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Economic Evaluation of Two Entrainment Reduction Technologies at Merrimack Station

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Executive Summary

This report provides an economic assessment of the costs and benefits of installing and operating two cooling water intake structure (CWIS) alternatives at Merrimack Station in relation to EPA's decision to reopen the public comment period for the Merrimack Station NPDES Draft Permit (EPA-Region 1 and NH DES 2017) and EPA's associated "Statement of Substantial New Questions for Public Comment" (EPA-Region 1 2017a). The two CWIS alternatives are: (1) retrofitting Merrimack Station to operate with a closed cycle recirculating cooling water system (CCRS) equipped with a plume-abated mechanical draft cooling tower (plume-abated MDCT); and (2) wedgewire half screens (WWS). These technologies are being considered as alternatives for reducing entrainment mortality at Merrimack Station. We refer to these collectively as Merrimack Entrainment Technology Alternatives.

A. Overview of Methodology and Data

As required under the U.S. Environmental Protection Agency's (EPA) 2014 final rule for existing facilities implementing Section 316(b) of the Clean Water Act (Existing Facilities Rule) (EPA 2014a), we estimate both social costs and social benefits. We develop our social costs and social benefits estimates using the standard economic approach, as described in EPA's *Guidelines for Preparing Economic Analyses*, subsequently *Guidelines* (EPA 2014b), and in the 2014 Existing Facilities Rule.

1. Social Costs Methodology and Data

As noted by EPA in the *Guidelines* (EPA 2014b) and in the Existing Facilities Rule, social costs represent the total burden imposed on the economy from the viewpoint of society (EPA 2014a, p. 48367; EPA 2014b, p. 8-1), rather than any individual stakeholder. The major categories of social costs are typically: (1) capital costs; and (2) annual operating and maintenance (O&M) costs (EPA 2014b, p. 8-8). The Existing Facilities Rule notes three additional categories that should be accounted for in evaluating the social cost of entrainment technology alternatives: (a) energy penalty costs, (b) installation electricity downtime costs, and (c) administrative costs (EPA 2014a, p.48370). Since both installation downtime costs and energy penalty costs relate to changes in Merrimack's electricity output, we refer to them collectively as electricity costs. Thus, to assess the social costs of installing and operating Merrimack Entrainment Technology Alternatives, we calculate costs for the following four categories:

1. *Capital cost*—one-time costs associated with acquiring, constructing, and installing the technologies plus the cost of major replacement;

2. *Operation and maintenance (O&M) costs*—annual recurring costs associated with operation and maintenance of the technologies, with the exception of any costs related to ongoing power losses;

3. *Electricity costs*—the costs to society related to changes in electricity generation and capacity at Merrimack, including the fuel and other costs from replacement power net of any savings at Merrimack; and

4. *Administrative costs*—the costs to Merrimack Station and public agencies to administer the alternatives (including costs of permit applications).

In accordance with the requirements of the Existing Facilities Rule, we also provide estimates of the compliance costs of the Merrimack Entrainment Technology Alternatives in Appendix A. Compliance costs, as defined in the Existing Facilities Rule, are the net costs borne by the facility, and thus do not include expected tax payments or costs borne by others, such as the regulatory agency's administrative costs (EPA 2014a, p.48428).

2. Social Benefits Methodology and Data

As noted by EPA in its Guidelines (EPA 2014b) and in the Existing Facilities Rule (EPA 2014a, p. 48368), social benefits represent the willingness-to-pay of households for the gains attributable to the Merrimack Entrainment Technology Alternatives (*e.g.*, changes in harvestable fish biomass). The major potential categories of benefits for this application are the following:

1. *Commercial fishing benefits*—the monetary value of additional fish harvested in commercial fisheries;

2. *Recreational fishing benefits*—the monetary value of additional fish catch by recreational anglers;

3. *Indirect benefits*—the value of additional forage available to harvested predators that contributes to additional commercial and recreational value; and

4. *Non-use benefits*—the value of the ecological changes that is not based upon potential use (e.g., value of bequests to future generations) (EPA 2014a, p. 48407).

Note that in the context of this report, fish includes finfish and macroinvertebrates.

3. Baseline Scenario

The costs of the proposed Merrimack Entrainment Technology Alternatives evaluated in this study are measured relative to a Baseline Scenario. As discussed in the main report, the Baseline Scenario assumes that, in the absence of the installation of new entrainment controls, the current Station configuration would continue in the future over the time period of our analysis. Accordingly, all costs and benefits estimates are calculated relative to this Baseline Scenario.

B. Summary of Results

1. Comparisons of Benefits and Costs

Table E-1 summarizes our preliminary estimates of the social costs, social benefits, and net social costs (i.e., social costs minus social benefits) for the Merrimack Entrainment Technology Alternatives over the period from 2019 to 2053. (To be consistent with terminology in the Existing Facilities Rule, we refer to discounted values as "net present values.") The results are presented for (real) discount rates of 3 and 7 percent, as required in the Existing Facilities Rule (EPA 2014a, p. 48428).These results indicate that the social costs outweigh the social benefits for both alternatives, with the net costs particularly great for plume-abated MDCT.

Table E-1. Summary of Present Values of Estimated Net Costs of Merrimack Entrainment Technology Alternatives ($2017 thousands)

Technology	Social Costs	Social Benefits	Net Social Costs
3% Discount Rate			
Wedgewire Half-screens	$10,711	$56	$10,655
Plume-abated MDCT	$112,727	$66	$112,662
7% Discount Rate			
Wedgewire Half-screens	$8,674	$29	$8,644
Plume-abated MDCT	$77,105	$33	$77,072

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in thousands of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

Using a discount rate of 3 percent the present value of social costs is about $10.7 million for WWS and about $112.7 million for plume-abated MDCT. In contrast, the estimated present value of social benefits is $56,000 for the WWS and $66,000 for plume-abated MDCT. Net social costs (i.e., social costs minus social benefits) are about $10.7 million for WWS and about $112.7 million for plume-abated MDCT.

Using a discount rate of 7 percent the present value of social costs is about $8.7 million for WWS and about $77.1 million for plume-abated MDCT. The estimated present value of social benefits is $29,000 for the WWS and $33,000 for plume-abated MDCT. Net social costs in present value terms are about $8.6 million for WWS and about $77.1 million for plume-abated MDCT. All results are relative to the current operating configuration at Merrimack Station, which, by definition, has net costs equal to zero.

2. Incremental Net Costs

Table E-2 shows the incremental costs and incremental benefits for each of the two alternatives relative to the alternative with the next lowest costs. For the WWS, the comparisons are to the Baseline Scenario, and thus there is no additional row; for the plume-abated MDCT, the comparisons are to WWS as shown by the additional row. These incremental values are the appropriate comparisons to judge whether or not the added costs of a more expensive alternative is justified by the benefits, as noted in the *Guidelines* (EPA 2014b p. 11-2) and in the economic literature (see, e.g., Boardman et al. 2011). The table also shows the ratio of costs to benefits, showing the dollars of cost per dollar of benefit.

Table E-2. Incremental Analysis of Alternatives of Merrimack Entrainment Technology Alternatives ($2017 thousands)

Technology	Social Costs	Social Benefits	Net Social Costs	Cost-Benefit Ratio
3% Discount Rate				
Wedgewire Half-screens	$10,711	$56	$10,655	192
Plume-abated MDCT	$112,727	$66	$112,662	1,714
-Incremental to Wedgewire Half-screens	$102,017	$10	$102,007	10,081
7% Discount Rate				
Wedgewire Half-screens	$8,674	$29	$8,644	295
Plume-abated MDCT	$77,105	$33	$77,072	2,333
-Incremental to Wedgewire Half-screens	$68,432	$4	$68,428	18,499

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in thousands of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

The comparisons in Table E-2 highlight the enormous disparity between costs and benefits for both of the alternatives, with the disparity particularly stark for the plume-abated MDCT alternative. For the 3 percent discount rate assumption, the plume-abated MDCT provides about $10,000 of additional benefits at an added cost of about $102.0 million; put in terms of the cost-benefit ratio, plume-abated MDCT costs society more than $10,000 in additional costs for every dollar of additional benefits. For the 7 percent discount rate assumption, the plume-abated MDCT provides about $4,000 of additional benefits at an added cost of $68.4 million, meaning that the option cost society roughly $18,000 in additional costs for every dollar of additional benefits.

The comparisons for WWS are not as dramatic, although this alternative also shows a large disparity between social costs and social benefits. As the cost/benefit ratio indicates, for every dollar of benefits, adopting WWS would result in $192 of additional cost under a 3 percent discount rate and $295 of additional cost under a 7 percent discount rate.

C. Implications of Sensitivity Cases and Excluded Categories

We performed some sensitivity analyses to evaluate the robustness of the results to various uncertainties. The results for two discount rates (3 percent and 7 percent) provide one case; as noted above, the principal results do not change under the two cases. We also considered different capacity factors for Merrimack, i.e., how frequently the units would operate in the future—parameters that affect the electricity costs. We also developed qualitative assessments of costs and benefits not included in the monetary values to assess whether omitting these values has a significant effect on the conclusions.

1. Sensitivity to Alternative Capacity Factors

Our analysis uses a “base-case” capacity factor assumption based on monthly average capacity factors by unit at Merrimack over the ten-year period from 2007-2016 (as reported in Enercon

2017). In Chapter V we provide a sensitivity analysis for two alternative capacity factor assumptions as requested by PSNH. Those results indicate that modifying the capacity factor assumption does not change any conclusions regarding the relative costs and benefits of the two Merrimack Entrainment Technology Alternatives.

2. Implications of Excluded Benefit and Cost Categories

Chapter V also includes qualitative assessments of the likely significance of omitted categories from the monetized estimates of social costs and social benefits. This section includes a discussion of omitted cost categories such as cost savings from reduced operation of the existing traveling water screens at Merrimack Station, distributional costs, transitional costs, and transactional costs, as well as a discussion of omitted benefits categories including indirect benefits and non-use benefits. Based on these qualitative assessments, we conclude that incorporation of these additional categories of costs and benefit would not be likely to change the relative costs and benefits of the Merrimack Entrainment Technology Alternatives in any significant way.

We provide a more thorough assessment of non-use benefits in Appendix C. As explained in Appendix C, we conclude that information to develop monetary estimates of non-use benefits is not available and that development of a separate study to estimate such values is not justified. We thus provide a qualitative assessment of non-use benefits. Based on biological information developed in light of economic criteria for assessing the likely significance of non-use benefits, we conclude that non-use benefits are not likely to be significant for both Merrimack Entrainment Technology Alternatives.

D. Conclusions

The following is a summary of the major conclusions of our evaluation of the social costs and social benefits of the two Merrimack Entrainment Technology Alternatives.

- Neither of the two fish protection alternatives we considered at Merrimack Station passes a social benefit-cost test, because the costs for both alternatives are substantially greater than the benefits.

- The net costs differ a great deal among the two alternatives. Using a 3 percent discount rate, the present values of the net costs (i.e., costs minus benefits) are about $10.7 million for WWS and about $112.7 million for plume-abated MDCT. Using a 7 percent discount rate, the net costs are about $8.6 million for WWS and about $77.1 million for plume-abated MDCT.

- The differences in net costs are even greater when the incremental benefits and incremental costs are compared, particularly for plume-abated MDCT. For the 7 percent discount rate assumption, the plume-abated MDCT provides $4,000 of additional benefits at an added cost of $68.4 million, meaning that the option costs society roughly $18,000 in additional costs for every dollar of additional benefits. Under a 3 percent discount rate, selecting plume-abated MDCT over WWS would mean incurring more than $10,000 in costs for every dollar of benefits. For WWS, the comparisons are about $192 of costs per additional dollar of benefit using 3 percent and about $295 of costs per additional dollar of benefit using 7 percent.

- These conclusions regarding the relative size of social benefits and social costs for the two alternatives do not change in any significant way if one considers (a) the discount rate used to calculate present values; (b) the effects of uncertainties regarding future Merrimack capacity factors; and (c) benefit and cost categories not quantified in this study, including non-use benefits.

I. Introduction

This report provides an economic assessment of the costs and benefits of installing and operating two cooling water intake structure (CWIS) alternatives at Merrimack Station in relation to EPA's decision to reopen the public comment period for the Merrimack Station NPDES Draft Permit (EPA – Region 1 and NH DES 2017) and EPA's associated "Statement of Substantial New Questions for Public Comment" (EPA-Region 1 2017a). The two CWIS alternatives are: (1) retrofitting Merrimack Station to operate with a closed cycle recirculating cooling water system (CCRS) equipped with a plume-abated mechanical draft cooling tower (plume-abated MDCT); and (2) wedgewire half-screens (WWS). These technologies are being considered as alternatives for reducing entrainment mortality at Merrimack Station. We refer to these collectively as Merrimack Entrainment Technology Alternatives.

A. Background on 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 108 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 330 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 – Region 1 2011).

Merrimack Station currently utilizes a once-through (or open-cycle) cooling system designed to withdraw a total of up to 287 million gallons per day ("MGD") of water from the Hooksett Pool portion of the Merrimack River (85.7 MGD for Unit 1 and 201.6 MGD for Unit 2), and then to discharge the water back to the river (Enercon 2017).

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 – Region 1 2011, Attachment D, pp. 267-268).

B. Objectives of this Study

The primary objectives of this study are to develop estimates of the social costs and social benefits of the two Merrimack Entrainment Technology Alternatives—as called for in the U.S. Environmental Protection Agency's (EPA) regulation for CWISs at existing power plants under Section 316(b) of the Clean Water Act (Existing Facilities Rule)—and to use these results to evaluate the net benefits (or net costs) of these alternatives. This study develops estimates of social costs called for in 40 CFR Part 122.21(r)(10)(iii) and social benefits called for in 122.21(r)(11). As called for in the Existing Facilities Rule, we also provide estimates of compliance costs in Appendix A.

C. Overview of Cost and Benefit Assessments

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 and then providing qualitative assessments for cost and benefit categories not included in the monetary evaluations.

1. Overview of Cost Assessments

The analysis relies on engineering information developed by Enercon (2017). As required in 40 CFR Part 122.21(r)(10)(iii), we develop estimates of the net present values and annualized values for costs associated with the Merrimack Entrainment Technology Alternatives. The underlying cost information provided by Enercon presumes costs would begin on July 1, 2019 and end on December 31, 2053. The analysis end date reflects the 30-year useful life of the WWS, which would become operational in 2024 (Enercon 2017). We use well-established economic methods to develop our cost estimates, drawing on the requirements in the Existing Facilities Rule as well as guidelines for preparing economic analyses developed by EPA (EPA 2014b, subsequently *Guidelines*), and the U.S. Office of Management and Budget (OMB) (OMB 2003) and the economics literature on cost assessment (e.g., Boardman et al. 2011).

2. Overview of Benefits Assessments

This analysis relies on detailed biological information developed by biological experts at Normandeau Associates (Normandeau 2017). As required in the 40 CFR Part 122.21(r)(11), we develop estimates of the net present values for social benefits associated with the Merrimack Entrainment Technology Alternatives. The underlying information provided by Enercon (2017) indicates that benefits would begin in 2024 and end on December 31, 2053, which reflects the 30-year useful life of the WWS (Enercon 2017). We use well-established economic methods to develop our benefit estimates, drawing on the requirements in the Existing Facilities Rule as well as EPA *Guidelines for Preparing Economic Analyses* (subsequently *Guidelines*) (EPA 2014c), the U.S. Office of Management and Budget (OMB; OMB 2003), and the economics literature on benefit estimation (e.g., Boardman et al. 2011).

D. Overview of Two Merrimack Entrainment Technology Alternatives

As noted, we quantify the costs and benefits of the following two alternatives.

1. *Wedgewire Half-screens (WWS)*. The seasonal use of Wedgewire Half-screens in front of the cooling water intake structure at both generating units

2. *Plume-abated MDCT*. The construction of mechanical draft cooling towers for year-round use in a closed-cycle cooling system for both generating units.[1]

1. Timing Assumptions

Table 1 displays the assumptions we use regarding the timing of the construction and operation of each cooling water intake alternative in our benefit-cost analysis. For the WWS we rely on scheduling information developed by Enercon (2017). For the plume-abated MDCT we rely on timing information developed by Enercon (2017), supplemented by the timing assumptions for closed-cycle cooling outlined in EPA's Substantial New Questions (EPA-Region 1 2017a, p.28). For both alternatives, it is assumed that the initial NPDES permit would be issued by July 1, 2019. Note that PSNH may appeal a decision to install either of the Merrimack Entrainment Technology Alternatives (Enercon 2017). It is assumed that this appeals process would last 42 months and the actual technology-specific construction process for both technologies would not begin until January of 2023 (Enercon 2017).[2] After the appeals process is complete, project duration for each of the technology options would depend on the length of time required for technology-specific permitting, procurement and construction, and any necessary construction outages (Enercon 2017).

