Memorandum
Environment and Resources

Date September 14, 2011

To Kelly Meadows, Tetra Tech

From Michael Fisher, Lisa Tarquinio

Subject Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station, Bow, NH

As requested by Tetra Tech and EPA Region 1, we performed analyses of the cost and affordability of alternative cooling water system (CWS) technology options for Merrimack Station, an electric power generating facility in Bow, New Hampshire. Merrimack Station is a coal-fired plant, with two generating units, Unit 1 with 120 MW capacity, and Unit 2 with 350 MW capacity. Merrimack is owned by Public Service of New Hampshire (PSNH), which is a wholly owned subsidiary of Northeast Utilities (NU), an electric power company based in Hartford, Connecticut (in this document, we abbreviate Northeast Utilities/Public Service of New Hampshire as NU/PSNH).

- For the assessment of cost, we calculated the present value and annualized cost of five alternative technology options, as specified by EPA Region 1, on the basis of both the nominal, after-tax costs to NU/PSNH (private cost analysis) and constant dollar costs to society (social cost analysis). As described below, these five options include installation of closed cycle cooling on one or both of the two generating units, with additional specifications concerning whether the closed cycle systems operate year-round, and with installation of specific intake structure upgrades.
- For the assessment of affordability, we reviewed the expected financing requirements of installing closed cycle cooling capability, with specific intake structure upgrades, at Merrimack Station and also assessed the potential impact on residential customer rates. In this analysis, we focused on a single technology option, as specified by EPA Region 1, in which closed cycle cooling would be installed on both of Merrimack Station's generating units and the units would operate the closed cycle cooling capability year round. In the later parts of this memorandum, this technology option is referred to as *Option 3: Closed Cycle - Units 1 and 2, full year operation; CWIS Upgrade A - Units 1 and 2.*

In the following sections, we summarize key elements of this analysis and findings.

1 Cost of CWS Technology Options for Merrimack Station – Private Cost Basis

1.1 General

- We used the costs – capital cost, cost of installation downtime, operation and maintenance (O&M), energy penalty – as reported in the NU/PSNH documents[1] provided to Abt Associates by EPA Region 1. We made no adjustments to these values except to move the costs that were initially developed in 2007 dollars to 2010 and, as appropriate, to move the costs to years beyond 2010 based on expected future changes in electricity cost/price values and plant operating costs:

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[1] *Response to United States Environmental Protection Agency CWA §308 Letter*, November 2007, and *Supplemental Alternative Technology Evaluation*, October 2009.

- Construction and O&M costs were brought forward from 2007 to 2010 based on the change in the Construction Cost Index (CCI) over that period (4.1 percent).
- Beyond 2010, we escalated O&M costs, on a nominal cost basis, at the average rate of change in the CCI over the 10-year period, 2001-2010 (3.5 percent).
- Construction outage costs – which reflect loss in electricity revenue and/or cost of replacement energy – were brought from 2007 to 2010 based on the reported change in electricity prices for New Hampshire from the U.S. Department of Energy (4.1 percent).[2]
- Energy penalty costs, which also reflect loss in electricity revenue and/or cost of replacement energy, were first brought forward first to 2010, using the same adjustment as for construction outage costs. These costs were then projected over the analysis period based on projected changes in electricity costs/prices for New Hampshire from the U.S. Department of Energy's *Annual Energy Outlook - 2010* (AEO). Because the AEO forecast is on a *real* dollar basis (i.e., with values that exclude the effects of general price inflation), we used an estimated rate of general inflation of 2.2 percent, based on the most recent 10 years of change in the GDP Deflator (from the U.S. Department of Commerce), to convert the *real* cost forecast into a nominal dollar forecast.

➢ *Table 1-1*, following page, shows the conversion from 2007 to 2010 values for *Option 3: Closed Cycle - Units 1 and 2, full year operation; CWIS Upgrade A - Units 1 and 2.*

➢ We performed the analysis for five technology options specified by EPA.

1.2 Discounting, Annualization, and Tax Treatment

➢ We discounted all costs – capital outlay, cost of construction outage, and O&M, and energy penalty – to a present value as of 2010, which for this analysis was used as the year of project construction, using an estimated weighted average after-tax cost of capital calculated for NU/PSNH.

