RESEARCH REPORT

PERFORMANCE EVALUATION OF THE ALMON STREET MULTI-UNIT RESIDENTIAL BUILDING

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Performance Evaluation of the Almon Street Multi-Unit Residential Building

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Disclaimer

This project was conducted for Canada Mortgage and Housing Corporation (CMHC) under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the author and do not necessarily reflect the views of CMHC or those divisions of CMHC that assisted in the study and its publication.

Abstract

This report documents the performance of a multi-unit residential building, located in Halifax, Nova Scotia, that was designed and constructed to meet the requirements of Natural Resources Canada's (NRCan) Commercial Building Incentive Program (CBIP). One of the primary objectives of CBIP is to reduce the energy consumption of buildings to a level that is 25 % below what the buildings would consume if constructed to the model National Energy Code for Buildings. Canada Mortgage and Housing Corporation commissioned a study to evaluate the extent to which the building met the CBIP energy requirements and to characterize the building's water consumption, indoor air quality and ventilation system performance. The results of the study are to be used to provide the building's owner with feedback on the performance of his building and where opportunities exist for improvements.

Keywords:

Multi-unit residential buildings, energy, water, indoor air quality, ventilation, heat recovery ventilators, field investigation

Executive Summary

Over the course of the past few years, Natural Resources Canada's (NRCan) Commercial Building Incentive Program (CBIP) has encouraged the design and construction of energy efficient buildings across the country by funding a design process that promotes the consideration of all aspects of the design of buildings in one, integrated, process. On of the primary objectives of CBIP is to reduce the energy consumption of buildings to a level that is 25% below what the buildings would consume if constructed to the model National Energy Code for Buildings (MNECB). One such project is an apartment building located in Halifax Nova Scotia, which is the first apartment building in Atlantic Canada designed to meet the CBIP requirements. Canada Mortgage and Housing Corporation commissioned a study to evaluate the extent to which the building met the CBIP energy requirements and to characterize the building's water consumption, indoor air quality and ventilation system performance.

The building is a wood-frame five storey building with an area of approximately 6,604 m^2 (71,060 ft^2) and an underground heated garage with an area of 1,250 m^2 (13,443 ft^2). The building contains 60 apartments housing a mix of families, singles and elderly persons.

The building envelope is very well insulated (RSI 3.52 walls, RSI 10.4 Roof, low E argon filled windows. The building uses one heat recovery ventilator per floor to provide tempered air to all rooms while providing exhaust capacity in all bathrooms. The heating for space and domestic hot water is provided by a dual medium efficiency oil-fired boiler system. The space heating is a combination of hydronic radiant in-floor heating and convector baseboards (on the 5th floor only).

The energy modeling estimated that if the building had been constructed to the MNECB, the total energy consumption (electricity & oil) would be 4,378,795 MJ. Therefore, to qualify for the CBIP support, the building was designed to have a total annual energy consumption of 2,844,981 MJ (i.e.; the energy target – which ambitiously exceeded the minimum CBIP requirements by 10%). However, based on the first year's utility invoices, the actual total annual energy consumption was 4,485,806 MJ which exceeded the original design energy target, the minimum CBIP requirement and the MNECB estimate.

The most probable reasons that the building did not meet the proposed design energy performance include:

1. The plug loads are higher than the reference and the proposed design, and
2. The domestic hot water loads are much higher than the reference and the proposed design
3. Overheating of the building due to in-suite and boiler controls.

While the building failed to meet either of the CBIP or MNECB targets for energy performance, the total annual energy consumption (158 ekWh/m^2) compared well with the average annual consumption of other multi-unit residential buildings contained in the CMHC HiSTAR database (278 ekWh/m^2).

The metered annual building consumption for water in 2003 was 10,227 cubic metres (m^3) or 170.5 m^3/suite. The per suite water consumption compares favourably to the average annual water consumption of the buildings contained in the CMHC HiSTAR database of 216 m^3/suite.

Central heat recovery ventilators (HRV) were installed on each floor level to provide outdoor air to the common corridors and each room in the individual apartments. Exhaust air is drawn back to the HRVs from the bathrooms in each apartment. Each HRV unit has a design capacity of 283 L/s (600 cfm) continuous flow, with 47 L/s (100 cfm) delivered for the corridors and 235 L/s (500 cfm) directed to the suites. Although this ventilation strategy represents a significant improvement over conventional approaches, the measured outdoor airflow rate was 73% of the design supply airflow rate and the measured exhaust flow rate is 66% of the design exhaust airflow rate. It was suspected the discrepancy between the design flow rates and those actually achieved in practice was due to duct installation problems that constricted airflow and resulted in leakage. In-suite measurements of airflow from the ventilation system indicated that there may be duct leakage or constricted flow that limited the delivery of outdoor air and the exhaust capacity for the bathrooms.

The indoor air quality monitoring found that the average temperatures in the three apartments monitored tended to exceed ASHRAE guidelines. This represents an occupant comfort issue (reflected in the occupant survey) and an energy efficiency opportunity in the form of better in-suite and central boiler controls. Relative humidity levels were typically acceptable. $C0_2$ levels were also generally acceptable but excursions above 1000 PPM were noted. The comments received during the occupant surveys reflected the monitoring results in that complaints regarding warm, stuffy indoor air were common.

While the performance of the building failed to meet ambitious design expectations, the energy efficiency measures and innovative ventilation strategy implemented represent significant improvements over conventional buildings. The failure of the building to fully meet its challenging performance targets reflects the need for the development and use of quality assurance processes that can ensure that what is designed and specified on paper is actually achieved in practice. This would include *continuous design review* to modify and optimize design details as construction proceeds; *diligent construction supervision* and *ongoing testing* of materials and systems as they are installed, as well as *system commissioning.* Nevertheless, the good performance of the building (and its potential to fully realize its original design objectives) reflects the success of building programs such as CBIP in moving the construction industry towards higher performing buildings.

Résumé

Au cours des dernières années, le Programme d'encouragement pour les bâtiments commerciaux (PEBC) de Ressources naturelles Canada (RNCan) a encouragé la conception et la construction de bâtiments éconergétiques à la grandeur du pays, en offrant un incitatif financier qui favorise l'étude de tous les aspects de la conception des bâtiments en un processus intégré. L'un des principaux objectifs du PEBC est de réduire la consommation d'énergie des bâtiments d'au moins 25 % par rapport à celle d'un bâtiment de référence construit conformément aux exigences du Code modèle national de l'énergie pour les bâtiments (CMNÉB). Un immeuble collectif d'habitation situé à Halifax, en Nouvelle-Écosse, est le premier immeuble d'appartements du Canada atlantique à avoir été conçu pour satisfaire aux exigences du PEBC. La Société canadienne d'hypothèques et de logement a commandé une étude visant à évaluer dans quelle mesure ce bâtiment répondait aux exigences du PEBC en matière de consommation énergétique, et quelle était sa performance relativement à la consommation d'eau, à la qualité de l'air intérieur et à la ventilation.

Il s'agit d'un bâtiment à ossature de bois de cinq étages possédant une surface de plancher d'environ 6 604 m^2 (71 060 pi^2) et un garage souterrain chauffé de 1 250 m^2 (13 443 pi^2). Il comprend 60 appartements occupés par des familles, des personnes seules et des aînés.

L'enveloppe du bâtiment est très bien isolée (RSI de 3,52 pour les murs, RSI de 10,4 pour la toiture, fenêtres à faible émissivité avec lame d'argon). Le bâtiment est doté d'un ventilateur-récupérateur de chaleur par étage, qui fournit de l'air tempéré à toutes les pièces en plus d'extraire l'air de toutes les salles de bains. L'eau pour le chauffage des locaux et l'eau domestique est chauffée à l'aide de deux chaudières à mazout à rendement moyen. Les appartements sont chauffés à l'eau chaude par rayonnement à partir du sol et à l'aide de plinthes chauffantes (au 5^e étage seulement).

