Energy Consumption in Mid and High Rise Residential Buildings in British Columbia

Graham Finch, MASc, Eric Burnett, PhD & Warren Knowles, P.Eng. [1]

ABSTRACT

Many residential buildings in British Columbia and other parts of North America have, or are, undergoing comprehensive rehabilitation largely to remedy moisture-related problems. For reasons primarily related to short-term cost, little or no attention has been directed at energy conservation strategies and/or, greenhouse-gas emissions. Nevertheless rehabilitation of the building enclosure does present a unique opportunity to examine and assess the actual energy-related performance of the in-service building, and to determine the energy impact of the building enclosure improvements.

To understand the impacts of building enclosure rehabilitation on the energy consumption of mid to high rise residential buildings in the Lower Mainland and Victoria, a large government and industry sponsored research project is currently underway. The principal objectives of the study are to review and assess the actual energy consumption of in-service mid and high rise residential buildings, and the impacts of building enclosure rehabilitation related improvements on the overall energy consumption at these buildings. The results of the study will also be used to develop better building enclosure design strategies that take into account energy conservation, and help reduce greenhouse gas emissions in both new and rehabilitated buildings.

This initial paper on the study presents baseline consumption data from 39 multi-unit residential buildings (MURBs) in the Lower Mainland and Victoria, BC. The data provides an understanding into the current level of energy consumption within mid to high rise residential buildings. The contribution of gas and electricity to overall energy consumption and, specifically, space heat and ventilation are discussed in detail. The disconnect between building energy consumption and billing to occupants for their share of total energy usage is highlighted.

INTRODUCTION

In British Columbia, particularly the Lower Mainland, there is a relatively recent trend for people to choose to live in multi-family mid and high-rise buildings greater than 4 stories in height. The reasons are many and varied: the shortage of suitable land, the climate, the desire to live close to populated centers, the views, etc. The developments may be private or public and tenure may be partial ownership, rental, or social housing. Preference is for individual ownership of each unit with shared ownership of the common areas, i.e., the walls, roofs, corridors, elevators and stairs, foyer, recreation areas, and parking garage. Management is by means of the elected strata council, and maintenance and building operation is typically contracted to property management firms. It is with these types of strata corporations or condominiums, which make up the majority of multi-family residential housing stock, that we are concerned.

The Lower Mainland of BC differs climatically from the rest of Canada. Summers are mild in that air conditioning is rarely necessary and the winters are also temperate and mild, but rain is

---

[1] Graham Finch, Warren Knowles & Eric Burnett - RDH Building Engineering Ltd, Vancouver, BC, Canada

significant in both overall quantity and duration. Both electricity and natural gas are comparatively inexpensive and in good supply. Therefore, buildings tend to be designed and constructed with a high proportion of visible glass, with less consideration given to environmental separation (including thermal bridging) compared to other building functions. These towers typically incorporate reinforced concrete structures, with structural elements also used as components of the building enclosure. Not surprisingly, a number of these buildings have turned out to be “leaky-condos” as well as having poor energy consumption characteristics, and ‘green’ or environmentally challenged.

From the owner’s perspective, the enclosure repairs are usually critical, costly and controversial. Critical because they have to be done and soon in order to keep the buildings safe; costly because they are disruptive and substantial, and controversial because it involves many owners and has social, economic and political ramifications. It happens also that the timing of the enclosure repairs is perhaps the best and only chance to make energy upgrades and also to address some of the “green” issues.

Accordingly, the first step of the study was to gather data on a large number of mid- to high-rise MURBs in the Lower Mainland and Victoria in order to ascertain the pre-enclosure repair energy consumption.

OBJECTIVE

The purpose of this paper is to specifically report and discuss the use of electricity and gas in a large sample of mid to high rise multi-unit residential buildings (MURBs) in the Lower Mainland and Victoria, BC.

BACKGROUND

In Canada, approximately 30% of all secondary energy is consumed in buildings (NRCan 2005). Of this 30%, residential buildings use approximately 16% and commercial and institutional buildings account for approximately 14%. Of the residential portion, 18% is used in apartment buildings. Secondary energy is energy used by final consumers (i.e. operation energy), and does not include the production and intermediate energy.

Energy intensity (total annual gas/electric/other fuel energy consumption per unit area) in buildings has been broken down by region and housing type within Canada by Natural Resources Canada (NRCan 2005). The average energy intensity for all types of households in British Columbia is 0.80 GJ/m^2 (222 kWh/m^2)[2], compared to 1.01 (281 kWh/m^2) for the entire country. Specifically related to low-rise apartment buildings (<5 storeys) in British Columbia, the average energy intensity is 0.86 GJ/m^2 (239 kWh/m^2), compared to 1.10 GJ/m^2 (306 kWh/m^2) for all of Canada. Data for high-rise apartment buildings (>5 storeys) or condominiums was not collected or specifically identified as part of this previous study. The study also found significant differences in the energy consumption in low-rise apartment buildings based on who paid for the energy. Where someone other than the occupant (i.e. landlord or strata corporation) was responsible for paying at least one of the dwellings energy source, the average energy intensity was 1.62 GJ/m^2 (450 kWh/m^2). In contrast, where occupants pay for all of their energy use the

---

[2] SI to IP Conversion: 1 kWh/m^2 = 3.155 kBtu/ft^2, therefore 222 kWh/m^2 is equal to 70.4 kBtu/ft^2
Also, 1 GJ = 277.78 kWh, 1 GJ = 9.48 Therms, 1 kWh = 3412 Btu, 1 Therm = 100,000 Btu

average energy intensity was 0.68 GJ/m2 (172 kWh/m^2). For this and other reasons, social and rental housing was excluded from the survey.

The focus of the study is specifically mid and high rise residential buildings. Data from the 2007 BC Hydro REUS study indicate that approximately 21% of the dwelling units in the Lower Mainland are within mid- and high-rise buildings (>5 stories).

A typical multi-unit residential building in BC uses natural gas and electricity energy sources in both the suites and in the common areas. A schematic of the typical space heating and ventilation system within a MURB is shown in the Appendix. Within each suite, electric baseboard heaters normally provide space heating, and are usually thermostatically controlled. Electricity is also used to power appliances, lights, fans, miscellaneous electrical devices and plug-loads. Natural gas domestic hot water heating is common. Natural gas fired boilers are also typically used in buildings with recreational amenities, including pools and hot-tubs. Distribution systems for domestic hot-water vary in efficiency, and have a significant impact on the amount of gas used. Buildings may also have in-suite fireplaces for aesthetic or partial space heating purposes.

