Energy Audit
Northumberland County
Recycling Centre

May 2010

MCW Custom Energy Solutions Ltd.

CONTINUOUS IMPROVEMENT FUND

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ENERGY AUDIT

NORTHUMBERLAND COUNTY RECYCLING CENTRE

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1.1 OVERVIEW OF PROJECT OBJECTIVES AND GOALS

This document has been prepared for the Northumberland County to complete an Energy Audit for the Recycling Centre performed by MCW Custom Energy Solutions Ltd. (MCW) in 2010. The purpose of this study is to identify energy and water efficiency improvements, costs and resulting energy and water savings for the Recycling Centre.

The energy and water efficiency improvements identified have been developed with the underlying design intent that existing building space conditions and occupant comfort will be as a minimum maintained, and in many cases improved. To do so, MCW has reviewed each of the following systems;

- Lighting
- Lighting Controls
- HVAC Systems
- Automated Building Controls Systems
- Domestic Water Conservation
- Renewable Energy Technology Opportunities

This Energy Audit outlines measures in relation to these systems which MCW feels would best allow the County to realize energy and water savings. It also describes the design and implementation necessary for each measure to succeed.

Every effort has been made to minimize costs while still ensuring that the Town maintains its goal of lower utility usage, reduced greenhouse emissions and renewed building infrastructure. Funding incentives wherever applicable, have been identified and have been used to reduce the initial capital costs of the measures.

The County has made a commitment to energy conservation. In this Energy Feasibility Study, MCW has developed a means to realize and maintain this commitment through its proposed measures, as well as providing the capacity to set a standard for energy use within the existing facility.

1.2 BUILDING SUMMARY

The summary of the building and the current utility consumption is shown in ***Table 1.1*** as follows:

Table 1.1: Current Utility Baseline

Description	Units	
Site	Recycling Centre	
Area of building	6,132 66,000	m^2 ft^2
Energy Used (2009)	1,524,946	ekWh
Electricity	716,557 2,886	kWh kW
Natural Gas	78,256	m^3
Water	788	m^3
Utility Costs (at 2009 rates)	$120,223	

1.3 EXECUTIVE PROGRAM SUMMARY

Proposed Program Summary

Energy and water efficiency improvements were reviewed and the expected savings and costs calculated. ***Table 1.2: Program Summary*** summarizes the costs, savings and incentives for the program developed for the facility. (Please see **Section 2 Program Summary)**

Table 1.2: Program Summary

Program	Utility Savings ($)	Total Cost ($)	Incentives ($)	Simple Payback (Yrs)
Northumberland County Recycling Centre				
Table 2.1: Energy Retrofit Program *(Sorted by Measure; All Measures)*	**$9,670**	**$82,933**	**$10,981**	**7.8**

An analysis of the building's electricity, natural gas and domestic water consuming systems shows **$120,223** of utility costs for January to December 2009:

- Electricity $90,042
- Gas $29,519
- Water $662

The savings from ***Table 2.1: Energy Retrofit Program*** represent **$9,670** (**8.0%** of the utility bill) in potential annual savings.

2.1 ENERGY RETROFIT PROGRAM & SAVINGS METHODOLOGY

Table 2.1 Energy Retrofit Program summarizes the proposed Retrofit Savings Program for the Recycling Centre. The program lists the proposed Energy Conservation Measures, the projected cost, annual savings, incentives, and the simple payback of all measures proposed.

2.2 PROJECT COSTS METHODOLOGY

Project Costs
Net costs for each measure have been secured through a combination of contractor pricing and direct MCW project experience with measures used in similar applications.

The Total Measure Costs include all of the costs to deliver a turn-key project including engineering, ESCo management fees, project management, construction management and administration, *excluding Taxes.*

Energy Savings
Savings have been developed using computer software programs, energy related handbooks, tabulated data, ASHRAE standards and direct MCW project experience with measures used in similar applications.

The savings shown are in adjusted 2009 dollars. Annual energy savings have been calculated using the latest utility rates provided by Northumberland County that reflects the 2009 billing year and are summarized in ***Table 2.1: Energy Retrofit Programs*** *f*or each measure.

Savings methodology for each measure is contained in the ***Savings Reconciliation Worksheets*** located at the end of each Measure write-up**.** Financial costing, savings, and simple payback for each Measure are included in ***Table 2.1: Energy Retrofit Programs***.

The ***Energy Retrofit Program*** summarized in ***Table 2.1*** provides a measure by measure cost and savings summary for the Audit assessed Energy Retrofit Measures.

2.3 UTILITIES SUMMARY

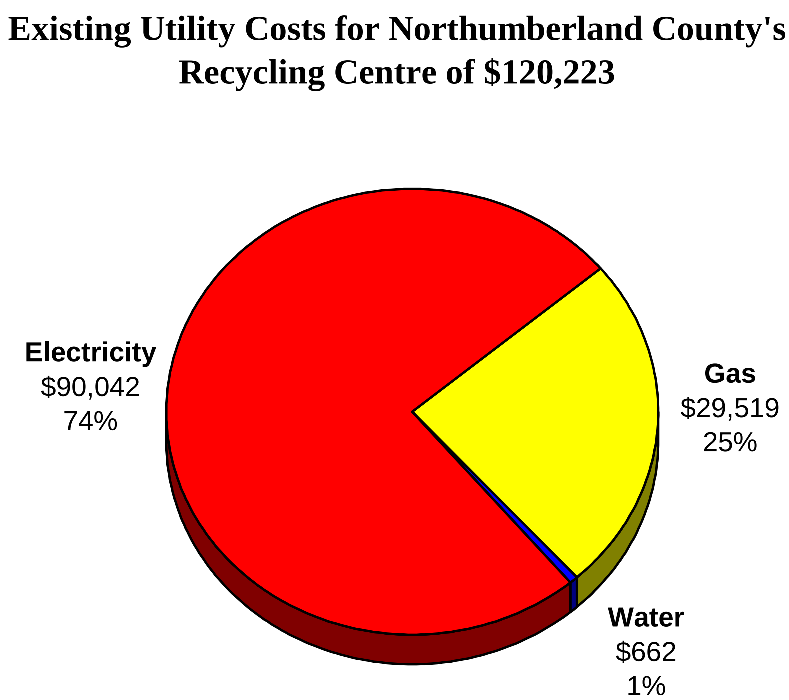
Analysis of the Northumberland Recycling Plant's electricity, natural gas and domestic water consuming systems shows **$120,223** of Utility Costs, using the rates detailed in **Section 3.1.** MCW estimates that **$9,670** (**8.0%** of the utility bill) in annual savings can be realized at the Building by implementing the recommended measures in ***Table 2.1*** (Energy Audit Program). Please refer to ***Figure 2.1*** for a graphical representation of the savings per utility cost and consumption.

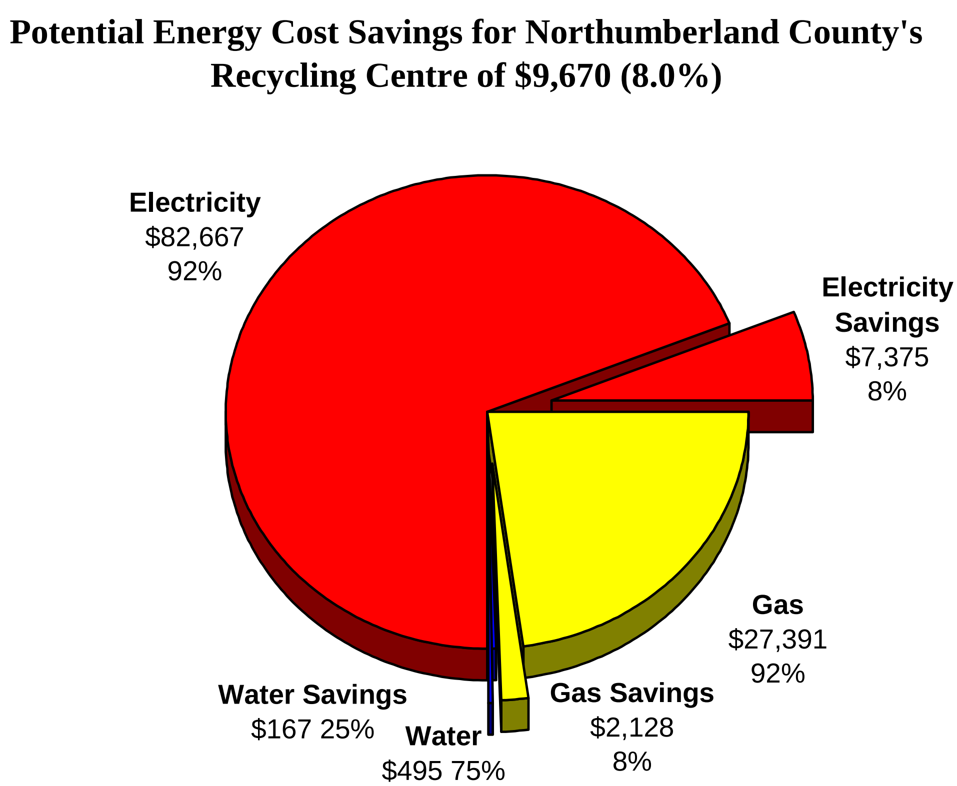
Table 2.1: Energy Retrofit Program

ENERGY RETROFIT PROGRAM MEASURES		ANNUAL SAVINGS Total Savings ($)[1 2]	Electrical kWh	Electrical GJ	Demand kW	Water m3	Natural Gas m3	Natural Gas GJ	Total GJ	Tonnes CO2e Saved	TOTAL COST[2 3] ($)	SIMPLE PAYBACK (YEARS)	Incentives NRCan ($)	Incentives Union Gas ($)	Incentives ERIP ($)	SIMPLE PAYBACK (YEARS)
SECTION																
4.0	**LIGHTING MODIFICATIONS**	**$4,100**	**31,872**	**115**	**164**				**115**	**6**	**$39,022**	**9.5**	**$1,147**		**$7,318**	**7.5**
A01	Lighting Retrofit & Redesign	$4,100	31,872	115	164				115	6	$39,022	9.5	$1,147		$7,318	7.5
5.0	**MECHANICAL MODIFICATIONS**	**$2,400**	**3,378**	**12**			**5,641**	**211**	**223**	**11**	**$8,120**	**3.4**	**$2,234**	**$282**		**2.3**
B01	MUA Controls Upgrade	$2,400	3,378	12			5,641	211	223	11	$8,120	3.4	$2,234	$282		2.3
6.0	**ELECTRICAL MODIFICATIONS**	**$3,000**			**279**						**$30,686**	**10.2**				
C01	Power Factor Correction	$3,000			279						$30,686	10.2				
7.0	**WATER CONSERVATION**	**$170**				**199**					**$5,105**	**30.0**				
D01	Domestic Water Fixture Retrofit	$170				199					$5,105	30.0				
A	***PROGRAM TOTAL***	$9,670	35,250	127	443	199	5,641	211	338	17	$82,933	8.6	$3,381	$282	$7,318	7.8

Notes:
1. **Rates used to calculate savings: Electricity - $0.07346/kWh, $10.729/kW, $0.377/m3 and Water - $0.840/$m^3$**
2. **Total Costs and Savings do not include taxes.**
3. **Total Costs assume a turnkey service delivery and include provision of Engineering, Project Management, Construction Management, Administration and Guaranteed.**
4. **NRCan 1:Natural Resource Canada ecoEnergy Retrofit Incentive Program ($10/GJ maximum of $250,000)**
5. **Union Gas: Commercial Incentive per project ($0.05/m3 maximum $15,000)**
6. **ERIP: Ontario Power Authority - Electricity Retrofit Incentive Program (prescriptive incentive for lamps, LED Lighting, occupancy sensors)**

Figure 2.1: Energy Audit Program Savings Graph for Northumberland County's Recycling Centre





2.4 INCENTIVE SUMMARY

The incentive amounts relate to the following incentive providers which can be either Local Distribution Companies (LDCs) or Government Agencies:

Table 2.2: Incentive Summary

Description	*Table 2.1: Energy Retrofit Program*	Details
NRCan ecoEnergy Retrofit Incentives for Buildings	$3,381	$250,000 maximum $10 per GJ
Union Gas Custom Application Program	$282	$0.05 per m3 of natural gas savings maximum $15,000
Ontario Power Authority Electricity Retrofit Incentive Program	$7,318	Prescription incentive for lamps, LED lighting, occupancy sensors.
Total	**$11,720**	

3.1 INTRODUCTION

Hydro One services the Northumberland County Recycling Centre's electricity requirements through one main meter, while Union Gas services its gas needs and the County its water needs. The following savings rates were used for the site:

	Electricity	Demand	Gas	Water
Savings Rates:	$0.07346/kWh	$10.729/kW	$0.377/m^3	$0.84/CM

Table 3.1 identifies the monthly breakdown of cost and consumption for each utility. The following utility-by-utility analysis has been undertaken to assess a number of different factors related to the utility consumption, demand and water use at the Recycling Centre.

