ENERGY CONSUMPTION IN MID- TO HIGH-RISE RESIDENTIAL BUILDINGS BOTH BEFORE AND AFTER ENCLOSURE REHABILITATION – A TOP-DOWN APPROACH

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ABSTRACT

In completing a major study of energy use in mid- to high-rise multi-unit residential buildings (MURBs) in BC, it was noted that there were a number of unexpected or unusual aspects to energy usage in this type of building. For example, energy data that was provided by the electrical and gas utility contained anomalies. On roughly a monthly cycle the following energy data was provided: the suites' electrical consumption (all suites together as one reading), the common areas electrical consumption (all common areas are provided as one reading), and gas consumption (usually from one meter reading). This data was correlated, normalized and then standardized in order to assemble annual and monthly records that were subjected to statistical analysis.

Six building are presented as case studies, each having a minimum of two years of energy data both before and after a full-scale building enclosure rehabilitation (replacement of exterior wall, window and roof assemblies to address moisture related deterioration). They are compared from the standpoint of energy use – site energy only. These buildings were extracted from a larger study of 62 buildings. It is important to note that reducing energy consumption was not one of the primary design criteria for the rehabilitation. Rather, the primary design criteria were water penetration resistance and durability of the assemblies.

In doing a top-down assessment of each building the total energy use is known (as opposed to a bottom-up approach where one has to know, assume or guess the consumption of each and every appliance or piece of equipment). Avoiding any assumption, one can arrive at monthly and annual estimates of suite electricity, common area electricity (elevators and other equipment, lighting, heating, etc.), and gas consumption (conditioning of ventilation air, domestic hot water, fireplaces, etc.). At the very least, a baseline amount and a variable amount of energy can be derived for each yearly period. This energy is for groups of end-uses and can be plotted against degree days or any other time or weather related axis. This paper presents an alternate energy analysis technique, and a number of conclusions can be drawn, some of them quite surprising when analyzing energy use in this manner. The analysis presented here complements the findings from the larger study where several alternate energy analysis techniques were used to analyze energy consumption end-use for each of the MURBs. This paper is best read in conjunction with the larger study report (RDH 2011).

INTRODUCTION

In a survey of 62 mid- to high-rise condominium MURBs in British Columbia, six buildings were chosen for further study. They had the following features in common:

- mid- to high-rise buildings – greater than 4 stories,
- similar residential suites – not social nor rental housing,
- privately owned – condominiums or strata,
- had undergone building enclosure rehabilitations (walls, windows and roofs),
- at least two years of delivered energy data both before and after enclosure rehabilitation, and
- are heated but not cooled, being located in a temperate climate.

This paper deals with the analysis of these six buildings and compares the energy performance of each with respect to pre- and post-enclosure rehabilitation. The buildings are assigned numbers for confidentiality.

DATA MANAGEMENT

The data and its initial analysis are covered in this section. Serving as an example the information on Building #62 is used. A similar process was adopted for Buildings #7, #17, #18, # 19, and #20, all of which had well defined pre- and post-enclosure rehabilitation stages.

Data

Monthly billing data was reported by the respective gas (Terasen Gas) and electric (BC Hydro) utilities. Ten years of data were generally supplied with a minimum of two years of complete data for the pre- and post-enclosure rehabilitation required for further analysis. This data was generally consistent, but there were a number of anomalies:

1. The gas readings were based on one meter for the whole building or complex. This usually included the roof-mounted make-up air ventilation system, the domestic hot water (DHW) heating system, and, if present, gas fireplaces in the suites. The common area electricity load was usually based on one meter which included the elevators and stairways, other loads common to the foyers and amenity spaces, the parking garage, outdoor lighting and corridors. The suite electric data was reported for each suite which included the normal cooking, washing, lighting and usual miscellaneous plug loads. The summed total data for all suites is reported in this analysis.
2. Readings were taken no more than 62 days apart. This means that for the analysis in this paper, where an intermediate reading was not taken the intermediate monthly billing was based on an estimate or an accounting guess.
3. Readings were dated but were by no means on the same day of each month.
4. Gas readings are for the amount of delivered gas. To obtain the amount of gas consumed in each activity would require individual metering of gas-powered equipment. Similarly, with electrical consumption we cannot ascertain the energy used for each individual device. Rather than assume any values, we use a top-down (as opposed to a bottom-up) analytical approach in this report. This report thus complements the other reports in the overall study, some of which use computer modeling to develop much greater detail with regard to energy use (Finch et al 2009, Hanam et al 2011, RDH 2011).
5. The readings vary, sometimes by a great deal, and these variations may or may not have a known cause. Meters malfunction or fail and have to be replaced from time to time and may result in erroneous data. To preserve a degree of statistical consistency the following approach was taken: where annual totals diverged by more than one standard deviation from their norm all energy data for the same year was ignored in this analysis approach.

The readings had to be correlated (for irregularities and gross statistical error), normalized (monthly and annually) and standardized (12 'months' of equal duration, in kWh or ekWh (equivalent kilowatt hours) for gas). The August 1st to July 31st analysis period was used so that it encompassed a full heating season.

Graphs

Graphs may be plotted of the consumption of gas or electricity per standard month versus time in twelve equal periods, for relevant years on the record. Each graph was plotted both as a histogram and as smooth, joined lines. The former provided accuracy while the latter provided continuity. The period of building enclosure rehabilitation was known for certain monthly periods. This period differentiated the pre- enclosure rehabilitation from the post- enclosure rehabilitation stage. The year(s) of data during this rehabilitation phase are excluded from the detailed analysis. A service system adjustment (SSA) stage is designated when a known major change to one or more service systems affects the energy consumption (i.e. boiler replacement, elevator repair, domestic hot water upgrade (i.e. continuous to on-demand system) a modification to the ventilation system, etc.). These years, when clearly reported and visible, are also excluded from the data considered for detailed analysis. These features and stages are shown in Figures 1 to 4 for Building #62 with the rehabilitation period denoted from May 2004 through May 2005.

