Economic Benefits of Installing a Closed-Cycle Cooling System at Salem Nuclear Generating Station

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Final Report

ECONorthwest
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ECONorthwest specializes in economics, planning, and finance. Established in 1974, ECONorthwest has four decades of experience helping clients make sound decisions based on rigorous economic, planning and financial analysis.

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Disclaimer

Delaware Riverkeeper Network commissioned the analysis described in this report.

Throughout the report we have identified our sources of information and assumptions used in the analysis. Within practical limits, ECONW has made every effort to check the reasonableness of the data and assumptions and to test the sensitivity of the results of our analysis to changes in key assumptions.

We gratefully acknowledge the assistance of individuals who provided us with information and insight. But we emphasize that we, alone, are responsible for the report's contents. We have prepared this report based on our own knowledge and training and on information derived from government agencies, the reports of others, and other sources believed to be reliable. ECONorthwest has not verified the accuracy of all such information, however, and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available. Responsibility for this research and findings lies solely with the authors.

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Executive Summary

Salem Nuclear Generating Station (Salem) is owned and operated by PSEG Power, LLC (PSEG) and Exelon Generation, LLC (Exelon). The plant, located in New Jersey, has two reactors with a combined capacity of 2,307 MWe. Both of the reactors use once-through cooling systems that withdraw up to 3,024 million gallons a day from the Delaware Bay. These once-through cooling systems result in entrainment and impingement (E&I) of aquatic life that increase mortality in many aquatic species across different life stages. However, there are alternatives, such as closed-cycle cooling systems, that reduce or avoid these impacts on aquatic life.

In this report, we describe the value of some of the potential benefits and costs associated with replacing Salem's existing once-through cooling system with a closed-cycle cooling system. The scope of this analysis is limited and is not intended to represent a comprehensive benefit-cost analysis. Rather, the results of this analysis shed light on some of the primary economic values associated with a closed-cycle cooling system's potential to reduce the harmful impacts on aquatic species in and around the Delaware Bay. In particular, they are intended to inform the economic question facing this context of whether or not the costs of a closed-cycle cooling system are wholly disproportionate to or significantly greater than the benefits they would generate.

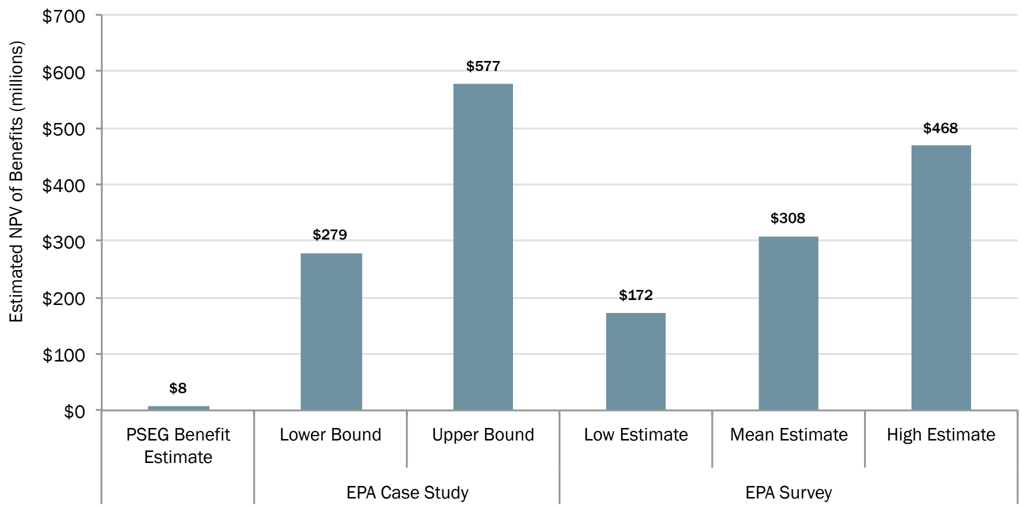
In this context, we describe the benefits in terms of the broad benefits to society that include consumptive and non-consumptive uses of resources at stake. We follow OMB and U.S. EPA guidance in this process, using available data to understand the set of benefits provided by a closed-cycle system at Salem, and the importance of these benefits in the Delaware Bay context. It is clear that the PSEG benefit estimates, which address only consumptive uses, are incomplete.

In its 2006 permit application, PSEG estimated the value of the fish saved by installing a closed-cycle cooling system at Salem – in terms of their potential annual recreational and commercial values, summed over a 34-year period – at roughly $8 million dollars. In contrast, a 2002 Case Study Analysis conducted by the EPA to illustrate the application of the 316(b) rulemaking, estimated the present value of the fish saved over the course of the next 20 years as being between $279 and $577 million.

To further establish the magnitude of the potential benefits from installing closed cycle cooling systems at Salem, we apply the results of a comprehensive, nation-wide valuation survey to estimates of mortality at Salem. The net present value of the 20-year stream of benefits estimated using this method is between $172 and $468 million, which supports the EPA's previous valuation results. Estimates based on the Habitat Equivalency Analysis technique derived from Natural Resource Damage Assessment methods are comparable or higher.

We emphasize, however, that these estimates still do not represent a full accounting of the value of benefits to be gained at Salem from preventing E&I, and that there are other (as-yet unquantified) factors that would magnify and add to these monetized values. These factors include increasing regional scarcity of affected species due to other disturbances in the Delaware Estuary, changing climate conditions, and the large number of endangered species and species with long-term population declines involved. It is likely that efforts to include these additional factors would raise annual benefits of the Project Alternative by millions of dollars.

Summary of Alternative NPV Benefit Estimates



We also review the affordability of costs associated with closed-cycle cooling at Salem, both from the private perspective of PSEG and Exelon as well as ratepayers. Overall, the data available suggest that the costs are affordable, and are not wholly disproportionate to or significantly greater than their resulting benefits to society.

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1 Introduction

The Salem Nuclear Generating Station (Salem) is jointly owned by PSEG Power, LLC (PSEG) and Exelon Generation, LLC (Exelon).[1] The station, located in Lower Alloways Creek, New Jersey, has two reactors with a combined production capacity of 2,307 MW.[2] Both reactors use once-through cooling systems that withdraw up to 3,024 million gallons a day from the Delaware Bay.[3] These once-through cooling systems result in entrainment and impingement (E&I) of aquatic life that increase mortality in many aquatic species across different life stages. However, there are alternatives, such as closed-cycle cooling systems, that reduce or avoid these impacts on aquatic life.

1.1 Objective of this Report

In this report, we look at two potential futures – one without the installation of closed-cycle cooling (the Baseline Scenario), and one with it (the Project Scenario). The objective of this analysis is to identify and describe the primary economic value of the benefits and costs associated with the Project Scenario relative to the Baseline Scenario. The scope of this analysis is limited and is not intended to represent a comprehensive benefit-cost analysis. Rather, the results of this analysis shed light on some of the primary economic values, both public and private, associated with the Project Scenario's potential to reduce the harmful impacts on aquatic species in and around the lower Delaware Bay. Similarly, this report does not include an economic impact analysis, so we do not estimate changes in employment and income, although we do discuss some of the impact implications.

1.2 Main Sources Used in this Report

Throughout our analysis, we rely primarily on a set of relevant documents to guide our understanding of the biophysical characteristics underlying the Baseline and Project Scenarios, and to inform our economic analysis of the potential value of benefits and costs associated with each scenario. Some of these documents are specific to Salem, while others are based on similar plants and also the general context of cooling water intake structures (CWIS). We rely on two studies, in particular, throughout our report - we refer to these sources by their short names (bolded):

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[1] PSEG has a 57.41 percent ownership interest, and the remaining 42.59 percent is owned by Exelon Generation Company, LLC. PSEG is the primary operator of the station. Government Printing Office. 2005. FR Doc No: E5-4101. Available online at: http://www.gpo.gov/fdsys/pkg/FR-2005-08-02/html/E5-4101.htm

[2] PSEG Investor FACT Book 2014-2015. PSEG Power Consolidated Balance Sheets. Page 43. Available online at: https://www.pseg.com/info/investors/pdf/factbook.pdf

[3] New Jersey Department of Environmental Protection. 2015. PSEG NUCLEAR LLC SALEM GENERATING STATION NJPDES - Surface Water Renewal Permit Action. Page 4. Available online at: http://www.nj.gov/dep/dwq/pdf/salem-draft-2015.pdf

- **EPA Case Study.** US Environmental Protection Agency (EPA). 2002. *Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. Part B: The Delaware Estuary Watershed Case Study*. EPA-821-R-02-002. Office of Water, Washington, DC.
- **EPA Benefits Analysis**. US EPA. 2014. *Benefits Analysis for the Final 316(b) Existing Facilities Rule*. EPA-821-R-14-005. This document also includes the **EPA Survey** *(Chapter 11).*

1.3 Structure of this Report

First, we describe the two scenarios (the Baseline Scenario and the Project Scenario) that we consider in our analysis. Then we present a brief summary of the potential biophysical effects associated with the Project Scenario relative to the Baseline Scenario in terms of economically valuable effects, focused on E&I associated with operations at Salem. In the next section, we use data and methodologies from other studies combined with our understanding of the Salem context to describe the potential value of the benefits and costs associated with the Project Scenario relative to the Baseline Scenario. We also discuss the affordability of the Project Scenario costs. We conclude the report by summarizing our results, and discussing the sensitivity of our results to a number of relevant variables.

2 Baseline and Project Scenarios

To understand the economic value of the benefits and costs associated with installing a closed-cycle cooling system at Salem, we compare two scenarios, the Baseline Scenario and the Project Scenario, to identify differences in effects on valuable goods and services for society.

Baseline Scenario. This describes current and future conditions at Salem with the existing, once-through cooling systems. We assume no changes to the fish protection technologies used at the facility.

Project Scenario. Under the Project Scenario, we assume that a closed-cycle cooling system is installed at Salem in 2016, and that the benefits and costs associated with the closed-cycle cooling system begin in 2016 and continue for a total of 20 years.

We do consider other effects that lead to changes over time for the affected resources. For example, as other conditions make resources and substitutes scarcer, the effects on these resources of the Baseline and Project Scenarios become more valuable.

