Assessment of ENERGY Use in Multi-Unit Residential Buildings

Multi-unit residential buildings (MURBs) are plagued by unpredictable energy consumption and also by the difficulty of effectively understanding and optimizing occupant behaviour. By examining their portfolio and conducting accurate benchmarking, MURB building owners and managers can better understand the performance of their buildings; identify problems relating to energy, water consumption, and occupant satisfaction; and use this knowledge to prioritise improvements. The outcomes can also provide designers, managers, and occupants with a better understanding of the key factors that influence energy use in these buildings.

Benchmarking has benefits for the building industry as a whole and also for individual buildings and their owners since it is often a fundamental step in the process of understanding and improving building performance. The US EPA has found that buildings which are benchmarked consistently use 2.4 per cent less energy than those that are not[1]. One of the features of benchmarking is that it depicts absolute consumption (in kWh/m^2/yr.) as opposed to a relative performance indicator (for example a 30 per cent reduction relative to MNEC), which gives owners the ability to prioritize and strategize more effectively.

Though slow to get started compared to commercial buildings, energy and water benchmarking in residential buildings is becoming more common. The US EPA Portfolio Manager benchmarking tool (arguably the largest benchmarking initiative in North America) is used by 260,000 buildings to measure and track energy performance, and since its introduction into Canada has been used for thousands of Canadian buildings[2].
In September, 2014 the US EPA introduced an Energy Star score for multi-residential buildings, something which is expected to grow the database and improve benchmarking for MURBs. Perhaps most importantly, both Toronto and Vancouver are considering the introduction of mandatory building energy use reporting in the near future; following the lead of several US cities such as New York.

The work presented here is the result of a research project carried out at Ryerson University, with funding from the Ontario Power Authority Conservation Fund. This research was designed to give owners of MURBs the ability to examine their portfolios and identify problems relating to energy and water consumption, as well as occupant satisfaction. The project established several levels of investigation.

The first was to collect basic physical information about the building including energy and water utility data, gross floor area, number of floors, age, heating type, and location. This provides the information to calculate basic energy use intensities (EUI) in kWh/m^2/yr and allows a simple benchmarking comparison to be made between buildings. Even this basic level of information is often difficult to assemble, with missing utility bills, inaccurate floor areas, inconsistent use of measuring units, etc. Thus, methods were developed to overcome these issues. In this step energy use data should be normalised for annual weather variations.

A second level of detail for data collection was carried out for some of the buildings. This included a building walk through to observe the building features and an interview with the property manager to collect general comments and clarifications. Also, the window to wall ratio (WWR) was calculated, a characteristic that can significantly affect energy use. This additional context provides a slightly more refined picture of what factors are driving a building's performance.

A further level of detail is relevant once problem buildings are identified and involves carrying out occupant surveys to identify specific issues in each building. Occupant surveys provide insight into the effects of design and management strategies, as well as sources of wasteful energy use. Questions cover the occupants' perception, satisfaction and/or behaviour with regard to comfort, acoustics, lighting, building design, and energy billing. An important function of the questionnaire is to understand how people behave in their suites. Alongside occupant surveys it may also be useful to carry out spot tests of the indoor environment, such as daylight, temperature or air quality testing.

Occupant surveys are an understudied approach to contextualising energy data which could prove valuable in understanding building performance, identifying occupant concerns, and potentially highlighting profligate energy and water consumption. Initially, this project intended to use questionnaires to measure certain behaviours which could then be used to explore the variations in the energy use between buildings. However, MURBs have particular characteristics that made it difficult to use this process. Only very few buildings have unit level sub-metering or individual heating bills that can be used to track individual suite usage. Also, it can be difficult to achieve good response rates (particularly in rental buildings). Nevertheless, questionnaires can be a useful tool in gathering feedback about how a building is meeting its occupants' needs, as well as in diagnosing problems that tenants might be facing.

In this study, data from 44 multi-residential buildings in southern Ontario was collected and analyzed. These buildings were primarily constructed between 1960 and 1980, except two built after 2000. For the majority of buildings, 5 years of utility data was available. Gross floor area was often unavailable from building owners, so this data was gathered through Google Maps, corroborated through digitized city maps (when available). Window to wall ratios were calculated using images of the building facades.