Natural gas is typically used to heat ventilation air using from rooftop gas-fired units which is distributed to the building corridors and suites by positively pressurizing the corridors. In this space heat system, gas-fired roof-top make-up air units (MAUs) heat outdoor air up to 15-21°C (59 to 70°F) year round, which is then ducted down through shafts and to the central corridor spaces on each floor within the building. From the corridors, this pressurized ventilation air is assumed to find its way into suites through door undercuts or other air-leakage pathways. Air is exhausted from individual suites by means of exhaust fans, through air leakage paths (both known and unknown) and occupants opening windows and exterior doors. In reality, this pressurized corridor approach suffers from a number of problems relating to the provision fresh air, as well as the distribution of heat. Air supplied to corridors may or may not find its way into all suites on a floor, as door undercuts may be blocked-off, due to pressure imbalances from wind and stack effect, or the fact that the air supplied to the hallways can more easily flow through elevator and other shaft openings than into the suites.

Two of the buildings in the study are 1980's vintage hydronic heated, with gas-heated hot-water supplied to baseboard heaters within each suite. The pressurized corridor approach is still utilized for ventilation air, but the electric baseboard heaters are replaced with hydronic baseboard heaters.

Study Buildings

For the study a total of sixty-four Multi-Unit Residential Buildings (MURBs) were initially selected for analysis. Fifty-one of the buildings are 10 to 33 storeys (high-rise) and thirteen of the buildings are 5 to 9 storeys (mid-rise), and they were all constructed between 1974 and 2002. Fifty-six of the buildings are located in Metro Vancouver, and eight in Victoria. The buildings were selected to be representative of typical MURB housing stock and contain buildings of forms common to other mid- and high-rise residential buildings in BC.

Data from thirty-nine of these buildings are covered here. Data from the other buildings was unsuitable for this paper due to a number of reasons including namely, missing or erroneous data, metering issues (i.e. single gas or electricity meters for several buildings grouped in complexes), difficulty in splitting consumption in buildings with mixed energy use (condominium plus commercial space on same meter), or lack of available data on the buildings at this time. All of the buildings use a combination of natural gas and electrical energy.

The data represents an approximate total of 4,400 residential suites with 4.6 million square feet of gross floor area where 173,000 GJ of natural gas and 44 million kWh of electricity is used per year. For reasons of confidentiality, buildings are referenced using a number from 1 through 64 for the study.

It needs to be appreciated that the study represents a *top-down* consumed energy analysis, i.e., the meter readings of the supplied energy are recorded and manipulated to assess usage. No consideration is given to the conversion effectiveness or efficiency, seasonal or otherwise, of any device in this phase of the study. Assumptions are few, and stated where they are made. This is quite different from a *bottom-up* analysis which is perforce done on a single building and the assumptions may be many and varied.

Data Analysis Procedure

For each of the buildings, at least 10 years of gas and electricity billing data from 1998 to 2008 was requested. The intent of looking at 10 year data was to understand how climate affects space heating consumption in MURBs, and then during the later parts of the study, capture at least 2-3 years of data post- building enclosure upgrade for comparison of energy savings.

BC Hydro and Terasen Gas are respectively the principal suppliers of electricity and natural gas to the buildings in the survey. Meters are read at fairly regular intervals of not more than 62 days, and the billing cycles are monthly. The metered data is divided by the period in days to obtain an average per day which then may be added in accordance with the calendar and, hence, *calendarized*. Consumption data is not normalized for weather or other effects, and it is as the name implies raw data. While the gas and electricity meters may not be read on the same date, calendarizing the data allows comparison of the monthly consumption for each. Weather normalization of the data will be performed during later phases of the study, to accurately compare the pre and post upgrade energy consumption.

Electricity is metered by suite for each unit (interior lighting, all appliances, heating and domestic hot-water if electric) and the electrical demand on all other devices (rooftop, elevators, all common areas including the pool, recreation rooms and outdoor lighting and parking areas) is read off usually one common meter. For each of the buildings, BC Hydro provided the Common Area consumption and an aggregate Suite consumption which summed all of the suites within the building together.

Natural Gas is normally metered on a single meter for the entire building. This means that all gas fired heating devices, even the fireplaces and domestic hot water and pools (if any), are included in the single reading. At some of the building complexes in the study, a single meter may be used for several buildings, even mixing in some commercial usage. Where the gas metering was mixed or questionable, those buildings were excluded from this study.

Electricity and Natural Gas data is combined in spreadsheets and total monthly energy consumption is calculated. Gas data is provided in GJ, but converted to an energy unit of kWh (1GJ = 277.78 kWh) for comparison and analysis in standard units. Monthly data is compared using a *standardised* month of 365/12 = 30.4167 days long (30.5 days during leap-year) so that all months can be compared equally. Thus the raw data has been both *calendarized* and *standardised.* This is especially relevant when, say, comparing January to February consumption.

Analyzing the annual data, we found that a continuous record from August 1st to July 30th provided the best 12 month period for our “calendar year”, because this completely and continuously covers the heating period. This has no impact on the average annual energy consumption data provided in this report.

As one of the larger goals of the study is to look at the impacts of energy savings from building enclosure rehabilitations, we focused on understanding the impacts of space heating energy. The seasonal heating contribution is clearly evident for both the electric and gas data for all of the buildings. Assuming that the space heating is either turned off or dormant for the summer (July and August) an average for the non-variable data can be established and subtracted from this heating data. This non-variable data baseline includes non-direct space heat usage, including domestic-hot water and gas appliances, for gas and a baseline for electricity, namely electrical appliances including stoves, all lighting, elevators, miscellaneous devices and plug loads, etc. Figure 1 presents total monthly energy consumption and Figure 2 presents total monthly space heat energy for building 31, a typical MURB in the study.