3 Biophysical Effects of the Baseline and Project Scenarios

In this section, we briefly summarize the biophysical effects of the Baseline and Project Scenarios. Salem is located on Delaware Bay, at the dividing line between the transitional and lower estuary. The facility's surroundings support a functional biological community with both freshwater and estuarine species, including important life stages of commercially and recreationally important fish species, as well as two endangered sturgeon species and three endangered sea turtle species. This area is a crucial component of the regional ecological landscape, and holds broader economic, social, and cultural importance. The existing once-through cooling system employed at Salem under the Baseline Scenario directly kills billions of aquatic organisms through E&I every year. Furthermore, the Baseline Scenario's effects on aquatic habitat have the potential to exacerbate the potential effects associated with climate change. The closed-cycle cooling system that would be employed at Salem under the Project Scenario decreases the extent of these negative effects.

3.1 Entrainment and Impingement

Salem is one of the 50 largest power plants in the U.S, and ranks in the top three in terms of cooling water use.[4] While temporal and spatial variability in fish populations makes direct comparison of E&I at individual facilities difficult, it is clear that Salem also causes some of the largest E&I-related fish mortality in the country. Given the size of Salem's water withdrawals, its location in an estuarine environment that serves as a nursery for a large variety and number of aquatic species, as well as the heightened vulnerability of these early life stages to E&I, it is not surprising that we were only able to identify one other facility, out of 550 evaluated by the EPA, with higher kill rates.[5] As reflected in EPA's survey results (described later in this report), the magnitude of fish kills at Salem are a matter of national interest and importance.

Throughout this document we make reference to both total organisms killed (which includes eggs, larvae, and adult fish), as well as age 1 equivalents (A1E). Converting organism counts to equivalent units of individual adults accounts for the number of eggs and larvae that would be expected to survive to adulthood under natural conditions, and provides a standard metric for comparing losses among species, years, and regions. For the section 316(b) rulemaking, EPA expressed E&I losses and values at all life stages as an equivalent number of age 1 individuals.

EPA summarizes historical E&I data for Salem in a 2002 case study analysis supporting the Section 316(b) Phase II Existing Facilities Rule. This information describes conditions under the

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[4] Salem's maximum intake capacity (3,024 MGD) far surpasses that of other power plants; see appendix listing in Sierra Club. 2011. *Giant Fish Blenders: How Power Plants Kill Fish & Damage Our Waterways*. Available at: http://vault.sierraclub.org/pressroom/media/2011/2011-08-fish-blenders.pdf. Additionally, most plants with comparable intake capacities have dedicated reservoirs and lakes, or the open ocean, as water sources. For additional water use data, see Union of Concerned Scientists. 2012. *UCS EW3 Energy-Water Database V.1.3*. www.ucsusa.org/ew3database.

[5] The Big Bend Power Station, a coal-fired power plant located in Tampa Bay, kills an estimated 7 billion A1E fish a year, on average. Bay Anchovy comprise over 99 percent of this mortality. US Environmental Protection Agency (EPA). 2002. *Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. Part D: Tampa Bay Case Study*. EPA-821-R-02-002. Office of Water, Washington, DC. Page D3-22.

Baseline Scenario. To estimate E&I under the Project Scenario, we assume an 87.4 percent reduction with closed cycle technology.[6]

Entrainment mortality accounts for over 99 percent of the fish killed at Salem (Table 1).[7] Entrained organisms under the baseline scenario average 14.7 billion a year, and impinged organisms 6.6 million per year. This equates to 356 million and 3 million adult equivalents, respectively, for a total of 360 million A1E fish killed in an average year.[8]

Table 1. Average Annual E&I at the Salem Nuclear Generating Station under the Baseline and Project Scenarios

		Baseline Scenario	Project Scenario	Fish Saved
Number of Organisms	Entrained	14,660,056,000	1,847,167,000	12,812,889,000
	Impinged	6,634,000	836,000	5,798,000
	Total	**14,666,689,000**	**1,848,003,000**	**12,818,687,000**
	% Entrained	99.95%		87.40%
	% Impinged	0.05%		
Equivalent Adults	Entrained	356,320,000	44,900,000	311,430,000
	Impinged	3,190,000	400,000	2,780,000
	Total	**359,510,000**	**45,300,000**	**314,210,000**
	% Entrained	99.11%		87.40%
	% Impinged	0.89%		

Sources: EPA Case Study, and US EPA. 2002. *316(b) Phase II EBA, Part C: National Benefits Chapter*. Page C2-1. Available online at: http://permanent.access.gpo.gov/websites/epagov/www.epa.gov/waterscience/316b/econbenefits/c2.pdf

Note: figures may not sum due to rounding.

Based on the figures presented above, the Baseline Scenario results in approximately 314,210,000 more E&I deaths per year (in terms of fish that would otherwise have survived to adulthood) than the Project Scenario, on average. In terms of the number of organisms entrained or impinged at any life stage, the Project Scenario reduces mortality by over 12 billion. E&I at Salem varies considerably, year-to-year, based on intake and production levels at the facility as well as inter-annual population fluctuations for individual species (Figure 1). The vast majority of fish losses at Salem are Bay Anchovy, one of the most abundant species in the Bay, and a primary food source for many other fish inhabiting the river, including weakfish, bluefish and striped bass.

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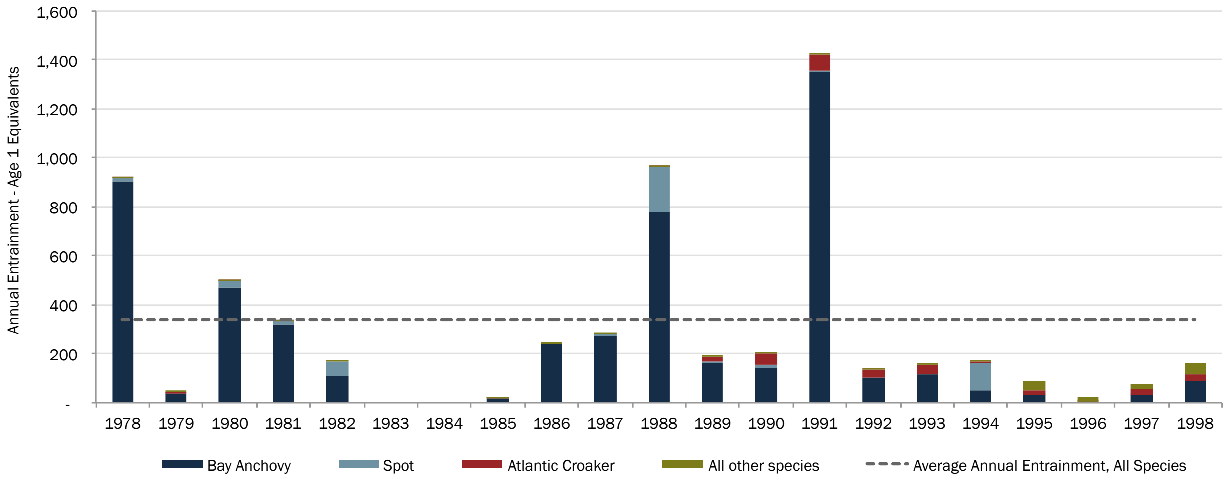
[6] EPA Benefits Analysis. Page 3-9. Note, however, that other studies (such as Versar. 1986. *Technical Review and Evaluation of Thermal Effects Studies and Cooling Water Intake Structure Demonstration of Impact for the Salem Nuclear Generating Station*) assume 95 percent reduction in E&I with closed-cycle cooling – commensurate with the average flow reductions that the facility would experience with the new technology. In light of this information, our estimates are conservative and likely underestimate the true number of fish saved.

While these estimates encompass only the period between 1978 -1998, they remain the most detailed available, and still accurately reflect current rates E&I at the plant. E&I data for 2004-2006, summarized in the 2015 Draft Permit, show similar magnitudes and patterns of mortality.

[7] Based on the mortality factors calculated by PSEG and included in the EPA Case Study, we assume 100 percent entrainment mortality.

[8] PSEG likely underestimates true E&I at Salem (see EPA Case Study, page B3-25).

Figure 1. EPA's Estimates of Annual Entrainment at the Salem Station, by Species, Expressed as Numbers of Age 1 Equivalents (1978 -1998)



Source: ECONorthwest based on data from the EPA Case Study

Note:

Estimates of Non-RIS species only became available after 1995

The station was shut down for the majority of 1996

'All other species' includes: Alewife, American Shad, Atlantic Menhaden, Blueback Herring, Silversides, Striped Bass, Weakfish, White Perch, Non-RIS Fishery Species, and Non-RIS Forage Species.

These annual mortality estimates are large enough to have population-level impacts.[9] Annual cooling water demand at Salem alone, for example, accounts for a 31 percent direct reduction in the local Bay Anchovy population.[10] Furthermore, these losses of aquatic organisms do not occur in isolation and instead are exacerbated by other forms of harm in the Delaware Estuary, including dredging by the Army Corps and other once-through cooling facilities. The EPA highlighted the Delaware River system as having large cumulative impacts from facilities with CWIS, with intake flows consuming roughly 20 percent of the total annual river flow.[11] Previous research suggests that cooling water intakes at Salem and the Delaware City Refinery (located across the river from Salem), together, can kill more than half of the striped bass population of

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[9] See, for example:

- Versar. 1986. *Technical Review and Evaluation of Thermal Effects Studies and Cooling Water Intake Structure Demonstration of Impact for the Salem Nuclear Generating Station*. Prepared for the New Jersey Department of Environmental Protection.
- Carpenter Environmental Associates, Inc. 2003. *Evaluation of Special Conditions Contained in Salem Nuclear Generating Station NJPDES Permit to Restore Wetlands, Install Fish Ladders, and Increase Biological Abundance Within the Delaware Estuary*. Prepared for Delaware Riverkeeper Network.
- Kahn, D. 2008. Delaware Division of Fish and Wildlife. *Impacts of Impingement and Entrainment Mortality by the Delaware City Refinery on Fish Stocks and Fisheries in the Delaware River and Bay*.

[10] Fletcher. 1990. *Flow Dynamics and Fish Recovery Experiments: Water Intake Systems*. Transactions of the American Fisheries Society.