La modélisation énergétique a révélé que si le bâtiment avait été construit selon le modèle du CMNÉB, sa consommation d'énergie totale (électricité et mazout) aurait été de 4 378 795 MJ. Pour obtenir l'aide financière du PEBC, le bâtiment a donc été conçu de manière à ce que sa consommation d'énergie totale annuelle s'établisse à 2 844 981 MJ (c.-à-d., son objectif énergétique – objectif très ambitieux qui excédait de 10 % l'exigence minimale du PEBC). Il semble toutefois, d'après les factures des services publics de la première année, que la consommation d'énergie totale annuelle réelle ait été de 4 485 806 MJ. Cette consommation est supérieure à l'objectif fixé lors de la conception du bâtiment. Elle est également supérieure à la consommation du modèle de référence du CMNÉB et ne respecte pas l'exigence du PEBC.

Si le bâtiment n'a pas atteint la performance énergétique prévue lors de la conception, il est fort probable que ce soit pour les raisons suivantes :

4. les charges aux prises de courant électrique sont plus élevées que prévu dans le bâtiment de référence et lors de la conception;
5. la consommation d'eau chaude domestique est beaucoup plus élevée que prévu dans le bâtiment de référence et lors de la conception;
6. le type de commande des chaudières et les thermostats individuels permettent aux utilisateurs de chauffer à des températures qui excèdent les températures recommandées.

Bien que le bâtiment n'ait pas atteint les objectifs du PEBC et du CMNÉB en matière de performance énergétique, sa consommation d'énergie annuelle totale (158 $ekWh/m^2$) se

compare avantageusement à la consommation moyenne annuelle (278 $ekWh/m^2$) des autres collectifs d'habitation faisant partie de la base de données HiSTAR de la SCHL.

La consommation d'eau annuelle du bâtiment en 2003 s'est chiffrée à 10 227 mètres cubes (m^3), ou 170,5 m^3/appartement. La consommation par appartement se compare avantageusement à la consommation d'eau annuelle moyenne des bâtiments faisant partie de la base de données HiSTAR de la SCHL, qui est de 216 m^3/appartement.

Des ventilateurs-récupérateurs de chaleur (VRC) centraux ont été installés à chaque étage pour alimenter en air frais les corridors communs et toutes les pièces des appartements. Les VRC extraient également l'air de toutes les salles de bains de l'immeuble. Chaque VRC a une capacité de 283 L/s (600 pi^3/min), soit 47 L/s (100 pi^3/min) dans les corridors et 235 L/s (500 pi^3/min) dans les appartements. Bien que cette stratégie de ventilation représente une amélioration importante par rapport aux stratégies usuelles, le débit d'air d'alimentation représente 73 % du débit prévu à la conception et le débit d'air d'extraction représente 66 % du débit prévu. On a pensé que l'écart entre les taux prévus et les taux réellement atteints était dû à une mauvaise installation des conduits qui faisait en sorte que le mouvement d'air était entravé, ce qui entraînait des fuites. Les mesures du débit d'air effectuées dans un appartement ont indiqué qu'il y avait peut-être une fuite dans les conduits ou que le débit était entravé, ce qui avait pour effet de réduire la capacité d'alimentation en air frais et la capacité d'extraction dans les salles de bains.

Les essais sur la qualité de l'air intérieur ont démontré que les températures moyennes dans les trois appartements examinés avaient tendance à être plus élevées que les lignes directrices de l'ASHRAE. Cela signifie que les occupants se préoccupent de leur confort (ce qui a été confirmé dans les entrevues avec les occupants) et qu'il y a place à amélioration des commandes des appartements et du système central de chaudières pour accroître l'efficacité énergétique. Les niveaux d'humidité relative étaient généralement acceptables. Les niveaux de CO_2 l'étaient également, mais on a noté quelques niveaux supérieurs à 1000 PPM. Les commentaires recueillis auprès des occupants interviewés ont confirmé les résultats des essais, car les plaintes sur la chaleur et sur l'air malsain étaient courantes.

Bien que la performance du bâtiment n'ait pas atteint les niveaux prévus, les mesures d'efficacité énergétique et la stratégie novatrice du système de ventilation installé dans le bâtiment constituent tout de même des améliorations importantes par rapport à ce qui se fait habituellement dans les bâtiments. Le fait que le bâtiment n'ait pas atteint les cibles de performance fixées par les concepteurs illustre la nécessité d'élaborer et d'utiliser des processus d'assurance de la qualité qui garantissent la réalisation des objectifs de conception. Ces processus porteraient notamment sur *l'examen continu du concept*, permettant de modifier et d'optimiser les détails de conception au fur et à mesure de l'avancement de la construction; sur la *surveillance attentive de la construction*; sur des *essais continus* sur les matériaux et systèmes à mesure de leur installation; ainsi que sur la *mise en service des installations mécaniques*. La bonne performance du bâtiment (et son potentiel de réaliser pleinement ses objectifs initiaux) indique que les programmes pour les bâtiments, comme le PEBC, réussissent à sensibiliser l'industrie de la construction aux bâtiments plus performants.

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1. Introduction

Over the course of the past few years, Natural Resources Canada's (NRCan) Commercial Building Incentive Program (CBIP) has encouraged the design and construction of energy efficient buildings across the country by funding a design process that promotes the consideration of all aspects of the design of buildings in one, integrated, process. On of the primary objectives of CBIP is to reduce the energy consumption of buildings to a level that is 25% below what the buildings would consume if constructed to the model National Energy Code for Buildings (MNECB). One such project is an apartment building located in Halifax Nova Scotia, which is the first apartment building in Atlantic Canada designed to exceed the CBIP requirements by having a total annual energy consumption that is 35% below the MNECB reference. Canada Mortgage and Housing Corporation commissioned a study to evaluate the extent to which the building met the CBIP energy requirements and to characterize the building's water consumption, indoor air quality and ventilation system performance. The results of the study are to be used to provide the building's owner with feedback on the performance of his building and where opportunities exist for improvements. The results will also be provided to NRCan to provide the agency with information regarding the actual energy performance of buildings designed to meet the CBIP requirements.

Figure 1: The Almon Street Building

The structure is a fully sprinklered, wood-frame five storey building with an area of approximately 6,604 m^2 (71,060 ft^2) and an underground heated garage with an area of 1,250 m^2 (13,443 ft^2). The building (Figure 1) contains 60 apartments housing a mix of families, singles and elderly persons. The primary physical characteristics of the building include:

Structure:

1. Woodframe construction, concrete topping on plywood floors,
2. Subgrade parking garage, insulated, heated

Building Envelope

1. 50mm X 150mm Woodframe wall construction, fiberglass batt insulation, nominal RSI 3.52 – mix of block and vinyl siding,
2. Wood frame truss attic space, mineral wool batt insulation, RSI 10.4,
3. Vinyl casement vertical slider windows, double pane, (low E with argon)

Mechanical Systems

1. Space Heating: Central Oil fired boilers. There are two boilers with a minimum efficiency of 82.8 % each. The room with the boilers is vented directly outdoors, Distribution system: hot water radiant floor heating on 4 of 5 floors, radiant baseboards on uppermost floor (2nd floor of dual storey units on 4th floor). Hydronic unit heaters in parking garage,
2. Domestic Hot Water: Central oil-fired boiler with a recirculating pump system
3. Ventilation: One Heat recovery ventilator installed on each floor to provide outdoor air to common corridors and individual apartments and to exhaust bathrooms in each apartment,
4. Elevator: Conventional hydraulic,
5. Air-conditioning: none

Electrical Systems:

1. Energy Efficient Lighting: Common areas LED exit signs, Compact Fluorescent (twin PL-13) wall sconces; Apartments: Kitchen Twin T-8 with electronic ballasts; Basement Garage: Twin T-8 with electronic ballasts Overall lighting density is 7.14 W/m^2 for the entire building,
2. Appliances: Standard efficiency clothes washers, dryers, dishwashers installed in each apartment,
3. Controls: Space heating: Wall mounted thermostats, Ventilation: Fan speed control for each heat recovery ventilator is on the individual HRVs.