Table 1. Construction and Operations Schedule for Merrimack Entrainment Technology Alternatives

Technology	NPDES Permit Date	Project Start Date	Project Completion Date	Operations Start Year	Operations End Year
Wedgewire Half-screens, Unit 1	7/1/2019	1/1/2023	10/31/2023	2024	2053
Wedgewire Half-screens, Unit 2	7/1/2019	1/1/2023	10/31/2024	2025	2053
Plume-abated MDCT	7/1/2019	1/1/2023	5/31/2026	2026	2053

Note: Project duration reflects all activities related to technology installation including permitting, engineering, construction, and construction-related outages. Chapter II provides a more detailed project schedule.

Source: Attachment 2 from Enercon (2017); EPA-Region 1 (2017a).

[1] Our analysis models year-round operation of closed-cycle cooling (rather than seasonal operation) based on the available information developed by Enercon (2017). Modeling seasonal operation of closed-cycle cooling would somewhat alter both the costs and benefits estimates, but would not change our conclusions regarding the relative magnitudes of the costs and benefits of the plume-abated MDCT technology option.

[2] Modifying the assumed 42-month appeals process duration to either a shorter or longer timeframe would not change our conclusions regarding the relative magnitudes of the costs and benefits of the Merrimack Technology Alternatives.

Table 2 presents the expected timing of the construction-related plant outages. The WWS is anticipated to require a six-week outage, which would occur during the last six weeks of construction (Enercon 2017). The Plume-abated MDCT is expected to require a tie-in outage of approximately two months after construction activities are completed (EPA-Region 1 2017a, p.28). As discussed in Chapter II and Appendix A, we assume that the two-month construction outage for the cooling tower alternative would occur in April and May. This assumption is based on the schedule outlined in EPA-Region 1 (EPA 2017a, p. 28), adjusted to reflect EPA's concern that the outage be done in a "shoulder" month (EPA 2017a, p. 26). This assumption also accounts for the engineering specification that the "tie-in would not be possible during the winter months and would need to occur sometimes during the April-October timeframe" (Enercon 2017, p. 9).

Table 2. Construction Outage Schedule for Merrimack Entrainment Technology Alternatives

Technology	Outage Start Date	Outage End Date
Wedgewire Half-screens, Unit 1	9/19/2023	10/31/2023
Wedgewire Half-screens, Unit 2	9/19/2024	10/31/2024
Plume-abated MDCT	4/1/2026	5/31/2026

Note: Note that construction outages are scheduled to align with periods of low Station operation and—for plume-abated MDCT—occur during the April-October timeframe (Encercon 2017). The schedule above adheres to both criteria.

Source: Attachment 2 from Enercon (2017); EPA-Region 1 (2017a), p.28.

2. Baseline Scenario

The social costs and benefits estimates are measured relative to a Baseline Scenario that reflects the future costs if neither of the two entrainment technologies were implemented. In the absence of the installation of new entrainment controls, the study assumes that the costs based upon the current configuration would continue in the future over the time period of our analysis. The current system in place at Merrimack thus represents the "Baseline" conditions for the economic analysis of the Merrimack Entrainment Technology Alternatives.

E. Outline of this Report

The remainder of this report is organized as follows.

- Chapter II provides estimates of the social costs of the Merrimack Entrainment Technology Alternatives including detailed information on the methodologies and data used.
- Chapter III provides estimates of the social benefits of the Merrimack Entrainment Technology Alternatives including detailed information on the methodologies and data used.
- Chapter IV includes comparisons of benefits and costs.

- Chapter V considers the robustness of our results, including two sensitivity cases related to the Station's future operations, as well as a qualitative evaluation of omitted costs and benefits;
- Chapter VI presents our conclusions.
- Chapter VII provides references.
- Appendix A provides compliance cost estimates.
- Appendix B provides information on our methodology for projecting future electricity prices.
- Appendix C provides information on our assessment of non-use benefits at Merrimack Station.

II. Evaluation of Social Costs

This chapter provides information on the social costs for the Merrimack Entrainment Technology Alternatives as required in 40 CFR Part 122.21(r)(10)(iii). We first provide a discussion of the methodologies and data used to estimate the social costs. We then provide an overview of the calculations used to estimate the social costs. This analysis relies on cost data developed by Enercon (2017, 2007[3]), EPA-Region 1 (2017a, 2017b), and PSNH (2017).

A. Methodology for Estimating Social Costs

This section provides information on the methodology used to estimate the costs of the two Merrimack Entrainment Technology Alternatives.

1. Components of Social Costs Estimated in This Study

The major categories of social costs are typically: (1) capital costs; and (2) operating and maintenance (O&M) costs (EPA 2014b, p. 8-8). The Existing Facilities Rule notes three additional categories that should be accounted for in evaluating the social cost of entrainment technology alternatives including energy penalty costs, installation downtime costs, and administrative costs (EPA 2014a, p.48370). Since both installation downtime costs and energy penalty costs relate to changes in Merrimack electricity output, we refer to them collectively as electricity costs. Thus, to assess the social costs of installing and operating Merrimack Entrainment Technology Alternatives, we calculate social costs for the following four categories:

1. *Capital costs:* one-time social costs associated with acquiring, constructing, and installing equipment as well as replacement of major components.

2. *Operation and maintenance (O&M) costs*: recurring social costs associated with operation and maintenance of the equipment, with the exception of any costs related to ongoing power losses.

3. *Electricity costs*: the social costs related to changes in electricity generation and capacity at Merrimack, which include the costs to replace the output net of any cost savings at Merrimack.

4. *Administrative costs*: the social costs incurred by Merrimack and public agencies to administer the alternatives (including costs of permit applications).

2. Discounting of Social Costs

Social costs are discounted at social discount rates, which reflect society's preference for present versus future consumption. We use (real) social discount rates of 3 and 7 percent, as

[3] The 2007 cost estimates this report relies on for plume-abated MDCT were developed by Enercon and provided in a joint-report by PSNH, Normandeau, and Enercon (PSNH et al. 2007).

recommended in the Existing Facilities Rule (EPA 2014a, p. 48367). Based upon the information provided by Enercon, we develop estimates of the net present values and annualized values for costs of the Merrimack Entrainment Technology Alternatives. (To be consistent with terminology in the Existing Facilities Rule, we refer to discounted values as "net present values.") The costs provided to us are assumed to begin on July 1, 2019 and end on December 31, 2053, which reflects the 30-year useful life of the WWS (Enercon 2017).

3. Underlying Cost Data

For the cost analysis we rely on information developed by Enercon as provided in their *Technical Memorandum to Document Technology Cost Inputs for Merrimack Station* (subsequently Technical Memorandum or Enercon 2017). Enercon (2017) includes detailed cost estimates for the WWS technology including information on project schedule, capital costs, O&M costs, and energy penalties. For the plume-abated MDCT, NERA relies on cost information originally developed by Enercon in a joint report with PSNH and Normandeau (PSNH et al. 2007) with various adjustments to account for the impact of the various plant and technological changes over the last decade based on guidance in Enercon (2017). Enercon's 2007 estimates include information on project schedule, capital costs, O&M costs, and energy penalties (PSNH et al. 2007). For our estimates of administrative costs we use information developed by PSNH and Region 1 of EPA. Note that NERA converts all dollar estimates to 2017 dollars based on historical inflation information from the U.S. Bureau of Economic Analysis (BEA 2017)

4. Baseline Scenario

Social costs are measured relative to a Baseline Scenario that reflects the future costs if neither of the two entrainment technologies were implemented. In the absence of the installation of new entrainment controls, the study assumes that the costs based upon the current configuration would continue in the future over the time period of our analysis. The current system in place at Merrimack thus represents the "Baseline" conditions for the economic analysis of the Merrimack Entrainment Technology Alternatives.

B. Social Costs of Merrimack Entrainment Technology Alternatives

This section presents the estimates developed for the four major categories of social costs: (1) capital costs; (2) operation and maintenance costs; (3) electricity costs; and (4) administrative costs, with an additional section that summarizes the total social cost estimates.

1. Capital Costs

Capital costs consist of the labor and material costs associated with the acquisition, construction, and installation of the Merrimack Entrainment Technology Alternatives as well as the costs of major replacement of elements over the lifetime of Merrimack. Cost data for initial capital cost expenditures provided to NERA by Enercon are broken down into three phases: permitting, engineering, and procurement/construction. In this section we provide (a) estimates of the total "overnight" costs and (b) estimates of the net present value of costs when account is taken of the timing of costs.

a. Components of Capital Costs

Overnight capital costs are engineering estimates of the total costs of installing the necessary structures and equipment based on contemporary prices for materials, equipment, and labor, assuming the modifications could be completed immediately (i.e., "overnight") (Enercon 2017). Thus, they exclude interest charges during construction, which engineering cost estimates sometimes include; discounting implicitly incorporates such interest charges because earlier expenditures receive more weight in the present value calculations.

Overnight capital costs include costs related to permitting, engineering, and construction. Enercon provided detailed estimates of the overnight capital costs for WWS in Attachment 1 of the Technical Memorandum (2017). For the plume-abated MDCT we rely on the capital cost estimate developed for conversion to closed loop cooling in Attachment 4 of PSNH et al. (2007). Based on guidance from Enercon (2017) we increase this capital cost estimate by 30 percent to account for the impact of the various plant and technological changes since 2007 (e.g., scrubber installation), as well as for any inconsistencies between the completeness of the WWS cost estimate and the 2007 plume-abated MDCT cost estimate. In particular, we note that the 2007 cost estimate does not include a cost estimate for permitting costs. Based on guidance from Enercon (2017), we assume the 30 percent cost increase would account for permitting costs, and that the permitting costs would comprise 2 percent of the total adjusted overnight capital costs. Table 3 summarizes the overnight capital costs from installation of the two Merrimack Entrainment Technology Alternatives organized by specific cost category.

Table 3. Overnight and Additional Capital Costs ($2017 million)

Technology	Overnight Permitting Costs	Overnight Engineering Costs	Overnight Construction Costs	Overnight Capital Costs
Wedgewire Half-screens	$0.18	$0.90	$8.98	$10.06
Plume-abated MDCT	$1.79	$1.96	$85.54	$89.28

Note: All dollar values in millions of fixed 2017 dollars. Overnight capital costs include all costs related to technology installation including permitting, engineering, and construction activities. Dollar year conversions are based on historical inflation from BEA.

Source: Attachment 1 of Enercon (2017); Attachment 4 of PSNH et al. (2007); BEA (2017).

b. Timing and Discounted Capital Costs

We rely on information developed in Enercon (2017) and EPA-Region 1 (2017) for the timing of capital costs for the Merrimack Entrainment Technology Alternatives. Enercon (2017) includes information on the permitting and engineering timing for both technology options, as well as a construction schedule for the WWS technology. Since Enercon has not developed an applicable construction schedule for the plume-abated MDCT technology (Enercon 2017), we rely on the construction schedule assumptions for closed-cycle cooling outlined in EPA’s Substantial New Questions (EPA-Region 1 2017a, p. 28), which indicates that PSNH should complete construction within 24 months and complete tie-in within 26 months of obtaining all necessary permits and approvals. Given information provided by Enercon (2017) indicating that tie-in activities could only occur during April-October, and EPA’s note (EPA-Region 1 2017a, p. 26) that outages should be scheduled during a shoulder season, we assume that the a two-month tie-in outage for plume-abated MDCT would occur in April-May of 2026.

For both technologies we assume that the NPDES effective permit date would be July 1, 2019. PSNH may appeal a decision to install either of the Merrimack Entrainment Technology Alternatives (Enercon 2017). It is assumed that this appeals process would last 42 months and the actual technology-specific permitting process for either technology would not begin until January of 2023 (Enercon 2017).[4]

Table 4 summarizes our assumptions regarding project timing. Note that WWS installation would involve a two-phase process, where the screens would first be installed and operated at Unit 1 and then subsequently at Unit 2 in the following year. We allocate the overnight costs associated with each project phase evenly across the months that they would be incurred. Again, as discussed above, we have adjusted the plume-abated MDCT tie-in outage to be in April-May of 2026.

[4] Modifying the assumed 42-month appeals process duration to either a shorter or longer timeframe would not change any conclusions regarding the relative costs and benefits of the Merrimack Technology Alternatives

Table 4. Timing of Capital Costs for Merrimack Entrainment Technology Alternatives

	Wedgewire Half-screens		Plume-abated MDCT	
	Unit 1	**Unit 2**	**Unit 1**	**Unit 2**
Permitting Start Date	1/1/2023	1/1/2023	1/1/2023	1/1/2023
Permitting End Date	6/30/2023	6/30/2023	12/31/2023	12/31/2023
Engineering Start Date	1/1/2023	1/1/2023	1/1/2023	1/1/2023
Engineering End Date	6/30/2023	6/30/2023	12/31/2023	12/31/2023
Construction Start Date	7/1/2023	7/1/2024	1/1/2024	1/1/2024
Construction End Date	10/31/2023	10/31/2024	12/31/2025	12/31/2025
Outage Start Date	9/19/2023	9/19/2024	4/1/2026	4/1/2026
Outage End Date	10/31/2023	10/31/2024	5/31/2026	5/31/2026

Note: Construction period includes time for procurement and construction.
Source: Attachment 2 from Enercon (2017); EPA-Region 1 (2017a), pp.26-28; and NERA calculations as explained in text.

Using these monthly expenditure schedules, we develop estimates of the net present values and annualized values of expenditures for capital costs; including permitting, engineering, and capital costs. Table 5 shows the net present value and annualized values estimates of capital costs for the Merrimack Entrainment Technology Alternatives. Note that the present value estimates of capital costs are substantially lower than the overnight costs because the costs are incurred in the future.

Table 5. Net Present Value and Annualized Capital Costs ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens	$8.65	$7.12	$0.42	$0.54
Plume-abated MDCT	$69.50	$55.57	$3.35	$4.24

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars.
Source: Attachment 1 from Enercon (2017); Attachment 4 from PSNH et al. (2007); NERA calculations as explained in text.

2. Operation and Maintenance Costs

Both Merrimack Entrainment Technology Alternatives involve the installation of equipment that would require ongoing upkeep. Maintaining this equipment entails O&M costs, including labor, materials, and outside services, as well as water treatment costs. Based on information from Enercon (2017) we assume that the WWS technology installation would be a two phase process by unit, where installation of the screens at Unit 1 would be complete by the end of October 2023 and operation would begin seasonally in 2024, and then subsequently at Unit 2 in 2025.

Enercon (2017) indicates that there would be an annual O&M cost of $29,400 for the WWS technology. Enercon notes that this annual O&M cost would be unrelated to the number of screens operating, and accordingly would be incurred in full once the technology becomes operational at Unit 1 (i.e., there would not be any O&M cost savings in year 2024). Based on information from Enercon (2017), our cost analysis accounts for an additional one-time O&M cost of $38,900 related to replacement of the air compressor. This replacement cost would be incurred after 20 years of operation in 2044.

Since the plume-abated MDCT would operate year round, we assume operation would begin in June 2026, the month after the completion of final tie-in activities. For the plume-abated MDCT we rely on information developed by Enercon in PSNH et al. (2007). Section 6.2.5 from PSNH et al. (2007) indicates that the annual O&M costs would be a function of the year of operation ranging from annual costs of $225,500 (2007 dollars) in the first year of operation to $625,500 (2007 dollars) for 16-30 years of operation. Section 6.2.6 of PSNH et al. (2007) provides information related to water treatment costs suggesting that the operation of plume-abated MDCT would increase the Station's water treatment costs by $175,000 (2007 dollars). Our estimates of annual fixed O&M costs account for both of these cost items converted to 2017 dollars based on inflation information in BEA (2017).

Table 6 summarizes the estimated average annual fixed O&M costs for the Merrimack Entrainment Technology Alternatives, as well as the operation schedule for both alternatives.

Table 6. Average Annual Fixed O&M Costs ($2017)

Technology	Operation Start Date	Operation End Date	Annual Fixed O&M Costs (Years 1-5)	Annual Fixed O&M Costs (Years 6-15)	Annual Fixed O&M Costs (Years 16+)
Wedgewire Half-screens	2024	2053	$29,400	$29,400	$29,400
Plume-abated MDCT	2026	2053	$464,499	$580,479	$928,418

Note: All dollar values are in constant 2017 dollars. There would be an additional O&M cost of $38,900 for WWS in 2044. WWS would become operational at Unit 1 only in 2024 and subsequently at both units in 2025. The full annual fixed O&M cost would be incurred in the first year of operation despite the screens only operating at Unit 1 (Enercon 2017). Dollar year conversions based on historical inflation from BEA.

