then provides background on benefit-cost analysis and the benefit-cost information that EPA has developed in the process of determining best technology available ("BTA") under Section 316(b) of the Clean Water Act for Merrimack Station. We note the limitations of EPA's analysis—notably the lack of monetary benefit estimates—as well as the objectives of this report to supplement EPA's information.

## A. Background on Merrimack Station's Cooling Water Intake Structure

This section provides background on Merrimack Station and its current cooling water intake structure ("CWIS").

### 1. Merrimack Station

Merrimack Station is located in Bow, New Hampshire and consists of two separate generating units, Unit 1 and Unit 2. Unit 1, which became operational in 1960, generates at a rated capacity of 120 MW, and withdraws once-through cooling water from the waters of the Merrimack River using a cooling water intake structure located in a bulkhead at the shoreline of Hooksett Pool. Unit 2, which became operational in 1968, generates at a rated capacity of 350 MW, and withdraws once-through cooling water from the Merrimack River using a separate cooling water intake structure located in a bulkhead approximately 120 feet downstream from the Unit 1 cooling water intake. Merrimack Station lies along the Hooksett Pool section of the Merrimack River. Hooksett Pool ranges in width from 500 to 700 feet, has a surface area of 350 acres, and ranges in depth from 6 to 10 feet under most flow conditions (EPA 2011a).

### 2. Cooling Water Intake Structure

Merrimack Station currently utilizes a once-through (or open-cycle) cooling system designed to withdraw up to 286 million gallons per day ("MGD") of water from the Hooksett Pool portion of the Merrimack River (85 MGD for Unit 1 and 201.6 MGD for Unit 2), and then to discharge the heated water back to the river (EPA 2011a).

Cooling water intake can affect aquatic life in the Hooksett Pool in two primary ways:

1. *Impingement*: occurs when fish—primarily small fish or juveniles of larger species—are caught and drawn against intake screens until the screens are rotated, and some of the fish may suffer mortality.

2. *Entrainment*: occurs when eggs and larvae of marine organisms are pulled with the water through the CWIS screens and into the cooling system of the plant, and some of the eggs and larvae may suffer mortality.

Each unit at Merrimack Station currently uses two traveling mesh screens that reduce fish losses. The screen system includes shelves and sprays to clear debris and fish from the screens (EPA 2011a, Attachment D, pp. 267-268).

## B. Background on Benefit-Cost Analysis

Benefit-cost analysis involves quantifying and monetizing (to the extent possible) the potential costs and benefits of various alternative actions and determining which action would yield maximum net benefits (i.e., benefits minus costs). Although costs and benefits can be compared to each other without monetizing benefits, the most sound and robust comparison method involves monetizing benefits to allow for direct comparison of costs and benefits in dollar terms.

The EPA *Guidelines* notes that benefit-cost analysis (with monetized benefits) is a component of a complete economic analysis (EPA 2010, p. 1-5). Of course, it is often not possible to quantify or monetize all costs and benefits, and other considerations that are not included in benefits and costs, such as equity issues, may also be relevant in determining which action to take.

Nevertheless, benefit-cost analysis can be an important tool for policymakers because it helps society put scarce resources to their best use. Indeed, the federal government requires agencies to perform benefit-cost analyses of major regulatory proposals (OMB 2003), and the EPA Proposed 316(b) Rule requires a site-specific benefit-cost analysis for the determination of BTA with respect to entrainment.

## C. Overview of the Draft NPDES Permit

This section provides an overview of EPA's draft NPDES permit for Merrimack Station.

### 1. Section 316(b) Requirements

Section 316(b) of the Clean Water Act requires that permits for cooling water intake structures "reflect the best technology available ("BTA") for minimizing adverse environmental impact." EPA last issued a water permit for Merrimack Station in 1992. This permit expired in 1997 but has been administratively extended pending issuance of a new permit. EPA issued a draft new water permit for Merrimack Station in September 2011.

## 2. EPA Evaluation of Alternative Technologies

The EPA Draft Permit evaluates various technologies associated with reducing fish mortality due to cooling water intake. These technologies include new traveling screens, wedgewire screens, fish return sluices, aquatic microfiltration barriers, intake barrier nets, and conversion to a closed-cycle cooling system through the installation of cooling towers. EPA describes the follow process of determining BTA:

> EPA compares technological alternatives, determines which are feasible and which achieve the greatest reductions in adverse environmental impacts (primarily entrainment and impingement), and considers various additional factors such as each option's cost, non-water environmental effects, energy effects, and a comparison of its costs and benefits) (EPA 2011a, Attachment D, p. vi).

EPA concluded that all technologies besides closed-cycle cooling were either infeasible (i.e., "unavailable" or "impracticable") and/or provided uncertain and/or inferior performance at Merrimack Station. EPA also considered various means of restricting the volume of cooling water withdrawals (e.g., variable speed pumps) but rejected these options because they would involve substantial reductions in Merrimack Station generation.

EPA then considered the costs and benefits of alternative configurations and operating schedules for closed-cycle cooling. The alternatives differed in terms of whether cooling towers would be installed at Unit 1, Unit 2, or both units, and in terms of the months during which the closed-cycle cooling system would operate each year.

## 3. EPA Benefit-Cost Analysis

Table 1 shows the estimated social costs and benefits of the five closed-cycle cooling alternatives considered in the draft permit. Social costs include construction, operating and maintenance ("O&M") and energy costs. EPA uses quantitative non-monetary measures of assessing potential benefits. Benefits are not monetized in the draft permit (and therefore they are not directly compared to social costs) because EPA claims doing so would have been "difficult, time-consuming, controversial and expensive" (EPA 2011a, Attachment D, p. 326).

**Table 1. EPA Benefit-Cost Analysis**

| | Cooling System | | Fish Return | | Social Cost | | I&E Reductions | | Estimated Percent Reduction | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Unit 1 | Unit 2 | Unit 1 | Unit 2 | Total | Annual | Impingement (thousands of fish) | Entrainment (millions of eggs / larvae) | Impingement | Impingement Mortality |
| 1 | CCC All Year | OTC | Type 1 | Type 2 | $44.7 | $4.1 | 3.64 | 2.97 | 26% | 47% |
| 2 | OTC | CCC All Year | Type 2 | Type 1 | $123.8 | $11.4 | 1.51 | 4.10 | 69% | 47% |
| 3 | CCC All Year | CCC All Year | Type 1 | Type 1 | $158.5 | $14.3 | 0.25 | 4.77 | 95% | 47% |
| 4 | CCC Seasonal | CCC Seasonal | Type 1 | Type 1 | $110.1 | $10.2 | 1.73 | 3.99 | 65% | 47% |
| 5 | CCC Seasonal | CCC Seasonal | Type 2 | Type 2 | $111.3 | $10.3 | 1.73 | 4.22 | 65% | 55%-66% |

Notes: Social costs are in millions of 2010 dollars.
Total social costs are present values as of 2010 using a real annual discount rate of 7.0 percent.
OTC: Once-through cooling (current configuration)
CCC: Closed-cycle cooling
Type 1 Fish Return: Year-round operation of existing traveling screens and new fish return system
Type 2 Fish Return: Ristroph through-flow traveling screens (or equivalent), low- and high-pressure wash, and new fish return system
Seasonal: CCC from April 1 to August 31 and OTC from September 1 to March 31
For the estimated percent reductions, the first column represents the estimated percent reduction in impingement based on reduction in intake volume and velocity with CCC. The second column represents the increase in survival of impinged fish based on a Type 1 or Type 2 Fish Return System.
Source: EPA (2011), Attachment D, Table 12-3, pp. 333

## 4. EPA Determination of Best Technology Available

The conclusion of the draft permit is that BTA for Merrimack Station would be Option 5 from the table above—operation of a closed-cycle cooling water system from April to August at both plant units. In addition, the draft permit would require Merrimack System to upgrade its fish return system for use throughout the year. EPA estimates that this requirement would lead to social costs of $111.3 million (present value as of 2010 in nominal dollars) (EPA 2011, Appendix D, p. 330). EPA noted that although Option 3 provides greater fish protection benefits, it was not warranted "on a cost-benefit basis" given the limited additional biological impingement gains it would provide (EPA 2011, Appendix D, p. 344).

EPA concludes that the costs of retrofitting Merrimack Station to closed-cycle cooling would be "significant but economically achievable for PSNH" (EPA 2011, Attachment D, p. ix), and warranted by the substantial environmental benefits that would result (EPA 2011, Attachment D, p. xvii). EPA recognizes the retrofit would lead to increased electricity rates (between $13 and $16 annually per customer), but deemed these increases "affordable and reasonable" (EPA 2011, Attachment D, p. x).

## D. Limitations of EPA Analyses

EPA's benefit-cost analysis of BTA alternatives appears to use well-accepted methods to estimate private and social costs and certain biological benefits, using the information available from the engineering and biological consultants engaged by PSNH. The EPA benefit-cost analysis, however, has two important limitations that we focus on in our report:

1. *Lack of monetary benefit information*. EPA does not provide information on the monetary value of biological benefits.

2. *Alternatives limited to cooling towers*. EPA restricts its analysis of alternatives to the baseline conditions and five alternatives, all of which would require cooling towers at Merrimack Station.

### 1. Monetization of Benefits

#### a. EPA's Explanation for Not Developing Monetary Benefit Estimates

The benefit information provided by EPA consists of additional fish eggs and larvae for entrainment gains and additional juvenile fish and adult fish saved for impingement gains. EPA is concerned that translating these estimates into dollar values (i.e., developing a monetized benefit estimate) "presents a nearly insurmountable task." (EPA 2011a, Attachment D, p. 325). EPA continues to explain why it has not developed monetary values.

> Estimating the monetary value of all these benefits, however, requires specialized data and expertise and is difficult, time-consuming, controversial and expensive. This is especially so with regard to estimating recreational use values and, even more so, for estimating non-use values arising from ecological improvements. All the benefits or values of ecological improvements, such as protecting fish, cannot necessarily be reduced to a money value, or at least reduced to a money value that can be generated with a reasonable effort and that will be generally accepted (EPA 2011a, Attachment D, p. 326).

With regard to potential commercial fishing benefits, EPA notes that "EPA Region 1 does not have this type of expert on staff and, therefore would likely need to expend funds to hire expert consulting services to develop such an estimate. Such an expenditure would not be justified here given that the result would be unlikely to have a material effect on the ultimate decision." (EPA 2011a, Attachment D, p. 327).

With regard to recreational fishing benefits, EPA writes that

> [D]eveloping a complete monetized recreational use estimate, taking into account both direct and indirect benefits, is a complex, time-consuming exercise what is subject to uncertainty and controversy. Again, specialized expertise and data collecting would be needed to undertake such an analysis and EPA would need to expend considerable funds to retain outside expert contractor assistance. EPA

> does not think that this type of expenditure of time and money is warranted in this case given that recreational benefits can be assessed qualitatively, and because the most important quotient of the benefits is likely to be from the overall ecological improvements that the various BTA options will provide which can be suitably evaluated from a qualitative perspective. (EPA 2011a, Attachment D, p. 327)

With regard to non-use benefits, EPA claims that "(a)s with recreational values, EPA can suitably evaluate these matters qualitatively without undertaking great expense to hire outside contracting assistance." (EPA 2011a, Attachment D, p. 327).

### b. Requirement for Monetary Benefit Estimates in EPA's Preferred 316(b) Rule Option

In its proposed rule—published in April 2011—addressing regulations for cooling water intake structures at existing power plants such as Merrimack Station ("Proposed 316(b) Rule"), EPA's preferred option requires a site specific assessment of monetized benefits for the determination of BTA with respect to entrainment. The following is a summary of EPA's explanation for this requirement.

> Because Executive Order 13563 directs agencies to propose and adopt rules only upon a reasoned determination that the benefits justify the costs, EPA is proposing to apply this same standard in BTA entrainment determinations. This approach is consistent with the framework EPA has traditionally followed and would allow for ***a full assessment in permit decisions of both qualitative and quantitative benefits and costs***. As designed, EPA's proposed requirement for the establishment of site-specific BTA entrainment requirements strikes an appropriate balance between environmental improvements and costs, allowing the permitting authority to consider all of the relevant factors on a site-specific basis and determine BTA on the basis of those factors…
>
> EPA expects that the [NPDES Permit] Director's decision about BTA controls will also reflect consideration of the costs and benefits (***monetized and non-monetized***) of the various control technologies considered for the facilities. (EPA 2011d, p. 22212, emphasis added)

### c. Requirement for Monetary Benefit Estimates in EPA's Guidelines for Preparing Economic Analysis

EPA also addresses the importance of developing monetary benefit estimates in the guidelines it has developed for preparing economic analyses of potential regulations. The following is a summary from EPA's *Guidelines* regarding the importance of monetizing benefits when possible:

> The aim of an economic benefits analysis is to estimate the benefits, *in monetary terms*, of proposed policy changes in order to inform decision making. Estimating benefits in monetary terms allows the comparison of different types of benefits in

> the same units, and it allows the calculation of net benefits — the sum of all monetized benefits minus the sum of all monetized costs — so that proposed policy changes can be compared to each other and to the baseline scenario (EPA 2010, p. 7-1, emphasis added).

### d. Implications for Merrimack Station Benefit-Cost Analysis

Both the requirements in EPA's preferred alternative for the proposed 316(b) rule and EPA's economic guidance document clearly and strongly indicate that benefits should be assessed in monetary terms to the extent feasible. As EPA's analysis makes clear, the potential costs of cooling towers at Merrimack Station are substantial. In light of these substantial costs there seems little justification for EPA not developing monetary benefit estimates. It would be important to assess whether the large social costs for cooling towers are justified from a benefit-cost perspective—as well to assess the relative costs and benefits of other fish protection alternatives—as part of a complete BTA determination for Merrimack Station.

## 2. Consideration of Alternatives to Closed-Cycle Cooling

### a. EPA's Explanation for Excluding Non-Cooling Tower Alternatives

In the draft permit, EPA only quantified the social costs of BTA options for converting Merrimack Station to closed-cycle cooling. It ruled out various once-through cooling options due to concerns of feasibility and effectiveness.

For example, EPA concluded that necessary conditions for wedgewire screen installations do not exist at Merrimack Station on a consistent and reliable basis during the period when fish eggs and larvae are present. Wedgewire screens were therefore rejected as an option for the BTA at Merrimack Station (EPA 2011a, Attachment D, p. 280). Similarly, EPA concluded that an aquatic microfiltration barrier does not constitute the BTA for Merrimack Station due to concerns over the size, the required maintenance and the effectiveness of the barrier (EPA 2011a, Attachment D, pp. 294-295).

### b. Other Information on the Feasibility of Non-Cooling Tower Alternatives

Enercon (2012a) concludes that EPA should not have ruled out the seasonal use of either cylindrical wedgewire screens or an aquatic microfiltration barrier due to feasibility concerns. Moreover, Enercon asserts that either of these options would provide similar environmental benefits without the associated drawbacks of the closed-cycle cooling option (Enercon, 2012a).

PNSH (2007) also provides information on various types of traveling screens that could be added at Merrimack Station. Modifications to the existing screens provide lower levels of environmental benefits, but at significantly lower social costs compared to either cooling towers, wedgewire screens or an aquatic microfiltration barrier. We understand from Enercon (2012b) that of these traveling screens, the Ristroph and Multi-Disc screens are suitable for use at

Merrimack Station, whereas the W Intake Protection (“WIP”) screens are not widely used at similar facilities due to certain operating complications.

### c. Implications for Merrimack Station Benefit-Cost Analysis

The additional information provided by Enercon indicates that a complete benefit-cost analysis should include alternatives other than cooling tower alternatives. At the least, Enercon (2012a) indicates that cylindrical wedgewire screens and aquatic microfiltration barriers should be included. As noted above, Ristroph screens and Multi-Disc screens are also feasible technology options at Merrimack Station (PSNH 2007, Enercon 2012b), so it would be appropriate to include these fish protection alternatives in a comprehensive analysis of benefits and costs.

## E. Objectives of This Report

The principal objective of this report is to supplement the EPA benefit-cost analysis to provide expanded and updated information. The two principal additional tasks are the following:

1. Develop monetary benefit values; and

2. Develop information on additional fish protection alternatives.

Both of these tasks are consistent with EPA guidance, including the guidance developed in EPA’s guidance document for preparing economic analyses of potential regulations as well as the recommended procedures in EPA’s preferred option for implementing Section 316(b) requirements to determine BTA for entrainment.

In addition to these two major objectives, we also use updated cost information for cooling towers (and other alternatives) developed by Enercon (2012a). As Enercon notes, the 2007 cost estimates on which EPA relies were preliminary and high-level estimates. In particular, for the 2007 cost estimates, “contingency multipliers” of 25 percent were added to all cost estimates to reflect the likely additional costs not included in the preliminary estimates. Enercon (2012a) concludes that the appropriate contingency multipliers are 55 percent.