Metering: All of the oil, and water for the building is bulk metered, each apartment is individually metered for electricity.

This project was initiated to evaluate the as-built performance of the building and to assess the extent to which the original project design goals were achieved. The air leakage characteristics of the building were determined, energy and water consumption was monitored, the unique heat recovery ventilation system performance was assessed and the indoor air quality was monitored during a late-winter early spring one week period. This report documents the energy efficient design features of the building, the CBIP performance requirements and how well the building is performing, both in comparison with the CBIP requirements and with other "typical" multi-unit residential buildings.

2. Scope of Work

The scope of work of this project involved the following tasks:

- Measurement of the air leakage characteristics of the building,
- Monitoring of the energy and water consumption of the building,
- Compilation of energy and water bills,
- Assessment of the ventilation system's performance, and
- Monitoring of several indoor air quality indicators during a week period.

2.1 Task 1A - Characterize the Air Leakage of the Building

The plans (architectural, mechanical, and electrical) of the building were reviewed to determine air leakage characteristics of the building which included the following subtasks:

1. Review the details used to seal the building envelope
2. Review the details used to seal an apartment unit – interior and exterior partitions
3. Determine what measures can be taken to improve the detailing – present same to property owner and design team

2.2 Task 1B - Measure the Air Leakage of the Building

Conduct Blower Door Tests to determine air leakage characteristics of building envelope and individual apartments, which included the following subtasks:

1. Identify air leakage locations,
2. Determine the air leakage characteristics of the overall building envelope ($L/s/m^2$ @ 75 Pa),
3. Determine what measures could be taken to improve the air leakage characteristics.

2.3 Task 2 - Measure the Energy Performance of the Building

A review of the CBIP energy simulation of the building was conducted and compared to actual energy usage. This work included the following subtasks:

1. Energy & water consumption data was gathered for the first 12 months of operation. The data was normalized with respect to floor area and degree-days,
2. Utility bills (electricity, water and oil) were compiled and compared with the energy simulation, differences were reconciled,
3. Energy end use points in terms of space heating, domestic hot water, ventilation, lighting, appliances, and equipment were estimated. Peak space heating load was estimated in terms of conduction, infiltration, and ventilation components, and
4. The HiSTAR data input form for the building was prepared and photo record was compiled.

2.4 Task 3 - Measure the Performance of the Heat Recovery Ventilation System

A review of the installation and ventilation performance of the HRV systems was undertaken and included the following subtasks:

1. Airflow measurements (supply and exhaust) were taken on each floor and within a number of apartments, and

2. The ability of the ventilation system to exchange, condition, distribute and circulate outdoor air to all areas of the building was assessed.

2.5 Task 4 – Measure IAQ and Survey Occupants for three Apartments for a two week period

The Indoor Air Quality was measured and the occupants of three apartments were surveyed:

1. The measured indoor air quality indicators were temperature, relative humidity, CO_2 and TVOCs), and
2. The occupants of the same apartments were surveyed to ascertain opinions relating to indoor environment (air quality, temperature, and humidity), comfort, and energy efficiency, functioning of innovative products or systems employed in building.

3. Task 1 – Characterization of the Air Leakage of the Building

3.1 Plan Review

Conventional construction detailing was used for the roof/wall/floor joints. There were no special provisions for air leakage control. The air barrier for the building consisted of 6 mil polyethylene sealed at penetrations including windows, doors, ventilation, electrical and plumbing penetrations. Airtight electrical boxes were not used. The space between window and door frames and the rough frame opening in the adjacent wall areas was sealed with spray in foam. At each floor level, the continuity of the air barrier system is provided by caulking the poly sheet into the plywood. These details reflect conventional approaches to sealing wood frame structures. This is further discussed Section 3.2.

3.2 Discussion of Air Leakage Tests

The results of the blower door tests are found in Appendix 1 - Building Leakage Test. The air leakage tests were conducted in the 'as-found' condition, that is the building's ventilation systems were on and the laundry room/kitchen range hoods were open. All the interior apartment doors were open and all the windows were closed so the test would measure the leakage area of the entire building without interference from internal partitions.

3.3 Comparison with Similar Buildings

To provide context to the air leakage measurements, it is useful to compare the test results with other multi-unit residential buildings. Table 1 details the test results in comparison with another recently constructed CBIP multi-unit residential building located in Dundas, Ontario and to other tested apartment buildings.

Table 1: Air Leakage Test Results

	Normalized Leakage Rate ($L/s/m^2$ @ 75 Pa)
Apartment # 417	2.48
Total Building	2.68
Other MURBs	0.83 – 10 (ave 2.73)
Governor's Road CBIP Building	1.18

The air leakage tests indicated that the building is more airtight than most of the other multi-unit residential buildings on record but not as tight as the CBIP Governor's Road building which was designed to be very air-tight. Considering that no extraordinary measures were taken to ensure the continuity of the air barrier system in the Almon Street building, it achieved a modest degree of airtightness. It is worthwhile to note that the air leakage test results would likely have been improved had the HRV systems been deactivated and sealed during the tests.

A smoke puffer was used to visually identify air leakage locations. The test results were categorized into three types: High Leakage, Low Leakage and No Leakage. The pictures are found in Appendix 1.

During the blower door test the following air leakage areas were noted:

<u>High Leakage - Main Level – Fourth Floor</u>

Kitchen Range Hood	(See Picture No. 1)
Kitchen Sprinkler Head	(See Picture No. 2)
Apartment Intercom Panel	(See Picture No. 3)
Electrical Panel	(See Picture No. 4)
Party Wall to Next Apartment	(See Picture No. 5)

<u>High Leakage – Bedroom Level – Fifth Floor</u>

Outside Wall Plugs – Small Bedroom	
Bedroom Sprinkler Head	
Closet Sprinkler Head	
Outside Wall Plugs – Large Bedroom – West Side	(See Picture No. 6)
Outside Telephone Plugs – Large Bedroom – West Side	(See Picture No. 6)

<u>Low Leakage - Main Level – Fourth Floor</u>

Window Trim for Living Room – South Side	(See Picture No. 7)
Electrical Plugs – South Side	
Kitchen Window Trim – West Side	(See Picture No. 7)
Living Room Fresh Air Supply	(See Picture No. 8)
Living Room Windows are not properly closing	(See Picture No. 9)
Dryer Duct Penetration	(See Picture No. 10)
Laundry Room Plumbing Penetrations	(See Picture No. 11)

<u>Low Leakage – Bedroom Level – Fifth Floor</u>

Bedroom Sprinkler Head	
Window Trim – Both Bedrooms	(See Picture No. 7)

<u>No Leakage</u>
Kitchen Plumbing Penetrations

The High Leakage areas were primarily the kitchen range hood which was equipped with in-effective back-draft dampers. Based on the observations above, it appears that much of the leakage from the apartments tested is from other adjacent zones and not as much appeared to be leaking in from outside. This tends to indicate that while the apartment exterior wall construction and air barrier may have been reasonable, there is plenty of leakage between apartments and apartments to adjacent common areas.

4. Task 2 – Energy Performance Evaluation

The purpose of this task was to conduct a review of the CBIP energy simulation of the building and compare it to actual energy usage. The sub-tasks were to:

- Gather energy consumption data over the first 12 months of operation and normalize it with respect to floor area and degree-days (data can be found in Appendix 2).
- Compare utility bills (electricity, oil) with the energy simulation and reconcile differences.
- Identify energy end use points in terms of space heating, domestic hot water, ventilation, lighting, appliances, and equipment. Identify peak space heating load in terms of conduction, infiltration, and ventilation components, and
- Document the building characteristics and energy/water consumption results in the CMHC HiStar database system.