Source: Enercon (2017); PSNH et al. 2007; BEA (2017).

Table 7 shows the net present value and annualized values of O&M costs discounted at 3 and 7 percent for both of the Merrimack Entrainment Technology Alternatives. All present values and annualized values are as of January 1, 2019.

Table 7. Net Present Values and Annualized Values of O&M Costs ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens	$0.52	$0.28	$0.03	$0.02
Plume-abated MDCT	$10.37	$4.81	$0.50	$0.37

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars.

Source: Enercon (2017); PSNH et al. (2007); NERA calculations as explained in text.

3. Electricity Costs

This section considers the social costs related to changes in Merrimack's electricity output due to the Merrimack Entrainment Technology Alternatives.

a. Potential Categories of Electricity Costs

The construction and operation of a technology change to the CWIS at Merrimack could have three potential effects on Merrimack's contributions to the electricity system, depending on the technology alternative being evaluated:

1. *Construction outages:* reductions in the electricity output of the plant when a new technology requires an outage in addition to the regularly-scheduled maintenance outages of the plant.

2. *Efficiency losses:* reductions in the electricity output of the plant when a new technology decreases the efficiency of electricity generation at the plant.

3. *Parasitic losses:* reductions in the electricity output of the plant when a new technology requires energy from the plant.

b. Changes in Electricity Output Due to Merrimack Entrainment Technology Alternatives

This section provides information on the change in electricity output due to the Merrimack Entrainment Technology Alternatives. We rely on information from Enercon (2017) and information developed by Enercon in PSNH et al. (2007).

i. Electricity Losses from Construction Outages

Both of the Merrimack Entrainment Technology Alternatives would require a construction related outage. Enercon (2017) indicates that the WWS technology would require two six week outages (one at each unit) for completion of final construction activities. Enercon assumes that these outages would occur during the final six weeks of the 18-week procurement and construction phase for each unit. Our modeling assumes this outage would occur in September and October..[5]

The plume-abated MDCT is expected to require a construction outage of approximately two months in addition to Merrimack Station's regularly scheduled maintenance (EPA-Region 1 2017, p.28). In order to minimize the costs and reflect the guidance from Enercon (2017) that tie-in activities could not take place during winter months, we assume that the two-month construction outage for the cooling tower alternative would occur in April and May rather than January and February, the two months after construction occurs. This assumption modifies the schedule outlined in EPA-Region 1 (2017)—which states that all tie-in outages would occur in months 25 and 26 of construction (p.28)—in order to comply with the EPA preference that the outage be during a "shoulder season" (rather than the peak season, which for Merrimack includes January and February). Since our analysis assumes a January 2024 construction start date, we assume the tie-in outage would occur in April and May 2026 for plume-abated MDCT.

[5] This schedule is based on Enercon's (2017) assumption that "the installation of the screens would be planned to coincide with periods of low operation" (p. 6).

Our analysis relies on average monthly capacity factors for each unit at Merrimack Station based on the 10 years (2007-2016) of historical plant operations data provided in Table 2 of Enercon (2017). Table 8 provides the average monthly capacity factors that we rely on to calculate the MWh loss in generation due to the construction outage. Table 9 shows the reduced electricity output that would occur because of the additional plant outage for the plume-abated MDCT. As requested by PSNH, we present sensitivity results for a 50 percent and 100 percent capacity factor assumption in an uncertainty analysis in Chapter V.

Table 8. 10-Year Average Monthly Capacity Factors at Merrimack Station by Unit (MWh)

Month	Unit 1	Unit 2	Combined
January	82%	82%	82%
February	81%	78%	78%
March	76%	66%	69%
April	36%	28%	30%
May	35%	19%	23%
June	40%	41%	41%
July	59%	53%	54%
August	49%	35%	39%
September	33%	22%	25%
October	25%	19%	20%
November	52%	29%	35%
December	73%	59%	63%
Average	**53%**	**44%**	**46%**

Note : Values reflect the average monthly operation for each unit at Merrimack based on 10-years of historical data (2007-2016). The combined column reflects the average monthly plant capacity factor based on a weighted average of the two units.

Source: Table 2 from Enercon (2017); NERA calculations as explained in text.

Table 9. Construction-Related Reductions in Net Electricity Output (MWh)

Technology	Outage Loss (MWh)
Wedgewire Half-screens	96,624
Plume-abated MDCT	168,541

Source: Enercon (2017); EPA-Region 1 (2017a), p.28; NERA calculations as explained in text.

ii. Annual Efficiency Power Losses

Enercon indicates that the plume-abated MDCT alternative would result in efficiency power losses of 0.16 MW for Unit 1 and 2.82 MW for Unit 2 (PSNH et. al 2007). Based on these losses, we calculate the annual MWh losses due to efficiency power losses by applying 10-year average monthly capacity factors by for each unit from Table 8. This calculation indicates that the plume-abated MDCT would result in an efficiency power loss of 11,632 MWh. Enercon indicates that the WWS would not affect the operational efficiency of the plant (Enercon 2017, p. 5). Table 10 summarizes the annual MWh losses in electricity output due to operational efficiency effects of the Merrimack Entrainment Technology Alternatives.

Table 10. Annual Efficiency Losses (MWh)

Technology	Efficiency Loss (MWh)
Wedgewire Half-screens	0
Plume-abated MDCT	11,632

Source: Enercon (2017); PSNH et al. (2007); NERA calculations as explained in text.

iii. Annual Parasitic Losses

Enercon indicates that the operation of both Merrimack Entrainment Technology Alternatives would require electricity and thus reduce the electricity output of Merrimack (Enercon 2017 and 2007). Operation of the WWS would result in an annual parasitic loss of 172 MWh (Enercon 2017). Enercon (2017) has indicated that during the year in which only Unit 1 screens are in operation, annual parasitic losses would be 49 MWh. Operation of the plume-abated MDCT would require 1.56 MW of electricity at Unit 1 and 5.14 MW of electricity at Unit 2 (Enercon 2007). Since Enercon notes that the cooling towers would only require energy during actual plant operation, we apply our base case capacity factor assumption by month and unit to develop an annual parasitic loss estimate of 13,312 MWh due to the plume-abated MDCT. Table 11 summarizes estimates of the annual parasitic losses due to the operation of the two Merrimack Entrainment Technology Alternatives.

Table 11. Annual Parasitic Losses (MWh)

Technology	Parasitic Loss (MWh)
Wedgewire Half-screens	172
Plume-abated MDCT	13,312

Source: Enercon (2017); PSNH et al. (2007)

c. Wholesale Electricity Prices

As explained above, wholesale electricity prices provide estimates of the social costs of reduced output because prices reflect the resource cost of supplying an additional unit of electricity to the grid. We developed forecasts of monthly wholesale electricity prices over the relevant time period for New Hampshire to value replacement electricity at Merrimack. These projections are based on annual wholesale electricity price projections from the U.S. Energy Information Administration (EIA) and provided in EIA (2017a). We supplement annual wholesale price projections from EIA with monthly price information from ISO-NE (2017) to estimate the month-by-month variation in electricity prices relevant for generation in New Hampshire. Appendix B describes our methodology and shows our monthly electricity price forecasts.

d. Social Costs of Changes in Electricity Output

i. Construction Outage Costs

Table 12 summarizes the net present value and annualized values of the estimated social costs of providing replacement electricity as a result of the construction outage for the plume-abated MDCT. These values reflect the difference between the social cost of replacement generation and the cost savings because Merrimack is not operating. Social costs of replacement generation are calculated by multiplying the generation losses by the electricity prices relevant for the outage period.

We develop estimates of the potential operating cost savings due to the two-month outage as the sum of estimated coal fuel savings and estimated O&M savings based on information from EIA. To model operations savings we rely on EIA's estimated variable O&M cost of $4.80 (2017$/MWh) for new scrubbed coal units from *Annual Energy Outlook 2014*.[6] We calculate coal fuel savings using coal price projections developed for EIA's *Annual Energy Outlook 2017* and an average heat rate of 10.98 (MMBtu/MWh) for Merrimack Station based on publically available fuel consumption and electricity generation data from Form EIA-923 (EIA 2017). Table 12 summarizes the resulting estimates of fuel cost savings and O&M savings due to the two six-week outages for WWS and the two-month outage for plume-abated MDCT—expressed as net present values and annualized values.

Table 12. Net Present Values and Annualized Values of Construction Outage Costs at Merrimack ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens				
Outage Replacement Power Cost	$4.06	$3.30	$0.20	$0.25
Outage Fuel Cost Savings	-$2.17	-$1.76	-$0.10	-$0.02
Outage Variable O&M Savings	-$0.39	-$0.32	-$0.02	-$0.13
Net Construction Outage Power Cost	**$1.50**	**$1.22**	**$0.07**	**$0.09**
Plume-abated MDCT				
Outage Replacement Power Cost	$6.51	$4.93	$0.31	$0.38
Outage Fuel Cost Savings	-$3.61	-$2.74	-$0.17	-$0.04
Outage Variable O&M Savings	-$0.65	-$0.49	-$0.03	-$0.21
Net Construction Outage Power Cost	**$2.25**	**$1.70**	**$0.11**	**$0.13**

Note: The construction outage cost savings include those due to reduced fuel costs and reduced variable O&M costs. Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All values are in millions of 2017 dollars. Values may not sum to totals due to rounding.

Source: EIA (2017a, 2017b, 2017c, 2014); ISO-NE (2017); NERA calculations as explained in text.

ii. Parasitic and Efficiency Costs

Table 13 summarizes the net present value and annualized social costs from reduced electricity output from efficiency and parasitic losses from the Merrimack Entrainment Technology Alternatives.

[6] EIA does not publish information on scrubbed coal variable O&M costs as part of its *Annual Energy Outlook* after 2014. Our analysis relies on the 2014 estimate converted to real 2017 dollars based on historical inflation information from BEA (2017).

Table 13. Net Present Values of Social Costs of Changes in Electricity Output at Merrimack ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens				
Net Construction Outage Costs	$0.00	$0.00	$0.00	$0.00
Parasitic Loss Costs	$0.21	$0.11	$0.01	$0.01
Efficiency Loss Costs	$0.00	$0.00	$0.00	$0.00
Total	**$0.21**	**$0.11**	**$0.01**	**$0.01**
Plume-abated MDCT				
Net Construction Outage Costs	$2.25	$1.70	$0.11	$0.13
Parasitic Loss Costs	$16.57	$8.14	$0.80	$0.62
Efficiency Loss Costs	$14.70	$7.22	$0.71	$0.55
Total	**$33.52**	**$17.07**	**$1.62**	**$1.30**

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All values in millions of 2017 dollars. Values may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

4. Administrative Costs

As noted, the Existing Facilities Rule calls for inclusion of administrative costs incurred by the facility and by the administrative agency in the calculation of social costs.

a. Private Administrative Costs

PSNH has provided estimates of the administrative costs the facility would incur under the implementation of the Merrimack Entrainment Technology Alternatives (PSNH 2017). Also provided by PSNH were estimates for the administrative costs associated with the "no new technology" Baseline Scenario.

Table 14 provides net present values and annualized values of the private administrative costs. Note that the costs for both of the technology options are negative relative to the baseline. This result is due to the assumption that some of the costs associated with the plant's ongoing permit renewal—including entrainment studies and reporting on current plant operations—would not be incurred if Merrimack were to install either of the Merrimack Entrainment Technology Alternatives. The estimated costs for the plume-abated MDCT technology are lower than those for the WWS due to more substantial anticipated cost savings associated with permit renewal over the lifetime of the technology.

Table 14. Net Present Values and Annualized Values for Private Administrative Costs ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens	-$0.08	$0.02	$0.00	$0.00
Plume-abated MDCT	-$0.56	-$0.26	-$0.03	-$0.02

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars.

Source: PSNH (2017); NERA calculations as explained in text.

b. Public Administrative Costs

EPA-Region 1 has provided information on the annual administrative costs it would incur as a result of the installation of the two Merrimack Entrainment Technology Alternatives (EPA-Region 1 2017b). EPA-Region 1 also provided information for the administrative costs associated with the "no new technology" baseline scenario. In particular, EPA-Region 1 provided public administrative costs in annual number of hours for four occupation groups: permit writer, biologists, management, and legal.

To develop dollar estimates of the public administrative costs provided by EPA-Region 1, NERA relied on EPA's methodology as described in its 316(b) Economic Analysis (2014c).

1. NERA obtained median hourly wage information available from the *Bureau of Labor Statistics Occupational Employment Statistics for May 2016* for the relevant occupation groups under NAICS code 99 (Federal, State, and Local Government (excluding state and local schools and hospitals) (BLS 2016a).

2. NERA converted all wage values from real 2016 dollars to real 2017 dollars based on GDP deflator information from BEA (2017).

3. To account for fringe benefits NERA then scaled up the hourly labor wages by 1.59 based on the average ratio of total hourly compensation to total wages and salaries for state and local government workers based on publically information from the U.S. Bureau of Labor Services (BLS 2017).

4. To account for indirect costs (i.e., overhead) NERA applied an additional indirect cost multiplier of 15 percent, based on the multiplier used by EPA for facilities and States to obtain a "fully loaded hourly rate" (EPA 2014c, p. 3-7).

5. NERA multiplied the fully loaded hourly rates by the hourly estimates for the associated occupation groups provided to EPA-Region 1 to develop dollar estimates for public administrative costs.

Table 15 provides net present values and annualized values of EPA administrative costs. As with private administrative costs, the public administrative costs for both of the Merrimack Entrainment Technology Alternatives are negative. This result is due to the assumption that some of the costs to EPA associated with administering and reviewing Merrimack's future 316(b) permit renewals would not be incurred if either of the Merrimack Entrainment Technology Alternatives were to be installed.

Table 15. Net Present Value of Public Administrative Costs ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens	-$0.08	-$0.07	$0.00	-$0.01
Plume-abated MDCT	-$0.10	-$0.08	$0.00	-$0.01

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars.

Source: EPA - Region 1 (2017b) and NERA calculations as explained in text.

5. Total Quantified Social Costs

Table 16 summarizes the total net present value and total annualized values of the social costs for Merrimack Entrainment Technology Alternatives. Present value total social costs are about $10.7 million for WWS and about $112.7 million for plume-abated MDCT using a 3 percent discount rate, and about $8.7 million and $77.1 million, respectively, using a 7 percent discount rate. Annualized total social costs are about $0.5 million for WWS and about $5.4 million for plume-abated MDCT using a 3 percent discount rate, and about $0.7 million and $5.9 million, respectively, using a 7 percent discount rate.

Table 16. Estimated Total Quantified Social Costs ($2017 million)

	Net Present Value		Annualized Cost	
Technology	**3%**	**7%**	**3%**	**7%**
Wedgewire Half-screens				
Capital	$8.65	$7.12	$0.42	$0.54
O&M	$0.52	$0.28	$0.03	$0.02
Electricity	$1.71	$1.33	$0.08	$0.10
Administrative	-$0.17	-$0.05	-$0.01	$0.00
Total	**$10.71**	**$8.67**	**$0.52**	**$0.66**
Plume-abated MDCT				
Capital	$69.50	$55.57	$3.35	$4.24
O&M	$10.37	$4.81	$0.50	$0.37
Electricity	$33.52	$17.07	$1.62	$1.30
Administrative	-$0.66	-$0.34	-$0.03	-$0.03
Total	**$112.73**	**$77.11**	**$5.44**	**$5.88**

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

III. Evaluation of Social Benefits

This chapter includes information on the methodology and results for social benefits of the two Merrimack Entrainment Technology Alternatives as required in 40 CFR Part 122.21(r)(11). We first provide a discussion of the component categories, underlying data, and the Baseline Scenario used to estimate the social benefits. We then develop the relevant social benefits estimates.

A. Methodology for Estimating Social Benefits

As noted in the Existing Facility Rule (EPA 2014a) social benefits represent the "increase in social welfare that results from taking an action," including "private benefits and those benefits not taken into consideration by private decision makers in the actions they chose to take" (EPA 2014a, p. 48432). We take the standard economic approach of using willingness-to-pay (WTP) to measure social benefits. This approach is consistent with the Existing Facilities Rule as well as with sound cost-benefit methodology (see, e.g., Boardman et al. 2011) and the approach set forth in the EPA *Guidelines* (EPA 2014b, Chapter 7).