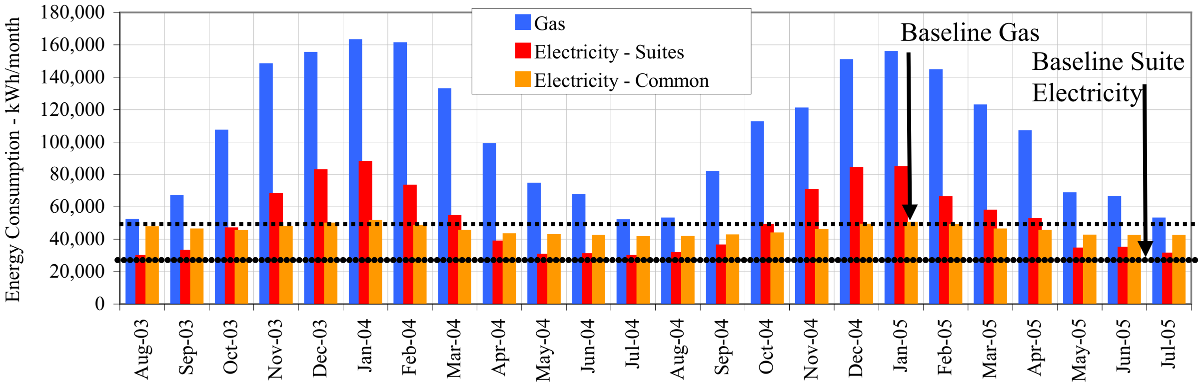

Figure 1: Building 31 – Monthly Energy Consumption, August 2003 to July 2005

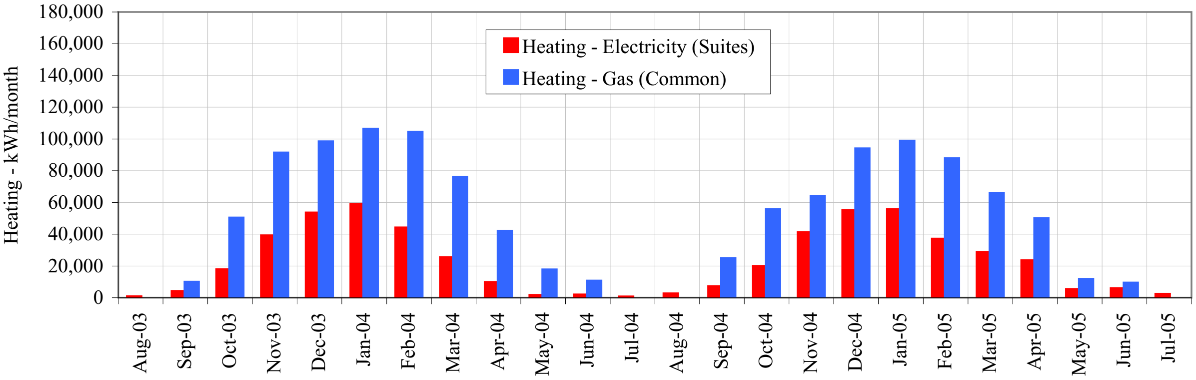

Figure 2: Building 31 – Monthly Space Heat Energy Consumption, August 2003 to July 2005

The assumption that baseline electric loads can be simply removed for the analysis of space heat was tested. Using data from the two gas hydronic heated buildings (#19 and #45); the monthly electricity consumption within a typical MURB can be analyzed without influence of a direct electric space heat component to demonstrate the seasonal variation in lighting and other electricity use. Neither of these buildings has air-conditioning, unless owners have provided their own portable units (which is reportedly uncommon in these units). It is also typical for some owners to purchase small electric space heaters to supplement baseboard heaters, particularly for unheated rooms such as enclosed balconies. The majority of energy used within building #45 is gas, accounting for 72% of the total energy used. Figure 3 plots the monthly common gas and suite and common area electricity consumption demonstrating the small seasonal variation in suite electricity in building #45.

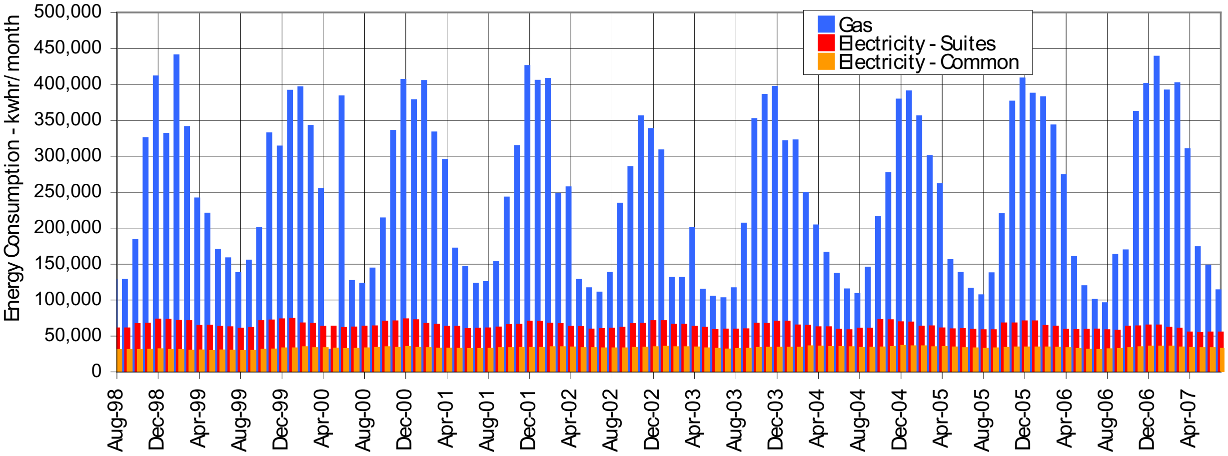

Figure 3: Building 45 – Monthly Suite and Common Area Electricity Consumption, August 1998 to July 2007

In building #45, on average the non-space heat seasonal variation was found to be 8% of the total annual suite electricity (annual range from 3% to 10%) and 4% of the annual common area electricity (range from 2% to 8%). In building #19, on average the non-heat seasonal variation was found to be 5% for the total annual suite electricity (range from 2% to 8%) and 6% for the annual common area electricity (range from 4% to 8%). Note that these percentages provided are for buildings where the space heat is provided by gas.