➢ The cost of capital is based on NU's capital structure, our estimate of NU's cost of equity capital, estimated debt costs based on NU/PSNH's current debt rating, and estimated marginal tax rate for NU/PSNH. The cost of equity capital reflects NU's historical equity pricing and estimated return to equity capital. In developing these estimates, we used data over a multiple year period for both the capital structure and the debt and equity cost values, to avoid a potentially anomalous estimate of cost of capital due to capital market conditions since late 2008. Our resulting estimate of the after-tax cost of capital for the technology options analysis is 5.3 percent on a nominal (i.e., to be used with *actual dollars*, *which include the effects of general price inflation*), after-tax basis.[3] The equivalent pre-tax value is 9.0 percent.[4] As described later in this memorandum, we used the pre-tax rate for assessing the potential electricity rate impact of closed cycle cooling installation at Merrimack Station.

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2 U.S. Energy Information Administration, Form EIA-826, "Monthly Electric Sales and Revenue Report" (data series for the years 2007-2010).

3 Depending on the timing of NU/PSNH's financing for technology installation, this estimated cost of capital could exceed, or be lower than, the financing costs that would actually be incurred.

4 For further comparison, the 9.0 pre-tax *nominal* value would be approximately equivalent to a pre-tax *real* discount rate of 6.6 percent (assuming general inflation of 2.2 percent). This 6.6 percent rate is comparable in concept to the 7.0 percent opportunity cost of capital discount rate (which, in concept, is also a pre-tax real discount rate) used in the social cost analysis. In other words, NU/PSNH's cost of capital is similar to, but modestly lower than, the overall "cost of capital" for society, as reflected in the discount rate used in the social cost analysis presented later in this memorandum.

Table 1-1: Conversion from 2007 Dollars to 2010 Dollars

all dollar values ($000)

Option Number 3	Original Data in 2007 Dollars	Data Converted into 2010 Dollars		Conversion Factor
Capital Cost of Technology	$59,551	$65,801	1.1049	CCI from 2007 to 2010
Closed Cycle Cooling System	$59,216	$65,430	1.1049	CCI from 2007 to 2010
Intake System Upgrades	$335	$370	1.1049	CCI from 2007 to 2010
Construction Outage Cost	$8,765	$9,128	1.0415	Electricity Price Change from 2007 to 2010
O&M Expense				
Cooling Tower				
Yrs 1-5	$400	$442	1.1049	CCI from 2007 to 2010
Yrs 6-15	$501	$553	1.1049	CCI from 2007 to 2010
Yrs 16-20	$801	$885	1.1049	CCI from 2007 to 2010
Intake Structure Upgrades				
Yrs 1-5	$60	$66	1.1049	CCI from 2007 to 2010
Yrs 6-15	$60	$66	1.1049	CCI from 2007 to 2010
Yrs 16-20	$60	$66	1.1049	CCI from 2007 to 2010
Total				
Total O&M, Yrs 1-5	$460	$508	1.1049	CCI from 2007 to 2010
Total O&M, Yrs 6-15	$561	$619	1.1049	CCI from 2007 to 2010
Total O&M, Yrs 16-20	$861	$951	1.1049	CCI from 2007 to 2010
Energy Penalty				
Energy Conversion Penalty	$1,880	$1,957	1.0415	Electricity Price Change from 2007 to 2010
Parasitic Loss	$4,226	$4,401	1.0415	Electricity Price Change from 2007 to 2010
Total Energy Penalty	$6,105	$6,359	1.0415	Electricity Price Change from 2007 to 2010

- We assumed the cooling tower and the intake structure upgrades to have a 20-year operating life for developing the time series of costs, calculating present value, and annualizing the total present value of costs.[5] All recurring costs were projected forward through 2030 (20 years *after* the assumed construction date of 2010 for technology installation, with a first operating year of 2011) using cost adjustment factors as outlined in *Table 1-1*, above, and annualized over the 21-year analysis period, 2010-2030: 1 year for technology installation plus 20 years of operation.
- All costs were adjusted to an after-tax basis using our estimate of NU/PSNH's combined federal and New Hampshire state marginal tax rate of 40.5 percent.
- For the tax analysis, we assumed that capital outlays would be depreciated over a 15-year period, consistent with allowed tax code treatment for capital assets with an estimated useful life of 16 to 20 years.

[5] The PSNH documents describe the cooling tower technology as having a 30-year useful life; however, certain equipment components are described as having a 20-year useful life. Since a longer useful life – and longer annualization periods – will typically give a lower annualized cost, we used the shorter 20-year useful life as the *primary* case analysis that is presented in this memorandum. This treatment avoids understating the potential cost on a discounted, annualized cost basis. Given the assumption of a 20-year operating life for the technology capital equipment, we annualized the resulting present value of costs over a 21-year analysis period (2010-2030). As an alternative case, we completed the analyses assuming a longer 30-year useful life and annualization period (31 years), which gives slightly lower annualized costs. The summary tables for the 30-year useful life (31-year annualization period) analysis are presented in the final section of this memorandum.

