Tower Labs @ MaRS

Energy Use in Two High-rise Condominium Towers in Toronto A Comparative Study

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Prepared by TowerLabs@MaRS and Provident Energy Management

For more information, contact: Jamie James, jjames@towerlabs.org, 416-673-6516

ONTARIO POWER AUTHORITY

TORONTO Atmospheric Fund

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Executive Summary

Condominium developers are hesitant to implement energy conservation measures (ECMs) due to the inability to recoup the increased capital expenditures while maintaining competitive market prices. With the introduction of the Toronto Atmospheric Fund's (TAF) Green Condo Loan, developers can take advantage of competitive loans to offset additional capital costs associated with ECMs. This report compares two similar buildings and their associated energy use to evaluate the effectiveness of implementing ECMs.

As part of the International Performance Measurement and Verification Protocol (IPMVP) Option C: Whole Facility, two similar buildings were compared. One built to (Model National Energy Code for Buildings) MNECB standards, the other took advantage of TAF's Green Condo Loan to achieve LEED Silver Certification. The Green Condo Loan was used to improve the HVAC and the building's envelope, with the intention of reducing the building's energy consumption. Two years worth of utility data was analyzed on a monthly basis to determine realized energy savings. The LEED Silver Building consumed an average 6% less electricity and an average 50% less natural gas. This provides a good model for future energy efficient condominium developments and confirms TAF's Green Condo Loan as being an innovative financing tool to help offset the cost of ECMs..

An energy model was developed for the LEED Silver Building in compliance with LEED NC Energy and Atmosphere EAc1. A validation of the energy model against actual consumption over the two-year reporting period is included with this report. The findings were that electricity and heating systems were modeled within 8% and 5% respectively of actual consumption. However; actual Domestic Hot Water (DHW) consumption was found to be 82% less than modeled, falling outside of the acceptable calibration range.

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1. Introduction

1.1. Overview

This report presents the energy savings of a newly built LEED Silver Certified condominium by Tridel in the Greater Toronto Area. The Measurement and Verification (M&V) Plan was developed to provide an understanding of the benefits of energy-efficient equipment and material in a condominium development.

The plan will follow the International Performance Measurement and Verification Protocol (IPMVP) Option C: Whole Facility. IPMVP is a generally accepted standard used worldwide to quantify the results of energy efficiency projects and programs. Option C: Whole Facility is best suited for new buildings with energy-efficient features, constructed in an area consisting of similar building type and occupancy. For this report the existing baseline building will be referred to as Building 1 and the LEED Silver Certified Building will be referred to as Building 2. Data obtained from utility meters and aggregated sub-meters was used to assess the energy performance of each building.

Additionally, the plan will reference the IPMVP Option D: Calibrated Simulation. An energy simulation was performed for the LEED Silver Certified Building and details about its calibration and results are included in this report.

1.2. Scope

This project involved gathering and comparing the energy data available for Building 1 and Building 2. Specifically, this involved:

- Listing the architectural, mechanical and electrical specifics for each building
- Creating spreadsheets for the monthly data found on Provident's Energy Management System (EMS)
- Gathering yearly, monthly, and daily data for numerous meters found in Provident's Obsidian System
- Comparing actual energy use of Building 2 to its energy model

1.3. Related Programs and Resources

Building 2 was one of the first condominiums in Toronto to achieve LEED Silver Certified status. To help achieve its goal of environmentally sustainable building design and performance, Tridel partnered with the Toronto Atmospheric Fund (TAF) on an innovative financing program: the Green Condo Loan.

1.3.1. Model National Energy Code for Buildings (MNECB)

The Model National Energy Code for Buildings (MNECB) is a companion to the National Building Code and contains minimum requirements for energy efficiency in new developments. The document, found on Natural Resources Canada's website (http://oee.nrcan.gc.ca/commercial/newbuildings/mnecb.cfm), includes detailed information on building envelope, lighting, electrical power, and heating, ventilating and air conditioning (HVAC) systems, which can offer major energy savings.

1.3.2. Leadership in Energy and Environmental Design (LEED)

LEED is the acronym for Leadership in Energy and Environmental Design and is administered by the Canada Green Building Council (http://www.cagbc.org). It promotes a whole-building approach to sustainability by recognizing performance and awarding points in six areas:

- Sustainable site development
- Energy efficiency and atmospheric impacts
- Materials and resource consumption, use and disposal
- Water efficiency
- Indoor environment quality
- Design innovation

Certification is based on the total point score achieved, following an independent review. There are four possible levels of certification: Certified, Silver, Gold, and Platinum.

Benefits of certifying a building include:

- Recognition for green building efforts
- Validation of achievement through third party review
- Qualification for a number of government and other incentives
- Contribution to a growing green building knowledge base

All buildings are designed and modeled to achieve energy savings 25% above MNECB. The model for Building 2 has been compared to actual data collected for this M&V Plan.

1.3.3. Toronto Atmospheric Fund (TAF)

LEED certification encompasses a wide variety of conservation measures, including energy use, and at TAF (http://www.toronto.ca/taf/) the focus is on the energy efficiency portion of LEED's many benefits. The Green Condo Loan is an innovative financing tool developed to help offset the cost of higher performing, energy-efficient equipment and material in condominiums and high rise developments. A lender helps finance the extra capital costs of energy efficient upgrades; such as, HVAC equipment, windows, appliances, and motors. The Condominium Corporation repays the loan to the lender from a portion of the funds that would otherwise be spent on heating, cooling, and electricity bills.

1.4. Literature Review

How Green Condos Became the Norm in Toronto
SBM Fall 2010
By Jim Harris

This article describes the benefits to developers, buyers, and the environment by implementing the Green Condo Loan facilitated by the Toronto Atmospheric Fund. In Toronto, where up to 90% of all new residential construction is condominiums, there is a growing need for energy efficiency programs that support reduction of a buildings energy consumption.

It is estimated that it costs an average of 2.5% more to construct an energy efficient building compared to a typical building built to the current building code.

The article highlights one of the obstacles for developers when embracing energy efficient solutions: split incentives. The developer pays the incremental costs of designing and building an energy efficient building while the buyers benefit from the lower operating costs. Developers have to remain cost comparable and the extra costs of green features may be too much for cost sensitive buyers.

The Green Condo Loan helps pay for the green upgrades. These upgrades can cost up to $3,000 per unit and with a typical Tridel Building, there are up to 300 units. This extra cost can add up to $1,000,000 for a new development.

In the article, Jim Harris goes over the benefits to the developer, the buyers, and the condo corporation after the building has been taken over. They are:

- The buyers benefit from $3,000 worth of energy efficient upgrades.
- The energy savings are greater than the loan repayment
- After the period of time that the loan is paid off, usually less than ten years, the operating savings benefit the owners directly.
- Owners are protected from increases to energy prices.
- Green buildings benefit from higher occupancy, premium rents, and higher resale values.

All these add to a win for the buyers, the developers, and the environment; a perfect win-win-win scenario.

Jim Harris. (2010). *How Green Condos became the norm in Toronto.* Available: http://www.sbmagazine.ca/archives/800. Last accessed 20th April 2011.