1. Potential Components of Social Benefits

The EPA *Guidelines* provide a summary of the benefit categories relevant to an assessment of ecological improvements, which is the general category of benefits for this assessment. EPA uses these benefit categories as a framework to develop estimates of monetary benefits in the Existing Facilities Rule (see EPA 2014d, pp. 4-3, 4-4). Economic textbooks provide similar frameworks for categorizing benefits related to ecological improvements.[7]

1. *Market Direct Use Benefits:* These benefits are related to goods directly used, and bought and sold in markets; for example, fish caught for eventual sale to consumers. (EPA 2014d, p.4-2)

2. *Nonmarket Direct Use Benefits:* These benefits consist of goods and services that have direct uses, but are not traded in the marketplace. Higher catch rates for recreational fishing provide a typical nonmarket direct use benefit. (EPA 2014d, p.4-2)

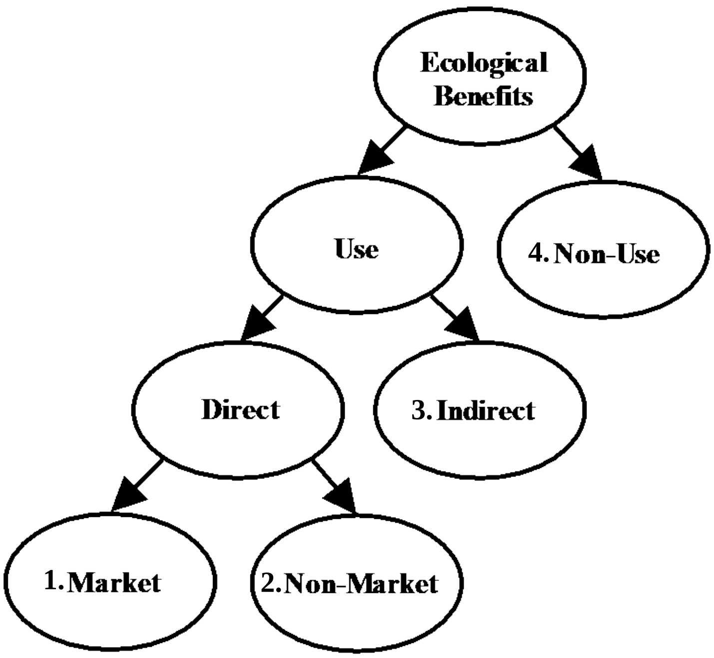
3. *Indirect Use Benefits:* These benefits occur through indirect or secondary effects on non-marketed and marketed goods (in primary and secondary markets). For example, an increase in the number of forage fish can increase the population of harvested species. Reducing I&E of forage species thus can result in indirect welfare gains for commercial and recreational fishers. (EPA 2014d, p.4-2)

4. *Non-use Benefits:* These benefits occur when individuals value improved environmental quality without any past, present, or anticipated future use of the resources in question. (EPA 2014d, p.4-2)

[7] See, e.g. Kolstad (2011, pp. 138-140), Boardman et al. (2011, Chapters 4 and 9), and Freeman (2003, Chapters 5 and 13).

Figure 1, adapted from the 2000 EPA *Guidelines* (EPA 2000) for assessing ecological benefits, provides a useful way of organizing and visualizing these potential benefit categories.[8] The figure divides the ecological benefits into two major categories: "use" benefits and "non-use" benefits. Use benefits consist of gains to those who use the additional resources provided by the various alternatives (e.g., commercial fishing), while non-use benefits consist of potential gains to those who do not expect any potential use gains (e.g. those who might value the bequest of changes to future generations). Use benefits can be further subdivided into three subcategories—market benefits, nonmarket, and indirect benefits—resulting in a total of four potentially relevant general ecological benefits categories as reflected in Figure 1.

Figure 1. Summary of Benefit Classification Scheme from EPA 2000 *Guidelines*



Source: EPA (2000, p. 70); see also EPA (2014c, p. 7-9).

Our assessment of social benefits from the Merrimack Entrainment Technology Alternatives considers each of these categories. In the following section we evaluate monetized benefits relevant to I&E at Merrimack and provide a qualitative overview of our conclusions regarding other benefits categories. Chapter V provides qualitative assessments of components of social benefits not monetized. Appendix C provides a detailed evaluation of non-use benefits and their significance for Merrimack Entrainment Technology Alternatives.

2. Discounting of Social Benefits

Social benefits are discounted at social discount rates, which reflect society's preference for present versus future consumption. We use social discount rates of 3 and 7 percent, as

8 The 2014 *Guidelines* provide a similar categorization but do not include this figure. See EPA (2014b, p. 7-15).

recommended in the Existing Facilities Rule (EPA 2014a, p. 48367).[9] We develop estimates of the net present value for benefits of the Merrimack Entrainment Technology Alternatives. (To be consistent with the Existing Facilities Rule terminology, we refer to the discounted values as "net present values.") The benefits are calculated over the period from January 1, 2019 to December 31, 2053, which reflects the 30-year useful life of the WWS (Enercon 2017), although benefits are not projected to begin until the year 2024 because of the time required to put the technologies in place (Enercon 2017).

3. Biological Benefits Information

We rely upon biological benefits presented in Normandeau (2017), which includes detailed estimates of "equivalent recruitment loss" to the recreational fishery in Hooksett Pool due to annual I&E at Merrimack Station. This information differs somewhat from the harvest and catch information that is often developed.

- *No commercial harvest*. Normandeau concluded that there was no commercial fishery in Hooksett Pool and thus there are no commercial benefits (Normandeau 2017, p. 14).

- *No information to calculate recreational harvest and catch*. Recreational benefits are typically developed based upon estimates of the additional recreational catch, which in turn are based upon information on recreational harvest (i.e., catch and keep) and estimates of recreational catch rates, i.e., the average number of fish caught per fish harvested. This information is not available for Hooksett Pool (Normandeau 2017, p. 14).

- *Information on equivalent recruitment loss*. Normandeau (2017) estimates equivalent recruitment loss to the recreational fishery as a proxy for total equivalent catch (i.e., the sum of catch-and-keep and catch-and-release). Equivalent recruitment loss is described as the number of equivalent "harvestable" fish lost due to the entrainment technologies at Merrimack Station, where the harvestable age of equivalence is defined as the "age first susceptible to angling gear" (i.e., recruited to the fishery) (Normandeau 2017, p. 3).

As a result of these complications, biological benefits for each of the two Merrimack Entrainment Technology Alternatives are based on the difference between the equivalent recruitment loss (by species) for the alternative and the baseline loss (i.e., under the current configuration). Note that this method is similar to the one used by EPA for the Inland region in their benefits analysis for the Existing Facilities Rule (EPA 2014d).

This measure of biological benefits (i.e., gains in "harvestable" fish) differs from the standard measure of recreational catch in two ways, which entail offsetting biases: (1) all of the incremental equivalent number recruited to the fishery (i.e., harvestable or catchable fish) are presumed to be caught (and valued) when in reality perhaps only a portion of a particular cohort of fish would be caught (overestimates benefit); and (2) "there are no multiple catches for

[9] The explicit recommendation in the Existing Facilities Rule is for social cost analyses. Since to be comparable, social costs and social benefits should be calculated using the same discount rate, these two discount rates are appropriate for social benefits as well.

individual fish, when it is possible that fish are caught multiple times in a year (underestimates benefit)" (Normandeau 2017, p. 3).

4. Baseline Scenario

Social benefits are measured relative to a Baseline Scenario that reflects the future biological conditions if neither of the two entrainment technologies were implemented. Accordingly, the Baseline Scenario reflects the current conditions at the facility that would be presumed to apply in future periods.

As a result, we calculate benefits from Merrimack Entrainment Technology Alternatives relative to the biological conditions in the Baseline Scenario. That is, as noted Baseline Scenario losses are compared to losses under the Merrimack Entrainment Technology Alternative benefits to calculate the biological benefits of the Merrimack Entrainment Technology Alternatives.

B. Social Benefits of Merimack Entrainment Technology Alternatives

This section develops estimates of the social benefits of Merrimack Entrainment Technology Alternatives. The benefits are calculated over the period from January 1, 2019 to December 31, 2053, which reflects the 30-year useful life of the WWS (Enercon 2017)—although benefits are not projected to begin until the year 2024 because of the time required to put the technologies in place (Enercon 2017).

1. Biological Benefits

Calculation of social benefits begins with biological estimates of the number of equivalent "harvestable" fish at the age first susceptible to angling for each Merrimack Entrainment Technology Alternative. This section reports the biological estimates developed by experts at Normandeau (2017).

a. Categorization of Species

Table 17 lists the species for which Normandeau (2017) modeled annual equivalent recruitment losses for each Merrimack Entrainment Technology Alternative relative to the existing CWIS baseline. Losses were estimated for "recreationally important" and "forage" species only (Normandeau 2017, p. 7). Indirect gains due to additional forage are estimated as additional recruitment of a predator species, assumed to be Age-2 Largemouth Bass (Normandeau 2017). Based upon Normandeau (2017), the target species listed below are assumed to represent 100 percent of species affected by I&E at Merrimack.

Table 17. Categories for Target Species

Catch Species	Forage Species
American Eel	Alewife
American Shad	Alosa sp.
Banded Sunfish	Blacknose Dace
Black Crappie	Bridle Shiner
Bluegill	Carp and Minnow Family
Brown Bullhead	Common Shiner
Chain Pickerel	Eastern Silvery Minnow
Largemouth Bass	Emerald Shiner
Pumpkinseed	Fallfish
Rainbow Smelt	Golden Shiner
Redbreast Sunfish	Herring Family
Rock Bass	Lepomis Species
Smallmouth Bass	Madtom Species
Walleye	Margined Madtom
White Perch	Spottail shiner
Yellow Bullhead	Sucker Family
Yellow Perch	Sunfish Family
	Tessellated Darter
	White Sucker

Note: We assume that target species represent 100 percent of species affected by I&E at Merrimack.
Source: Normandeau (2017)

As discussed below, monetary benefits are estimated using the Inland region fish values included in EPA's benefits analysis for the Existing Facilities Rule (EPA 2014d). EPA (2014d) provides marginal values per recreationally caught fish for several species groups. Normandeau (2017) indicates that the four relevant species groups for the target species at Merrimack Station are panfish, small game, walleye/pike, and bass (Normandeau 2017, p. 7). Table 18 presents the categorization of the 17 recreationally caught target species.

Table 18. Species Group Categorization

Species	EPA Species Group
American Eel	Panfish
American Shad	Small Game
Banded Sunfish	Panfish
Black Crappie	Panfish
Bluegill	Panfish
Brown Bullhead	Panfish
Chain Pickerel	Walleye/Pike
Largemouth Bass	Bass
Pumpkinseed	Panfish
Rainbow Smelt	Panfish
Redbreast Sunfish	Panfish
Rock Bass	Panfish
Smallmouth Bass	Bass
Walleye	Walleye/Pike
White Perch	Panfish
Yellow Bullhead	Panfish
Yellow Perch	Panfish

Note: Largemouth Bass was used as the equivalent predator to target forage species.
Source: Normandeau (2017)

b. Annual Gains to the Recreational Fishery

This section summarizes Normandeau (2017) estimates of annual changes in recruitment to the recreational fishery in Hooksett Pool under the Baseline Scenario and the two Merrimack Entrainment Technology Alternatives. Although we report totals for modeled species in this section to provide indications of the nature of the biological gains, the estimates from Normandeau (2017) are by individual species. We use the detailed estimates by individual species in the calculation of monetary benefits.

Table 19 shows the Normandeau (2017) estimates of annual recreational fishery recruitment losses under the Baseline Scenario and the two Merrimack Entrainment Technology Alternatives. Note that because of the trophic (e.g. foraging) relationships in aquatic fish communities, species without direct recreational value provide forage value to species with recreational use value. Changes to forage species populations lead to changes in the biomass available in the ecosystem to predator species (indirect forage benefits). For this analysis, Normandeau (2017) developed estimates of the indirect changes in recreational species due to changes in forage species by translating changes in the forage species into increases in an equivalent predator, Age -2 Largemouth Bass.

Table 19. Annual Recreational Fishery Losses at Merrimack (Numbers of Fish)

Technology	Entrainment	Impingement	Total
Baseline	1,699	254	1,953
Wedgewire Half-screens	256	184	440
Plume-abated MDCT	85	13	98

Note: Baseline I&E reflect existing CWIS operations.
Source: Normandeau (2017)

Table 20 uses the estimated annual losses to calculate the annual gains for Merrimack Entrainment Technology Alternatives relative to the Baseline Scenario, separated into gains due to entrainment and gains due to impingement. As shown in the table, estimated annual gains to recreational fishery recruitment are 1,513 fish for WWS and 1,855 for plume-abated MDCT.

Table 20. Annual Recreational Fishery Gains Relative to the Baseline Scenario (Numbers of Fish)

Technology	Entrainment	Impingement	Total
Wedgewire Half-screens	1,443	70	1,513
Plume-abated MDCT	1,614	241	1,855

Source: Normandeau (2017)

c. Annual Gains to the Recreational Fishery by Species Group

To develop information on the value that households place on the biological benefits, the fishery recruitment gains are summarized by species group. Table 21 provides estimates of annual recruitment gains by species group for the Merrimack Entrainment Technology Alternatives relative to the Baseline Scenario.

Table 21. Annual Recreational Fishery Gains Relative to the Baseline Scenario by Species Group (Numbers of Fish)

Technology	Wedgewire Half-screens	Plume-abated MDCT
Panfish	1,086	1,278
Small Game	0.1	0.1
Walleye/Pike	1	8
Bass	427	569
Total	1,513	1,855

Note: Values account for production forgone of forage species (i.e. indirect benefits) associated with gains in forage. Values may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

2. Value of Recreational Fishing Benefits

This section considers the monetary benefits to recreational fishermen from implementation of the Merrimack Entrainment Technology Alternatives, using biological information discussed in the previous section and dollar values described below. For ease of exposition, we refer to the biological gains as additional recreational catch.

a. Valuation of Additional Recreational Catch

We use the benefit transfer methodology to value the additional recreational catch due to the Merrimack Entrainment Technology Alternatives. Benefit transfer is a widely used approach that allows analysts to use results from prior studies to develop benefit values for a new regulation (see EPA 2014d, p. 7-1).

The values we use as the basis of benefit transfer are based upon a "meta-analysis" sponsored by EPA that combines results from numerous recreational fishing studies to provide a means of estimating the marginal value per fish of additional catch for recreationally-relevant species as a function of catch rates and other variables. The meta-analysis is described in EPA's benefits analysis for the Existing Facilities Rule (EPA 2014d, Chapter 7 Recreational Fishing Benefits).

EPA's estimates of marginal value per recreationally harvested fish are broken down by several species groups and regions (EPA 2014d). We used the relevant species groups for the Inland region, as these most closely mapped onto the target species determined by Normandeau (2017). Table 22 shows the Inland region recreational values for the species groups in this study, measured in dollars per additional fish caught.

Table 22. Recreational Catch Values ($2017/fish)

Species Group	Recreational Catch Value
Panfish	$1.21
Small Game	$6.12
Walleye/Pike	$10.29
Bass	$4.68

Source: NERA calculations as explained in text.

b. Net Present Values of Recreational Benefits

We calculate the annual recreational benefits of the Merrimack Entrainment Technology Alternatives for each species group as the product of the increase in the recreational catch and the recreational value per fish.

Table 23 provides our estimates of the net present values of recreational benefits for the two Merrimack Entrainment Technology Alternatives over the period from 2019 to 2053. At a discount rate of 3 percent, recreational benefits are about $56,000 for WWS and about $65,000 for plume-abated MDCT. At a 7 percent discount rate, the recreational benefits are $33,000 for plume abated MDCT and about $29,000 for WWS.

Table 23. Net Present Values of Recreational Fishing Benefits ($2017)

	Discount Rate	
Technology	**3%**	**7%**
Wedgewire Half-screens	$55,655	$29,353
Plume-abated MDCT	$65,774	$33,053

Note: Net present values are computed as of January 1, 2019 for benefits accruing between January 1, 2019 and December 31, 2053. Dollar values are presented in fixed 2017 dollars. Benefits estimates for each technology are relative to the existing CWIS baseline.

Source: NERA calculations as explained in text.

3. Commercial Fishing Benefits

As discussed above, there are no commercial biological benefits for Merrimack Entrainment Technology Alternatives. Note that this result is consistent with EPA's analyses of benefits for the Inland region. EPA does not estimate benefits from commercial fishing harvests for the Inland region in their 2014 benefits analysis for the Existing Facilities Rule (EPA 2014d, Chapter 6 Commercial Fishing Benefits). EPA's decision to exclude commercial benefits for the Inland Region is based upon "negligible commercial fishing harvest in this region" (EPA 2014d, p. 6-11). Note that this conclusion is in alignment with EPA's 2011 determination that "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 – Region 1 2011, Attachment D, p. 326).

4. Non-use Benefits

Non-use 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).

Appendix C provides an assessment of 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 develop a costly study 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.