[11] EPA Benefits Analysis. Page 2-18.

the Delaware River in a given year. Similarly, the two facilities combined have been estimated to kill up to 23 percent of all the Weakfish found in the River.[12]

3.2 Biophysical Effects within the Context of Climate Change

Over the past 40 years, average annual temperatures in the northeast US have increased by about 1.1°C, which has contributed to more frequent days with very high temperatures and rising sea surface temperatures.[13] In the coming decades, temperatures in the northeast US are expected to increase an additional 1.4–2.2°C in the winter and 0.8–1.9°C in the summer. These rising temperatures will increase the importance and value of avoiding additional temperature increases for vulnerable aquatic organisms.

Water at the Salem discharge point is 0 to 15 °F (0 to 8.3 °C) warmer than the estuary water to which it is being discharged, and the average temperature increase at the discharge is from 8 to 10 °F (4 to 6 °C).[14] The Delaware River Basin Commission (DRBC) temperature standards for Water Quality Zone 5 of the Delaware Estuary (where the Salem discharge is located) state that the temperature in the river may not be raised above ambient by more than 4 degrees Fahrenheit (°F; 2.2 degrees Celsius [°C]) during non-summer months (September through May) or 1.5°F (0.8°C) during the summer (June through August). However, Salem has received a variance and has been exempt from these temperature standards since it began operation in 1977.[15] Salem's thermal plume under the Baseline Scenario is likely to contribute to increased mortality as water in the Delaware River increases in temperature due to climate change.

4 Economic Value of Benefits and Costs

In this section, we describe the economic value of the potential benefits and costs associated with using closed-cycle cooling technology at Salem. In economic terms, the objective of this section is to calculate the total economic value of these benefits and costs. It is crucial when conducting a benefit-cost analysis to make every attempt to estimate the value of all substantial benefits and costs, as otherwise the results are biased towards the subset of effects that can be

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[12] Kahn, D. 2008. Delaware Division of Fish and Wildlife. *Impacts of Impingement and Entrainment Mortality by the Delaware City Refinery on Fish Stocks and Fisheries in the Delaware River and Bay*. Available at: https://delaware.sierraclub.org/sites/delaware.sierraclub.org/files/documents/2012/06/Kahn%202008.pdf

[13] Karl, T., J. Melillo, and T. Peterson. 2009. *Global Climate Change Impacts in the United States*. Cambridge University Press.

[14] U.S. Nuclear Regulatory Commission. 2011. *Essential Fish Habitat Assessment - Salem Nuclear Generating Station Units 1 and 2 Hope Creek Generating Station*. Available online at: http://pbadupws.nrc.gov/docs/ML1103/ML110320668.pdf

[15] NOAA National Marine Fisheries Service. 2014. *Endangered Species Act Section 7 Consultation Biological Opinion - Continued Operation of Salem and Hope Creek Nuclear Generating Stations NER-2010-6581*. Available online at: https://www.greateratlantic.fisheries.noaa.gov/protected/section7/bo/actbiops/salemhcnmfsfinalbiopjuly172014.pdf

easily monetized. The Office of Management and Budget (OMB) provides clear guidance to all federal agencies concerning regulatory analysis in Circular A-4.[16]

> *"Where all benefits and costs can be quantified and expressed in monetary units, benefit-cost analysis provides decision makers with a clear indication of the most efficient alternative, that is, the alternative that generates the largest net benefits to society... When important benefits and costs cannot be expressed in monetary units, BCA is less useful, and it can even be misleading, because the calculation of net benefits in such cases does not provide a full evaluation of all relevant benefits and costs."*

The U.S. Environmental Protection Agency (EPA) references Circular A-4 and uses similar principles to develop its *Guidelines for Preparing Economic Analyses.*[17]

> *"Estimating benefits in monetary terms allows the comparison of different types of benefits in the same units, and it allows the calculation of net benefits – the sum of all monetized benefits minus the sum of all monetized costs – so that proposed policy changes can be compared to each other and to the baseline scenario."*

Particularly in a context where the benefits and costs are widespread and not captured by markets, careful and comprehensive steps must be taken to fully capture all substantial benefits and costs. Under such conditions, non-consumptive uses can be a substantial share of the value, but market-based prices for these values do not typically exist.

Figure 2 demonstrates the major components contributing to total economic value. The left side of Figure 2 shows use value. Direct use value describes the value associated with the direct use of a particular good or service. In this case, direct uses could include commercial and recreational uses of fish in and around Salem. Indirect use value describes goods and services that are inputs to other final goods and services directly used by people. In this case, indirect use values for example could include the value of forage fish lost to E&I that would have otherwise supported fish populations that people directly consume.

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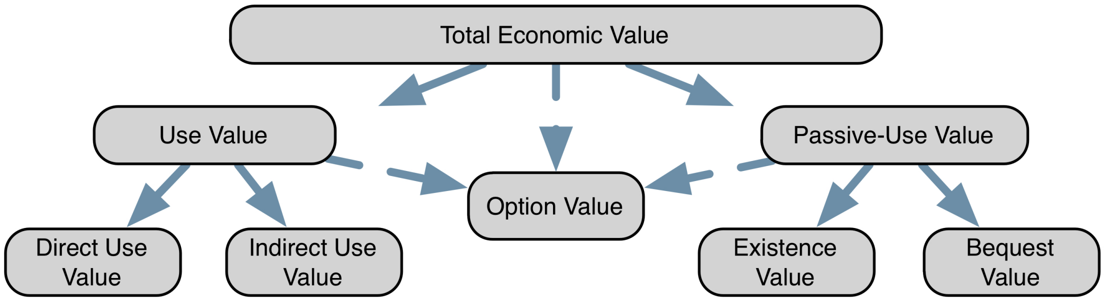
[16] Office of Management and Budget. 2003. Circular A-4. http://www.whitehouse.gov/omb/circulars_a004_a-4.

[17] U.S. Environmental Protection Agency. 2010. Guidelines for Preparing Economic Analyses. December. http://yosemite.epa.gov/ee/epa/eed.nsf/pages/guidelines.html.

Figure 2. Components of Total Economic Value



Source: ECONorthwest

The right side of Figure 2 shows passive-use value (sometimes called non-use value), which represents nature's values that exist when there is no direct or indirect use of an ecosystem by humans. For example, if a person who does not engage in fishing and does not consume fish would nonetheless be willing to pay higher energy bills to reduce fish losses, then we would refer to that willingness to pay as passive or non-use value. EPA describes passive use values as:

> *"... the value that individuals may attach to the mere knowledge of the existence of a good or resource, as opposed to enjoying its direct use. It can be motivated for a variety of reasons, including bequest values for future generations, existence values and values of paternalistic altruism for others' enjoyment of the resource."* [18]

Passive-use values are less obvious than use values, but – in some instances – can represent a greater total value because they incorporate demands from a larger population. Figure 2 separates passive-use value into two categories. One, called existence value, comes from people's desire for the continued existence of a species, landscape, or some other aspect of an ecosystem, or of the ecosystem as a whole. The other, called bequest value, arises because people desire to ensure that the ecosystem will be available for enjoyment by future generations. The middle of Figure 2 shows another component of the total value, called option value. An option value refers to the benefit of maintaining an opportunity to derive services from an ecosystem in the future. It can originate from either side of Figure 2.

For passive-use values, survey-based stated preference techniques are typically necessary because they are considered by economists to be the only available tools for such values. EPA states in its *Guidelines*:

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[18] U.S. Environmental Protection Agency. 2010. Guidelines for Preparing Economic Analyses. December. http://yosemite.epa.gov/ee/epa/eed.nsf/pages/guidelines.html.

"Revealed preference methods cannot capture nonuse values, such as those associated with the existence of biological diversity... stated preference methods may be employed when researchers want to identify the widest possible spectrum of values, both use and nonuse."[19]

OMB recognizes that stated preference techniques might be the only available means to appropriate value estimates, and these techniques have applied widely and rigorously:

"Stated Preference Methods (SPM) have been developed and used in the peer-reviewed literature to estimate both "use" and "non-use" values of goods and services. They have also been widely used in regulatory analyses by Federal agencies, in part, because these methods can be creatively employed to address a wide variety of goods and services that are not easy to study through revealed preference methods... A stated-preference study may be the only way to obtain quantitative information about non-use values…"[20]

The biological effects of Salem's once-through cooling technologies are precisely of the nature that necessitate consideration of non-market values as recommended by OMB and EPA guidelines. By affecting such basic levels of important species, once-through cooling can have widespread and uncertain effects, both spatially and throughout trophic levels of important aquatic ecosystems. Of high relevance to the Salem context, once-through cooling likely affects federally-listed endangered species such as the Shortnose sturgeon, Atlantic sturgeon and the green sea turtle, as well as more common species (such as blueback herring and alewife) that have experienced widespread declines from historical levels. Economic research on passive-use values suggests particularly high value for rare species, as further described below. These Salem characteristics combined with OMB and EPA guidance, as well as economic theory, all dictate that any benefit-cost analysis for Salem must include passive-use values.

The remainder of this section of the report has three parts. In the first part, we identify and summarize the economic benefits associated with the Project Scenario relative to the Baseline Scenario. In the second part, we identify and describe the costs associated with the two scenarios. In the third part, we bring benefits and costs together to discuss the net differences between the two scenarios in economic terms.

4.1 Project Benefits

In this section, we describe the economic value of the benefits associated with the Project Scenario relative to the Baseline Scenario. As described above, the total economic value of the benefits associated with a particular biophysical effect has many components. For discussion of benefits, we begin with summarization of previous benefit estimates produced by PSEG and the

[19] U.S. Environmental Protection Agency. 2010. Guidelines for Preparing Economic Analyses. December. http://yosemite.epa.gov/ee/epa/eed.nsf/pages/guidelines.html.

[20] OMB Circular A-4.

U.S. EPA. Then, as a separate validation exercise, we apply the results of a stated preference survey completed by the EPA (the *EPA Survey)* to further demonstrate the economic value of E&I reduction. We also briefly consider valuation based on Habitat Equivalency Analysis and the associated replacement costs sometimes used to represent benefit values.

