Pre-Project Energy Audit

ABC OFFICE BUILDING
85 FIRST STREET
SOMEVILLE, PROVINCE

Prepared By: AAA Engineering Ltd.
123 Second Street
Someville, PR A1B 2C3
(123) 456-7890

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Pre-Project Energy Audit

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1. Executive Summary

1.1 Background of the Project

AAA Engineering was asked to complete an energy audit of the ABC Office Building located at 85 First Street in Someville, Province. Jane Smith, P.Eng, evaluated the building on April 20, 2009.

This building, constructed in 1967, is a 6-storey office building and has a floor space of 4,100 m^2 (approx. 44,000 ft^2). The building envelope consists of two-thirds glazing units and one-third wall assembly, making the building vulnerable to energy loss due to window degradation. However, at the present, the building's envelope appears to be in satisfactory condition. The building has T12 lighting on the main floor, basement, stairwells, and utility and storage rooms, with T5 pendant and compact fluorescent pot lighting on the 2nd through 6th floors. One central AHU provides HVAC for the whole building. The building is heated by one 3,500 MBh fire tube hot water boiler and one 150 Ton centrifugal chiller.

The energy intensity of the building in 2007 was 1.89 gigajoule per square metres (GJ/m^2).

Normalized Annual Utility Costs and Consumption for 85 First St. in 2007:

Annual Utility Usage	Costs	Consumption	Intensity (GJ/m^2)
Electricity	$61,808	4,666 GJ	1.14
Natural Gas	$36,960	3,080 GJ	0.75
Total	**$98,768**	**7,746GJ**	**1.89**

1.2 Energy Efficiency Measure Overview

The main opportunities for energy conservation at the 85 First Street involve upgrading of the aging mechanical equipment, lighting upgrades, and optimization of the recently installed direct digital control (DDC) system. First, it is recommended that the original boiler and chiller, both installed in 1969, be replaced with modern systems that will be significantly more efficient and more appropriately sized.

The building has been recently upgraded with a new state-of-the-art DDC system that now needs to be customized to take full advantage of this technology. This optimization will focus on the heating system, through a number of more advanced control strategies to make the building as efficient as possible using outside air for heating and cooling when possible, as well as reducing simultaneous heating and cooling in the building.

We also recommended a number of lighting measures to replace the remaining aging and less efficient florescent T12 lighting, reduce lighting levels in some areas and reduce run hours as much as possible.

Finally, we recommended a communications strategy to encourage client staff to promote conservation and to highlight organizational environmental values. The costs associated with each of these recommended measures are summarized below.

1.3 Summary Report Table

Summary Measures	Initial Cost	Annual Savings			Simple Payback
		Dollar	Gas	Electricity	
3.1.1.2 HE Boiler Upgrade	$110,000	$10,500	878 GJ		10.5
3.1.2 Chiller Upgrade	$72,000	$6,800		421 GJ	10.6
3.1.3 AHU SF Motor Upgrade	$1,200	$160		17 GJ	7.5
3.1.4.1 SAT Reset	$2,000	$283	24 GJ		7.1
3.1.4.2 CO_2 Sensors	$2,500	$277	23 GJ		9.0
3.1.4.3 Free Cooling	$7,000	$1,923		206 GJ	3.6
3.1.4.4 VSD Optimization	$1,500	$188		20 GJ	8.0
3.2 Lighting	$7,500	$1,200		50 GJ	6.3
3.3 Education	$3,000				
3.4 Engineering Fees	$15,000				
Total	**$221,700**	**$21,331**	**925 GJ**	**714 GJ**	**10.4**

1.4 Allocation of Funds

These energy efficiency measures have the potential to reduce the **energy footprint** of the building by 21**%**. Should measures meet with your approval then we recommend that **$221,700** be budgeted for the implementation of capital projects to achieve an annual savings of **714 GJ** of electrical consumption and **925 GJ** of natural gas consumption. When the building achieves these savings, the annual savings will be **$21,331** at current energy prices.