The Utility Accounting software program called METRIX was used to assess the utility data. This program takes the raw utility information and assesses based on correlations to weather or any building operational variable that can be plotted and then compared to the raw utility info.

Section 3.2 Electricity Analysis:

- Electricity costs account for 74.9% of the bill and consumption accounts for only 47.0% of the total use. This difference between cost and consumption weightings shows that the high cost of electricity has a direct impact on the bill even though the portion of the total energy use is much smaller.
- Consumption and demand fluctuate throughout the year due to the operational parameters of the building.
- An assessment in METRIX found no weather correlation.

Section 3.3 Natural Gas Analysis:

- Natural Gas costs account for 24.6% of the bill and consumption accounts for 53.0% of the total use. This difference between cost and consumption weightings shows that one equivalent unit of gas is larger than a similar equivalent unit of electricity. As such Measures which would reduce natural gas consumption would have a more direct impact on the utility bill.
- Consumption peaks in the winter months as expected.
- An assessment in METRIX found an expected strong weather correlation in the winter period related to the heating component of gas use at the site.

Section 3.4 Domestic Water Analysis:

- Domestic Water costs account for 0.6% of the bill.
- Consumption experiences no weather related spike.
- An assessment in METRIX found no weather correlation.

Table 3.1 Actual Consumption Profile for the Northumberland County Recycling Centre

Monthly Consumption Profile CY 2009 ***Area of Site: 66,000 ft²***

1 Northumberland County Recycling Centre

Month	Electricity: Main kWh Use	Bill Match Tune Y/N	kW Demand	KVA Demand	Power Factor (%)	Electricity Bill ($)	kWh/ ft²	Cost/ ft²	Fuel Oil/Natural Gas/Propane (r Efficiency: 100%): Gas M^3 Usage	Bill Match Tune Y/N	Total Usage ekWh	Gas Bill ($)	Heating Bill ($)	ekWh/ HDD	ekWh/ ft²	Cost/ ft²
Jan-09	70,281	N	240.0	288.0	83.3%	$9,896	1.06	$0.15	17,356	N	179,287	$8,114	$8,114	193	2.72	$0.12
Feb-09	60,095	N	240.0	288.0	83.3%	$7,626	0.91	$0.12	17,623	N	182,047	$7,946	$7,946	271	2.76	$0.12
Mar-09	66,206	N	244.0	288.0	84.7%	$8,083	1.00	$0.12	14,650	N	151,333	$6,623	$6,623	261	2.29	$0.10
Apr-09	59,076	N	240.0	288.0	83.3%	$7,528	0.90	$0.11	5,761	N	59,510	$2,237	$2,237	168	0.90	$0.03
May-09	51,437	N	235.0	283.0	83.0%	$3,929	0.78	$0.06	1,795	N	18,539	$616	$616	93	0.28	$0.01
Jun-09	59,586	N	244.0	297.0	82.2%	$7,779	0.90	$0.12	1,165	N	12,030	$405	$405	151	0.18	$0.01
Jul-09	41,252	Y	240.0	297.0	80.8%	$6,333	0.63	$0.10	87	Y	901	$24	$24	23	0.01	$0.00
Aug-09	52,965	Y	244.0	302.0	80.8%	$7,316	0.80	$0.11		Y						
Sep-09	60,096	N	235.0	292.0	80.5%	$7,778	0.91	$0.12		N						
Oct-09	53,474	N	230.0	283.0	81.3%	$6,233	0.81	$0.09	3,384	N	34,957	$645	$645	100	0.53	$0.01
Nov-09	65,697	N	235.0	283.0	83.0%	$7,814	1.00	$0.12	4,841	N	50,009	$867	$867	117	0.76	$0.01
Dec-09	76,392	N	259.0	297.0	87.2%	$9,727	1.16	$0.15	11,595	N	119,776	$2,041	$2,041	169	1.81	$0.03
CY 2009[1]	**716,557**		**2,886.0**	**3,486.0**	**82.8%**	**$90,042**	**10.86**	**$1.36**	**78,256**		**808,389**	**$29,519**	**$29,519**	**180.0**	**12.25**	**$0.45**
Baseline[2]	**716,557**		**2,886.0**	**3,486.0**	**82.8%**	**$90,042**	**10.86**	**$1.36**	**78,256**		**808,389**	**$29,519**	**$29,519**	**180.0**	**12.25**	**$0.45**

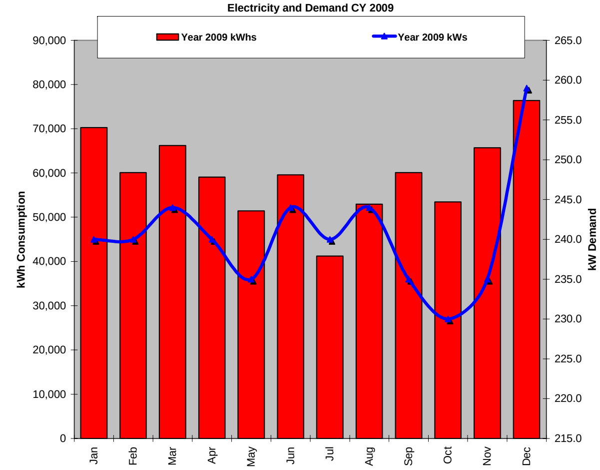
Month	Water & Sewage: m^3 Usage	Water Bill ($)	m^3/ ft²	Totals: Total Usage (ekWh)	Total Bill ($)	ekWh/ ft²	Cost/ft² ($)	Peterborough AWOS Weather Data: HDDs	CDDs
Jan-09			-	249,568	$18,011	3.78	$0.27	928.5	
Feb-09	88	$74	0.00	242,142	$15,646	3.67	$0.24	671.8	
Mar-09			-	217,539	$14,705	3.30	$0.22	579.0	
Apr-09	83	$70	0.00	118,586	$9,834	1.80	$0.15	353.5	
May-09			-	69,976	$4,546	1.06	$0.07	198.6	0.9
Jun-09	74	$62	0.00	71,616	$8,247	1.09	$0.12	79.7	21.3
Jul-09			-	42,153	$6,357	0.64	$0.10	39.0	15.8
Aug-09	196	$165	0.00	52,965	$7,481	0.80	$0.11	36.8	50.9
Sep-09			-	60,096	$7,778	0.91	$0.12	121.1	4.0
Oct-09	198	$166	0.00	88,431	$7,045	1.34	$0.11	348.2	
Nov-09			-	115,706	$8,681	1.75	$0.13	427.4	
Dec-09	149	$125	0.00	196,168	$11,892	2.97	$0.18	708.2	
CY 2009[1]	**788**	**$662**	**0.01**	**1,524,946**	**$120,223**	**23.11**	**$1.82**	**4,491.8**	**92.9**
Baseline[2]	**788**	**$662**	**0.01**	**1,524,946**	**$120,223**	**23.11**	**$1.82**	**4,491.8**	**92.9**

NOTES:

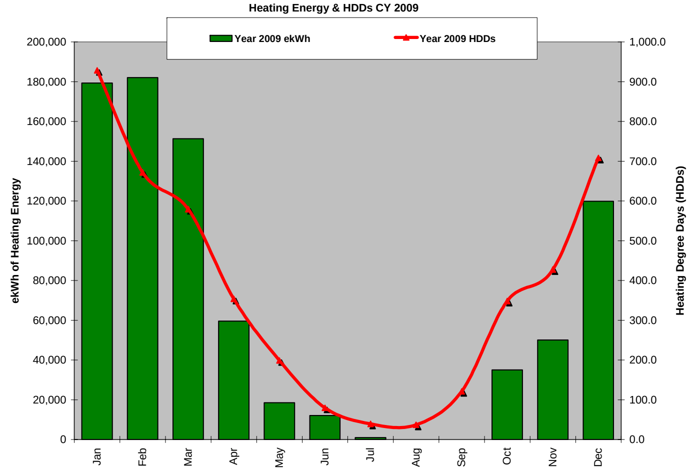
1. All costs presented above are actual costs and include levies, credits, corrections, and exclude GST municipal charges and monthly service charges.
2. Savings rates carried: **$0.07346 /kWh** **$10.729 /kW** **$0.377 /m3 of Gas** **$0.840 /m³ of Water**

(Yellow) Suggested Baseline for the Audit.

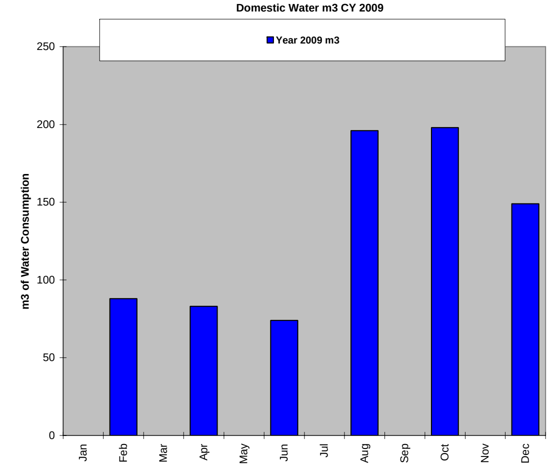
Electricity and Demand CY 2009



Heating Energy & HDDs CY 2009



Domestic Water m3 CY 2009



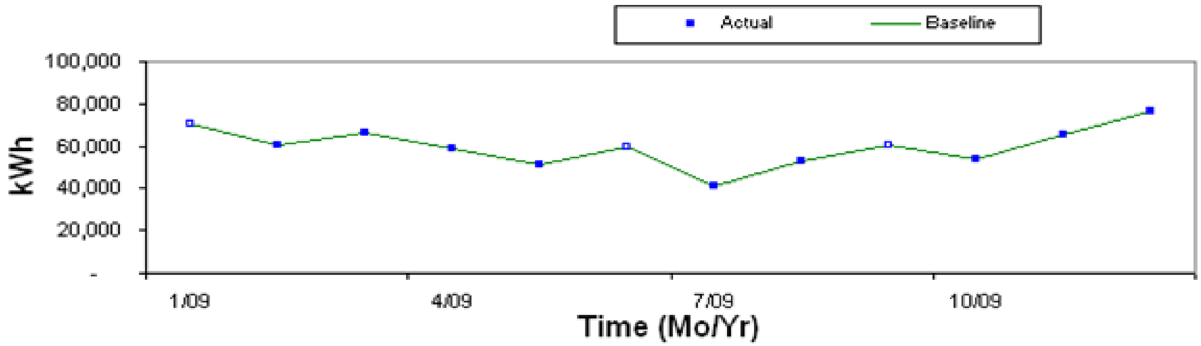
3.2 ELECTRICITY ANALYSIS

The electricity consumption bar chart in ***Figure 3.1*** for the Northumberland County Recycling Centre shows the impact of the weather and building operations variability components on the usage trend over one year. Consumption and demand fluctuate throughout the year due to the operational parameters of the building. Electricity costs (from ***Table 3.1*** – Adjusted for Savings Rates carried) account for 74.9% of the total bill and represent 47.0% of the energy intensity for the Northumberland County Recycling Centre.