4.1.1 Previous Benefit Estimates

PSEG Benefit Estimate

The 2006 PSEG permit application states an intention of looking at market and non-market, including passive-use values, but only quantifies market-based consumptive values for fish. Relying primarily on commercial landing prices and values for recreational sportfishing, they estimate the total benefit to be gained from the installation of closed-cycle cooling at Salem, over a 34-year assessment period, at $7.67 million (2015$).[21]

In addition to basing its calculations on artificially low E&I figures, the overriding presumption of this market-based approach is that all other species either entrained or impinged are not economically significant. With this omission, PSEG does not provide sufficient data to estimate the overall benefits to society of the Project Scenario, as required by OMB and EPA guidelines. The 2006 application predates EPA's 2014 rule and the applicable guidance documents, and does not contain the necessary components pursuant to the 2014 rule; accordingly, in its draft NJPDES permit the New Jersey Department of Environmental Protection requires that the application be revised and updated "*… to include an analysis of social benefits. …"The dollar values in the social benefits analysis should be based on the principle of willingness-to-pay (WTP), which captures monetary benefits by measuring what individuals are willing to forgo in order to enjoy a particular benefit. While the Director must consider benefit and cost information, the Director will also determine if this information is of sufficient rigor to make a decision on entrainment controls on the basis of this information. For instance, the Director may decide not to rely on benefit-cost information in establishing the entrainment controls when the benefits analysis includes only a qualitative discussion of nonuse benefits. Willingness-to-pay for nonuse 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.""*[22]

However, there are other sources of information that can be used to address these gaps and inform present day decision-making. Specifically, a nationwide stated preference survey conducted by the EPA, expressly for the purpose of evaluating the social benefits associated with reduced E&I mortality, provides information sufficient to assess the magnitude of these omitted benefit categories. Additionally, comparing PSEG's existing estimates with other estimates (based on more rigorous analysis of Salem's E&I data and potential commercial and recreational values), suggests that PSEG's treatment of these categories is also insufficient, and

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[21] PSEG Nuclear LLC. 2006. *NJPDES Permit Application – Attachment 6-22 Detailed Benefit Results*.

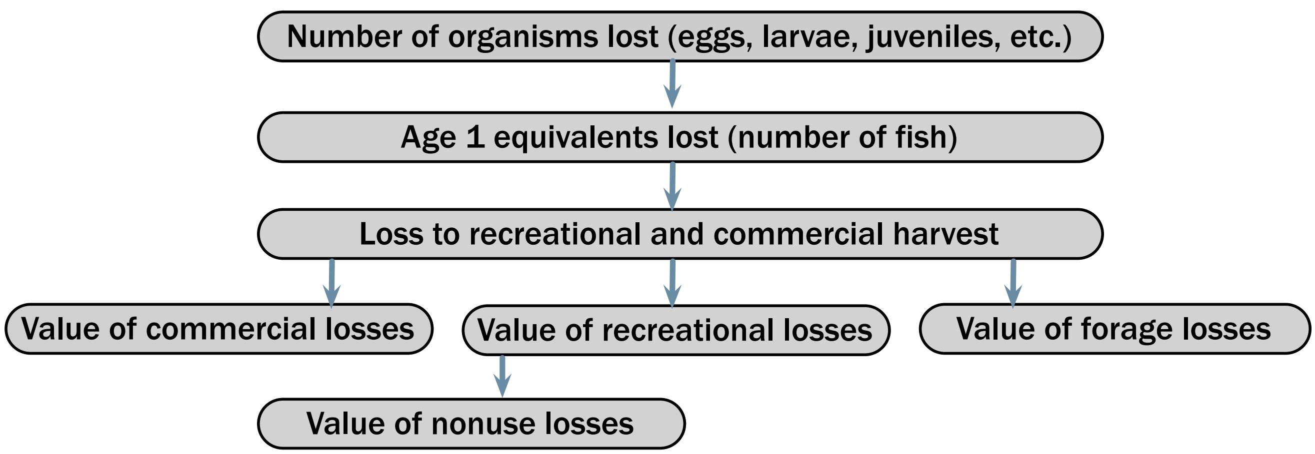
[22] New Jersey Department of Environmental Protection. 2015. PSEG NUCLEAR LLC SALEM GENERATING STATION NJPDES - Surface Water Renewal Permit Action. Page 61. Available online at: http://www.nj.gov/dep/dwq/pdf/salem-draft-2015.pdf

the estimates off by orders of magnitude. We examine these analyses and data sources in greater depth in the following sections.

EPA Benefit Estimates

In 2002, as part of its 316(b) rulemaking, the EPA produced a series of case studies focused on specific regions and facilities to illustrate appropriate approaches to economic valuation of reduced losses from E&I. One of these case studies focused on Delaware Bay, with Salem as the primary extrapolation model. In addition to detailed consideration of E&I data, summarized previously, it also included a more comprehensive consideration of benefits than PSEG's permit application. EPA's approach and valuation categories are shown in Figure 3.

Figure 3. EPA's general approach to the valuation of fish losses from E&I



Source: Adapted from EPA Case Study

In addition to estimating market-based values for species with commercial and recreational uses (using methods similar to those applied in PSEG's 2006 permit application), EPA also considered the value of forage species and passive-use benefits. This is appropriate given that only 3.3 percent of total baseline A1E mortality in the Delaware Estuary can be assigned a direct use value from recreational or commercial fishing.[23] EPA used two general methods to estimate the indirect value of forage species. The first involved conversion of the estimated increase in forage species to an equivalent amount of higher trophic level species, and the second considers the cost of replacing the individuals through hatchery production.[24]

Absent a full stated preference survey (considered to be the most accurate method of measuring passive-use benefits) at the time, EPA used three alternate means to estimate non-use values. These include assignment based on use values, benefits transfer, and habitat replacement costs. Under the first method, they assume that non-use benefits are a fixed proportion of the total of

[23] EPA Benefits Analysis. Page 3-8

[24] EPA Benefits Analysis

the previous three benefits categories – in this case, it was a 50 percent "rule of thumb" portion of the recreational fishing benefit.[25]

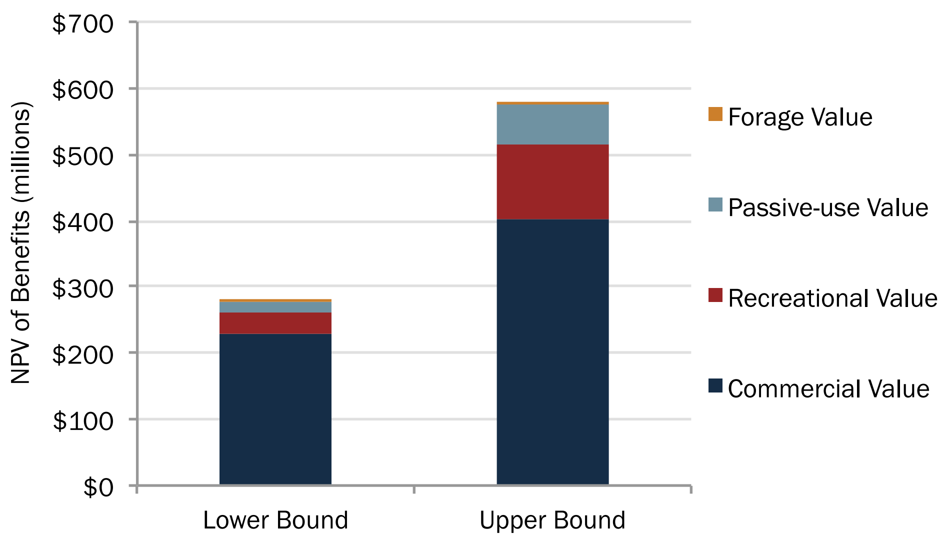
The results of EPA's valuation exercise are shown in Table 2 and Figure 4. Annual values for the benefits of reduced E&I at Salem were estimated as being between $18 and $38 million. The stream of annual benefits, over the course of 20 years, discounted at a rate of 3 percent, would sum to $279 and $577 million.

Table 2. EPA's estimate of the benefits of reduced E&I at Salem (2015$)

Valuation Category and Method	Estimate	Annual Value Estimate			20-Yr Net Present Value		
		Impingement	Entrainment	Total	Impingement	Entrainment	Total
Commercial: Total Surplus (*Direct Use, Market*)	Low	$250,000	$14,700,000	$14,940,000	$3,831,000	$225,260,000	$228,938,000
	High	$430,000	$25,720,000	$26,150,000	$6,589,000	$394,128,000	$400,717,000
Recreational (*Direct Use, Nonmarket*)	Low	$20,000	$2,120,000	$2,140,000	$306,000	$32,486,000	$32,793,000
	High	$80,000	$7,470,000	$7,550,000	$1,226,000	$114,469,000	$115,695,000
Nonuse (*Passive Use, Nonmarket*)	Low	$10,000	$1,060,000	$1,070,000	$153,000	$16,243,000	$16,396,000
	High	$40,000	$3,730,000	$3,770,000	$613,000	$57,158,000	$57,771,000
Forage (*Indirect Use, Nonmarket*)							
Production Foregone	Low	$0	$80,000	$80,000	$0	$1,226,000	$1,226,000
	High	$0	$140,000	$140,000	$0	$2,145,000	$2,145,000
Replacement		$0	$180,000	$180,000	$0	$2,758,000	$2,758,000
Total (Com + Rec + Nonuse + Forage)	Low	$280,000	$17,950,000	**$18,230,000**	$4,291,000	$275,062,000	**$279,353,000**
	High	$560,000	$37,100,000	**$37,660,000**	$8,581,000	$568,513,000	**$577,094,000**

Source: EPA Case Study

Figure 4. EPA's estimate of the benefits of reduced E&I at Salem (2015$)



Source: ECONorthwest based on data from the EPA Case Study

Note: figures may not sum due to rounding.

4.1.2 Total Economic Value Based on Results from the EPA Survey

In 2014, the US EPA published standards for cooling water intake structures as part of its responsibilities under Section 316(b) of the Clean Water Act, at 76 FR 22174. As part of its analyses, the agency conducted a stated preference survey to estimate the total willingness to

[25] EPA Case Study

pay (WTP) for improvements to fishery resources affected by E&I at 316(b) facilities. The results of the analysis provide a relatively comprehensive account of passive-use values associated with changes in E&I.[26]

Objectives. The US EPA states "[the *EPA Survey*] *presents data collected from a stated preference study that EPA conducted regarding total (use plus non-use) benefits from reductions in fish mortality at cooling water intake structures*."[27] In other words, the *EPA Survey* was implemented to quantify the total economic value associated with reducing E&I at cooling water intake structures by installing filters and closed-cycle cooling systems.