4.1 Discussion of Energy Results

4.1.1 Commercial Building Incentive Program Energy Model

The original energy target for the building was a 35 % reduction in energy use as compared to the equivalent building built to the Model National Energy Code for Buildings (MNECB). However, based on the annual energy consumption compiled through utility metering information, it was found that the actual annual energy consumption was 58% more than the original performance target, 37% above the minimum CBIP requirement (25% below 4,378,795 MJ) and 2.5% above the reference MNECB building. The energy and water utility consumption data can be found in Appendix 2

Energy Consumption:

The reference MNECB electrical energy consumption is 1,477,584 MJ.
The designed CBIP compliant electrical energy target is 984,531 MJ.
The actual metered electricity consumption is 1,148,598 MJ

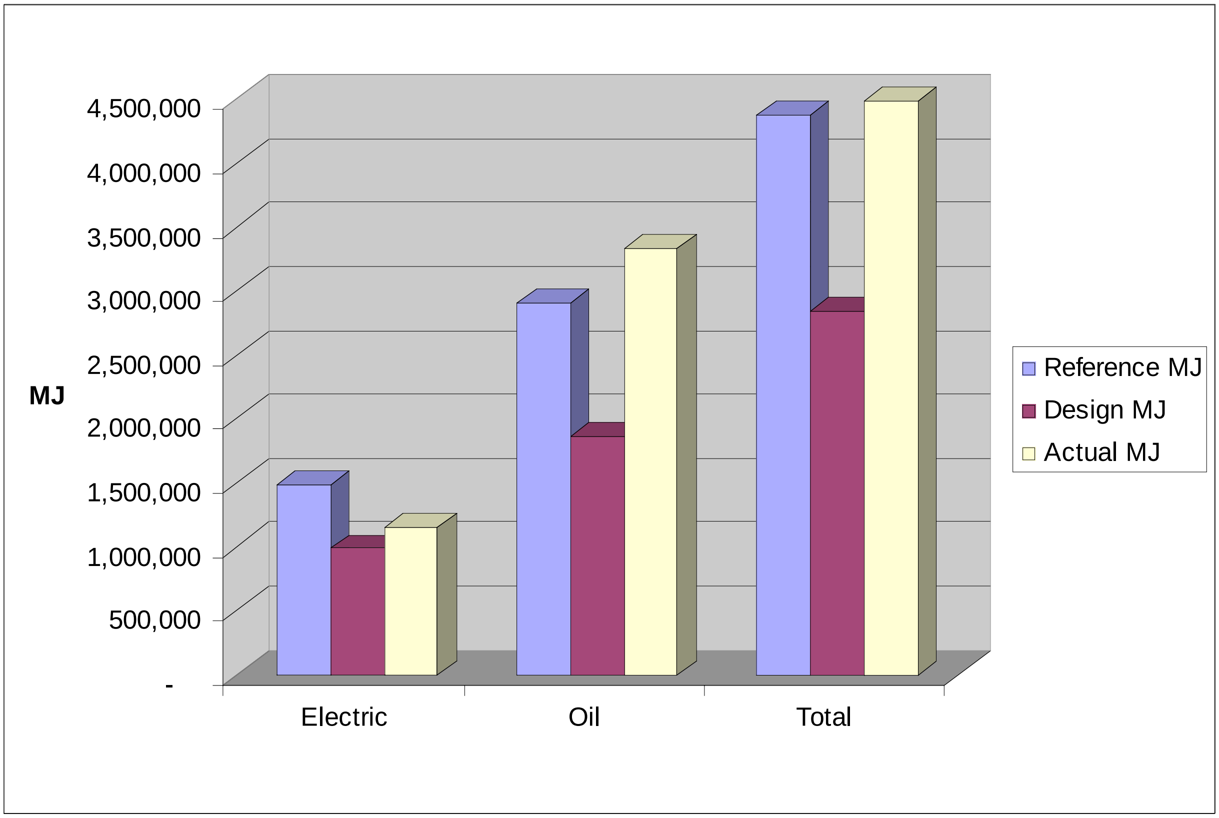
The reference MNECB fuel oil energy consumption is 2,901,211 MJ
The designed CBIP compliant fuel oil energy target is 1,860,450 MJ
The actual metered fuel oil consumption is 3,337,208 MJ.

The total reference MNECB energy (electrical & oil) consumption is 4,378,795 MJ
The total designed CBIP compliant energy (electrical & oil) target is 2,844,981 MJ
The total actual metered energy consumption is 4,485,806 MJ.

The actual electricity consumption is 22.3 % below the reference MNECB budget and 16.7 % higher than the design target. The actual oil consumption is 15.0 % higher than the reference MNECB budget and 78.8 % higher than the design target.

This is shown for the electricity and oil in Figure 2.

Figure 2 – Annual Energy Consumption Comparison



The actual building consumption did not meet the design target energy consumption nor the minimum CBIP requirements (25% below reference MNECB building). The possible reasons for the discrepancy include higher use of electricity via "plug loads", higher domestic hot water loads and control of the space heating system – both at the boiler and within the apartments.

Energy Cost:

The total reference 2003 MNECB energy cost (electrical & oil) is \$ 77,775 or \$ 9.90 per m^2. The total designed CBIP compliant energy (electrical & oil) cost is \$ 53,445 or \$ 6.81 per m^2. The reference and designed energy costs were adjusted slightly to account for a bug in the heating pumping energy. The actual metered electricity and oil for 2003 was \$31,551.28 and \$38,462.08 respectively for a total of \$ 70,013 or \$ 8.91 per m^2.

Table 3 - Degree Days Comparison

	Actual Degree Days	Normal Degree Days	Difference Actual versus Normal
Jan-03	753	703	7.1%
Feb-03	677	636	6.5%
Mar-03	610	582	4.7%
Apr-03	459	415	10.5%
May-03	300	274	9.5%
Jun-03	104	121	-14.0%
Jul-03	9	32	-71.8%
Aug-03	23	26	-9.7%
Sep-03	52	107	-51.5%
Oct-03	228	275	-17.4%
Nov-03	378	415	-8.8%
Dec-03	544	606	-10.2%
	4,137	4,193	-1.3%

Comparison with Similar Buildings

As a comparison to this building a similar sized building (80 units) in Halifax built in 1964 which has no heat recovery ventilation and shuts down the corridor ventilation in the winter used a total of 1,220 MJ/m^2 or 315 kWh/m^2 and $ 20.22 per m^2.

While the building failed to meet either of the CBIP or MNECB targets for energy performance, the total annual energy consumption (158 ekWh/m^2) compared well with the average annual consumption of other multi-unit residential buildings contained in the CMHC HiSTAR database (278 ekWh/m^2).

4.1.2 Effect of Weather on Energy Performance of the Building

Table 3 shows that the actual degree-days for the closest weather station (Shearwater in Dartmouth, Nova Scotia) during the January to May period (representing 62 % of the total degree-days) was 7.2 % cooler than normal, while October to December was 11.3 % warmer than normal. Overall there were 1.3 % less degree-days than normal. Therefore the equivalent kWh/m^2/degree-day for each energy source is as follows:

The reference MNECB electricity equivalent kWh/m^2/degree-day is 0.013.
The design CBIP compliant electricity equivalent kWh/m^2/degree-day is 0.008.
The actual electricity equivalent kWh/m^2/degree-day is 0.010.

The reference MNECB oil equivalent kWh/m^2/degree-day is 0.025.
The design CBIP compliant oil equivalent kWh/m^2/degree-day is 0.016.
The actual oil equivalent kWh/m^2/degree-day is 0.029.

The reference MNECB total equivalent kWh/m^2/degree-day is 0.037.
The design CBIP compliant total equivalent kWh/m^2/degree-day is 0.024.
The actual total equivalent kWh/m^2/degree-day is 0.038.

Table 4 shows the electrical consumption from the EE-4 energy simulation, which uses the DOE-2 simulation engine. The results of the simulation are labeled DOE, while the actual consumption is labeled Actual.

The table shows the breakdown into the major electrical consumers, which are the area lights, miscellaneous equipment (plug and process loads), space heat, pumps, ventilation fans and domestic hot water. In the case of this building there are no electrical space heat and domestic hot water loads.