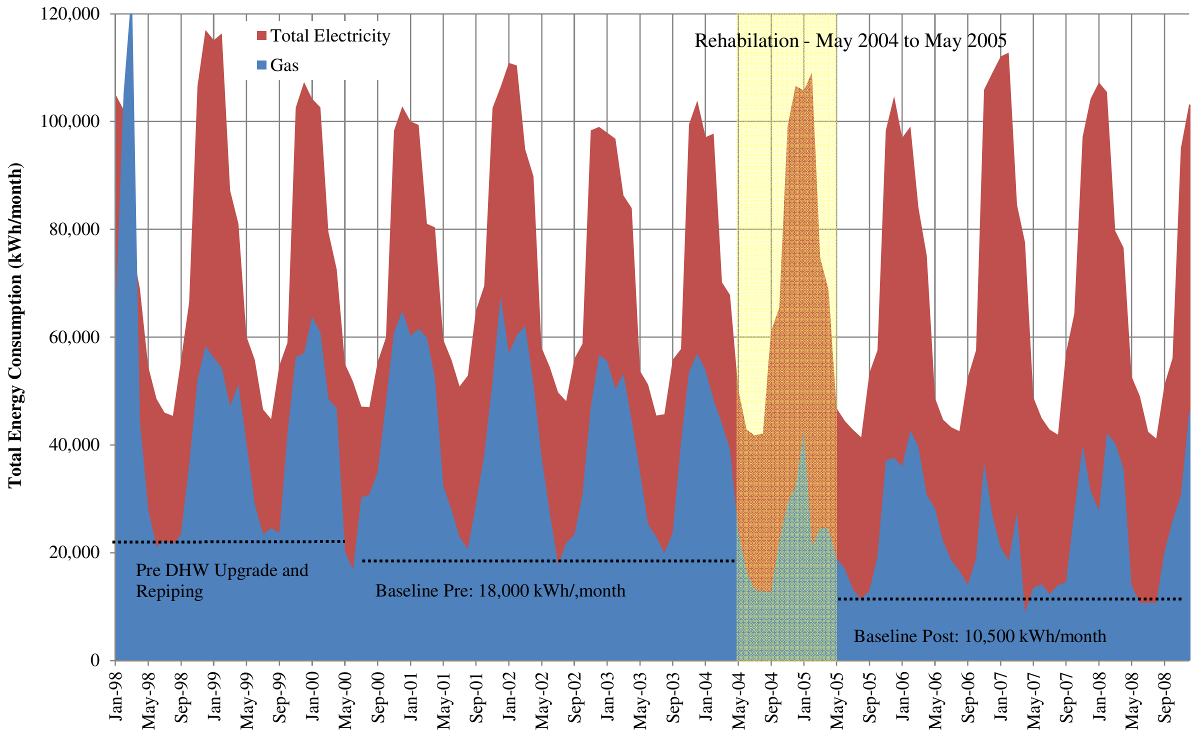

Figure 1. Monthly Electricity and Gas Energy Consumption Comparison – Building 62