Client Information

Name and Address: ABC Office Building
85 First Street, Someville, Province

Contact Information: John Doe
Property Manager
Phone: (123) 456 – 7890

2. Building System Overview

2.1 Overview

The building was constructed and opened in 1969, and is a 6-storey facility that is normally occupied from Monday to Friday from 8 am to 5 pm and has a floor space of 4,100 m^2. While some office staff work after hours and on weekends, the building is sparsely occupied during these times. This building is predominately office space.

2.2 Mechanical Systems

HVAC is provided by one large air handling unit (AHU) located on the roof of the building and a number of fan coil units located throughout the building. Heat is provided by the building's original 3,500,000 Btu/hr boiler installed in 1969. Cooling is provided by a 150 ton chiller, also original in 1969. Individual split DX air conditioning units have been added to the server rooms located on each floor allowing the main building cooling systems to be shut down during the winter. A heat exchanger was installed in 1994 to make use of free cooling provided by the cooling tower, reducing the amount of time the chiller needs to be run. Domestic hot water is provided by a gas fired 85 gallon hot water tank and recirculation pump.

All mechanical systems are controlled by a DDC control system that was upgraded in 2004 with overrides provided to individual floors, and a control strategy to save energy under partial occupancy after hours and on weekends. The boiler and water heater are natural gas fired. All major equipment is listed on page A1-A3 of the Appendix indicating their annual energy consumption, operating schedule and area served.

2.3 Electrical System

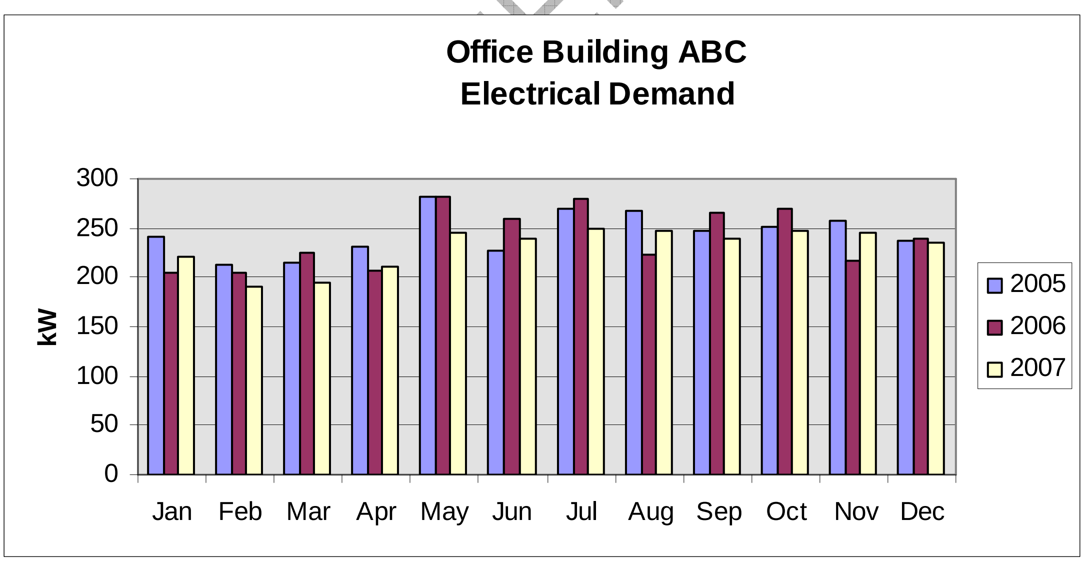
The building has a 600 V / 1,600 amp service, peak monthly demand of 249 kW during summer, and a minimum monthly demand of 192 kW during spring. Monthly demand and consumption profiles can be found in Section 3.5 of this study.