The difference in electricity consumption is appears to be represented by the difference between estimates for the plug loads for the actual building versus those assumed for the computer simulation. The computer model assumes plug load energy use at 7.5 watts per square metre, which is lower than the actual consumption from the individual electricity apartment consumption provided by the local utility. The difference is 61,693 kWh (222,095 MJ) per year or 1,029 kWh per apartment per year. The monthly difference is 86 kWh (2.9 kWh/day) or a 360 watt load for an 8 hour day. A typical computer consumes between 50 to 200 watts and a large TV: 100 watts, and various plug-in lamps (3 x 60 watts), that is probably most of the 360-watt load.

The differences between the models assumptions for plug loads and actual plug loads should be explored further in order to reconcile differences.

Table 4 - Electricity Comparison

	DOE Electricity Monthly kWh	DOE HouseLights Monthly kWh	DOE Apt Lights Monthly kWh	DOE Recep/ Process Monthly kWh	DOE Fans Monthly kWh	Actual Electricity Monthly kWh	Actual Exterior Lights Monthly kWh	Actual Corridor Lights * Monthly kWh	Actual Fans * Monthly kWh	Actual Lights/Plug Loads Monthly kWh
Jan-03	20,002	8,681	2,219	9,677	1,106	27,192	175.5	8,681.1	1,106	17,229
Feb-03	17,986	8,681	2,219	8,741	1,106	27,192	175.5	8,681.1	1,106	17,229
Mar-03	20,284	8,681	2,219	9,677	1,106	27,104	175.5	8,681.1	1,106	17,142
Apr-03	20,157	8,681	2,219	9,365	1,106	27,104	175.5	8,681.1	1,106	17,142
May-03	22,578	8,681	2,219	9,677	1,106	26,227	175.5	8,681.1	1,106	16,264
Jun-03	22,899	8,681	2,219	9,365	1,106	26,227	175.5	8,681.1	1,106	16,264
Jul-03	23,696	8,681	2,219	9,677	1,106	26,547	175.5	8,681.1	1,106	16,584
Aug-03	23,696	8,681	2,219	9,677	1,106	26,547	175.5	8,681.1	1,106	16,584
Sep-03	22,933	8,681	2,219	9,365	1,106	26,732	175.5	8,681.1	1,106	16,770
Oct-03	22,534	8,681	2,219	9,677	1,106	26,732	175.5	8,681.1	1,106	16,770
Nov-03	20,567	8,681	2,219	9,365	1,106	25,727	175.5	8,681.1	1,106	15,764
Dec-03	20,030	8,681	2,219	9,677	1,106	25,727	175.5	8,681.1	1,106	15,764
	257,362	104,173	26,630	113,939	13,270	319,055	2,106	104,173	13,270	199,506
					Difference	61,693	kWh			

4.1.3 Oil Use Comparison

Table 5 shows the comparison between the energy simulation and the actual usage.

Table 5 - Oil Use Comparison

	DOE Fuel Oil Total litres	DOE DHW Fuel Oil Monthly Litres	DOE Space Heating Fuel Oil Monthly Litres	Actual Fuel Oil Total litres	DHW Fuel Oil Monthly Litres	Actual Space Heat Fuel Oil Monthly litres
Jan-03	8,320	508	7,812	12,863	3,300	9,563
Feb-03	7,544	508	7,036	11,907	3,300	8,607
Mar-03	6,946	508	6,438	8,810	3,300	5,510
Apr-03	4,986	508	4,478	7,326	3,300	4,026
May-03	3,282	508	2,774	6,944	3,300	3,644
Jun-03	2,075	508	1,567	4,735	3,300	1,435
Jul-03	1,625	508	1,117	5,085	3,300	1,785
Aug-03	1,587	508	1,079	3,301	3,300	1
Sep-03	1,905	508	1,397	3,359	3,300	59
Oct-03	3,290	508	2,782	3,979	3,300	679
Nov-03	4,986	508	4,478	8,355	3,300	5,055
Dec-03	7,677	508	7,169	7,178	3,300	3,878
	54,223	6,096	48,126	83,840	39,600	44,240

The Domestic Hot Water (DHW) fuel oil was estimated based on fuel oil consumption in the summer months (August and September) when no space heating occurred. It should be recognized that this is a rough assumption as DHW load will vary based on the temperature of the water delivered to the building, which in some regions can vary by as much as 15^0C from summer to winter. Thus the assumed DHW load likely underestimates the actual annual DHW load.

If the DHW load of 3,300 litres per month is subtracted from the actual total oil consumption then the simulation space heat load and the actual space heat load are within 8 % of each other, with the simulation being higher. This is consistent with the fact that low domestic hot water consumption is compensated by higher space heat consumption. (Only 7 % of the DHW energy is available to offset the space heating load before it washes down the drain).

It should be noted that the simulation model for this building assumed a DHW load of 508 litres of oil per month which is significantly less than the actual estimated consumption of 3,300 litres per month. If the model is adjusted to use the ASHRAE hot water load of 151 litres per apartment per day, the modeled domestic hot water related oil consumption would rise to 1,750 litres per month for a total of 21,000 litres of No. 2 oil per year – which is still short of, but closer to, the actual DHW related oil consumption for this building.

It is worth noting that the annual water consumption per apartment is 170 m^3 which is not excessive when compared to average residential use in Canada. By extension, it does not appear that domestic hot water use is extraordinary either inferring that the actual DHW oil consumption may be more representative of actual fuel use than the energy models currently estimate. Therefore the computer model could be adjusted from 508 litres of oil per month (or 6,096 litres per year) to 1,750 litres of oil per month or 21,000 litres of oil per year for domestic hot water heating – although this is still short of the 3,300 litres of oil per month that appeared to be consumed by the building over the first year of operation. This in turn increases the modeled CBIP compliant overall building energy consumption by 812,700 MJ per year.

Adjusted Energy Model

Based on the energy analysis, if the energy model was adjusted to reflect what could be considered to be more realistic plug and DHW loads, the CBIP compliant target energy model would be 1,148,594 MJ (electrical) and 2,438,487 MJ (oil) for a total of 3,587,081 MJ. Table 6 shows the monthly figures. The actual building's energy consumption is 1,148,594 MJ or 319,053 kWh (electrical) and 3,244,462 MJ or 901,284 kWh (oil) for a total of 4,392,040 MJ or 1,220,011 kWh.

Table 6

Total Energy Comparison

	Adjusted DOE Total ekWh	Actual Total ekWh	Difference Actual vs Predicted
Jan-03	122,485	165,463	35.1%
Feb-03	112,128	155,192	38.4%
Mar-03	107,997	121,811	12.8%
Apr-03	86,793	105,860	22.0%
May-03	70,904	100,877	42.3%
Jun-03	58,245	77,124	32.4%
Jul-03	54,160	81,205	49.9%
Aug-03	53,794	62,028	15.3%
Sep-03	56,432	62,836	11.3%
Oct-03	70,921	69,506	-2.0%
Nov-03	87,203	115,545	32.5%
Dec-03	115,596	102,891	-11.0%
	996,657	1,220,337	22.4%