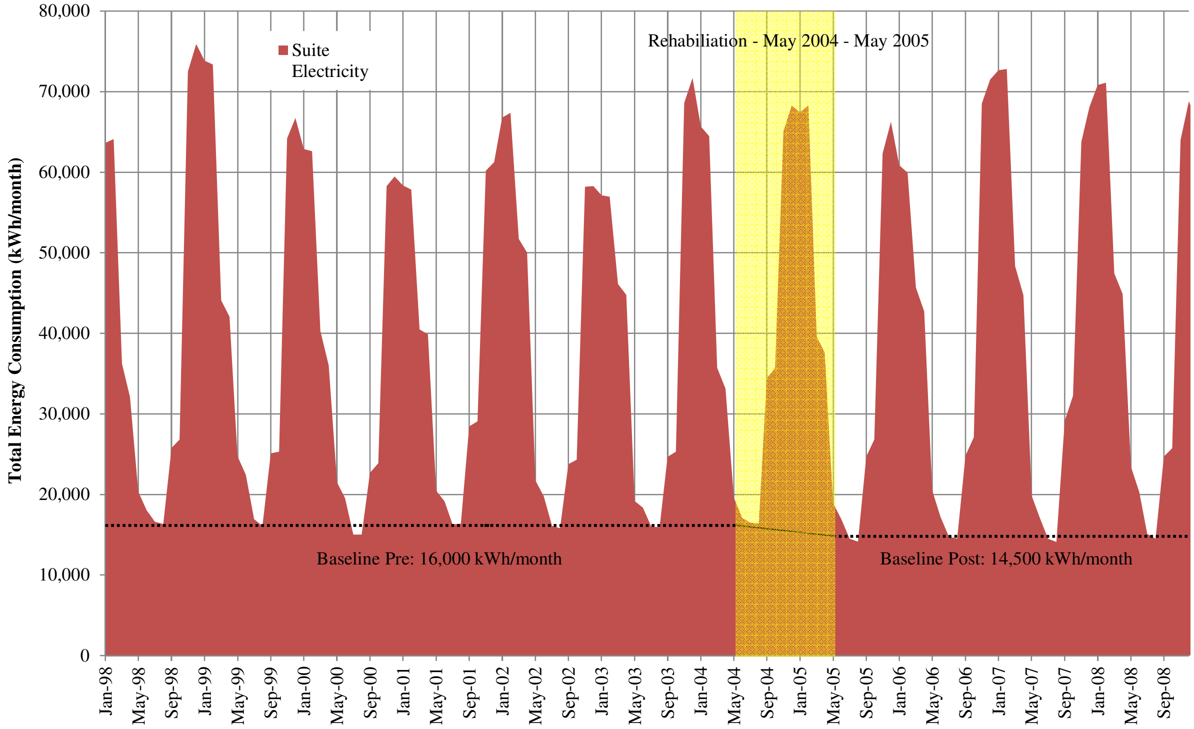

Figure 2: Monthly Suite Electricity Consumption – Building 62

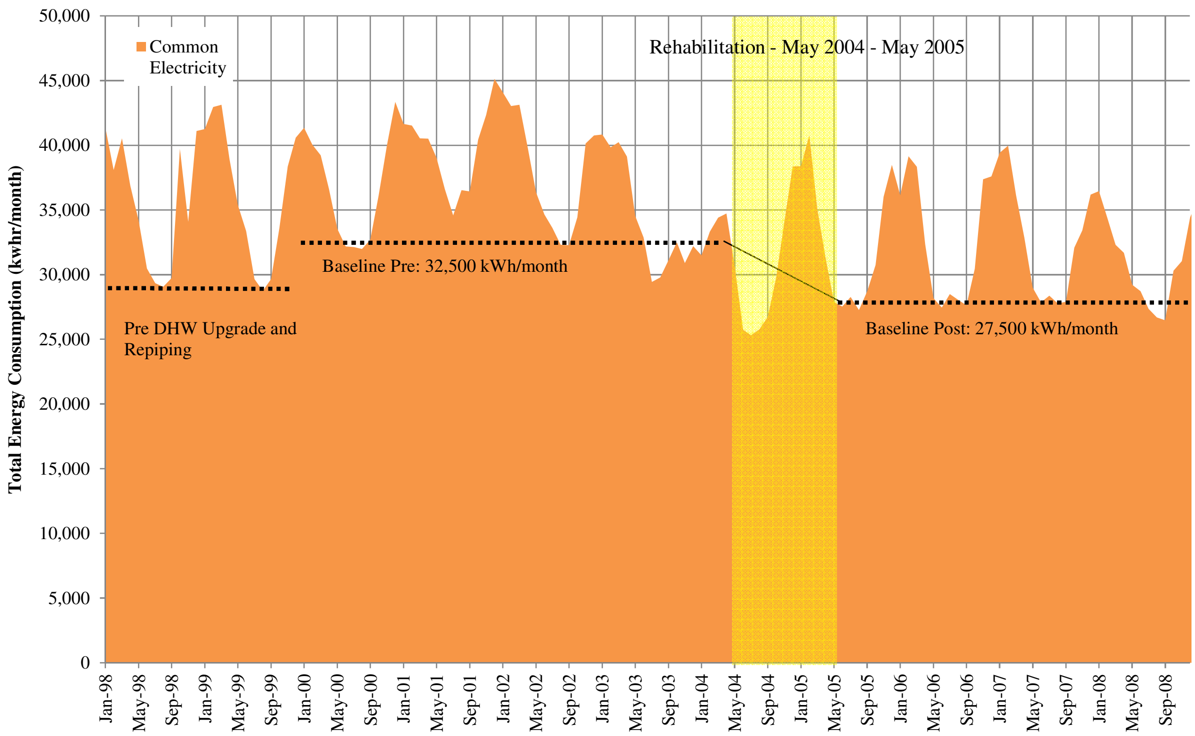

Figure 3: Monthly Common on Area Electricity Consumption

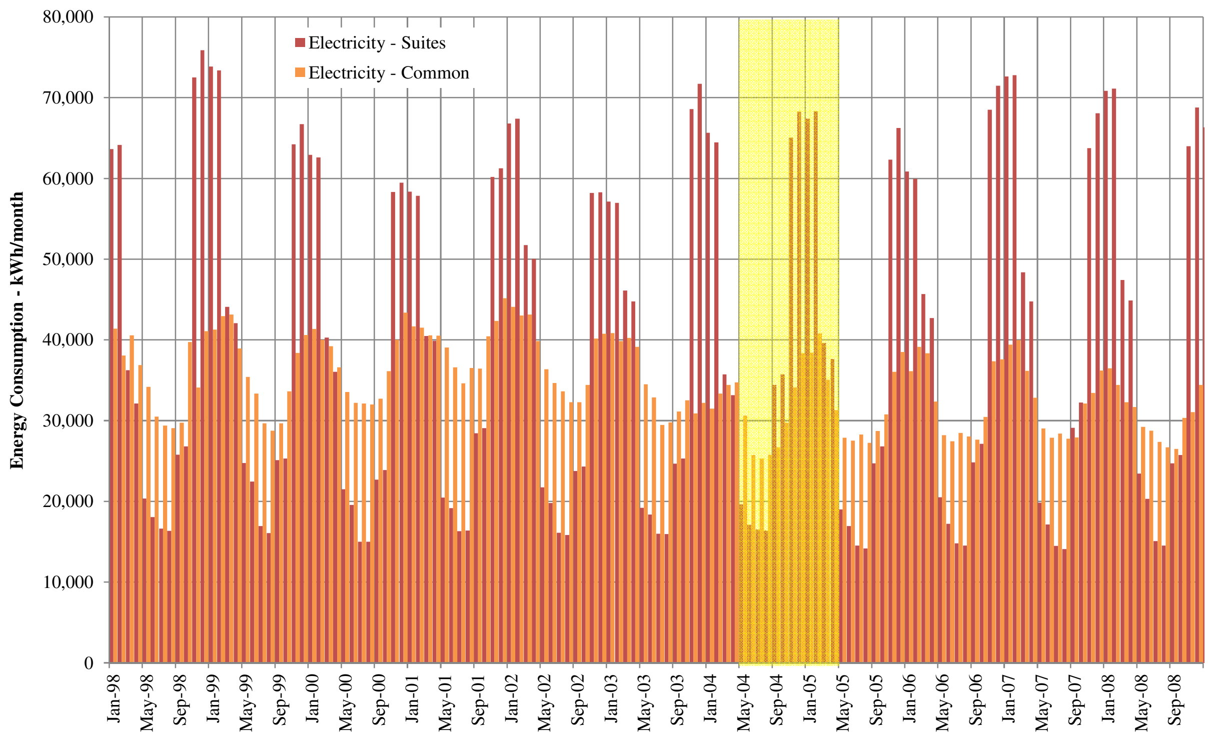

Figure 4: Monthly Energy Consumption Comparison

Baselines

On the three graphs showing consumption of gas, electricity in suites, and electricity elsewhere in the building (i.e. common areas, stairways and elevator shafts) the pre- and post-enclosure rehabilitation phases are clearly visible on either side of the rehabilitation period. Recall that the buildings are heated, but not air-conditioned and hence do not have a summertime cooling load. The graphs clearly show an annual pattern of a base load and a variable peak load. This pattern is not as consistent for the variable common electric load each year. However, the amount of common electricity consumed, especially in the variable peak load, is generally the smallest of the three.

For the three continuous plots of gas, suite electricity and common electricity (Figures 1, 2 and 3) it is remarkably simple to establish, visually, the best fit to the bottom of each valley (approximately July and August of each year) for the baselines for both the pre- and post-rehabilitation stages for each of the three energy categories. For comparison, this baseline value is very close to the number determined by different statistical regression techniques. These baselines represent at least two things:

1. Below the baseline the consumption is effectively constant, and above it the demand or load is not. This variable amount generally changes with the temperature (the monthly HDD) is listed) as well as the wind speed and direction, rain and snow and the outdoor climate in general (Table 1).
2. The stage at which very little or no space heat is required does not mean that energy is not provided. Gas and electricity for DHW and for space heat in the suites (cold days, gas pilot lights particularly for fireplaces, etc.) are still needed.

Data Analysis

Based on the two or more years (1st August to 31st July) of pre- and post-enclosure rehabilitation data, a set of averages can be developed. Table 1 shows a set of averages for building #62. Note that the energy consumption has not been normalized for weather conditions (HDD) using this technique. The HDD information is provided in Table 1 for reference only.