## F. Organization of This Report

The remainder of this report is organized to develop an updated benefit-cost analysis of various fish protection alternatives at Merrimack. Chapter II summarizes the alternatives considered and provides some basic information on each of them. Chapter III develops information on the social costs of the alternatives. Chapter IV provides information on the social benefits of the alternatives. Chapter V summarizes the benefit-cost information, including information on net benefits. Chapter VI provides uncertainty analyses with respect to key model parameters. Chapter VII provides conclusions and implications of the benefit-cost results for determination of BTA at Merrimack Station.

# II. Cooling Water Intake Alternatives

As noted by Enercon in its comments on the draft permit, various technologies are available to reduce impingement and entrainment at Merrimack Station (Enercon 2012a).

## A. Overview of Five Alternatives

We quantify the costs and benefits of the following five alternatives:

1. *Ristroph Screens*. The seasonal use of Ristroph traveling screens in front of the cooling water intake structures, and an upgraded fish return system.

2. *Multi-Disc Screens*. The seasonal use of Multi-Disc traveling screens in front of the cooling water intake structures, and an upgraded fish return system.

3. *Cylindrical Wedgewire ("CWW") Screens*. The seasonal use of a passive fine-mesh screen system with 1.5 millimeter slot sizes in front of the cooling water intake structures, and an upgraded fish return system for year-round use.

4. *Gunderboom Marine Life Exclusion System*. The seasonal deployment of the Gunderboom Marine aquatic microfiltration barrier in front of the cooling water intake structures, and an upgraded fish return system for year-round use ("Gunderboom MLES").

5. *Cooling Towers*. The construction of mechanical draft cooling towers for seasonal use in closed-cycle cooling system for both generating units, and an upgraded fish return system for year-round use.

As noted, the cooling tower alternative is the same as the option that EPA has recommended as BTA in the draft NPDES permit for Merrimack Station.

## B. Assumptions Regarding Potential Construction and Operation

Table 2 displays the assumptions we use regarding the timing of the construction and operation of each cooling water intake alternative in our benefit-cost analysis. These assumptions are illustrative and for the purpose of the development of our preliminary benefit-cost assessment.

For each alternative, it is assumed that initial capital costs occur from 2012 to 2014 and operations begin in 2015 and end in 2035. Also displayed in Table 2 is the timing of the expected outage due to the construction of the cooling towers. The draft permit notes that the cooling towers are expected to require a construction outage of roughly three weeks in addition to Merrimack Station's regularly scheduled maintenance (EPA 2011a, Attachment D, p. 150), whereas an additional outage is not anticipated for the other alternatives (Enercon 2009, 2012b). As discussed in Chapter III and Appendix A, we assume that the three-week construction outage for the cooling tower alternative would occur in October to avoid overstating the potential costs of replacement power.

**Table 2. Timing of Construction and Operations Cooling Water Intake Alternatives**

| Alternative | Construction Start Date | Construction End Date | Construction Outage Start Date | Construction Outage End Date | Operations Start Year | Operations End Year |
|---|---|---|---|---|---|---|
| Ristroph Screens | 7/1/2012 | 12/31/2014 | No Outage | No Outage | 2015 | 2035 |
| MultiDisc Screens | 7/1/2012 | 12/31/2014 | No Outage | No Outage | 2015 | 2035 |
| CWW Screens | 7/1/2012 | 12/31/2014 | No Outage | No Outage | 2015 | 2035 |
| Gunderboom MLES | 7/1/2012 | 12/31/2014 | No Outage | No Outage | 2015 | 2035 |
| Cooling towers | 7/1/2012 | 12/31/2014 | 10/1/2014 | 10/21/2014 | 2015 | 2035 |

Source: Lengths of expected outages are from EPA 2011a.

# III. Costs of Cooling Water Intake Alternatives

We developed preliminary cost estimates for the cooling water intake alternatives using information presented by EPA in its support documentation for Merrimack Station's draft NPDES permit, supplemented by information from Enercon (2009, 2012a, 2012b) and PSNH (2007). This chapter provides information on the methodology for developing cost estimates and the preliminary results.

## A. Overview of Cost Methodology

In estimating costs, we take the standard economic approach of measuring costs to society as a whole ("social costs"). This approach is consistent with sound cost-benefit methodology and the approach set forth in the EPA *Guidelines* (EPA 2010).

### 1. Social Opportunity Costs

A complete assessment of the total social cost of an action (e.g., a regulation or a set of permit requirements) would encompass all social opportunity costs, as noted in the EPA *Guidelines*:

> Social cost represents the total burden that a regulation will impose on the economy. It is defined as the sum of all opportunity costs incurred as a result of a regulation where an opportunity cost is the value lost to society of any goods and services that will not be produced and consumed as a result of a regulation (EPA 2010, p. 8-1).

EPA defines compliance costs as follows:

> Compliance costs (also known as abatement costs) are the costs firms incur to reduce or prevent pollution to comply with a regulation. They are usually composed of two main components: capital costs and operating costs (EPA 2010, p. 8-8).

EPA has previously noted that while social costs include other types of costs (for example, the costs to the government of researching, enacting and enforcing a regulation), compliance costs are typically the most significant component of total social costs:

> The largest fraction of direct social costs arises from the real-resource compliance costs due to the new regulation. These new compliance costs arise from the installation, operation, and maintenance of new capital equipment, or are a result of changes in the production process that raise the price of producing the good (EPA 2000, p. 119).

Note that although EPA refers to "new regulation," real-resource compliance costs generally are the largest fraction of direct social costs for other types of regulations. This report primarily focuses on the potential real-resource compliance costs of the cooling water intake alternatives and thus excludes some other social costs from the quantitative analysis. We discuss non-quantified costs at the end of this section.

### 2. Components of Real-Resource Compliance Costs

Two major categories make up the real-resource compliance costs of the fish-protection alternatives.

1. *Construction/capital costs* include the one-time costs related to construction and installation of cooling water intake alternatives. These costs include direct capital and labor costs, indirect costs (related to feasibility studies, permitting, and verification and monitoring programs), and power costs related to construction outages. In some cases, additional capital costs are needed after the initial construction period to replace some equipment.

2. *Operating and maintenance (O&M) costs* are the ongoing costs related to changes in operating and maintenance of equipment for the fish-protection alternatives as well as changes in power due to net incremental electricity needed to operate the equipment ("parasitic losses") and impacts on the efficiency of electricity generation ("efficiency losses").

### 3. Assumptions Used in Cost Assessments

Costs are measured as expenditures or other costs incurred in connection with a fish-protection alternative. The current technology and expected operations are used as the baseline for measuring costs and fish protection benefits. We assume Merrimack operates in the future at the 2009 capacity factors of 85.7 percent for Unit 1 and 72.1 percent for Unit 2 (EPA 2011a, Attachment D, p. 151), which imply a weighted average capacity factor of 76.1 percent for Merrimack Station as a whole. (As discussed below, we consider the sensitivity of the results to differences in future capacity factors.) By assumption, maintaining the current technology and operating according to expected operations has costs (and benefits) of $0.

## B. Construction/Capital Costs

Construction/capital costs consist of the capital, labor, and material costs associated with the construction and installation of cooling water intake alternatives. As noted above, in some cases additional capital costs are needed after a period to replace equipment. Construction/capital costs are grouped into (1) capital costs; and (2) construction outage costs.

### 1. Capital Costs

The capital costs for cooling towers are based upon estimates provided in the draft permit[1], with two modifications. First, the contingency factor has been changed from 25 percent to 55 percent

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[1] These cost estimates assume a conversion to closed-loop cooling for year-round operation of the cooling towers. The seasonal use of cooling towers—which would require switching from closed-loop to once-through cooling—may result in different cost estimates (Enercon 2012b).

of total costs, as updated in Enercon (2012a). This updated contingency factor is also used for the Ristroph screens, Multi-Disc screens and CWW screens. Second, we added roughly $0.1 million in cooling tower capital costs for new fish return sluices in each generating unit, which are included in the EPA's description of its preferred cooling tower alternative at Merrimack Station. These costs are from Enercon (2009), which incorporated the costs of fish return sluices into its capital estimates for CWW screens and the Gunderboom MLES (Enercon 2009).

Table 3 shows the schedule and estimates of capital costs for each alternative.[2] The capital costs are based upon estimates in PSNH (2007),[3] Enercon (2009) and EPA (2011a) and the updated contingency factors in Enercon (2012a, 2012b). The total capital costs for the Gunderboom MLES include the costs of replacing certain components.[4]

**Table 3. Capital Cost Estimates and Schedules (Thousands $2010)**

| Alternative | Construction Start Date | Construction End Date | Initial Capital Costs (undiscounted) | Total Capital Costs (discounted) |
|---|---|---|---|---|
| Ristroph Screens | 7/1/2012 | 12/31/2014 | $1,767 | $1,576 |
| Multi-Disc Screens | 7/1/2012 | 12/31/2014 | $2,942 | $2,624 |
| CWW Screens | 7/1/2012 | 12/31/2014 | $8,063 | $7,192 |
| Gunderboom MLES | 7/1/2012 | 12/31/2014 | $10,070 | $13,001 |
| Cooling towers | 7/1/2012 | 12/31/2014 | $84,926 | $75,746 |

Notes: All dollar values are in thousands of 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations based upon PSNH (2007), EPA (2011a), Enercon (2009), and Enercon (2012a)

### 2. Construction Outage Energy Costs

Table 4 shows the assumed construction outage schedule for each alternative. None of the alternatives except for the cooling towers is expected to require a construction outage (Enercon 2009, 2012b). EPA (2011a) notes that the cooling towers are expected to require a construction outage of roughly three weeks beyond Merrimack Station's regularly scheduled maintenance (EPA 2011a, Attachment D, p. 150). Based upon projected monthly electricity prices for New Hampshire (see Appendix A), we assume that the three-week construction outage for the cooling

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[2] All dollar values in this report are adjusted to 2010 dollars using the GDP price deflator of the U.S. Bureau of Economic Analysis (from the website www.bea.gov, accessed on January 20, 2012).

[3] As noted in Attachment 4 – Section 5 of PSNH (2007), the capital cost estimate for the Multi-Disc screens does not include allowances for structural modifications (or design) to the intake. Multi-Disc screens are designed such that they can be installed within the typical guide rails used by the current traveling water screens; however, the condition of the guide rails, and the intake structures themselves, has not be analyzed to ensure that no changes would be necessary. While a specific need for structural modifications has not been identified, Enercon cautions the use of the capital cost estimates previously provided due to the potential for significant cost escalation should structural modifications be required (Enercon 2012b).

[4] This includes capital and contingency costs of approximately $5.6 million in the 10th year of operation, $1.3 million in 17th year of operation and $5.7 million in the 20th year of operations (adjusted to 2010 dollars) based upon Enercon (2009, 2012b).

tower alternative would occur in October to avoid overstating the potential costs of replacement power.

**Table 4. Construction Outage Schedules**

| Alternative | Construction Outage Start Date | Construction Outage End Date |
|---|---|---|
| Ristroph Screens | No Outage | No Outage |
| Multi-Disc Screens | No Outage | No Outage |
| CWW Screens | No Outage | No Outage |
| Gunderboom MLES | No Outage | No Outage |
| Cooling towers | 10/1/2014 | 10/21/2014 |

Source: EPA (2011a), Enercon (2009), and NERA assumption for timing of cooling tower construction outage

During the construction outage for the cooling towers alternative, Merrimack Station would not produce any energy, and thus other facilities would need to provide replacement energy.[5] Wholesale electricity prices provide a measure of the additional resources—and thus the social costs—required to produce the replacement power. To provide estimates of the power costs related to the construction outage (and ongoing O&M, as described below), we developed wholesale electricity price projections for New Hampshire. We estimated the cost of replacement energy by multiplying the lost energy during the construction outage by the projected wholesale electricity prices. [6] The complete methodology and data we used to develop these wholesale electricity price projections are provided in Appendix A.

During a construction outage at Merrimack Station, fuel costs would be avoided. To estimate the fuel cost savings, we used the heat rate of Merrimack Station and coal price projections from the U.S. Energy Information Administration (EIA 2011a). The average heat rates of Unit 1 and Unit 2 at Merrimack Station are 11,116 and 10,864 million British thermal units (MMBtu) per MWh, respectively (EIA 2011b).

Table 5 shows the present value of construction outage energy costs using a 7 percent real discount rate, which the U.S. Office of Management and Budget suggests as the default discount rate to be used in a regulatory analysis (OMB 2003). The present values range from zero for the screens and the Gunderboom MLES to roughly $2 million for cooling towers.

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[5] Replacement capacity also would need to be supplied by other facilities. The cost of this replacement capacity is not quantified in this analysis because we lacked a reliable method of forecasting future capacity prices. If included, the cost of replacement capacity would add to the total cost of the cooling tower alternative. The potential magnitude of this cost is discussed in the section on non-quantified costs.

[6] Note that these energy costs are based on market prices. The extent to which these prices reflect air emissions and other external costs is discussed below in the context of non-quantified costs.

**Table 5. Present Values of Construction Outage Energy Costs (Thousands 2010$)**

| Alternative | Replacement Energy | Fuel Cost Savings | Construction Outage Cost |
|---|---|---|---|
| Ristroph Screens | $0.0 | $0.0 | $0.0 |
| Multi-Disc Screens | $0.0 | $0.0 | $0.0 |
| CWW Screens | $0.0 | $0.0 | $0.0 |
| Gunderboom MLES | $0.0 | $0.0 | $0.0 |
| Cooling towers | $5,238 | -$3,215 | $2,023 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Negative values are cost savings from outage.
Source: NERA calculations as explained in text

### 3. Summary of Construction/Capital Costs

Table 6 summarizes the estimated present values of total construction/capital costs for each alternative. The present values of total construction/capital costs are far greater for the cooling towers than for the other alternatives.

**Table 6. Present Values of Total Construction Costs (Thousands 2010$)**

| Alternative | Total Capital Costs | Construction Outage Costs | Total Construction Costs |
|---|---|---|---|
| Ristroph Screens | $1,576 | $0 | $1,576 |
| Multi-Disc Screens | $2,624 | $0 | $2,624 |
| CWW Screens | $7,192 | $0 | $7,192 |
| Gunderboom MLES | $13,001 | $0 | $13,001 |
| Cooling towers | $75,746 | $2,023 | $77,768 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

## C. Operating and Maintenance Costs

The cooling water intake alternatives involve installation of equipment that would require ongoing upkeep. Maintaining this equipment entails operating and maintenance (O&M) costs. This section provides information on the ongoing O&M costs of the fish-protection alternatives, including ongoing power losses.

### 1. Schedules and Annual Costs

Ongoing O&M costs for each alternative are assumed to begin after construction is complete. Table 7 summarizes the period in which O&M costs are incurred for each alternative and shows the estimated annual O&M costs, based on information provided in the draft permit, Enercon (2009) and PSNH (2007).

On account of the expected seasonal deployment of each fish protection alternative, annual O&M costs are apportioned over the months of April through August for the cooling towers (EPA 2011a) and April through July for the Ristroph screens, Multi-Disc screens, CWW screens and the Gunderboom MLES (Enercon 2009, 2012b).

Table 7 shows that the annual O&M costs are largest for the cooling towers. For the Ristroph and Multi-Disc screens, annual O&M costs are not expected to be appreciably larger (if at all) compared to current operations (PSNH 2009, p. 95).

**Table 7. O&M Cost Schedule and Annual Costs (Thousands 2010$)**

| Alternative | O&M Start Year | O&M End Year | Annual O&M Costs |
|---|---|---|---|
| Ristroph Screens | 2015 | 2035 | $0 |
| Multi-Disc Screens | 2015 | 2035 | $0 |
| CWW Screens | 2015 | 2035 | $67 |
| Gunderboom MLES | 2015 | 2035 | $461 |
| Cooling Towers | 2015 | 2035 | $933 |

Notes: O&M costs for cooling towers increase over time, so this table shows the average annual cost.
All dollar values are in thousands of constant 2010 dollars.
Source: EPA (2011a), Enercon (2009), PSNH (2007)

### 2. Net O&M Costs

Certain O&M costs at the Merrimack Station facility would be avoided during the construction outage required to build the cooling towers (as noted above, the other alternatives likely would not require a construction outage, so there would be no avoided O&M costs for these alternatives). We estimated the potential savings in O&M costs based on a reported variable O&M cost of $4.25/MWh from the U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2011 (EIA 2011b). We combine the O&M costs with the O&M savings and show the present value of net O&M costs in Table 8.