1.3 Summary of Costs and Related Analysis Assumptions

Table 1-2: Analysis Case Costs , below, summarizes the costs, after adjustment to 2010 dollars, used in this analysis.

Table 1-2: Analysis Case Costs *(all dollar values in 2010 dollars $000)*

Option Number	**1**	**2**	**3**	**4**	**5**
Technology Option	Closed Cycle - Unit 1, full year operation; CWIS Upgrade A - Unit 1, CWIS Upgrade B - Unit 2	Closed Cycle - Unit 2, full year operation; CWIS Upgrade A - Unit 2, CWIS Upgrade B - Unit 1	Closed Cycle - Units 1 and 2, full year operation; CWIS Upgrade A - Units 1 and 2	Closed Cycle - Units 1 and 2, seasonal operation; CWIS Upgrade A - Units 1 and 2	Closed Cycle - Units 1 and 2, seasonal operation; CWIS Upgrade B - Units 1 and 2
Capital Cost of Technology	**$25,948**	**$47,976**	**$65,801**	**$65,801**	**$66,931**
Closed Cycle Cooling System	$24,769	$46,914	$65,430	$65,430	$65,430
Intake System Upgrades	$1,179	$1,062	$370	$370	$1,500
Construction Outage Cost	$2,331	$6,798	$9,128	$9,128	$9,128
O&M Expense					
CCCS (full year basis)					
Yrs 1-5	$150	$367	$442	$442	$442
Yrs 6-15	$191	$470	$553	$553	$553
Yrs 16-20	$314	$778	$885	$885	$885
Intake Structure Upgrades					
Yrs 1-5	$66	$66	$66	$66	$66
Yrs 6-15	$66	$66	$66	$66	$66
Yrs 16-20	$66	$66	$66	$66	$66
Total (accounting for CCCS cost with seasonal operation reduction)					
Total O&M, Yrs 1-5	$216	$434	$508	$250	$250
Total O&M, Yrs 6-15	$257	$536	$619	$297	$297
Total O&M, Yrs 16-20	$380	$844	$951	$435	$435
Fraction of Year CCCS Operated	100.0%	100.0%	100.0%	41.7%	41.7%
Energy Penalty (full year basis)					
Energy Conversion Penalty	$105	$1,852	$1,957	$1,957	$1,957
Parasitic Loss	$1,025	$3,376	$4,401	$4,401	$4,401
Total Energy Penalty	$1,130	$5,229	$6,359	$2,649	$2,649

Total energy penalty cost accounts for CCCS cost with seasonal operation reduction.

Key points relative to these cost estimates and related analyses:

- In a few instances, NU/PSNH reported different cost values at different places in the *Response to United States Environmental Protection Agency CWA §308 Letter*, November 2007 – e.g., Attachment 4, Section 5, page 7, reported a value of $1,342,700 ($2007) for Ristroph Thru-Flow Traveling Screens (Cooling Water Intake Structure Upgrade B), while the table on page 95 of the primary document reported a value of $1,357,000 ($2007) for this same technology. In these instances, we used the higher of the reported values for this analysis.

- From the NU/PSNH documentation, it is not clear whether the cost of the Fish Return System (Cooling Water Intake Structure Upgrade A), $335,100 ($2007), reflects installation for one or both generating units. We used this single cost value in the analyses regardless of whether the system is specified for a single generating unit or both generating units.
- To develop a single generating unit cost for Cooling Water Intake Structure Upgrade B, we apportioned the total installation cost over the two units based on the reported cost of the *traveling screens* for the separate generating units, from the table in Attachment 4, Section 5, page 7, of *Response to United States Environmental Protection Agency CWA §308 Letter*, November 2007.
- The reported full-year annual O&M and energy penalty values for cooling tower operation were reduced to a 5-month basis for the seasonal operation cases (options 4 and 5) by multiplying the full-year cost values by 41.7 percent (5/12 = 0.417, reflecting 5 months of seasonal operation, April through August). This assumption may understate the energy penalty value to the extent that foregone electricity sales would have occurred at higher average prices during the summer peak operating season than in the total year.

1.4 Total Private Cost

As requested by the EPA, we report total private costs for the Merrimack Station technology options both *including*, and *not including*, the cost of the intake structure upgrades, as summarized in *Table 1-2*, above.

Table 1-3, below, applies these costs and analytic treatments in calculating the present value and annualized cost for the Merrimack Station technology options *including the intake structure upgrades*, on a private cost basis. These, and all subsequent, present values are as of 2010, the year of project construction assumed for this analysis.