2. Baseline Definition and Development

2.1. Baseline Definition

The energy savings of Building 2 cannot be directly measured. Instead, the energy savings are determined by comparing the energy use of two similar buildings; one built according to MNECB and the other LEED Silver Certified. Therefore, the energy savings in Building 2 are the absence of energy used when compared to Building 1. The following equation is comparable to the equation found in the IPMVP [Volume 1, Chapter 4.1, page 13 and in Volume 3, Chapter 3.1, page 7]

Energy Savings = Energy use of Building built to MNECB – Energy use of Building Certified LEED Silver
± Adjustments

OR

Energy Savings = Building 1 – Building 2
± Adjustments

2.2. Baseline Development Process

The baseline chosen for this M&V plan is a similar building built within the same master plan as Building 2. The baseline building, Building 1, does not subscribe to LEED or any other energy efficient program. It is a typical condominium built to MNECB standards. Building 1 was occupied in the spring of 2007 and Building 2 was occupied in the summer of 2008.

Even though Building 1 and Building 2 are built to different stardards, there remains many similaities between the two which makes Building 1 an excellent baseline for Building 2 in this M&V Plan. The similarities between the two buildings are as follows, both buildings:

- are very similar in architectural design
- have comparable floor plans and number of suites
- are oriented differently but are generally exposed to the same weather conditions
- share similar occupancy and demographics
- are operated by the same building operator

According to the IMPVP, consideration must be given to any factor that may need to be adjusted in the baseline. These factors, which may be predictable or non-predictable, include weather, amount of space being heated or cooled, indoor environment standards, occuapancy type and schedule, and/or equipment changes. For the purpose of this comparison, none of these factors are applied to the adjustments of the baseline. Both Building 1 and Building 2 are similarly operated and any difference in the energy use results are to be included in Building 2's energy savings.

To determine the the energy use of both buildings, monthly elctricity and natural gas utility bills, as well as in-suite electrical meters are used. The reporting period for this M&V plan utilizes two years of data for the comparison; from January 1, 2009 to December 31, 2010. This reporting period adequately represents operating conditions of a normal operating cycle in which all energy facts are known about both buildings.

3. M & V Plan

3.1. Intent

Provident Energy Management Inc. (PEMI) achieved LEED Credit EAc5 M&V for Building 2. With the implementation of advanced metering, data can be analyzed to provide ongoing accountability of building energy performance. This data has been used in the report along with monthly utility bills.

3.2. IPMVP Option

Two IPMVP options are available for determining the energy savings of Building 2: Option C (Whole Building Comparison) or Option D (Whole Building Calibrated Simulation).

M &V Option	How Savings are Calculated	Typical Application
C. Whole Building Comparison	Projected baseline energy use determined by measuring the whole building energy use of similar buildings without the Energy Conservation Measures (ECM).	New buildings with energy efficient feature are added to a commercial park consisting of buildings of similar type and occupancy.
D. Whole Building Calibrated Simulation	Projected baseline energy use is determined by energy simulation of the Baseline under the operating conditions of the M&V period.	Savings determination for the purposes of a new building Performance Contract, with the local energy code defining the baseline.

The purpose of this report is to calculate total facility energy performance, and because of the availability of data for Building 1, IPMVP Volume 3, Part 1, EVO 30000 – 1:2006 and IPMVP Volume 1, EVO 10000 – 1:2010, Option C was chosen as a way of determining energy savings in Building 2.

3.3. Reporting Period

Twenty-four months of continuous data is used in the reporting period: January 1, 2009 through to December 31, 2010.

Building 1 was occupied in 2007 and Building 2 was occupied in 2008 but the start of 2009 was chosen as the beginning of the reporting period. This allowed both buildings to be operational for a period of time before including their data in the comparison. By using two years of data, short-term variations are averaged out to best represent a typical operating cycle.

4. Building Overview

4.1. Building Information

Building 1 and Building 2 are part of a community master plan within the Greater Toronto Area. The buildings are comparable in many aspects of design and occupancy. The similarities allow for the buildings to be used for comparison.

	General Information	
	Building 1	**Building 2**
Location	Etobicoke, ON	
Climate	Toronto 716240 (CWEC)	
Orientation	North-South	East-West
Use	Multi-Unit Residential	
Rec. Center	Shared	
Price (Present Value*)	\$3918 /m²	\$4176 /m²
Floor Area	29374 m²	31570 m²

** Present Value represents the price if they were sold today as pre-construction units. Prices are based on 6% increase each year for the price of pre-construction condominium units in Toronto.*

	Occupancy Profile	
	Building 1	**Building 2**
1 Bedroom	50.15%	48.50%
2 Bedroom	49.85%	50.00%
3 Bedroom	N/A	1.50%

4.2. Architecture

Building 2 was designed to perform 25% percent better than MNECB. The architectural information for Building 1 was unavailable but it is known that Building 1 was built to MNECB standards. Due to the lack of architectural information, all comparison values used for Building 1 are based on MNECB.

U Values in USI watts/m²/deg.°C	Envelope	
	Building 1	**Building 2**
Walls	0.77†	0.5
Window Fixed	3.2†	2.63
Window Operable	3.4†	2.68
Glass Door	3.4†	2.68

† Represents data taken from the MNECB.

4.3. Mechanical

The mechanical systems for the two buildings are comparable in size and design but differ in capacity.

	HVAC	
	Building 1	**Building 2**
Primary Boilers	534.86 kW (x 4 boilers) 80% Thermal Eff.	366.34 kW (x 4 boilers) 85% Thermal Eff.
Heating Boilers	893.87 kW (x 3 boilers) 80% Thermal Eff.	586.14 kW (x 4 boilers) 85% Thermal Eff.
DHW	296 kW (x 2 boilers) 80% Thermal Eff.	293.07 kW (x 2 boilers) 85% Thermal Eff.
Chiller	230 Tons (x 2 chiller) 2.5 COP†	340 Tons (x 1 chiller) 5.8 COP
Cooling Tower	230 Tons (x 2 cooling tower)	340 Tons (x 1 cooling tower)

Both Buildings, 1 and 2, have similar in-suite 2-pipe fan coil systems. The main difference between the two buildings' HVAC configurations is that Building 2 has an Energy Recovery Ventilator (ERV) in its Air Handling Unit (AHU).

	HVAC Configuration	
	Building 1	**Building 2**
Air Handling	2 AHU's provide heating and cooling to common areas via corridors, stairwells, etc… Both AHU's transfer heat through a water to glycol heat exchanger	2 AHUs provide heating and cooling to common areas via corridors, stairwells, etc… Both AHUs transfer heat through water to glycol heat exchanger. The AHUs are equipped with ERVs with a recovery effectiveness of 58%.
Pump Type	Single Speed†	Variable Speed
In-Suite Fan Coils	2-pipe	2-pipe

4.4. Electrical

The electrical systems in both buildings are designed as per MNECB standards.

	Electrical	
	Building 1	**Building 2**
Residential Lighting, W/m^2	9†	9†
Common Lighting, W/m^2	8.6†	8.6†
Plug Loads, W/m^2	5†	5†

† Represents data taken from the MNECB.

5. Utility Analysis

5.1. Methodology

PEMI is responsible for the handling of energy bills for Building 1 and Building 2. PEMI maintains two distinct energy databases; Energy Management System (EMS) for bulk utility level energy data, and Obsidian for detailed in-suite level energy data. Utility energy data and in-suite energy data were compared for both buildings by accessing PEMI records. For the purpose of this M&V Plan, only utility level natural gas and electricity bills plus in-suite electrical data have been used for the energy use comparison.