**Table 8. Present Value of Net O&M Costs (Thousands 2010$)**

| Alternative | O&M Costs | O&M Cost Savings | Net O&M Costs |
|---|---|---|---|
| Ristroph Screens | $0 | $0 | $0 |
| Multi-Disc Screens | $0 | $0 | $0 |
| CWW Screens | $601 | $0 | $601 |
| Gunderboom MLES | $4,137 | $0 | $4,137 |
| Cooling Towers | $7,255 | $588 | $6,667 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

### 3. Operations Energy Costs

Some of the cooling water intake alternatives would reduce Merrimack Station's net energy output on an ongoing basis. The changes would come from two sources:

1. *Parasitic losses*, or increased auxiliary load requirements, which reflect increases in the amount of energy that Merrimack Station requires for operation during generation; and

2. *Efficiency losses*, or performance penalties, which reduce the amount of energy that can be generated at Merrimack Station per unit of fuel consumption.

As a result of these changes, Merrimack Station would provide less electricity to the grid than it would if the particular fish protection technology were not in place. The ongoing energy cost impacts would begin in 2015, when each of the alternatives would presumably begin operation.

Table 9 summarizes operations energy losses in terms of the power losses in MW and the net annual MWh losses that would need to be replaced under the various technologies. To estimate the costs associated with these energy losses, we multiply the reductions in net energy by the projected prices of replacement energy (shown in Appendix A).[7] Table 9 shows the estimated present values of operations energy losses.[8] Note that the losses—and thus the power costs—are far greater for the cooling towers than for the other cooling water intake alternatives. We assume that neither the Ristroph screens nor the Multi-Disc screens entail any energy losses, but Enercon (2012b) has noted that further review of these alternatives would be needed to determine the net operational energy loss or gain compared to the current screens.

**Table 9. Operations Energy Losses and Costs**

| Alternative | Operations Capacity Loss (MW) | Annual Operations Energy Loss (MWh) | Present Value of Operations Energy Costs (Thousands 2010$) |
|---|---:|---:|---:|
| Ristroph Screens | 0.00 | 0 | $0 |
| Multi-Disc Screens | 0.00 | 0 | $0 |
| CWW Screens | 0.09 | 199 | $108 |
| Gunderboom MLES | 0.09 | 201 | $109 |
| Cooling Towers | 9.68 | 26,519 | $14,520 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: Enercon (2009) and NERA calculations as explained in text

### 4. Total O&M Costs

Total O&M costs are calculated by adding the net O&M costs and the operations energy costs. Table 10 shows the estimated present values of total O&M costs.

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[7] Note that these energy costs are based on market prices, and they will understate the social costs of replacement energy if there are costs associated with additional electricity generation that are external to the market. The potential sources of replacement energy and magnitudes of these external benefits are discussed in Chapter V.

[8] The estimates of annual operations costs are significantly larger in the draft permit, which assumes a constant $72 per MWh electricity price and a 100 percent capacity factor at Merrimack Station, relying on analyses by Abt (2011) and PSNH (2007). As explained above, our calculations differ in that we use a forecast of monthly New Hampshire electricity prices until 2035 (based upon EIA 2011) and the 2009 average capacity factor for Merrimack Station of 76.1 percent (EPA 2011a).

**Table 10. Present Values of Total O&M Costs (Thousands 2010$)**

| Alternative | Net O&M Costs | Operations Energy Costs | Total O&M Costs |
|---|---:|---:|---:|
| Ristroph Screens | $0 | $0 | $0 |
| Multi-Disc Screens | $0 | $0 | $0 |
| CWW Screens | $601 | $108 | $709 |
| Gunderboom MLES | $4,137 | $109 | $4,247 |
| Cooling Towers | $6,667 | $14,520 | $21,187 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

## D. Total Quantified Costs

Table 11 shows the present value of total costs, i.e., the sum of construction and O&M costs. Total costs range from about $1.6 million for the Ristroph screens to about $99.0 million for the cooling towers.

**Table 11. Total Quantified Costs (Thousands 2010$)**

| Alternative | Construction Costs | O&M Costs | Total Quantified Costs |
|---|---:|---:|---:|
| Ristroph Screens | $1,576 | $0 | $1,576 |
| Multi-Disc Screens | $2,624 | $0 | $2,624 |
| CWW Screens | $7,192 | $709 | $7,901 |
| Gunderboom MLES | $13,001 | $4,247 | $17,248 |
| Cooling Towers | $77,768 | $21,187 | $98,955 |

Note: All dollar values are in thousands of constant 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

# IV. Benefits of Cooling Water Intake Alternatives

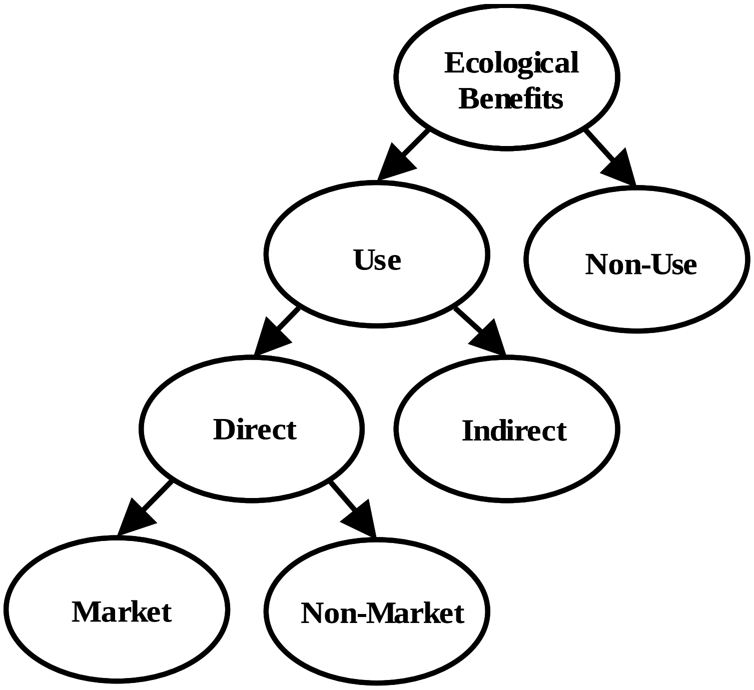
We developed preliminary monetary benefit estimates for the cooling water intake alternatives building upon the biological information presented by EPA in its supporting documentation for Merrimack Station's draft NPDES permit, supplemented by information from ASA (2012a). This chapter provides information on the methodology for developing benefit estimates and the preliminary results.

## A. Overview of Benefit Methodology

The relevant social benefits are the values that individuals in society place on changes in fish populations that could result from the introduction of cooling water intake alternatives at Merrimack Station. The EPA *Guidelines* provide a framework for assessing these benefits. The *Guidelines* emphasize developing complete benefit estimates by considering the various categories of benefits that would be provided (EPA 2010, pp. 7-3—7-6).

The EPA *Guidelines* provide a summary of the benefit categories relevant to an assessment of ecological improvements, which is the general category of benefits relevant to this assessment. We use the EPA *Guidelines* framework and the related framework in the EPA environmental and economic benefits analysis as part of the 316(b) Proposed Rule for existing facilities (EPA 2011c). These frameworks provide a systematic way to identify the potential types of benefits that may be generated.

Figure 1, adapted from the *Guidelines*, provides a way of organizing the relevant categories based on how they are experienced. The figure divides the ecological benefits into two major categories: "use" benefits and "non-use" benefits. Use benefits can be further subdivided into three subcategories—market benefits, non-market benefits, and indirect benefits—resulting in a total of four ecological benefits categories. Of these categories, market benefits and non-market benefits are considered direct benefits because they involve direct benefits to users. The other category of use benefits, indirect benefits, relates to ecosystem benefits that accrue to users through indirect paths. These three use-benefit categories relate to the gains that individuals may obtain from use of the ecological resource, in this case the additional fish populations in the Hooksett Pool portion of the Merrimack River and elsewhere. The fourth category—non-use benefits—consists of benefits that are not associated with any direct use by people.



Source: Adapted from EPA (2010, pp. 7-9)

**Figure 1. Summary of Benefit Classification Scheme from EPA *Guidelines***

EPA uses a similar set of benefit categories in its Proposed Rule for existing power plants under Section 316(b) of the Clean Water Act (EPA 2011c). The benefit categorization system from the Proposed Rule is discussed below and in Chapter V on benefit-cost comparisons.

## B. Assessment of Benefit Categories

This section uses EPA's framework to identify the specific benefits to be quantified in this benefit-cost analysis of cooling water intake alternatives at Merrimack Station. The objectives are to ensure that the benefits assessment is complete, and that analytic resources to quantify benefits are focused on key issues, as recommended in the EPA *Guidelines*:

> Resources should be focused on benefit categories that are likely to influence policy decisions. (EPA 2010, p. 7-3)

The following excerpt from the EPA *Guidelines* provide additional guidance on determining which benefit categories to include in a benefit-cost analysis.

> Determine which benefit categories to include in the overall benefits analysis using at least the following three criteria:
>
> 1. Which benefit categories are likely to differ across policy options, including the baseline option? Analysts should conduct an assessment of how the physical effects

of each policy option will differ and how each physical effect will impact each benefit category.

2. Which benefit categories are likely to account for the bulk of the total benefits of the policy? The cutoff point here should be based on an assessment of the magnitude and precision of the estimates of each benefit category, the total social costs of each policy option, and the costs of gathering further information on each benefit category. A benefit category should not be included if the cost of gathering the information necessary to include it is greater than the expected increase in the value of the policy owing to its inclusion. The analyst should make these preliminary assessments using the best quantitative information that is readily available, but as a practical matter these decisions may often have to be based on professional judgments.
3. Which benefit categories are especially salient to particular stakeholders? Monetized benefits in this category are not necessarily large and so may not be captured by the first two criteria. (EPA 2010, p. 7-4)

As this excerpt from the EPA *Guidelines* suggests, the goal of a benefits assessment should be to identify key benefit categories and assess them carefully, rather than to attempt to monetize every possible category.

### 1. Market Benefits

Market benefits consist of primary products that are bought and sold as factors of production or final consumption products. Increases in the numbers of adult fish caught by commercial fishermen and sold in various fish markets throughout the United States would constitute market benefits.

To determine whether the market benefits category would be relevant for cooling water intake alternatives at Merrimack Station, we reviewed information in EPA's supporting documentation for the 316(b) Proposed Rule (EPA 2011c) regarding commercial fishing of the relevant species, as identified in ASA (2012a). According to the EPA, "significant commercial use values are unlikely to be associated with fish lost to the Merrimack Station CWISs because the Merrimack River is not a commercial fishing resource" (EPA 2011a, Attachment D, p. 326). Thus, we concluded that market benefits related to commercial fishing are not relevant to benefit estimation for the cooling water intake alternatives at Merrimack Station.

### 2. Non-market Direct Use Benefits

Increases in the numbers of adult fish that are valued by recreational anglers would yield recreational benefits as a result of increased harvests. Moreover, fish that are caught but released also yield recreational benefits.

EPA's supporting documentation for the 316(b) Proposed Rule (EPA 2011c) notes that species affected at Merrimack are caught by recreational anglers. We allocated all the potential increases in fish harvests from ASA (2012a) to recreational anglers. This assumption may overstate benefits if some additional fish are caught by commercial anglers, because the data in EPA

(2011c) indicate that recreational values are significantly greater than commercial values. For example, EPA (2011c, Appendix H, p. H-6) indicates that the commercial wholesale ("ex-vessel") price of yellow perch (one of the species with the largest potential increases in harvests as identified in ASA 2012a) is $1.45/lb (2009$), which is equivalent to about $0.36 per fish (based on average weights discussed below). EPA (2011c, p. 7-5) indicates that the recreational value for yellow perch is more than $1 per fish, or almost three times the commercial wholesale price. This pattern of higher recreational values than commercial values is consistent across fish species. Thus, if we allocated a portion of the increased fish harvests to commercial anglers, the benefit values would be smaller.

### 3. Non-market Indirect Use Benefits

The use benefits of an ecosystem include indirect benefits in the form of valued ecosystem functions. Because of interdependencies of species within an ecosystem, species without direct commercial or recreational value have *indirect* effects on species that do have direct use value. In particular, increases in forage fish species serve as additional food sources (i.e., contribute to the survival and weight gain) for commercial and recreational species. We developed estimates of indirect benefits from additional forage fish for the various alternatives using information developed by ASA (2012a) on the additional adult equivalent harvested species associated with changes in forage fish.

### 4. Nonuse Benefits

Nonuse benefits include values that people place on a resource beyond those attributed to direct or indirect use. Examples of non-use benefits include bequest benefits (values for future generations) and existence benefits (knowing that the resource exists in an improved state).

In its draft permit for Merrimack Station, the EPA notes the difficulty of measuring non-use benefits and determining the associated monetized valuations:

> [E]fforts to develop a monetized estimate of the non-use benefits (direct and indirect) to be derived from the aquatic organisms saved by each BTA option, and from the various ecological improvements (e.g., healthier community of aquatic organisms, improved habitat value) that would accompany saving those organisms, are not warranted. As with recreational values, EPA can suitably evaluate these matters qualitatively without undertaking great expense to hire outside contracting assistance. Moreover, attempting to develop an estimate of the non-use values of protecting these natural resources would be an exceedingly difficult, time-consuming and expensive task. Once again, specialized expertise and data collection would be needed to undertake such an analysis. EPA would need to expend considerable funds to retain outside expert contractor assistance and any results would nevertheless undoubtedly be highly controversial. Undertaking that sort of effort for the BPJ determination of the BTA under CWA §316(b) for this permit is not reasonable and, indeed, will rarely be sustainable for individual permits given current economic analysis tools. (EPA 2011a, Attachment D, p. 327)

We use the criteria developed by Freeman (2003) to assess the likely significance of non-use values in this case, and thus the usefulness of attempting to develop empirical estimates of non-use benefits. Freeman suggests the following two criteria for evaluating whether non-use values for fish protection are likely to be significant in a particular circumstance:

1. The resource is unique; and

2. The loss would be irreversible or subject to a long recovery period.

Appendix B provides an assessment for the likely significance of non-use values related to the biological benefits at Merrimack station. This assessment leads us to conclude that non-use benefits at Merrimack are not likely to be significant and therefore it would not be sensible to attempt to develop monetary values. We discuss the significance of not monetizing potential non-use benefits below in the context of information excluded from the quantified estimates.

## C. Increases in Fish Harvests

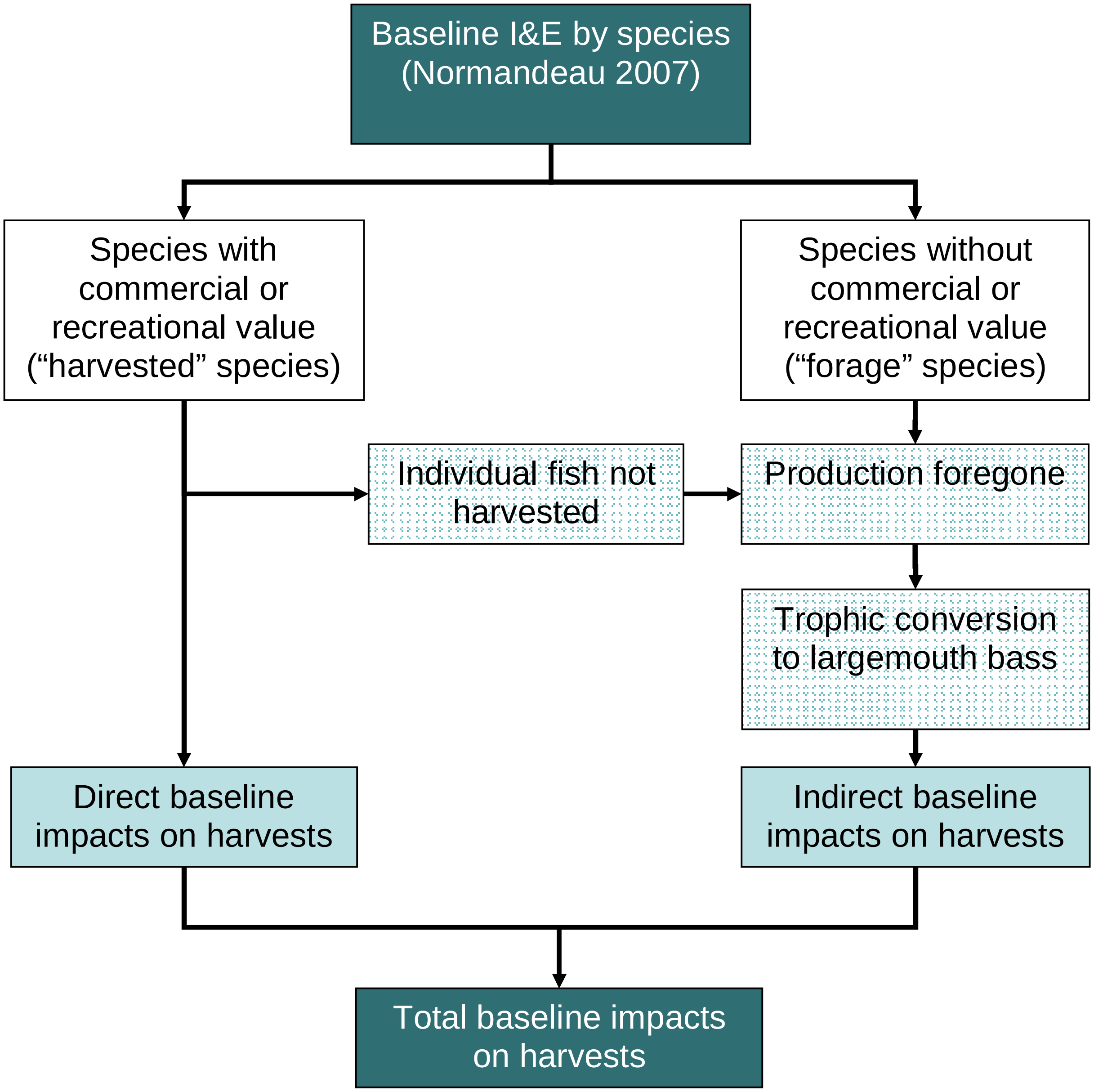
The potential benefits of the cooling water intake alternatives at Merrimack Station are based on the potential increases in harvests of various species of fish. To calculate the potential increase in fish harvests for each alternative, we used species-specific data from ASA (2012a) on the baseline harvest impacts of impingement and entrainment (“I&E”) at Merrimack Station and used I&E reduction percentages for each alternative from Normandeau and EPA. These calculations generated potential increases in harvest for each type of species with a monetary value.