Table 1-3: Present Value and Annualized Cost of Technology Options (including intake system upgrades), Private Cost Basis

	Technology Option				
	1	2	3	4	5
Present Value of Cost Element ($000)					
Initial Outlays and Depreciation					
Capital Outlay	**$25,948.0**	**$47,976.5**	**$65,800.6**	**$65,800.6**	**$66,930.6**
Depreciation Tax Benefit	**-$7,111.8**	**-$13,149.4**	**-$18,034.6**	**-$18,034.6**	**-$18,344.3**
Construction Outage Expense					
Cost: Income Loss	$2,330.6	$6,797.6	$9,128.2	$9,128.2	$9,128.2
Tax Adjustment	-$944.5	-$2,754.7	-$3,699.2	-$3,699.2	-$3,699.2
Net Cost, Construction Outage	**$1,386.1**	**$4,042.9**	**$5,429.0**	**$5,429.0**	**$5,429.0**
Total Initial Cost, Net Tax	**$20,222.3**	**$38,870.0**	**$53,195.1**	**$53,195.1**	**$54,015.3**
Annual Expenses					
O&M Expense					
Cost	$4,568.5	$9,631.1	$11,069.3	$5,260.5	$5,260.5
Tax Adjustment	-$1,851.4	-$3,903.0	-$4,485.8	-$2,131.8	-$2,131.8
Net Cost, O&M Expense	**$2,717.1**	**$5,728.1**	**$6,583.5**	**$3,128.7**	**$3,128.7**
Total Energy Penalty					
Cost: Revenue Loss	$15,824.1	$73,234.8	$89,059.0	$37,107.9	$37,107.9
Tax Adjustment	-$6,412.7	-$29,678.4	-$36,091.1	-$15,038.0	-$15,038.0
Net Cost, Total Energy Penalty	**$9,411.4**	**$43,556.4**	**$52,967.8**	**$22,069.9**	**$22,069.9**
Total Annual Cost/(Gain), After-Tax	**$12,128.5**	**$49,284.5**	**$59,551.3**	**$25,198.6**	**$25,198.6**
Total After-Tax Cash Flow Cost/(Gain), Present Value at 5.3%	**$32,350.8**	**$88,154.4**	**$112,746.3**	**$78,393.7**	**$79,213.9**
Annual Equivalent Cost at 5.3% over 21 years	**$2,599.4**	**$7,083.3**	**$9,059.2**	**$6,299.0**	**$6,364.9**

Table 1-4, below, applies these costs and analytic treatments in calculating the present value and annualized cost for the technology options *not including the intake structure upgrades*, on a private cost basis. Compared to the values in *Table 1-3*, the capital outlay and O&M outlays are reduced by the amounts associated with the intake structure upgrades, as documented in *Table 1-2*.

Table 1-4: Present Value and Annualized Cost of Technology Options (not including intake system upgrades), Private Cost Basis

	Technology Option				
	1	**2**	**3**	**4**	**5**
Present Value of Cost Element ($000)					
Initial Outlays and Depreciation					
Capital Outlay	**$24,769.2**	**$46,914.5**	**$65,430.4**	**$65,430.4**	**$65,430.4**
Depreciation Tax Benefit	**-$6,788.7**	**-$12,858.3**	**-$17,933.1**	**-$17,933.1**	**-$17,933.1**
Construction Outage Expense					
Cost: Income Loss	$2,330.6	$6,797.6	$9,128.2	$9,128.2	$9,128.2
Tax Adjustment	-$944.5	-$2,754.7	-$3,699.2	-$3,699.2	-$3,699.2
Net Cost, Construction Outage	**$1,386.1**	**$4,042.9**	**$5,429.0**	**$5,429.0**	**$5,429.0**
Total Initial Cost, Net Tax	**19,366.7**	**38,099.0**	**52,926.3**	**52,926.3**	**52,926.3**
Annual Expenses					
O&M Expense					
Cost	$3,457.1	$8,519.7	$9,957.9	$4,149.1	$4,149.1
Tax Adjustment	-$1,401.0	-$3,452.6	-$4,035.4	-$1,681.4	-$1,681.4
Net Cost, O&M Expense	**$2,056.1**	**$5,067.1**	**$5,922.5**	**$2,467.7**	**$2,467.7**
Total Energy Penalty					
Cost: Revenue Loss	$15,824.1	$73,234.8	$89,059.0	$37,107.9	$37,107.9
Tax Adjustment	-$6,412.7	-$29,678.4	-$36,091.1	-$15,038.0	-$15,038.0
Net Cost, Total Energy Penalty	**$9,411.4**	**$43,556.4**	**$52,967.8**	**$22,069.9**	**$22,069.9**
Total Annual Cost/(Gain), After-Tax	**$11,467.5**	**$48,623.5**	**$58,890.3**	**$24,537.6**	**$24,537.6**
Total After-Tax Cash Flow Cost/(Gain), Present Value at 5.3%	**$30,834.2**	**$86,722.5**	**$111,816.6**	**$77,463.9**	**$77,463.9**
Annual Equivalent Cost at 5.3% over 21 years	**$2,477.5**	**$6,968.2**	**$8,984.5**	**$6,224.3**	**$6,224.3**

