ENVIRONMENTAL ASSESSMENT TOOL FOR MULTIFAMILY BUILDINGS

PHASE III FINAL REPORT

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Final Report

Environmental Assessment of Four Buildings

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RÉSUMÉ

Il s'agit d'un rapport provisoire de la Phase III d'une initiative de recherche visant l'examen des méthodes existantes d'évaluation environnementale des bâtiments en vue d'élaborer un outil d'évaluation exhaustif des collectifs d'habitation.

La SCHL souhaite que soient mises au point les exigences relatives à un outil d'aide exhaustif pour l'évaluation de la consommation de l'énergie et des ressources, de la durabilité, des incidences sur l'environnement, de la qualité de l'air intérieur et de tout l'éventail des autres domaines propres aux collectifs d'habitation. L'outil d'aide servira à :

- évaluer les immeubles dits écologiques,
- sensibiliser les consommateurs et les gens de l'industrie aux enjeux liés aux bâtiments écologiques,
- déterminer la conformité potentielle des immeubles durables à une réglementation future dans ce domaine et
- évaluer l'impact des travaux de rattrapage éconergétique dans les bâtiments existants.

Puisque la majorité des outils en usage ont été mis au point pour les immeubles à bureaux, ils conviennent moins aux collectifs d'habitation. La SCHL désirait, d'une part, repérer les éléments des outils disponibles sur le marché pour le secteur commercial que l'on pourrait adapter aux collectifs d'habitation et, d'autre part, améliorer les éléments sous-développés ou combler les lacunes. Un tel outil, s'il était mis en œuvre, favoriserait l'utilisation de critères de conception environnementaux dans le secteur résidentiel. De tels bâtiments, qui incorporent des technologies, des techniques et des matériaux novateurs, offrent des avantages à la société qu'on ne peut pas évaluer par l'entremise des méthode classiques de comptabilité du prix de revient.

À l'aide d'un outil d'évaluation environnementale pour les collectifs d'habitation, on devrait pouvoir encourager les concepteurs à ne pas s'en tenir à la simple conformité, ainsi que promouvoir la sensibilisation et favoriser la compréhension des enjeux en matière de développement durable et mieux positionner les collectifs d'habitation performants dans le marché. Les outils doivent positionner les ensembles par rapport aux limites connues et théoriques des réalisations courantes si on espère faire de la sensibilisation et des incitatifs les fondements des objectifs d'un programme.

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CONTENT

1. INTRODUCTION

1.1 Background

This is a report on the third phase of an assessment of existing environmental assessment methods with the intent of identifying the basis for a comprehensive multifamily residential assessment tool.

CMHC wishes to identify the requirements of a comprehensive tool to assess energy and resource use, durability, environmental impact, indoor air quality and a host of other areas in multifamily residential buildings. The assessment tool is needed to:

- evaluate sustainable building projects;
- raise industry and consumer awareness of sustainable building issues;
- assess compliance with future sustainable building regulations;
- assess the impact of energy retrofits on existing buildings.

Most of the tools in use were developed for commercial offices and may not adequately assess multifamily buildings. CMHC wished to identify elements of the existing commercial tools adaptable to multifamily buildings, while developing other elements that were underdeveloped or missing. Such a tool, in the end, would, on application, encourage further use of environmental design criteria in this sector. Such buildings incorporate innovative technologies, materials and techniques which offer societal advantages which cannot be valued by conventional cost accounting.

With an environmental assessment tool for multi-unit residential buildings, it should be possible to encourage design beyond compliance, promote awareness and understanding of sustainable issues and properly position advanced multifamily buildings. Tools should identify where a project is in relation to the known and theoretical bounds of achievement if education and incentive are to be key components of a program's intent.

1.2 Results of Phase I – Review and Comparison of Existing Assessment Methods

Phase I [13] involved an in-depth paper study of six building assessment tools – BREEAM Canada, BEPAC, GBC'98, ATHENA, OPTIMIZE and BEES. Phase I was restricted to reviewing published documentation and manuals supplied by CMHC on each of the environmental assessment methods (BREEAM, BEPAC, GBC'98). A Beta version of the BEES Program, an early non-commercial version of ATHENA and the OPTIMIZE software, were reviewed using both written documentation and software versions of the programs.