Figure 3.1 Electricity Meter METRIX Consumption Assessment

METRIX Meter Tuning

Project: Northumberland County **Site: Northumberland County** **Area: Recycling Centre**
Meter: NRC-E1 **Unit: kWh(Qty OnPk)** **Account:**



From	To	# Days	Reading	Incl?	HDD	CDD	Offset	Baseline	Deviation
12/31/08	01/31/09	32	70,281	☐	0.0	0.0	70,281	70,281	0.0%
02/01/09	02/28/09	28	60,095	☒	0.0	0.0	60,095	60,095	0.0%
03/01/09	03/31/09	31	66,206	☒	0.0	0.0	66,206	66,206	0.0%
04/01/09	04/30/09	30	59,076	☒	0.0	0.0	59,076	59,076	0.0%
05/01/09	05/31/09	31	51,437	☒	0.0	0.0	51,437	51,437	0.0%
06/01/09	06/30/09	30	59,586	☐	0.0	0.0	59,586	59,586	0.0%
07/01/09	07/31/09	31	41,252	☒	0.0	0.0	41,252	41,252	0.0%
08/01/09	08/31/09	31	52,965	☒	0.0	0.0	52,965	52,965	0.0%
09/01/09	09/30/09	30	60,096	☐	0.0	0.0	60,096	60,096	0.0%
10/01/09	10/31/09	31	53,474	☒	0.0	0.0	53,474	53,474	0.0%
11/01/09	11/30/09	30	65,697	☒	0.0	0.0	65,697	65,697	0.0%
12/01/09	12/31/09	31	76,392	☒	0.0	0.0	76,392	76,392	0.0%
Sum/Average/Max		**366**	**716,557**		**0.0**	**0.0**	**716,557**	**716,557**	**0.0%**

NRC-E1 [Northumberland County] (Account #): Tuning Period is 366 days from 12/31/08 until 12/31/09.
Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (kWh) = Offset

The Baseline Equation has a Net Mean Bias of 0%. The underlying regression has a R^2=0
Baseline Costs are calculated using Average Total Cost/Consumption.

Explanations and Assumptions:

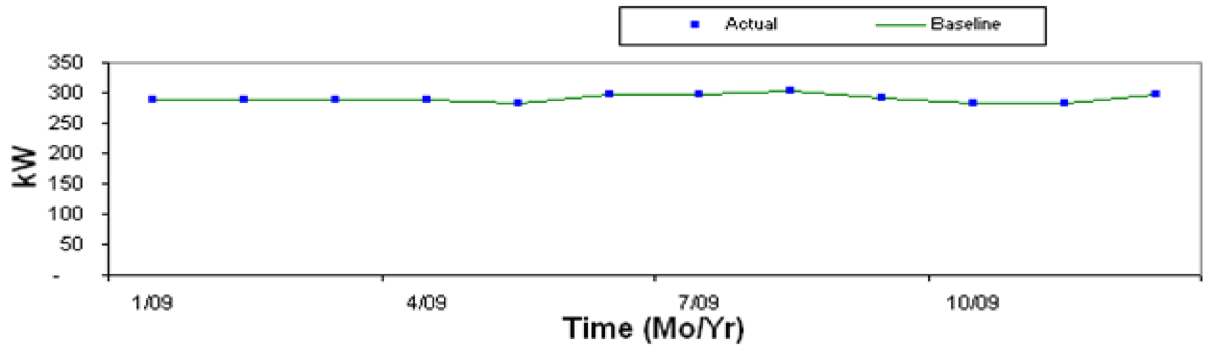
☐ (empty checkbox) under 'Incl?' indicates that the bill is excluded from the regression. However the Baseline Equation is always applied for all billing periods, even those exluded from the regression.
Multiplier and Offset are derived from Modification(s) in effect during the tuning period and are replicated annually for all future periods.

Figure 3.1 represents the Metrix meter tune for electricity consumption at the Northumberland County Recycling Centre. Illustrated here are the billing periods for the monthly loads that encompass the reference baseline that totalled 716,557 kWhs for the electricity meter. These readings are then bill-matched and replicated in the future with no weather dependency. This formulates the adjusted baseline equation of **Baseline (kWh) = Offset**.

Figure 3.2 Electricity Meter METRIX Demand Assessment

METRIX Meter Tuning

Project: Northumberland County **Site: Northumberland County** **Area: Recycling Centre**
Meter: NRC-E1 **Unit: kW(Dmd OnPk)** **Account:**



From	To	# Days	Reading	Incl?	HDT	CDT	Offset	Baseline	Deviation
12/31/08	01/31/09	32	288	☒	0.0	0.0	288	288	0.0%
02/01/09	02/28/09	28	288	☒	0.0	0.0	288	288	0.0%
03/01/09	03/31/09	31	288	☒	0.0	0.0	288	288	0.0%
04/01/09	04/30/09	30	288	☒	0.0	0.0	288	288	0.0%
05/01/09	05/31/09	31	283	☒	0.0	0.0	283	283	0.0%
06/01/09	06/30/09	30	297	☒	0.0	0.0	297	297	0.0%
07/01/09	07/31/09	31	297	☒	0.0	0.0	297	297	0.0%
08/01/09	08/31/09	31	302	☒	0.0	0.0	302	302	0.0%
09/01/09	09/30/09	30	292	☒	0.0	0.0	292	292	0.0%
10/01/09	10/31/09	31	283	☒	0.0	0.0	283	283	0.0%
11/01/09	11/30/09	30	283	☒	0.0	0.0	283	283	0.0%
12/01/09	12/31/09	31	297	☒	0.0	0.0	297	297	0.0%
Sum/Average/Max		**366**	**3,486**		**0.0**	**0.0**	**3,486**	**3,486**	**0.0%**

NRC-E1 [Northumberland County] (Account #): Tuning Period is 366 days from 12/31/08 until 12/31/09.
Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (kW) = Offset

The Baseline Equation has a Net Mean Bias of 0%. The underlying regression has a R^2=0
Baseline Costs are calculated using Average Total Cost/Consumption.

Explanations and Assumptions:

☐ (empty checkbox) under 'Incl?' indicates that the bill is excluded from the regression. However the Baseline Equation is always applied for all billing periods, even those exluded from the regression.
Multiplier and Offset are derived from Modification(s) in effect during the tuning period and are replicated annually for all future periods.

Figure 3.2 represents the Metrix meter tune for electricity demand at the Northumberland County Recycling Centre. Illustrated here are the billing periods for the monthly loads that encompass the reference baseline that totalled 6,080 kWs for the electricity meter. These readings are then bill-matched and replicated in the future with no weather dependency. This formulates the adjusted baseline equation of **Baseline (kW) = Offset**.

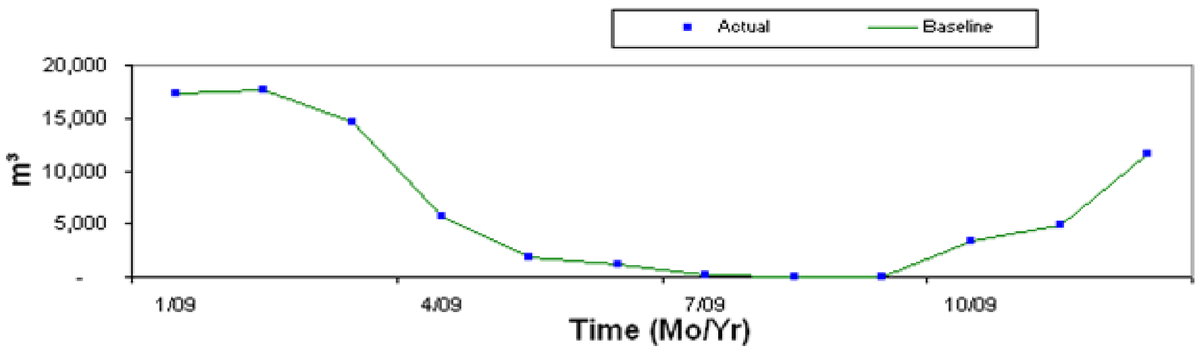
3.3 NATURAL GAS ANALYSIS

The gas consumption bar chart in ***Figure 3.3*** for the Northumberland County Recycling Centre shows the impact of the weather and building operations variability components on the usage trend over one year. Consumption peaks in the winter, decreases in the spring, falls to baseload levels in the summer and begins to rise through the autumn. Natural gas costs (from ***Table 3.1*** – Adjusted for Savings Rates carried) account for 24.6% of the total bill and represent 53.0% of the energy intensity for the Northumberland County Recycling Centre.

Figure 3.3 Natural Gas Meter METRIX Consumption Assessment

METRIX Meter Tuning

Project: Northumberland County **Site: Northumberland County** **Area: Recycling Centre**
Meter: NRC-G1 **Unit: m³(Qty OnPk)** **Account:**



From	To	# Days	Reading	Incl?	HDD	CDD	Offset	Baseline	Deviation
12/17/08	01/20/09	35	17,356	☒	0.0	0.0	17,356	17,356	0.0%
01/21/09	02/18/09	29	17,623	☒	0.0	0.0	17,623	17,623	0.0%
02/19/09	03/19/09	29	14,650	☒	0.0	0.0	14,650	14,650	0.0%
03/20/09	04/20/09	32	5,761	☒	0.0	0.0	5,761	5,761	0.0%
04/21/09	05/20/09	30	1,795	☒	0.0	0.0	1,795	1,795	0.0%
05/21/09	06/18/09	29	1,165	☒	0.0	0.0	1,165	1,165	0.0%
06/19/09	07/21/09	33	87	☒	0.0	0.0	87	87	0.0%
07/22/09	08/24/09	34	-	☒	0.0	0.0	-	-	0.0%
08/25/09	09/22/09	29	-	☒	0.0	0.0	-	-	0.0%
09/23/09	10/20/09	28	3,384	☒	0.0	0.0	3,384	3,384	0.0%
10/21/09	11/18/09	29	4,841	☒	0.0	0.0	4,841	4,841	0.0%
11/19/09	12/18/09	30	11,595	☒	0.0	0.0	11,595	11,595	0.0%
Sum/Average/Max		**367**	**78,257**		**0.0**	**0.0**	**78,257**	**78,257**	**0.0%**

NRC-G1 [Northumberland County] (Account #): Tuning Period is 367 days from 12/17/08 until 12/18/09.
Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (m³) = Offset

The Baseline Equation has a Net Mean Bias of 0%. The underlying regression has a R^2=0
Baseline Costs are calculated using Average Total Cost/Consumption.