As discussed below, species that are not harvested and thus do not have a monetary value still contribute to the potential benefits of the cooling water intake alternatives, because such “forage” species may be eaten (either as live prey or dead biomass) by predator species with a monetary value. Moreover, individual fish of valued species that are not harvested (and instead die of natural causes) may also be eaten (again either as live prey or dead biomass) by predator species with monetary value. Thus, the potential increases in fish harvests include the “direct” effects of reducing I&E for valued species as well as the “indirect” effects of making more prey and biomass available to valued predator species.

The following subsections provide an overview of ASA’s baseline harvest impact calculations, the categorization of species as either harvested or forage species, ASA’s baseline harvest impact estimates, Normandeau and EPA’s I&E reduction percentages for each cooling water intake alternative, and the potential harvest increase estimates for each alternative.

### 1. Overview of ASA’s Baseline Harvest Impact Calculations

Figure 2 summarizes the steps that ASA (2012a) followed to convert the baseline I&E loss data from Normandeau (2007) into baseline impacts on fish harvests. Note that the baseline I&E loss data and baseline impacts on fish harvests reflect recent historical conditions at Merrimack Station, and these conditions are expected to continue in the future at the same levels if no changes are made to Merrimack Station’s CWIS.



Note: I&E refers to impingement and entrainment.

**Figure 2. Summary of Steps in Calculating Baseline Impacts on Fish Harvests**

For entrainment, the organisms affected are eggs and larvae. For impingement, the organisms affected are young fish. The number of organisms lost due to impingement and entrainment can appear to be quite large. However, most of those organisms are eggs or larvae, and very few of them would survive to adulthood. Most eggs do not survive to the larval stage, most larvae do not survive to become juveniles, and most juveniles do not reach adulthood.

To convert the baseline I&E losses into baseline impacts on fish harvests, ASA distinguished between species with commercial or recreational value ("harvested" species) and species without commercial or recreational value (“forage” species). I&E losses of harvested species have direct impacts on fish harvests. I&E losses of forage species have indirect impacts on fish harvests because they are eaten by predator species with commercial or recreational value. Individual fish of valuable species that are not harvested also may be eaten by predator species with commercial or recreational value, so they also contribute to indirect impacts.

To estimate the indirect impacts, ASA first calculated the production foregone for forage species and the individual fish of valuable species that are not harvested. Production foregone represents the biomass available in the ecosystem to predator species. ASA then calculated trophic conversion of this biomass to predator species, because only a fraction of the available biomass would actually be consumed by predator species. ASA indicated that it would be reasonable to use largemouth bass as the assumed predator species for indirect impacts.

Additional information on these calculations is provided in ASA (2012a).

### 2. Species Categories

Table 12 lists the 11 target species for which ASA (2012a) estimated baseline harvest impacts. ASA identified ten of the species as having commercial or recreational value (“harvested” species). ASA identified spottail shiner as not having commercial or recreational value (“forage” species). As noted above, ASA indicated that it would be reasonable to use largemouth bass, a harvested species, as the assumed predator species for indirect impacts.

**Table 12. Target Species Categorization: Harvested or Forage**

| Target Species | Category |
|---|---|
| Pumpkinseed | Harvested |
| Bluegill spp.* | Harvested |
| Smallmouth Bass | Harvested |
| Largemouth Bass | Harvested |
| Black Crappie | Harvested |
| Spottail Shiner spp.* | Forage only |
| Yellow Perch | Harvested |
| White Sucker | Harvested |
| Yellow Bullhead | Harvested |
| Brown Bullhead | Harvested |
| Rainbow Smelt | Harvested |

Note: (*) Bluegill spp. indicates bluegill and related sunfish species. Spottail shiner spp. indicates spottail shiner and related minnow species.
Source: ASA (2012a, p. 2-11)

ASA (2012a, p. 1-4) estimated that the 11 target species listed in Table 12 account for 89.4 percent of the total baseline loss (in terms of mass) from impingement and account for 91.9 percent of the total baseline loss (in terms of mass) from entrainment at Merrimack Station. We scaled up the potential benefits of the cooling water intake alternatives to reflect other species beyond the 11 target species, as discussed further below.

As discussed in more detail below in the section on valuation, we used values per fish from EPA (2006), the recreational fishing meta-analysis on which EPA based its recreational valuations for its recent 316(b) proposal (EPA 2011c). This meta-analysis provides values per fish for a small number of species categories. ASA (2012b) has indicated that the two relevant species categories in the meta-analysis for the target species at Merrimack Station are bass and panfish. Table 13 presents the categorization of the 10 harvested target species as either bass or panfish. Note that spottail shiner is not categorized in this table because it is not a harvested species.

**Table 13. Harvested Species Categorization: Bass or Panfish**

| Harvested Species | Category |
|---|---|
| Pumpkinseed | Panfish |
| Bluegill spp. | Panfish |
| Smallmouth Bass | Bass |
| Largemouth Bass | Bass |
| Black Crappie | Panfish |
| Yellow Perch | Panfish |
| White Sucker | Panfish |
| Yellow Bullhead | Panfish |
| Brown Bullhead | Panfish |
| Rainbow Smelt | Panfish |

Source: ASA (2012b)

The following tables on the baseline harvest impacts of I&E at Merrimack Station and the potential increases in fish harvests from the cooling water intake alternatives condense the biological data from ASA (2012a) into sums for bass and panfish for valuation using the results of EPA's meta-analysis.

### 3. Baseline Harvest Impact Estimates

The following tables summarize ASA's estimates of annual baseline harvest impacts due to I&E at Merrimack Station in terms of bass and panfish species.

#### a. Baseline for Direct Harvest Impacts

Table 14 shows the direct baseline harvest impacts.

**Table 14. Estimated Annual Direct Baseline Fishery Harvest Impacts (lbs)**

| | Impingement | Entrainment | Total |
|---|---|---|---|
| Bass | 17 | 0 | 17 |
| Panfish | 81 | 312 | 393 |
| Total | 98 | 312 | 410 |

Source: NERA calculations based on ASA (2012a, p. 2-11) and species categories in Table 13

### b. Baseline for Indirect Harvest Impacts

Table 15 shows the baseline production foregone impacts in terms of bass, panfish, and forage species. As noted above, production foregone represents the biomass available in the ecosystem to predator species, but not all of it is actually consumed. Note that all species contribute to production foregone (including not only the forage species, spottail shiner, but also all the harvested species) and thus they all contribute to indirect harvest impacts.

**Table 15. Estimated Annual Production Foregone Baseline Impacts (lbs)**

| | Impingement | Entrainment | Total |
|---|---|---|---|
| Bass | 41 | 0 | 41 |
| Panfish | 181 | 1,973 | 2,154 |
| Forage | 0 | 187 | 187 |
| Total | 222 | 2,160 | 2,382 |

Source: NERA calculations based on ASA (2012a, p. 2-12) and species categories in Table 13

ASA (2012a, p. 2-10) noted that a trophic transfer coefficient of 10 percent could be used to convert the production foregone to predator species biomass, and an annual exploitation rate of 25 percent could be used to estimate impacts on fishing harvests. Thus, 2.5 percent of the production foregone impacts above in Table 15 would translate into harvest impacts for the assumed predator species, largemouth bass. Table 16 shows the estimated annual indirect baseline impacts.

**Table 16. Estimated Annual Indirect Baseline Impacts (lbs)**

| | Impingement | Entrainment | Total |
|---|---|---|---|
| Bass | 6 | 54 | 60 |
| Panfish | 0 | 0 | 0 |
| Total | 6 | 54 | 60 |

Source: NERA calculations based on Table 15 and parameters from ASA (2012a, p. 2-10)

### c. Baseline for Total Harvest Impacts

Table 17 presents estimated total annual baseline harvest impacts (the sum of direct and indirect impacts) due to I&E at Merrimack Station.

**Table 17. Estimated Total Annual Baseline Harvest Impacts (lbs)**

| | Impingement | Entrainment | Total |
|---|---|---|---|
| Bass | 23 | 54 | 77 |
| Panfish | 81 | 312 | 393 |
| Total | 104 | 366 | 470 |

Source: Sum of Table 14 and Table 16

### 4. Impingement and Entrainment Reduction Percentages

The I&E reduction percentages for each cooling water intake alternative are based on information from Normandeau and EPA. Because the original reduction figures from Normandeau and EPA were defined relative to a full flow assumption at both units for 365 days a year (Normandeau 2009, pp. 1-2), but the ASA impact estimates reflect current operations at Merrimack Station, we rescaled the reductions to be relative to current operations.

The rescaling process we used to develop estimates of the effectiveness of the various alternatives relative to current operations can be illustrated by the calculations for Cooling Towers. Cooling Towers can achieve a 97 percent adult equivalent loss reduction according to EPA (2011a, Attachment D. p. 305). This is relative to a regulatory baseline of 17,852 adult equivalent losses (Normandeau 2009, p. 43), which implies Cooling Towers reduce adult equivalent losses to (1 - 0.97) * 17,852 = 536. Current operations can achieve a 17 percent adult equivalent loss relative to the regulatory baseline (Normandeau 2009, p. 43), which results in total losses arising from current operations of (1 - 0.17) * 17,852 = 14,829 adult equivalents. To determine the effect of Cooling Towers relative to current operations, we determined the percentage reduction in adult equivalent losses from the installation of Cooling Towers relative to current operations as follows: (14,829 - 536) / 14,829 = 0.96, or 96 percent. A similar procedure was repeated to determine the modified adult equivalent loss percentage reductions for the remaining fish protection alternatives.

Table 18 summarizes the assumed I&E reduction percentages for this analysis, broken down by impingement and entrainment (as some of the options only reduce impingement). These reduction percentages are assumed to be uniform for all types of species (bass and panfish).

**Table 18. Harvest Impact Reductions Relative to Baseline**

| Alternative | Impingement | Entrainment |
|---|---|---|
| Ristroph Screens | 46% | 0% |
| Multi-Disc Screens | 56% | 0% |
| CWW Screens | 81% | 75% |
| Gunderboom MLES | 73% | 78% |
| Cooling Towers | 96% | 96% |

Source: NERA calculations based on PSNH (2007, pp. 70, 74) for the Ristroph and Multi-Disc screens, Normandeau (2009, p. 18) for CWW screens, (EPA 2011a, Attachment D, p. 294) for Gunderboom MLES, and EPA (2011a, Attachment D, p. 305) for Cooling Towers

### 5. Potential Increases in Fish Harvests

Table 19 summarizes the potential increases in fish harvest (relative to baseline conditions) for each alternative, based on the baseline harvest impacts above in Table 17 and the reduction percentages for each alternative above in Table 18.

## D. Valuation of Fish Harvest Benefits

We valued the potential increases in fish harvests shown above using recreational values from EPA’s regional benefits assessment for the Phase III 316(b) Final Rule (EPA 2006). EPA’s recreational values are based on a meta-analysis of many studies of recreational fishing.

EPA’s analysis estimated the marginal value that recreational anglers place on an additional harvested fish, broken down by several species categories and regions. We used the “bass” and “panfish” species categories for the Inland region, as these most closely mapped onto the target species determined by ASA (2012a).

**Table 19. Estimated Annual Increases in Fish Harvests (in pounds)**

| Alternative | Impingement | Entrainment | Total |
|---|---|---|---|
| Ristroph Screens | | | |
| Bass | 10 | 0 | 10 |
| Panfish | 37 | 0 | 37 |
| Total | 48 | 0 | 48 |
| Multi-Disc Screens | | | |
| Bass | 13 | 0 | 13 |
| Panfish | 45 | 0 | 45 |
| Total | 58 | 0 | 58 |
| CWW Screens | | | |
| Bass | 18 | 41 | 59 |
| Panfish | 66 | 234 | 300 |
| Total | 84 | 275 | 358 |
| Gunderboom MLES | | | |
| Bass | 16 | 42 | 59 |
| Panfish | 59 | 243 | 302 |
| Total | 76 | 285 | 361 |
| Cooling Towers | | | |
| Bass | 22 | 52 | 73 |
| Panfish | 78 | 300 | 377 |
| Total | 99 | 351 | 451 |

Source: NERA calculations based on Table 17 and Table 18

### 1. Determining the Value of a Pound of Additional Catch

In its 316(b) Phase III Final Rule regional analysis, the EPA estimated the marginal recreational value per fish for bass and panfish for the inland region based on a meta-analysis of relevant studies (EPA 2006). The EPA's meta-analysis model derived the recreational angler valuations of catching an additional fish based on 48 original studies, comprising 391 estimates (EPA 2006, p. A5-10). We provide additional background information on methods for determining marginal recreational fish values along with a description of meta-analyses specifically in Appendix C and focus here on how we adjusted the values that the EPA estimated for the purposes of our assessment.

Table 20 summarizes the marginal recreational values from EPA's study and provides the monetary estimates updated to 2010 dollars.

**Table 20. EPA Marginal Recreational Values per Fish for Bass and Panfish ($/fish)**

| EPA Species Category | EPA Marginal Value (2004 $/fish) | Marginal Value (2010 $/fish) |
|---|---|---|
| Bass | $7.59 | $8.70 |
| Panfish | $0.89 | $1.02 |

Note: Adjustments to 2010 dollars were calculated using the GDP price deflator of the U.S. Bureau of Economic Analysis.

Source: EPA (2006, p. A5-26) for 2004 $ / fish marginal recreational values.

As the EPA marginal recreational values are defined on a per fish basis, in order to convert our baseline pound estimates into monetary values, we need to make an assumption about the average weights of bass and panfish. We decided to make conservative assumptions (i.e., ones likely overstating the benefits) regarding the relevant species' average weights, and so chose weights on the lower end of the respective ranges (as a lower average weight would result in a higher $/lb valuation given the constant $/fish estimates from the EPA).

For both smallmouth and largemouth bass (i.e., the EPA's "bass" species category), we assumed an average weight of 1 lb, although the typical weight range for these two types of bass is 1 to 1.5 lbs (Schultz 2004, pp. 40, 50).

To determine the average weight for the EPA's inland "panfish" fish category, we used a conservative estimate for all the panfish species of 0.25 lbs. This corresponds to the lower end of the weight range for yellow perch, whose weight ranges from 0.25 to 0.75 lbs (Schultz 2004, p. 151) and is one of the panfish species which dominates the equivalent loss estimates due to impingement and entrainment (ASA 2012a).

The resulting $/lb recreational valuations for bass and panfish are shown in Table 21. As can be seen, even with the conservative assumption regarding the average weight of a panfish, bass is more than twice as valuable per pound relative to panfish.

**Table 21. Marginal Recreational Values per Pound for Bass and Panfish (2010 $/lb)**

| EPA Species Category | EPA Marginal Value (2010 $/fish) | Assumed Average Weight (lbs) | Marginal Value (2010 $/lb) |
|---|---|---|---|
| Bass | $8.70 | 1.00 | $8.70 |
| Panfish | $1.02 | 0.25 | $4.08 |

Source: EPA (2006, p. A5-26) for 2004 $ / fish marginal recreational values, Schultz (2004) for assumed average weights.

### 2. Adjusting Additional Catch Valuation for Catch and Release

As not all caught fish are kept, we adjusted the marginal recreational values from the previous section to account for the fact that each fish may be caught and released multiple times; and hence, that each fish's adjusted marginal value is a direct function of how many times it is caught.