Table 1: Building 62 Energy Consumption Analysis

ANNUAL SUMMARY			CONSUMPTION ANALYSIS AND DISTRIBUTION					
Time Period		Years of Data	Gas Total/Year kwhr	Electrictiy Suites kwhr	Electricity Common kwhr	Electricity Total kwhr	Total Energy Building kwhr	Annual HDD 18C
Aug 1998 - Jul 1999		SSA	493,244	514,762	438,385	953,147	1,446,391	2,804
Aug 1999 - Jul 2000		SSA	490,708	455,222	426,045	881,267	1,371,975	2,812
Aug 2000 - Jul 2001		1	556,741	431,754	458,559	890,313	1,447,055	2,929
Aug 2001 - Jul 2002		2	520,929	488,741	475,544	964,285	1,485,214	2,884
Aug 2002 - Jul 2003		3	466,472	438,817	436,783	875,599	1,342,072	2,629
Aug 2003 - Jul 2004			433,409	458,328	372,074	830,402	1,263,810	2,567
Aug 2004 - Jul 2005	Rehab		271,099	483,111	383,842	866,953	1,138,051	2,630
Aug 2005 - Jul 2006		4	336,165	455,838	391,295	847,133	1,183,297	2,685
Aug 2006 - Jul 2007			228,903	496,384	394,686	891,070	1,119,973	2,806
Aug 2007 - Jul 2008		5	308,602	500,325	377,538	877,863	1,186,465	3,037
Average of 7 years			**407,317**	**467,169**	**415,211**	**882,381**	**1,289,698**	**2,791**
Standard Deviation			110,231	29,473	36,715	43,771	133,305	149
Coefficiant of Variation			27.1%	6.3%	8.8%	5.0%	10.3%	5.3%
**Data outside one standard deviation (highlighted in blue) have been eliminated in the averages below								
Pre-Upgrade Avg		1, 2 3	514,714	453,104	456,962	910,066	1,424,780	2,814
SD Pre-Upgrade			45,454	31,064	19,430	47,528	74,125	162
CV Pre-Upgrade			8.8%	6.9%	4.3%	5.2%	0.052	5.8%
Post-Upgrade Avg		4, 5	322,383	478,081	384,417	862,498	1,184,881	2,861
SD Post-Upgrade			19,490	31,457	9,727	21,730	2,240	249
CV Post-Upgrade			6.0%	6.6%	2.5%	2.5%	0.002	8.7%

			MONTHLY BASELINE (DETERMINED GRAPHICALLY)			ANNUAL BASELINE			TOTAL ANNUAL VARIABLE ENERGY (TOTAL ANNUAL - ANNUAL BASELINE)			TOTAL ANNUAL ENERGY USAGE			
			Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	SUM
Pre-Enclosure Retrofit		1, 2, 3	18,000	16,000	32,500	216,000	192,000	390,000	298,714	261,104	66,962	514,714	453,104	456,962	1,424,780
Post-Enclosure Retrofit		4, 5	10,500	14,500	27,500	126,000	174,000	330,000	196,383	304,081	54,417	322,383	478,081	384,417	1,184,881
% Change			42%	9%	15%	42%	9%	15%	34%	-16%	19%	37%	-6%	16%	
% Change Relative to the total*						6.3%	1.3%	4.2%	7.2%	-3.0%	0.9%	13.5%	-1.8%	5.1%	

*total refers to the average for all years of the total energy in the building: This value is 1,424,780 kWh

% Overall Savings		16,8%
Overall Savings (kWh/ year)		239,899

Example Building #62

For Building #62, two years 1998-99 and 1999-2000 are not included because mechanical modifications to the domestic hot water system were made (SSA or service system adjustment). Also note that before the enclosure rehabilitation was implemented, the entire 2003-04 data is left out of the detailed analysis because the common electrical amount deviates by more than one Standard Deviation. Thus, for the pre-enclosure rehabilitation period:

- the gas baseline is 216,000 kWh annually,
- the suites electric baseline is 192,000 kWh annually,
- the common area electric baseline is 390,000 kWh annually.

The enclosure rehabilitation occurred during the August 2004 to July 2005 period; consequently this entire year was ignored.

After the rehabilitation, for the three years that represent the post-enclosure rehabilitation performance (note that the entire 2006-07 year is left out because the gas amount deviates by more than one Standard Deviation):

- the gas baseline is 126,000 kWh annually,
- the suites electric baseline is 174,000 kWh annually,
- the common area electric baseline is 330,000 kWh annually.

Using the established baselines for the building, the variable energy consumption can now be determined from the data. Accordingly, for Building #62 pre-enclosure rehabilitation:

- the variable gas consumption was 298,714 kWh annually,
- the variable suites electricity was 261,104 kWh annually,

- the variable common area electricity was 66,962 kWh annually.

And, post-enclosure rehabilitation:

- the variable gas consumption was 196,383 kWh annually,
- the variable suites electricity was 304,081 kWh annually,
- the variable common area electricity was 54,417 kWh annually.

Therefore, for the rehabilitation work done on this building the savings in energy is:

- 192,331 kWh or 37% in gas or 13.5% in total energy,
- -24,977 kWh or -5.5% in suite electricity or -1.8% in total energy (a gain),
- 72,545 kWh or 16% in common electricity or 5.1% in total energy.

Adding the above there was an overall annual energy saving of 239,899 kWh. This represents a total savings of 16.8%.

The baseline gas consumption was reduced by 90,000 kWh (mainly DHW) and the variable gas was reduced by 102,331 kWh (the major portion being gas for heating of ventilation air). This indicates that the main savings in energy, 13.5%, was probably due to the DHW over the year and the ventilation system over the winter. It was known that some service system repairs were done at the same time as the enclosure rehabilitation.

The common area electricity was reduced - the baseline by 60,000 kWh or 15% or 4.2% overall and the variable component by 12,545 kWh or 19% or 0.9% overall. The latter is a relatively small amount.

The baseline electricity for the suites was reduced by 18,000 kWh or 9%, or 1.3% relative to the total energy, while the variable component was *increased* by 42,977 kWh or -16%, or -3% overall. As the bulk of the enclosure rehabilitation involved the improved thermal performance (U-value) and the air tightness of the above-grade façade, the fact that the space heating increased seems counter-intuitive. However, with less heat assistance from the common areas (lower supply and less hot ventilation air entering through the openings and cracks in the doors), more heat must be provided from in-suite sources to maintain comfort levels with the result that the variable in-suite energy (heating) is increased. The decrease in gas consumption (13.5%) was sufficient to require an increase in the variable electricity in the suites of 3% overall. *Clearly* there is an exchange of gas-fired ventilation heat in the common areas and the electric heat in the suites in this building. This is demonstrated in further detail using calibrated computer modeling the full report (RDH 2011)

It is now possible to develop tables that may be used to compare buildings. For Building #62 pre- and post-enclosure rehabilitation energy and various pre- and post-enclosure rehabilitation building characteristics are shown in Table 1. Similar tables have been prepared for the other buildings, namely Tables 2, 3, 4, 5, and 6 provided in the Appendix.