Explanations and Assumptions:

☐ (empty checkbox) under 'Incl?' indicates that the bill is excluded from the regression. However the Baseline Equation is always applied for all billing periods, even those exluded from the regression.
Multiplier and Offset are derived from Modification(s) in effect during the tuning period and are replicated annually for all future periods.

Figure 3.3 represents the Metrix meter tune for gas consumption at the Northumberland County Recycling Centre. Illustrated here are the billing periods for the monthly loads that encompass the reference baseline that totalled 78,257 m^3 for the gas meter. These readings are then bill-matched and replicated in the future with no weather dependency. This formulates the adjusted baseline equation of **Baseline (m^3) = Offset**.

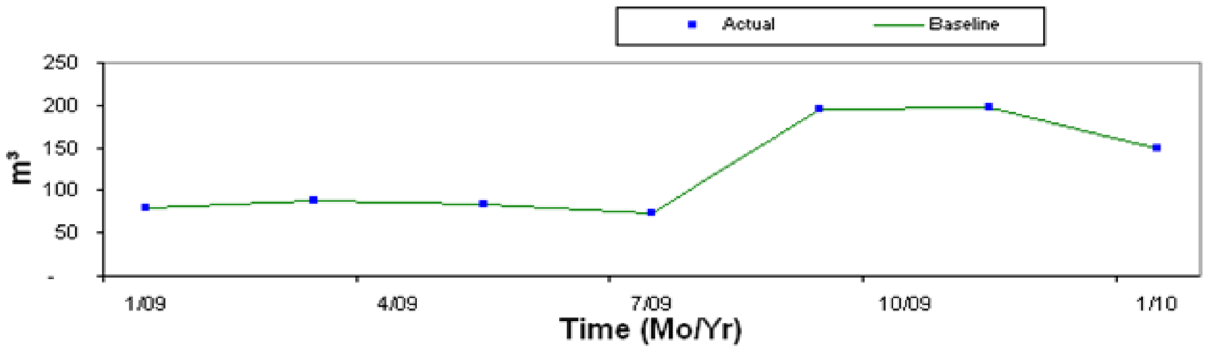
3.4 DOMESTIC WATER ANALYSIS

The water consumption bar chart in ***Figure 3.3*** for the Northumberland County Recycling Centre shows the impact of the weather and building operations variability components on the usage trend over one year. Consumption peaks in the winter, decreases in the spring, falls to baseload levels in the summer and begins to rise through the autumn. Domestic water costs (from ***Table 3.1*** – Adjusted for Savings Rates carried) account for 0.6% of the total bill.

Figure 3.3 Natural Gas Meter METRIX Consumption Assessment

METRIX Meter Tuning

Project: Northumberland County **Site: Northumberland County** **Area: Recycling Centre**
Meter: NRC-W1 **Unit: m³(Qty OnPk)** **Account:**



From	To	# Days	Reading	Incl?	HDD	CDD	Offset	Baseline	Deviation
11/10/08	01/20/09	72	80	☒	0.0	0.0	80	80	0.0%
01/21/09	03/19/09	58	88	☒	0.0	0.0	88	88	0.0%
03/20/09	05/20/09	62	83	☒	0.0	0.0	83	83	0.0%
05/21/09	07/21/09	62	74	☒	0.0	0.0	74	74	0.0%
07/22/09	09/22/09	63	196	☒	0.0	0.0	196	196	0.0%
09/23/09	11/18/09	57	198	☒	0.0	0.0	198	198	0.0%
11/19/09	01/19/10	62	149	☒	0.0	0.0	149	149	0.0%
Sum/Average/Max		**436**	**868**		**0.0**	**0.0**	**868**	**868**	**0.0%**

NRC-W1 [Northumberland County] (Account #): Tuning Period is 436 days from 11/10/08 until 01/19/10.
Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

Baseline (m³) = Offset

The Baseline Equation has a Net Mean Bias of 0%. The underlying regression has a R^2=0
Baseline Costs are calculated using Average Total Cost/Consumption.

Explanations and Assumptions:

☐ (empty checkbox) under 'Incl?' indicates that the bill is excluded from the regression. However the Baseline Equation is always applied for all billing periods, even those exluded from the regression.
Multiplier and Offset are derived from Modification(s) in effect during the tuning period and are replicated annually for all future periods.

Figure 3.3 represents the Metrix meter tune for domestic water consumption at the Northumberland County Recycling Centre. Illustrated here are the billing periods for the monthly loads that encompass the reference baseline that totalled 868 m^3 for the gas meter. These readings are then bill-matched and replicated in the future with no weather dependency. This formulates the adjusted baseline equation of **Baseline (m^3) = Offset**.

4.1 INTRODUCTION

4.1.1 Overview

The primary objective of the proposed lighting retrofit and redesign is to reduce the operating and maintenance costs attributed to lighting while maintaining or improving current lighting conditions. This objective requires that existing lighting conditions be evaluated based on Illuminating Engineering Society of North America's (IESNA) principles and the following general criteria.

A detailed audit and retrofit for each area within the building is included for Measures A01 in the lighting database contained in **Appendix A**. Every room in the building was examined according to the following general criteria:

Existing Fixture Lamp and Ballast Type

This key element is to determine the feasibility of lamp and ballast retrofits and new wiring configurations that allow sharing of ballasts. This includes existing design configurations (fixture spacing, ceiling heights, and obstacles in the areas) which affect the installation of new technologies. These factors directly impact the savings that can be realised by a proposed retrofit/redesign.

Occupant Requirements

The intended usage of each space was noted to ensure proposed lighting retrofits were compatible with the tasks being performed. Where possible a standard approach to retrofitting similar areas was undertaken to provide design continuity.

Hours of Operation

Estimates of run time hours for lighting throughout each area were constructed from information obtained from the following sources:

- Direct observation of light usage through site visit.
- Consultation with the staff regarding general operating profiles of the buildings.

Electrical Rates

A discussion of marginal savings rates for reductions in electrical demand and consumption is given in **Section 3.1**.

4.1.2 Energy Conservation Measures

The measure descriptions given below are intended to provide a brief overview of the proposed Measures A01 as shown in the lighting database spreadsheet (**Appendix A)**.

Linear Fluorescent Lamps and Electronic Ballasts

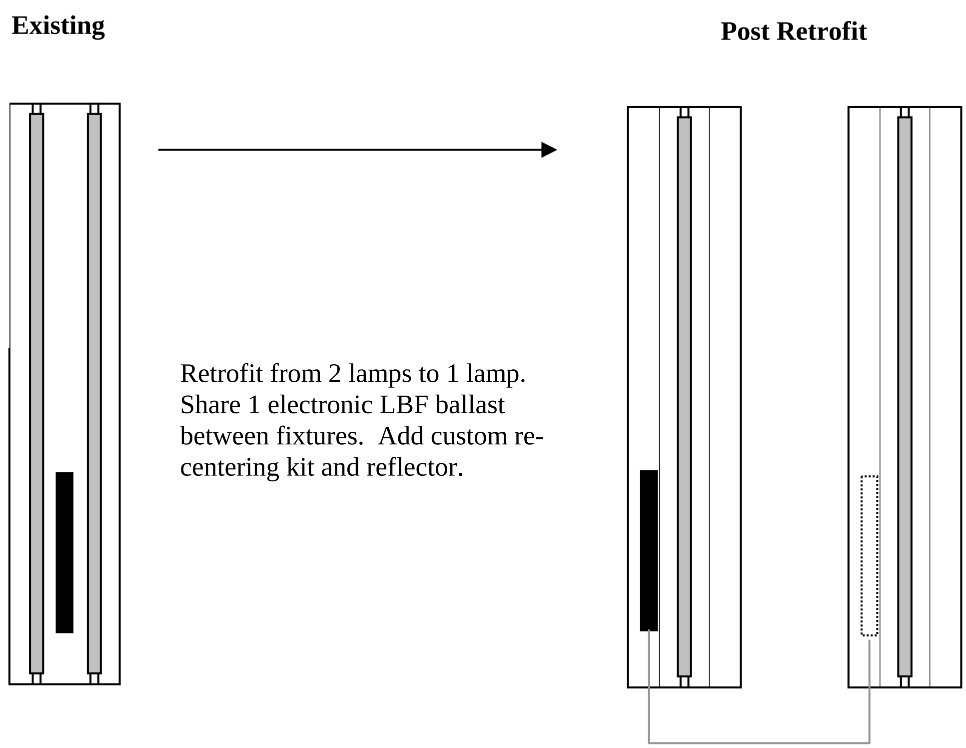
The conversion from T12 fluorescent lamps to T8 fluorescent lamps is advantageous for a number of reasons. The reduced input wattage of T8 lamps results in a significant decrease in electrical demand compared to T12 lamps. This translates directly to electrical consumption and utility cost savings. The improved quality of phosphors used in T8 lamps also provide a higher quality of light (measured by the increase in Colour Rendering Index) and improved fixture efficiency due to the smaller diameter of the tubes (8/8" instead of 12/8").

Standardization of the fluorescent lamp type will help simplify the lamp replacement procedure and help reduce future lamp costs by economies of scale. MCW also proposes to use premium high efficiency ballasts that will lower the consumption of the retrofitted fixtures by a few additional watts without compromising light levels.

Custom Fitted Reflectors

We propose to add custom fitted reflectors to certain fixtures to improve fixture efficiency where delamping is proposed. The reflective surface of this item, as well as its shape and construction, cause an increase in the coefficient of utilisation for the fixture which results in more light escaping from the confines of the fixture and being directed to the desired surface.

Figure 4.1: Diagram of de-lamped fixture with reflector kit and tandem wired ballast.



PCB Ballasts and Lamp Recycling

The lighting program does not include for the removal, storing and disposal of PCB Ballasts. For the purpose of this study, it was estimated that 50% of all electromagnetic ballasts in the building that have not yet been retrofitted, may contain PCB's. MCW has budgeted $10.00 per ballast for sorting, labelling, storing and disposing of ballasts that contain PCB's.

The lighting program does not include for the recycling of lamps into component materials and the subsequent disposal of hazardous mercury. Although this is not specifically required by law, it allows Northumberland County to take a leadership role in the promotion of environmentally sensitive work. We have priced lamp recycling at $0.50 per equivalent 4 ft lamp, not including the cost of storage drums. We estimate the cost of ballast disposal and lamp recycling to be $250.00.

Maintenance Deferrals

The proposed retrofits will have the short term benefit of delaying the need for replacement of lamps and ballasts. The full scale replacement with new lamps also provides the option of allowing the facility to embark on a group re-lamping program in the future. This may be particularly beneficial because of the difficulty associated with accessing some of these fixtures due to high ceilings.

The visual appearance of retrofitted fixtures will be improved as a result of the cleaning performed when the lamps and ballasts are changed. This process improves the efficiency of existing fixtures which have become less efficient due to dust and dirt accumulation.

High Intensity Discharge (H.I.D.) Lamps

The main recycling and sorting bays contain high intensity discharge lamps and ballasts. The efficiency of these fixtures varies greatly depending on the specific technology used.

Metal halide lamps have a colour of light similar to mercury sources but operate much more efficiently. High pressure sodium fixtures provide an even greater lumen per watt ratio, but these light sources give off an orange colour light and compromise colour rendering abilities.

The newest Metal halide lamp is a Pulse Start lamp and this new technology reduces lamp lumen depreciation, wattage and colour shift and provides a more consistent light and quicker hot re-strike compared to standard metal halide lamps.