To account for the benefits of catch-and-release, we used 2011 data from the National Marine Fisheries Service ("NMFS") to estimate recreational catch-and-release rates for the relevant species for New Hampshire. The total catch for striped bass for New Hampshire in 2011 was 100,571 pounds, 21,820 of which was kept (i.e., harvested). This results in an estimated catch-and-release rate of 4.6. We used this catch-and-release figure for striped bass as a proxy for the catch-and-release rate for both panfish and bass because no catch-and-release data were available for Merrimack River from NMFS for panfish or bass.

The adjusted marginal recreational values for panfish and bass are shown in Table 22.

**Table 22. Adjusted Marginal Recreational Values per Pound for Bass and Panfish (2010 $/lb)**

| EPA Species Category | Marginal Value (2010 $/lb) | Catch-and-release Rate | Adjusted Marginal Value (2010 $/lb) |
|---|---:|---:|---:|
| Bass | $8.70 | 4.6 | $40.04 |
| Panfish | $4.08 | 4.6 | $18.78 |

Source: Table 21 for 2010 $ / fish marginal recreational values, NERA calculations as described in text.

The potential annual benefits of an alternative are equal to the potential annual increase in pounds of fish harvested (from Table 19) times the marginal value per pound (from Table 22). Table 23 shows the annual benefits estimates for each alternative. To account for other species beyond the 11 target species, we scaled the impingement benefits up by a factor of 1 / 0.894 = 1.119 and scaled the entrainment benefits up by 1 / 0.919 = 1.088 based on ASA's estimates of the 11 target species' shares of baseline impingement and entrainment.

**Table 23. Annual Benefits of Cooling Water Intake Alternatives (2010$)**

| Alternative | Impingement | Entrainment | Total |
|---|---|---|---|
| Ristroph Screens | | | |
| Bass | $415 | $0 | $415 |
| Panfish | $700 | $0 | $700 |
| Non-target species | $132 | $0 | $132 |
| Total | $1,247 | $0 | $1,247 |
| Multi-Disc Screens | | | |
| Bass | $506 | $0 | $506 |
| Panfish | $852 | $0 | $852 |
| Non-target species | $161 | $0 | $161 |
| Total | $1,518 | $0 | $1,518 |
| CWW Screens | | | |
| Bass | $731 | $1,622 | $2,353 |
| Panfish | $1,232 | $4,394 | $5,627 |
| Non-target species | $233 | $530 | $763 |
| Total | $2,196 | $6,546 | $8,743 |
| Gunderboom MLES | | | |
| Bass | $659 | $1,686 | $2,346 |
| Panfish | $1,110 | $4,570 | $5,681 |
| Non-target species | $210 | $551 | $761 |
| Total | $1,979 | $6,808 | $8,787 |
| Cooling Towers | | | |
| Bass | $867 | $2,076 | $2,942 |
| Panfish | $1,460 | $5,625 | $7,085 |
| Non-target species | $276 | $679 | $955 |
| Total | $2,603 | $8,379 | $10,982 |

Note: All dollar values are in constant 2010 dollars.
Totals may differ slightly from the sum of columns because of independent rounding
Source: NERA calculations as explained in text

## E. Total Quantified Benefits

Table 24 presents the present values of the potential benefits as of January 1, 2012 using a real annual discount rate of 7 percent. The present values of the estimated benefits vary from about $11,000 for Ristroph screens to about $102,000 for Cooling Towers.

**Table 24. Annual and Present Values of Benefits of Fish-Protection Alternatives (2010$)**

| Alternative | Annual | PV |
|---|---:|---:|
| Ristroph Screens | $1,247 | $11,445 |
| Multi-Disc Screens | $1,518 | $14,113 |
| CWW Screens | $8,743 | $80,548 |
| Gunderboom MLES | $8,787 | $81,737 |
| Cooling towers | $10,982 | $101,642 |

Note: Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent in constant 2010 dollars.

Source: NERA calculations as explained in text

# V. Benefit-Cost Comparisons

In this chapter we compare costs and benefits for the five fish-protection alternatives. We first summarize the quantified results, combining the cost and benefit estimates from the previous sections. We then review the potential costs and benefits that we have not quantified and explain why we believe that quantifying and including them, if it were possible, would not change our major benefit-cost assessments.

## A. Benefits, Costs and Net Costs

Table 25 summarizes the estimated present values of benefits, costs, and net costs of the cooling water intake alternatives. Our analysis yields negative net benefits for all of the alternatives and cases considered; i.e., the benefits are less than the costs. Thus, for ease of exposition, we report net costs (costs minus benefits) rather than net benefits. Net costs are the same as net benefits in terms of magnitude, but the sign is reversed.

The net costs vary greatly for the five alternatives. Net costs range from about $1.6 million for the Ristroph screens to about $98.9 million for the cooling tower alternative. These results indicate that none of the five alternatives generates net benefits compared to the status quo option, for which net costs are equal to zero.

**Table 25. Summary of Present Values of Estimated Net Costs of Alternatives (Thousands 2010$)**

| Alternative | Costs | Benefits | Net Costs |
|---|---:|---:|---:|
| Ristroph Screens | $1,576 | $11 | $1,564 |
| Multi-Disc Screens | $2,624 | $14 | $2,610 |
| CWW Screens | $7,901 | $81 | $7,820 |
| Gunderboom MLES | $17,248 | $82 | $17,166 |
| Cooling Towers | $98,955 | $102 | $98,854 |

Note: All values are in thousands of 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Source: NERA calculations as explained in text

Table 26 provides additional comparisons of the alternatives. The table shows the costs and benefits of each alternative and the incremental costs and incremental benefits for each of the alternatives relative to the alternative with the next lowest net costs. For CWW screens, the cost-benefit ratio is about 98, meaning that for every dollar of social benefit, society would have to pay $98 of costs. For Gunderboom, that ratio is about 211. But the ratio for Gunderboom increases to almost 7,900 based upon the incremental costs and incremental benefits relative to CWW screens ($9,347,055/$1,189=7,859), reflecting the fact that the benefits are virtually the same for the two alternatives but the Gunderboom costs are more than twice the costs of CWW screens.

The incremental comparisons for Cooling Towers also are revealing about the full cost-benefit implications of selecting Cooling Towers rather than less expensive alternative. The cost-benefit ratio for Cooling Towers is very large (974) based upon total costs and benefits. But the ratio increases to roughly 4,100 based upon the incremental costs and incremental benefits of Cooling Towers relative to Gunderboom, and it increases to roughly 4,300 relative to CWW screens. These CWW results mean that for every dollar of additional benefit for Cooling Towers relative to CWW screens, society would pay about $4,300 in costs. Note that this same incremental analysis was used by EPA to conclude that year-around use of Cooling Towers was not warranted relative to seasonal use of Cooling Towers (although the benefits were not expressed in monetary values because—according to EPA—the required expertise to monetize benefits was unavailable).

**Table 26. Incremental Analysis of Alternatives (Thousands 2010$)**

| Alternative | Costs | Benefits | Net Costs | Cost-Benefit Ratio |
|---|---|---|---|---|
| Ristroph Screens | $1,576 | $11 | $1,564 | 138 |
| Multi-Disc Screens | $2,624 | $14 | $2,610 | 186 |
| *- Incremental to Ristroph Screens* | *$1,048* | *$3* | *$1,046* | *393* |
| CWW Screens | $7,901 | $81 | $7,820 | 98 |
| *- Incremental to Multi-Disc Screens* | *$5,277* | *$66* | *$5,210* | *79* |
| Gunderboom MLES | *$17,248* | *$82* | *$17,166* | 211 |
| *- Incremental to CWW Screens* | *$9,347* | *$1* | *$9,346* | *7,859* |
| Cooling Towers | $98,955 | $102 | $98,854 | 974 |
| *- Incremental to Gunderboom MLES* | *$81,708* | *$20* | *$81,688* | *4,105* |
| *- Incremental to CWW Screens* | *$91,055* | *$21* | *$91,033* | *4,317* |

Note: All values are in thousands of 2010 dollars.
Present values are calculated as of January 1, 2012 based upon annual values from 2012 to 2035 using a real annual discount rate of 7 percent.
Net costs and cost-benefit ratios may differ from differences and quotients of costs and benefits shown in the table because of rounding.
Source: NERA calculations as explained in text

## B. Non-Quantified Benefits and Costs

The basic steps in the benefit-cost analysis presented above include identifying the relevant alternatives, determining the effects of these alternatives on fish losses, valuing the fish protection benefits and estimating the negative effects (costs) to the extent feasible in dollar terms, and calculating the net costs. It is also important to consider the potential effects that are not monetized. Both EPA and OMB recommend qualitatively describing the effects and implications of omitting these factors when presenting the overall results. EPA notes:

> Some consequences of environmental policies are difficult to represent in the definitive, quantitative terms of conventional social cost analysis…The relative significance of social cost categories that are not quantified — or are quantified but not valued — should be described in the social cost analysis (EPA 2010, p. 8-12).

Similarly, OMB states:

> A complete regulatory analysis includes a discussion of non-quantified as well as quantified benefits and costs. A non-quantified outcome is a benefit or cost that has not been quantified or monetized in the analysis. When there are important non-monetary values at stake, you should also identify them in your analysis so policymakers can compare them with the monetary benefits and costs. When your analysis is complete, you should present a summary of the benefit and cost estimates for each alternative, including the qualitative and non-monetized factors affected by the rule, so that readers can evaluate them (OMB 2003, p. 3).

In this section we discuss the omitted costs and benefits qualitatively and consider their effects on the overall results.

### 1. Qualitative Assessments of Non-Quantified Costs

Table 27 summarizes costs that we did not quantify and indicates qualitatively their likely impacts on each of the alternatives. We explain each briefly below.

**Table 27. Qualitative Impacts of Non-Quantified Costs on Fish-Protection Alternatives**

| Omitted Cost | Ristroph Screens | Multi-Disc Screens | CWW Screens | Gunderboom MLES | Cooling Towers |
|---|---|---|---|---|---|
| Cost of replacement generation capacity | – | – | ↑ | ↑ | ↑ |
| Increased fish losses from replacement generation | – | – | ↑ | ↑ | ↑ |
| Costs of air emissions | – | – | ? | ? | ? |
| Noise during construction and operation of tower | – | – | – | – | ↑ |
| Visual impacts of tower | – | – | – | – | ↑ |
| Fogging and icing from tower | – | – | – | – | ↑ |

Note: "↑" indicates consideration of omitted cost would increase cost of alternative. "↓" indicates consideration would reduce cost of alternative. "?" indicates that it is unclear whether consideration of omitted cost would increase or reduce cost of alternative.

Source: NERA analysis.

#### a. Costs of Replacement Generation Capacity

In addition to the loss in energy due to the construction and operation of the cooling water intake alternatives, some or all of Merrimack Station's capacity would not be available to the grid for some time periods. This capacity would need to be replaced by other generators. We did not include these additional capacity costs in our calculations because we lacked a reliable method of forecasting future capacity prices. Recent capacity prices in ISO-New England have been on the order of $1 per kW-month.[9] This value suggests that the cost of replacement capacity would be small compared to the cost of replacement generation that is included in our estimates. If

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[9] Capacity prices are from the ISO-NE website (www.iso-ne.com), accessed on January 16, 2012.

included in our analysis, these additional capacity costs would increase the total costs of the cooling water intake alternatives.

### b. Increased Fish Losses from Replacement Generation

The cooling water intake alternatives with power losses would lead to additional power generated at other facilities (to offset the reduced output provided to the grid from Merrimack Station). Some of those facilities may utilize water intake systems, in which case increasing generation at those plants would increase cooling water flows, which could increase I&E at those plants or require additional expenditures for fish protection. Those costs (or negative fish-protection benefits) are not included in this analysis, resulting in a possible understatement of total costs.

### c. Costs of Air Emissions from Replacement Generation

The electricity market prices include costs related to three major air pollutants because they are covered by cap-and-trade programs. The electricity market prices include costs for $CO_2$, $SO_2$, and $NO_X$ emissions in the form of their projected allowance prices under the cap-and-trade systems that cover those pollutants. If the emissions cap is binding, an increase (or decrease) in emissions from one source will lead to an equivalent decrease (or increase) in emissions from other sources. Note, however, that an increased demand for allowances—due to a potential increase in the demand for electricity generation—may lead to higher allowance prices and higher overall costs of meeting the cap. We do not include these possible effects.

The quantified costs also do not include the social costs of emissions of pollutants not covered by cap-and-trade programs. In particular, the costs do not include the potential adverse effects of particulate matter and mercury emissions. These costs could be positive or negative depending upon the net effect of changes at Merrimack and changes related to replacement generation.

Parasitic and efficiency losses due to the electricity needed to operate a fish protection alternative at Merrimack Station (from 2015 to 2035 in our analysis) would tend not to affect Merrimack fuel use, and thus overall emissions at Merrimack. But emissions could increase due to the increased generation from other power plants to replace the electricity that would have otherwise been provided to the grid by Merrimack Station. Detailed electricity system modeling would be required to know the sources of this replacement electricity. If the replacement generators use fossil-fuel to produce electricity—which is most likely—the replacement generation would increase the social costs of the cooling water intake alternatives.

The situation is different for the construction outage power losses because a decrease in emissions from Merrimack would offset the increase in emissions from replacement power. If the emissions rates of the replacement generation are lower than those from Merrimack Station, the social costs of cooling towers would be somewhat lower than our estimates.

These considerations indicate that adding the costs of air emissions to our analysis would result in increased costs for the CWW screens and the Gunderboom MLES. (Ristroph screens and Multi-Disc screens would not be affected because they do not incur power costs.) For the cooling tower, the impact on total costs could be positive or negative depending primarily on the average emissions rates of replacement generation relative to emission rates for Merrimack. We would not expect these costs—either positive or negative—to be significant relative to the overall costs for any of the fish protection alternatives.

#### d. Other Adverse Effects Associated with Cooling Towers

There are several additional non-quantified costs associated with the cooling towers.

§ *Noise*. Construction and operation of the cooling tower and related infrastructure would generate noise, with possible negative impacts on surrounding areas.

§ *Visual impacts of tower*. The cooling tower would be a large structure—which could have negative aesthetic effects.

§ *Fogging and icing*. The plume discharged from the cooling tower could have a negative impact due to the formation of fog and ice on nearby roads.

Quantification of these effects would increase estimated costs for the cooling tower alternative.

#### e. Summary and Implications of Non-Quantified Costs

For each of the categories of non-quantified costs discussed in this section—with the sole possible exception of air emissions costs for the cooling tower alternative—including unquantified costs would tend to increase the social cost of cooling water intake alternatives. Consideration of these non-quantified costs thus tends to reinforce our basic conclusion that none of the cooling water intake alternatives analyzed in this study has net benefits.

### 2. Qualitative Assessments of Non-Quantified Benefits

Our benefits assessment considers the relevant benefit categories described both in the EPA *Guidelines* (EPA 2010) and in the §316(b) environmental and economic benefits analysis replacement rule for existing facilities (EPA 2011c), and quantifies the relevant benefits categories that are most significant. Several other benefit components included in these two sets of documents are not included in the quantified benefits because we judged them either to be irrelevant or unlikely to be significant relative to the benefits that are quantified.

Table 28 summarizes potential benefit categories—adapted from the categories included in the analyses supporting the EPA §316(b) draft rule—and explains how we assessed each one for purposes of our benefits assessment.

#### a. Market Benefits

As noted, we understand that the fish protection alternatives at Merrimack would not lead to additional commercial catch and thus we quantify the commercial benefits at zero. To the extent that some of the additional catch would be made by commercial fishermen, overall benefits would be lower than we calculate. We value all the increases in fish gains at recreational values per pound, which are greater than ex vessel commercial values. This implies that we may have overestimated direct benefits.

We assessed the other categories of potential subcategories of market goods in Table 28 and concluded that none would be significant relative to the benefits that we calculate for the various fish protection alternatives. Since there are no increases in commercial landings, there should be no related increases in equipment sales, rental and repair, no related increases in bait and tackle sales, no increases in consumer market choices, and no increases in choices in restaurant meals (although there are independent reasons to expect that these other subcategories would not be significant). We would not expect the changes in fish populations in Hooksett Pool to lead to any significant increases in property values near the water or any significant increases in ecotourism.