Survey Design. The *EPA Survey* used a choice experiment format in which "*respondents are presented with a set of multi-attribute alternatives and asked to select their preferred alternative, much as one might choose a preferred option in a public referendum*."[28] Respondents were shown two hypothetical policy options, as well as a status quo option, and were asked to choose the policy they prefer. Each policy option was accompanied by five associated effect categories: (1) commercial fish populations, (2) total fish populations, (3) fish saved from water intakes (based on age-one-equivalents), (4) conditions of aquatic ecosystems, and (5) increases in household cost of living. For example, relative to the status quo scenario, one of the hypothetical scenarios may increase commercial fish harvests by 3 percent and total fish populations by 4 percent. It may prevent the loss of 5 percent of E&I-related fish loss, and improve the conditions of aquatic ecosystems by 2 percent. However, in addition to these improvements in biophysical conditions, the cost of living for each household would increase by $48 per year.[29] There were a total of 72 unique Option A vs. Option B pairs sent out to survey respondents. There were five sample populations for the survey: (1) Northeast, (2) Southeast, (3) Inland, (4) Pacific, and (5) National. Each survey used regional values in describing how the hypothetical policies would affect biophysical variables for the region as a whole.

Survey Implementation. The US EPA pre-tested drafts of the survey instrument with six focus groups (8-10 participants each) and a set of eight, one-on-one cognitive interviews.[30] Once the US EPA finalized the survey instrument, it mailed out a total of 7,840 regional versions of the survey to households across the four regions, as well as 960 national versions of the survey to households across the country. Table 3 summarizes the states included in each of the regions, the target sample size, the number of households surveyed, the number of completed surveys received, and the response rate.

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[26] EPA Benefits Analysis

[27] EPA Survey

[28] EPA Survey

[29] EPA Survey

[30] EPA Survey

Table 3. Summary of Survey Implementation Statistics

Survey Region	States Included	Target Sample Size	Number of Households Surveyed	Completed Surveys Received	Response Rate
Northeast	CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT	417	1,440	421	31 percent
Southeast	AL, FL, GA, LA, MS, NC, SC, TX, VA	562	1,920	506	30 percent
Pacific	CA, OR, WA	289	1,040	311	32 percent
Inland	AR, AZ, CO, ID, IA, IL, IN, KS, KY, MI, MN, MO, MT, ND, NE, NM, NV, OH, OK, SD, TN, UT, WI, WV, WY	732	2,480	787	36 percent

Source: EPA Benefits Analysis. Page 11-9.

Notes: Undeliverable surveys are not incorporated into the response rate.

Survey Analysis. The *EPA Survey* used a mixed logit model to calculate region-specific estimates of marginal household WTP for reductions in E&I-related losses. Put simply, the model assumes that the preferences of each region's respondents fall within a distribution, and uses differences in their WTP (represented by a policy's increase in cost of living) and differences in fish-related benefits (represented by a reduction in E&I losses) to isolate average annual household WTP values for marginal changes in E&I losses. The models develop estimates for household willingness to pay for each category of effects and at each regional scale, including national. The amounts of household willingness to pay for the four categories of effects are considered non-additive.

Survey Results. The *EPA Survey* provided results that focused on the survey results from the northeast region. Table 4 summarizes the results for the northeast region across the four categories of effects. The category of interest for application to E&I mortality is "fish saved", as this is the category of effect that EPA estimates.[31] The implicit price for fish saved represents the amount the average household is willing to pay for a 1 percent reduction in fish mortality from water intakes. It is $1.53 (2015$), with a 95 percent confidence interval of $1.01–$2.02. In other words, the results show that the average household in the northeast would be willing to pay $1.53 per year for a 1 percent decrease in E&I-related fish loss, within northeast waterways, relative to a baseline of 1.1 billion fish lost per year.[32] Results from the national survey (which quoted a baseline loss of 2.5 billion fish per year) are also shown in Table 4. According to the most recent data from the US Census, there are 23,750,310 households in the northeast region, and 91,158,236 households in the rest of the country (minus Alaska and Hawaii).[33]

[31] EPA is able to estimate the change in "fish saved" with closed cycle cooling, but does not currently estimate changes in the other attribute categories. Therefore if there are separate, additional improvements in the other attributes as well, the value estimate for "fish saved" alone is an underestimate of value.

[32] U.S. EPA. 2011. *Supporting Statement for Information Collection Request for Willingness to Pay Survey for Section 316(b) Existing Facilities Cooling Water Intake Structures: Instrument, Pre-Test, and Implementation*. These totals may differ from more current estimates of E&I, and figures can vary based on which facilities are included (just power plants or all facilities with CWIS, for example),

[33] U.S. Census Bureau. 2009-2013 American Community Survey 5-Year Estimates. *S1101: Households and Families*.

Table 4. Annual Household WTP for E&I-related Changes in Fish Populations for the Northeast Region and the U.S (2015$)

Survey Population	Attribute	Implicit Price	95 percent Confidence Interval
Northeast	Commercial fish population	$10.92	$6.84 - $15.75
	Fish population (all fish)	$3.28	-$4.80 - $11.54
	Fish saved	$1.53	$1.01 - $2.19
	Aquatic ecosystem condition	$10.35	$1.53 - $20.15
National	Commercial fish population	-$0.86	$2.35 - $5.83
	Fish population (all fish)	$0.43	$6.17 - $11.96
	Fish saved	$0.30	$0.69 - $1.13
	Aquatic ecosystem condition	-$13.04	-$3.73 - $5.51

Source: EPA Benefits Analysis. Page 11-29.

Notes: The implicit prices and the 95 percent confidence interval represent the amount a household would be willing to pay, each year, for a 1 percent change in the attribute, relative to baseline attribute levels. The EPA focus is on the attribute “fish saved”. EPA has not estimated changes in the other attributes and does not use them for reduced E&I WTP estimation, although they suggest that a focus on “fish saved” alone is likely an underestimate.

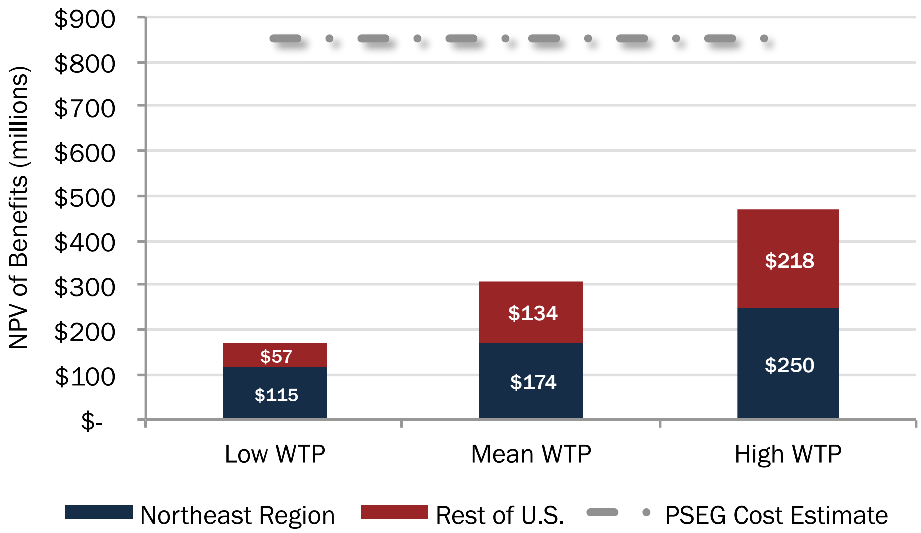
We apply the results from the *EPA Survey's* analysis of surveys from the northeast region and the rest of the nation (using results from the national survey) to quantify the total economic value to northeastern and U.S. households of the benefits related to E&I reductions under the Project Scenario. Since the *EPA Survey* did not differentiate between the types of values households derive from changes in E&I, the estimates of household WTP can be interpreted in terms of total economic value. As stated in the *EPA Survey*, the stated preference survey and analysis were conducted specifically to quantify the value of all benefits (use and non-use) associated with changes in E&I.[34] However, we note that the survey does not account for effects on a number of non-fish species as well as effects on threatened, endangered, and other protected species, for example.

As previously stated, the Baseline Scenario results in approximately 314,210,000 more E&I-related A1E fish deaths per year than the Project Scenario, on average. Based on the *EPA Survey's* baseline E&I estimate across the northeast region and the rest of the U.S, preventing this level of mortality would generate annual household benefits between $11 and $29 million dollars, with a mean estimate of $19 million a year. Over 20 years at a 3 percent discount rate, and taking into account projected population increases, the value would be $172 million, $308 million, and $468 million, net present value (NPV), corresponding to the low, mean, and high WTP values shown in Table 4. [35]

[34] EPA Survey

[35] U.S. Census Bureau. 2014. *National Population Projections*. Available online at: http://www.census.gov/population/projections/data/national/2014.html

Figure 5. Monetized NPV Benefit Estimates, based on the EPA Survey



Source: ECONorthwest based on data from the EPA Survey

Discounting is included for benefits and costs over time to account for differences in preference regarding when a cost or benefit occurs. Receiving a benefit earlier than later often means opportunities to build on that benefit, and costs that occur earlier than later tend to have greater burden because of opportunity costs of the money (e.g. other investment opportunities) and related factors. For fish populations though, there might not always be strong reasons to prefer earlier benefits than later. In fact, a more uniform distribution of benefits over time, for population and general ecological stability, might be the most preferable. Convention holds to include discounting for calculation of net present values, but if the above benefit streams were not discounted, the total benefits over 20 years would range from $205 to $558 million. Furthermore, while the *EPA Survey* is designed for a 20 year timeframe, benefits of the capital investments for the Project Scenario would certainly continue beyond that range and in an undiscounted calculation could more than double the benefits.