In buildings with electric baseboards, where we are actually concerned with this seasonal variation, electric baseboard space heat energy accounts for on average 40% of the suite electricity. As the suite electricity load is on average 50% higher in the electric baseboard heated buildings than these two hydronic buildings (due to the space heat portion), the non-heat seasonal variation is estimated to only account for between 1% and 4% of the total electricity. As these non-heat seasonal variations are relatively negligible, and attempting to factor out their contribution would add an unnecessary unknown error, the electric space heat can be determined with reasonable accuracy using the baseline method. Moreover, these seasonal variations in lighting and electricity actually contribute to the heating of the building (i.e. incandescent light bulbs), and in turn offset the required space heat from other mechanical sources.

To assess the impact of the baseline gas assumption, the total energy consumption is plotted versus monthly heating degree days (an indicator of required space heat energy per month) in Figure 4 for building #45. More correctly, the plot should show heating degree days versus space heat load, however as we are attempting to determine the baseline load in the gas for zero space heat, these plots are more useful.

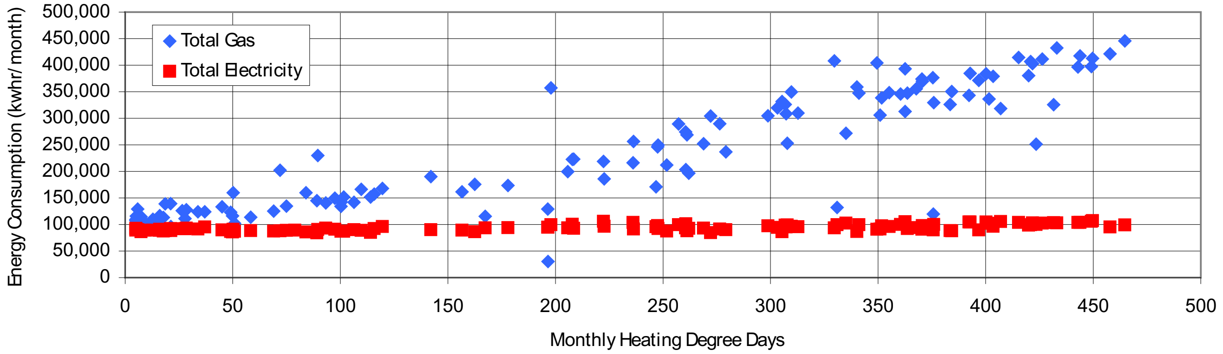

Figure 4: Building 45 – Monthly Electricity and Gas Consumption versus Heating Degree Days (Celcius)

Significant scatter exists in the relationship between gas consumption and heating degree days during the heating months however trends are apparent. Electricity consumption is typically more predictable and correlates well with the heating degree day value. During the summer months (HDD <50) the scatter in gas consumption diminishes, and a baseline energy load for only the domestic hot-water portion of the natural gas becomes apparent, particularly below 10 HDD. An average of the gas consumption at only the lowest HDD values is calculated as an appropriate baseline indicating zero space heat for each building. This is equivalent to weather normalizing the data, and selecting the minimum baseline value. The baseline gas value is the monthly energy required for heating the domestic hot water, cooking with gas stoves, and indoor pool water heating.

Once baseline consumption values of electricity and gas are determined, the monthly total and space heating energy consumption data is determined. This is broken down into the following for each building on a monthly and annual basis:

- Total Gas Consumption
    - Total Gas for Base-line Usage (i.e. for heating of domestic hot-water, gas stoves, heating of indoor pools and hot-tubs)
    - Total Gas for Space Heating (i.e. for heating of ventilation air within rooftop make-up air units, gas for hydronic heated buildings, and for gas fireplaces in some suites).
- Total Electricity Consumption
    - Total Suite Electricity
        - Suite Electricity for other baseline non-primary or non-direct heating uses (i.e. baseline lighting, appliance, and plug loads)
        - Suite Electricity for Space Heating (i.e. Electric baseboards)
    - Total Common Area Electricity

      No baseline was obtained for this as the seasonal difference was small and there was not a clear cut delineator between the two main uses described as follows;
        - Common baseline electricity for other devices (i.e. fans, ventilation systems, pumps, elevators, indoor and outdoor lighting, parking garage etc.)
        - Common variable electricity for space heating (if electric re-heat or baseboard heaters are used in the corridors or elsewhere)

Note that the conversion effectiveness of raw energy purchased to energy consumed in the building can be taken as 100% for electric devices while the seasonal conversion efficiency of the gas heating-plant and appliances depends on the device and varies between about 40% and 90%. At this time during the study, we are only concerned with the supply of energy, and even though 1 GJ of gas purchased does not equal 1 GJ of gas energy output, it does not affect the consumption data reported here.

Statistically, the data set is variable, like the buildings chosen for the study. However as the buildings are all within the same geographical and weather region and all are privately owned residential, the variability of the used energy consumption data is fairly good. Average (mean) values are close to median values.

ENERGY CONSUMPTION

Total Energy Consumption

Total energy consumption for 39 MURBs is presented in this section. Figure 5 presents the total energy consumption for all of the buildings, normalized by gross floor area, sorted from low to high, with the overall electricity and gas energy portions indicated.

Average energy use intensity for MURBs in the Lower Mainland and Victoria is 213 kWh/m^2/yr for the 39 buildings analyzed in the study. A range from 144 to 299 kWh/m^2/yr was observed in the well distributed sample set. Of the 39 study buildings, 34 are in Metro Vancouver and 5 are in Victoria. The average for Vancouver is 220 kWh/m^2/yr and Victoria is 166 kWh/m^2/yr. Per heating degree day, the average energy consumption of the buildings is 0.080 kWh/m^2/yr per HDD in Vancouver, where the average heating-degree day (18°C baseline) is 2741 for the study period. In Victoria, per heating degree day the average consumption is 0.061 kWh/m^2/yr per HDD where the average heating degree day is 2712 for the study period. The 1971-2000 Environment Canada, 30-year annual average heating degree day value is 2750 for Vancouver and 3040 for Victoria, different than that seen over the past decade. Although the analysis to determine the cause(s) of the differences between Vancouver and Victoria will be part of a later subsequent study, it is anticipated that the differences in suite usage and occupant behaviour (greater proportion of retired residents and less occupants per suites in the Victoria buildings) is be a factor contributing to in these results.