**Table 28. Summary Assessment of EPA §316(b) Major Benefit Categories**

| Benefit Categories | Assessed for Significance? | Monetized? | Notes |
|---|---|---|---|
| **Market Goods, Direct and Indirect Use** | | | |
| Increased commercial landings | Yes | Yes | Assumed no commercial fishing |
| Increases in: | | | |
| Equipment sales, rental, and repair | Yes | No | Assessed and determined not to be significant |
| Bait and tackle sales | Yes | No | Assessed and determined not to be significant |
| Consumer market choices | Yes | No | Assessed and determined not to be significant |
| Choices in restaurant meals | Yes | No | Assessed and determined not to be significant |
| Property values near the water | Yes | No | Assessed and determined not to be significant |
| Ecotourism | Yes | No | Assessed and determined not to be significant |
| **Nonmarket Goods, Direct Use** | | | |
| Improved value of recreational fishing | Yes | Yes | Measured by recreational fish benefits |
| Improved value of subsistence fishinig | Yes | No | Assessed and determined not to be significant |
| Increase in recreational fishing participation | Yes | No | Assessed and determined not to be significant |
| **Nonmarket Goods, Indirect Use** | | | |
| Increase in value of boating, scuba-diving, and near-water recreational experience | Yes | No | Assessed and determined not to be significant |
| Increase in boating, scuba-diving, and near-water recreation participation | Yes | No | Assessed and determined not to be significant |
| **Nonuse Goods** | | | |
| Increase in nonuse values such as existence, altruism, and bequest | Yes | No | Assessed and determined not to be significant |

Source: Categories derived from EPA 2011c. Other information based on NERA analysis as explained in text.

### b. Non-market Direct Use Benefits

The non-market recreational use benefits are included in our estimates. We are not aware of any subsistence fishing related to Hooksett Pool catch and even if some of the recreational catch would qualify, there are several reasons why the change in benefits would be insignificant (i.e., the fraction of the additional fish caught that would be for subsistence is likely to be small and any difference in the value placed on additional fish catch may not be significant). We also judged the effect of any change in recreational participation to be insignificant. To the extent the increased participation is reflected in the increased recreational catch, the value is already included in the calculations. We would not expect any effect that was not reflected in the increased catch to be significant (e.g., those attracted to the Pool by the additional catch who do not actually catch any fish).

### c. Non-market Indirect Use Benefits

As noted above, the indirect use benefits monetized as part of our analysis includes the value of changes in forage fish species that serve as food sources (i.e., contribute to the survival and weight gain) for recreational species.. The two categories listed in Table 30 relate to increases in both the activity and the value associated with boating, scuba-diving, and near-water recreational experiences (which would include observing fish or watching aquatic bird fish or catch aquatic invertebrates). We see no reason to believe that the increases in the numbers of the various fish species at the Hooksett Pool would have any effect on the participation rates or values of any of these activities.

### d. Non-use Benefits

As noted above and discussed in more detail in Appendix B, we assessed the potential for non-use benefits and concluded that such benefits are not likely to be significant and thus not useful to quantify, particularly given the substantial costs that would be associated with developing reliable estimates. There seems no reason to believe that the gains in populations of the various species at Hooksett Pool due to the fish protection alternatives would lead to significant values related to existence, altruism, bequest or appreciation of ecological services apart from human uses or motives.

### e. Summary and Implications of Non-quantified Benefits

We conclude that none of these non-quantified benefit categories, individually or collectively, would be large enough to reverse the basic conclusion above that none of the cooling water intake alternatives at Merrimack Station would generate benefits greater than the costs. For those non-quantified benefits to make a material difference they would have to be many times larger than the quantified benefits. Indeed, there are various conservative assumptions in calculating the quantified benefits that mean that the *likely* benefits would be smaller than the values developed in this study. Given the large differences in costs and benefits of the cooling water intake alternatives analyzed above—particularly for the cooling tower alternative—we conclude that the consideration of non-quantified benefits would not have a material impact on the principal conclusions of our analysis regarding the net costs of fish protection alternatives at Merrimack.

# VI. Uncertainty Analyses

The quantitative benefit-cost results presented thus far reflect our “base-case” results. The estimates of the individual components of costs and benefits are based on sound economic methods using detailed biological and engineering information.

This section discusses uncertainties in the underlying information and provides sensitivity analyses for two key parameters related to the cost and benefit assessments. We begin by discussing the role of uncertainty analysis in benefit-cost studies and the reasons for selecting the two factors for analysis. We then present results from sensitivity analyses related to these two key factors: (1) the capacity factor for future operation of Merrimack Station: and (2) the discount rate used to convert streams of benefits and costs into present value terms.

## A. Uncertainty Analysis in Benefit-Cost Analysis

### 1. General Considerations

Economists and policy analysts have long recognized that benefit-cost analyses, no matter how careful and thorough, inevitably are subject to uncertainty because such analyses comprise multiple components, at least some of which cannot be estimated with certainty. For example, in this case the impingement and entrainment estimates contain some uncertainty because of underlying biological study design, sampling data, and modeling assumptions, all of which are inherently variable. Actual costs may differ from engineering cost estimates for various reasons, including revisions during the detailed design stage, unexpected changes in the prices of components, and unanticipated conditions discovered during construction.

The EPA *Guidelines for Preparing Economic Analysis* emphasizes the importance of uncertainty analysis and ways in which uncertainty can be addressed. According to the *Guidelines*, “Every analysis should address uncertainties resulting from the choices the analyst has made” (EPA 2010, p. 11-11). EPA stresses the importance of assessing and describing uncertainty in economic analyses and recommends using sensitivity analyses on key variables when possible, which “allows the reader to assess the importance of the assumptions made for the central case” (EPA 2010, p. 11-11).

EPA’s *Guidelines* stress the importance of accounting for uncertainty, but also recognize that consideration of all possible uncertainties is not possible. As a result, uncertainty analyses should focus on the most critical uncertainties, those most likely to make a material difference to decision makers:

> Because performing an alternative analysis on all the assumptions in an analysis is prohibitively resource intensive, the analyst should focus on the assumptions that have the largest impact on the final results of the particular analysis (EPA 2010, p. 11-11).

## 2. Explanations for Developing Uncertainty Analyses for Capacity Factors and Discount Rates

We have focused on the uncertainty related to two key factors: (1) the capacity factor for future operation of Merrimack Station: and (2) the discount rate used to convert streams of benefits and costs into present value terms. Although there are other uncertain parameters related to the biological, engineering and economic information (e.g., baseline impingement and entrainment, effectiveness and costs of the various fish protection alternatives, values that recreational fishermen place on additional catch), these two factors both seem important. It would of course be possible to develop additional sensitivity analyses.

### a. Importance of Merrimack Capacity Factors

As noted above, our analyses assume a constant 76.1 percent capacity factor for Merrimack Station. This estimate is based upon the average capacity factors of the two generating units in 2009, weighted by the total capacity of the two units.

The future capacity factor at Merrimack Station could be significantly different from the average 2009 level for a variety of reasons. Future Merrimack generation will be determined in part by the relative cost of coal-fired and other generation, notably natural gas. Natural gas prices have historically been quite variable, leading to changes in the extent to which coal units are dispatched at different time periods (see EIA 2011a). Large changes in the relative costs of coal-fired and natural gas-fired generation could lead to increases or decreases in the utilization of the Merrimack Station generation units. In addition, new environmental regulations have the potential to affect generation costs and thus future utilization levels at Merrimack Station. To provide an indication of the significance of future capacity utilization, we develop estimates for 50 percent capacity utilization and 100 percent capacity utilizations, values that tend to bound (symmetrically) the 76. 1 percent capacity factor used in the base case results.

### b. Importance of the Discount Rate

The discount rate affects the calculations of the present values of both costs and benefits. The EPA *Guidelines* (EPA 2010) suggest that present values should be calculated using both an intra-generational real discount rate based on the consumption rate of interest (2-3 percent), as well as a discount rate based on the average real pre-tax real rate of return (7 percent). OMB’s circular on regulatory analysis recommends using 7 percent but suggests that a higher rate of 10 percent may also be appropriate (OMB 2003).

Based upon this guidance from EPA and OMB, we have performed sensitivity analyses using discount rates of 3 percent and 10 percent to complement the base case calculations using a 7 percent discount rate.

## B. Benefits, Costs and Net Costs Using Alternative Capacity Factors

Table 29 displays the total benefits and costs of each fish protection alternative for the "base case" of a 76.1 percent capacity factor and the two sensitivity cases using capacity factors of 50 percent and 100 percent.

**Table 29. Estimated Costs and Benefits of Fish Protection Alternatives for Various Capacity Factors (Thousands 2010$)**

| | Costs | Benefits | Net Costs | Δ Net Costs |
|---|---|---|---|---|
| *Base Case (76.1% capacity factor)* | | | | |
| Ristroph Screens | $1,576 | $11 | $1,564 | --- |
| Multi-Disc Screens | $2,624 | $14 | $2,610 | --- |
| CWW Screens | $7,901 | $81 | $7,820 | --- |
| Gunderboom MLES | $17,248 | $82 | $17,166 | --- |
| Cooling Towers | $98,955 | $102 | $98,854 | --- |
| *50% capacity factor* | | | | |
| Ristroph Screens | $1,576 | $8 | $1,568 | $4 |
| Multi-Disc Screens | $2,624 | $9 | $2,615 | $5 |
| CWW Screens | $7,864 | $53 | $7,811 | ($9) |
| Gunderboom MLES | $17,210 | $54 | $17,157 | ($9) |
| Cooling Towers | $94,177 | $67 | $94,110 | ($4,743) |
| *100% capacity factor* | | | | |
| Ristroph Screens | $1,576 | $15 | $1,561 | ($4) |
| Multi-Disc Screens | $2,624 | $19 | $2,606 | ($4) |
| CWW Screens | $7,935 | $106 | $7,829 | $9 |
| Gunderboom MLES | $17,282 | $107 | $17,175 | $9 |
| Cooling Towers | $103,331 | $134 | $103,197 | $4,344 |

Note: Entries are present values (discounted at 7 percent) expressed in thousands of constant 2010 dollars.
Source: NERA calculations as explained in text.

### 1. Results for Different Capacity Rates

Changing the assumed capacity factors has two opposing effects on the net cost figures. Lowering the capacity factor reduces the required replacement energy costs and therefore reduces the total social costs of each alternative that requires replacement energy (which includes all of the alternatives except the Ristroph screens and the Multi-Disc screens).

In contrast, lowering the capacity factor decreases the intake of cooling water, which decreases baseline impingement and entrainment. The implication of the lower baselines is that the reductions in impingement and entrainment are smaller for each fish protection alternative (i.e., the same percentage reduction in impingement and entrainment results in fewer saved fish when the baseline is lower).

The relative magnitude of these two opposing effects determines how net costs are affected by a change in capacity factors. For the Ristroph and Multi-Disc screens, a change in the capacity factor does not lead to a change in social costs, so the change in benefits fully determines the effect on net costs. For the CWW screens, Gunderboom MLES and Cooling Towers, a change in the capacity factor leads to a change in benefits, but the table above shows that this effect is outweighed by the larger change in total costs. Therefore, a decrease (increase) in the assumed capacity factor will lead to an increase (decrease) in net costs for the Ristroph screens and Multi-Disc screens, and a decrease (increase) in net costs for the CWW screens, Gunderboom MLES and Cooling Towers.

### 2. Implications of the Sensitivity Results

Uncertainty regarding the future capacity factor for Merrimack does not have any appreciably effect on the costs and benefits—and thus the net costs—of fish protection alternatives other than the cooling tower alternative. Even for cooling towers, changing the capacity factor from 76.1 percent to 50 percent would reduce the net costs by less than 5 percent. Thus, although future capacity factors are uncertain, this uncertainty would not affect the principal conclusion that the social costs are much greater than the social benefits for the fish protection alternatives. Put another way, this conclusion is robust with respect to uncertainty on the future capacity factor at Merrimack Station.

## C. Benefits, Costs and Net Costs Using Alternative Discount Rates

Table 30 provides estimates of the costs, benefits, and net costs of the five fish protection alternatives for the base case discount rate of 7 percent and the two sensitivity cases using discount rates of 3 percent and 10 percent.

### 1. Results for Different Discount Rates

For all alternatives, a 3 percent discount rate results in larger net costs than under the base case results (i.e., the fish protection alternatives appear to be less attractive with a 3 percent discount rate than a 7 percent discount rate). This result may seem counterintuitive, because projects with large up-front capital costs and benefits that extend over many years tend to have larger net benefits at lower discount rates. In this case, however, the costs are so much greater than benefits for all alternatives that a lower discount rate increases the present value of the costs by more than it increases the present value of the benefits, despite the fact that a majority of the costs occur earlier in the projection period than do the benefits.

As shown in the bottom section of the table, increasing the discount rate to 10 percent reduces the net costs of all the alternatives compared to the 7 percent discount rate. This reduction in net costs reflects the large imbalance between costs and benefits. Despite the majority of the costs taking place before the benefits, the present value of net costs still decreases with a higher discount rate because the decrease in present value costs is larger than the decrease in present value benefits.

## 2. Implications of the Sensitivity Results

The net costs of various fish protection alternatives—particularly cooling towers—change substantially under different discount rates. For cooling towers, the net costs range from about $89 million under a 10 percent discount rate to $117 million using a 3 percent discount rate. Despite these differences, however, our principal conclusion regarding cooling towers (and the other fish protection alternatives) is robust—costs exceed benefits by a substantial margin under all three discount rates.

**Table 30. Estimated Costs and Benefits of Fish-Protection Alternatives for Various Discount Rates (Thousands 2010$)**

| | Costs | Benefits | Net Costs | Δ Net Costs |
|---|---|---|---|---|
| *Base Case (7% discount rate)* | | | | |
| Ristroph Screens | $1,576 | $11 | $1,564 | --- |
| Multi-Disc Screens | $2,624 | $14 | $2,610 | --- |
| CWW Screens | $7,901 | $81 | $7,820 | --- |
| Gunderboom MLES | $17,248 | $82 | $17,166 | --- |
| Cooling Towers | $98,955 | $102 | $98,854 | --- |
| *3% discount rate* | | | | |
| Ristroph Screens | $1,680 | $18 | $1,662 | $98 |
| Multi-Disc Screens | $2,798 | $22 | $2,776 | $166 |
| CWW Screens | $8,786 | $125 | $8,661 | $840 |
| Gunderboom MLES | $23,808 | $127 | $23,681 | $6,515 |
| Cooling Towers | $117,479 | $159 | $117,321 | $18,467 |
| *10% discount rate* | | | | |
| Ristroph Screens | $1,505 | $9 | $1,496 | ($68) |
| Multi-Disc Screens | $2,506 | $11 | $2,495 | ($115) |
| CWW Screens | $7,393 | $60 | $7,333 | ($488) |
| Gunderboom MLES | $14,321 | $61 | $14,260 | ($2,906) |
| Cooling Towers | $89,543 | $76 | $89,467 | ($9,386) |

Note: Entries are present values (discounted at 7 percent in the base case) expressed in thousands of constant 2010 dollars.

Source: NERA calculations as explained in text.

# VII. Overall Conclusions

This report provides an economic assessment and supplementary information to the analyses prepared by the EPA regarding the cooling water intake requirements in the draft NPDES permit for Merrimack Station. In particular, we evaluate the social costs and benefits of five fish protection alternatives at Merrimack and reach the following overall conclusions.

- None of the fish protection alternatives we considered at Merrimack Station passes a social benefit-cost test, because the costs for all five alternatives are substantially greater than the benefits.

- This conclusion does not change if one considers the factors excluded from the quantitative monetary assessments or the effects of uncertainties regarding future Merrimack capacity factors or the discount rate used to calculate present values.

- The net costs differ a great deal among the alternatives. The present values of the net costs range from about $1.6 million for Ristroph screens to about $98.9 million for Cooling Towers.

- The differences in net costs are even greater when the incremental benefits and incremental costs are compared as one considers choosing increasing costly alternatives. Selecting Cooling Towers as BTA rather than CWW screens would mean that society would be paying about $4,300 in costs for every dollar of additional benefit.

These results lead to the conclusion that the Cooling Tower alternative is not BTA at Merrimack Station based upon the benefit-cost yardsticks used by EPA in the draft permit, because its costs are “wholly disproportionate” and “significantly greater” than its benefits by any reasonable definition of those terms. Of the five alternatives we considered (which does not include the status quo, which has net costs equal to zero by definition), the Ristroph screens alternative has the lowest net costs and are therefore would be the most attractive option for BTA at Merrimack Station based upon the preliminary benefit-cost results (although, as noted above, it would be useful to develop additional information to provide a more complete comparison of the Ristroph and Multi-Disc screen alternatives).

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# Appendix A. New Hampshire Wholesale Electricity Price Projections

This appendix provides information on the wholesale electricity price projections that were used to value the cost of replacement energy for fish-protection alternatives at Merrimack Station. As discussed in the main report, power output at Merrimack Station would be reduced during construction outages and on an ongoing basis due to parasitic losses and efficiency losses. This appendix displays the methodology for estimating the costs of the additional energy that would be needed to replace the energy from Merrimack Station.