4.1.3 Habitat Replacement Cost Estimates

Courts have shown a preference for market-based values when awarding compensation for damages, even when associated with natural resources. From this impetus and others, Habitat Equivalency Analysis was developed to identify the total restoration of ecological function necessary to fully compensate society on net for damages.[36] Typically the approach is used for consideration of damages that have already occurred. Applying it to ongoing future damages presents challenges. While the full details of the analysis are not available, NPDES permit support documentation for the nearby Delaware City Refinery and Power Plant (DCR) did

[36] National Oceanic and Atmospheric Administration. Habitat Equivalency Analysis. https://www.darrp.noaa.gov/economics/habitat-equivalency-analysis.

include a brief estimation of the restoration costs to offset losses from once-through cooling at the facility.[37]

The DCR has annual total I&E adult mortality of 1.8 million organisms. This is half of one percent of annual total adult mortality at Salem. Still, the Habitat Replacement Cost for DRC is estimated at $429 million (2011 dollars). This estimate is based on an assumption of restoration costs of $2023 per acre. There are several factors that suggest the equivalent habitat replacement costs for Salem would be greater, including:

- It is unlikely that sufficient restoration opportunities would exist for such a massive offset in Delaware Bay. If there were, diminishing returns would dictate that costs per acre would climb, and benefits per acre would likely decline with increasing total acreage involved.
- With such a sizable restoration effort, there would likely be extensive restoration project failures that would increase costs or increase the total acreage requirement over the project lifespan. Failures would be known and unknown (unperceived).
- It is likely infeasible to find extensive sites with no habitat function currently, and that means technically exist to restore such sites to full habitat production potential.

The habitat replacement cost estimates for DRC, if even remotely correct, combined with the orders of magnitude of greater total mortality for Salem, and the confounding factors that would further increase costs, suggest that a Habitat Equivalency Analysis or Habitat Replacement Cost approach for estimating benefits of the Project Scenario at Salem would generate much higher value estimates than either of the reported methods above. Such a calculation would likely drive benefit estimates into the billions of dollars.

4.1.4 Unquantified Benefits

The benefit estimates presented here amount to roughly half of the estimated total cost of installing closed cycle cooling systems at Salem. However, we emphasize that these estimates reflect only the readily quantifiable and monetizeable benefits, which represent an unknown portion of total benefits. Unquantified benefits, described in this section, further narrow this gap.

Benefits from Reduced Thermal Pollution

Thermal pollution from Salem's intakes is likely to induce additional fish mortality, especially during the warm summer months. Effluent from Salem regularly exceeds the Delaware River Basin Commission's water quality regulations for temperature (see section 3.2). Thermal impacts from Salem occur during seasons of particular importance for critical life stages, and temperatures within the plume exceed thresholds for the spawning of federally-listed species

[37] State of Delaware Division of Water Resources. 2011. *BTA Determination – NPDES Permit Requirements For Cooling Water Intake and Discharges at Delaware City Refinery and Power Plant (DCR). Fact Sheet, Attachment A*. Pgs. 7, 49.

including Shortnose sturgeon and Atlantic sturgeon. Other important species have similar potential effects of elevated water temperatures including American shad, white perch, and striped bass. Temperatures are also outside of optimal for other life stages of these fish species as well as channel catfish, bluegill and others. Heightened temperature can stress species and, even when this stress does not directly lead to mortality, it can contribute to reduced overall population fitness.[38]

By and large, the literature describing the effects of thermal plumes on aquatic organisms uses qualitative terms rather than site-specific quantitative estimates. After reviewing the literature, we have found one study reporting plume-related fish deaths at the Oyster Creek Nuclear Generation Station (Oyster Creek), along Barnegat Bay in New Jersey.[39] From 1972–1982, researchers at Oyster Creek recorded an average of 240,450 plume-related fish deaths, per year. The average annual impingement at Oyster Creek from 1975–1977 was about 6.5 million aquatic organisms.

Operational Benefits

Installation of closed-cycle cooling at Salem would introduce several operational advantages, including fewer reactor shutdowns due to clogged intakes, as well as reduced need for maintenance dredging.[40]

Benefits Associated with Increased Survival of Forage and Juvenile Fish

Economic valuation of I&E losses is complicated by the lack of market value for forage species, which, in the case of Salem, comprise a large proportion of total losses. Bay anchovy have no direct market value, but nonetheless form a critical component of estuarine food webs. While the EPA included forage species impacts in its economic benefits calculations, the final estimates likely underestimate the full value of the losses imposed by I&E.[41]

As stated previously, only 3.3 percent of total baseline A1E mortality in the Delaware Estuary can be assigned a direct use value from recreational or commercial fishing.[42] According to a review of the environmental impacts caused by power plant cooling water intake structures in California, entrained and impinged species also *"…provide many other ecosystem services of value to humans. In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to impingement and entrainment are critical to the continued functioning of the ecosystems of which they are a part. Examples of ecological and public services potentially disrupted by*

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[38] E.g., McBryan, T. L., et al. "Responses to temperature and hypoxia as interacting stressors in fish: implications for adaptation to environmental change."*Integrative and comparative biology* 53.4 (2013): 648-659.

[39] Samson, J. and N. Simmons. 2005. *Position Paper on Oyster Creek Nuclear Generation Station's Cooling Water System*.

[40] See, for example, Gallo, B. 2011. '*Salem 1 nuclear reactor taken offline again because of Delaware River 'grassing' clogging cooling water intake'*. South Jersey Times. Available online at: http://www.nj.com/salem/index.ssf/2011/04/salem_1_reactor_taken_offline.html

[41] EPA Benefits Analysis. Page C2-3.

[42] EPA Benefits Analysis. Page 3-8.

impingement and entrainment losses but not addressed by commercial and recreational fishing valuations include…:

- *disruption of public uses other than fishing, such as diving and nature viewing*
- *disruptions of ecological niches and ecological strategies used by aquatic species*
- *disruptions of organic carbon and nutrient transfer through the food web*
- *alterations of food web structure*
- *decreased local biodiversity*
- *disruption of predator-prey relationships*
- *disruption of age class structures of species because a disproportionate number of eggs, larvae, and juveniles are lost*
- *disruption of public satisfaction with a healthy ecosystem.*

Many of these services are provided by the early life stages lost to impingement and entrainment, and can be maintained only by the continued presence of these life stages in their natural habitats. For example, aquatic food webs require orders of magnitude more organisms in the lower trophic levels to support harvested species and other top level consumers…"[43]

Additionally, stated preference studies, if interpreted as representing the total economic value, rely upon the knowledge and survey context education of respondents to consider secondary effects. For example, fish saved are likely to have additional trophic effects in terms of support for other species.[44] There might be important cultural significance to certain communities of the fish saved or trophic effects, and those benefits might be relevant to respondents not bearing those benefits directly themselves. In short, such a study for practical reasons is limited to the set of benefits respondents are aware of or can be made aware of during the survey process. Uncertainties in secondary effects make discrete specification of these effects difficult, but there are likely to be some.

At an ecosystem-scale, the benefits offered by PSEG for commercial and recreational fishing, and the fish-specific benefits of the *EPA Survey* do not comprehensively capture the benefits to the regional ecosystem of maintaining the important resources and actors provided under the Project Scenario. As scientific understanding improves of ecological linkages and interdependencies in the Delaware Bay, particularly as society sees unintended consequences of

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[43] Strange, E., D. Allen, D. Mills, and P. Raimondi. 2004. *Research on Estimating the Environmental Benefits of Restoration to Mitigate or Avoid Environmental Impacts Caused by California Power Plant Cooling Water Intake Structures*. Stratus Consulting, Inc. California Energy Commission, PIER Energy-Related Environmental Research. 500-04-092. Available online at:
http://www.swrcb.ca.gov/rwqcb3/water_issues/programs/diablo_canyon/docs/09_09_05_staff_report/item15_attachment5.pdf

[44] Desmond Kahn, Ph.D (retired, Delaware Division of Fish and Wildlife) personal communication. September 8, 2015.

declines in particular elements such as sturgeon, new categories of benefits will likely come to light that would be provided by the Project Scenario.

Potential Benefits Associated with Endangered Species

Two endangered sturgeon species (Atlantic & Shortnose) and three threatened or endangered turtle species (Kemp's Ridley sea turtle; Green sea turtle, and the Loggerhead sea turtle) are harmed by Salem's operations under the Baseline Scenario. In its 2014 biological opinion on Salem's reactor site operations, the National Marine Fisheries Service concluded that the site is "likely to adversely affect but not likely to jeopardize continued existence" of these species. Despite this finding, a certain level of annual mortality for each of these species is still expected and (to a certain extent) allowed at Salem.

For example, between 1978 and 2010 an estimated 71 sea turtles were impinged or entrained at Salem, with an annual value of 0 to 6 turtles killed a year.[45] These E&I rates are also subject to the same year-to-year variability that we observe for other species; for example, in the first half of 2014, rates of E&I of endangered Shortnose sturgeon were four times higher than rates predicted in the 2014 NMFS Bi-Op cited above. Additionally, two Kemp's Ridley sea turtles were taken over the same period, compared with a predicted one every three years.[46] Due to low population sizes, even low levels of E&I can represent a substantial portion of the annual reproduction of these populations – lengthening recovery time, or hastening the demise of the population and the species as a whole.[47]

The Project Scenario would help to alleviate many of the adverse effects on endangered and threatened species. While the *EPA Survey* considers the potential value associated with fish and aquatic ecosystems, it does not attempt to tease out additional value associated with preventing harm to endangered or threatened species. Passive use values are of particular relevance for rare species, and all else being equal, people are willing to pay to protect organisms of endangered species, and typically are willing to pay more than for abundant species.[48] The *EPA Survey* does not address the benefits of reducing mortality for endangered species, and PSEG in no way addresses these values. A complete economic analysis of the Project Scenario requires information sufficient to more precisely describe the effects of once-through cooling at Salem on listed species.

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[45] NMFS and USFWS. 2014. *Endangered Species Act Section 7 Consultation Programmatic Biological Opinion*. Page 27. Available online at: http://www2.epa.gov/sites/production/files/2015-04/documents/final_316b_bo_and_appendices_5_19_2014.pdf

[46] Montgomery, J. 2014. '*US agency's Salem fish-kill study condemned*'. The News Journal. Available online at: http://www.delawareonline.com/story/news/local/2014/07/23/us-agencys-salem-fish-kill-study-condemned/13070641/

[47] EPA Benefits Analysis. Page 2-12.