5. Total Quantified Social Benefits

Our assessment of social benefits from the Merrimack Entrainment Technology Alternatives considers a range of potential benefits categories, including recreational fishing benefits, commercial fishing benefits, and non-use benefits. As the Merrimack River is not a commercial fishing resource and we do not develop monetary values for non-use benefits, the total quantified social benefits are equal to our estimates of recreational benefits for the Merrimack Entrainment Technology Alternatives from 2019 to 2053, which are presented in Table 23 above. We provide qualitative evaluations of potential social benefits categories that are not monetized in Chapter V and Appendix C (non-use benefits).

IV. Benefit-Cost Comparisons

In this chapter we compare costs and benefits for the two Merrimack Entrainment Technology Alternatives and develop estimates of net benefits (costs). The following chapter discusses potential costs and benefits that we have not quantified and explains why we believe that quantifying and including them, if it were possible, would not change our major conclusions.

A. Benefits, Costs and Net Costs

Table 24 summarizes the estimated present values of benefits, costs, and net costs of the Merrimack Entrainment Technology Alternatives over the period from 2019 to 2053. 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 results are presented for (real) discount rates of 3 and 7 percent, as required in the Existing Facilities Rule (EPA 2014a, p. 48428).

These results indicate that the social costs outweigh the social benefits for both alternatives, with the net costs particularly great for closed-cycle cooling.

Table 24. Summary of Present Values of Estimated Net Costs of Merrimack Entrainment Technology Alternatives ($2017 thousand)

Technology	Social Costs	Social Benefits	Net Social Costs
3% Discount Rate			
Wedgewire Half-screens	$10,711	$56	$10,655
Plume-abated MDCT	$112,727	$66	$112,662
7% Discount Rate			
Wedgewire Half-screens	$8,674	$29	$8,644
Plume-abated MDCT	$77,105	$33	$77,072

Note: Net present values are computed as of January 1, 2019 for costs and benefits between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

Using a discount rate of 3 percent the present value of social costs is about $10.7 million for WWS and about $112.7 million for plume-abated MDCT. In contrast, the estimated present value of benefits is $56,000 for the WWS and $66,000 for plume-abated MDCT. Net social costs (i.e., social benefits minus social costs) are about $10.7 million for WWS and about $112.7 million for plume-abated MDCT. All results are relative to the current operating configuration at Merrimack Station, which, by definition, has net costs equal to zero.

Using a discount rate of 7 percent the present value of social costs is about $8.7 million for WWS and about $77.1 million for plume-abated MDCT. The estimated present value of social benefits is $29,000 for the WWS and $33,000 for plume-abated MDCT. Note that although annual benefits are somewhat greater for the plume-abated MDCT than for the WWS, the present value of benefits for WWS is greater than for the plume-abated MDCT because WWS can be installed earlier. Net social costs in present value terms are about $8.6 million for WWS and about $77.1 million for plume-abated MDCT.

B. Incremental Analysis

Table 25 shows the incremental costs and incremental benefits for each of the two alternatives relative to the alternative with the next lowest costs. For the WWS the comparisons are to the Baseline Scenario and thus there is no additional row; for the plume-abated MDCT, the comparisons are to WWS as shown by the additional row. These incremental values are the appropriate comparisons to judge whether or not the added costs of a more expensive alternative is justified by the benefits, as noted in the *Guidelines* (EPA 2014b p. 11-2) and in the economic literature (see, e.g., Boardman et al. 2011). The table also shows the ratio of costs to benefits, showing the dollars of cost per dollar of benefit.

Table 25. Incremental Analysis of Alternatives of Merrimack Entrainment Technology Alternatives ($2017 thousand)

Technology	Social Costs	Social Benefits	Net Social Costs	Cost-Benefit Ratio
3% Discount Rate				
Wedgewire Half-screens	$10,711	$56	$10,655	192
Plume-abated MDCT	$112,727	$66	$112,662	1,714
-Incremental to Wedgewire Half-screens	$102,017	$10	$102,007	10,081
7% Discount Rate				
Wedgewire Half-screens	$8,674	$29	$8,644	295
Plume-abated MDCT	$77,105	$33	$77,072	2,333
-Incremental to Wedgewire Half-screens	$68,432	$4	$68,428	18,499

Note: Net present values are computed as of January 1, 2019 for costs and benefits between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

The comparisons in Table 25 highlight the enormous disparity between costs and benefits for both of the alternatives, with the disparity particularly stark for the plume-abated MDCT alternative. For the 3 percent discount rate assumption, the plume-abated MDCT provides about $10,000 of additional benefits at an added cost of about $102.0 million; put in terms of the cost-benefit ratio, plume-abated MDCT costs society more than $10,000 in additional costs for every dollar of additional benefits. For the 7 percent discount rate assumption, the plume-abated MDCT provides about $4,000 of additional benefits at an added cost of $68.4, meaning that the option costs society roughly $18,000 in additional costs for every dollar of additional benefits.

The comparisons for WWS are not as dramatic, although this alternative also shows a large disparity between social costs and social benefits. As the cost/benefit ratio indicates, for every dollar of benefits, adopting WWS would result in $192 of additional cost under a 3 percent discount rate and $295 of additional cost under a 7 percent discount rate.

V. Implications of Sensitivity Cases and Omitted Costs and Benefits

The quantitative benefit-cost results presented thus far reflect “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 “base-case” information and provides sensitivity analyses related to the capacity factor for future operation of Merrimack Station. The chapter also provides qualitative assessments of cost and benefit categories that are excluded from the monetary evaluations.

A. Implications of Alternative Merrimack Capacity Factors

Our sensitivity cases focus on the uncertainty related to the capacity factor for future operation of Merrimack Station. Note that 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 Merrimack Entrainment Technology Alternatives, values that recreational fishermen place on additional catch). It would of course be possible to develop additional sensitivity analyses.

1. Alternative Capacity Factors for Sensitivity Case

As noted above, our analyses use a “base-case” capacity factor assumption to estimate changes in electricity generation from the Merrimack Entrainment Technology Alternatives. Our base-case assumption is based on 10-year monthly average capacity factors by unit calculated based on historical Merrimack operations data from 2007-2016 as included in Enercon (2017). The 10-year average capacity utilization for Unit 1 is 53 percent and for Unit 2 is 44 percent, with an average capacity utilization for the plant of 46 percent.

To provide an indication of the significance of future capacity utilization, we were asked by PSNH to develop estimates for two sensitivity cases, 50 percent capacity utilization and 100 percent capacity utilizations.

2. Qualitative Assessments of Changes in Capacity Utilization on Net Costs

Increasing the assumed capacity factors has two opposing effects on the net cost figures for the two technologies, one leading to increased costs and one leading to increased benefits. On the one hand, increasing the capacity factor increases the required replacement energy during construction outage and therefore increases the total social costs of both alternatives. On the other hand, raising the capacity factor increases the intake of cooling water, which increases overall impingement and entrainment. Greater impingement and entrainment in the baseline means the reductions in impingement and entrainment are larger for both Merrimack Entrainment Technology Alternatives; put another way, the same percentage reduction in impingement and entrainment results in more saved fish when the baseline is higher.

The relative magnitude of these two opposing effects determines how net costs of plume-abated MDCT are affected by a change in capacity factors. Table 26 shows that an increase in the assumed capacity factor will lead to an increase in net costs for both of the Merrimack Entrainment Technology Alternatives.

3. Benefits, Costs, and Net Costs Using Alternative Capacity Factors

Table 26 displays the total benefits and costs of the two Merrimack Entrainment Technology Alternatives for the "base case" capacity factor assumption and the two sensitivity cases.

Table 26. Estimated Costs and Benefits of Merrimack Entrainment Technology Alternatives for Various Capacity Factors (2017$)

Technology	Social Costs	Social Benefits	Net Social Costs
Base-Case (10-Year Average Capacity Factor)			
3% Discount Rate			
Wedgewire Half-screens	$10,711	$56	$10,655
Plume-abated MDCT	$112,727	$66	$112,662
7% Discount Rate			
Wedgewire Half-screens	$8,674	$29	$8,644
Plume-abated MDCT	$77,105	$33	$77,072
50% Capacity Factor			
3% Discount Rate			
Wedgewire Half-screens	$12,675	$61	$12,553
Plume-abated MDCT	$113,485	$72	$113,341
7% Discount Rate			
Wedgewire Half-screens	$10,265	$32	$10,201
Plume-abated MDCT	$78,001	$36	$77,929
100% Capacity Factor			
3% Discount Rate			
Wedgewire Half-screens	$16,137	$122	$16,076
Plume-abated MDCT	$147,762	$144	$147,690
7% Discount Rate			
Wedgewire Half-screens	$13,075	$64	$13,043
Plume-abated MDCT	$95,964	$72	$95,928

Note: Entries are present values expressed in thousands of constant 2017 dollars. Values may not sum to totals due to rounding.
Source: NERA calculations as explained in text

4. Implications of the Sensitivity Results for Benefit-Cost Comparisons

A shift to 100 percent capacity utilization would have a substantial effect on the benefits of both WWS and plume-abated MDCT, with estimated benefits more than doubling from the base case values. (Since the base case is similar to 50 percent capacity factor, that case does not lead to substantial changes in benefits.) The 100 percent case also leads to substantial increases in social costs for the plume-abated MDCT.

Although the benefits and costs change substantially under the 100 percent capacity factor case, the overall conclusions regarding the net costs do not change. The social costs remain significantly greater than the social benefits for both of the Merrimack Entrainment Technology Alternatives. Put another way, social costs are so much greater than social benefits that uncertainties about future capacity factors would not change the major conclusions regarding the net costs of both Merrimack Entrainment Technology Alternatives.

B. Qualitative Assessments of Factors Omitted from Calculation of Costs and Benefits

In this section we provide qualitative assessments of cost and benefit categories that are omitted from our quantitative analyses. This section relates to costs and benefits categories for which there is no sufficient data, resources, or methodology available to develop reliable monetized estimates. Thus, we provide a qualitative discussion of the likely significance of these omitted costs and benefits categories on the overall conclusions of our analysis.

In all instances we conclude that while we are unable to develop monetized cost or benefits estimates, values for these omitted categories would be unlikely to have any significant bearing on the conclusions for the relative costs and benefits of the Merrimack Entrainment Technology Alternatives.

1. Qualitative Discussion of Factors Omitted from Calculation of Costs

This section considers the effects of factors that are not included in the quantified social costs.

a. Costs Savings from Reduced Operation of Existing Screens

Enercon (2017) indicates that implementation of either WWS or plume-abated MDCT at Merrimack Station would involve the continued partial operation of the Station’s current traveling water screens, although no specific estimates are provided. Given the uncertainty in how this partial operation would precisely impact the parasitic losses and annual O&M costs associated with the continued operation of the existing traveling water screens, our cost estimates for the annual O&M costs and parasitic losses assume that the existing screens would continue operating in full and thus ignore any potential cost savings from reduced utilization.

This limitation suggests a potential overstatement of the social costs estimates related to the fixed O&M costs and parasitic losses for the Merrimack Entrainment Technology Alternatives to the extent that they do not account for the potential cost savings associated with the partial operation of the existing traveling water screens at the Station. However, as Table 16 indicates, the total social costs for both WWS and plume-abated MDCT are heavily determined by capital costs. Indeed, omitting O&M costs and power costs altogether would not change the overall conclusions of the relative costs and benefits of the Merrimack Entrainment Technology Alternatives.

b. Other Non-quantified Costs

Our monetized estimate of social costs focus on the key categories of social costs as identified in 40 CFR Part 122.21(r)(10)(iii) and the EPA *Guidelines* (2014b), including capital costs, O&M costs, electricity costs, and administrative costs of the Merrimack Entrainment Technology Alternatives. There are, however, other potential categories of social costs beyond the costs we consider.

The following are potential additional categories of costs of the Merrimack Entrainment Technology Alternatives that have been identified by EPA in the *Guidelines* (EPA 2014b, p. 8-9).

- *Distributional Costs.* In general, benefit-cost analysis focuses on total net benefits instead of any individual "winners" or "losers." Distributional costs are those that relate to how certain entities or societal groups are impacted by the imposition of a regulation.
- *Transaction Costs.* Transaction costs are those incurred in making an economic exchange beyond the cost of production of a good or service. They may include the costs of searching out sellers, bargaining, and enforcing contracts for any additional required purchases.
- *Transitional Costs.* Transitional costs are any short-term costs incurred during the adjustment to a new market equilibrium. These costs may include the costs of training workers in the use of new pollution control equipment.

Although EPA notes these categories in its *Guidelines*, none of these categories were assessed by EPA in the Final Rule. We follow EPA in not including these categories in our cost estimates.

2. Qualitative Discussion of Factors Omitted from Calculation of Social Benefits

This section considers the effects of factors that are not included in the quantified harvest benefits or in the dollar values developed for recreational benefits. We use the framework developed in the benefit discussion to evaluate benefits in the following categories.

- Market direct use benefits;
- Market indirect use benefits;
- Non-market indirect use benefits; and
- Non-use benefits.

a. Market Direct Use 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 evaluating the Merrimack Entrainment Technology Alternatives, we reviewed information in EPA's 2014 benefits analysis for the Existing Facilities Rule (EPA 2014d, Chapter 6 Commercial Fishing Benefits). As previously noted, EPA excludes the Inland region from its analysis of commercial fishing harvests "due to a negligible commercial fishing harvest in this region" (EPA 2014d, p. 6-11). Additionally, in its 2011 permit determinations for CWIS at Merrimack Station, EPA states that "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-Region 1 2011, Attachment D, p. 326). Thus, we conclude that market benefits related to commercial fishing are not relevant to benefit estimation for Merrimack Entrainment Technology Alternatives.

b. Market Indirect Use Benefits

Market indirect use benefits are benefits that occur through indirect or secondary effects on marketed goods. The following are the specific items listed in EPA's summary of market indirect use benefits:

1. Increases in commercially valuable species due to an increase in the number of forage fish.[10]
2. Increases in equipment sales, rental, and repair.
3. Increases in bait and tackle sales.
4. Increases in consumer market choices.
5. Increases in choices in restaurant meals.
6. Increases in property values near the water.
7. Increases in ecotourism (charter trips, festivals, and other organized activities with fees such as river walks). (EPA 2014d, p. 4-3)

Note that EPA's Benefits Analysis for the Final Section 316(b) Existing Facilities Rule (EPA 2014d) does not provide specific explanations for why these particular items are listed as indirect

[10] The table does not include the effects of increases in forage fish on commercial species, although it is provided as the example of indirect market benefits (EPA 2014d, p. 4-2).

market use benefits. We distinguish forage fish effects from the other items, which relate to effects on secondary markets as discussed below.

As explained in Chapter III, fish species without direct commercial (market) value have indirect effects on species with direct use value. In particular, increases in forage fish species serve as additional food sources for valuable species that could be harvested commercially. Commercial fishing benefits are not relevant to this application, and thus there are no indirect use benefits as they pertain to commercial fishing.

Other indirect use benefits are best categorized as relating to indirect or secondary markets, i.e., impacts on other markets due to the increase in commercial fish as represented by increased landings by commercial fishermen. Many markets might be affected; increases in fishing could increase the demand for fishing boats and equipment, which in turn could increase the demand for aluminum, which could increase the demand for electricity. The question related to benefit assessment is, how many of these markets do we need to evaluate in order to determine the benefits of the policy, in this case the policy to install either Merrimack Entrainment Technology Alternative?

These secondary market effects can be ignored so long as prices do not change in these markets (Kolstad 2011, p. 117).[11] As assumed in textbook explanations, the market for fishing equipment is assumed to be a constant cost sector, i.e., one in which the long-run cost of production (and thus the price) does not change as the quantity produced changes (Kolstad 2011, p. 118). Similarly, under the assumption of constant costs, there will be no price effect in the commercial fishing equipment market. Thus, the indirect effects in the commercial fishing market would not lead to additional social benefits (i.e., consumer and producer surplus).

Thus, we conclude that omitting the indirect market benefits related to secondary market (and related) effects from the quantified benefits estimates are not likely to significantly affect the overall benefit results.

c. Nonmarket Indirect Use Benefits

Non-market indirect use benefits are benefits that occur through indirect or secondary effects on non-marketed goods. As noted, increases in catch for recreational fishermen provides the direct use non-market benefits. The following are the specific items listed in EPA's summary of non-market indirect goods:

1. Increase in recreationally valuable species due to an increase in the number of forage fish.[12]

2. Increase in value of boating, scuba diving and near-water recreational experiences due to enjoying/observing fish while boating, scuba diving, hiking or picnicking.

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[11] This presumes that there are no market distortions, as Kolstad notes (Kolstad 2011, p. 117, fn. 3).

[12] As with market indirect benefits, EPA does not list forage fish effects in this table. They are relevant for non-market effects for the same reasons explained by EPA (as noted above) for market effects.