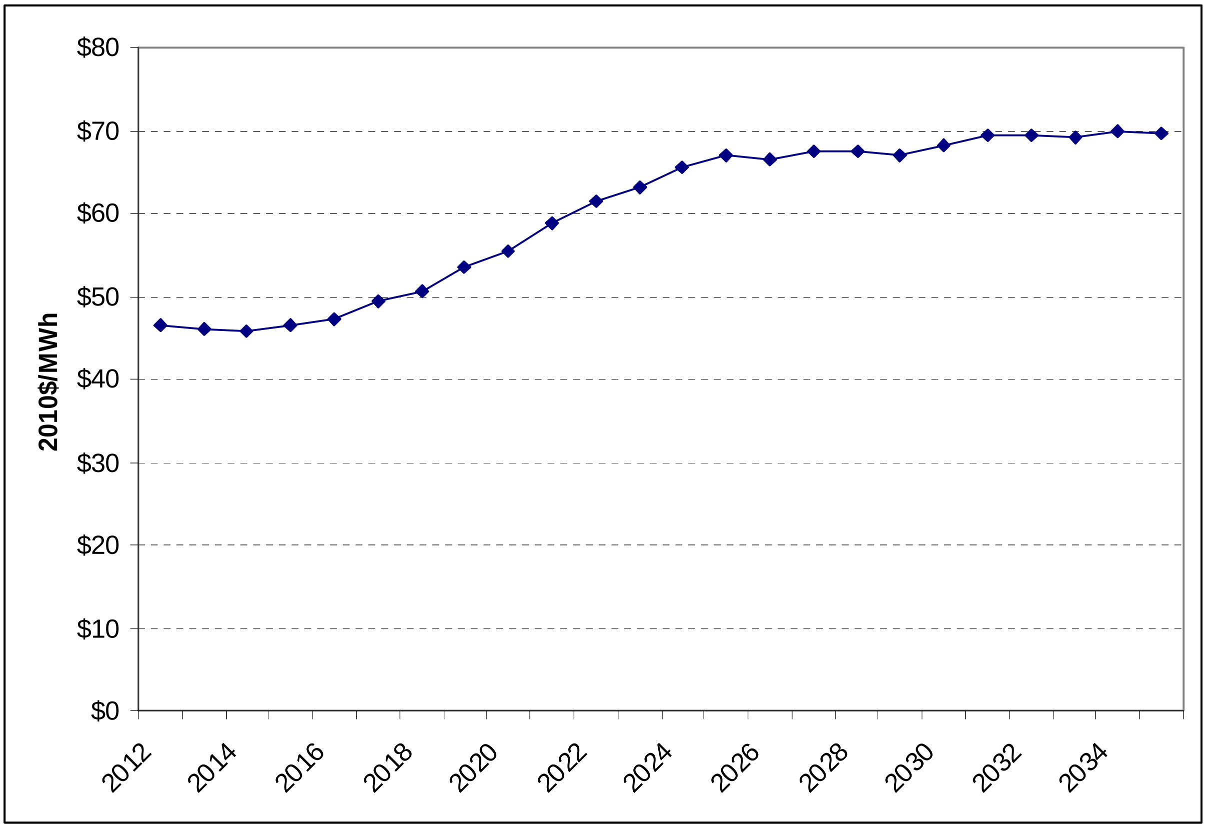
The electricity price projections used to value the cost of replacement energy at Merrimack Station are New Hampshire forecasted monthly wholesale prices from 2012 to 2035. This appendix describes the methodology for developing these electricity price projections and presents the results.

## A. Methodology

The methodology for developing New Hampshire wholesale electricity price projections is based on scaling historical prices from New England's Independent System Operator ("ISO-NE") and projections of New England annual average prices from the U.S. Energy Information Administration's (EIA) National Energy Modeling System (NEMS). In particular, the methodology uses the historical prices from ISO-NE by region—including prices for New Hampshire—to scale the annual NEMS projections for New England and thereby create price projections for New Hampshire in each month and year of the analysis period.

We base these price projections on NEMS results for *Annual Energy Outlook* (*AEO*) *2011* (EIA 2011), which EIA published as its baseline projections for national and regional energy prices and quantities through 2035. Figure A-1 shows the NEMS projections of average annual wholesale electricity prices for the New England region. As shown in Figure A-1, average annual New England wholesale electricity prices increase from approximately $48/MWh (2010$) in 2012 to $70/MWh in 2035.

**Figure A-1. Projected Average Annual New England Wholesale Electricity Prices**



Source: NEMS (EIA 2011)

To scale the New England average annual wholesale electricity prices in Figure A-1 to New Hampshire, we multiplied them by the average historical ratio of New Hampshire wholesale electricity prices to New England electricity prices. We used hourly real-time ISO-NE prices from 2006 to 2010 to calculate this ratio. The average ratio of hourly wholesale electricity prices in New Hampshire to hourly wholesale electricity prices in New England as a whole is 0.98.

To scale the resulting average annual New Hampshire wholesale electricity prices by month of the year, we multiplied them by historical ratios of average monthly New Hampshire prices to average annual New Hampshire prices. As above, we used hourly real-time ISO-NE prices from 2006 to 2010 to calculate these ratios. As shown in Table A-1 , the ratios of average monthly to average annual New Hampshire wholesale electricity prices range from 0.92 in March to 1.18 in January.

**Table A-1. Ratios of Monthly to Annual New Hampshire Electricity Prices**

| Month | Ratio |
|---|---|
| January | 1.18 |
| February | 1.07 |
| March | 0.92 |
| April | 0.93 |
| May | 1.00 |
| June | 1.00 |
| July | 1.06 |
| August | 1.04 |
| September | 0.85 |
| October | 0.84 |
| November | 0.87 |
| December | 1.14 |

Note: Ratio of average monthly New Hampshire to average annual New Hampshire electricity prices.
Source: NERA calculations based on ISO-NE historical data (ISO-NE 2012)

## B. Price Projections

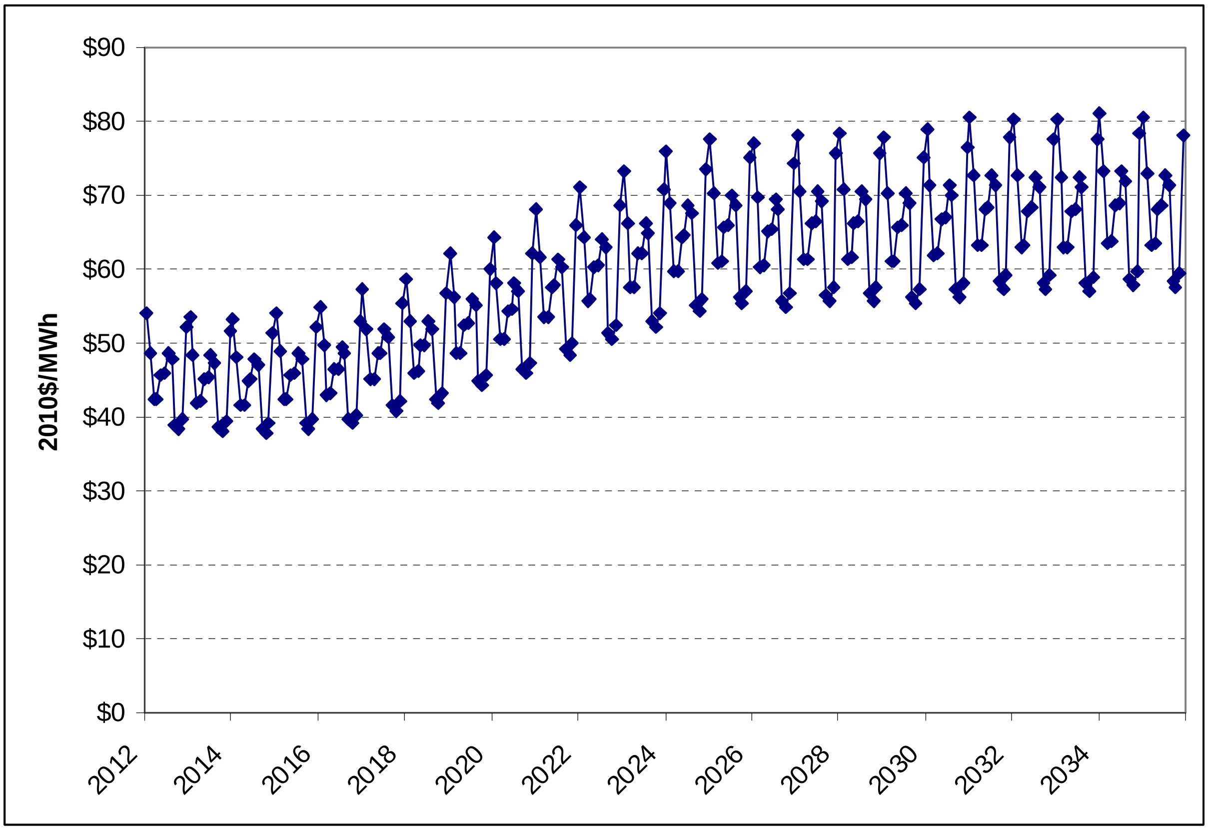
Table A-2 and Figure A-2 show the resulting average monthly wholesale electricity price projections for New Hampshire. The prices exhibit the monthly patterns shown in Table A-1 and the long-range trends in Figure A-2.

**Table A-2. Monthly New Hampshire Wholesale Electricity Prices (2010$/MWh)**

| | 2012 | 2015 | 2020 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|
| January | 53.94 | 53.12 | 64.31 | 77.57 | 78.98 | 80.63 |
| February | 48.77 | 48.03 | 58.16 | 70.15 | 71.42 | 72.92 |
| March | 42.32 | 41.68 | 50.46 | 60.87 | 61.97 | 63.27 |
| April | 42.39 | 41.75 | 50.55 | 60.97 | 62.08 | 63.38 |
| May | 45.64 | 44.95 | 54.43 | 65.65 | 66.84 | 68.24 |
| June | 45.83 | 45.14 | 54.65 | 65.91 | 67.11 | 68.51 |
| July | 48.69 | 47.95 | 58.05 | 70.02 | 71.29 | 72.79 |
| August | 47.82 | 47.09 | 57.02 | 68.77 | 70.02 | 71.49 |
| September | 39.05 | 38.46 | 46.56 | 56.16 | 57.18 | 58.38 |
| October | 38.44 | 37.86 | 45.83 | 55.28 | 56.28 | 57.46 |
| November | 39.72 | 39.12 | 47.36 | 57.12 | 58.16 | 59.38 |
| December | 52.16 | 51.37 | 62.20 | 75.02 | 76.38 | 77.98 |

Source: NERA calculations as explained in text

**Figure A-2. Monthly New Hampshire Wholesale Electricity Prices**



Source: NERA calculations as explained in text

## C. References

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# Appendix B. Non-Use Benefits Assessment

As noted in Chapter IV, EPA's categorization of potential benefits includes benefits not associated with any direct use. These benefits—termed non-use benefits—may arise if individuals value the change in an ecological resource without the prospect of using the resource or enjoying the option to use the resource in the future.

This appendix provides the methodology and information used to assess potential non-use benefits from fish protection alternatives at Merrimack.

## A. EPA Guidelines and Non-Use Values

The EPA *Guidelines* provide a definition of non-use value and the motivations that can lie behind non-use values.

> Non-use value is the value that individuals may attach to the mere knowledge of the existence of a good or resource, as opposed to enjoying its direct use. It can be motivated for a variety of reasons, including bequest values for future generations, existence values and values of paternalistic altruism for others' enjoyment of the resource. (U.S. EPA 2010, p. xiii

Although this definition provides some sense of the circumstances that might give rise to non-use values it does not provide much guidance on when such values are likely to be important. Non-use benefits are difficult (and expensive) to estimate because estimating non-use benefits requires the use of "stated preference" surveys that are complicated and that are expensive and time consuming to conduct correctly. As the EPA *Guidelines* point out,

> Considering the challenges in conducting reliable stated preference valuation studies even for well-defined and familiar commodities (described in detail in Section 7.4.2), this compounds the extra complications already discussed. (U.S. EPA 2010, p. 7-20)

The need to rely upon "challenging" valuation methods to develop reliable estimates of non-use benefits suggests that it is important to first determine whether non-use benefits are likely to be important in order to avoid committing to an expense analysis that might not provide important information.

## B. Evaluation of Potential Importance of Non-Use Benefits Using Criteria in the Economic Literature

The economic literature on non-use valuation provides guidance on situations in which non-use values are likely to be important. In his well-regarded text on measuring environmental and resource values, Freeman (2003) reviews the literature on non-use values, considering the situations in which non-use values are likely to be important. He concludes by noting that, while the literature is unresolved on this issue, non-use values are likely to be important when the resource in question is special or unique and the loss or injury is irreversible (or subject to a prolonged recovery):

> Another important question is, when are nonuse values likely to be important? The long literature on nonuse values emphasizes the ***uniqueness or specialness of the resource in question*** and the ***irreversibility of loss or injury***. For example, economists have suggested that there are important nonuse values in preserving the Grand Canyon in its natural state and in preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes. Moreover, the literature does not suggest that nonuse values are likely to be important where recovery from an injury is quick and complete, either through natural processes or restoration (Freeman 2003, pp. 156-157, emphasis added).

### 1. Importance of Resource Uniqueness

Freeman's review of this literature suggests two operative criteria for evaluating whether non-use value for fish protection is likely to be significant:

1. The resource is unique; and

2. The loss would be irreversible or subject to a long recovery period.

If *both* of these criteria are not met, Freeman (2003) suggests that the non-use values are likely not to be important.

We focus on the issue of whether or not the resources associated with fish protection benefits at Merrimack are unique, as Freeman considers this term. The second criterion—whether the effect would be irreversible or subject to a long recovery period—would not be relevant if the resource affected were not unique. Note that the issue is not whether or not the Hooksett Pool or the Merrimack River are unique, but rather whether or not the biological benefits associated with the various fish protection benefits at Merrimack are unique.

To develop conclusions regarding the nature of the potential non-use benefits at Merrimack, we consider three considerations:

§ Whether the resources at Merrimack include threatened and endangered species;

§ Whether the resources at Merrimack include federally-mandated species; and

§ Whether the species at Merrimack represent subpopulations of widely dispersed wildlife species.

### 2. Threatened and Endangered Species

Non-use benefits may be considered important—and the resources at stake could be considered unique—if the fish benefits at Merrimack Station include species classified as threatened or endangered by the National Marine Fisheries Service ("NMFS") or the United States Fish and Wildlife Service ("USFWS"). The EPA reviewed the information provided by both of these agencies regarding currently protected species and concluded that there are "no federally-listed endangered or threatened species present in the area of the Merrimack River where Merrimack Station discharges pollutants and withdraws water for cooling, namely the Hooksett Pool" (EPA 2011a, p. 57).

We conclude from these observations that there would be no non-use benefits associated with threatened and endangered species at Merrimack.

### 3. Federally-Managed Species

It is possible that non-use benefits could be considered important—and the resource unique—if the fish protection benefits at Merrimack Station included federally-mandated species, although it seems likely that there would need to be other circumstances present (e.g., that the gains represented a significant change in the species population). EPA reports that anadromous Atlantic salmon are the only federally-managed species believed to be present within the Hooksett Pool of the Merrimack River (EPA 2011a, p. 54). Its presence is limited to the period of out-migration during mid-to-late spring when stocked Atlantic salmon smolt head from upstream rearing habitat down to the sea.

EPA notes that Merrimack Station has the potential to impact Atlantic salmon through various ways, two of which are related to the cooling water intake structure:

§ Impinging smolts on the traveling screens of the plant's two cooling water intake structures; and

§ Reducing foraging opportunities through entrainment of aquatic organisms.

EPA notes that Atlantic salmon are not expected to be present in the Hooksett Pond as eggs or larvae, and thus entrainment would not be a major concern (EPA 2011a, p. 55).

EPA's discussion indicates that impingement of Salmon smolts is unlikely for several reasons.

§ Salmon smolts are typically two to three years old before they start their seaward migration;

§ Salmon smolts are known to be strong swimmers;

§ Although Salmon smolts are attracted to flow velocity—and thus could be attracted to the Merrimack Station's intake structure—the river flow velocities are usually higher than the plant's intake velocities during the period when smolts would be likely to be transiting Hooksett Pool (late April to late May); and

- Merrimack Station did not report capturing any Atlantic smolt during its two-year impingement study (June 2005 to June 2007) (EPA 2011a, p. 56).

EPA’s discussion also indicates that reductions in forage opportunities are not likely to be significant. Of the aquatic and terrestrial insects typically eaten by Atlantic salmon smolts, many are benthic and thus less likely to be pulled into the Merrimack intake structures, and it is unlikely that smolts remain in the Hooksett Pond long enough for them to be adversely affected by a reduction in forage opportunities (EPA 2011a, p. 57).

We conclude from this EPA information that there would not be any non-use benefits associated with Atlantic salmon due to the various cooling water intake alternatives at Merrimack Station.