Comparing energy use normalized per suite, additional averages and trends for total building energy consumption are shown in Figure 6, sorted from low to high and noted by study building ID.

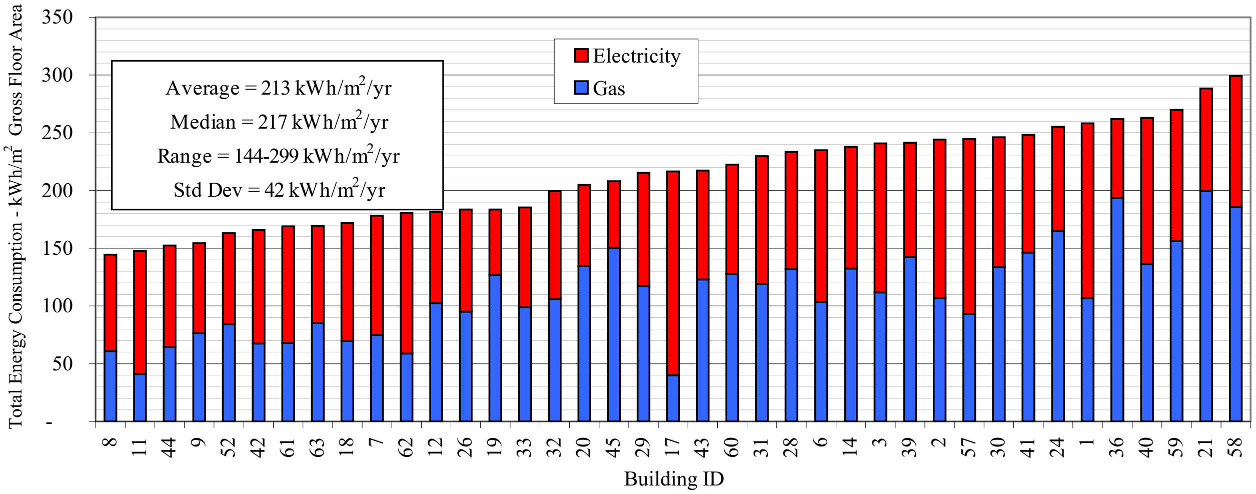

Figure 5: Total Energy Usage per Gross Floor Area –Split by Electricity (Common & Suite) and Gas

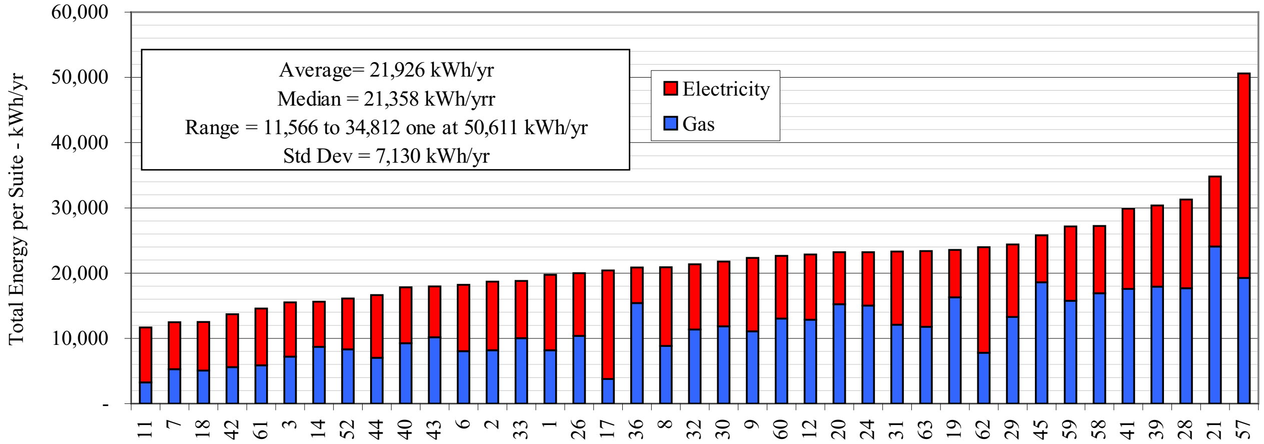

Figure 6: Total Building Energy Consumption Normalized by Suite, divided between Total Electricity and Gas

The energy use per suite is on average 21,926 kWh/yr within a range from 11,566 to 34,812 kWh/yr (with one building at 50,611 kWh/yr). Building 57, with the highest consumption at 50,611 kWh/yr, is a high-end luxury condominium with suites in the 2000+ ft2 range and is a building with full amenities including air conditioning, in-suite fireplaces, and common area recreation centre and pool.

From the average total energy use per suite, 10,443 kWh/yr is electricity, and 11,486 kWh/yr (41 GJ/yr) is gas. On average, 5,828 kWh/yr of electricity is typically used within the suite, and remaining 4,615 kWh/yr is designated common electricity which is apportioned to each suite. Within each suite on average 2,196 kWh/yr of 5,828 kWh/yr (38%) of the suite electricity is used for space heat. On average 51% of the gas used within these building is for space heat, therefore per suite 5,870 kWh/yr (21 GJ/yr) of energy is used for space heat.

Distribution of Space Heat Energy

The buildings in the study have similar mechanical systems, with centrally provided gas heated air to pressurized corridors, and electric baseboard heaters in suites. Buildings 19 and 45 have hydronic heat baseboard heaters in suites instead of electric baseboard heaters. Several of the buildings have in-suite gas-fireplaces in some of the suites (i.e. penthouse suites). Buildings 21, 36 and 58, have fireplaces within all of the suites, and based on the gas consumption data, appear to be providing much of the space conditioning heat to the suites (albeit largely inefficiently). The distribution of energy which is used for space heat, for both electricity and gas, is shown in Figure 7. Furthermore, the percentage of space heat which is from gas sources is shown in Figure 8.