In Phase I the Team developed categories and criteria for multifamily building assessments, developed content and scope for each criteria and used this in its evaluation of the six tools. All were found to be still under development, intent was often not yet translated into practice and missing parts were under development or about to be released. A detailed issue-by-issue, side-by-side review and critique of the methods was presented in the Phase I report. Conclusions on attributes and weaknesses of the tools for application to multifamily buildings were delineated and specific recommendation for changes were made.

1.3 Results of Phase II – Field Evaluation of Existing Tools

Phase II [14] was intended to provide the Team with an understanding of how the current environmental assessment methods were applied in practice. Members of the Team accompanied BREEAM and BEPAC assessors to the building selected for the pilot assessment to provide an insiders' and outsiders' perspective on the input requirements, to observe how the tool is applied in practice and to compare the results and interpretations.

The intent of this phase was to evaluate how the assessment tools performed in the field (essentially Part 2 of the Environmental Assessment Methods review).

Building B, located in Mississauga, Ontario was recommended as the pilot building. With cooperation from the designer of Building B, and from the management of Building B, a site visit and building assessment were completed in August, 1997.

The BEPAC assessor was Karl Flood, Tescor Energy Services, Inc. The BREEAM assessor was Jiri Skopek, ECD Energy and Environmental Canada Ltd. Two members of the Team accompanied the assessors to test the GBC'98 input format as well as to assess variations in how the two assessors dealt with the same issues.

The Team also applied ATHENA and OPTIMIZE to Building B in order to determine the level of effort required, the ease of using the program, and the quality of the results. Developers at the ATHENA Institute were contracted to assist with the implementation of ATHENA. The report from Phase II contains observations and results of the analysis. Limited comparisons between the tools were possible.

1.4 Phase III Scope and Method of Approach

In Phase III, four buildings have been assessed using parts of the GBC'98 [1] methodology. The four buildings are: Building A, Building B, Building C, and Building D. The four buildings will be assessed side by side to illustrate how the GBC'98 assessment works and how it will compares four somewhat different buildings.

The following categories will be evaluated and scored:

R1 Energy
R2 Land
R3 Water
E1 Airborne Emissions
E2 Solid Waste
E4 Other Loadings
Q1 Air Quality
Q2 Thermal Quality
Q3 Visual Quality
Q4 Noise and Acoustics

Q5 Controllability
P1 Design and Construction Process
P2 Building Operations Planning
C1 Location and Transportation
C2 Loadings on Immediate Surroundings
Accessibility

1.5 Buildings for Assessment

1.5.1 Building A

Building A was built in 1981 as a market-ready condominium complex. The complex consists of 704 apartment-units and 51 townhouses. Building A was built at a time when energy use and conservation were high on the list of public priorities. Due to the second oil embargo in 1979, the Government of Canada's National Energy Program was developed to ensure self-sufficiency for energy sources. Thus, a selling feature of the development was its downtown location which allowed short commuting times for those working downtown as well as access to Toronto's public transit system. Heat pumps, a relatively new technology being promoted at the time, were used in Building A.

Building A was not designed as an advanced, or 'showcase' building, however, some elements of good urban design correspond to sustainable design. Building A is located in an area of downtown Toronto which had, at the time, undergone significant deterioration. The area consisted of light manufacturing, neglected industrial buildings, and aging houses. The high density upscale complex was instrumental in further development in the area. Originally, all apartments in the complex were rentals; vacancy rates at the time were less than 0.5%. Building A now contains occupant-owned condominium apartments.

The development consists of three joined apartment blocks, along the east, north and west sides of the site, with a row of townhouses to the south closing in a courtyard in the middle. The north wing of the complex, which is along King Street, acts as a sound buffer for the interior part of the development and the residential area behind. The townhouses reinforce the traditional residential character of the surrounding area and provide a transition to the higher density apartments. Along King Street is 370m^2 of retail space intended to service the occupants of the building and participate in the existing commercial strip. Extensive recreational facilities are also in the building including: squash courts, movie theatres, meeting spaces, and a fitness area.

All apartments were built with large conservatories/sunrooms enclosed by single-pane glass. Originally, these rooms were not counted as heated space on zoning applications. During recent renovations, double-glazing was installed to better insulate the space.