### 4. Other Species

Chapter IV includes a list of the eleven major species represented in impingement and entrainment sampling at Merrimack and information on the number of organisms and adult equivalent fish that could be protected if the Cooling Water alternative (the alternative with the largest benefits) were in place. The maximum number of additional pounds of biological gains is 159 pounds for White Sucker

The question for consideration with regard to these species and the accompanying biological benefits is the following: do the biological gains represent “a subpopulation of a widely dispersed wildlife species”? If so, as Freeman (2003) notes, there is little argument for attributing non-use benefits to the fish protection gains.

We have not undertaken a study of the prevalence of the various species affected at Merrimack. But it seems clear that the gains to each of the species due to Cooling Towers at Merrimack represent a very small fraction of the total for each of these species and that these species are widely dispersed.

In terms of the basic motivations that could give rise to non-use benefits, it seems highly unlikely that individuals would place any significant value in a bequest of these gains to future generations, in knowing of the existence of these gains, or a paternalistic altruism for others’ enjoyment—presumably through recreational fishing gains—of these resources.

We conclude that the fish benefits that would be gained can be characterized as “subpopulations of a widely dispersed wildlife species” and thus according to Freeman (2003) not likely to have important non-use benefits.

## C. Overall Assessment

The assessments in this Appendix all indicate that non-use benefits associated with the fish protection benefits at Merrimack from Cooling Towers (and other alternatives) are not likely to be important and are not worthy of empirical estimation using a contingent valuation study.

- No arguably-unique resources are affected, either in the form of threatened and endangered species or federally-mandated species.

- Each of the resources (species) affected can be characterized as "subpopulation of a widely dispersed wildlife species" and thus according to the economic literature, not likely to have important non-use benefits.

- None of the basic motivations that could give rise to non-use benefits—bequest, existence, or paternalistic altruism—seems at all likely to generate important non-use benefits at Merrimack.

For these reasons, we conclude that non-use benefits are not likely to be important components of the benefits at Merrimack and costly attempts should not be made to develop defensible estimates of their potential magnitudes.

## D. References

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U.S. EPA. 2010. *Guidelines for Preparing Economic Analyses*. Washington, D.C.: Office of the Administrator, December.

U.S. EPA. 2011a. Draft National Pollutant Discharge Elimination System (NPDES) Permit to Discharge to Waters of the United Stated Pursuant to the Clean Water Act (CWA). Boston, MA. September.

# Appendix C. Valuation of Recreational Fishing Benefits

This appendix provides the conceptual background both on non-market valuation methods that are used to value recreational fishing benefits and on the methodology that was used in this study (meta-analysis) to develop estimates of the benefits for Merrimack Station.

## A. Conceptual Background

Access to recreational fishing and fish caught by recreational anglers are classic non-market commodities. Typically, recreational fishing services are not packaged and sold by private producers to private customers (although guide services and the like do exist), so market prices do not exist to indicate the value that recreational anglers place on fishing trips or fish caught. Nevertheless, economists have developed and implemented several methods for valuing recreational fishing benefits.

Recreational anglers do not purchase recreational fishing trips in a formal market, but they certainly value the trips they make, as revealed by the fact that they are willing to incur various identifiable costs in the course of these trips (Lesser, Dodds, and Zerbe 1997). Direct monetary costs of recreational fishing trips include the costs of fishing supplies (bait, for example), gasoline for travel, any boat or shore access fees that might be required, and other expenses. Additionally, the costs of recreational fishing trips include the opportunity cost of time. Time spent traveling to and from the fishing site, as well as time spent fishing at the site itself, is time that could otherwise have been spent on other leisure activities, such as hiking or reading, or on activities that generate monetary value, such as studying or working. Both the direct monetary costs and the opportunity costs of recreational fishing trips indicate that recreational anglers have a willingness to pay (WTP) for recreational fishing. If the recreational anglers did not value these trips, they would not take them. The benefits of a recreational fishing trip, which underlie the willingness to pay for it, come from a variety of trip attributes, including the number of fish caught or harvested (or expected to be caught or harvested) on the trip. Anglers reveal the value that they place on these benefits through their willingness to pay more (travel farther) for fishing in locations with higher catch rates (all else being equal).

One method for estimating anglers’ willingness to pay for recreational fishing opportunities is to ask them directly about their willingness to pay for the opportunities (Freeman 2003). Because this technique involves posing hypothetical questions to survey respondents, methods that use it are commonly called “stated preference,” as opposed to methods that use the more traditional economic techniques of “revealed preference.” Revealed preference methods involve observing how consumers’ preferences for a product are revealed by their market behavior in responses to changes in the price or quality of a product.

Some recreational fishing studies have used the contingent valuation approach, a stated preference valuation technique, but there are reasons to prefer estimates based on actual behavior (i.e., revealed preference) if available (Arrow et al. 1993). In particular, many economists are concerned that estimates of willingness to pay based on contingent valuation studies may not reflect actual values, as survey respondents may not actually behave in accordance with estimates of their WTP based on stated preference techniques (Portney 1994).

Contingent valuation may be useful in some situations where no data are available on actual behavior, but available information on travel costs and catch rates for fishing sites provides the opportunity to use revealed preference methods to estimate the value of recreational fishing benefits. For a particular fishing site, different anglers face different travel costs. Similarly, an individual angler faces different travel costs for different sites that provide different expected catches. The actual decisions made by anglers in response to differences among available sites—the anglers' revealed preferences—provide an economically sound basis for estimating the value of recreational fishing opportunities and of fishing site attributes such as the expected fishing success or catch rate at a site (Freeman 2003).

## B. Travel Costs as Indicators of Willingness to Pay

A large portion of the costs of a recreational fishing trip (in particular, a substantial portion of the costs that determine the choice of fishing site) depend directly on distance traveled. Gasoline costs, other costs associated with vehicle use (wear and tear on a personal vehicle, for example), and the opportunity cost of time spent traveling all depend on distance traveled. Figure C-1 shows an illustrative demand curve for recreational fishing trips at a hypothetical fishing site based on distance from the site. The demand curve illustrates the relationship between the number of trips per year to the site that an average angler is willing to pay for and the cost per trip, as captured by distance traveled. In this example, if the typical angler lived 50 miles from the hypothetical site, he would take 20 trips to the site per year, but if the site were only 30 miles away, he would take 30 trips per year, or 10 more trips.

Different anglers would likely have different individual demand curves for a particular fishing site, but the average demand curve for the site can be estimated statistically using data on trips taken to the site by anglers from varying distances (Tietenberg and Lewis 2008). The dependence of the average demand curve on specific characteristics of anglers (income levels, for example) also can be estimated statistically with the inclusion of relevant additional data about the anglers.

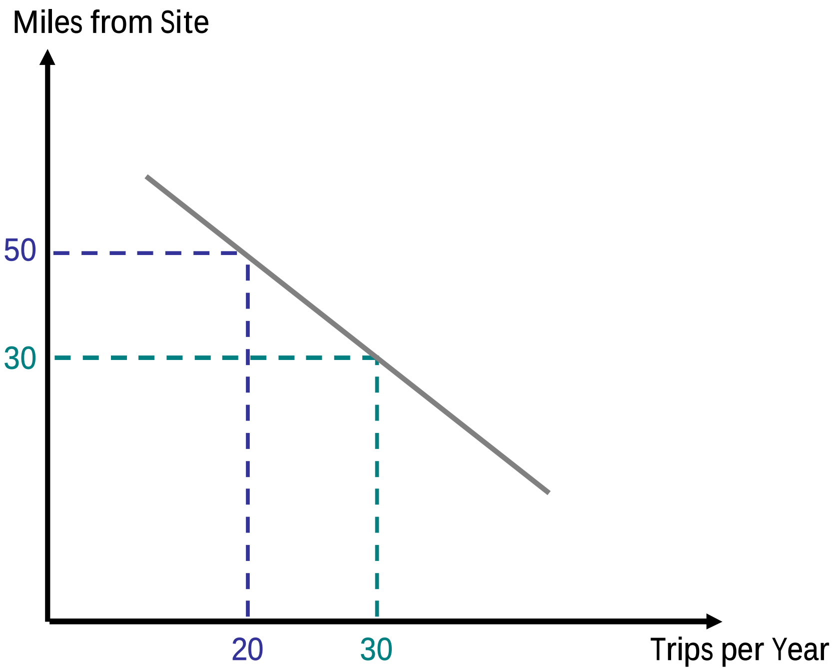

**Figure C-1. Hypothetical Distance-Based Demand Curve for Recreational Fishing Trips**

Travel costs do not capture anglers' complete willingness to pay for recreational fishing trips to a site; by definition, they capture the component of willingness to pay that relates to distance traveled. However, analysis of travel costs does allow the estimation of anglers' responses to changes in variables that influence anglers' willingness to pay. With a dataset of individual fishing trips that includes trips to a variety of fishing sites, one can estimate the relationship between willingness to pay for fishing trips (as reflected by willingness to travel) and a number of other variables, including the expected catch rates at individual fishing sites (i.e., indicators of how many fish an angler might expect to catch per trip).

## C. Illustration of Willingness to Pay for Additional Catch

Figure C-2 shows illustrative demand curves for recreational fishing trips at two hypothetical fishing sites that are identical except in that they offer different (high and low) catch rates. If only the site with the low catch rate were available, the average angler would take 20 trips to the site per year if he lived 50 miles away and 30 trips to the site per year if he lived 30 miles away. If only the site with the high catch rate were available, the average angler would take 25 trips to the site per year if he lived 50 miles away and 35 trips to the site per year if he lived 30 miles away. Viewed differently, the average angler would be willing to pay more (travel further) for a given number of trips to the site with the high catch rate than for the same number of trips to the site with the low catch rate.

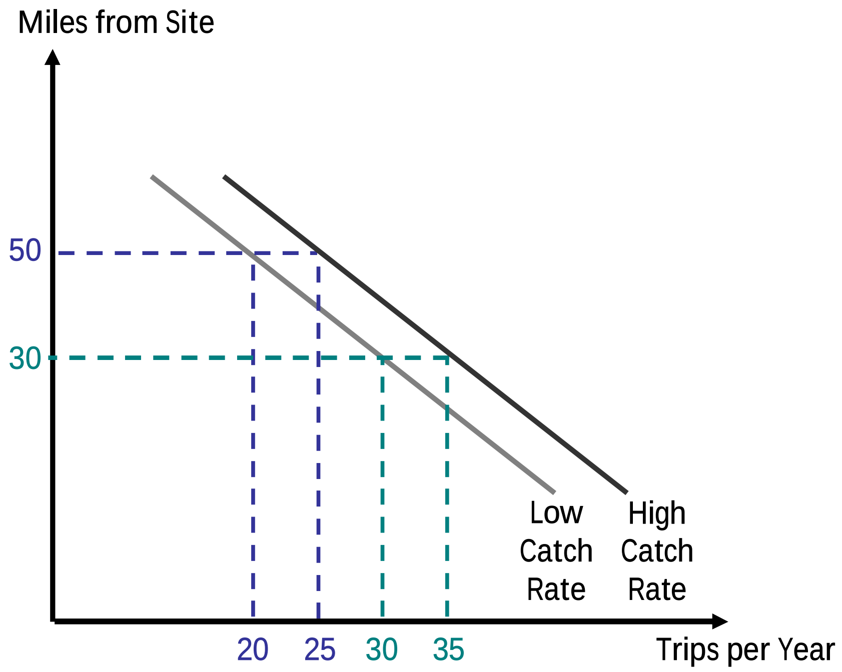

**Figure C-2. Hypothetical Distance-Based Demand Curves for Recreational Fishing Trips to Sites with Low and High Catch Rates**

With access to both hypothetical sites, the average angler would likely make some trips to one site and some to the other. If he lived 30 miles from the site with the low catch rate and 50 miles from the site with the high catch rate, he might do the following: (1) instead of visiting the site with the high catch rate 25 times per year (as he would do if he had no other options), he might visit this site only 20 times and (2) instead of visiting the site with the low catch rate 30 times (as he would do if he had no other options), he might visit the site 10 times per year. In this hypothetical situation, the angler would take 30 total trips per year. To take 30 total trips per year in the least expensive way in this example, the angler would simply take every trip to the nearest site (the site with the low catch rate). Since this hypothetical average angler actually takes 20 trips to the site with the high catch rate, he is expressing a willingness to pay, through a willingness to travel farther, for a higher catch rate.

A statistical analysis of the behavior of anglers faced with choices among fishing sites with different expected catch rates and other attributes can determine empirically how anglers' willingness to pay depends on the catch rate at a site and, therefore, how much anglers would be willing to pay for improvements in the catch rate.

## D. Direct Approaches to Empirical Valuation

Economists have developed two basic empirical approaches to modeling recreational fishing demand: (1) the travel cost model of recreation demand (TCM) and (2) the random utility model (RUM) (Freeman 2003). Using the basic concept that travel costs reflect willingness to pay, both approaches allow the analyst to estimate statistically the values that recreational anglers place on the marginal fish caught.

Note that, like other statistical analyses, the development of valid recreational fishing demand models, whether TCM or RUM, requires careful implementation (Freeman 2003 and Lesser, Dodds and Zerbe 1997). Data on recreational fishing trips generally come from surveys of actual fishing trips, so a sound analysis should ensure that the design and administration of the surveys avoid various types of bias (e.g., sampling bias, non-response bias). Additionally, since travel costs include the opportunity cost of time spent traveling; the analysis should include reasonable assumptions about the value of anglers' time. If these and other considerations (e.g., model specification) are handled appropriately, an analysis using either a TCM or RUM can produce useful valuation estimates that incorporate data on the actual behavior of anglers.

## E. Benefit Transfer Approaches to Empirical Valuation

TCMs and RUMs are the most commonly used *direct* approaches to valuing recreational fishing benefits. These approaches involve collecting primary data from the sites under consideration and constructing detailed statistical models to estimate benefits at those sites. Most benefit-cost analyses of regulations or permitting decisions, however, do not attempt to develop original empirical studies. Instead, they rely on "benefits transfer" methods. Benefits transfer methods involve synthesizing results from pre-existing direct studies of recreational benefits at similar sites into a meaningful valuation estimate for the specific site(s) under consideration. EPA's *Guidelines* (EPA 2010) notes the advantages of the benefits transfer approach:

> Benefit transfer is necessary when it is infeasible to conduct an original study focused directly on the policy case. Original studies are time consuming and expensive; benefit transfer can reduce both the time and financial resources required to develop estimates of a proposed policy's benefits (EPA 2010, p. 7-45).

An original study of the species and area relevant to the recreational fishing benefits evaluated in this study would require the development of an extensive dataset and accompanying data analysis. Because a few previous original studies have estimated values for recreational fishing benefits, the benefits transfer approach is more practicable in this case. The benefits transfer approach allows the filtering of study results based on their quality and relevance.

### 1. Benefits Transfer Methods

EPA's *Guidelines* discuss the alternative benefits transfer methods:

> There are several approaches for transferring values from study cases to the policy case. These include unit value transfers, value function transfers, and non-structural or structural meta-analysis. (EPA 2010, p. 7-46).

A meta-analysis, if feasible, is the most rigorous of the benefits transfer methods. Therefore, in our own assessment, we use the meta-analysis developed the EPA in its 316(b) Phase III Final Rule (2006) to develop estimates for analyzing the potential recreational benefits associated with the proposed fish-protection alternatives. We discuss our approach in more detail below.

### 2. Meta-Analysis Methodology

The objective of a meta-analysis is to combine results from different empirical studies by using statistical methods to fit a base model that is intended to reflect the differences among the study results. A meta-analysis relies on theoretically sound assumptions about the relationship used to fit different study results. For example, estimating the relationship between the value of catching an additional fish and the initial catch rate requires judgment about the general form of the relationship. In this case, one could reasonably assume, in accordance with economic theory, that the marginal value should decrease as the catch rate increases.

Although the studies incorporated in the meta-analysis may have different results for the value placed on additional catch (either per fish or per pound), these differences may arise from widely different circumstances. For example, two studies of recreational fishing benefits may provide different results for the marginal value of an additional fish caught, but the results may reflect differences in the initial catch rate, i.e., the "baseline" catch rate to which the marginal fish caught is additional. The study with the lower marginal value might be based on an area where recreational anglers already catch many fish, while the study with the higher marginal value might be based upon an area where recreational anglers typically catch relatively few fish. In this case, the studies' results would not be inconsistent; they could simply represent different points on a single curve that relates the marginal value of an additional fish caught to the initial catch rate.

A meta-analysis relies, for precision, on the inclusion of multiple study results that must be comparable in measurable ways. Thus a meta-analysis gains from careful translation of study results into comparable inputs. Because the results of any given study are subject to random variation, the statistically fitted curve will typically not perfectly fit the data. Additionally, to the extent that aspects of the included studies differ in ways that are not captured by the assumed meta-analysis relationship, these differences will also prevent the statistically fitted curve from perfectly fitting the data.

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