Meters Installed	Building 1	Building 2
In-Suite Electrical	✓	✓
In-Suite Thermal Heating		✓
In-Suite Thermal Cooling		✓
Bulk Natural Gas	✓	✓
Bulk Electricity	✓	✓

5.2. Utility Meters - EMS Data

PEMI keeps records of Building 1 and Building 2s' natural gas and electricity utility bills on their EMS. There is no indication of estimated monthly bills. Further studies of Building 2's energy use patterns have shown no reason to suspect any inaccuracy with the monthly data provided on EMS.

To have accurate data based on calendar months, all energy data was pro-rated using the process outlined in Appendix A.

5.3. Sub-Meters - Obsidian Data

PEMI offers complete metering and billing services. As part of LEED EAc5 M&V Building 2's sub-metering includes heating boilers, pumps, cooling tower, chiller, residential thermal heating and cooling, and residential electricity. Building 1, however, does not have the same level of sub-metering as Building 2, and only in-suite electrical meters having been installed. For the purpose of this M&V plan, and to remain consistent between both buildings, only in-suite electrical data has been used in the comparison.

5.4. Data Analysis

For data analysis, meter readings needed to be downloaded and aggregated to be properly analyzed in Microsoft's Excel. Reports produced from Obsidian were manually checked for inconsistencies and errors such as negative meter readings and meter "noise". "Noise" is a result of the accuracy rating of a meter and may result in small consumption readings in months that should have no consumption values. This was found predominantly in Building 2's thermal meters. No such errors were found for either building's electrical meters.

IPMVP, Volume 1, Appendix B-4 requires a stated accuracy for the meters which is published by the meter manufacturer, from laboratory test. For this M&V plan, the meters' precision was not taken into account. It is assumed that any error in precision or accuracy, would be spread throughout both buildings, as they both have similar meters and meter configuration in respect to their placement.

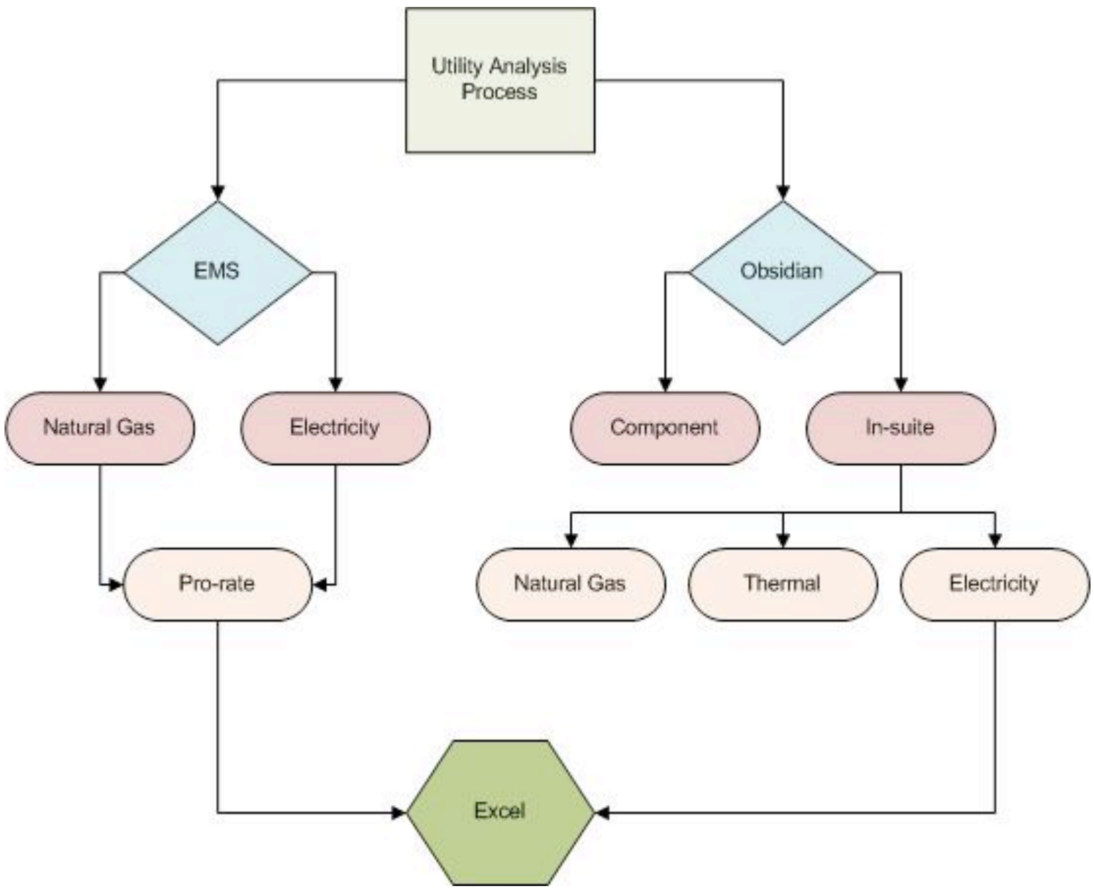

Figure 1, Utility Analysis Flow Chart

6. Findings

6.1. Building 1 vs. Building 2 – Metered Energy Consumption

The reporting period data for Building 1 and Building 2 was taken from EMS and Obsidian. For each building the energy consumption data was averaged to represent a typical year. The two-year reporting period lessened the impact of short-term variations; such as, a cooler year for 2009 and a warmer year for 2010.

6.1.1. Residential Electricity

For the reporting periods, Building 1's annual average residential electricity consumption is 18% above that of Building 2's.