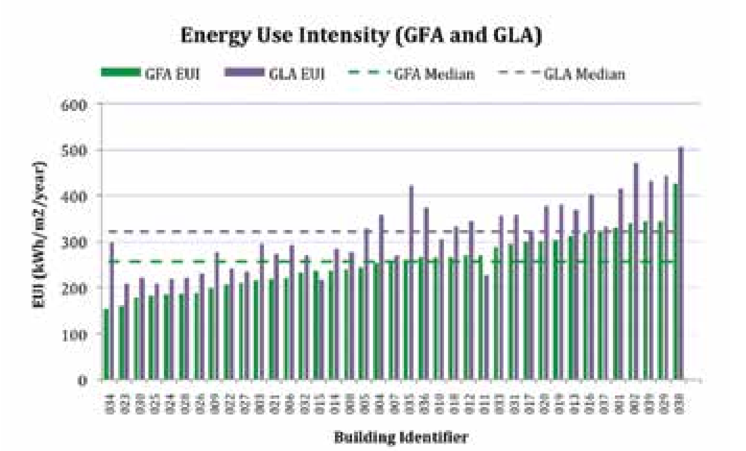

Figure 1: Energy use intensity, all buildings. Data is presented ascending for GFA EUI.

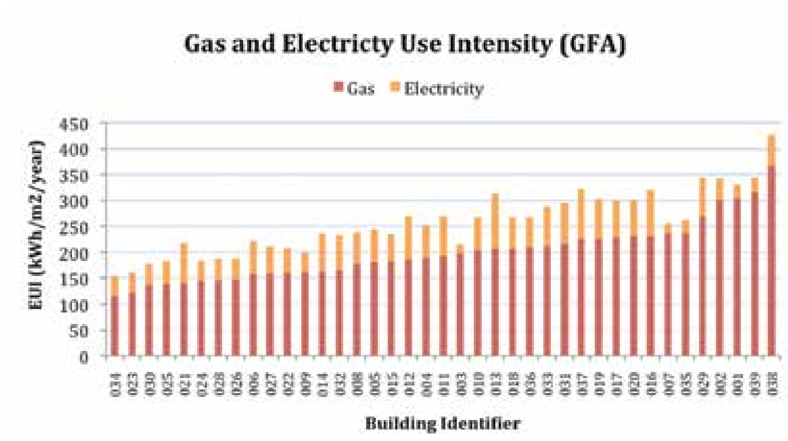

Figure 2: Gas and electricity use.

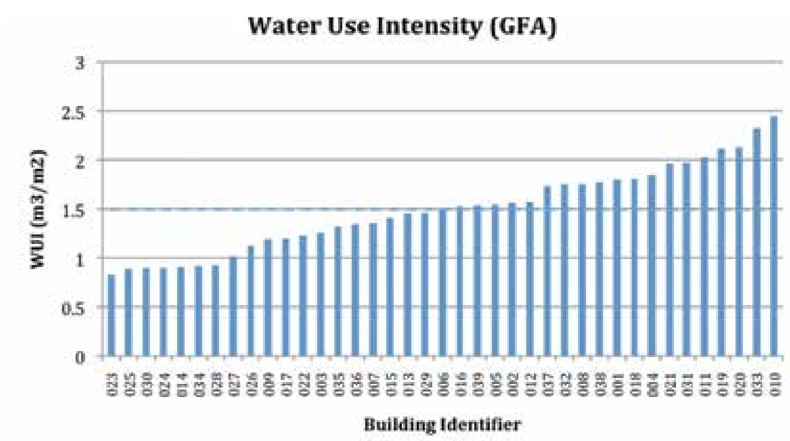

Figure 3: Water use intensity.

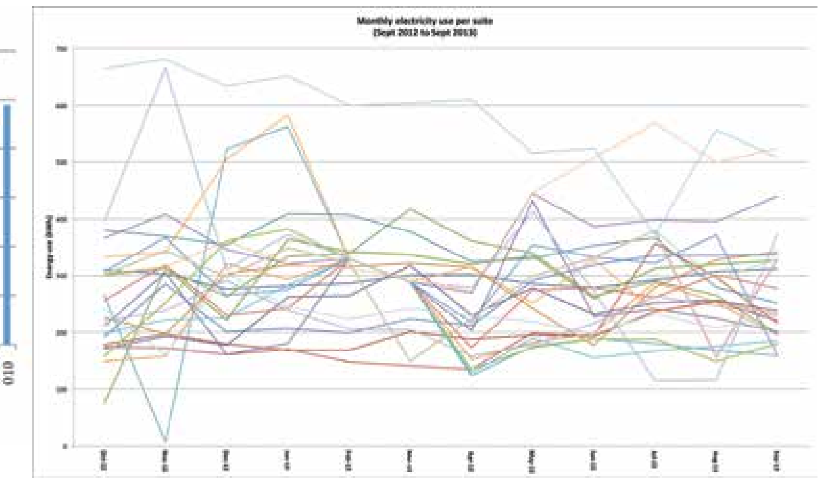
Figure 4: Monthly electricity use per suite.