Exit Signs

The primary types of exit signs found in this building was an LED exit sign. MCW feels that LED exit signs are energy efficient and do not require replacement. .

4.2 A01 LIGHTING RETROFIT & REDESIGN

The Northumberland County Materials and Recycling Facility consist of two primary areas, the office area and the recycling and sorting area. MCW conducted a lighting audit of both areas and found several different types of lighting. Energy savings opportunity exists in both locations.

The office areas are primarily using recessed fixtures with T8 lamps and an electronic ballast. Fixtures are either 1'x4' with two T8 lamps and one electronic ballast, or 2'x4' with four T8 lamps and one electronic ballast. MCW proposes delamping these fixtures to reduce the number of lamps by half (***Figure 4.1***). This retrofit would include recentering the lamps in the fixture and adding a custom fitted white powder coated reflector. The addition of a reflector increases the efficiency of the fixture, allowing more light to reach the task, instead of being lost within the fixture.

The main sorting and loading areas are lit using 1000W High Intensity Discharge (HID) Metal Halide lamps. These lamps consume considerable energy and the fixtures are very old and inefficient. Light output is drastically reduced due to dirt accumulation and the inefficient design of the fixture. Furthermore, HID lamps have a long restrike time, taking upwards of 15 minutes before reaching full brightness. Additionally when one lamp burns out, there is a dark spot in that area. MCW proposes to replace existing inefficient fixtures, with a new 2'x4' fixture using six T5HO lamps. We propose to use two fixtures for every one of the existing HID fixtures in place. Using linear fluorescent lamps not only matches or exceeds existing light levels but also saves energy. The use of T5HO lamps also allows maintenance crews additional time to change lamps as when one burns out, the remaining lamps continue to be illuminated, eliminating the presence of a dark spot under the fixture.

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SAVINGS RECONCILIATION SHEET
A01 LIGHTING RETROFIT & REDESIGN

MEASURE DESCRIPTION: **Ref. A01**	Retrofit all existing fixtures that contain T12 lamps and electromagnetic ballasts to fixtures complete with 28W T8 lamps and high efficiency electronic ballasts. Replace existing HID lamps in main bay area, to use T5HO fixtures.

ASSUMPTIONS:	a) Existing Lighting Load = 579 kW b) Existing Lighting Usage = 126,541 kWh

CALCULATIONS:	a) Calculation Using Microsoft Access Database (see **Appendix A**) b) Retrofit Load = 415 kW c) Retrofit Usage = 94,668 kWh d) Rates were used based on building information found in **Section 3**.

SAVINGS:	**ANNUAL DEMAND SAVINGS:** **ANNUAL CONSUMPTION SAVINGS**:	**164** **31,872**	**kW** **kWh**
	SAVINGS RECONCILED AT:	**$4,100**	

5.1 INTRODUCTION

The list of considered measures is shown in the following table:

Table 5.1: Mechanical Measures

Measure Ref.	Measure Description
B01	MUA Controls Upgrade
B02	Solar Air Heating

This section provides the details of all the considered measures including savings calculations.

5.2 B01 MUA UNIT CONTROLS UPGRADE

Where simple electric thermostats exist, it is often recommended that a ‘Programmable’ type thermostat be installed to take advantage of varying occupancy within the controlled space. A Programmable Thermostat utilizes the fact that a given space or building does not usually need as much heating or cooling when it is unoccupied. The unoccupied temperature setpoints can be ‘setback’ during times of heating and raised during times of cooling to more energy efficient levels which are defined by the users/administrator. As long as enough time is given for the desired conditions to be met *before* the space becomes occupied (usually in the mornings), there is no difference in comfort for the building occupants.

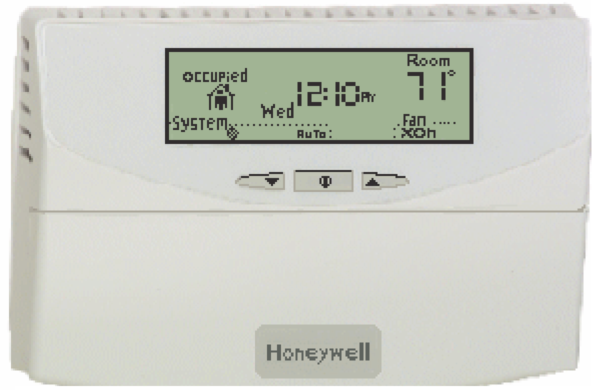


Figure 5.1: Typical Programmable Thermostat

Additionally, the commercial type Programmable Thermostats that we recommend, rather than the often misused residential type units, are better suited to multi-user applications. Administrator privileges can be given to each unit which deters others from tampering with the sensitive temperature setpoints and Time of Day schedules. This feature often improves comfort levels over the long-term as the thermostat continues to function accurately without interruption from unfamiliar users.

Currently, MUA-1 which serves the Tipping Floor area of the plant has stand-alone controls and supply’s a constant air temperature of 18°C for the area. This heating strategy operates 24/7 throughout the heating season. During the summer months the heating is locked-out and the unit serves as a ventilation unit only.

We propose to install a programmable thermostat for MUA-1. A significant aspect of a controls system upgrade is usually the optimization of the Time-of-Day (TOD) schedules. Time-of-Day scheduling consists of a start time, a stop time, and the days of the week to which the program applies. Where appropriate, multiple start and stop times are implemented to accurately reflect building and area occupancy. Override features allow equipment operation when the building is occupied outside normal hours. Included in this controls upgrade will be the following energy savings strategies:

Night Cycle

In the Tipping Floor area, the make up air unit operates to maintain space temperature during unoccupied hours since there is no perimeter radiation. As a result we plan to implement this energy saving strategy. Space sensors will be used to determine the “fan on” and/or “supply heat” command to maintain a low limit of 10 to 12ºC for the heating cycle for MUA-1.

Night Setback/Set-Up (NSB)

Proper control of a building's heating, ventilating and air conditioning systems when the building is unoccupied can provide significant energy savings. For the Tipping Floor unit MUA-1, by adjusting the unoccupied temperature set point down to 10℃ in the heating season, energy savings can be realized. The unoccupied set points are selected in order to minimize energy use during these unoccupied periods, while maintaining limits to ensure that the most economical warm up period is maintained. Special consideration will have to be given to the Tipping Floor area since it does not have perimeter radiation.

SAVINGS RECONCILIATION SHEET
BUILDING AUTOMATION CONTROLS
B01 MUA CONTROLS UPGRADE

MEASURE DESCRIPTION: Ref. B01	Installation of a programmable thermostat, providing time-of-day schedules for MUA-1 and instituting energy savings strategies such as night cycle and night setback.

ASSUMPTIONS:

1. The determination of the annual heating requirements was based on the degree days method using the values available from the National Building Code of Canada (NBC).
2. Degree Days Below 18ºC (DDh) = 4,491
3. Degree Days Above 18ºC (DDc) = 93
4. Indoor Temperature = 18ºC (Heating)
5. Outside Temperature = -20ºC (Heating)
6. Indoor humidity factor (H1) = 6g/kg (Heating), 10.8g/kg (Cooling)
7. Outdoor humidity factor (H2) = 1g/kg (Heating), 14.5g/kg (Cooling)
8. Heating System Efficiency = 85%
9. 100% outside air system
10. Heating Value of Natural Gas (btu/GJ) = 947,813
11. Conversion Factor (GJ's to m3 of Natural Gas) = 26.86
12. Horsepower to Brake Horsepower conversion coefficient = 0.746
13. Motor Load (%) = 0.70
14. Motor Efficiency (%) = 0.80
15. Electrical savings rate = $0.07346/kWh.
16. Natural Gas savings rate = $0.377/m3

CALCULATIONS:

The potential savings associated with the implementation of Control Upgrade scheduling is summarized below for Northumberland Recycling Plant. A sample calculation for MUA-1 follows:

Electrical Motor Energy Savings (kWh):
= (Motor Brake horsepower x 0.746kW/hp)/Efficiency x trimmed hours

Total Electrical Motor Energy Savings for MUA-1:
= ((10) x 0.75 x 0.746)x0.70 x 500
= 3,440 kWh/yr
= 3,440 kWh/yr x $ 0.07346/kWh
= **$252/yr**

CALCULATIONS:	<u>Heating Gas Savings:</u> Heating Gas potential savings were based on existing gas consumption and the estimated gas consumption. The gas savings is the difference between the two conditions. Heating savings for MUA-1: $Q_{existing}$ = ((1.08 x CFM_{OA})x(ΔT) x (Runtime Hours) / (947,813 x System Efficiency x Combustion Efficiency) = (1.08 x 14,000 x (18°C) x 3,107)/ (947,813 x 0.85 x 0.85) = 2,611 GJ/yr $Q_{proposed}$ = ((1.08 x CFM_{OA})x(ΔT) x (Runtime Hours) / (947,813 x System Efficiency x Combustion Efficiency) = (1.08 x 14,000 x (16°C) x 2,934)/ (947,813 x 0.85 x 0.85) = 2,401 GJ/yr Total annual heat saved = Qe + Qp = 2,611 – 2,401 = 210 GJ Total annual heating savings = 210 GJ x 26.86 m3 of NG/GJ x 0.377$/kWh = **$2,126** **Annual Potential Savings MUA-1:** = $252 + $2,126 = $2,378/yr

SAVINGS:	**ANNUAL CONSUMPTION SAVINGS:**	**3,378** **5,640**	**kWh** **m3 of NG**
	SAVINGS RECONCILED AT:	**$2,378**	

5.2 B02 SOLAR AIR HEATING

A solar wall is an air heating system based on metal cladding that is installed on the south-facing wall of a building. The system operates in a very simple manner using economical and environmentally-benign solar energy to heat ventilation air:

- Dark-coloured metal cladding is heated by solar radiation
- A plenum at the top of the cladding is ducted to the fresh air intake of an existing air handling unit
- Outside air is heated as it passes through small perforations throughout the surface of the solar wall
- The preheated air rises in the cavity to a plenum at the top of the wall and into the air handling unit
- A bypass damper allows the air handling system to operate without preheat in shoulder seasons and in cooling season

Figure 5.1: Solarwall, CFB Cold Lake, AB

The solar wall also reduces building heat loss during the winter by increasing the thermal insulation (R-Value) of the wall on which it is mounted. On the south-facing wall, heat lost to the cavity between the metal panels and the building is captured by the incoming air and returned to the building along with the heated fresh air. Even at night, a solar wall acts to reduce building heat loss.

Figure 5.2: SolarDuct ventilation air preheating system

Another solar air preheating option is the Solar Duct (shown above in ***Figure 5.2***) which eliminates the need to have a south facing wall by allowing solar air heating to be installed on a building's roof. This modular system can be ballasted or fastened on a rooftop and is ducted to the nearest fresh air intake.

Solar air preheat systems are economical in buildings that have significant makeup air requirements. They are most appropriate in new construction when used to replace building cladding and when the solar components can be integrated with the mechanical system design.

Currently, there is one makeup air unit (MUA-1) serving the tipping floor area of the building which is a potential candidate for a solar air heating system. The existing system is sized at approximately 14,000 CFM for supply air and has a direct-fired natural gas burner to provide heating for the tipping floor area. A SolarWall system would be engineered to cover approximately 2,800 square feet of exterior wall area and be sized for an intake of 14,000 cfm. The system will include installation of a small fan to blow the heated air to the air handling unit and a bypass damper to allow free cooling when the heated air is not required.

The costs for this system would be approximately $300,000 with a potential energy savings of $6,000. While this does not provide an attractive payback within the scope of the energy study, this could be revisited in the future if desired by the client. Therefore, it has not been included in this feasibility study.