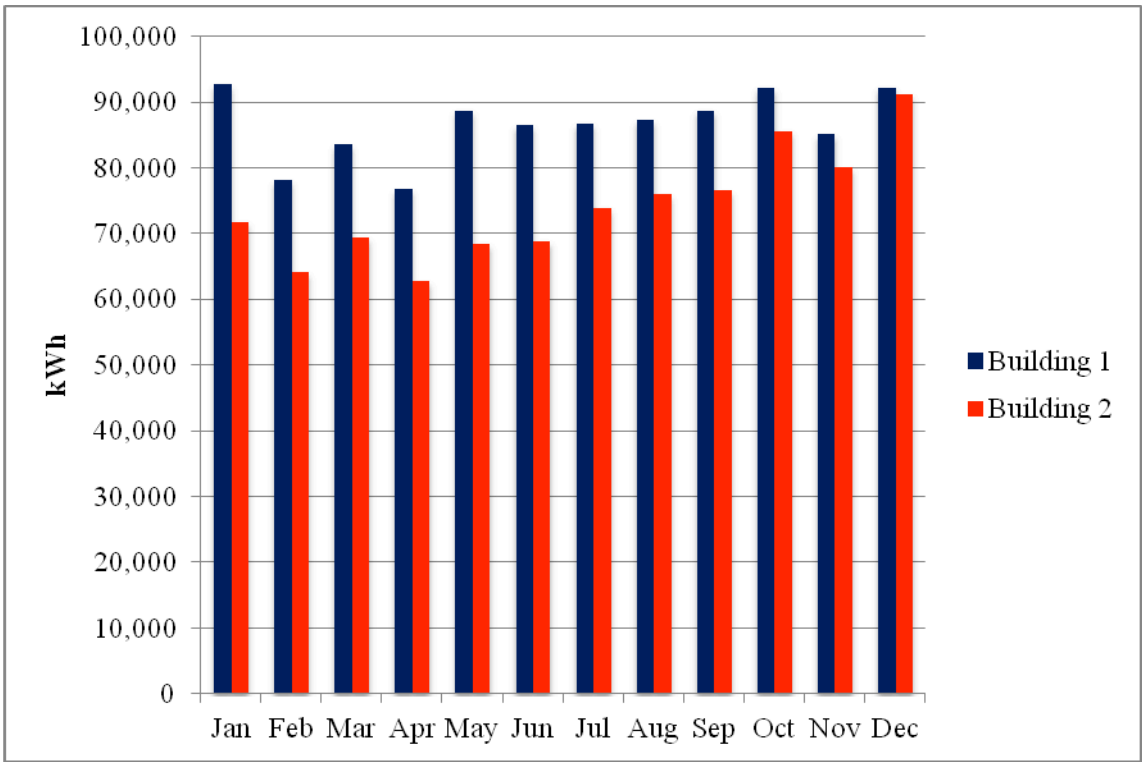

Figure 2, 2009/2010 Average Residential Electricity Comparison

6.1.2. Building Electricity

Energy use comparison of Building 1 and Building 2 show similarities in fall, winter, and spring. Large savings for Building 2 occur in the summer. This may be attributed to a higher performing cooling plant.

For the reporting periods, Building 1's annual average building electricity consumption is 7% above that of Building 2's. For a full building comparison breakdown refer to Appendix B.

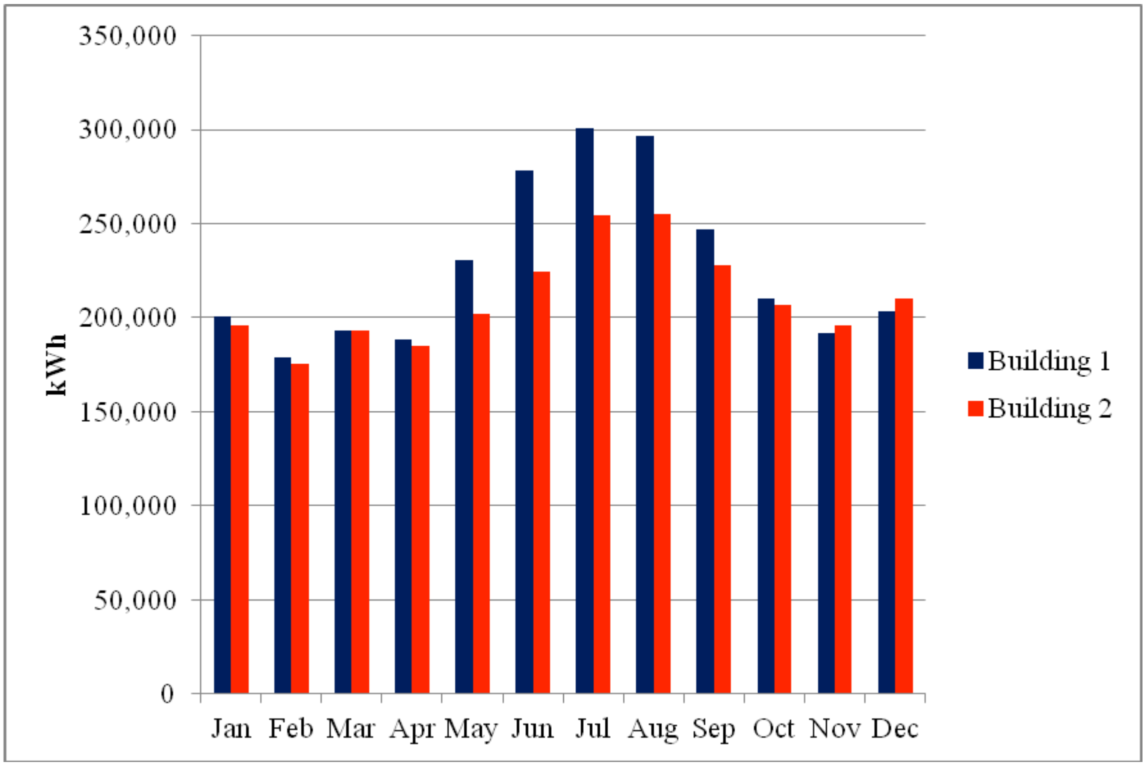

Figure 3, 2009/2010 Average Building Electricity Comparison

6.1.3. Building Natural Gas

Year-round, Building 2 performs much better in regards to natural gas consumption. For the reporting periods, Building 1's annual averaged natural gas consumption is 105% above that of Building 2's.

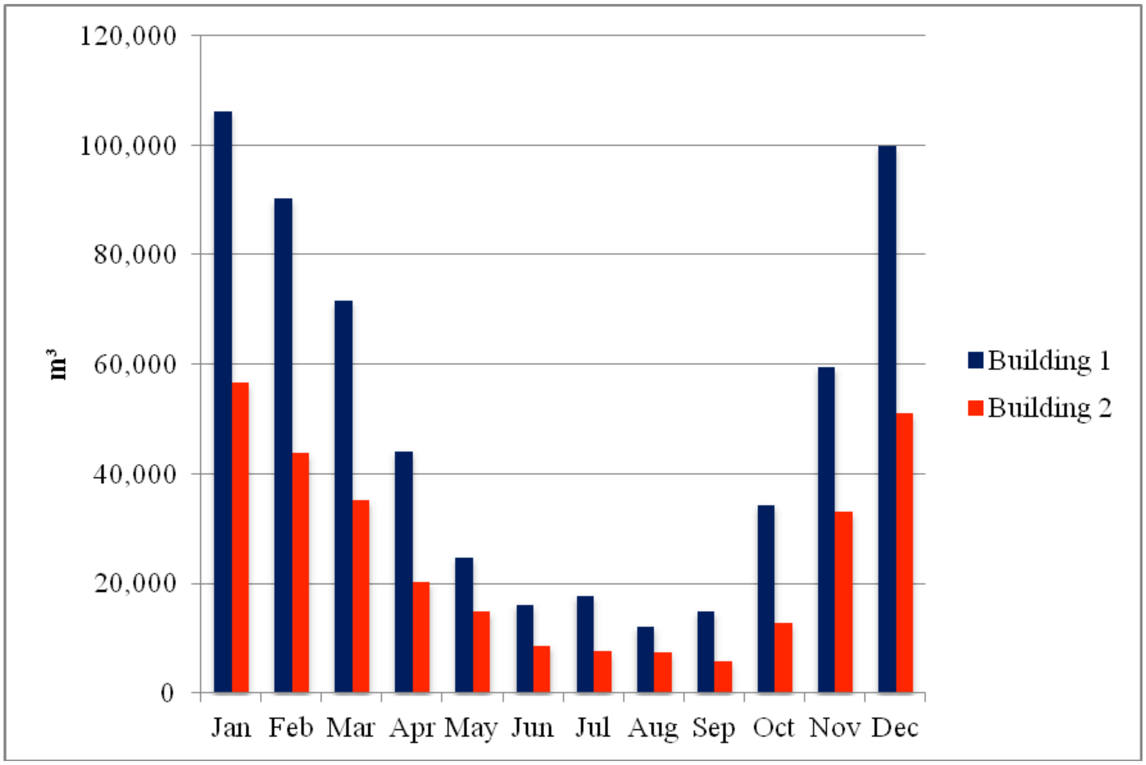

Figure 4, 2009/2010 Average Building Natural Gas Comparison

6.1.4. Energy Intensity

Natural gas and electricity were converted from their metered units (kWh, m3) to Megajoules (MJ) so the data could be analyzed for energy intensity. The comparison shows that Building 2 has an energy intensity 41% lower than Building 1.