1.5.2 Building B

Building B is a 248-unit rental apartment complex. It was designed to provide social housing and a denser urban form in a sprawling suburban area. The complex includes a street-level retail area, access to public transportation, and a sense of community which has succeeded in creating a pedestrian presence in an automobile-dominated area. The quality of housing is high enough to attract a mix of income groups - those that pay full market rent and others who receive subsidies. Building B consists of two buildings, of 13 stories and 7 stories. The seven story building steps down from 7 to 4 stories to better blend in with the surrounding single detached houses.

The project was conceived and planned through cooperation amongst architects, engineers, and developers, beginning early on in the process. Achievements which have made Building B among the most advanced in Canada include: energy conservation, reduced environmental impacts, and superior indoor air quality for residents.

The engineers on this project were intent on proving that ASHRAE 90.1, a common building standard, was unambitious. Overall design resulted in an expected reduction of energy consumption of 50% prescribed by ASHRAE 90.1. Wall and roof insulation values were increased 70% over conventional construction; window R-value was increased 100% by using triple-glazed, argon-filled, low emissivity windows. Cooling loads were further reduced by using spectrally-selective glass. Energy requirements for hot water were decreased through the use of a co-generation system. Fan energy normally required to distribute heated or cooled air was also decreased within suites by relying on passive distribution by ceiling-mounted fin tube convectors. High efficiency lighting is used throughout suites and common areas.

Environmental impacts of the building have been decreased by reducing the requirement for automobile use. Building B is located close to many amenities and is on a major bus route with frequent service (5-7 minutes). Building B has even incorporated a street-level retail area with a restaurant, delicatessen, grocery store, bank and other amenities.

The two buildings share a co-generation system which uses natural gas to produce 80% of the electricity requirements of the building. The waste heat from the system is used to produce domestic hot water and as a heat source for an absorption chiller. Heating is supplied to units by hot water heated from waste heat. Chilled water from the absorption chiller provides cooling for the suites. Emissions of greenhouse gases associated with energy production for the building are reduced to a third of that for conventional generation through the use of the natural gas co-generation system. Overall efficiency of the co-generation system is 90%.

Conventional apartments use pressurized hallways to distribute fresh air into individual units. Building B has aimed to improve its indoor air quality by delivering fresh air through balanced heat recovery ventilators contained in each unit. Units are sealed from the hallways to avoid any cross-contamination.

Building B challenged conventional building techniques by designing an apartment complex that provides high quality housing with minimal environmental impacts. Capital costs for providing the energy saving features are expected to be recovered over time through reductions in operating costs. Building B has received national and international recognition as a milestone on the path to sustainable development including a World Habitat Award in 1996.

1.5.3 Building C

Building C is an 8-storey multi-unit residential building located in downtown Montreal. The project includes 78 condominium units with commercial space at street level, one level of underground parking and an inside courtyard. The building is located in the Ville-Marie district of central Montreal, and is in close proximity to the Berri-UQAM subway station, Voyageur bus terminal, train station, and shopping. The building is tiered to better fit with the streetscape with eight storeys facing Boulevard Rene-Levesque, seven storeys on Rue St-Andre and five storeys on Rue St-Christophe. Balconies open onto the interior courtyard from all sides as well as on St. Christophe. Two adjacent three-storey residential buildings are separated from Building C by a common wall and backyard.

This building was part of a redevelopment of the district to celebrate Montreal's 350th anniversary. The architectural concept responds to the revitalization of Boulevard Rene-Levesque with a strong residential focus and a community pharmacy. Due to zoning laws adopted in 1993, Building C is intended to restore the residential character to this largely commercial area.

This building was conceived by a development team in conjunction with an architect, engineering team and specialists dealing with indoor air quality and environmental viability. This building was a regional finalist in a national competition. The base building was completed in 1995 and some condos are being completed upon sale.

Building C focused on the development of effective mechanical and ventilation systems to keep its occupants healthy and comfortable while maintaining energy efficiency. The central ventilation system brings fresh air into every room in the suite. Air filtration, air exhaust and heat recovery systems are incorporated into the building. The walls have a thermal resistance of R28 and the roof has a thermal resistance of R39.

The designers originally considered a four step pre-heating system for domestic hot water including grey-water heat recovery, solar energy pre-heating, garage exhaust air heat recovery, and air-conditioning unit heat recovery. None of the measures were incorporated due to financial constraints. Two direct-contact water heaters are used which operate with high efficiency and low NO_x and CO emissions.