The present value of total cost on this basis provides an estimate of the potential impact of technology installation and operation on the business value of the NU/PSNH enterprise – *if the technology options were installed with no change in NU/PSNH revenue.* As we describe in *Section 3: Assessing the Affordability of Installing Closed Cycle Cooling Capability at Merrimack Station*, we anticipate that NU/PSNH will recover the costs of technology installation and operation through increased rates to electricity consumers as provided under the regulated utility ratemaking framework applicable in New Hampshire.

2 Cost of CWS Technology Options for Merrimack Station – Social Cost Basis

Our estimate of the social cost of technology installation and operation uses all of the costs and concepts as outlined above, with the following adjustments:

- Costs are accounted for on a constant dollar, inflation-adjusted basis in 2010 dollars – e.g., ongoing O&M and energy penalty expense is not escalated over the life of the analysis.
- All values are accounted for on a pre-tax basis, since society bears the full cost of the resources used in constructing and operating the cooling tower, independent of any tax considerations.
- The present value and annualized costs are calculated using a 7 percent *real* discount rate.

Table 2-1, below, presents the social cost analysis. These costs include the cost of the cooling water intake structure upgrades, as described above, and thus correspond, on a social cost basis, to the private cost analysis presented in *Table 1-3*.

Table 2-1: Present Value and Annualized Cost of Technology Options, Social Cost Basis

	Technology Option				
	1	2	3	4	5
Present Value of Cost Element ($000, 2010 dollars)					
Initial Outlays and Depreciation					
Capital Outlay	$25,948.0	$47,976.5	$65,800.6	$65,800.6	$66,930.6
Construction Outage Expense	$2,330.6	$6,797.6	$9,128.2	$9,128.2	$9,128.2
Total Initial Cost	$28,278.6	$54,774.1	$74,928.9	$74,928.9	$76,058.8
Annual Expenses					
O&M Expense	$2,740.0	$5,718.4	$6,598.4	$3,159.0	$3,159.0
Total Energy Penalty	$13,670.7	$63,268.7	$76,939.4	$32,058.1	$32,058.1
Total Annual Cost/(Gain)	$16,410.7	$68,987.1	$83,537.9	$35,217.1	$35,217.1
Total Cost/(Gain), Present Value at 7.0%	$44,689.3	$123,761.2	$158,466.7	$110,146.0	$111,275.9
Annual Equivalent Cost at 7.0% over 21 years	$4,124.3	$11,421.8	$14,624.7	$10,165.3	$10,269.5

The social cost presented in *Table 2-1* probably overstates the social cost of replacement electricity during generating system downtime for technology installation, since the marginal cost of replacement generation is very likely less than the cost of net revenue loss and electricity purchases as reported by PSNH.

3 Assessing the Affordability of Installing Closed Cycle Cooling Capability at Merrimack Station

As described in the foregoing sections, installation and operation of cooling water system technology options will require that NU/PSNH make capital outlays and incur additional operating costs and related effects (i.e., energy penalty). We anticipate that these costs will be recovered by NU/PSNH through increased electricity rates as provided under the New Hampshire Public Service Commission's rate regulation framework. As such, NU/PSNH's electricity consumers, and not the company's shareholders, will "pay for" the compliance technology. Nevertheless, technology installation will require that NU/PSNH finance the capital outlays, and this requirement could pose an affordability challenge to the company depending on its financial circumstances. In addition, as described, we anticipate that technology installation and operation will lead to increased electricity rates to NU/PSNH's electricity customers, which could also pose an affordability challenge. In this section, we assess technology affordability from these perspectives: financial challenge to NU/PSNH and rate impact to residential electricity consumers.

We performed these assessments for *Option 3: Closed Cycle - Units 1 and 2, full year operation; CWIS Upgrade A - Units 1 and 2.*

3.1 Affordability of Technology Installation to NU/PSNH

We considered three measures of financial affordability:

1. The required increase in NU/PSNH's assets for technology installation
2. The capital outlay in relation to NU/PSNH's historical capital expenditure levels
3. The potential interest charges for the debt component of financing in relation to NU/PSNH's current interest accounts.