3. Increase in boating, scuba diving and near-water recreational participation. (EPA 2014d, p. 4-4)

We provide estimates of nonmarket indirect use benefits insofar as they pertain to benefits from increases in forage fish species on recreational catch.

We would not expect the relatively small theoretical increases in fish populations and catch from Merrimack Entrainment Technology Alternatives to lead to a significantly increased value of aquatic and near-water recreational activities, including enjoying or observing fish while boating, scuba-diving, hiking, or picnicking or watching aquatic birds fish or catch aquatic invertebrates. Barnthouse (2017) concludes that “there is no evidence that operation of Merrimack Station – including entrainment of early life stages of fish, zooplankton, phytoplankton, and any other organisms present in the river – has caused any appreciable harm to the fish community of the Merrimack River” (Barnthouse 2017). This implies that there would be “no appreciable benefit to the fish community, either direct or indirect, from implementing new technologies to reduce entrainment” and “no benefit to any fish-eating birds or mammals that depend on the fish community” (Barnthouse 2017). Thus, we conclude that omitting this potential benefit category from the quantified benefits estimates is not likely to significantly affect the overall results.

d. Non-use Benefits

As noted in Chapter III, Appendix C provides our assessment of potential non-use benefits from Merrimack Entrainment Technology Alternatives. We conclude that any potential non-use benefits are not likely to be significant based upon the biological information included in Barnthouse (2017) and the criteria for significance that have been developed in the economic literature.

VI. Conclusions

This study evaluates the benefits and costs of two entrainment technology alternatives at Merrimack Station. The two CWIS alternatives are: (1) retrofitting Merrimack Station to operate with a closed cycle recirculating cooling water system (CCRS) equipped with a plume-abated mechanical draft cooling tower (plume-abated MDCT); and (2) wedgewire half screens (WWS). The following is a summary of the major conclusions of our evaluation of the social costs and social benefits of the two Merrimack Entrainment Technology Alternatives.

- Neither of the two fish protection alternatives we considered at Merrimack Station passes a social benefit-cost test, because the costs for both alternatives are substantially greater than the benefits.

- The net costs differ a great deal among the two alternatives. Using a 3 percent discount rate, the present values of the net costs (i.e., costs minus benefits) are about $10.7 million for WWS and about $112.7 million for plume-abated MDCT. Using a 7 percent discount rate, the net costs are about $8.6 million for WWS and about $77.0 million for plume-abated MDCT.

- The differences in net costs are even greater when the incremental benefits and incremental costs are compared, particularly for plume-abated MDCT. For the 7 percent discount rate assumption, the plume-abated MDCT provides $4,000 of additional benefits at an added cost of $68.4 million, meaning that the option costs society roughly $18,000 in additional costs for every dollar of additional benefits. Under a 3 percent discount rate, selecting plume-abated MDCT over WWS would mean incurring more than $10,000 in costs for every dollar of benefits. For WWS, the comparisons are about $192 of costs per additional dollar of benefit using 3 percent and about $295 of costs per additional dollar of benefit using 7 percent.

- These conclusions regarding the relative size of social benefits and social costs for the two alternatives do not change in any significant way if one considers (a) the discount rate used to calculate present values; (b) factors excluded from the quantitative monetary assessments; (c) the effects of uncertainties regarding future Merrimack capacity factors; and (d) benefit and cost categories not quantified in this study, including non-use benefits.

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Appendix A: Compliance Costs of Merrimack Entrainment Technology Alternatives

This chapter provides estimates of compliance costs as called for in the Existing Facilities Rule. The costs are based upon the social cost information developed in Chapter II and the methodology for calculating compliance costs outlined below.

A. Compliance Costs Methodology

1. Components of Compliance Costs Estimated in this Study

The Existing Facilities Rule calls for the calculation of compliance costs, which are defined by EPA as the "costs firms incur to reduce or prevent pollution to comply with a regulation" (EPA 2014a, p. 8-8). Thus, to calculate compliance costs for the Merrimack Entrainment Technology Alternatives, we adjust each category of social costs described above to remove costs that would not be incurred by the Owner.

A major difference between social costs and compliance costs is the effect of taxes. When a facility makes investments or incurs expenditures to comply with regulations, it typically will have lower income. This reduced income results in a lower tax burden. Such changes in tax payments do not affect the social costs of the investments or expenditures; but the tax effects do change the net cost to the company. To reflect this difference, after-tax costs are used to estimate compliance costs, whereas pre-tax costs are used to estimate social costs (EPA 2014b, p. 48367, 48428). Based on a federal corporate income tax rate of 35 percent and a New Hampshire business profits tax of 7.5 percent[13], we assume that the total effective tax rate on net income for the facility owner is 38.88 percent (IRS 2016, NH DRA 2017).[14]

The Existing Facilities Rule also notes that "any outages, downtime, or other impacts to facility net revenue, are included in compliance costs, while only that portion of lost net revenue that does not accrue to other producers can be included in social costs," (EPA 2014b, p.48428). This distinction seems to imply that there may be a difference between the social and compliance costs for electricity. However, in a wholesale electricity market such as the one organized by ISO-NE (the relevant organization for purposes of this analysis), the compliance costs and social

[13] The state of New Hampshire business profits tax (BPT) is currently 8.2 percent. This tax schedule indicates that the BPT will be reduced to 7.9 percent after December 31, 2018, with subsequent reductions to 7.7 percent after December 31, 2019, and 7.5 percent after December 31, 2021. For our analysis, we model a BPT of 7.9 percent and an associated effective tax rate of 40.14 percent in 2019, and a BPT of 7.7 percent and an associated effective tax rate of 40.00 percent in 2020 and 2021. The modeling of compliance costs accounts for the effects of this tax schedule appropriately. (NH DRA 2017)

[14] For example, assume a taxable corporate income of $100 million in the state of New Hampshire. Then, assume that this taxable income is first subject to an initial New Hampshire state corporate income tax rate of 7.50%, yielding $7.50 million in state tax revenue. The remaining $92.5 million of the original taxable income is then subject to the federal corporate income tax rate of 35%, yielding $32.38 million in corporate tax revenue. Of the original $100 million, a total of $39.88 million are lost as tax revenue, implying an effective corporate tax rate of 39.88%.

costs would be the same.[15] The following example shows this equivalence. For the facility, the revenues lost from not producing a given megawatt-hour (MWh) would be based on the electricity price for the MWh less any costs the facility saved because of the reduced output. Suppose, for example, that the electricity price is $50/MWh and the facility's incremental cost to produce that MWh is $20/MWh. Thus, the lost revenue would be $30/MWh; this lost revenue would be included in the compliance cost calculations. Now consider the social costs if the facility did not produce a MWh of electricity, i.e., the resource costs to society that would be incurred. In a well-functioning electricity market, the electricity price reflects the cost of providing the marginal MWh for any given time period, which would be $50/MWh in our example. Against these resource costs would be subtracted the resource cost savings at the facility, which are assumed to be $20/MWh in the simple example. Thus, the social cost of the reduction in output of the MWh is equal to $30/MWh, the same as the lost revenue (or compliance cost).

In summary, we modify our social cost estimates for the following four categories of costs to reflect the costs incurred by the plant ownership.

1. *Capital costs.* To estimate compliance capital costs, we assume the plant ownership would finance the investments with a 20-year loan and thus the annual private costs are equal to the costs of both the principle and interest on the loan. (The choice of 20-years for the loan is based upon best professional judgment on how such capital costs might be financed.) The compliance costs associated with construction of Merrimack Entrainment Technology Alternatives are thus equal to the after-tax annual costs of financing the investments in the Merrimack Entrainment Technology Alternatives.

2. *O&M costs.* The only adjustment from the social annual O&M costs is for the tax treatment—compliance costs are estimated after tax, using the 38.88 percent tax rate.

3. *Electricity costs.* The compliance electricity costs represent the loss in revenue for Merrimack from changes in net electricity generation at Merrimack. The only adjustment from the social electricity costs is for the tax treatment—compliance costs for electricity are estimated after tax, using the 38.88 percent tax rate.

4. *Administrative costs.* Compliance costs include only the administrative costs incurred by Merrimack, and thus exclude any public administrative costs. Administrative compliance costs for Merrimack are estimated after tax, using the 38.88 percent tax rate.

2. Discounting of Compliance Costs

Compliance costs are also discounted to calculate net present values as of January 1, 2019, but to do so, we use an estimate of a private (real) discount rate. The specific rate we use is 5.5 percent, based on information from the EIA on the weighted average cost of capital for investments in the

[15] See https://www.iso-ne.com/about/what-we-do/three-roles/administering-markets for an overview of the wholesale electricity market and https://www.iso-ne.com/about/what-we-do/three-roles for an overview of ISO-NE.

electricity industry (EIA 2017a). The compliance costs are evaluated over the same analysis period as the social costs.

3. Baseline Scenario

Both social costs and compliance costs are measured relative to a Baseline Scenario that reflects the future costs if neither of the two entrainment technologies were implemented. In this context, the Baseline Scenario would reflect the current conditions at the facility that would be presumed to apply in future periods.

B. Estimates of Compliance Costs

1. Capital Costs

We do not have information on the method that the Station Owner would use to finance the capital costs. Based on best professional judgment, we assume that the Owner would finance the initial capital costs associated with each technology through a 20-year loan with monthly payments at an interest rate equal to the real after-tax weighted average cost of capital (WACC) for the power sector of 5.5 percent (EIA 2017a) and that the loan term would begin on January 1, 2023, the assumed permitting start state for both of the Merrimack technology alternatives. We account for the full private costs associated with the loan, including principal and interest payments on the loans.

These loan costs would be deductible as expenses. Thus, the compliance costs for capital costs due to the construction of the various technologies would be equal to the after-tax costs of financing the loan. We assume that the Owner would pay for the costs related to replacement parts in the year in which they are incurred (also in after-tax dollars).

Table A-1 summarizes the net present value and annualized values of the compliance capital costs based on these calculations and those explained in Chapter II for social costs.

Table A-1. Net Present Value and Annualized Compliance Capital Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens	$4.90	$0.37
Plume-abated MDCT	$43.53	$3.32

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All values in millions of 2017 dollars.
Source: NERA calculations as explained in text.

2. Operation and Maintenance Costs

Since annual costs would be paid by the Owner as they are incurred, the only adjustment from social costs to compliance costs is to convert all social O&M costs to after-tax compliance costs based upon the effective corporate income tax rate described above. Table A-2 summarizes present and annualized value estimates for compliance costs related to fixed O&M costs.

Table A-2. Net Present Value and Annualized Compliance Fixed O&M Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens	$0.21	$0.02
Plume-abated MDCT	$3.80	$0.29

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars.
Source: NERA calculations as explained in text.

3. Electricity Costs

a. Construction Outage Costs

As discussed above, the loss in revenues to the Owner due to the construction outage is equal to the social costs. Thus, the only adjustment from social costs to compliance costs is to convert the annual social costs to after-tax costs. We do this by applying the effective corporate income tax rate as described above.

Table A-3 summarizes the present and annualized value estimates for compliance costs due to construction outage. The table shows the losses in revenues as well as the savings in fuel and variable O&M costs.

Table A-3. Net Present Value and Annualized Compliance Net Construction Outage Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens		
Outage Power Cost	$2.14	$0.16
Outage Fuel Cost Savings	-$1.14	-$0.09
Outage Variable O&M Savings	-$0.14	-$0.01
Net Construction Outage Power Cost	**$0.86**	**$0.07**
Plume-abated MDCT		
Outage Power Cost	$3.29	$0.25
Outage Fuel Cost Savings	-$1.82	-$0.14
Outage Variable O&M Savings	-$0.22	-$0.02
Net Construction Outage Power Cost	**$1.24**	**$0.09**

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. Values may not sum to totals due to rounding.
Source: NERA calculations as explained in text.

b. Operational Power Losses

Since costs related to operational power losses would be paid by the Owner as they are incurred, the only adjustment from social costs to compliance costs is to convert all social operational costs to after-tax compliance costs. We do this by applying the effective corporate income tax rate described above.

Table A-4 summarizes the present and annualized value estimates for compliance costs related to efficiency power losses. Table A-5 summarizes the present and annualized value estimates for compliance costs related to parasitic power losses.

Table A-4. Net Present Value and Annualized Compliance Efficiency Loss Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens	$0.00	$0.00
Plume-abated MDCT	$5.60	$0.43

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. All cost estimates are relative to the costs that would be incurred under the baseline.

Source: NERA calculations as explained in text.

Table A-5. Net Present Value and Annualized Compliance Parasitic Loss Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens	$0.08	$0.01
Plume-abated MDCT	$6.31	$0.48

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. All cost estimates are relative to the costs that would be incurred under the baseline.

Source: NERA calculations as explained in text.

4. Administrative Costs

Only the administrative costs incurred by the Owner are included in the compliance costs estimates. Accordingly, public administrative costs (those incurred by EPA-Region 1) are excluded from the compliance cost calculations.

Since administrative costs would be paid by the Owner as they are incurred, the only adjustment from social costs to compliance costs is to convert the private administrative costs to after-tax costs by applying the corporate income tax rate as described above.

Table A-6 provides the net present value and annualized value of the administrative cost estimates for both of the technology alternatives.

Table A-6. Net Present Value and Annualized Compliance Administrative Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens	-$0.01	$0.00
Plume-abated MDCT	-$0.22	-$0.02

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. All cost estimates are relative to the costs that would be incurred under the MRTS baseline.

Source: NERA calculations as explained in text.

5. Total Quantified Compliance Costs

Table A-7 summarizes the net present values and annualized values of the estimated compliance costs for the Merrimack Entrainment Technology Alternatives. Present value total compliance costs range from about $6.0 million for wedgewire half-screens to about $60.3 million for plume-abated MDCT. Annualized total compliance costs range from about $0.5 million for wedgewire half-screens to about $4.6 million for plume-abated MDCT.

Table A-7. Estimated Total Quantified Compliance Costs ($2017 million)

	Net Present Value	Annualized Cost
Technology	**5.5%**	**5.5%**
Wedgewire Half-screens		
Capital	$4.90	$0.37
O&M	$0.21	$0.02
Electricity	$0.94	$0.07
Administrative	-$0.01	$0.00
Total	**$6.04**	**$0.46**
Plume-abated MDCT		
Capital	$43.53	$3.32
O&M	$3.80	$0.29
Electricity	$13.15	$1.00
Administrative	-$0.22	-$0.02
Total	**$60.26**	**$4.59**

Note: Net present values are computed as of January 1, 2019 for costs incurred between January 1, 2019 and December 31, 2053. All dollar values in millions of fixed 2017 dollars. Values may not sum to totals due to rounding.

Source: NERA calculations as explained in text.

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Appendix B: Electricity Price Forecasts

This appendix describes the methodology used to estimate monthly wholesale electricity prices from 2019 through 2053 relevant for New Hampshire. As explained in Chapter II, wholesale electricity prices are used to value the social costs and the compliance costs of the decrease in power output at Merrimack due to the installation and operation of Merrimack Entrainment Technology Alternatives. Wholesale electricity prices are an appropriate measure of the real-resource costs of small changes in power output because they reflect the marginal cost of supplying an additional unit of electricity to the grid.

This appendix provides background on the relevant wholesale electricity markets, describes the methodology for developing electricity price projections, and presents the resulting forecasts.

A. Background on New England Wholesale Electricity Markets

Until late in the twentieth century, electricity throughout the United States was generated and distributed primarily by vertically-integrated utilities that had an exclusive franchise within a given area and were subject to rate-of-return (cost-of-service) price regulation. Many states still rely on that traditional regulatory structure.

Starting in the 1990s, several states moved to a vertically-disintegrated system in which regulated investor-owned utilities ("IOUs") buy most of the power they need to serve their customers' demand from wholesale generating companies, with the prices being determined by the market. These purchases can occur through spot markets administered by "Independent System Operators," such as the Independent System Operator New England ("ISO-NE"), that manage markets in which generators bid to provide power to the system. The electricity currently generated at Merrimack Station is sold in power markets organized by ISO-NE.

The ISO-NE is responsible for operating and planning the New England power system, and administering wholesale electricity prices. The ISO-NE coordinates dispatch and sets wholesale electricity prices (which differ from retail electricity prices primarily because they do not include transmission and distribution costs) through hourly uniform clearing price auctions using bids from suppliers and demand-response resources.

The two main components of the ISO-NE wholesale electricity market are: (1) energy markets for buying and selling wholesale electric power, and (2) a forward capacity market for ensuring long-term system reliability.[16]

1. ISO-NE Energy Markets

The ISO-NE runs a day-ahead market and a real-time market for electricity. The day-ahead market provides generators with advanced notice of power requirements and incentive to

[16] The energy and capacity prices are the largest components of wholesale electricity prices, but various "ancillary services" are also required to support the reliable operation of the transmission system. For example, important ancillary services include spinning and non-spinning reserves and regulating resources.