Buildings Analysis

Table 7 lists the buildings included in this survey and provides some pertinent facts about them. In addition, the following should be noted:

- None of these buildings were repaired with energy as the major design criteria. Enclosure rehabilitations were largely necessitated by moisture related problems. Rehabilitation was usually very expensive and unavoidable, with the result that the lowest capital cost tended to be the main design criteria.

- MURBs are generally different from other building types, not only in size and shape but also in service systems, use, and maintenance.
- While mid- to high-rise MURBs are a specific building type, there are differences between the six buildings in Table 7. Only four buildings have similar features, and one of them is in Victoria rather than the lower mainland. Building #19 has gas-fired hydronic heating in the suites and #17 has unconditioned make-up air for ventilation and relies on electricity for heating of the common areas and the DHW.
- All of the energy data is site-based as opposed to source (point of generation).
- For these six buildings the average energy savings is 3.8%, ranging from a high of 16.8% to a low of -13.8% (or an increase in energy consumption of 13.8%). This is quite a range and is obviously the result of other factors that out-weigh the gains from the enclosure rehabilitation.
- For comparison, the percent total energy savings determined by statistical methods and weather normalization from the full report (RDH 2011) is compared for the six buildings presented here plus for an additional five buildings for a total of eleven which underwent a similar analysis in Figure 5.

Table 7: Some Details of the Selected Study Buildings and Summary of Total Energy Savings

Building Number	No. of Floors	No. of Suites	Suite Space Heating	Ventilation System	Domestic Hot Water	Percent Total Energy Savings
#62	21	55	Electric baseboards & fireplaces	Gas-heated make-up air	Gas-fired boiler	16.8%
#20	10	58	Electric baseboards & fireplaces	Gas-heated make-up air	Gas-fired boiler	4.0%
#7	15	128	Electric baseboards	Gas-heated make-up air	Gas-fired boiler	-1.6%
#18	22	186	Electric baseboards	Gas-heated make-up air	Gas-fired boiler	-13.8%
#19	10	94	Hydronic baseboards	Gas-heated make-up air	Gas-fired boiler	6.6%
#17	12	68	Gas fireplaces and electric baseboards	Unconditioned make-up air	Electrically heated	10.7%

Another point to note is the mix of gas to total energy and the nature of the change involved. Table 8 shows that Building #17 uses the least gas by far (since only gas fireplaces are present). Building #62 has the largest gas savings. Two buildings use more than 66% gas and two use more than 41% gas.

Table 8: Proportion of Total Gas Energy to Total Energy

Building #	#62	#20	#7	#18	#19	#17
Pre-Rehabilitation	36%	66%	43%	41%	68%	19.4%
Post-Rehabilitation	27%	66%	44%	44%	69%	18.4%

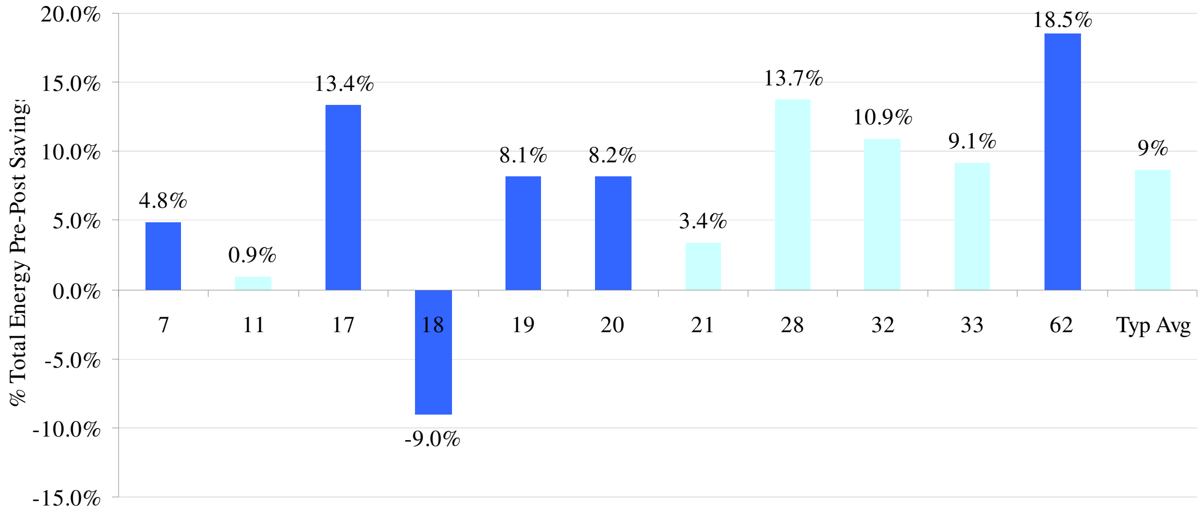

Figure 5: Pre- to Post Rehabilitation Energy Savings Determined by Statistical Methods and Weather Normalization for Comparison (RDH 2011)

In general the total energy savings determined by the method discussed here correspond well with the savings determined using more time consuming statistical methods and weather normalization. It should be noted that the overall percent savings tend to be higher where weather normalization was used only as the 2007-2008 weather year (used in all of the post-rehabilitation cases) had 9% to 10% more heating degree days in Vancouver and Victoria than the average, and the highest, in the 10-year study period. This cooler post-rehabilitation year resulted in higher energy use in all buildings in the study and affects the results here.

Building #20 and #7 each had the same annual baseline gas pre- and post-rehabilitation load which meant that the non-variable loads for DHW, the make-up air heating load for ventilation air, and any pilot lights were unchanged. The annual baseline suite electrical load increased by 1.3% for Building #20 and only the baseline common electrical load decreased by 0.7% for Building #7. For both buildings the main changes occurred in the annual variable gas and electrical loads (i.e. space heat); for #20 a small savings in both fuels, and for #7 a small increase in both fuels. For building #20 it appears that the enclosure rehabilitation was substantial enough to influence the space heat requirements for the suites. However, any energy savings that occurred as a result of the building enclosure rehabilitation at #7 were likely obscured by the interchange of heat from the corridors into the suites, and other service system changes.

On the other hand, the baseline loads for Building #62 all decreased with gas declining the most at 6.3%. With an additional 7.2% savings in the variable gas load, the total gas load decreased 13.5%. Gas accounts for much of the energy saving of 16.8%. This suggests that the rehabilitation in Building #62 incorporated one or more service system adjustments, possibly a change in boilers and perhaps a setpoint adjustment for the DHW or ventilation air. This required an increase in variable suite energy which also led to increased consumption of energy for heating of the corridors to supplement the variable common electrical load.

For Building #19 the repairs to the enclosure seem to have improved the energy consumption with hydronic gas heating and electricity in the suites both being reduced. The common electrical load going down in the summer and up in the heating season suggests a turning down of the setpoint temperature in the corridors as part of the rehabilitation. The total energy saving was 6.6%, which is significant.