From our analysis of these measures, we assess the financing requirements for Option 3 technology installation to be affordable by the company.

3.1.1 Required Increase in NU/PSNH's Assets for Technology Installation

As reported in NU's Form 10-K for the fiscal year ending December 31, 2010, the NU subsidiary NU/PSNH held assets for Property, Plant and Equipment (PPE) of approximately $2.05 billion. We estimated that the increase in assets and associated financial capital (liabilities and equity) for installing closed cycle cooling capability for both generating units (Option 3) would be approximately $68.8 million (2010 dollars). This value includes an estimated allowance for debt and equity charges on construction work in progress (CWIP) of approximately $3 million. We calculated the CWIP value assuming that the outlays for technology installation ($65.8 million) would occur uniformly over the one-year construction period at the pre-tax cost of capital described earlier (9.0 percent). The resulting total asset value – $68.8 million – would represent approximately 3.4 percent of the NU/PSNH's PPE asset base.

We also note that NU/PSNH's current debt rating, BBB/Baa2, falls within the range of *Investment Grade* debt, as conventionally assessed by organizations such as Standard and Poor's and Moody's.[6]

Given the small size of this asset increase relative to the company's current PPE base and the company's current financial condition as indicated by the BBB debt rating, we judge this required addition to assets, and the accompanying increase in capital to finance the asset increase, to be affordable by the company.

3.1.2 Capital Outlay in Relation to Historical Capital Expenditure Levels

In the NU/PSNH's three most recent fiscal years (2008, 2009, 2010), the company made investments in PPE of $239 million, $266 million, and $296 million, respectively, or an average of $267 million for these years. The anticipated total outlay capital outlay, including CWIP, for the Option 3 technology installation would represent approximately 26 percent of the average over the three years. Again, we judge this outlays to be affordable by the company.

3.1.3 Potential Interest Charges

If NU/PSNH financed the technology outlays entirely by debt at an estimated debt cost of 6.3 percent[7], the annual interest payment in the first year would be approximately $4.3 million. In fiscal year 2010, NU/PSNH incurred interest expense of approximately $231 million. Accordingly, the interest charge, assuming the outlay is fully financed by debt, would represent less than 2 percent of the company's current interest expense. Again, we judge this level of interest expense to be affordable by the company.

3.2 Affordability to Residential Ratepayers

As a second concept of affordability, we assessed the potential rate effect from technology installation on NU/PSNH's residential ratepayers. For this assessment, we calculated an approximate total revenue requirement and residential customer rate effect[8] as follows:

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6 Current debt rating from Standard & Poor's Company report, September 14, 20110; also, NU/PSNH 10-K for year ending December 31, 2010. For credit quality characterization, see, for example, *Moody's Rating Symbols and Definitions*, Moody's Investors Service, June 2009, pages 8, 10.

7 Yield on "Intermediate Grade Corporate Bonds" for Barron's index of 10 medium-grade corporate bonds, for week ending July 29, 2011. http://online.barrons.com/public/page/9_0210-weeklybondstats.html. Accessed August 5, 2011. Note: this rate is slightly higher than the longer-term average of debt cost used in the cost of capital calculation for NU/PSNH, and thus yields a slightly higher interest cost than would result from the interest rate in the cost of capital calculation. We used this higher rate to avoid understating the possible interest charge associated with debt financing of the compliance technology outlay.

8 We don't expect that these calculations will match precisely the ratemaking treatment that NU/PSNH would follow in seeking recovery of cooling water system technology costs from the New Hampshire Public Service Commission. For

- We assumed that the capital outlay, including CWIP charges, of $68.8 million would be placed into rate base and recovered on a straight-line basis over the estimated 20 years of equipment life. If the equipment value is recovered over a longer period, the annual recovery amount would be proportionately less.
- We estimated an annual return on capital from each year's rate base value using the pre-tax cost of capital value of 9.0 percent, as described earlier in this memorandum.
- We estimated an allowance for working capital as 0.2 percent of the capital outlay based on NU/PSNH's framework for estimating the rate impact from installing scrubber technology at Merrimack Station, as described in a submission to the New Hampshire Public Utilities Commission, dated September 2, 2008.[9]
- Other expenses – annual operating and maintenance, energy penalty – were charged annually, on a pre-tax basis with inflation adjustment, as described in *Section 1.3: Summary of Costs and Related Analysis Assumptions*.
- The sum of these items yields an approximate annual revenue requirement from technology installation and operation. Over the 20-year analysis period, the annual revenue requirement averages approximately $15.3 million, ranging from a high of $16.0 million in year 2 following completion of technology installation to a low of $14.6 million in year 15 of technology operation. The return on capital component of the revenue requirement declines over time as the capital balance is retired from rate base. However, as explained above, our analysis includes an allowance for inflation in operating and maintenance and energy penalty costs. As a result, these values increase over time and eventually offset the annual decrease in the return on capital component of the revenue requirement. To the extent that annual operating expenses increase at a lower rate than assumed in this analysis, the annual revenue requirement and customer rate impact would be less.
- We followed two approaches in allocating the total annual revenue requirement to the residential segment of NU/PSNH's customers.
    - In the first approach, we allocated the total annual revenue requirement to the residential segment of NU/PSNH's customers based on the average percentage of total electricity revenue received from residential customers over the preceding 5 years (2006-2010): 44 percent.[10] The percentage of revenue received from residential customers exceeded this value in 2009 and 2010 as commercial/industrial sales declined during the recent period of