Energy Intensity	
	MJ/m^2
Building 1	1,100
Building 2	647

6.2. Energy Model Comparison

6.2.1. Energy Model Comparison Methodology

In the IPMVP Option D, whole building energy consumption is compared to the energy model. The IPMVP references American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) Guideline 14 for the "minimum compliance requirements to ensure a fair level of confidence in the savings determination results" (ASHRAE Guideline 14). When following the Whole Building Calibrated Simulation Performance Path, the guideline states, in section 6.3.3.4.4.2, that the energy model is "generally considered calibrated if it falls within 10%" of actual monthly utility data using the Mean Bias Error (MBE) method. When using the Coefficient of Variation Root Square Mean Error ((CV)RSME) method, the model is generally considered calibrated if it falls within 15% of the actual utility data. For a full breakdown of MBE and (CV)RSME please refer to Appendix C.

MBE was the method chosen for this report. A statistical (CV)RSME approach would have been conducted had the results been within tighter margins.

The IPMVP Option D recommends preparing a post occupancy energy model by either creating a new model or recalibrating an existing one. For the purposes of this project a new energy model was not constructed. The intention of section 6.2 is not to recalibrate an existing energy model but to validate it. The energy model for Building 2 has already been reviewed and accepted under LEED NC EAc1.

6.2.2. Electricity

The electricity usage for Building 2 was compared to the model on a monthly level with actual utility data averaged over 2009 and 2010. Results from using the MBE indicated that some months fell out of the calibration requirements. Refer to Appendix D for detailed monthly calibration findings. However, when results are averaged over a year, the model's variance from actual energy usage is within 8%.

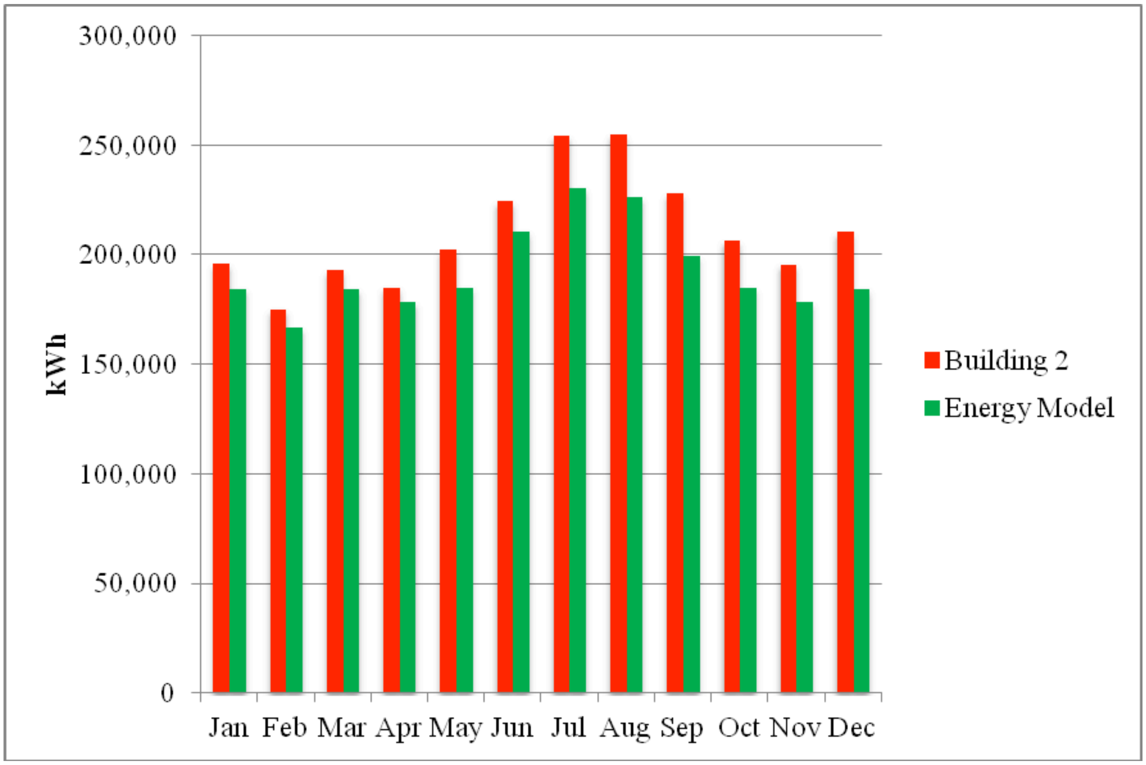

Figure 5, Building 2 Electricity vs. Model

6.2.3. Natural Gas

Unlike electricity, actual natural gas consumption had a much larger variance from the results of the model. The comparison yielded an average variance of 40%. The results from comparing the actual natural gas consumed with the model exceed the 10% calibration requirement. January, February and December were the only months that fell within the 10% calibration requirement. The largest variance occurred from June to October. To better understand the results, the DHW system baseline was established by observing natural gas consumption during non-heating months. A reason for the larger variance in the summer months can be attributed to the difficulty of modeling schedules for DHW systems. If the natural gas is measured just for the primary and heating boilers the average variance from the energy model is only 5%. Even though the primary and heating boilers are considered calibrated, the DHW boilers have considerable variance from the model resulting in the overall average falling outside of the calibration range. It is worth noting that even though the DHW comparison is considered to be non-calibrated, Building 2's DHW system performs better than the energy model in every month.

Figure 6, Building 2 Natural Gas vs. Model

6.2.4. Energy Intensity

Natural gas and electricity were converted from their metered units (kWh, m3) to Megajoules (MJ) so the data could be analyzed for energy intensity. The comparison shows that Building 2 has an energy intensity 7% lower than the energy model projected.

Energy Intensity	
	MJ/m^2
Building 2	647
Model	697

6.3. Modeled vs Actual Energy Costs and Green Loan Costs

Estimated energy costs as predicted by the energy model were compared to *actual* energy costs for Building 2. These results were in turn compared to actual energy costs of Building 1, and to the Common Element Assessment associated with principal and interest payments of the Building 2 Green Loan. This information helps to understand the relationship between the predicted savings that were leveraged for the TAF green loan and the costs of the financing. The original intent of the green loan program was to leverage a portion of the modeled savings, leaving room for error and for condo owners to benefit from some of the savings netted after paying back the lender.

The first table compares the actual bulk building meter data of Building 1 and Building 2. Building 2, which has more floor area than Building 1, recorded a 25% reduction in energy costs in relation to the first building.

Actual Building Energy Costs			
	Electricity	Natural Gas	Total Energy
Building 1	$281,931.07	$221,099.25	$503,030.32
Building 2	$258,312.06	$119,851.53	$378,163.59
Cost reduction between Bldg 1 and Bldg 2			$124,866.73

The second table compares the estimated energy costs for Building 2 to the energy costs estimated by the building energy performance model. Actual energy use recorded was 5% *lower* than the energy model predicted. Since the energy model was used to estimate the cash flow from energy cost savings in order to finance the green loan and provide net savings to the Condominium Corporation simultaneously, these results indicate that the *net savings* to the Condominium Corporation are greater than anticipated by the developer.