Building # 17 also had a significant energy saving of 10.7%. Of this saving 5.8% is due to a reduction in baseline electrical energy to the suites. In addition, the variable gas energy was for fireplaces in each apartment and was reduced by 3.0%. This combined with the reduction of variable electricity shows that the post-enclosure repair has been effective by at least this much.

Building #18 had an increase in energy consumption post-rehabilitation. This result is primarily due to increases in gas consumption (10.9%) for DHW, and make-up air heating for ventilation. Discussions with property management indicate that this increase is likely the result of changes to make-up air unit operation, set point adjustment, and flow adjustment. Enclosure rehabilitation would appear to have been regressive with an increased variable suite energy load. This and a small increase in the common variable electrical load go some way to offset the reduction in variable gas energy which is the only apparent reduction of energy in post-rehabilitation performance. This building is analyzed in much greater detail within the full report (RDH 2011), and interesting suite orientation related effects were found to result in some anomalies.

CONCLUSIONS

The energy consumption of six multi-unit residential buildings (MURBs) have been studied, both pre- and post-rehabilitation (exterior walls, windows and roofs) using a top down approach. For this sample of MURBs, it is evident that the enclosure rehabilitation plus other changes (mainly to the service systems) were instrumental in reducing the total energy used in four buildings and increasing it in two (one when weather normalization was considered). It is apparent that modifications to the service systems can have a greater influence on energy usage (positive or negative) than the enclosure rehabilitation. If the reduction of energy use had been a primary or, even a secondary, design criteria for the enclosure rehabilitation, there is little doubt that the post-rehabilitation performance would have been better (unfortunately, minimizing initial capital cost was typically the primary design criteria). It is also clear that the principal consumers of energy are the service systems in this case the domestic hot water (DHW) and make-up air heat for the ventilation air systems.

Enclosure rehabilitations can be effective at reducing energy consumption. However, the benefits gained can be overshadowed if the service systems are not adequately addressed at the same time. The make-up air heating for the ventilation system is the first priority because it is an inefficient method of ventilating and heating the common areas, particularly the corridors. Although the DHW system may consume less energy than the ventilation system, it also needs to be improved. Improvement however is dependent on cost, both present and future; the relative cost of energy will probably have to increase significantly to alter the status quo. This presumes, of course, that the incentives or subsidies for change are not government and/or utility driven. Another obstacle to a change in strategy is the fact that enclosure rehabilitations often need to done immediately and the cost savings associated with modification of the service systems are time dependent and the savings initially modest.

One point that needs emphasizing is that energy improvements to a building must be made by the service system engineers and the building enclosure engineers acting together and in a cooperative fashion; whether in the rehabilitation of existing buildings or the design of new buildings. Improvements in design are needed, as are the consideration of issues such as compartmentalization, individual metering by suite, heat recovery, better measurement of data, etc.

ACKNOWLEDGMENTS

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APPENDIX: Data Tables for Selected Buildings

Table 2: Building 20

Rehabilitation March 2005 to Dec 2005

ANNUAL SUMMARY		CONSUMPTION ANALYSIS AND DISTRIBUTION					
	Years	Gas Total/Year	Electrictiy Suites	Electricity Common	Electricity Total	Total Energy Building	Annual Heating Degree Days
Time Period	of Data	kWh	kWh	kWh	kWh	kWh	18C
Aug 1998 - Jul 1999		0	259,330	179,472	438,802	438,802	2,804
Aug 1999 - Jul 2000		60,797	274,191	168,304	442,494	503,292	2,812
Aug 2000 - Jul 2001	1	918,572	286,335	177,630	463,965	1,382,537	2,929
Aug 2001 - Jul 2002	2	912,180	300,129	181,257	481,386	1,393,566	2,884
Aug 2002 - Jul 2003	3	893,939	271,970	170,773	442,743	1,336,682	2,629
Aug 2003 - Jul 2004	4	852,955	300,252	168,302	468,554	1,321,509	2,567
Aug 2004 - Jul 2005		864,690	307,995	180,795	488,790	1,353,480	2,630
Aug 2005 - Jul 2006		719,439	296,344	176,358	472,702	1,192,141	2,685
Aug 2006 - Jul 2007	5	840,839	266,364	176,541	442,905	1,283,745	2,806
Aug 2007 - Jul 2008	6	884,537	260,765	179,056	439,821	1,324,358	3,037
Average All Years	**6**	**883,837**	**280,969**	**175,593**	**456,562**	**1,340,399**	**2,809**
SD All Years		**31,352**	**17,148**	**5,010**	**17,161**	**41,085**	**181**
CV All Years		**4%**	**6%**	**3%**	**4%**	**3%**	**6%**
****Data outside one standard deviation has been eliminated in the averages below**							
Pre-Upgrade Avg	4	894,411	289,672	174,490	464,162	1,358,573	2,752
SD Pre-Upgrade		29,542	13,488	5,993	16,070	34,889	181
CV Pre-Upgrade		3%	5%	3%	3%	3%	7%
Post-Upgrade Avg	2	862,688	263,565	177,799	441,363	1,304,051	2,922
SD Post-Upgrade		30,899	3,959	1,778	2,180	28,718	163
CV Post-Upgrade		4%	2%	1%	0%	2%	6%

		MONTHLY BASELINE			ANNUAL BASELINE			TOTAL ANNUAL VARIABLE ENERGY (TOTAL			TOTAL ANNUAL ENERGY USAGE			
	Years of Data	Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	SUM
Pre-Enclosure Retrofit	4	39,000	15,000	14,000	468,000	180,000	168,000	426,411	109,672	6,490	894,411	289,672	174,490	1,358,573
Post-Enclosure	2	39,000	16,500	14,000	468,000	198,000	168,000	394,688	65,565	9,799	862,688	263,565	177,799	1,304,051
% Change		0.0%	-10.0%	0.0%	0.0%	-10.0%	0.0%	7.4%	40.2%	-51.0%	3.55%	9.01%	-1.90%	
% Change Relative to the total*					0.0%	-1.3%	0.0%	2.3%	3.2%	-0.2%	2.34%	1.92%	-0.24%	

*total refers to the pre-upgrade average for the total energy in the building. The value is: 1,358,573 kWh