2.4 Lighting System

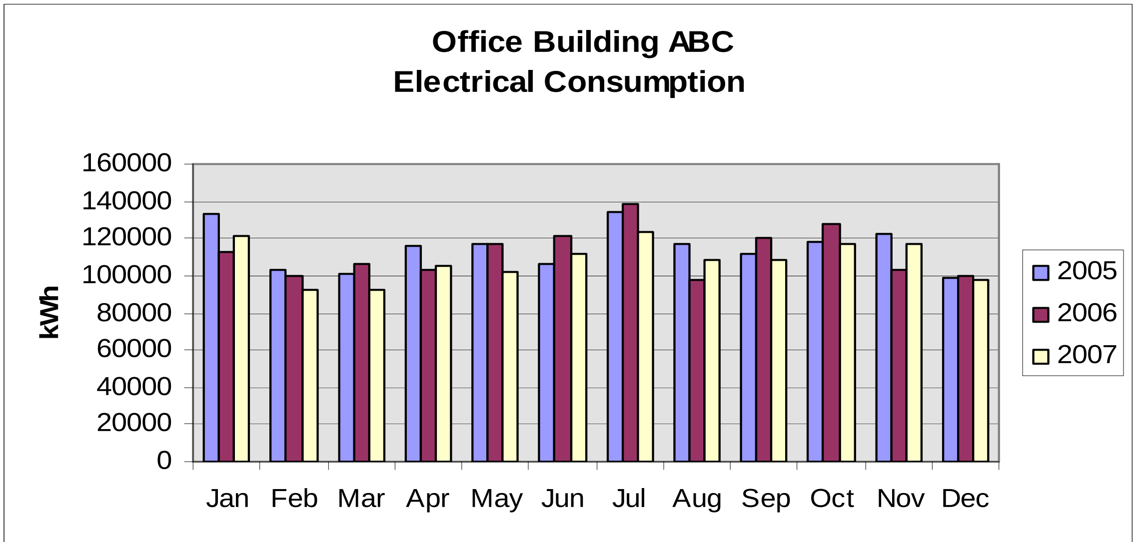
The lighting systems throughout the building are a mix of T12 in the basement, stairwells, utility rooms, and main floor with T5 linear fluorescent and CFL on the 2nd-6th floors and in the lobby. The walk through found a number of areas with high lighting levels as well as a number of spaces were lit while unoccupied. A detailed room-by-room inventory of the lighting systems can be found in Appendix B.

2.5 Energy Analysis

The main purpose of the energy audit was to analyze the building's energy profile and develop energy-efficient measures. To understand the patterns of energy consumption, we have analyzed the electrical demand and consumption profiles as well as the gas consumption profile for the building. The following graphs highlight trends in energy consumption that help us identify areas for potential conservation.