Estimated vs Actual Building 2 Energy Costs	
	Total Energy
Estimated Building 2 Energy Costs (modeled)	$399,042
Actual Building 2 Energy Costs	$378,163.59
Additional Savings (Actual vs Estimated)	$20,878.41

The next table quantifies the annual net savings when comparing the energy costs of Building 1 and Building 2 after deducting the principal and interest costs of the TAF Green Loan.

Building 2 TAF Green Loan Costs	
	Total Energy
Gross Cost Savings between Bldg 1 & Bldg 2	$124,866.73
Less Building 2 TAF Green Loan Costs	-$87,832.32
Net Savings to Bldg 2 Condominium Corporation	$37,034.41

Although there is no perfect way to compare two buildings and their energy use, it is possible to obtain an illustrative understanding of the relative scale of two otherwise essentially similar buildings by normalizing gross floor area differences using an energy cost intensity factor. The next table compares cost intensity of the two buildings, as well as the energy model and the green loan, based on floor area.

Energy Cost Intensity		
	$\$/m^2/yr$	$/SF/yr
Building 1	$17.13	$1.59
Building 2	$11.98	$1.11
Building 2 Model	$12.57	$1.17
Green Loan Cost	$2.77	$0.26

The last table applies the energy cost intensity factor of Building 1 to Building 2 in order to get an impression of the overall energy cost savings if both buildings had the same gross floor area.

Illustrative Comparison of Cost Savings Based on Energy Cost Intensity	
	Total Energy
Building 2 "Illustrative" Baseline Normalized to Building 1 Energy Costs Intensity ($17.13/m2/yr)	$540,636.86
Less Actual Building 2 Energy Costs	-$378,163.59
Less TAF Green Loan Costs	-$87,832.32
Net "Illustrative" Savings to Condominium Corp	$74,640.95

The comparisons from this section provide conclusive evidence that the TAF Green Loan leveraged energy cost savings in excess of the actual costs of the financing. For example, the pro rata share of the Green Loan cost for the owner of an 850 square foot dwelling unit would amount to approximately $220 per year ($18/month); whereas the pro rata energy savings that could be attributed to that same dwelling unit are on the order of $405 per year ($33/month) – a net saving of 45%. (Disclaimer: This assessment does not account for a weighted ratio between in-suite energy consumption and common area energy consumption.)

7. Recommendations

7.1. Metering

Metering energy consumption is only half the equation when it comes to monitoring and analyzing a building's performance. It requires an operator to look at, understand, and be able to draw conclusions from the data that is being produced. Although US Department of Energy states that there is no "one size fits all approach" to metering, it is a recommendation of this report that a high-level metering template be constructed and added upon to achieve additional results. A standardized metering practice can be put together in-house, or developed by a third-party as per the users metering goals.

7.1.1. Goals

Setting goals is the key to a successful metering and data logging process. The user needs to determine:

- Where meters will be installed
- What variables will be metered
- Who will collect and analyze the data
- What are the intended outcomes of metering; for example: billing, monitoring, or efficiency calculations
- Future requirements if a project is to be built in multiple stages

It is a recommendation of this report that when an energy model is created for a project, the metering system should, at a minimum, accommodate the ability to directly compare as-built data to the energy model. This should be regardless of whether a submittal to LEED or any other third party rating system is involved.

7.1.2. System Construction

The US Department of Energy (Metering Best Practices) defines the process of combining utility/thermal/efficiency data with software as an energy information system (EIS). The EIS should be developed based on the metering system and how the outputs will be used to fulfill the goals as per section 7.1.1. By building the software platform and metering system simultaneously, it ensures that the user is addressing the set goals of the metering system. For proper analysis, the software and metering system should be developed.

Having the ability to analyze collected data is a must to fully understand the operation of a building. The analysis template must be constructed so that data can be easily imported for future analysis. These templates can be Excel spreadsheets developed in-house to complex third party analysis software. Both methods have advantages, with the sensitivity of the information determining whether it needs to be kept in-house or can be handled by a third party. Creating in-house systems may be advantageous for users that have an existing IT department.

7.1.3. Energy Model Recalibration

As part of any project that requires energy modeling, the scope of that project should be extended to include the recalibration of the model. Recalibrating the model for post occupancy allows the user to refine the modeling process and account for as-built factors that may have been overlooked.

In the case of Building 2, the as-built conditions outperformed the model. For third party programs or funding that require an energy model, more credits or funding may be achieved by demonstrating high building performance with a defensible energy model.

8. Conclusions

8.1. Building Comparison

A comparison was made between two similar buildings in the same community, one designed to meet MNECB standards, the other implementing energy efficiency measures to achieve LEED Silver Certification. Due to their similarities in design, occupancy and location, direct comparison was achievable with no normalization process required. The findings support that a reduction of energy consumption is achievable and measurable by subscribing to LEED Certification.

8.2. Actual vs. Energy Model

The findings concluded the validity of performing energy models for analyzing whole building energy consumption. Electricity and heating system consumption were within the acceptable calibration range when comparing modeled energy use to metered consumption. When DHW was analyzed it found that every month was outside of the calibration range representing an overestimation of occupancy in the model's DHW schedules.

8.3. TAF

By applying for TAF's Green Condo Loan, the objectives of reducing the energy use of Building 2 has been met. The Green Condo Loan's required 25% reduction of energy use has been surpassed, and the energy savings seen in Building 2 is an average of 41% below that of a typical condominium built to MNECB standards. The extra cost of implementing Building 2's ECMs, which were instrumental in reaching its goal, were paid for by the loan and the purchaser benefits from the extra savings. All these have added up to the perfect win for the buyers, the developers, and the environment; truly, a win-win-win scenario.

9. References/Bibliography

ASHRAE Guideline 14. 2002

IPMVP Volume 1, 2010

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Metering Best Practices, October 2007, US Department of Energy

APPENDIX A – DATA PRORATING CALCULATIONS

PRORATING DATA INTO CALENDAR MONTHS

Each commodity bill needs to be divided by the number of days in the billing period to calculate the average daily consumption and average daily cost.

This figure includes numerous non-commodity costs such as metering fees and service fees; however, the client (PEMI) is satisfied with this method. Performing a sensitivity analysis on commodity prices will therefore be inaccurate; however, one can state that "if overall energy costs fluctuate" as opposed to "if commodity prices fluctuate".

This "all-in" average daily number was applied to the number of days that fell within each calendar month of the each bill as shown in the example below.