% Overall Savings	4.0%
Overall Savings (kWh/ year)	54,522

Table 3: Building 7

Rehabilitation Feb 2004 to Oct 2004

ANNUAL SUMMARY		CONSUMPTION ANALYSIS AND DISTRIBUTION					
	Years of	Gas Total/Year	Electrictiy Suites	Electricity Common	Electricity Total	Total Energy Building	Annual Heating Degree Days
Time Period		kWh	kWh	kWh	kWh	kWh	18C
Aug 1998 - Jul 1999		0	549,618	385,507	935,125	935,125	2,864
Aug 1999 - Jul 2000		0	589,083	369,986	959,069	959,069	2,884
Aug 2000 - Jul 2001		456,173	561,580	376,358	937,938	1,394,111	2,996
Aug 2001 - Jul 2002	1	751,246	584,384	368,337	952,721	1,703,967	2,971
Aug 2002 - Jul 2003	2	631,632	522,020	363,046	885,066	1,516,699	2,658
Aug 2003 - Jul 2004	3	620,041	584,821	363,772	948,593	1,568,634	2,652
Aug 2004 - Jul 2005	4	689,970	528,522	354,029	882,552	1,572,521	2,698
Aug 2005 - Jul 2006	5	717,714	564,651	352,211	916,862	1,634,577	2,778
Aug 2006 - Jul 2007	6	594,779	582,952	367,097	950,049	1,544,827	2,897
Aug 2007 - Jul 2008	7	707,072	574,181	356,471	930,651	1,637,723	3,157
Average All Years	**7**	**673,208**	**563,076**	**360,709**	**923,785**	**1,596,993**	**2,860**
SD All Years		**58,030**	**26,855**	**6,437**	**30,102**	**64,661**	**190**
CV All Years		**9%**	**5%**	**2%**	**3%**	**4%**	**7%**
****Data outside one standard deviation has been eliminated in the averages below**							
Pre-Upgrade Avg	2	691,439	553,202	365,692	918,894	1,610,333	2,815
SD Pre-Upgrade		84,579	44,098	3,741	47,839	132,418	222
CV Pre-Upgrade		12%	8%	1%	5%	8%	8%
Post-Upgrade Avg	2	712,393	569,416	354,341	923,757	1,636,150	2,878
SD Post-Upgrade		7,525	6,738	3,012	9,750	2225	245
CV Post-Upgrade		1%	1%	1%	1%	0%	9%

		MONTHLY			ANNUAL			TOTAL			TOTAL			
	Years of Data	Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	SUM
Pre-	2	25,500	28,500	30,200	306,000	342,000	362,400	385,439	211,202	3,292	691,439	553,202	365,692	1,610,333
Post-	2	25,500	28,500	29,200	306,000	342,000	350,400	406,393	227,416	3,941	712,393	569,416	354,341	1,636,150
% Change		0.0%	0.0%	3.3%	0.0%	0.0%	3.3%	-5.4%	-7.7%	-19.7%	-3.0%	-2.9%	3.1%	
%					0.0%	0.0%	0.7%	-1.3%	-1.0%	0.0%	-1.3%	-1.0%	0.7%	

*total refers to the pre-upgrade average for the total energy in the building. The value is: 1,610,333 kWh

% Overall Savings	-1.6%
Overall	-25,817

Table 4: Building 18

August 2006 - July 2007

ANNUAL SUMMARY		CONSUMPTION ANALYSIS AND DISTRIBUTION					
	Years	Gas Total/Year	Electrictiy Suites	Electricity Common	Electricity Total	Total Energy Building	Annual Heating Degree Days
Time Period	of Data	kWh	kWh	kWh	kWh	kWh	18C
Aug 1998 - Jul 1999		0	829,337	541,632	1,370,969	1,370,969	2,804
Aug 1999 - Jul 2000		69,056	791,162	530,800	1,321,963	1,391,018	2,812
Aug 2000 - Jul 2001		961,296	775,254	529,537	1,304,791	2,266,087	2,929
Aug 2001 - Jul 2002	1	980,749	819,932	545,009	1,364,941	2,345,690	2,884
Aug 2002 - Jul 2003	2	956,575	796,248	530,451	1,326,699	2,283,274	2,629
Aug 2003 - Jul 2004	3	949,082	837,496	536,412	1,373,908	2,322,990	2,567
Aug 2004 - Jul 2005	4	920,770	825,073	567,292	1,392,365	2,313,135	2,630
Aug 2005 - Jul 2006	5	902,502	874,125	565,515	1,439,641	2,342,143	2,685
Aug 2006 - Jul 2007		1,098,420	925,808	637,872	1,563,680	2,662,100	2,806
Aug 2007 - Jul 2008	6	1,241,892	906,154	577,592	1,483,746	2,725,638	3,037
Aug 2008 - Jul 2009	7	1,063,178	934,609	558,517	1,493,125	2,556,303	2,980
Average All Years	**7**	**1,002,107**	**856,234**	**554,398**	**1,410,632**	**2,412,739**	**2,773**
SD All Years		**117,689**	**50,321**	**17,464**	**62,991**	**164,688**	**190**
CV All Years		**12%**	**6%**	**3%**	**4%**	**7%**	**7%**

Pre-Upgrade Avg	5	941,936	830,575	548,936	1,379,511	2,321,446	2,679
SD Pre-Upgrade		30,720	28,576	16,776	41,272	25,222	122
CV Pre-Upgrade		3%	3%	3%	3%	1%	5%
Post-Upgrade Avg	2	1,152,535	920,381	568,054	1,488,436	2,640,970	3,008
SD Post-Upgrade							
CV Post-Upgrade							

		MONTHLY BASELINE			ANNUAL BASELINE			TOTAL ANNUAL VARIABLE ENERGY			Annual Energy			SUM
	Years of Data	Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Sum
Pre-Enclosure Retrofit	5	45,000	47,000	42,000	540,000	564,000	504,000	401,936	266,575	44,936	941,936	830,575	548,936	2,321,446
Post-Enclosure Retrofit	2	66,000	47,000	42,000	792,000	564,000	504,000	360,535	356,381	64,054	1,152,535	920,381	568,054	2,640,971
% Change		-46.7%	0.0%	0.0%	-46.7%	0.0%	0.0%	10.3%	-33.7%	-42.5%	-22.4%	-10.8%	-3.5%	
% Change Relative to the total*					-10.9%	0.0%	0.0%	1.8%	-3.9%	-0.8%	-9.1%	-3.9%	-0.8%	

*total refers to the pre-upgrade average for the total energy in the building. The value is: 2,321,446 kWh