6.1 C01 POWER FACTOR CORRECTION

Resistive devices, like electric resistance heaters and incandescent lights transform all the power supplied to the device into heat or useful energy. Inductive devices, like motors, use some of the power supplied to the device to energize the inductive windings and create a magnetic field. This power, called reactive power, is alternately stored and given up by the windings, but is not used to do actual work. When this happens, the line supplying power to the device now carries the actual power used by the device and the reactive power created by the device.

Actual power used by the device is measured in kW, reactive power created by induction devices is measured in kVAr, and the apparent power in the supply lines is measured in kVA. The mathematical relationships between these types of power are described by the "power triangle" shown below in ***Figure 6.1***.

$$\mathbf{Ps = (Pa^2 + Pr^2)^{1/2}}$$

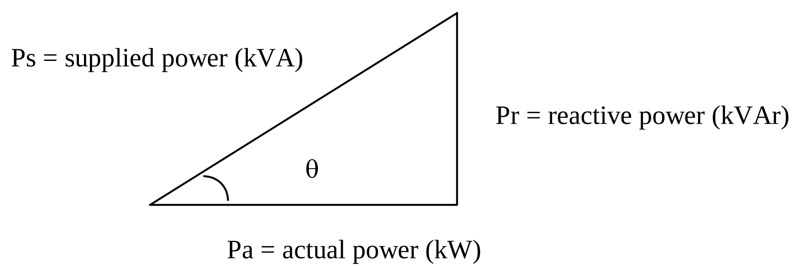


Figure 6.1: Power Triangle

The ratio of the actual power consumed by equipment (Pa) to the power supplied to equipment (Ps) is called the power factor.

$$\mathbf{PF = Pa / Ps = kW / kVA = \cos\theta}$$

Devices which generate/require large amounts of reactive power in relation to actual power consumed have low power factors. Such devices include:

- Motors
- HID and fluorescent lights with low PF ballasts
- Devices which convert AC power to DC power such as:
  - DC drives
  - Welding machines
  - VFDs
  - Induction furnaces

Fully loaded motors generally have a power factor of about 80%. However, if the motor is under loaded, the fraction of reactive power (for the coil) to actual power (for mechanical work) increases and the power factor decreases.

Two potential problems are associated with low power factor. First many utilities have explicit or implicit charges for low power factor. This is the case with Hydro One who services Northumberland County's Recycling Centre. Secondly, low power factor increases the current, and hence losses, in transformers and the electrical distribution system. These losses cost money and generate excess heat in the electrical distribution system, which may shorten equipment lifetime or cause production or operational shut downs. These potential problems are discussed in the sections that follow.

Power Factor Charges and Penalties

Some utilities charge for low power. To measure power factor, the most common type of utility meter measures the total kVAr-hours and kVA-hours over the billing period and calculates the average power factor as:

PF = Cos [ArcSin (kVArh / kVAh)]

The most common methods of charging for low power factor are (noted if applicable or not for Northumberland County's Recycling Centre):

1. Adding a demand penalty when the power factor dips below a set amount (usually **90%**). This is the case with the Hydro One service to Northumberland County's Recycling Centre.

For example: a utility electricity rate specifies a demand penalty of:

$$\text{kWactual}\left(\frac{0.9 - \text{PF}}{\text{PF}}\right) \text{ when PF} < 0.9$$

If actual power was 100 kW, the power factor was 80%, and the avoided cost of demand were $10.729 /kW, the monthly power factor charge would be:

$$100\,\text{kW}\left(\frac{0.9 - 0.8}{0.8}\right) = 12.5\,\text{kW}$$

12.5 kW x $10.729 /kW = **$134**

2. Basing the demand charge on the supplied power Ps (kVA), rather than the actual power used Pa (kW). This is the case with the Hydro One service to Northumberland County's Recycling Centre as Hydro One takes the higher of the two readings if the assessed power factor is below **90%**. Logically if it is below 90% then the kVA reading will always be higher.

For example, if we apply Northumberland's billed kVA charge of $10.729 /kVA per month and if the actual demand was 100 kW and the power factor was 80%, the implicit monthly power factor charge would be:

$$kVA_{PF = 80\%} = kW / PF = 100\ kW / 0.8\ kW/kVA = 125\ kVA$$
$$kVA_{PF = 90\%} = kW / PF = 100\ kW / 0.9\ kW/kVA = 111\ kVA$$
$$Penalty = \$10.729\ /kVA\text{-}month \times (KVA_{PF = 80\%} - KVA_{PF = 90\%})$$
Penalty = $10.729 /kVA-month x (125 kVA – 111 kVa) = $**150 /month**

Power Losses and Excess Heat Generation

In addition to possible power factor charges, low power factor also results in excess current in the electrical distribution system upstream from the device. The excess line current results in increased resistive losses, and hence heat gain, in the wiring and electrical distribution equipment. The quantity of line losses associated with low power factor correction can be calculated as noted below.

LL_1 = Line loss before power factor correction
LL_2 = Line loss after power factor correction
% Line Loss Savings = $(LL_1 – LL_2) / LL_1$

$$\mathbf{LL_1 = I^2{}_1R_1 = (kVA_1/V_1)^2 R_1 =[(kW_1/PF_1) / V_1]^2 R_1 = [kW^2 R / V^2]_1 / PF_1^2}$$

Thus:

$$\mathbf{LL_2 = [kW^2 R / V^2]_2 / PF_2^2}$$

Assuming everything remains constant except for the power factor:

$$\mathbf{[kW^2 R / V^2]_1 = [kW^2 R / V^2]_2 = [kW^2 R / V^2]}$$

And,

% Line Loss Savings = $(LL_1 – LL_2) / LL_1$
% Line Loss Savings = $[(kW^2 R / V^2) / PF_1^2 – (kW^2 R / V^2) / PF_2^2] / (kW^2 R / V^2)_1 / PF_1^2$
% Line Loss Savings = $[1 / PF_1^2 – 1 / PF_2^2] / 1 / PF_1^2$
% Line Loss Savings = $1 – (PF_1/ PF_2)^2$

For example, if the power factor were improved from 80% to 90%, the percent line loss savings would be:

$$\textbf{\% Line Loss Savings} = 1 - (PF_1/ PF_2)^2 = 1 - (80\%/ 90\%)^2 = 21\%$$

In addition, the heat generation in upstream electrical distribution equipment would be reduced by 21%. This may or may not be significant. If the electrical circuits are fully loaded and tripping due to excess current, then power factor correction could mitigate this problem.

Although percent line loss savings are relatively high, total energy savings are typically small since line losses are small. For example, if line losses are 2% of the total power draw, the total power savings from correcting the power factor would be:

$$2\% \times 21\% = 0.42\%$$

Sizing Capacitors and Estimating Savings

Capacitors work by canceling reactive power and current on the primary or upstream side of the capacitor. For example, if a motor operates at 70% power factor, installing a capacitor in the power supply line to the motor would reduce reactive power and line current on the primary side of the capacitor, but would not change the line current on the secondary (motor) side of the capacitor. Thus, installing capacitors directly upstream from low-power-factor loads reduces line current throughout the plant's electrical distribution system; whereas installing capacitors directly down stream of the utility meter at the electrical service entrance to the plant, results in power factor correction for utility billing purposes, but will not reduce line losses and overheating throughout the building. Refer to ***Figure 6.2*** for a graphical representation.

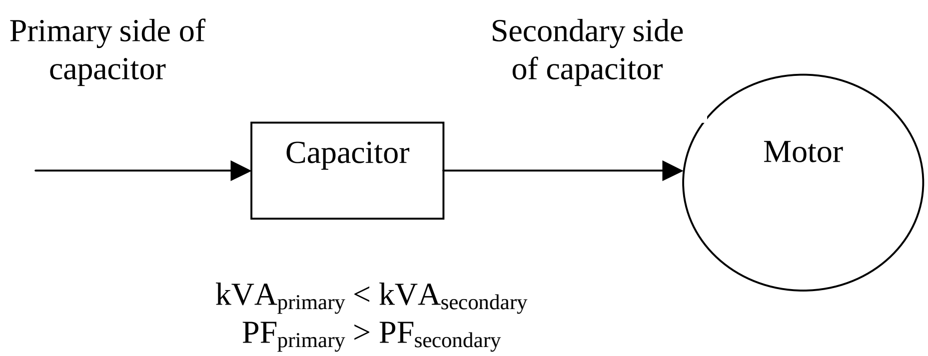


Figure 6.2: Capacitor Placement

The two primary types of capacitors are oil-filled and gas-filled. Oil-filled capacitors typically last about 60,000 hours and may introduce voltage transients to the downstream equipment. In addition, the oil is potentially flammable and may contain toxins requiring special disposal. Nitrogen and helium gas-filled capacitors last about 120,000 hours, filter voltage transients, are non-flammable and non-toxic. However, the substantially lower cost of oil-filled capacitors make them much more popular than gas-filled capacitors.

Capacitors are sized by the amount of reactive power (kVAr) they can cancel. Simple capacitors are sized to compensate for a fixed amount of power. "Stepped" capacitors have internal controls that adjust the amount of reactive power compensation. MCW recommends this option for most applications where larger capacitors are required and there is are fluctuations in the power factor over the year.

Adding too much capacitance can push the system from "lagging" to "leading"; for example, adding too much capacitance may change the power factor from 85% to 105%. Although leading power factor does not harm equipment, purchasing excess capacitors is expensive and serves no useful purpose. In addition some meters may read a leading 105% power factor as 85%. Because of these reasons, MCW recommends a conservative approach to power factor correction in which the power factor never goes past 90% since that is the upper limit of Hydro One's penalty.

A simple method to size the amount of capacitor kVAr required is described in the steps that follow:

1. Find kVAr for each month: Pr (kVAr) = Pa (kW) x Tan[Cos^{-1}(PF)]
2. To increase PF as close to 0.9 as possible, recommend additional capacitance equal to minimum monthly kVAr during the past 12 months. This approach minimizes the possibility of adding too much capacitance.
3. Subtract the recommended capacitance (kVAr) from recorded (kVAr) for each month. This difference represents the reactive power (kVAr) if the recommended capacitance were added.
4. Recalculate PF, kVA or kVAr and electricity costs for each month, using the reactive power calculated in the previous step. These costs represent the costs if the recommended capacitance had been added.
5. Calculate savings as the difference between the actual costs and the costs calculated in the previous step.
6. To estimate the implentation cost, we note that the installed cost of capacitors is about about $50 /kVAr depending on control complexity and size.

Power Factor Situation Analysis

Electrical equipment that generates inductive loads, such as motors, creates current that is not in phase with the current supplied by the electric utility. Inductive loads cause the current waveform to lag behind the voltage waveform. This causes a portion of the energy to return to the source, hence leaving less usable power for the equipment. The power associated with this unusable current is called reactive power (kVAr). Because some energy is returned to the source, a higher supply power (kVA) must be generated by the utility in order to meet equipment needs. The ratio of power consumed by equipment (kW) to total power in the electrical lines (kVA) is called the power factor. Low power factor can be corrected by adding capacitors, which are rated in terms of kVAr. Please refer to ***Figures 6.3*** and ***6.4*** that follow.