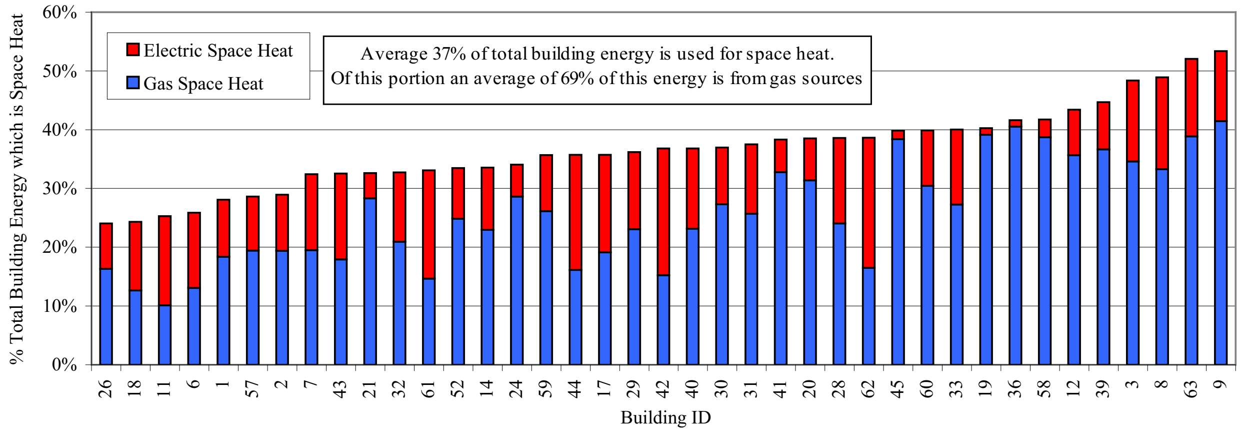

Figure 7: Approximate Percentage of Total Energy which is used for Space Heat, Split by Portion of Gas and Electricity

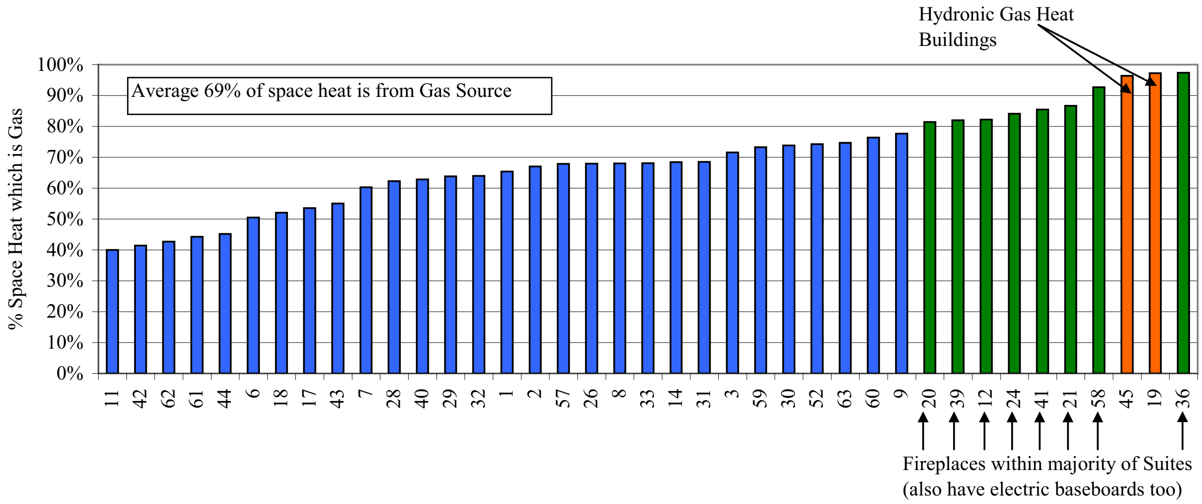

Figure 8: Approximate Percentage of Total Building Space Heat which is from Gas Energy

As shown, the predominant space heat energy source for these MURBs is gas. Even in buildings without gas fireplaces, gas remains the predominant space heat source. This space heat gas is that used to heat the air within the make-up air units for ventilation. Only 5 of the buildings have less than 50% of their space heat energy from gas heat (provided by makeup air unit), with none less than 40%.

Removing the hydronic heated buildings from the population data set has a negligible impact on the overall averages, and instead of 69% space heat from gas, the non-hydronic buildings use on average 67% of space heat from gas sources.

Influence of Predominant Energy Source on Consumption

The influence of predominant energy source and specifically the predominant space heat energy source is analyzed in an attempt to understand the differences in energy consumption within the buildings of the study. Consider the total energy consumption for each building plotted against its gross floor area in Figure 9. As shown, there are an equally distributed set of more and less efficient buildings than the average of 213 kWh/m^2/yr. It is of interest to understand why buildings are more or less energy efficient.

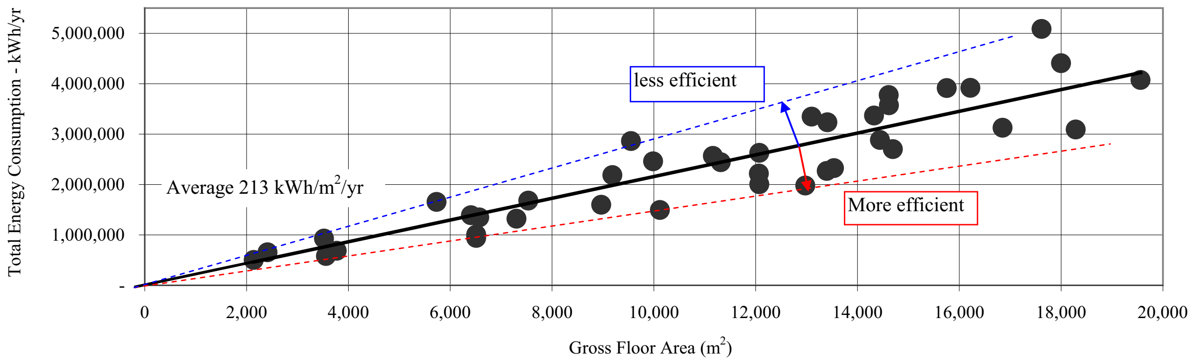

Figure 9: Total Energy Consumption versus Gross Floor Area

To understand which buildings are more efficient, the buildings are grouped by predominant energy source. Four categories were developed for the analysis:

- gas dominant (>55% of total energy consumption is gas) - 13 of 39 buildings,
- electricity dominant (>55% of total energy consumption is electricity) – 13 of 39 buildings,
- no dominant consumption (gas/electric consumption is between 45 and 55%) – 11 of 39 buildings, and
- hydronic gas heat – 2 of 39 buildings.