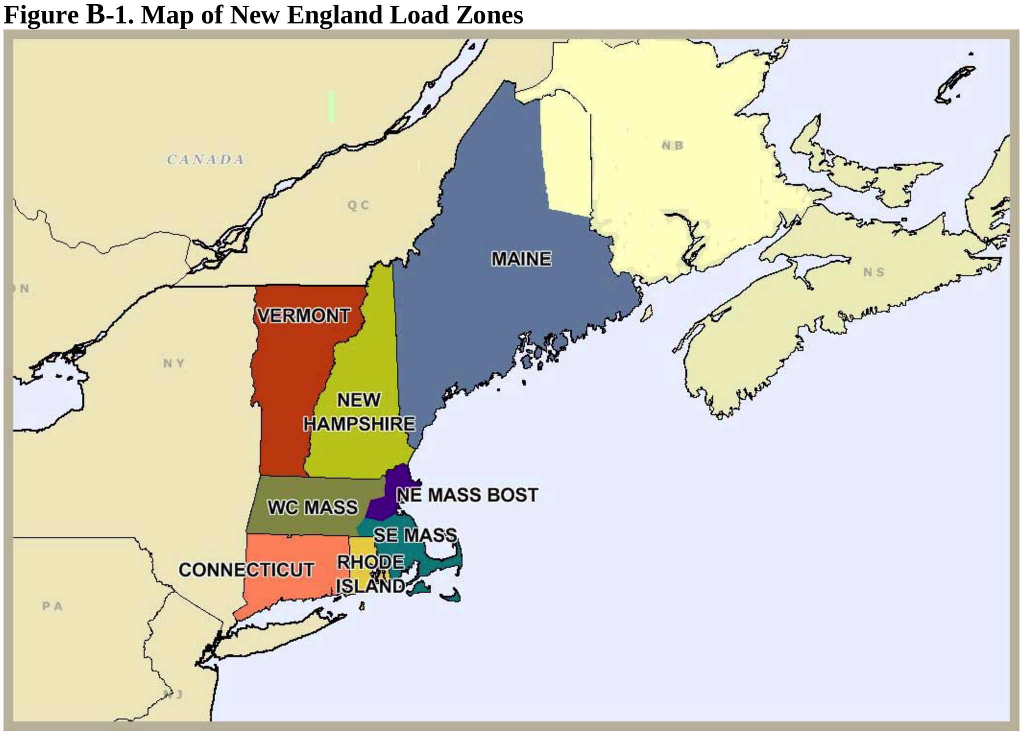
perform as scheduled. The real-time market enables the ISO-NE to efficiently balance the system because conditions can change from the time the day-ahead market is run. The ISO-NE also handles the scheduling of direct transactions between buyers and sellers.

These energy markets ensure a reliable and economic supply of electricity to the high-voltage power grid. The Day-Ahead Energy Market creates a financially binding schedule for the purchase and sale of electricity the day prior to operation. However, since actual supply and demand differs on the operation day, the Real-Time Energy Market settles the difference in prices by either charging or paying out the local marginal price (LMP). The LMP allows ISO-NE to efficiently reflect the value of energy in different location, and varies based on load, generation, and physical limitations of the power plant. The LMPs are measured at over 1000 pricing points, or “pnodes,” spread throughout New England.

The region is divided into eight load zones: Maine (ME), New Hampshire (NH), Vermont (VT), Rhode Island (RI), Connecticut (CT), Western/Central Massachusetts (WCMA), Northeast Massachusetts and Boston (NEMA), and Southeast Massachusetts (SEMA). Generators are paid the real-time LMP for their pnode, and participants serving demand pay the price at their respective load zone (ISO-NE 2014).

A map of the load zones can be seen in Figure B-1.

Figure B-1. Map of New England Load Zones



Source: FERC 2012

LMPs are determined by a system of supply offers and demand bids. LMPs differ across locations because transmission and reserve constraints prevent the next cheapest MW from flowing to all locations on the grid. Even when the cheapest MW can reach all regions, the marginal cost of physical losses results in different LMPs across the grid. Small changes in net power output at Merrimack would be expected to lead to changes in power generated at the "marginal unit" (i.e. the lowest cost unit that is available to generate additional electricity).

2. ISO-NE Capacity Market

The ISO-NE also administers a capacity market in which companies supplying power to customers (i.e., load-serving entities, or "LSEs") can purchase the capacity required to meet their capacity obligations. The goal of the capacity market is to ensure that sufficient resources are available to meet projected load on a long-term basis and encourage the development and maintenance of sufficient generation capacity in New England.

Capacity providers (i.e. power plants) make their generation capacity available to load-serving entities (that is, they "bid into" the capacity market), and in return receive payments from LSEs. In effect, LSEs pay the power plants for the assurance that the power plants could provide power if called upon. The presence of capacity markets thus provides incentives for investment in generation capacity so that there will be capacity sufficient to meet load, even in times of peak electricity demand. The capacity market provides a mechanism for generation units that operate only in peak demand periods—which typically have high marginal costs and relatively low fixed costs—to recover their fixed costs.

To set capacity prices, the ISO-NE uses a demand curve relating to capacity and price that incorporates a "reserve margin" by which generation capacity should exceed projected peak load. Small changes in generation capacity at Merrimack would be valued based upon prices in the ISO-NE capacity market.

B. Electricity Price Projections

We estimate the social costs of changes in net electricity output at Merrimack using the marginal cost of replacement energy on the grid. As explained above, the real-resource costs of supplying an additional unit of electricity to the grid can be estimated using the wholesale prices of electricity. This section describes our methodology for estimating wholesale electricity prices over the relevant period, which is from 2019 through 2053. Although wholesale energy prices are set hourly, it is sensible to provide price projections for more aggregated time periods. As discussed below, we develop average monthly price projections.

1. Overview of Methodology

To value replacement electricity for Merrimack, we develop monthly wholesale electricity price projections for New Hampshire for the years 2019 through 2053 using annual wholesale electricity price projections from the U.S. Energy Information Administration's National Energy Modeling System ("NEMS") (EIA 2017a) and historical wholesale electricity prices from ISO-NE (2017).

2. Overview of the National Energy Modeling System (NEMS)

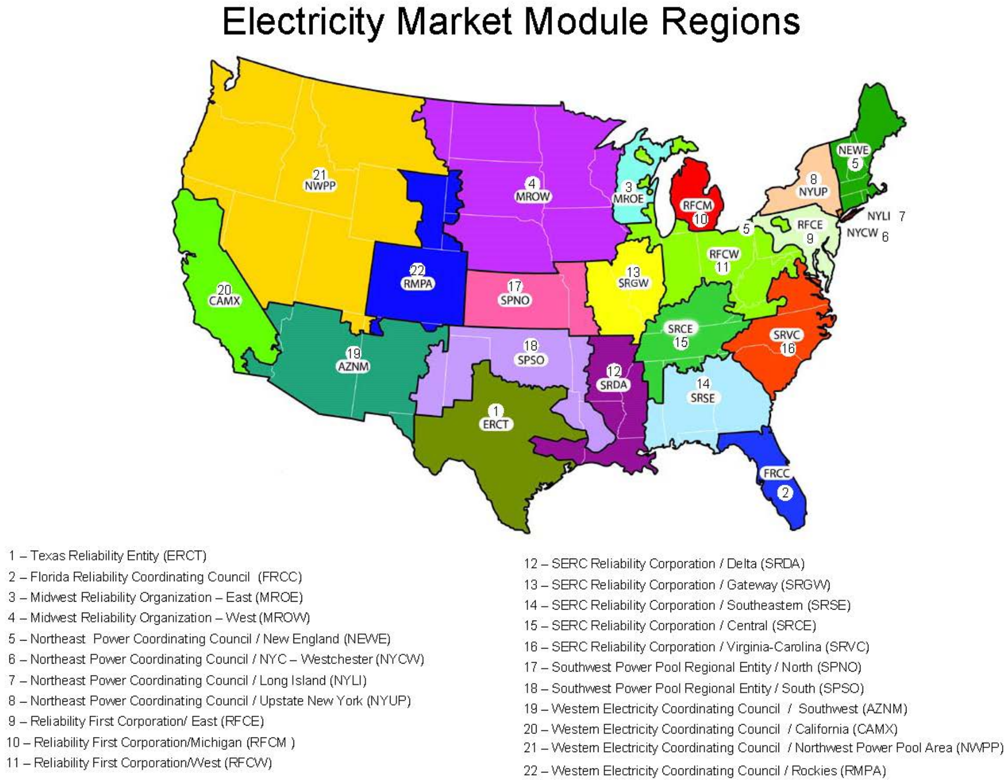
The EIA uses NEMS to form baseline projections for national and regional energy prices and quantities, which are published in the *Annual Energy Outlook* each year. NEMS is a detailed energy and economic model developed and maintained by the EIA Office of Energy Analysis to provide projections of domestic energy-economy markets in the long term and to perform policy analyses requested by decision-makers in the White House, Congress, Department of Energy, and other government agencies.

NEMS models the supply and demand of energy and other markets at regional levels, taking into account interactions among regions. The level of regional detail for the end-use demand modules is the nine Census divisions used by the United States Census Bureau. Other regional structures include production and consumption regions specific to oil, natural gas, and coal supply and distribution, the North American Electric Reliability Corporation ("NERC") regions and sub-regions for electricity, and the Petroleum Administration for Defense Districts ("PADDs") for refineries.

Figure B-2 provides a map of the electricity market module regions modeled by NEMS. For our purposes we use the "Northeast Power Coordinating Counsel / New England," (NEWE) region, a sub-region of the NERC regional entity "Northeast Power Coordinating Counsel,"[17] as it directly aligns with the ISO-NE region. This allows us to apply detailed historical zone-level data from ISO-NE to the NEMS estimates for the NEWE region to distinguish trends in New Hampshire wholesale electricity prices relative to the general New England regional prices. From there we develop average New Hampshire wholesale electricity price projections as described below.

[17] NERC is the central organization responsible for ensuring the reliability of the North American Bulk-Power System. NERC is decentralized into eight regional reliability organizations that are responsible for ensuring the electricity sector reliability within their region, including the Northeast Power Coordinating Counsel.

Figure B-2. NEMS Electricity Market Module Regions



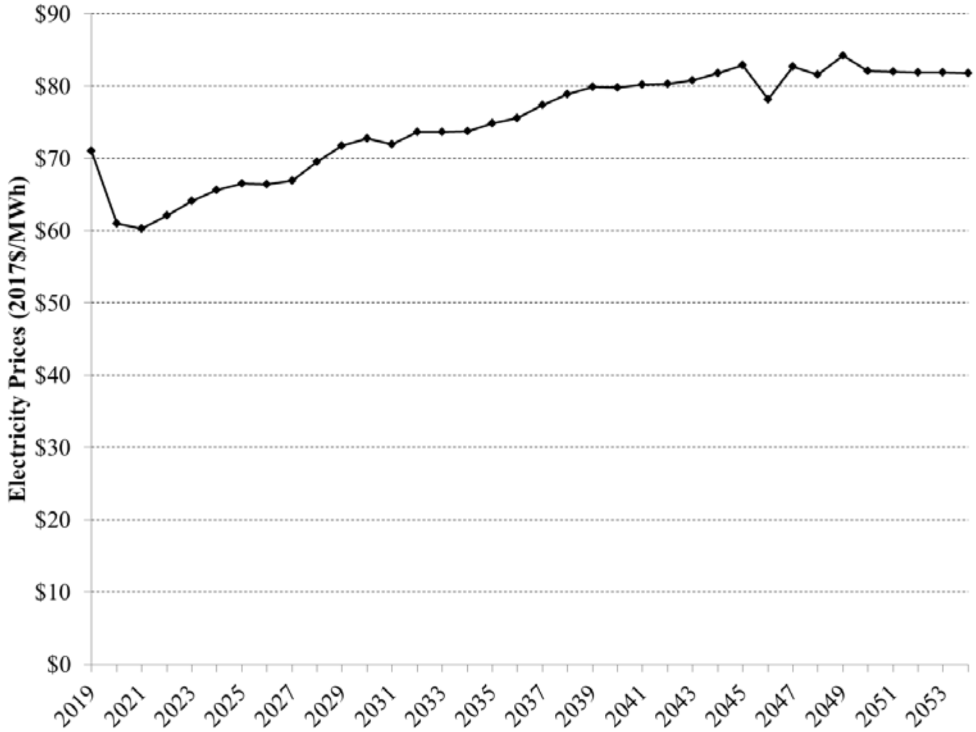
Source: EIA 2017b

3. NEMS Annual Price Projections

The NEMS data consist of annual projections of wholesale electricity prices (including generation, capacity and ancillary services) for the years 2019 through 2050, and are the foundation of our price projections. Since our projection must extend through 2053 to cover the entire analysis period, we extrapolate 2051-2053 using the average growth rate over the period 2046-2050. Figure B-3 displays the NEMS projections of average annual wholesale electricity prices (converted to 2017 dollars using inflation information from US Bureau of Economic Analysis) for the AEO 2017 Reference Case without the Clean Power Plan for the Northeast Power Coordinating Counsel / New England region.

The ISO-NE provides hourly values for LMPs and load in New Hampshire and New England from 2011 through 2016. We used these data to compute an average ratio of New Hampshire to New England LMPs of approximately 1.016, i.e., on average New Hampshire electricity prices are about 1.6 percent greater than prices for the New England region. The NEMS annual price forecast for the New England region is adjusted by this ratio to generate a New Hampshire annual price forecast from 2019 to 2053. We then adjusted the NEMS annual price forecast for New England by this ratio to generate a New Hampshire annual price forecast.

Figure B-3. Projected Average Annual Wholesale Electricity Prices for New England Region ($2017/MWh)



Source: New England Generation Prices, Annual Energy Outlook 2017 (EIA 2017a); NERA calculations as explained in text.

4. Monthly Electricity Price Variability

Electricity prices can vary substantially by month due largely to changes in electricity demand during different seasons of the year. The NEMS model provides only annual price projections. We use historical data from ISO-NE to estimate the likely variability in electricity prices by month over the course of the year.

In particular, we calculate historical ratios of average monthly prices to average annual prices for New Hampshire. We use 2011 to 2016 monthly prices from ISO-NE to calculate these ratios. As shown in Table B-1, the ratios of average monthly to average annual wholesale electricity prices range from 0.76 in October to 1.41 in January. These ratios show that electricity prices are generally higher in the summer and winter when demand is high and lower in the fall and spring when demand is relatively low. Thus, a change in electricity output at Merrimack during the summer or winter months would result in a higher given social or compliance cost than one that occurred during the fall or spring.

Table B-1. Ratios of Average Monthly to Average Annual Wholesale Electricity Prices

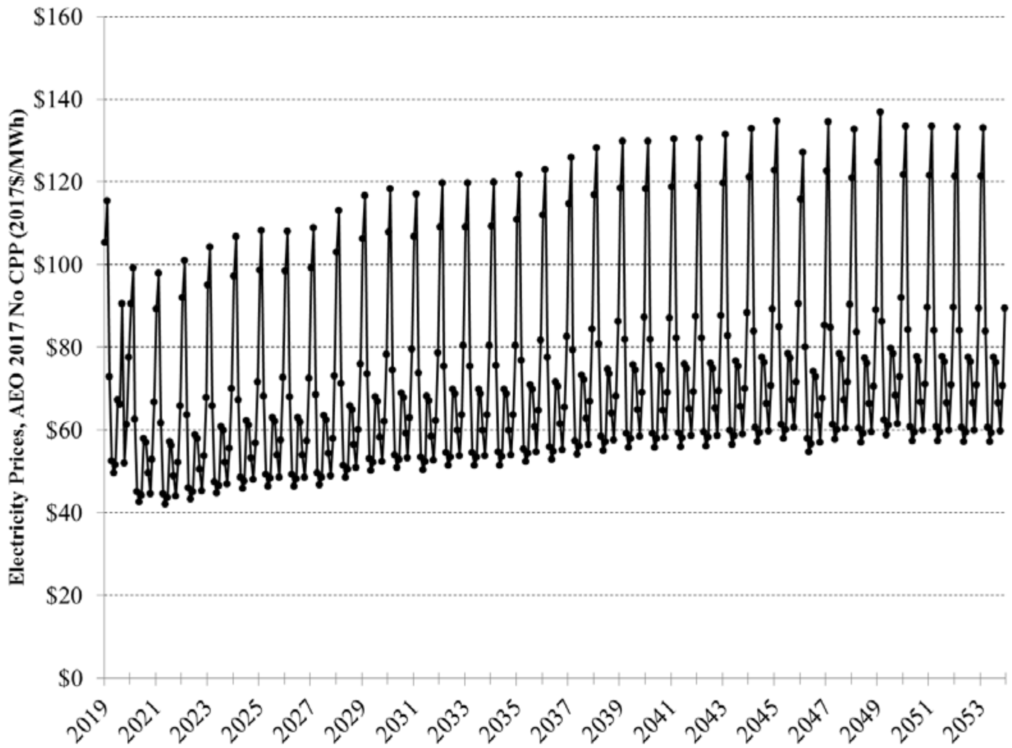
Month	Ratio
January	1.414
February	1.336
March	1.006
April	0.827
May	0.904
June	0.904
July	1.154
August	0.904
September	0.865
October	0.757
November	0.829
December	0.827

Source: NERA calculations based on ISO-NE historical data (2017).