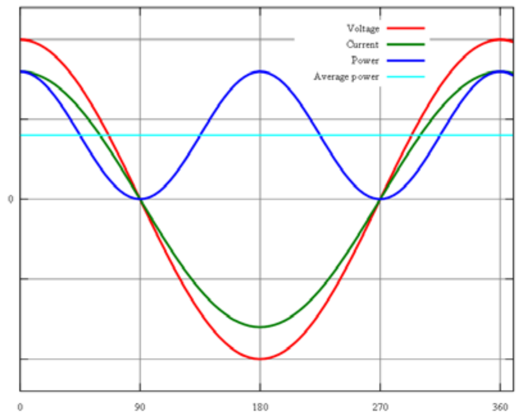


Figure 6.3: Power Factor at Unity

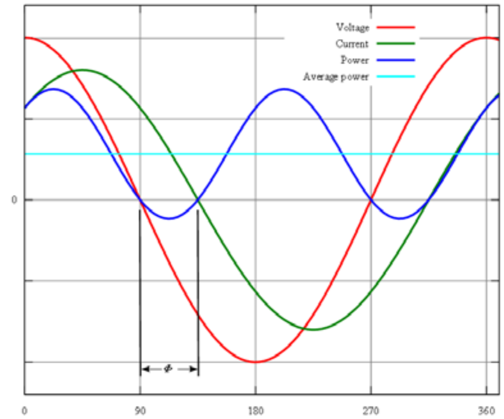


Figure 6.4: Power Factor at 71%

The diagram below shows the relationship between the various types of power: supplied power (kVA), reactive power (kVAr), and actual used power (kW). The quantity of each type of power can be calculated using trigonometric relations defined by the power triangle in ***Figure 6.5***.

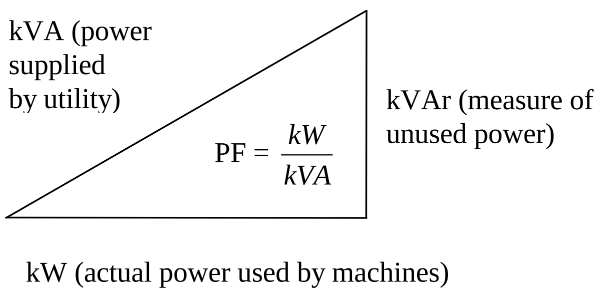


Figure 6.5: Relationship between Types of Power

Power factor is ratio of the actual power, kW, and supplied power, kVA. The power factor can be calculated using the following relationships:

$$\mathbf{PF = kW / kVA = \cos(\tan^{-1}(kVAr/kW))} \qquad \mathbf{(1)}$$

Reactive power is a measure of the unused power in the lines. The reactive power can be calculated using the following relationship:

$$\mathbf{Reactive\ Power\ (kVAr) = kW \times \tan(\cos^{-1}(PF))} \qquad \mathbf{(2)}$$

The supplied power (kVA) can be calculated from the reactive power (kVAr) and power factor from the following relationship:

$$\mathbf{kVA = kVAr/\sin(\cos^{-1}(PF))} \qquad \mathbf{(3)}$$

Recommendations

It is in Northumberland's best interest to maintain a 90% power factor since the building is being billed on the higher of the two metered kW or kVA. To maintain a 90% power factor:

- Purchase equipment with high power factor ratings, such as high power factor lighting ballasts.
- Avoid or replace dramatically oversized motors, since under-loaded motors have low power factors.

These two points are part of this Energy Feasibility Study. MCW recommends that a complete power factor and harmonics study be undertaken. This will take into account the post implementation power factor situation if lighting retrofits and mechanical retrofits that will assist the existing power factor situation.

For the purposes of this study a preliminary assessment of the existing power factor situation was undertaken based on the available utility data provided. Snapshots of the existing power factor situation with detailed calculations of the potential improvements through adding power factor correction capacitance are provided in ***Table 5.1*** that follows. A more in depth harmonics study and site review will be required to finalize the savings and costs.

Table 6.1: Power Factor Correction Opportunities at Northumberland County Recycling Centre

	Per Unit Demand Charge	Billed Amount	Actual PF	Actual kVAs	Actual kWs	kVAR Metered	kVAR required	New kVA	New PF	New $	Potential $ Savings	Potential kVA Savings	Max kVAR Required
Jan-09	$10.73	$3,090	83.3%	288.0	240.0	159.2	159.2	266.7	90.0%	$2,861	$229	21	
Feb-09	$10.73	$3,090	83.3%	288.0	240.0	159.2	159.2	266.7	90.0%	$2,861	$229	21	
Mar-09	$10.73	$3,090	84.7%	288.0	244.0	153.0	153.0	271.1	90.0%	$2,909	$181	17	
Apr-09	$10.73	$3,090	83.3%	288.0	240.0	159.2	159.2	266.7	90.0%	$2,861	$229	21	
May-09	$10.73	$3,036	83.0%	283.0	235.0	157.7	157.7	261.1	90.0%	$2,801	$235	22	
Jun-09	$10.73	$3,187	82.2%	297.0	244.0	169.3	169.3	271.1	90.0%	$2,909	$278	26	
Jul-09	$10.73	$3,187	80.8%	297.0	240.0	175.0	175.0	266.7	90.0%	$2,861	$325	30	
Aug-09	$10.73	$3,240	80.8%	302.0	244.0	178.0	178.0	271.1	90.0%	$2,909	$331	31	
Sep-09	$10.73	$3,133	80.5%	292.0	235.0	173.3	173.3	261.1	90.0%	$2,801	$331	31	
Oct-09	$10.73	$3,036	81.3%	283.0	230.0	164.9	164.9	255.6	90.0%	$2,742	$294	27	
Nov-09	$10.73	$3,036	83.0%	283.0	235.0	157.7	157.7	261.1	90.0%	$2,801	$235	22	
Dec-09	$10.73	$3,187	87.2%	297.0	259.0	145.4	145.4	287.8	90.0%	$3,088	$99	9	
TOTALS		$37,402	**82.8%**	3,486.0	2,886.0	1,951.8	178.0	3,206.7	**90.0%**		**$2,997**	**279.33**	**187**

SAVINGS RECONCILIATION WORKSHEET
C01 POWER FACTOR CORRECTION

MEASURE DESCRIPTION: Ref. C01	This measure consists of reviewing the existing installed capacitance if operational or decommissioned. It also involves performing a harmonics study and reviewing the size of new capacitance (variable or fixed) that can be added to improve the power factor on the various electricity metering points into the building.

ASSUMPTIONS:	**1.** Harmonics study to be performed at the site. **2.** Demand data January to December2009 (12 month period) used to determine Power Factor opportunities. **3.** Savings calculations are based on added kVAR capacitance decreasing the kVA readings to bring the Power Factor to unity. **4.** Existing capacitance, breakers and other equipment will be reviewed for reuse. Costs carried assume this equipment is not useable.

CALCULATIONS:	Please refer to the calculations in ***Table 6.1***.

SAVINGS:	**DEMAND KVA SAVINGS:**	**279**	**kVAs**
	SAVINGS RECONCILED AT:	**$2,997**	

7.1 D01 DOMESTIC WATER RETROFITS

An audit of all of the water consuming fixtures, which included an investigation and inspection of domestic water use, fixture flow rates and fixture maintenance condition, was completed for the facility.

This report outlines the opportunities to achieve domestic water savings by replacing high use domestic water fixture with low consumption technology. The renewal and standardization of domestic water fixtures also provides reductions in maintenance and inventory costs while improving sanitation in washrooms. Major improvements have been achieved in the design of low consumption water fixtures in the last decade, such as improved low consumption flushing mechanisms and toilet bowl designs that effectively evacuate contents with reduced water flow. In addition, tamper-proof faucet aerators contribute to these savings.

In general, the proposed domestic water retrofits entail:

- Replacing high consumption tank toilets with low consumption tank toilets;
- Replace urinal flush valves with low flow models while maintaining existing china;
- Installing new control stops in all flush valves to facilitate fixture retrofit and to reduce future maintenance requirements;
- Replacing high flow bathroom and kitchen faucet aerators with tamper-proof low flow aerators; and

Tank Toilets

Tank toilets compensate for low available water pressure and flow rates by accumulating water in a tank before each flush. A tank toilet retrofit entails replacing the existing standard tank toilet with a new 6 L flush tank toilet (both the tank and bowl are replaced). Additional savings may be generated by installing dual flush toilets which can be actuated to flush either their full rated volume to evacuate solid waste, or a reduced flush volume to evacuate liquid waste. While conventional tank toilets use a lever to flush the toilet, dual flush units provide the user with a choice of two buttons. Flush volume for a conventional flush is the same as a normal tank toilet however the reduced flush is only 3L. Users will use the 3L option more often the 6L option; if one assumes a 2:1 ratio of 3L:6L uses then a dual flush toilet saves 33% over a traditional 6L unit. Dual flush toilets have been proposed for all washrooms that lack urinals. All tank toilets should be required to MaP test to 800g by an independent group.

Figure 7.1: Tank Toilet Dual Flush Actuator

Flush Valve Urinals

Flush valve urinals operate similarly to flush valve toilets in that they are connected directly to the building's water supply. Flush valves can either be exposed or concealed. The flow rate of urinals flush valves is highly variable. Whereas some urinals use as much as 10 litres per flush, others barely flush at all. Traditionally, low consumption urinals flush valves are metered to use 1.9 litres per flush and can be installed with existing urinal porcelain. Unlike toilets, urinal china design is not critical when switching to a lower flush volume as there are no solids to evacuate, and would not be replaced. Where existing urinal flush valves are not flushing properly, this retrofit will not generate water savings but will improve sanitation and reduce drain trap maintenance. Waterless urinals were considered, however the expected savings generated were greatly reduced by the expected increase in maintenance and operation costs, which led to an unacceptable payback. Replacing control stops as part of flush valve retrofits facilitates the retrofits and future maintenance of the valves. The functionality of drain trap seal primers is maintained as part of this retrofit

Faucets

Faucet aerators impede the flow of water through the fixture, and are found in a variety of flow rates. Low flow aerators cause turbulence that mixes air with the incoming water stream creating a flow that is more effective at wetting the user without splashing back. Many of the faucets encountered during the walkthrough were either missing aerators or had aerators installed that were rated of higher flow then required for the intended use of the bathroom. Changing out faucet aerators is a quick and effective way to save water as well as any energy used to heat the water.

For areas where only hand washing is required, the suggested flow rate is 1.9 L/min (0.5 gpm). In all cases it is recommended to install vandal proof aerators as this will ensure lasting savings. Please note however that this has not been included in the measure cost.

Incentives

Currently, the County of Northumberland does not offer an incentive program for domestic water retrofits.

SAVINGS RECONCILIATION SHEET
D01 DOMESTIC WATER RETROFITS

MEASURE DESCRIPTION: REF. D01	The proposed domestic water retrofits involve replacing any applicable toilets, faucets, and urinal flush valves with new, proven low-flow technology equivalents.

ASSUMPTIONS:	a) Population estimates provided by building staff or management. b) No Savings have been carried for hot water energy. c) Fixture load factors (per person): Male washroom use every 3.5 hours, female use every 2.5 hours Where urinals exist, ratio of toilet to urinal use is 2:1. Three bathroom faucet uses every four washroom visits (20 seconds). One kitchen faucet use every per 4 hours (30 seconds).