	$ekWh/m^2$	$(ekWh/ft^2)$
Actual	155.4	14.4
Predicted	126.9	11.8

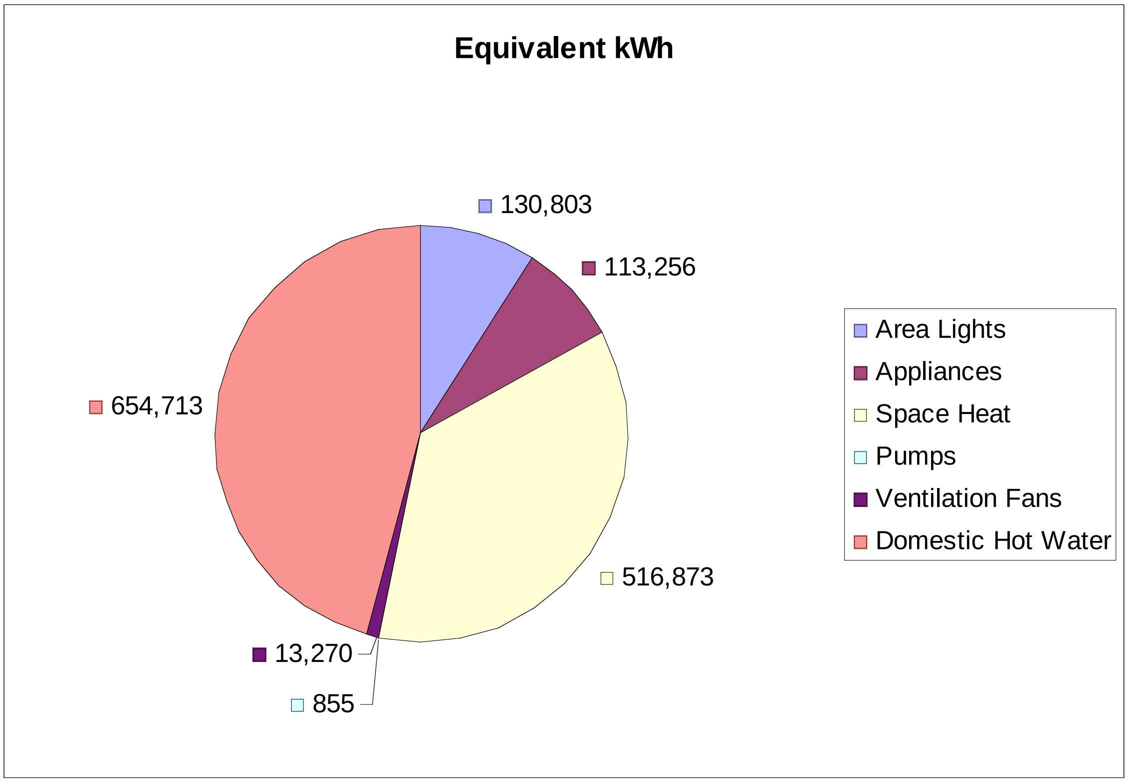
The adjusted DOE total includes the additional plug loads of 61,693 kWh and the additional DHW load of 21,000 litres of oil consumption.

Even with the adjustments for higher hot water and plug loads, the building, based on the first full year of energy data, uses 22.4 % more energy than the adjusted CBIP compliant target.

4.1.4 Energy End Use Summary

The annual total energy is shown by end use in Figure 3.

Figure 3 – Energy End Use



4.1.5 Water Consumption Comparison

The metered annual building consumption for water in 2003 was 10,227 cubic metres (m^3) or 170.5 m^3/suite at an estimated cost of $12,470 for an average cost of $1.22 per m^3 (1,000 litres). The per suite water consumption compares favourably to the average annual water consumption of the buildings contained in the CMHC HiSTAR database of 216 m^3/suite.

The domestic hot water usage was estimated to be 6,213 m^3/year or 17,022 litres per day (17.022 m^3) as calculated from the summer monthly oil consumption. The hot water boilers consumed 3,300 litres of oil per month during the summer months at average cost of $0.40 per litre. This provided a total annual cost of $15,840 for the hot water heating energy. Therefore the total cost of a cubic metre of domestic hot water was $ 2.55 per m^3.

A spot check of the showerhead and kitchen and bathroom faucet flow rates indicated that they all met or exceeded the Model National Energy Code requirements of less than 9.5 L/min (2.5 USGPM) for the showerheads and 8.5 L/min (2.2 USGPM) for the faucets.

5. Task 3 – Measure the Performance of the Heat Recovery Ventilation System

As previously indicated, Task 3 consisted of conducting a review of the installation and performance of the HRV, which included the following subtasks:

- Airflow measurements (supply and exhaust) at floor and apartment levels
- Assess ability of ventilation system to exchange, condition, distribute and circulate outdoor air to all areas of the building.

Ventilation System Description:

The apartments and common corridors on each floor are ventilated by heat recovery ventilators installed on each floor. Each HRV supplies fresh air to every habitable room and area on the floor it serves on a continuous basis. The HRVs also draw exhaust air from the bathrooms in each apartment on the floors they serve and vent it outdoors. Kitchens are provided with independently ducted range hoods and clothes dryers are also separately vented outdoors. The capacity of the HRVs is controlled by a central fan speed switch in the HRV closet on each floor.

Ventilation System Requirements:

The ventilation system for the building was designed to Part VI of the National Building Code as the strategies involves the use of central heat recovery ventilators installed on each floor that serve a number of apartments and common areas. Therefore, the outdoor air guidelines specified by ASHRAE Standard 62-2001 "Ventilation for Acceptable Indoor Air Quality" have been used.

Outdoor Air Requirements: ASHRAE standard 62 requires outdoor air rates for residential occupancies of 0.35 air changes per hour (ACH) but not less than 7.5 L/s/person. The design ventilation rate specified for the HRVs serving the occupied areas of the building, including common corridors, is 1,416 L/s. Based on a floor area of 6,604 m^2 and an interior volume of 14,726 m^3, this outdoor air rate provides 0.21 L/s/m^2 of floor area or 0.35 ACH – meeting the ASHRAE requirements.

Exhaust Air Requirements: ASHRAE Standard 62 requires 50 L/s per kitchen if intermittent exhaust is installed. As the apartments are equipped with independently ducted range hoods with a design capacity of 27 L/s, therefore the ASHRAE requirement is not satisfied. For the bathrooms, which are continuously exhausted by the central HRV systems, ASHRAE Standard 62 requires 10 L/s continuous. As there are 60 apartments with 105 bathrooms served by the HRVs, 1,050 L/s total building exhaust capacity through the HRVs is required. As the design capacity of the HRVs serving the building is 1,416 L/s, this design requirement is met.

In order to assess the degree to which the HRV systems were capable of exchanging, distributing and circulating ventilation air throughout the building, while providing exhaust capacity to the bathroom, the flow rates of the HRVs on each floor were measured, at the HRVs, and in a limited number of apartments.

5.1 Airflow Measurement Results

Table 7 documents the results of the air flow measurements by taking a velocity profile for each of the HRV flow speed settings (low, medium, high) as follows:

Table 7: Airflow Measurements for Individual Floor Heat Recovery Ventilators

Main Floor	Supply	Exhaust
Low	74 L/s	56 L/s
Medium	89 L/s	81 L/s
High	103 L/s	116 L/s
Design	**283 L/s**	**283 L/s**
Second Floor	Supply	Exhaust
Low	116 L/s	116 L/s
Medium	182 L/S	223 L/S
High	297 L/s	330 L/s
Design	**283 L/s**	**283 L/s**
Third Floor	Supply	Exhaust
Low	107 L/s	56 L/s
Medium	141 L/s	190 L/s
High	231 L/s	297 L/s
Design	**283 L/s**	**283 L/s**
Fourth Floor	Supply	Exhaust
Low	70 L/s	35 L/s
Medium	99 L/s	66 L/s
High	190 L/s	116 L/s
Design	**283 L/s**	**283 L/s**
Fifth Floor	Supply	Exhaust
Low	66 L/s	36 L/s
Medium	99 L/s	48 L/s
High	215 L/s	69 L/s
Design	283 L/s	283 L/s
Totals	Supply	Exhaust
Low	433L/s	299 L/s
Medium	610L/s	608 L/s
High	1,036 L/s	928 L/s
Design	**1,416 L/s**	**1,416 L/s**

The results are discussed in Section 5.2 Comparison with Design.

Table 8 documents the airflow measurements for four individual apartments including the three apartments (#112, #306, and #417) where the indoor air quality surveys were conducted. The technique used to measure the airflows is the CMHC Garbage Bag Air Flow Test. Unfortunately, this test method proved to be non-applicable for measuring the relatively small airflows coming from the circuline grilles in each room. The test protocol indicates that if the bag fill time is greater than 12 seconds, the airflow can be assumed to be effectively 0 litres per second. Therefore, any flow less than 10 L/s (20 CFM) would not be detected. As each apartment can only receive 17 L/s (1,036 L/s / 60 apartments) and this flow is divided among two or three grilles in each apartment, the test method was incapable of detecting the flow in four of the five apartments tested.