Figure 1 shows weather normalized energy use intensity (EUI) calculated using both gross floor area (GFA) and gross leasable area (GLA) for the 39 buildings. GLA excludes a building's circulation, mechanical and common areas, meaning that GLA will always be the smaller than GFA. Therefore, lower EUI values result when using GFA, and higher from GLA. These metrics are each relevant to their own contexts, GFA is more common in research and technical studies, whereas GLA is more common in industry benchmarks (because it is of more interest to building owners). The ratio between GFA and GLA varies between buildings depending on the amount of common spaces in the building.

Using the EUI calculated with GFA it can be seen in Figure 1 that the buildings vary by a factor of nearly three from 154 kWh/m^2/yr to 427 kWh/m^2/yr. It is easy to identify the best and worst performing buildings for further investigation.

Figure 2 shows the breakdowns of the EUIs into energy sources (electricity and natural gas). This breakdown makes it apparent that natural gas (mainly for heating and hot water) appears to be driving energy use in these buildings. On average the buildings use nearly 200 kWh/m^2/yr of gas and 60 kWh/m^2/yr of electricity. Also of note is the wide variation between electricity use, which varies by a factor of three between the lowest quartile and the top quartile; some buildings such as 003, 007 and 035 have considerably lower usage levels than the mean. This appears to be due to demographics as well as well as the amount of air conditioning used. For example the highest electricity user, building 013, is one of only two buildings to have a central A/C system.

Similar comparisons are possible for water use intensity in each building. **Figure 3** shows the water use in m^3 of water per m^2 of floor area per year. The performance varies from below 1 m^3/m^2/yr to nearly 2.5 m^3/m^2/yr. This again highlights which buildings are performing poorly and should be targeted for improvements.

For three buildings, suite level sub-metered electricity use data was available. This data is depicted in **Figure 4**, in which each series shows the electricity usage patterns of an individual suite. Examining these series illustrates that electricity use varies widely between suites and between times of the year. Efforts to connect these variations to specific occupant behaviour and unit orientation were unsuccessful due to insufficient survey response rates. Other work has revealed that questionnaires can be useful in producing insight into this variability, and suggests that the key determinants of electricity usage include air conditioner use, number of devices, etc.

Next steps would be to consider detailed benchmarking which aims to identify the characteristics within a building portfolio that are likely to drive energy use. If the most relevant characteristics can be identified, measures can be put in place to improve the building's performance. This can be done through a regression analysis which measures the relationship between each building characteristic and energy use. In this project a limited investigation showed that while the physical characteristics of the building no doubt affect the building's energy use, they are by no means the sole driver. WWR and numbers of underground parking levels were found to be the most significant factors (of the characteristics studied), respectively, explaining 33 per cent and 12 per cent of the variation.

It appears that occupant behaviour has a large impact on energy use in these buildings and is in many cases almost totally independent of physical characteristics. Thus, in conclusion both occupant behaviour and physical characteristics of MURBs need to be addressed to make significant inroads to reducing energy and water use.

A summary of the procedure for the methodology discussed in this article is as follows:

1. Collect data about portfolio of buildings
2. Process data using spreadsheet
3. Input into Portfolio Manager for corroboration
4. High-level analysis of data (e.g., comparisons to other portfolios)
5. Interview those familiar with building operations, and walk through the building
6. Report energy use intensity to interested parties
7. Identify buildings to prioritise and conduct further research (e.g., questionnaires, detailed technical investigations, IEQ testing)
8. Use results to plan energy conservation measures

The process is described in more detail in a best practice guide available to download at http://www.ryerson.ca/graduate/buildingscience/student/2014_opa.html

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[1] US Environmental Protection Agency. (2012). Benchmarking and Energy Savings. Retrieved from http://www.energystar.gov/buildings/tools-and-resources/datatrends-benchmarking-and-energy-savings (accessed October 9, 2014).

[2] http://www.nrcan.gc.ca/energy/efficiency/buildings/energy-benchmarking/whypm/3733

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