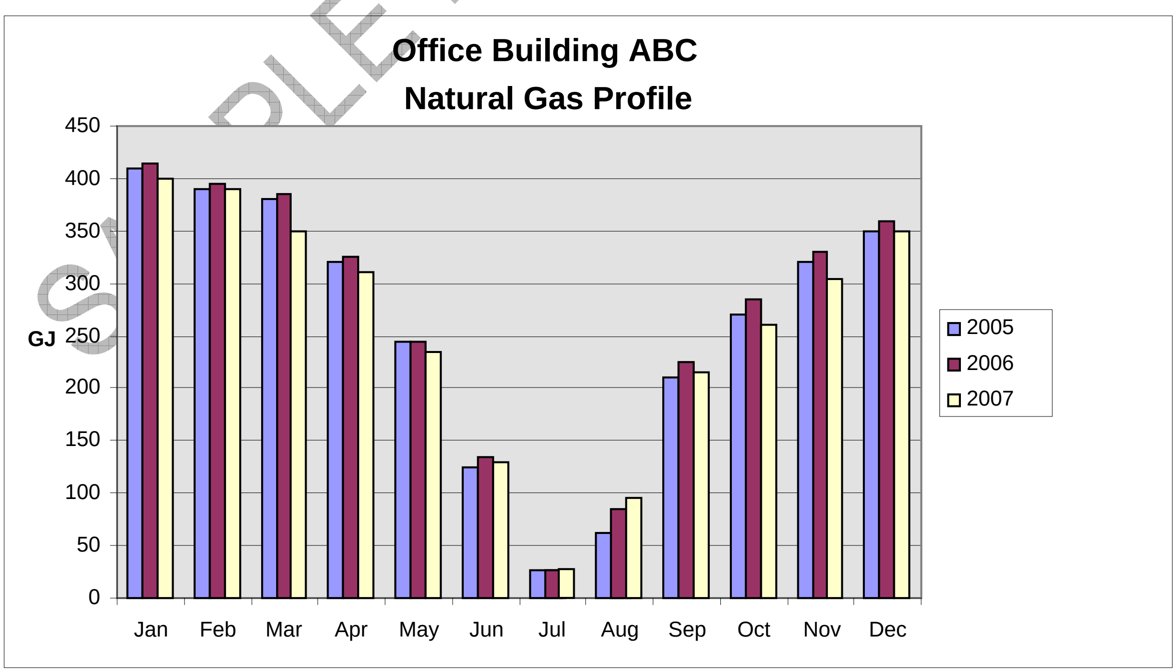


We notice that power demand has a relatively consistent load profile ranging from 190 to 275 kW of peak load in our baseline year. For our baseline, summer peak demand approaches 275 kW, though it drops from January through March. Demand currently remains near peak levels throughout the fall and winter, when reduced chiller usage should significantly decrease peak load. This represents a financial opportunity, as it should be possible to reduce peak demand charges in the fall and winter.