Similarly, for the exhaust, 928 L/s of total exhaust capacity distributed amongst 105 bathrooms provides 8.8 L/s per bathroom. This is below the range limit of the garbage bag test procedure.

The speed of the HRVs was set at the highest speed to get a measurement of the maximum possible airflows in the building.

Table 8: Airflow Measurements for Individual Apartments

Apartment 112	Flowrate	Comments
Living Room	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bedroom	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bathroom	n/a L/s	Exhaust - time to deflate is greater than 12 seconds
Apartment 306	**Flowrate**	**Comments**
Living Room	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bedroom	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bathroom	n/a L/s	Exhaust - time to deflate is greater than 12 seconds
Apartment 308	**Flowrate**	**Comments**
Living Room	7 L/s	Supply – time to fill is 7 seconds
Main Bedroom	9 L/s	Supply – time to fill is 8 seconds
Main Bathroom	7 L/s	Exhaust – time to deflate is 7 seconds
Apartment 310	**Flowrate**	**Comments**
Living Room	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bedroom	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bathroom	n/a L/s	Exhaust - time to deflate is greater than 12 seconds
Apartment 417	**Flowrate**	**Comments**
Living Room	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bedroom	n/a L/s	Supply – time to fill is greater than 12 seconds
Main Bathroom	n/a L/s	Exhaust - time to deflate is greater than 12 seconds
Design Conditions	**Flowrate**	**Comments**
Living Room	5 L/s	Supply
Main Bedroom	7.5 L/s	Supply
Main Bathroom	7.5 L/s	Exhaust

5.2 Comparison with Design

Based on the airflow measurements, the following conclusions can be made:

- the first floor is 64 % below the required minimum fresh air requirement at the high speed,
- the second floor is 5 % above the required minimum fresh air requirement at the high speed,
- the third floor is 18 % below the required minimum fresh air requirement at the high speed,
- the fourth floor is 59 % below the required minimum fresh air requirement at the high speed,
- the fifth floor is 24 % below the required minimum fresh air requirement at the high speed, and
- the total building is 27 % below the required minimum fresh air requirement at the high speed.

The maximum flow rate provided by all of the HRVs is 1,036 L/s which is 0.12 L/s/m^2 or 0.2 ACH which fails to meet the design specification for the system and the code requirement provided by ASHRAE. The total continuous exhaust measurement of 928 L/s does not meet the minimum ASHRAE rates of 1,050 L/s for 105 bathrooms in building (20 per floor for Floors 1, 2, and 3, 22 on Floor 4 and 23 on Floor 5). The system is also unbalanced and would have to be balanced to meet the maximum of either the supply or exhaust requirement – in this case the supply at 1,416 L/s.

At the time of the site visit, the HRVs were operating on the medium speed which was below the design rate assumed in the energy model. As the energy model assumed a ventilation rate of 1,416 L/s, actual energy usage attributable to the ventilation system would be significantly less. This, in turn, implies that if the ventilation system were operating to specification, energy usage would be higher and the actual energy consumption would further exceed targets.

The results of the insuite flow measurements indicate that, although the HRVs are drawing in outdoor air and are exhausting air (although not to specification or code), they may not be as effective at delivering air to the apartments. Duct leakage, connection problems (as witnessed by the cross connection of supply ducts with exhaust ducts in one installation), long duct runs and perhaps too many fittings could be undermining the performance of the system. The failure of the system to perform to specification was found to have an impact on air quality which is discussed in the following section.

6. Task 4 – Measure IAQ and Survey Occupants

Indoor Air Quality was measured and occupant surveys were conducted in three apartments.

1. Temperature, Relative Humidity, CO_2 and TVOCs were measured in 3 apartments, and
2. The occupants of the same apartments were surveyed to ascertain opinions relating to indoor environment (air quality, temperature, humidity), and comfort.

6.1 Indoor Air Quality Results

Table 9 provides the results of the air quality survey for the three apartments. The information was collected in Imperial units and converted to Metric. The measurements were taken in the living room.

Table 9: Indoor Air Quality Monitoring Results

		Apartment 112	Apartment 306	Apartment 417
Temperature (^0C)	Max	27.7	28.9	24.4
	Min	26.1	20.6	17.8
	Ave	26.9	25.8	23.7
Relative Humidity (%)	Max	57	49	37
	Min	26	19	20
	Ave	31	24	23
CO_2 (PPM)	Max	1257	1382	1202
	Min	442	697	252
	Ave	717	862	524
TVOC (mg/m^3)	Week average	0.35	0.21	0.20

Apartment 112
Test Period March 31 to April 4, 2004 at 9:36 AM when test was terminated

Apartment 306
Test Period March 31 to April 4, 2004 at 7:45 AM when test was terminated

Apartment 417
Test Period March 31 to April 4, 2004 at 9:36 AM when test was terminated

6.2 Thermal Comfort Review

Requirements for thermal comfort can be summarized as:
- ♦ Satisfactory temperature,
- ♦ Satisfactory humidity, and
- ♦ Adequate ventilation.

At 50 % relative humidity the recommended temperatures by ASHRAE Standard 55 is 24.4 ºC (76 ºF) in summer and 21.7 ºC (71 ºF) in winter. The recommended range for relative humidity by ASHRAE is 40-60 % in summer and 20-40 % in winter. Ventilation has been discussed in the previous section of the report.

All of the apartments were warmer than is recommended by ASHRAE and this presents an energy efficient opportunity for the building management. The relative humidity was in the recommended range of 20-40 %.

6.3 Indoor Air Quality Review

Carbon Dioxide

Carbon dioxide is a common odorless gas that exists outdoors and indoors. It is a byproduct of combustion and human respiration. The long-term average level of CO_2 outdoors is 250 to 350 PPM. ASHRAE Standard 62 indicates that comfort (odour) criteria with respect to human bio-effluents are likely to be satisfied if a ventilation system is able to maintain indoor CO_2 concentrations less than 700 PPM above the outdoor air concentrations. Hence, good practice would keep the levels below 1,000 PPM. Health Canada recommends that the long-term level of CO_2 be no more than 3,500 PPM.

All of the apartments had average CO_2 levels higher than 700 PPM except for Apartment 417 and the entire apartment experienced times when CO_2 exceeded 700 PPM. This indicates that the mechanical ventilation system may not be adequately providing the apartments with fresh air to handle loads at all times.

TVOCs

Total volatile organic compounds are emitted by many materials and processes. People react differently to VOCs but there is concern that exposure to VOCs could have adverse affects on human health. There are no Provincial Guidelines in Nova Scotia for TVOC exposure, but good practice indicates that limit should be less than 5.0 mg/m^3.[1]

The TVOC is well below the 'good practice' guidelines.

6.4 Occupant Survey Review

A survey was done of the occupants in three apartments. The building is located in an urban setting with no unusual pollution sources within 1 kilometre of the building. The building has synthetic carpet with separate foam underlay over a concrete floor. The gypsum walls are painted with latex. The gypsum ceiling is also painted with latex. The bathroom and kitchen floors have ceramic tile. The kitchen cabinets and doors are made of particleboard.

First Apartment

There are two occupants, who spend about 80 % of the time in the apartment. They both smoke but do it outdoors. There is paint and solvents stored in the apartment. They used furniture polish within the last 30 days prior to the placement of the VOC badges. The occupants rate the air quality as average; however they find the air to be stuffy and humid. This tends to support the observations of poor ventilation system performance and intermittent high CO_2 levels in the apartments.

Second Apartment

There are two occupants, who spend about 75 % of the time in the apartment. One person smokes about 12 cigarettes per day. There is a plug-in air freshener used daily in the apartment. The occupants rate the air quality as average.

Third Apartment

There are two occupants, who spend about 40 % of the time in the apartment. They both smoke but do it outdoors. There is hobby art acrylic paint stored in the apartment. They used carpet deodorizer within the last 30 days prior to the placement of the VOC badges. The occupants rate the air quality as average.