Billing Dates:	March 12-April 11	Billing Dates:	April 12- May 11
Commodity Consumption:	10000m^3	Commodity Consumption:	8000m^3
Commodity Cost:	\$3000	Commodity Cost:	\$2700
Number of Billing Days	30	Number of Billing Days	29
Average Daily Consumption	=10000m^3/30	Average Daily Consumption	= 8000m^3/29
	=333m^3/day		= 276m^3/day
Days in April:	11	Days in April:	19
April Consumption	= 11 x 333m^3		= 19x276m^3
	= **3663m^3**		= **5244m^3**
Average unit cost	=\$3000/10000	Average Unit Cost	=\$2700/8000
	= \$0.30/m^3		= \$0.34/m^3
April Cost	= 3663x\$0.30	April Cost	= 5244x\$0.34
	= **\$1099**		= **\$1770**

e.g. Prorated Gas Consumption for April is 3663m^3+ 5244m^3 totaling **8907m^3**.
e.g. Prorated Gas Cost for April is \$1099 + \$1770 totaling **\$2869**

APPENDIX B – Building Comparison Analysis

Electricity

Electricity

Building 1 kWh 2009	Building 2 kWh 2009	Building 1 kWh 2010	Building 2 kWh 2010
193929.90	184369.41	206850.84	207560.00
173353.60	165917.14	184885.63	184406.67
188593.30	185622.86	198185.02	200429.89
185415.12	183620.00	191261.42	186783.45
231886.56	193868.97	229718.10	210810.32
267782.47	207276.49	288644.33	241625.81
281059.85	246254.55	320370.54	262559.73
286589.45	253825.00	306608.32	255949.14
245021.60	224030.17	249322.31	232095.00
211003.05	199424.83	208790.43	213723.75
195601.05	189798.57	187434.10	201656.25
205735.33	203421.43	200655.32	217612.50

	Building 1 Average	Building 2 Average	
Jan	200390.37	195964.71	2.26%
Feb	179119.62	175161.90	2.26%
Mar	193389.16	193026.37	0.19%
Apr	188338.27	185201.72	1.69%
May	230802.33	202339.64	14.07%
Jun	278213.40	224451.15	23.95%
Jul	300715.19	254407.14	18.20%
Aug	296598.89	254887.07	16.36%
Sep	247171.95	228062.59	8.38%
Oct	209896.74	206574.29	1.61%
Nov	191517.58	195727.41	-2.15%
Dec	203195.33	210516.96	-3.48%
		Average	**6.95%**

Natural Gas

Natural Gas

Building 1 m3 2009	Building 2 m3 2009	Building 1 m3 2010	Building 2 m3 2010
107436.50	56822.35	104937.10	56822.35
90358.67	43814.99	90281.31	43814.99
79068.02	35317.56	64097.63	35317.56
48494.78	20330.96	40009.54	20330.96
23672.95	14905.79	25990.60	14905.79
15118.83	8751.21	17344.03	8751.21
14269.54	7662.75	21485.96	7662.75
12643.61	7579.70	11754.03	7579.70
17926.63	4156.27	12047.66	7675.69
42414.17	10801.93	26314.72	15075.51
54483.02	33084.20	64708.75	33084.20
93605.78	51147.51	106165.67	51147.51

	Building 1 Average	Building 2 Average	
Jan	106186.80	56822.35	86.88%
Feb	90319.99	43814.99	106.14%
Mar	71582.82	35317.56	102.68%
Apr	44252.16	20330.96	117.66%
May	24831.78	14905.79	66.59%
Jun	16231.43	8751.21	85.48%
Jul	17877.75	7662.75	133.31%
Aug	12198.82	7579.70	60.94%
Sep	14987.15	5915.98	153.33%
Oct	34364.44	12938.72	165.59%
Nov	59595.88	33084.20	80.13%
Dec	99885.72	51147.51	95.29%
		Average	**104.50%**

APPENDIX C – MBE and RSME

Mean Bias Error (MBE)

$$\frac{Actual - Model}{Actual} = MBE$$

Root Square Mean Error (RSME)

$$\sqrt{\frac{\sum_{i=1}^{n}(x_{1,i} - x_{2,i})^2}{n}}. \quad = \text{RSME}$$

x1 = Actual

x2 = Model

n = Number of days per month

Coefficient of Variation (CV) RSME

$$\frac{RSME}{X} = (CV)\ RSME$$

X = Mean

(CV) RSME Examples

July 2010

Elec

July

	Resi	Deactivated	Cooling	CAE	Total OBS kWh	%	Remainder kWh	Total Actual kWh	Model kWh		MBE	RSME
1	2555.839	178.97	1252	1205.135	3939.944	0.023318256	2182	6122	7263.475		-18.64%	1301971.91
2	2390.888	165.535	1539	1309.102	3865.525	0.022877813	2141	6007	7468.184		-24.33%	2135665.04
3	2624.937	184.527	2713	1993.484	4802.948	0.028425879	2661	7463	7572.157		-1.46%	11808.2373
4	2828.478	184.527	4426	2430.562	5443.567	0.032217334	3015	8459	7618.844		9.93%	705819.332
5	2542.114	80.413	6000	2844.288	5466.815	0.032354925	3028	8495	7223.725		14.97%	1616395.75
6	2954.107	113.301	7941	3343.211	6410.619	0.037940757	3551	9962	7717.961		22.52%	5034431.93
7	2926.929	106.174	7980	3362.085	6395.188	0.03784943	3543	9938	8246.068		17.02%	2861741.09
8	2885.893	97.851	8274	3452.239	6435.983	0.038090872	3565	10001	8645.565		13.55%	1837554.05
9	2769.945	83.609	5369	2786.716	5640.27	0.033381505	3124	8765	8544.636		2.51%	48401.3789
10	2779.495	157.95	4749	2820.496	5757.941	0.034077932	3190	8947	7629.767		14.73%	1736401.19
11	3029.241	186.651	4930	2405.049	5620.941	0.033267108	3114	8735	7863.063		9.98%	759582.032
12	2725.836	189.985	5008	2688.479	5604.3	0.03316862	3104	8709	8029.387		7.80%	461525.832
13	2708.271	195.878	5635	2850.077	5754.226	0.034055945	3187	8942	8230.371		7.96%	506017.228
14	2658.137	179.938	5605	2820.496	5658.571	0.033489818	3135	8793	7367.473		16.21%	2032349
15	2755.927	186.36	5965	2911.416	5853.703	0.034644692	3243	9096	7330.945		19.41%	3116482.28
16	2728.908	192.395	6098	2871.875	5793.178	0.03428648	3209	9002	7374.396		18.08%	2649905.18
17	2928.103	179.507	6169	2871.121	5978.731	0.035384661	3312	9291	7496.676		19.31%	3218117.03
18	3078.178	179.507	5098.5	2496.9	5754.585	0.03405807	3188	8942	7589.087		15.13%	1831125.19
19	2690.785	196.978	4964.5	2623.08	5510.843	0.032615502	3053	8564	7827.317		8.60%	541991.011
20	2570.79	210.852	4250	2452.94	5234.582	0.030980472	2900	8134	7276.18		10.55%	736240.311
21	2774.618	154.015	4948	2614.805	5543.438	0.032808413	3071	8614	6846.29		20.52%	3125392.8
22	2633.388	184.76	4865	2559.931	5378.079	0.031829748	2979	8357	6704.861		19.77%	2730257.7
23	2608.918	201.849	5092	2900.361	5711.128	0.033800873	3164	8875	6993.828		21.19%	3537860.76
24	2801.57	195.789	5065	2972.929	5970.288	0.035334692	3307	9277	7060.274		23.90%	4915945.62
25	2964.935	162.72	3201	1882.77	5010.425	0.029653816	2775	7786	7309.282		6.12%	227162.832
26	2635.208	199.272	4561	2357.79	5192.27	0.030730052	2876	8068	7155.435		11.32%	833640.535
27	2617.085	189.616	4936	2578.53	5385.231	0.031872077	2983	8368	7061.125		15.62%	1708769.02
28	2670.417	188.411	4753	2777.002	5635.83	0.033355228	3122	8758	6285.742		28.23%	6110772.34
29	2589.46	172.27	4064	2242.955	5004.685	0.029619844	2772	7777	6471.448		16.79%	1704409.65
30	2420.537	170.677	3190	1954.34	4545.554	0.026902513	2518	7064	7248.42		-2.62%	34189.287
31	2467.165	156.282	2743	2041.085	4664.532	0.027606675	2584	7248	7395.472		-2.03%	21629.8269
	84316.102			79421.249	168963.92	1	93595.81304	262559.733	230847.454	average	11.05%	