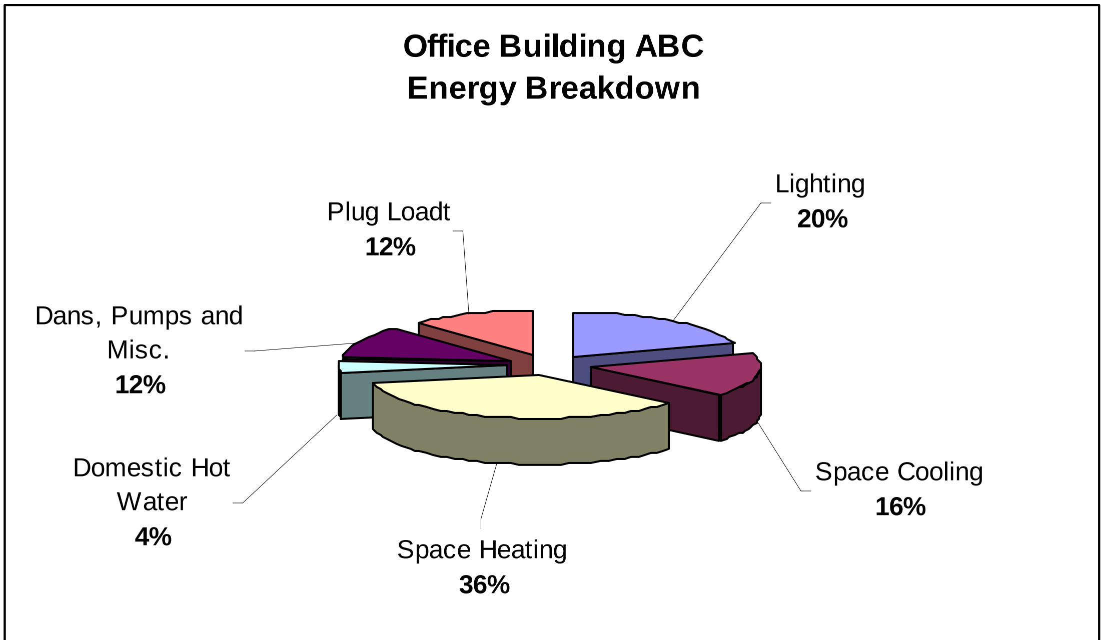


The electrical consumption profile has remained similar for the past three years with a slight drop in utility consumption during 2007. For 2006 we notice a small peak in July likely due to increased use of the chiller for cooling during an unusually warm month. However, consumption stays near peak levels throughout much of the year with noticeable decreases only in December, February, and March. January consumption in particular seems to be very high, nearly equaling mid summer levels. Through autumn and most of winter there is no significant drop in consumption that would normally be expected from reduced cooling loads. Based on this analysis, we feel there is potential for energy savings from recommissioning of the building's DDC system.

In the profile shown below, gas consumption reduces significantly during the summer months, though remains surprisingly high during August when the boiler should be shut down with only domestic water heating required. In general, gas consumption declined noticeably in 2006 from 2005 levels and appears to be still lower in 2007. We will investigate to ensure that annual DDC schedules, occupancy patterns, and override controls are operating correctly to prevent such a spike in consumption from occurring again in the future.



The building energy breakdown chart shows our estimate of the energy consumption associated with electrical and gas usage. The main building energy use is building heating followed by lighting, cooling mechanical systems (fans, pumps, etc…) and plug load. The breakdown assists us in evaluating potential energy-efficient measures. For example the large plug load represents a great opportunity to realize savings through an occupant education campaign.



	Gigajoules (GJ)	%
Lighting	1549	20
Space Cooling	1239	16
Space Heating	2790	36
Domestic Hot Water	310	4
Fans, Pumps and Misc.	931	12
Plug Load	931	12
TOTAL	**7,746**	**100**

3. Energy Conservation Opportunities

3.1 Mechanical/HVAC Opportunities

The primary purpose of this study was to identify energy conservation opportunities at ABC Office Building located at 85 First Street. We have identified and analyzed many potential opportunities to save energy and cost by modifying and upgrading mechanical systems at this facility, and we will explain these ideas in detail in this section. Note for financial savings estimates, we have used a rate of $12.00 / GJ for natural gas, and current electricity rates of $6.79 / kW of demand, and $0.0332 / kWh for consumption. While we believe that these prices are likely to increase in the future we have chosen to be conservative and have not factored this into our analysis.

3.1.1 Boiler Upgrade Projects

The building is still heated using the original fire tube hot water boiler that was installed 38 years ago. Boiler efficiency for a product of this era was 70% (or less) under full load. Under part load, this efficiency drops significantly, and according to our analysis even in the coldest winter the boiler would be firing on average less than 3 cumulative hours per day under full load. Based on this information, we assume that the existing boiler operates the majority of run hours under partial load with an average combustion efficiency of 65%, which is typical of products from this era. Page A1 of the appendix shows the rough breakdown of gas consumption for the boiler and water heater.

One of the best opportunities for energy conservation lies with the replacement of the existing heating boiler with either a mid efficiency boiler or a high efficiency boiler.

3.1.1.1 Mid-Efficiency Boiler

Current boiler technology captures the majority of the heat of combustion before the exhaust gas leaves the chimney, in addition to providing modulation control to enable the boiler to work well under part load. For the purposes of this study we will evaluate a mid efficiency boiler replacement as the baseline, with an upgrade to a high efficiency condensing boiler as a potential option. The existing boiler has a heating capacity of 3,347,000 Btu/hr, though a rough heating load calculation performed as part of a boiler replacement study by ZZZ boiler company estimates the building's heating load requirement at 1,350,000 BTU/hr, or roughly 40% of the existing boiler's capacity. We evaluated a 2,000,000 Btu/hr mid efficiency boiler with full modulation as our baseline replacement option, though it is quite likely that a smaller condensing boiler will suffice.

We estimate that the installation of a new 2,000,000 Btu/hr mid efficiency boiler with full modulation will cost $70,000 including engineering design and project management. This new system will improve the heating system efficiency to approximately 85%, saving about 20% (654 GJ) of current gas consumption resulting in an annual savings of $7,850 per year at current gas prices.