% Overall Savings	-13.8%
Overall Savings (kWh/ year)	-319,524

Table 5: Building 19

Hydronic Heating system, Rehabilitation March 2004 to Feb 2005

ANNUAL SUMMARY		CONSUMPTION ANALYSIS AND DISTRIBUTION					
	Years of	Gas Total/Year	Electrictiy Suites	Electricity Common	Electricity Total	Total Energy Building	Annual Heating Degree Days
Time Period	Data	kWh	kWh	kWh	kWh	kWh	18C
Aug 1998 - Jul 1999		1,654,402	456,773	240,274	697,047	2,351,448	2,804
Aug 1999 - Jul 2000		1,117,817	471,742	237,642	709,384	1,827,201	2,812
Aug 2000 - Jul 2001		1,643,839	453,468	234,242	687,710	2,331,549	2,929
Aug 2001 - Jul 2002	1	1,533,110	467,448	232,462	699,909	2,233,019	2,884
Aug 2002 - Jul 2003	2	1,480,995	466,515	236,932	703,446	2,184,441	2,629
Aug 2003 - Jul 2004	3	1,509,814	472,521	239,497	712,018	2,221,832	2,567
Aug 2004 - Jul 2005	REHAB	1,332,151	469,434	226,605	696,039	2,028,190	2,630
Aug 2005 - Jul 2006	4	1,433,003	450,174	211,147	661,321	2,094,324	2,685
Aug 2006 - Jul 2007	5	1,446,086	433,960	201,622	635,582	2,081,668	2,806
Aug 2007 - Jul 2008	6	1,410,389	419,835	197,504	617,339	2,027,727	3,025

Average All Years	**9**	**1,469,939**	**454,715**	**225,702**	**680,417**	**2,150,357**	
SD		**157,892**	**17,966**	**17,236**	**34,335**	**163,439**	
CV		**11%**	**4%**	**8%**	**5%**	**8%**	

****Data outside one standard deviation has been eliminated in the averages below**

Pre-Upgrade Avg	3	1,507,973	468,828	236,297	705,124	2,213,097	2,752
SD Pre-Upgrade		26,106	3,232	3,560	6,226	25,440	181
CV Pre-Upgrade		2%	1%	2%	1%	1%	7%
Post-Upgrade Avg	3	1,429,826	434,656	203,424	638,081	2,067,907	2,839
SD Post-Upgrade		18,059	15,182	6,998	22,098	35,367	172
CV Post-Upgrade		1%	3%	3%	3%	2%	6%

		MONTHLY BASELINE (DETERMINED GRAPHICALLY)			ANNUAL BASELINE			TOTAL ANNUAL VARIABLE ENERGY (TOTAL ANNUAL - ANNUAL BASELINE)			TOTAL ANNUAL ENERGY USAGE			
	Years of Data	Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Sum
Pre-Enclosure Retrofit	3	50,000	35,500	19,200	600,000	426,000	230,400	907,973	42,828	5,897	1,507,973	468,828	236,297	2,213,097
Post-Enclosure Retrofit	3	50,000	34,200	16,200	600,000	410,400	194,400	829,826	24,256	9,024	1,429,826	434,656	203,424	2,067,907
% Change		0.0%	3.7%	15.6%	0.0%	3.7%	15.6%	8.6%	43.4%	-53.0%	5.2%	7.3%	13.9%	
% Change Relative to the total*					0.0%	0.7%	1.6%	3.5%	0.8%	-0.1%	3.5%	1.5%	1.5%	

*total refers to the pre-upgrade average for the total energy in the building. The value is: 2,213,097

% Overall Savings	6.6%
Overall Savings (kWh/ year)	145,191

Table 6: Building 17

ANNUAL SUMMARY		CONSUMPTION ANALYSIS AND DISTRIBUTION					
	Years of	Gas Total/Year	Electrictiy Suites	Electricity Common	Electricity Total	Total Energy Building	Annual Heating Degree Days
Time Period	Data	kWh	kWh	kWh	kWh	kWh	18C
Aug 1998 - Jul 1999	1	450,215	694,107	408,764	1,102,871	1,553,086	2,804
Aug 1999 - Jul 2000	2	300,627	687,640	410,948	1,098,589	1,399,215	2,812
Aug 2000 - Jul 2001	3	307,100	766,195	483,750	1,249,945	1,557,045	2,929
Aug 2001 - Jul 2002	4	240,842	740,226	431,687	1,171,913	1,412,755	2,884
Aug 2002 - Jul 2003	5	67,132	721,957	433,551	1,155,508	1,222,640	2,629
Aug 2003 - Jul 2004		154,696	697,236	456,135	1,153,372	1,308,067	2,567
Aug 2004 - Jul 2005		75,332	668,432	442,785	1,111,217	1,186,549	2,630
Aug 2005 - Jul 2006	6	182,867	640,214	433,389	1,073,603	1,256,470	2,685
Aug 2006 - Jul 2007	7	250,306	624,146	420,688	1,044,833	1,295,140	2,806
Aug 2007 - Jul 2008	8	285,666	651,619	412,128	1,063,747	1,349,412	3,037
Average All Years	**8**	**260,594**	**690,763**	**429,363**	**1,120,126**	**1,380,721**	**2,823**
SD All Years		**109,750**	**50,222**	**24,298**	**68,202**	**125,869**	**130**
CV All Years		**42%**	**7%**	**6%**	**6%**	**9%**	**5%**
****Data outside one standard deviation has been eliminated in the averages below**							
Pre-Upgrade Avg	3	282,856	731,354	442,128	1,173,482	1,456,339	2,875
SD Pre-Upgrade		36,529	40,022	37,507	75,690	87,477	59
CV Pre-Upgrade		13%	5%	8%	6%	6%	2%
Post-Upgrade Avg	3	239,613	638,659	422,068	1,060,728	1,300,341	2,843
SD Post-Upgrade		52,227	13,802	10,698	14,620	46,689	179
CV Post-Upgrade		22%	2%	3%	1%	4%	6%

		MONTHLY BASELINE			ANNUAL BASELINE			TOTAL ANNUAL VARIABLE ENERGY			TOTAL ANNUAL ENERGY			
	Years of Data	Gas (kWh/ month)	Suites Electric (kWh/ month)	Common Electric (kWh/ month)	Gas (kWh/ year)	Suites Electric (kWh/ year)	Common Electric (kWh/ year)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	Gas (kWh)	Suites Electric (kWh)	Common Electric (kWh)	SUM
Pre-Enclosure Retrofit	3	0	42,000	31,500	0	504,000	378,000	282,856	227,354	64,128	282,856	731,354	442,128	1,456,339
Post-Enclosure Retrofit	3	0	35,000	31,500	0	420,000	378,000	239,613	218,659	44,068	239,613	638,659	422,068	1,300,341
% Change		0.0%	16.7%	0.0%	0.0%	16.7%	0.0%	15.3%	3.8%	31.3%	15.3%	12.7%	4.5%	
% Change Relative to the total*					0.0%	5.8%	0.0%	3.0%	0.6%	1.4%	3.0%	6.4%	1.4%	

*total refers to the pre-upgrade average for the total energy in the building. The value is: 1,456,339 kWh

% Overall Savings	10.7%
Overall Savings (kWh/ year)	155,998