EMS Consumption	EMS-Obs
262560	93596

Total MBE 0.1207812

Mean 8469.66881

SUMMATION	58093555.4
Spread	1873985.66
RSME	1368.93596
(CV) RSME	16.16%

December 2010

Elec

Dec

	Resi	Deactivated	Cooling	CAE	Total OBS kWh	%	Remainder kWh	Total Actual kWh	Model kWh		MBE	
1	2459.351	467.856	0	29.388	2956.595	0.028891514	3040	5997	5981.327		0.26%	237.024163
2	3014.61	471.078	0	30.049	3515.737	0.034355386	3615	7131	5977.688		16.17%	1329676.53
3	3579.971	580.266	0	93.842	4254.079	0.041570381	4374	8628	5975.052		30.75%	7039981.6
4	2805.399	580.266	0	131.326	3516.991	0.03436764	3616	7133	5971.741		16.28%	1349329.52
5	2676.321	440.72	0	131.145	3248.186	0.031740908	3340	6588	5973.257		9.33%	378084.671
6	2594.159	399.45	0	129.07	3122.679	0.030514468	3211	6334	5956.235		5.96%	142391.479
7	2599.944	397.056	0	129.07	3126.07	0.030547604	3214	6340	5924.33		6.56%	173164.81
8	2499.792	378.614	0	129.277	3007.683	0.02939074	3093	6100	5971.263		2.12%	16661.3822
9	2955.737	444.399	0	130.462	3530.598	0.034500606	3630	7161	5972.524		16.60%	1412346.56
10	3227.265	490.344	0	128.383	3845.992	0.037582601	3955	7801	5975.485		23.40%	3331207.91
11	2722.05	365.006	0	127.921	3214.977	0.031416394	3306	6521	5973.721		8.39%	299280.823
12	2520.692	387.258	0	128.175	3036.125	0.029668672	3122	6158	5970.836		3.04%	35041.4243
13	2604.771	372.041	0	126.876	3103.688	0.03032889	3191	6295	5952.354		5.44%	117450.42
14	2497.274	376.91	0	124.953	2999.137	0.029307229	3084	6083	5916.932		2.73%	27581.4128
15	2418.494	376.91	0	124.86	2920.264	0.028536491	3003	5923	5967.889		-0.76%	2011.95933
16	2878.615	408.471	0	126.052	3413.138	0.033352801	3510	6923	5969.679		13.77%	908262.911
17	3173.482	468.152	0	125.149	3766.783	0.03680858	3873	7640	5963.383		21.95%	2811007.03
18	2641.392	368.388	0	127.132	3136.912	0.030653551	3226	6362	5962.67		6.28%	159824.912
19	2648.418	365.44	0	127.552	3141.41	0.030697505	3230	6372	5961.173		6.44%	168429.113
20	2559.971	370.401	0	129.594	3059.966	0.029901644	3146	6206	5945.603		4.20%	68007.3177
21	2623.874	387.876	0	126.333	3138.083	0.030664994	3227	6365	5913.686		7.09%	203527.448
22	2540.727	329.357	0	124.931	2995.015	0.02926695	3080	6075	5956.831		1.94%	13880.8615
23	2842.301	418.778	0	124.723	3385.802	0.033085676	3481	6867	5954.654		13.29%	832855.117
24	3138.765	452.803	0	125.633	3717.201	0.03632407	3822	7539	5960.449		20.94%	2493161.95
25	2753.379	350.23	0	122.89	3226.499	0.031528985	3318	6544	5972.923		8.73%	326307.344
26	2711.948	335.551	0	127.64	3175.139	0.031027101	3265	6440	5971.92		7.27%	219084.944
27	2681.58	358.019	0	129.39	3168.989	0.030967004	3259	6428	5958.593		7.30%	219884.419
28	2752.904	350.94	0	132.211	3236.055	0.031622365	3327	6564	5922.461		9.77%	410979.93
29	2509.016	370.802	0	131.182	3011	0.029423153	3096	6107	5964.136		2.34%	20430.0403
30	2934.261	402.233	0	130.682	3467.176	0.033880854	3565	7032	5962.094		15.22%	1145362.33
31	3311.571	452.551	0	132.284	3896.406	0.038075241	4006	7903	5962.694		24.55%	3764387.84
	85878.034			3738.175	102334.375	1	105225.625	207560	184763.583	average	10.24%	

EMS Consumption	EMS-Obs
207560	105226

Total MBE 0.10983049

Mean 6695.48387

SUMMATION	29419841
Spread	949027.13
RSME	974.180235
(CV) RSME	14.55%

APPENDIX D – Energy Model Calibration Analysis

Electricity

	Building 2	EE4	Mean Bias Error	
Jan	195964.7	184764	5.72%	Calibrated
Feb	175161.9	166818	4.76%	Calibrated
Mar	193026.3	184481	4.43%	Calibrated
Apr	185201.7	178468	3.64%	Calibrated
May	202339.6	185239	8.45%	Calibrated
Jun	224451.1	210985	6.00%	Calibrated
Jul	254407.1	230632	9.35%	Calibrated
Aug	254887.0	226465	11.15%	Not Calibrated
Sep	228062.5	199802	12.39%	Not Calibrated
Oct	206574.2	185097	10.40%	Not Calibrated
Nov	195727.4	178486	8.81%	Calibrated
Dec	210516.9	184619	12.30%	Not Calibrated
		Average	**8.12%**	

1 Therm	=105.51	MJ
1 MJ	=0.0261084	m3

Energy Model Therms	Energy Model MJ	Energy Model m3
21184	2235123.8	58355.5
18403	1941700.5	50694.6
15311	1615463.6	42177.1
9396	991371.9	25883.1
6164	650363.6	16979.9
4788	505181.8	13189.4
4580	483235.8	12616.5
4677	493470.2	12883.7
5034	531137.3	13867.1
8313	877104.6	22899.7
12735	1343669.8	35081.0
18857	1989602.0	51945.3

Natural Gas

	Building 2	EE4	Mean Bias Error	
Jan	56822.3	58355.1	-2.70%	Calibrated
Feb	43814.9	50694.3	-15.70%	Not Calibrated
Mar	35317.5	42176.9	-19.42%	Not Calibrated
Apr	20330.9	25882.9	-27.31%	Not Calibrated
May	14905.7	16979.8	-13.91%	Not Calibrated
Jun	8751.2	13189.4	-50.72%	Not Calibrated
Jul	7662.7	12616.4	-64.65%	Not Calibrated
Aug	7579.7	12883.6	-69.98%	Not Calibrated
Sep	5915.9	13867.0	-134.40%	Not Calibrated
Oct	12938.7	22899.6	-76.99%	Not Calibrated
Nov	33084.2	35080.8	-6.04%	Calibrated
Dec	51147.5	51945.0	-1.56%	Calibrated
		Average	**-40.28%**	

Boiler Isolation

Actual - Whole Building	40086.2
Model - Whole Building	44022.5
DHW Actual Baseline	7477.4
DHW Model Baseline	13139.1
Actual Whole building minus DHW	32608.8
Model Whole building minus DHW	30883.4
	5.29%