5. Electricity Price Projections

The final step of our methodology is to combine the annual wholesale electricity price projections with the estimates of monthly price variability from the ISO-NE data. In particular, we multiply the New Hampshire annual wholesale electricity prices by the ratios of monthly price variability to obtain estimates of monthly New Hampshire wholesale electricity prices from 2019 through 2053. Figure B-4 provides information on the resulting average monthly wholesale electricity price projections for New Hampshire in 2017 dollars.

Figure B-4: Monthly New Hampshire Wholesale Electricity Price Projections ($2017/MWh)



Source: NERA calculations as explained in text.

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Appendix C: Non-Use Benefits Assessment

As noted in Chapter III, 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. Note that in this context, the "resource" is the set of changes in fish population (or other aquatic changes) due to the alternatives.

This appendix provides the methodology and information used to assess potential non-use benefits from Merrimack Entrainment Technology Alternatives.

A. Introduction and Methodology

In accordance with economic principles and the guidance in EPA's final Existing Facilities Rule, our assessment of non-use benefits from Merrimack Entrainment Technology Alternatives proceeds in three steps: (1) determine whether existing information is available to provide a monetary estimate of the non-use benefits of reduced impingement and entrainment (I&E) at Merrimack Station; (2) if no existing information is available, use guidance from the economic literature to determine whether non-use benefits are likely to be significant; and (3) in light of the results of the economic assessment, determine whether it would be appropriate to develop an independent study of non-use benefits. The results of these steps allow us to provide conclusions regarding non-use benefits from Merrimack Entrainment Technology Alternatives.

1. Concept of Non-use Benefits

The economic literature, U.S. Environmental Protection Agency (EPA) guidelines for economic analysis, and documentation from EPA 316(b) rulemakings all include discussions of benefits not associated with any direct use by people, i.e., non-use benefits. Non-use benefits may arise if people value the change in an ecological resource without the prospect of using the resource or enjoying the option to use it in the future.

EPA's Guidelines for Preparing Economic Analyses, for example, note that there are various possible types of non-use values.

1. Bequest value, where an individual places a value on the availability of a resource to future generations;
2. Existence value, where an individual values the mere knowledge of the existence of a good or resource; and
3. Paternalistic altruism, where an individual places a value on others' enjoyment of the resource (EPA 2014a, p. xiv).

The Guidelines note that environmental policies may have non-use benefits from improvements to "relevant species populations, communities, or ecosystems" (EPA 2014a, p. 7-9). In terms of improvements to relevant species populations, people may, for instance, attach non-use benefits to preserving an endangered species (EPA 2014a, p. 7-18).

With respect to the 316(b) regulations, EPA proposes that non-use benefits include the value that individuals place on knowing that increased fish protection would enable a species to exist or an aquatic ecosystem to be healthy (EPA 2014b, p. 48350, EPA 2014c, p. 4-7).

B. Non-use Benefits in EPA's Final Existing Facilities Rule

This section summarizes EPA's 2014 final Existing Facilities Rule as it relates to non-use benefits. The final Existing Facilities Rules was issued in 2014 and preceded by (1) the Phase I Rule (proposed in 2000, finalized in 2001); (2) the Phase II Rule (proposed in 2002, finalized in 2004); (3) the Phase III Rule (proposed in 2004, finalized in 2006); (4) the proposed Existing Facilities Rule issued in 2011; and (5) the stated preference survey released in 2012 in the context of the proposed Existing Facilities Rule.

1. Overview of Final Existing Facilities Rule

In 2014, EPA issued its final Existing Facilities Rule for existing electric generating plants and other existing facilities that replaced both the Phase II and Phase III rules. As suggested in the proposed Existing Facilities Rule, the Final Rule sets national standards for impingement reduction and calls for site-specific evaluations to determine the Best Technology Available for entrainment reduction.

The Final 316(b) Rule reiterated many of the qualitative assessments related to non-use benefits from the proposed Existing Facilities Rule. EPA references the academic literature to support its position that "the public holds significant value for service flows from natural resources well beyond those associated with direct uses" (EPA 2014c, p. 4-8).

EPA did not use the survey it had sponsored to monetize the non-use benefits of the Final 316(b) Rule. EPA stated that "[b]ased on consideration of public comment, EPA decided not to employ the survey results for purposes of decision-making in this rule, or include them in assessing the total benefits of the rule" (EPA 2014b, p. 48325). Instead, EPA used the same "partial estimates" of non-use benefits for the North Atlantic and Mid-Atlantic regions that it used in the proposal, despite the criticism of these estimates.

2. Site-Specific Assessment of Non-use Benefits in the Final Existing Facilities Rule

In regard to site-specific assessments, the final Existing Facilities Rule requires that evaluations of benefits of entrainment technologies include assessments of use and non-use benefits (EPA 2014b, p. 48351). This assessment must include a narrative description of any potential non-use benefits, and non-use benefits should be quantified or monetized when possible using appropriate economic valuation methods (EPA 2014b, p. 48428).

EPA indicates that non-use benefits should be monetized if there is suitable data to do so with well-accepted methods:

> If appropriate data are available from benefits transfer or conducting stated preference studies or other sources that can be applied to the site being evaluated,

> these should be used to monetize non-use values. Otherwise, non-use values should be evaluated quantitatively and/or qualitatively (EPA 2014b, p.48371).

If appropriate data are unavailable, monetization of non-use benefits is not required as part of the site-specific benefits assessment:

> Willingness-to-pay for non-use benefits can be measured using benefits transfer or a stated preference survey. However, the rule does not require the Director to require a facility owner or operator to conduct or submit a stated preference survey to assess benefits (EPA 2014b, p. 48368).

EPA also reiterated that the results of its stated preference survey published in 2012 "were not specifically designed to be statistically representative at the facility level for the assessment of benefits for individual site-level permitting decisions" (EPA 2014b, p. 45380).

With regard to site-specific consideration of costs and benefits, EPA indicates that the Director must consider, among other factors, "monetized, quantified and qualitative social benefits and social costs of available entrainment controls, including ecological benefits and benefits to any threatened and endangered species" (EPA 2014b, p. 48351). Moreover, EPA indicates that the Director should not ignore non-monetized benefits. "Instead, the Director should consider what the magnitude of the non-monetized benefits would have to be in order to justify the costs" (EPA 2014b, p. 48351). In other words, if the costs of entrainment technologies are determined to be greater than the associated "use benefits," the magnitude of the non-use benefits necessary to make up this difference should be considered. EPA does not, however, provide any guidance on how such considerations should influence the Director's assessment of the relationship between social benefits and social costs.

C. Assessment of Potential Non-Use Benefits from Merrimack Entrainment Technology Alternatives

As noted above, our assessment of non-use benefits from Merrimack Entrainment Technology Alternatives proceeds in three steps: (1) determine whether existing information is available to provide a monetary estimate of the non-use benefits of reduced I&E at Merrimack Station; (2) if no existing information is available, use guidance from the economic literature to determine whether non-use benefits are likely to be significant; and (3) given the results of the economic assessment, determine whether it would be appropriate to develop an independent study of non-use benefits. The results of these steps allow us to provide conclusions regarding non-use benefits from Merrimack Entrainment Technology Alternatives in the final section of this appendix.

1. Assessment of Existing Information to Monetize Non-use Benefits from Merrimack Entrainment Technology Alternatives

EPA indicated in the Existing Facilities Rule that non-use benefits should be monetized if suitable results exist from an existing study or a study that could be used as the basis for benefit transfer. No existing study of non-use benefits related to Merrimack Station has been performed.

We thus focused on determining if there were existing studies that could be used as the basis for benefit transfer.

As a threshold matter, benefit transfer analysis is only a valid approach when a prior study has evaluated a comparable commodity, where comparability includes the nature of the environmental changes (in this case, potential increases in various fish populations) and the location of the change (in this case, Hooksett Pool or Merrimack River). EPA has noted this element of the benefits transfer approach, cautioning that "the less similar are the commodities valued in the existing ecological benefit studies …the less valid will be the transfer of the resulting value estimate or function (EPA 2014a, p. 7-19). In its Guidelines for Preparing Economic Analyses, EPA states:

> Study cases potentially suitable for use in benefit transfer should be similar to the policy case in their: (1) definition of the environmental commodity being valued (include scale and presence of substitutes); (2) baseline and extent of environmental changes; and (3) characteristics of affected populations. Analysts should avoid using benefit transfer in cases where the policy or study case is focused on a "good" with unique attributes or where the magnitude of the change or improvement across the two cases differs substantially (EPA 2014a, p. 7-46).

Therefore, we performed a literature review of potential studies that might be used as the basis for benefit transfer. Consistent with the EPA recommendation to "develop an explicit set of selection criteria to evaluate each of the potentially relevant studies for quality and applicability to the policy case," NERA used the following two criteria for benefit transfer study selection (EPA 2014a, p. 7-45):

1. The study pertains to a comparable commodity and environmental change (potential increases in fish populations similar to those relevant at Merrimack); and

2. The study pertains to a comparable site (i.e., it is sufficiently similar to Hooksett Pool or, more generally, Merrimack River).

We conducted an extensive literature search for relevant studies pertaining to water bodies located within the Merrimack River Watershed, with particular attention given to sites similar to the Hooksett Pool. Table C-1 summarizes the studies uncovered in our literature search and our evaluations of their appropriateness for benefits transfer based upon the two benefit transfer criteria provided above. We conclude that no studies are appropriate to use as the basis for benefits transfer to develop non-use values for Merrimack Entrainment Technology Alternatives.

Table C-1. Summary of Studies Uncovered in Literature Search

Study	Adequately Similar Commodity and Evironmental Change	Adequately Similar Study Site
Troy (2012)	No	No
Oster (1977)	No	Yes
Pemigewasset River Local Advisory Committee (2013)	No	Yes
U.S. Atlantic Salmon Assessment Committee (2009)	No	No
Steinback (2014)	No	No
Mavrommati, Borsuk, and Howarth (2017)	No	Yes
University of Connecticut (1999)	No	No

Source: NERA.

2. Economic Criteria on the Likely Significance of Non-use Benefits

The economics literature on non-use valuation provides some guidance on situations in which non-use values are likely to be significant. We use this literature to structure a qualitative assessment of the likely significance of non-use benefits due to the hypothetical installation and operation of Merrimack Entrainment Technology Alternatives.

Freeman (2003) reviews the literature on non-use values, considering the situations in which non-use values are likely to be important:

> Another important question is, when are non-use values likely to be important? The long literature on non-use 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 non-use 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 non-use values because of the availability of close substitutes. Moreover, the literature does not suggest that non-use 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).

Thus, Freeman's (2003) review of this literature suggests two operative criteria for evaluating whether non-use value for fish protection is likely to be important:

1. The affected resource is unique, in contrast to effects on a widely dispersed wildlife species; and

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

Freeman (2003) recognizes that there is no generally accepted method of determining whether a resource is sufficiently unique or a resource change is of sufficient duration to generate important non-use values (p. 157). But he suggests that unless the two criteria mentioned above are met, non-use values are unlikely to be important. Freeman (2003) also notes that stated preference methods should be used cautiously, as it is extremely difficult to perform such studies well (p. 183).

a. Implications for Potential Significance of Non-use at Merrimack Station

The Freeman criteria can be used to evaluate the potential significance of non-use benefits from the installation of Merrimack Entrainment Technology Alternatives. We consider the two factors (uniqueness and irreversibility) in terms of the changes in T&E species and other species.

i. 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"). EPA earlier 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 – Region 1 2011, p. 57). A similar conclusion was reached in Barnthouse (2017), which states that "none of the fish species collected in the surveys conducted by Normandeau (2011, 2017) are classified as threatened or endangered" (Barnthouse 2017, p. 36). We conclude from these observations that there would be no non-use benefits associated with threatened and endangered species at Merrimack.

As a precaution, we note that non-use benefits may also be considered important 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). In 2011, EPA reported that anadromous Atlantic salmon were the *only* federally-managed species believed to be present within the Hooksett Pool of the Merrimack River (EPA – Region 1 2011, p. 54). However, EPA acknowledged that Atlantic salmon were not expected to be present in Hooksett Pool as eggs or larvae, and thus entrainment would not be a major concern (EPA – Region 1 2011, p. 55). The USFWS has since ended the Merrimack River Atlantic Salmon Program (effective September 5, 2013), due to low population returns and declining budgets (USFWS 2013). Atlantic salmon are no longer stocked in the Merrimack River. We conclude from EPA information and the 2013 termination of the salmon restoration program that there would not be any non-use benefits associated with Atlantic salmon from Merrimack Entrainment Technology Alternatives.

ii. Other Species

Chapter III includes a list of the thirty-six 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 either of the Merrimack Entrainment Technology

Alternatives were in place. The question for consideration with regard to these species and the accompanying biological benefits is the following: do the biological gains constitute a “unique” resource or would they be to a “subpopulation of a widely dispersed wildlife species” (Freeman 2003)? If the benefits from Merrimack Entrainment Technology Alternatives constitute the latter, Freeman (2003) notes that they would not be likely to generate significant non-use values.

We are not aware of a study of the prevalence of the various species affected at Merrimack Station. However, analyses of the fish population and community composition of Hooksett Pool have been conducted using electrofishing survey data from 1972 through 2013 (Normandeau Associates 2011). These analyses confirm that many fish species in Hooksett Pool have “fluctuated in abundance without any apparent trend” (Barnthouse 2017, p. 11). Moreover, “per year diversity index values from the sampling years in the 2000s were higher than the values from the sampling years in the 1970s, indicating that the diversity of the fish community in Hooksett Pool and therefore the biological health of that community has generally increased not decreased, over the past forty years” (Normandeau Associates 2012, pp. 1-2).

As discussed above, Barnthouse (2017) concludes that “there is no evidence that operation of Merrimack Station – including entrainment of early life stages of fish, zooplankton, phytoplankton, and any other organisms present in the river – has caused any appreciable harm to the fish community of the Merrimack River” (Barnthouse 2017, p. 36). This implies that were would be “no appreciable benefit to the fish community, either direct or indirect, from implementing new technologies to reduce entrainment” and “no benefit to any fish-eating birds or mammals that depend on the fish community” (Barnthouse 2017, p. 36).

Given this information, the potential gains to each of the species that would be affected by Merrimack Entrainment Technology Alternatives represent a very small fraction of the total population and biological benefits would accrue to “subpopulations of a widely dispersed wildlife species” (Freeman 2003). Under these conditions, the species affected by I&E at Merrimack would not constitute unique resources. Thus, by Freeman’s (2003) criteria, non-use benefits from Merrimack Entrainment Technology Alternatives would not likely be significant as judged by impacts on non-T&E species.

3. Appropriateness of Developing a Stated Preference Study to Monetize Non-use Benefits

In principle, a well-designed stated preference study could be used to measure the potential non-use benefits associated with reduced I&E at Merrimack Station. As noted in EPA (2014a) Guidelines, however, obtaining reliable results from a stated preference study is very difficult. Indeed, we are not aware of any instance in which non-use benefits have been estimated for changes in I&E in the context of a site-specific 316(b) benefits valuation study.

In light of the substantial costs and difficulty of developing a site-specific assessment of non-use benefits, as well as the conclusion that non-use benefits are not likely to be significant in this situation, we conclude that it is not appropriate to develop a stated preference study to assess non-use benefits from Merrimack Entrainment Technology Alternatives. This conclusion is consistent with EPA Guidelines, as noted above.

D. Conclusions Regarding Non-use Benefits from Merrimack Entrainment Technology Alternatives

The assessments in this appendix all indicate that non-use benefits associated with the fish protection benefits from Merrimack Entrainment Technology Alternatives are not likely to be important and are not worthy of empirical estimation using a contingent valuation study. We instead provide a qualitative evaluation of non-use benefits.

Non-use benefits cannot be monetized as there is no available study that could be used appropriately as the basis for benefit transfer.

- 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, are unlikely to have important non-use benefits.

In accordance with guidance provided by economic literature and the final Existing Facilities Rule, we thus conclude that non-use benefits from Merrimack Entrainment Technology Alternatives are not likely to be significant.

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