[48] Brown, G. M., & Shogren, J. F. 1998. Economics of the Endangered Species Act. *The Journal of Economic Perspectives*, *12*(3), 3-20; Loomis, J. B., & White, D. S. 1996. Economic benefits of rare and endangered species: summary and meta-analysis. *Ecological Economics*,*18*(3), 197-206; See, for example, Richardson, L., and J. Loomis. 2009. "The Total Economic Value of Threatened, Endangered and Rare Species: An Updated Meta-Analysis." *Ecological Economics*. 68(5): 1535-1548.

One study looked specifically at the public’s willingness to pay for efforts aimed at protecting bottlenose sturgeon.[49] In this study, researchers used a referendum contingent valuation survey to determine the relationship between non-use values for two endangered species, Peregrine falcons and Shortnose sturgeon, and the respondents' environmental attitudes. The researchers elicited responses by mailing questionnaires to a random sample of 1,200 Maine residents over the age of 18. The researchers constructed survey mechanism according to the National Oceanic and Atmospheric Administration’s guidelines on conducting stated preference studies. In the surveys, researchers asked respondents if they would vote for a referendum that would protect a population of bottlenose sturgeon at the mouth of the Kennebec River from future dredging and water pollution. The respondents were also told that supporting these efforts would cost them a one-time fee of $1–$49 (2015$). The results of the analysis suggest that, on average, individuals were willing to pay a one-time fee of about $37 (2015$).

Another way to consider the value society derives from protecting threatened or endangered species is to consider federal and state expenditures aimed at protecting a particular population, which can be considered a revealed preference value. The US government relies on the Endangered Species Act (ESA) to prevent extinction and to help promote the health of threatened and endangered species populations. In 2013, there were a total of 1,466 species listed as threatened or endangered under the ESA. The US Fish and Wildlife Service oversees ESA-related spending, and in fiscal year 2013, it reported a total of $1.7 billion in ESA-related expenditures.[50] Table 5 shows expenditures for each of the endangered species impacted by Salem’s operations. Federal spending on these five species alone totaled nearly $22 million in FY 2013 ($2015).

These studies and data along with the extensive literature on the high economic value of protecting listed species because of their rarity suggest that there would be a high premium for reduced mortality of listed species in comparison to non-listed species. While an appropriate estimate that is completely additive to the stated preference total economic value estimates reported earlier is likely difficult to estimate, evidence suggests something likely in the tens of millions of dollars annually or greater.

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[49] Kotchen, M.J. And S. Reiling. 2000. "Environmental Attitudes, Motivations, and Contingent Valuation of Nonuse Values: A Case Study Involving Endangered Species.” *Ecological Economics*. 32: 93-107.

[50] US Fish and Wildlife Service. 2013. *FY 2013 Federal and State Endangered and Threatened Species Expenditures.*

Table 5. Total FY2013 Reported Expenditures (2015$)

Species	Spending
Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)	$3,698,859
Shortnose sturgeon (*Acipenser brevirostrum*)	$3,327,189
Green sea turtle (*Chelonia mydas*)	$2,829,495
Kemp's ridley sea turtle (*Lepidochelys kempii*)	$5,725,572
Loggerhead sea turtle (*Caretta caretta*) - Northwest Atlantic DPS	$6,229,931

Source: US Fish and Wildlife Service. 2013. *Federal and State Endangered and Threatened Species Expenditures*. http://www.fws.gov/Endangered/esa-library/pdf/2013.EXP.FINAL.pdf

Notes: All annual expenditures were adjusted for inflation, using the consumer price index, to 2015 dollars. These cost estimates are based only on state and federal expenditures that are specifically assigned to each species. They do not include any land acquisition costs.

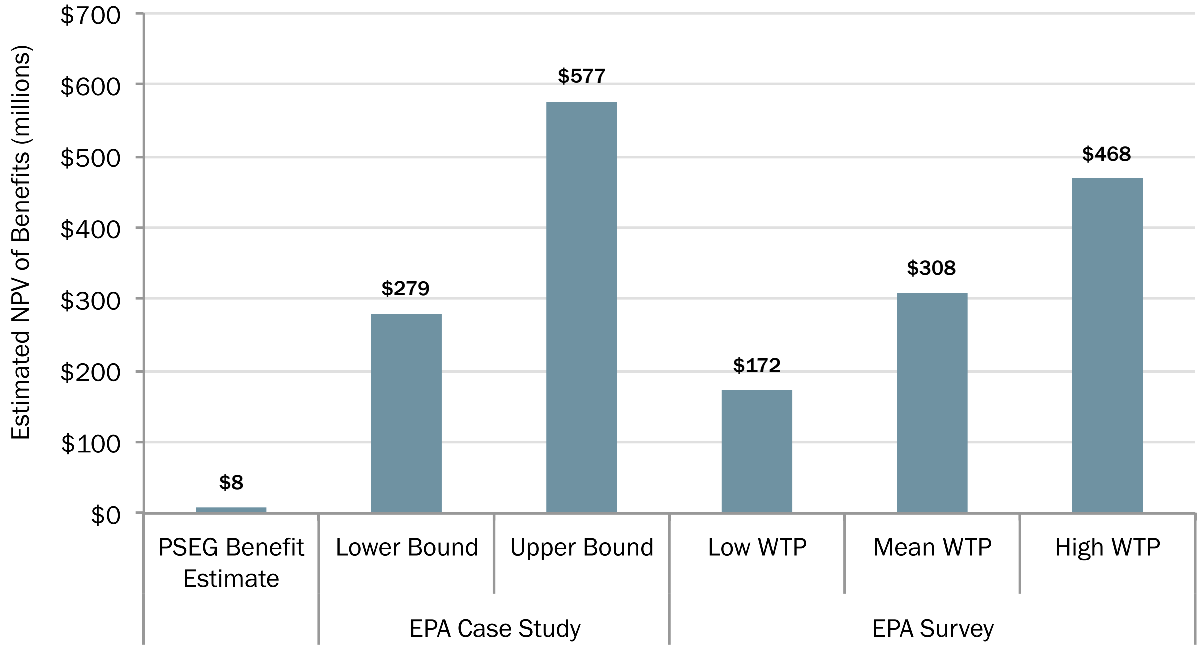
Climate Change-Related Benefits

Climate change is likely to affect aquatic ecosystems in ways that are detrimental to native species adapted to prior conditions. The Project Scenario contributes to mitigating the detrimental conditions, and therefore, Project Scenario benefits will likely become more important and valuable in the future. If climate change drives fish populations down, at least for the local fish populations currently affected by Salem's operation, then the increased scarcity increases the marginal value of fish. In other words, as fish become more rare, each individual fish becomes more valuable. Thus, for the same number of fish saved, the percent of the baseline population saved increases, and those fish saved were each individually more valuable than the marginal fish when populations were higher. Data do not allow an estimate of the magnitude of this potential population difference, and corresponding additional value.

4.1.5 Summary of Benefits

Overall, federal guidance, economic theory, biological data, and valuation research by the EPA all suggest that the benefit estimates provided by PSEG fail to represent and capture the total economic value of benefits of the Project Scenario. We present multiple estimates in the range of hundreds of millions of dollars and higher that more fully account for these values. We emphasize, however, that there are other (as-yet unquantified) factors that would magnify and add to these monetized values. These factors include increasing regional scarcity of affected species due to other disturbances in the Delaware Estuary, changing climate conditions, and the large number of endangered species as well as species with documented population declines involved.

Figure 6. Summary of Alternative Monetized NPV Benefit Estimates



Source: ECONorthwest based on data from sources cited above

4.2 Affordability to PSEG and Exelon

The comparison of benefits and costs for regulations under Section 316(b) of the Clean Water Act is not a strict benefit-cost analysis, but rather an effort to do what is most protective of water quality, while making accommodations for extreme cost disparities. The current test in use within New Jersey and many other states is that the best technology available (BTA) must be used (best from a water quality perspective) at an existing facility unless the costs are wholly disproportionate to their environmental benefits.

An additional consideration is the overall affordability of the technology to the facility's owner(s). As explained in the Delaware City Refinery's BTA determination:

"Decades of court cases have established the idea that if a technology is not "affordable", then it is not really "available". To the limited extent that considerations of "Affordability" are allowable in BTA Determinations under Clean Water Act §316(b), the assessment of "Economic Achievability" considers the resources available from the parent corporation of a NPDES permittee."[51]

In this section, we discuss three measures of financial affordability within the context of the costs that PSEG and Exelon would incur under the Project Scenario: (1) the increase in assets the companies would require to install the technology and annual loan payments in the context of annual revenues and cash flow, (2) the capital outlay associated with the Project Scenario

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[51] State of Delaware Division of Water Resources. 2011. *BTA Determination – NPDES Permit Requirements For Cooling Water Intake and Discharges at Delaware City Refinery and Power Plant (DCR). Fact Sheet, Attachment A*. Page 3.

relative to historical levels of each companies capital expenditures, and (3) the potential interest charges for the debt component of financing. Note that wherever we refer to PSEG or Exelon in the following paragraphs, we are specifically referring to the subsidiaries PSEG Power, LLC and Exelon Generation Company, LLC.

Required increase in assets

The estimated total installed cost of the Project Scenario is $815 to 852 million.[52] We accept this estimate by PSEG without replication or review by engineers. The yearly amortized cost (assuming a 20-year repayment period and an interest rate of 4.91percent) for this amount would be 68 million, not including tax deductions. We assume that PSEG and Exelon would share costs according to their ownership shares in the station (57.41 percent, and 42.59 percent, respectively).[53]

Property, Plant, and Equipment (PPE) asset base: According to PSEG's Form 10-K for the fiscal year ending December 31, 2014, PSEG held assets for PPE of about $7.5 billion.[54] According to Exelon's Form 10-K for the fiscal year ending December 31, 2014, Exelon held assets for PPE of about $23 billion.[55] **The total installed cost of the Project Scenario would represent about 2.8 percent of PSEG and Exelon's combined PPE asset base.**

Annual operating revenues: According to PSEG's Form 10-K for the fiscal year ending December 31, 2014, PSEG's annual operating revenues were $5.4 billion.[56] According to Exelons's Form 10-K for the fiscal year ending December 31, 2014, Exelon's operating revenues were $17.4 billion.[57] **The annual amortized cost of the Project Scenario would represent 0.3 percent of PSEG and Exelon's combined annual operating revenues.**

Based on the firms' annual revenues, it would take just over a day of operations to cover the annual loan associated with the Project Scenario (the loan would cost $67.9 million a year, while the firms make roughly $62.5 million a day).