example, our estimates of revenue requirements will probably not use exactly the same allowed return/cost of capital values that NU/PSNH would use; in addition, our treatment of depreciation and tax considerations will likely not match NU/PSNH's treatment. Further, in allocating the estimated revenue requirements to ratepayers, our estimate will again be an approximation and not match precisely the allocation methods that NU/PSNH would use for ratemaking. Nevertheless, the calculations should provide an approximate estimate of the potential rate effect to residential consumers.

9 The State of New Hampshire before the Public Utilities Commission. Public Service Company of New Hampshire, Merrimack Station Scrubber Project, Request for Information, Docket No. DE 08-103, September 2, 2008.

10 NU Form 10-K for the fiscal year ending December 31, 2010. Electricity revenue, sales and customer account data are for the NU/PSNH segment. Assigning the residential share of the revenue requirement to residential customers based on the fraction of total revenue received from the residential segment *before calculating a cost per kWh sold*, yields a higher charge to residential customers on a per kWh basis than if the additional cost per kWh were calculated on the basis of total electricity sales to all customers. This difference reflects the difference in electricity tariff structure for residential customers compared to other customer classes. Depending on the specific approach followed by NU/PSNH in allocating the cost of the cooling water system modifications over rate classes, this approach may overstate the rate effect to residential consumers.

economic weakness. However, we expect that the percentage of revenue from residential customers will decline as the economy recovers and commercial/industrial sales revive. Using the average annual revenue requirement of $15.3 million, approximately $6.8 million of the total revenue requirement would be expected to be recovered from residential customers, based on this allocation approach.

  - As indicated in footnote 8, page 8, the allocation based on the share of total electricity revenue by customer class may overstate the rate recovery from the residential class. As an alternative, we also calculated the rate effect on the basis of electric energy consumed, using the quantity of electricity sales, for all customer classes, as the basis of estimating the residential customer allocation. In this case, the revenue requirement assigned to the residential class amounted to approximately $5.8 million, based on the average profile of electricity consumption over the 5-year period, 2006-2010, or approximately 15 percent less than estimated by the total revenue allocation method described above.

- We calculated an average charge per kWh of electricity consumed by dividing the annual residential revenue requirement values by the average residential electricity sales quantity over the preceding 5 years. During this period, residential sales averaged approximately 3,100 GWh.

  - By the first revenue allocation approach, based on the residential customer class' total share of electric revenue, the resulting average yearly increase in residential electricity rates from installation and operation of closed cycle cooling capability at Merrimack Station would be $0.0022 or 0.22¢ per kWh.

  - By the alternative, energy consumption-only allocation approach, the average yearly increase in residential electricity rates would be about $0.0018 or 0.18¢ per kWh.[11]

- Over this same 5-year period, electricity sales per residential customer averaged 7,492 kWh annually, or 624 kWh monthly. Multiplying the estimated increase in electricity rates per kWh by the electricity consumption quantities yields an average annual increase per household customer over the 20-year analysis period of approximately $16.19, or $1.35, monthly, under the first allocation approach. The early years impact is slightly higher at $16.95 for the full year, or $1.41 monthly, in the second year following cooling tower installation (the year with the estimated highest rate impact). Under the second allocation approach, the average annual increase per household customer is approximately $13.83, or $1.15, monthly, over the 20 year-analysis period. Again, the rate impact in the early years is slightly higher at $16.49 for the full year, or $1.21 monthly, in the second year following cooling tower installation.

- On an annual basis, over the 5-year period, the average annual residential customer electricity payment ranged from approximately $1,100 to $1,260[12], and shows an increasing trend. In relation to the final year value, $1,260, the estimated average annual increase in electricity costs per residential customer from CWS technology installation at Merrimack Station is approximately 1.3 percent, using the first allocation approach, or 1.1 percent, using the second allocation approach.