CALCULATIONS:

Water savings are based on the difference between the average flow rate of building's existing fixtures and the average flow rate for the building's fixtures after the retrofit.

$$Savings = Occ * Hrs * Use * (Flow_{PRE} - Flow_{POST}) * 365/1000$$

Where: ***$Flow_{PRE}$*** = Average Pre-Retrofit flow rate in L/use
$Flow_{POST}$= Average Post-Retrofit flow rate in L/use
Occ= Average number of daily building occupants
Hrs = Average time each occupant spends in the building
Use= Average number of uses per hour

Sample Calculation:

$$Savings = \frac{150 \text{ Occupants} * 8 \text{ Hrs/Occupant} * 1 \text{ Use/3Hrs} * (13L-6L) * 365 \text{days/year}}{1000 \text{ L/m}^3}$$

Savings = 1,022 m^3

SAVINGS:			
	ANNUAL CONSUMPTION SAVINGS:	**199**	**m^3 Water**
	SAVINGS RECONCILED AT:	**$168**	

Please refer to ***Table 7.1*** below for the water baseline model and savings calculations spreadsheet.

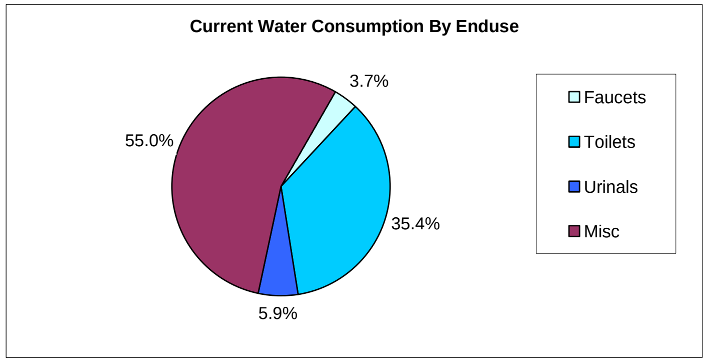
Table 7.1: Water Baseline Model and Savings Calculations Spreadsheet

Northumberland
Domestic Water Model

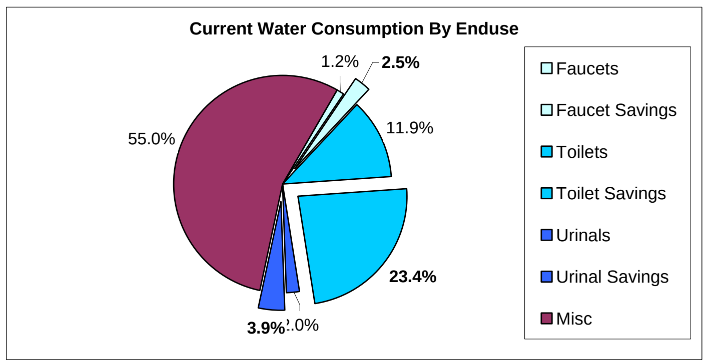
Scenario 1

	Existing Fixtures	Proposed Fixtures	Count	Existing Fixtures (L/Use)	Proposed Fixtures (L/Use)	Existing Domestic Use (m3/year)	Proposed Domestic Use (m3/year)	Yearly Savings (m3/year)	Yearly Savings ($/year)
Zone 1 - Mens	Faucet Aerator- 5.7 Lpm	Faucet Aerator - 1.9 Lpm	2	1.4	0.5	10.4	3.5	7.0	$6
	Tank Toilets Floor - 13L	Tank Toilets Floor - 6L	2	13.0	6.0	45.0	20.8	24.3	$20
	Flush Valve Urinal Wall - 5.7 Lpf	Flush Valve Urinal - 1.9L	2	5.7	1.9	39.3	13.2	26.2	$22
Zone 2 - Ladies	Faucet Aerator- 5.7 Lpm	Faucet Aerator - 1.9 Lpm	2	1.4	0.5	14.6	4.9	9.7	$8
	Tank Toilets Floor - 13L	Tank Toilets Floor Dual	4	13.0	4.0	191.1	58.8	132.3	$111
					TOTALS	301	101	199	$168

Current Water Consumption By Enduse (m3/year)	
Faucets	25
Toilets	236
Urinals	39
Misc	367
	668



Proposed Water Consumption By Enduse (m3/year)	
Faucets	8
Faucet Savings	**17**
Toilets	80
Toilet Savings	**157**
Urinals	13
Urinal Savings	**26**
Misc	367
	668



APPENDIX A
LIGHTING RETROFIT & REDESIGN
LINE BY LINE

Northumberland Material and Recycling Facility
Appendix A Lighting Retrofit & Redesign Line by Line

Room Information						Existing Fixture Information				Proposed Fixture Information				Total	Consumption (kWh)			Demand (kW)		
BldgNo	BldgName	RoomNo	Type	Ceil	FC	Code	Mnt	Lens	Qty	Code	Mnt	Lens	Qty	Hours	Existing	Retrofit	Savings	Existing	Retrofit	Savings
001	Northumberland Material and Recycling Facility	200 BOOTH	AUX	TBA	20	3-2441-T8	REC	K12	8	N/C	REC	K12	8	2,346	2,102.40	2,102.40	-	10.75	10.75	-
001	Northumberland Material and Recycling Facility	200 BOOTH	AUX	TBA	20	1-EXLED-E	SUR	EXR	1	N/C	SUR	EXR	1	8,760	26.28	26.28	-	0.04	0.04	-
001	Northumberland Material and Recycling Facility	2ND FL	COR	TBA		1-1421-T8	REC	K12	2	1-1411-T8-KIT-RWH	REC	K12	2	2,086	241.94	116.80	125.14	1.39	0.67	0.72
001	Northumberland Material and Recycling Facility	2ND FLOOR CONF	CON	TBA		1-2441-T8	REC	K12	9	1-2421-T8-KIT-RWH	REC	K12	9	1,043	1,051.20	516.21	534.99	12.10	5.94	6.16
001	Northumberland Material and Recycling Facility	2ND FLOOR OFFICES	STO	STC		1-1421-T8	SUR	WRA	4	N/C	SUR	WRA	4	1,043	241.94	241.94	-	2.78	2.78	-
001	Northumberland Material and Recycling Facility	2ND FLOOR OFFICES	OFF	STC		1-1421-T8	REC	K12	1	1-1411-T8-KIT-RWH	REC	K12	1	1,043	60.49	29.20	31.29	0.70	0.34	0.36
001	Northumberland Material and Recycling Facility	2ND FLOOR OFFICES	OFF	STC		1-2441-T8	REC	K12	3	1-2421-T8-KIT-RWH	REC	K12	3	1,043	350.40	172.07	178.33	4.03	1.98	2.05
001	Northumberland Material and Recycling Facility	502 BOOTH	AUX	TBA	20	3-2441-T8	REC	K12	4	N/C	REC	K12	4	2,346	1,051.20	1,051.20	-	5.38	5.38	-
001	Northumberland Material and Recycling Facility	504 BOOTH	AUX	TBA	20	3-2441-T8	REC	K12	12	N/C	REC	K12	12	2,346	3,153.60	3,153.60	-	16.13	16.13	-
001	Northumberland Material and Recycling Facility	BAY	GAR	STC	18	3-1421-T8	WAL	WRA	1	N/C	WAL	WRA	1	2,346	138.44	138.44	-	0.71	0.71	-
001	Northumberland Material and Recycling Facility	BAY	GAR	TBA	20	3-1421-T8	SUR	VAP	5	N/C	SUR	VAP	5	2,346	692.20	692.20	-	3.54	3.54	-
001	Northumberland Material and Recycling Facility	BAY	GAR	TBA	20	3-2442	SUR	VAP	4	3-2441-T8-LBF	SUR	VAP	4	2,346	1,482.94	901.03	581.91	7.58	4.61	2.98
001	Northumberland Material and Recycling Facility	BAY	GAR	TBA	20	3-1421-T8	CHA	K12	3	N/C	CHA	K12	3	2,346	415.32	415.32	-	2.12	2.12	-
001	Northumberland Material and Recycling Facility	BAY	GAR	STC	18	3-HID-MH1000	STE	LOW	18	3-N2463-T5-HO	STE	CAG	36	2,346	45,614.57	30,409.71	15,204.86	233.28	155.52	77.76
001	Northumberland Material and Recycling Facility	BAY	GAR	STC	18	1-EXLED-E	WAL	EXR	3	N/C	WAL	EXR	3	8,760	78.84	78.84	-	0.11	0.11	-
001	Northumberland Material and Recycling Facility	ELECTRICAL	ELE	STC	18	3-1421-T8	WAL	WRA	2	N/C	WAL	WRA	2	261	30.76	30.76	-	1.42	1.42	-
001	Northumberland Material and Recycling Facility	EXTERIOR	EXT	STC		3-HID-MH400	SUR	KEY	6	3-HID-MH320-PLS	SUR	KEY	6	4,380	11,878.56	9,671.04	2,207.52	32.54	26.50	6.05
001	Northumberland Material and Recycling Facility	EXTERIOR	EXT	STC		3-HID-MH1000	SUR	KEY	2	N/C	SUR	KEY	2	4,380	9,460.80	9,460.80	-	25.92	25.92	-
001	Northumberland Material and Recycling Facility	EXTERIOR	EXT	STC		3-HID-MH400	SUR	NON	2	3-HID-MH320-PLS	SUR	KEY	2	4,380	3,959.52	3,223.68	735.84	10.85	8.83	2.02
001	Northumberland Material and Recycling Facility	EXTERIOR	EXT	STC		3-HID-HPS150	WAL	PAK	13	N/C	WAL	PAK	13	4,380	10,818.60	10,818.60	-	29.64	29.64	-
001	Northumberland Material and Recycling Facility	LUNCH ROOM	LUN	STC		1-2441-T8	REC	K12	6	1-2421-T8-KIT-RWH	REC	K12	6	1,304	876.00	430.18	445.82	8.06	3.96	4.10
001	Northumberland Material and Recycling Facility	OFFICE	OFF	TBA	170	1-2441-T8	REC	K12	10	1-2421-T8-KIT-RWH	REC	K12	10	2,346	2,628.00	1,290.54	1,337.46	13.44	6.60	6.84
001	Northumberland Material and Recycling Facility	OFFICE	OFF	TBA	170	1-1421-T8	REC	K12	4	1-1411-T8-KIT-RWH	REC	K12	4	2,346	544.37	262.80	281.57	2.78	1.34	1.44
001	Northumberland Material and Recycling Facility	OFFICE 1	OFF	TBA		1-2441-T8	REC	K12	2	1-2421-T8-KIT-RWH	REC	K12	2	2,346	525.60	258.11	267.49	2.69	1.32	1.37
001	Northumberland Material and Recycling Facility	OFFICE 2	OFF	TBA		1-2441-T8	REC	K12	2	1-2421-T8-KIT-RWH	REC	K12	2	2,346	525.60	258.11	267.49	2.69	1.32	1.37
001	Northumberland Material and Recycling Facility	OFFICE 3	OFF	TBA		1-2441-T8	REC	K12	2	1-2421-T8-KIT-RWH	REC	K12	2	2,346	525.60	258.11	267.49	2.69	1.32	1.37
001	Northumberland Material and Recycling Facility	RAW MATERIAL	GAR	STC	18	1-EXLED-E	WAL	EXR	1	N/C	WAL	EXR	1	8,760	26.28	26.28	-	0.04	0.04	-
001	Northumberland Material and Recycling Facility	RAW MATERIAL	GAR	STC	20	3-HID-MH1000	STE	LOW	11	3-N2463-T5-HO	STE	CAG	22	2,346	27,875.57	18,583.71	9,291.86	142.56	95.04	47.52
001	Northumberland Material and Recycling Facility	VESTIBULE	VES	DRY		1-I75PAR38	REC	P06	3	1-CF23PAR38	REC	P06	3	730	164.25	50.37	113.88	2.70	0.83	1.87