To further conceptualize and contextualize these costs (while acknowledging that these companies both rely on a much broader array of revenue generating facilities and activities, as

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[52] According to the 2006 permit application, the capital cost for retrofitting mechanical draft cooling towers is estimated at $814,844,200 and the capital cost for retrofitting natural draft cooling towers $852,440,200. For this affordability analysis we use the highest cost ($852 million), but overall affordability is even greater given that there is a cheaper cost option ($812 million). We also assume that these figures include all installation costs, including costs associated with debt and equity charges on construction work in progress (CWIP).

[53] Exelon Corporation. 2014. *Summary Annual Report*. Page 27. Available online at: http://www.exeloncorp.com/performance/investors/financialreports.aspx

[54] PSEG Investor FACT Book 2014-2015. PSEG Power Consolidated Balance Sheets. Page 52. Available online at: https://www.pseg.com/info/investors/pdf/factbook.pdf.

[55] Exelon Corporation. 2014. *Form 10-K*. Page 221. Available online at: http://www.exeloncorp.com/performance/investors/financialreports.aspx

[56] PSEG Investor FACT Book 2014-2015. PSEG Power Consolidated Balance Sheets. Page 52.

[57] Exelon Corporation. 2014. *Form 10-K*. Page 221.

reflected in the preceding calculations), we can also place these costs in terms of Salem's own operations and profits. Based on available data (specifically, PSEG's current realized price of $53 per MWh, the station's average annual production level of 19 million MWh and an assumed 300 days of operation a year, with 65 for refueling activities), we calculate that **the annual cost of the loan could be easily covered by production at the facility itself, and would require about 20 days of operation a year.**[58]

Annual cash flow: According to PSEG's Form 10-K for the fiscal year ending December 31, 2014, PSEG's annual net cash flow from operating activities was $1.4 billion.[59] Meanwhile, Exelon's operating revenues are projected to be $3.5 billion in 2015.[60] **The annual amortized cost of the Project Scenario would represent 1.4 percent of PSEG and Exelon's combined annual cash flows.**

According to Moody's, PSEG Power has a long term rating of Baa1, while Exelon Generation has a rating of Baa2. [61] Neither are currently on watch, and both ratings fall within Moody's range of investment-grade ratings.[62] The Project Scenario's installed cost relative to PSEG's PPE asset base along with PSEG's credit ranking suggest that the increase in assets the Project Scenario requires would be affordable to PSEG in terms of available credit and ability to pay the loan.

Capital outlay in historical context

In its Form 10-K for the fiscal year ending December 31, 2014, PSEG Power projected its capital construction and investment expenditures (excluding nuclear fuel purchases) for the next three years. PSEG's projected expenditures total $555 million in 2015, $395 million in 2016, and $265 million in 2017.[63] PSEG's average expenditures on capital construction and investments from 2015-2017 total about $405 million per year. In its Form 10-K for the fiscal year ending December 31, 2014, Exelon Generation projected its capital expenditures (excluding nuclear fuel purchases) for 2015 to be $2,375 million.

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[58] PSEG. 2015. "*PSEG Announces 2015 Second Quarter Results*". Available online at: https://www.pseg.com/info/media/newsreleases/2015/2015-07-31.jsp#.Vfhdl51VhBc

[59] PSEG Investor FACT Book 2014-2015. PSEG Power Consolidated Balance Sheets. Page 52.

[60] Exelon Corporation. 2014. *Form 10-K*. Page 221.

[61] Current rating from Moody's company report, 2015: https://www.moodys.com/research/Moodys-changes-PSEG-Inc-outlook-to-positive-affirms-subsidiary-ratings--PR_333720 and http://www.streetinsider.com/Credit+Ratings/Exelon+Corp.+(EXC),+Pepco+(POM)+Ratings+Affirmed+by+Moodys%3B+Pepco+Outlook+to+Positive/10855998.html

[62] Moody's Investors Services. 2015. *Moody's Rating Symbols & Definitions*. March. https://www.moodys.com/sites/products/AboutMoodysRatingsAttachments/MoodysRatingsSymbolsand%20Definitions.pdf

[63] PSEG. 2014. *Form 10-K*. Available online at: http://investor.pseg.com/sites/pseg.investorhq.businesswire.com/files/report/additional/PSEG_10K2014.pdf

The total installed cost of the Project Scenario ($852 million) represents about 31 percent of the companies combined annual capital expenditure, and the annual loan payment just 2 percent.

Potential interest charges

According to Barron's index of 10 medium-grade corporate bonds, the current yield on intermediate grade corporate bonds is 4.91 percent.[64] The annual interest payment in the first year (based on a total installed cost of $852 million) would be about $42 million. In 2012, 2013, and 2014, PSEG and Exelon's combined interest expenses totaled $490 million, $473 million, and $480 million respectively.[65] **The Project Scenario's annual interest payment in the first year ($32 million) represents about 8.7 percent of the two companies average annual interest expenses over the past three years (about $481 million).**

4.3 Affordability to Residential Ratepayers

PSEG and Exelon are members of the Pennsylvania, New Jersey, Maryland Interconnection, L.L.C. (PJM) regional transmission organization and Salem sells its electricity in the PJM power pool.[66] In order to determine the affordability of the Project Scenario from the perspective of ratepayers, we first estimate the annual cost of the Project Scenario, and then put that cost within the context of the rates customers currently pay. Assuming a 20-year loan period, and an interest rate of 4.91 percent, the annual payment on the $852 million total installed cost of the Project Scenario totals about $68 million each year (split between the two owners).

From 2007–2010, average annual net generation at Salem totaled about 19 million MWh.[67] Assuming that all the energy Salem generates goes to residential customers, and that all costs associated with the Project Scenario would be transferred to these residential customers through increases in their electricity rates, the Project Scenario would increase electricity rates by $0.0036 per kWh.[68] As of 2015, PSEG's residential service rates ranged from $0.180361–$0.195146 per kWh depending on the season and the energy used by each household, along with a monthly service charge of $2.43.[69] Taken alone, the potential increase in costs associated with the Project Scenario represent about 1.8 percent–2.0 percent of PSEG's per-unit electricity rates for residential customers. PSEG's average residential customer uses 7,360 kWh of electricity each year. Given the range of per-unit rates and the monthly service charge, an average customer pays about $1,360–$1,470 for electricity each year. **The potential increase in electricity costs**

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[64] Barron's. September 07, 2015. Weekly Bond Statistics. Retrieved on Sept 11th, 2015 from http://www.barrons.com/public/page/9_0210-weeklybondstats.html

[65] Exelon Corporation. 2014. *Form 10-K*. Page 221.

[66] New Jersey Department of Environmental Protection. 2015. PSEG NUCLEAR LLC SALEM GENERATING STATION NJPDES - Surface Water Renewal Permit Action. Page 2.

[67] US EPA. 2010. eGRID. Available online at: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

[68] $0.0036/kWh = ($67,880,996 / 19,069,767 MWh) * 0.001 MWh/kWh

[69] Residential Service Rates for PSE&G Effective on Jaunary, 2015. http://www.pseg.com/info/environment/ev/rlm-rs_rates.jsp

associated with the Project Scenario total about $26 per customer per year, which represents about 1.9 percent of an average customer's current annual cost.

Because the New Jersey energy market is deregulated and supplied competitively though, the actual share of costs borne by ratepayers is likely to be lower than the $26 estimate above. Energy consumers in New Jersey exist under utility jurisdictions known as the "incumbent provider". Under New Jersey energy deregulation law the supply portion of the bill is separate from the delivery portion of the bill.[70] Consumers can choose between numbers of suppliers. Electricity is delivered throughout New Jersey by the regional transmission organization PJM.[71] 51 million people and 164,900 MW of generating capacity across 14 states are connected through 62,550 miles of transmission lines by PJM. PJM has 1,376 generation sources. The energy generation market that supplies New Jersey with capacity has become increasingly competitive in recent years. Consumers can choose where they buy their electricity, so there is an incentive for suppliers to lower prices. This competition has also spurred more long-term contracts between utilities and their suppliers in order to avoid price spikes. [72]

In general, residential and commercial demand in New Jersey is inelastic.[73] This means that a change in price generates a percent change in demand that is less than the percent change in price. Consequently in general, more of the change in price is borne by consumers than producers, but producers do bear a share of that cost. Furthermore, evidence across the country demonstrates that a share of communities is typically willing to pay more for "green energy" supply that is less destructive for the environment.[74] Overall then, ratepayers will bear a share of the increased costs, but if properly communicated, they can receive benefit from knowing that their energy consumption is more environmentally responsible than otherwise.

5 Summary of Results

Our analysis suggests that closed-cycle cooling would provide a range of economically-valuable goods and services that OMB and EPA guidance suggest should be included in consideration of benefits and costs. Available data suggest annual benefits in the tens of millions of dollars per year and net present benefits over time into the hundreds of millions and even billions of dollars, particularly in the context of other factors reducing fish populations in the Delaware

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[70] State of New Jersey, Public Utility Board, "Shop for Energy Suppliers". http://www.nj.gov/bpu/commercial/shopping.html

[71] http://www.pjm.com/about-pjm.aspx

[72] Johnson, Tim. "Shopping Around for Cheaper Power". NJ Spotlight. http://www.njspotlight.com/stories/10/0624/2022/

[73] Regional Differences in the Price-Elasticity of Demand For Energy, Rand Corporation, 2005

[74] Roe, B., Teisl, M. F., Levy, A., & Russell, M. 2001. US Consumers' Willingness to Pay for Green Electricity. Energy Policy, 29(11), 917-925.

Bay. Thus, costs are not wholly disproportionate to environmental benefits nor are they significantly greater than benefits.

Moreover, these costs are likely affordable to PSEG and Exelon, the plants owners, based on similar and ongoing expenditures and financing conditions. Ratepayers would likely bear some of the costs, but ratepayers have shown a willingness to pay additional for energy generated by more environmentally-responsible means.