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11 This value does not vary by customer class, and could be calculated directly by dividing the total revenue requirement by the total electricity sales quantity.

12 Calculated from NU Form 10-K for the fiscal year ending December 31, 2010, using electricity revenue, sales and customer account data for the NU/PSNH segment.

3.3 Summary Cost Tables Assuming 30-year Useful Life for Compliance Equipment

The following tables report present value and annualized cost on private cost (see *Table 3-1*, below) and social cost (see *Table 3-2*, following page) bases for the technology options *including the intake structure upgrades*, assuming a compliance technology life of 30 years. All other analytic treatments are the same as described in the preceding sections.

Table 3-1: Present Value and Annualized Cost of Technology Options, Private Cost Basis

	Technology Option				
	1	**2**	**3**	**4**	**5**
Present Value of Cost Element ($000)					
Initial Outlays and Depreciation					
Capital Outlay	**$25,948.0**	**$47,976.5**	**$65,800.6**	**$65,800.6**	**$66,930.6**
Depreciation Tax Benefit	**-$7,111.8**	**-$13,149.4**	**-$18,034.6**	**-$18,034.6**	**-$18,344.3**
Construction Outage Expense					
Cost: Income Loss	$2,330.6	$6,797.6	$9,128.2	$9,128.2	$9,128.2
Tax Adjustment	-$944.5	-$2,754.7	-$3,699.2	-$3,699.2	-$3,699.2
Net Cost, Construction Outage	**$1,386.1**	**$4,042.9**	**$5,429.0**	**$5,429.0**	**$5,429.0**
Total Initial Cost, Net Tax	**$20,222.3**	**$38,870.0**	**$53,195.1**	**$53,195.1**	**$54,015.3**
Annual Expenses					
O&M Expense					
Cost	$7,019.0	$15,069.7	$17,195.7	$8,062.3	$8,062.3
Tax Adjustment	-$2,844.5	-$6,107.0	-$6,968.5	-$3,267.3	-$3,267.3
Net Cost, O&M Expense	**$4,174.6**	**$8,962.7**	**$10,227.1**	**$4,795.1**	**$4,795.1**
Total Energy Penalty					
Cost: Revenue Loss	$21,223.4	$98,223.0	$119,446.4	$49,769.4	$49,769.4
Tax Adjustment	-$8,600.8	-$39,804.9	-$48,405.7	-$20,169.0	-$20,169.0
Net Cost, Total Energy Penalty	**$12,622.6**	**$58,418.1**	**$71,040.8**	**$29,600.3**	**$29,600.3**
Total Annual Cost/(Gain), After-Tax	**$16,797.2**	**$67,380.8**	**$81,267.9**	**$34,395.4**	**$34,395.4**
Total After-Tax Cash Flow Cost/(Gain), Present Value at 5.3%	**$37,019.5**	**$106,250.8**	**$134,463.0**	**$87,590.5**	**$88,410.7**
Annual Equivalent Cost at 5.3% over 31 years	**$2,469.2**	**$7,086.9**	**$8,968.6**	**$5,842.2**	**$5,896.9**

Table 3-2: Present Value and Annualized Cost of Technology Options, Social Cost Basis

	Technology Option				
	1	**2**	**3**	**4**	**5**
Present Value of Cost Element ($000, 2010 dollars)					
Initial Outlays and Depreciation					
Capital Outlay	**$25,948.0**	**$47,976.5**	**$65,800.6**	**$65,800.6**	**$66,930.6**
Construction Outage Expense	**$2,330.6**	**$6,797.6**	**$9,128.2**	**$9,128.2**	**$9,128.2**
Total Initial Cost	**$28,278.6**	**$54,774.1**	**$74,928.9**	**$74,928.9**	**$76,058.8**
Annual Expenses					
O&M Expense	**$3,430.3**	**$7,250.4**	**$8,324.2**	**$3,948.3**	**$3,948.3**
Total Energy Penalty	**$17,316.5**	**$80,141.3**	**$97,457.8**	**$40,607.4**	**$40,607.4**
Total Annual Cost/(Gain)	**$20,746.7**	**$87,391.7**	**$105,781.9**	**$44,555.7**	**$44,555.7**
Total Cost/(Gain), Present Value at 7.0%	**$49,025.3**	**$142,165.8**	**$180,710.8**	**$119,484.6**	**$120,614.5**
Annual Equivalent Cost at 7.0% over 31 years	**$3,912.1**	**$11,344.4**	**$14,420.2**	**$9,534.5**	**$9,624.7**