3.1.1.2 High-Efficiency Boiler

As previously mentioned, ZZZ boiler company has provided the owner with a budget quotation and analysis to replace the existing boiler with a condensing boiler that will raise the heating peak efficiency to 95%. It is important to note that this level of efficiency is only achievable with careful integration of the return water temperature control. If return water temperatures cannot be kept below 50ºC then the system efficiency will fall back below 90%. It will be possible to keep water return temperatures this cool if a control strategy is implemented effectively to control the variable speed drive on the heating water pump serving the AHU and fan coils. This may reduce the heat exchanger response time on the fan coil units, and we would recommend that the fan coils be verified to function properly at lower water temperatures before this option proceeds.

We estimate that the installation of a new high efficiency boiler will cost $110,000 including engineering design and project management. If this new system improves the heating system efficiency to 95%, it will save 30% (878 GJ) of current gas consumption resulting in an annual savings of $10,500 per year at current gas prices.

3.1.2 Chiller Upgrade

Similar to the situation with the boiler, the original 1969 centrifugal chiller still provides cooling for the building. In addition to being outdated and inefficient technology, it has also been noted by a supplier representative that the existing 150 ton chiller may be oversized for this building, further reducing its operating efficiency by running at a small fraction of its design capacity for much of the cooling season.

Simply due to advances in technology over 40 years, we estimate that energy consumption of the existing chiller can be cut in half using a new state of the art unit operating at partial and full load. At partial load, the existing centrifugal chiller uses hot gas bypass to create a false load to be able to run at minimal capacity; this form of operation is inefficient. With a 25% gain in technology efficiency, and a further 25% gain in part load efficiency using a centrifugal or screw chiller, we can significantly improve the way we deliver cooling to this building. We have analyzed energy consumption for the existing chiller and have found that the chiller currently consumes 334,304 kWh of electricity, representing an operating cost of $11,433 per year.

Replacing the existing chiller with new state-of-the-art equipment represents an important opportunity for energy savings in this building. We estimate that the installation of a new high efficiency chiller of slightly lower capacity of the existing equipment could result in energy savings of 117,000 kWh (421GJ), and a reduction of peak summer demand by as much as 70kW, with a cost savings of about $6,800 per year. Budget pricing for replacement with a slightly smaller sized centrifugal chiller is approximately $72,000, representing a simple payback of 10.6 years.

3.1.3 AHU Supply Fan Motor Upgrade

The replacement of the existing 15 hp AHU supply fan motor, which appears to be the original equipment, with a new model should yield at least a 10% improvement in motor efficiency, raising motor efficiency to above 90%. This represents a savings of 4,697 kWh (17GJ) and $160 per year. The estimated budget for this project is $1,200, representing a simple payback of 7.5 years. The addition of a variable speed drive to the supply fan motor was also investigated, but due to the fact that it supplies the entire building the fan speed could not be reduced a sufficient amount to justify the expense.

3.1.4 DDC Optimization

A new DDC system has recently been added to 85 First Street. This new DDC system provides a great opportunity to implement a number of new energy savings features that we recommend to customize the controls based on our review of building operations. These features are described below with an estimate of cost and energy saving provided for each measure. The estimated savings from these DDC measures assumes the replacement of the existing boiler with the high efficiency condensing option (Item 4.1.1.2).

3.1.4.1 Supply Air Temperature Reset

This will form a part of the Boiler Outdoor Air Lockout strategy. SAT reset insures that the AHU supply air temperature is selected to minimize energy consumption due to re-heating while still satisfying comfort conditions throughout the building. This program will look at space temperatures in various areas of the building, and will adjust the SAT to optimize the system. In this way, a reduction in re-heating will contribute to small energy savings throughout the year. While it is difficult to estimate exactly how much energy this will save, we believe that a minimum of 2% of the heating bill could be eliminated using this technique. This represents 24 GJ of natural gas and $280 per year. We estimate that a budget of $2,000 will be required to implement this strategy with a simple payback of 7.1 years. Note that some rebalancing is required to solve problem zones after a SAT strategy is implemented, so we have included a small budget for this.