Using the same data-points as in the previous figure, the categories are highlighted in Figure 10. Trend lines have been approximated to indicate the differences in total energy consumption versus the dominant energy source. Not all buildings fit the correlation, and possible reasons for discrepancies are noted. While the population may be statistically insignificant, the purpose is to highlight the relative differences in the study buildings.

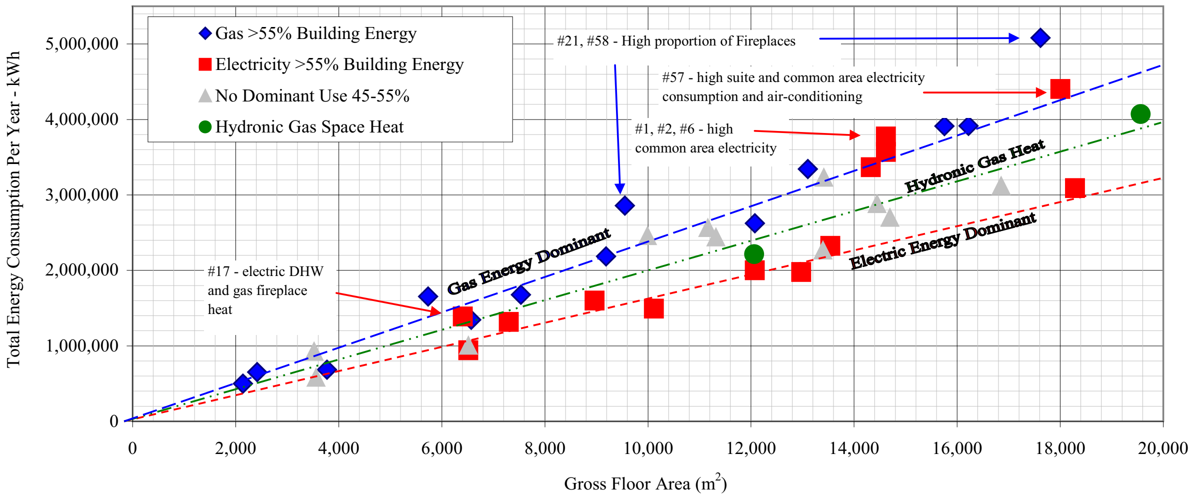

Figure 10: Total Energy versus Gross Floor Area, Split between Gas and Electric Energy Dominated Buildings.

From the plot, it is shown that the gas energy dominated buildings use on average more energy than the electric dominated buildings. This may be largely attributable to the efficiency losses of gas appliances. In the dataset above, the average consumption for all buildings is 213 kWh/m^2/yr, whereas the gas dominated buildings use on average 238 kWh/m^2/yr, the hydronic gas buildings 200 kWh/m^2/yr, and the electric dominated buildings 160 kWh/m^2/yr.

As it is apparent that the space heat energy is the driving contributor to the energy consumption between buildings, the total space heat portion of the buildings' energy is analyzed in greater detail. Four slightly different categories were developed, specific to the space heat contribution:

- gas space heat >70% of the total space heat (Lesser contribution of electric baseboards) - 15 of 39 buildings,
- gas space heat <55% of the total space heat (Higher contribution of electric baseboards) - 9 of 39 buildings,
- gas space heat >55% and <70% - 13 of 39 buildings, and
- hydronic gas heat - 2 of 39 buildings.

The total space heat consumption intensity is plotted against gross floor area in Figure 11. Trend lines again have been approximated to indicate the differences in space heat energy versus the dominant energy source.

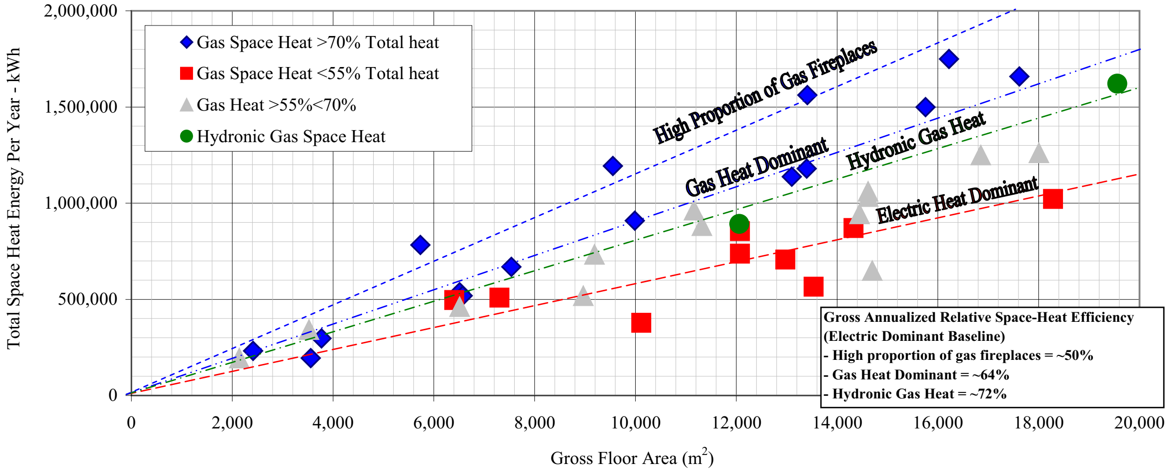

Figure 11: Space Heat Energy versus Gross Floor Area, Split between Gas and Electric Space Heat Dominated Buildings.

Here, the differences in buildings become even more evident. A gross annualized relative space heat efficiency factor was determined for each of the building types compared to the electric baseline. Those buildings with a high proportion of gas fireplaces used for space heat have an efficiency factor of approximately 50% compared to the electric dominated buildings. Those buildings which are more gas dominant (i.e. higher contribution of make-up air ventilation to suites) have an efficiency factor of approximately 64%. The hydronic gas space heat buildings have an efficiency factor of 72%. These factors would be lower still compared to an entirely electric space heated building (100% site heat efficiency), however the baseline "electric dominated" category of building still relies on gas for <55% of the space heat. The use of modeling in later phases of the study will help determine a more suitable baseline for comparison and determination of more accurate heating system efficiencies.