[1] Personal Communication – Stewart Sampson P. Eng. Director Occupational Health and Safety Division, NS Dept. of Labour – July 22, 2004

Conclusions

The building's normalized total annual energy consumption is 158 ekWh/m^2. This compares well with the average annual consumption of other multi-unit residential buildings contained in the CMHC HiSTAR database of 278 ekWh/m^2. While the overall energy use is relatively low, the building failed to meet its design performance target and the minimum performance expectations of CBIP. However, present performance and the number of opportunities that exist to reduce energy consumption indicate that the energy targets are achievable. The energy analysis and subsequent evaluation of assumptions used in energy modelling for both electrical plug loads and domestic hot water energy use indicate that the assumptions may be optimistic – at least in this specific case study

Building ventilation system represents a significant improvement over conventional design strategies in that it provides outdoor air to every habitable room while providing exhaust flow from bathrooms – and included heat recovery to reduce the associated energy use. However, the testing found that the system was failing to meet performance expectations due to suspected problems in the air distribution ducting and system commissioning (or lack thereof). If properly installed and operated, the system should provide exceptional indoor air quality throughout the building. However, the indoor air quality monitoring and occupant surveys indicate that the system is not performing as well as it should.

While opportunities exist to improve the performance of this building, it appears to be meeting the original design objectives. The building consumes significantly less energy and water than conventional multi-unit residential buildings. The advanced ventilation strategy, once fully commissioned to meet design intentions, should provide a high level of indoor air quality while controlling heating costs associated with the supply of outdoor air during the heating season.

While the performance of the building failed to meet ambitious design expectations, the energy efficiency measures and innovative ventilation strategy implemented represent significant improvements over conventional buildings. The failure of the building to fully meet its challenging performance targets reflects the need for the development and use of quality assurance processes that can ensure that what is designed and specified on paper is actually achieved in practice. This would include *continuous design review* to modify and optimize design details as construction proceeds; *diligent construction supervision* and *ongoing testing* of materials and systems as they are installed, as well as *system commissioning.* Nevertheless, the good performance of the building (and its potential to fully realize its original design objectives) reflects the success of building programs such as CBIP in moving the construction industry towards higher performing buildings.

Appendix 1: Air Leakage Test Results and Photo Record of Air Leakage Locations

Photo 1: Kitchen Rangehood – air leakage from outside duct

Photo 2: Sprinkler Head Air Leakage


Photo 3: Intercom/Alarm Panel

Photo 4: Electrical Panel

Photo 5: Party Wall Between Units

Photo 6: Partition Wall Electrical Sockets and Phone Jacks

Photo 7: Leaky Window Trim

Photo 8: Living Room Ventilation Air Supply Diffuser

Photo 9: Window Closure Problem

Photo 10: Dryer Duct Penetration

Photo 11: Laundry Services – Penetration of Interior Wall

Appendix 2: Utility Billing Information (common areas and individual apartments)

ELECTRICITY:

Utility Bills

Note: Information for utility records is for all common areas and apartments.

Central Metering:	Meter#1 (House)	(Y/N)
Unit by Unit Metering:		(Y/N)

Billed Usage- Electricity

Billing Date			Energy	Peak Demand	Cost
Month	Day	Year (XXXX)	(kWh)	(kW)	excluding taxes
11	26	2002			
12	26	2002	9,300	17.2	
1	28	2003	9,300	17.2	$ 1,426.24
2	28	2003	9,120	18.9	
3	26	2003	9,120	18.9	$ 1,446.72
4	26	2003	8,320	16.3	
5	27	2003	8,320	16.3	$ 1,286.57
6	27	2003	8,580	16.3	
7	28	2003	8,580	16.3	$ 1,326.02
8	25	2003	8,730	16.4	
9	25	2003	8,730	16.4	$ 1,344.83
10	25	2003	7,770	18.0	
11	25	2003	7,770	18.0	$ 1,277.47
			103,640		$ 8,107.85

Utility Bills

Note: Information for utility records is for all common areas and apartments.

Superintendant	Apartment	112	(Y/N)
		(466-4666)	(Y/N)

Billed Usage- Electricity

Billing Date			Energy	Peak Demand	Cost
Month	Day	Year (XXXX)	(kWh)	(kW)	excluding taxes
11	26	2002			
12	26	2002	449	0.1	
1	28	2003	449	0.1	$ 98.89
2	28	2003	541	0.1	
3	26	2003	541	0.1	$ 114.82
4	26	2003	464	0.1	
5	27	2003	464	0.1	$ 101.47
6	27	2003	524	0.1	
7	28	2003	524	0.1	$ 111.46
8	25	2003	559	0.1	
9	25	2003	559	0.1	$ 117.92
10	25	2003	514	0.1	
11	25	2003	514	0.1	$ 119.08
			6,098		$ 663.64

Utility Bills

Note: Information for utility records is for all common areas and apartments.

Apt	Energy (kWh)	Cost	Apt	Energy (kWh)	Cost

101	4,450	$	484.29
102	6,623	$	720.78
103	1,790	$	194.80
104	3,756	$	408.76
105	2,008	$	218.53
106	4,736	$	515.41
107	5,180	$	563.73
108	3,227	$	351.19
109	2,019	$	219.73
110	4,402	$	479.07
111	4,645	$	505.51
112	-	$	-
	42,836	$	4,661.80

201	8,221	$	894.68
202	5,250	$	571.35
203	2,321	$	252.59
204	1,819	$	197.96
205	2,777	$	302.22
206	2,529	$	275.23
207	1,761	$	191.65
208	2,467	$	268.48
209	3,379	$	367.73
210	6,053	$	658.74
211	4,359	$	474.39
212	4,756	$	517.59
	45,692	$	4,972.62

Apt	Energy (kWh)	Cost	
301	3,773	$	410.61
302	5,050	$	549.59
303	3,749	$	408.00
304	2,289	$	249.11
305	2,044	$	222.45
306	2,596	$	282.52
307	5,464	$	594.64
308	2,881	$	313.54
309	2,019	$	219.73
310	4,402	$	479.07
311	4,645	$	505.51
312	4,645	$	505.51
313	6,094	$	663.20
	49,651	$	5,403.47

Apt	Energy (kWh)	Cost	
401	5,001	$	544.25
402	6,468	$	703.91
403	2,896	$	315.17
404	5,009	$	545.13
405	5,435	$	591.49
406	2,980	$	324.31
407	3,476	$	378.29
408	4,260	$	463.61
409	1,378	$	149.97
410	3,436	$	373.94
411	4,525	$	492.45
412	4,201	$	457.19
413	7,092	$	771.82
414	1,629	$	177.28
415	3,698	$	402.45
416	4,918	$	535.22
417	3,884	$	422.69
418	2,501	$	272.18
419	2,644	$	287.74
420	3,713	$	404.08
421	4,877	$	530.76
422	1,482	$	161.28
	71,138	$	7,741.89

FUEL OIL CONSUMPTION

6116 Almon St. Oil Consumption for 2002-2003

Billed Usage- Fuel Oil

Billing Date Month	Year (XXXX)	Billed Liters	
11	2002	6,581.4	
12	2002	8,431.0	
1	2003	12,862.5	
2	2003	11,907.0	
3	2003	8,809.9	
4	2003	7,326.1	
5	2003	6,944.2	
6	2003	4,734.6	
7	2003	5,084.5	
8	2003	3,300.6	
9	2003	3,358.5	
10	2003	3,979.0	
11	2003	8,355.2	
12	2003	7,178.1	
		83,840	litres
		22,150.6	US Gallons

Fuel Type:

- ○ Propane
- ◉ #2 Fuel Oil
- ○ #6 Fuel Oil

WATER CONSUMPTION

6116 Almon St. Water Utility Bills for 2002-2003

Billed Usage- Water

Billing Date Month	Day	Year	**Water Use**
10	25	2003	
1	21	2003	2,100.0
4	25	2003	2,380.0
7	22	2003	2,055.0
10	23	2003	2,230.0
1	22	2002	1,462.2
			10,227.2

Water in Units of:

- ○ gallons
- ◉ m^3
- ○ Mlbs (M means 10^3)