3.1.4.2 Addition of CO_2 Sensors and Damper Controls

The addition of carbon dioxide (CO_2) sensors to the return air duct on the AHU will provide valuable additional information to the building operator to allow better control of the mixed air dampers. Using this new data on CO_2 levels coming back from the space, we can adjust the minimum position of the mixed air damper during very cold or very hot days so that we reduce the amount of ventilation if space conditions allow this. In this way, we control the quality of air in the space based on the number of people that are using the rooms at the moment. These sensors can also be linked to the override program to ensure that sufficient ventilation is provided to a specific tenant that uses the space after hours on a regular basis. We estimate this will save a further 23 GJ in natural gas savings, or $280 per year. Estimated cost for this new sensor and additional programming is $2,500, representing a simple payback of 9.0 years.

3.1.4.3 Free Cooling Optimization

For a significant portion of the year, it is possible to use fresh air from outside to cool the space rather than using a mechanical device to cool the air we use in our building. Additionally, a free cooling heat exchanger has been installed at 85 First Street that allows the cooling tower to provide air cooled water to the AHU without operating the chiller when cooling loads are small. Taking advantage of this fact, we want to maximize the amount of free cooling that is available by ensuring that our outside air dampers are 100% open whenever OAT is less than return air temperature during a cooling mode. As the operation of the free cooling heat exchanger system still consumes significant amounts of energy to drive the cooling towers pump and fans, we want to ensure that outdoor air is used for cooling whenever possible. When this is not sufficient, cooling tower free cooling shall be staged on second. Finally the chiller will be turned on only when mechanical cooling is required. We will want to optimize the set point for locking out the mechanical cooling to approximately 10ºC to ensure that free cooling is being used as much as possible before any mechanical cooling occurs. We estimate that this optimization project will save 15% or 57,203 kWh (206GJ) of chiller/cooling tower consumption, representing $1,923 per year in energy savings. We estimate that the cost to implement this programming is $7,000, with a simple payback of 3.6 years.

3.1.4.4 Optimization of Existing Variable Speed Drives

Two variable speed drives (VSD) are already in place, connected to the cooling tower fans and the hot water supply pump. In both cases, during the site visit, the motors attached to these VSD's were observed to be running at 100%. Further investigation of the DDC system revealed the control program for the VSD for the hot water supply pump was being manually overridden, causing the pump to run continuously at 100%. Programs should be implemented using the existing control hardware for both systems to reduce the speed of these motors when they are not required to be running at full load to meet the heating or cooling demands of the building. We estimate that this will cost $1,500 to make the programming changes and could save at least 20% of the energy consumed by the cooling tower fans and the hot water supply pump, saving 5,652 kWh (20GJ) and $190 per year, representing a payback of 8.0 years.

3.1.4.5 Mechanical Opportunity Summary

We have summarized the mechanical energy conservation measures below.

Summary HVAC	Initial Cost	Annual Savings			Simple Payback
			Gas	Electricity	
3.1.1.2 HE Boiler Upgrade	$110,000	$10,500	878 GJ		10.5
3.1.2 Chiller Replacement	$72,000	$6,800		421 GJ	10.6
3.1.3 AHU SF Motor Upgrade	$1,200	$160		17 GJ	7.5
3.1.4.1 SAT Reset	$2,000	$283	24 GJ		7.1
3.1.4.2 CO_2 Sensors	$2,500	$277	23 GJ		9.0
3.1.4.3 Free Cooling	$7,000	$1,923		206 GJ	3.6
3.1.4.4 VSD Optimization	$1,500	$188		20 GJ	8.0
Total HVAC Measures	**$196,200**	**$20,131**	**925 GJ**	**664 GJ**	**9.7**

3.2 Lighting Opportunities

The lighting technology in the building is a mix of high efficiency lighting technology, located on the 2^{nd}-6^{th} floors that have been recently renovated, and older florescent lighting located in the rest of the building. Upgrading this older lighting technology represents the largest energy savings opportunity in lighting.