For comparison, equipment efficiencies of the gas space heating appliances are approximately 80% for the hydronic gas-heat boilers, 75-80% for the make-up air ventilation units, and much less for gas fireplaces. Therefore the efficiency factors developed for the buildings as a whole are comparable, and expectedly less to account for distribution and other system energy losses. Determining these space heat system efficiency factors is another goal during the later part of the study.

These apparent differences between gas and electric dominated buildings will be further investigated in the next phase of the work. In particular the role of ventilation make-up air coupled with gas space heat in these buildings requires further investigation. It is however evident that the efficiency of the make-up air unit (typically 75-80%), will have a significant impact on gas energy consumption. High efficiency (>90%) condensing make-up air ventilation units may be preferable to reduce energy consumption.

Energy Consumption End Use

For the 39 MURBs in the study, a summary of average energy consumption and distribution of energy sources is determined. As each building is unique, a range of values are provided.

- Average high-rise MURB consumes 213 kWh/m^2/yr (range of 144 to 299 kWh/m^2/yr)
- Average size of the MURBs within the study is 18 floors (5-33 floors), 11,023 m2 (range of 2,142 to 19,563 m^2) and contains 113 suites (range of 16-212 suites).
- 49% of the energy is electricity, 102 kWh/m^2/yr (range of 28 to 82% Electricity)
    - 57% of electricity is used in suites (range of 33 to 77%)
        - 38% of suite electricity is used for electric baseboard heating (range of 6 to 61%)
        - 62% is used for appliances, lighting, electronics, etc (range of 39 to 94%)
    - 43% of electricity is used in common areas (range of 23 to 67%)
        - 100% is used for operation of elevators, lighting, HVAC distribution, ventilation, plumbing, fans, pumps, parking garage etc. Also within pools, hot-tubs and other amenity areas. A very small portion is used for electric baseboard heat in lobby or other common areas
    - 22% of the total electricity (suites and common) is used for space heat (range of 4 to 36%)
- 51% of the energy is gas, 111 kWh/m^2/yr (range of 18 to 72% Gas)
    - 51% is used for space heat within make-up air units and fireplaces (where provided, range of 30 to 83%, or 100% where electric hot-water)
    - 49% is used for domestic hot-water (range 17% to 60%, or 0% where electric-hot water)
- 37% of the total building energy is used for space heat (range of 24 to 53%)
    - 69% of space heat is from gas (range of 40 to 97%),
    - 31% of the remaining space heat is from the in-suite electric baseboard heaters or other electrical heating appliances (range of 3% to 60%).

Building Operating Energy Costs and the Disconnect Between Consumption and Billing

Assuming 7¢/kWh for electricity and $11 /GJ for gas, average 2010BC Hydro and Terasen utility rates, the operating costs of the 39 MURBs can be compared without allowing for inflation and rate changes. For the 39 buildings in the study, the average total energy cost ranges from $27,000 to $260,000 and the mean of all buildings is $128,000 per year. Of this, $49,000 is spent on gas, and $79,000 on electricity. For the building as a whole this represents a significant amount of money (in the order of $1.07 per square foot of floor area per year). Per suite the total energy cost ranges from $700 to $3000 per suite per year, for an average of $1186.

Individual occupants typically pay directly for the suite electricity, and are invoiced on a monthly basis. On the other hand, the monthly invoices for gas and the common area electricity are paid directly by the collective owner group (Strata Corporation). The monthly fee paid by the individual owners to the Strata Corporation includes for the cost of this energy, but also includes a number of non-energy costs and the occupants typically never see these energy bills. Therefore, the average energy distribution and associated costs per suite are as follows:

- 28% for suite electricity or $408 per year paid by the suite owner or occupant.
- 21% for common area electricity or $323 per year paid by Strata Corporation.
- 51% for gas (MAU space heat and DHW) or $455 per year paid by Strata Corporation.

Of the per suite total of $1186 paid per year, 36% ($34 per month) is paid by the owner or occupant, and 64% ($65 per month) is paid by the Strata Corporation. Clearly, the actual amount paid by the occupant is small and this disconnects the owner or occupant from the relative size of the total annual energy bill which on average is $128,000. This disconnect is a hurdle which must be overcome in order to effectively reduce energy consumption. It is also clear that the central HVAC and electrical systems have a large impact on total energy usage. Therefore energy efficiency improvements made to central shared systems will result in significant benefits.

CONCLUSIONS

Multi-Unit Residential Buildings in the Lower Mainland and Victoria, BC consume on average 213 kWh/m^2/yr of energy. Of this energy, 49% is electricity and 51% is natural gas. 37% of the total building energy is used for space heating, of which, 69% of the space heat energy is from gas.

Although the majority of the buildings were initially designed to be electrically heated, the primary energy source for space conditioning heat is gas, typically from heating of ventilation air. This appears to be the result of the inefficiencies of make-up air unit gas heaters and ventilation distribution systems within MURBs, pressurized corridor ventilation systems, air leakage, and occupant behaviour. The use of fireplaces for space heating is also shown to be inefficient. Buildings which rely more on gas than electricity for space heat typically use more energy, likely because of the inefficient gas-heat distribution systems. Distribution system aside, the efficiency of the appliances used to turn natural gas into space heat or heat for domestic hot-water will have a large impact on the total building energy consumption.

The majority of energy usage in MURBs is paid for by the Strata Corporation, and not the individual owners, resulting in a disconnect between the energy users and the collective client. There is a need for an improvement in the energy efficiency of MURBs as a whole, as the overall cost to each building and society is high and will likely continue to increase unless changes to the design, construction and operation of these buildings are made.

REFERENCES

NRCan 2005. National Energy Use Database – Energy Use Handbook. Natural Resources Canada. Available online: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/databases.cfm?attr=0

NRCan 2006. Survey of Household Energy Use (SHEU), Detailed Statistical Report - 2003 Data. Natural Resources Canada. Office of Energy Efficiency.

RDH 2009. Energy Consumption and Conservation in Mid and High Rise Residential Buildings in British Columbia Report #1: Energy Consumption and Trends. RDH Building Engineering Ltd. Report to Study Partners. February 2009.

APPENDIX - Typical MURB Heating and Ventilation System Schematic