3.2.1 Lighting Retrofits

Outside of the 2^{nd}-6^{th} floors, the rest of the building has 2-lamp T12 luminaires. This form of lighting design is outdated, and can be upgraded in most cases by simply changing the ballasts and lamp holders inside the existing light fixtures. In the case of the 2 lamp luminaires, they can be retrofit with 2 lamp T8 lamps using a high ballast factor ballast and mirrored reflectors. There are approximately 125 of these fixtures that could be retrofit. In several locations however, very low usage of these fixtures does not justify the expenditure based on energy savings alone, though we do recommend that all of these units be retrofit to maintain consistency in the building, and to improve the lighting quality in the space. Approximately 50 retrofit locations of moderate to high use fixtures can be recommended based on energy use alone. The summaries are detailed as follow:

- 50 x 2-lamp T-12 in stairwells and corridors to be replaced by 30 x 2-lamp T-8 fixtures

Since those are operated in areas that are lighted 24 hours per day, the savings are substantial. It is estimated that the savings for the measure can be 50 GJ. At a replacement cost of approximately $150 per fixture, the total cost will be $7,500 with estimated savings of $1,200.

Summary Lighting	**Initial Cost**	**Annual Savings**			**Simple Payback**
			Gas	**Electricity**	
4.2.1 Lighting Retrofits	**$7,500**	**$1,200**		50 GJ	6.3
Total Lighting Measures	**$7,500**	**$1,200**		**50 GJ**	**6.3**

3.3 Conservation Education and Communication

So far we have addressed energy conservation using technology, but one of the best ways to reduce energy consumption is through education of staff. Many people leave computers and lighting on when they leave their office for a few hours or even overnight. Crafting a simple memo to all employees to indicate that the organization is striving to become more environmental and reduce energy consumption can have a big effect. In this memo, staff can be asked to do their part to reduce our combined impact on the environment, by turning off their computers, and lighting immediately after they leave a room, both at work and at home. By explaining that ABC Properties cares about Climate Change, and is doing their part to reduce greenhouse gas emissions, management can ask each individual client to do their part. We would recommend the creation of a small 'sustainability' communications strategy to send the message to staff that this program is in place, and ongoing, with follow up memos (with educational energy saving ideas), and later messages that celebrate success. We estimate that this communication and education strategy will cost a maximum of $3,000. In addition to the potential financial savings, the positive public relations may warrant this expense.

3.4 Energy Consulting and Project Management

So that the building owner can accurately analyze the overall costs for this project, we estimate that approximately $15,000 of budget will be required for consulting on this project. These estimated costs include the initial energy audit, as well as time to help direct the implementation of the projects described.

4. Potential Financial Incentives

4.1 Federal Government

Natural Resources Canada (NRCan) offers the **ecoENERGY Retrofit – Small and Medium Organizations** financial incentive (ecoENERGY Retrofit Incentive for Buildings) for energy-saving upgrades in facilities of 20,000 m^2 or less. ABC could receive up to $10 per gigajoule of estimated annual energy savings, up to 25 percent of eligible project costs, to a maximum of $50,000 per project or $250,000 per organization. This document will act as the pre-project energy audit which is required as part of the application form. It is important that ABC does not start the work or incur eligible costs prior to written approval from NRCan.
http://ecoaction.gc.ca/retrofit

4.2 Utilities

There may also be other incentives, grants or rebates available from local energy utilities which could help reduce the costs of the recommended measures.
http://oee.nrcan.gc.ca/programs-directory

Report Certified By:

Jane Smith, P. Eng.
April 22, 2009

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