This building has showcased a number of innovative techniques and materials and equipment. These features include humidified fresh air for each suite, high-efficiency central gas-fired heating, heat recovery ventilators and an advanced building envelope.

1.5.4 Building D

Building D is a 4-storey, 84 unit apartment building located in Ottawa. The building is a housing co-operative and the level of technical knowledge within the group was substantial. The project was located on a site within an established neighbourhood within walking distance of downtown.

This building was conceived by a team consisting of the co-op client group, an architect, specialist engineering consultants for structural, electric and mechanical, an envelope specialist, a landscape architect and a construction company. The development consultants were from the Co-operative Housing Federation of Eastern Ontario. The building was completed in 1996 at a cost of approximately $650/m^2$.

Many green technologies and features were incorporated into Building D, including: a combination space and water heating system in each unit; separate natural gas metering in each unit; heat recovery ventilators in each unit; restricted surface parking spaces for cars (8); 200 underground storage spaces for bicycles; balconies are constructed separately from the interior floor slab eliminating the thermal bridge; four recycling rooms on each floor; rain water collection and reuse; energy efficient interior and exterior lighting.

This housing project's integrated approach to sensitive environmental issues is perhaps unique. Energy efficiency is a priority, as is the use of recycled materials, preservation of trees and other vegetation on the site and reducing operational waste.

2. ASSESSMENT OF SUBJECT BUILDINGS

Chapter 2 contains an environmental assessment of the four buildings described in Chapter 1. Building A has been chosen as an example of a market-ready building which serves as a reference in some categories.

2.1 Explanation of Scoring

Scoring is based on the GBC'98 manual [1]. The maximum score is always five; a score of zero is given for the industry norm, and negative two (-2) represents a greater environmental impact than typical industry practice. The GBC'98 performance scales have not been reproduced in this document and it may be helpful to the reader to consult the manual. Three examples of scoring in the GBC'98 manual are shown below:

(1) Some categories are scored based on a quantitative measure which is compared to the reference building. For this type of category, where appropriate, the reference building will be Building A. An example of this is *R1.3 Energy Consumption* with the Performance Scale shown in Table 2.1. It is apparent that the maximum score of 5 is very difficult to obtain; even for a commendable performance such as a 50% reduction in energy use, the score is only 2.7.

Table 2.1: Performance Scale for R1: Energy Consumption

Score	Performance
-2	The annual operating energy per unit area of floor area of the case study building is 45% GREATER than that of the reference building
-1	The annual operating energy per unit area of floor area of the case study building is 20% GREATER than that of the reference building
0	The annual operating energy per unit area of floor area of the case study building is EQUIVALENT than that of the reference building
1	The annual operating energy per unit area of floor area of the case study building is 25% LESS than that of the reference building
2	The annual operating energy per unit area of floor area of the case study building is 40% LESS than that of the reference building
3	The annual operating energy per unit area of floor area of the case study building is 55% LESS than that of the reference building
4	The annual operating energy per unit area of floor area of the case study building is 65% LESS than that of the reference building
5	The annual operating energy per unit area of floor area of the case study building is 70% LESS than that of the reference building

(2) Some categories are scored quantitatively but have the measure defined in the manual already and do not require a reference building. An example of this type of scoring is *E2.1.1-Dedicated recycling storage and handling areas and systems*. In a category such as this, there is no reference building and each category will be scored against the Performance Scale given. The Performance Scale is reproduced in Table 2.2.

Table 2.2: Performance Scale for E2.1.1:
Dedicated recycling storage and handling areas and systems

Score	Performance
-2	Non-applicable
-1	Non-applicable
0	The case study building contains a central storage area for solid waste of 0.75m² per 1000m²; and there is a dedicated storage area on each floor of 0.5m²
1	
2	
3	The case study building contains: a central storage area for solid waste of 0.75m² per dwelling unit; an area for recycling, storage, separation, and handling; and a dedicated storage area on each floor of 0.5m² per dwelling unit and 0.5m² in each dwelling unit kitchen;
4	
5	The case study building contains: a central storage area for solid waste of 1.0m² per dwelling unit; an area for recycling, storage, separation, and handling; and a dedicated storage area on each floor of 0.75m² per dwelling unit and 0.75m² in each dwelling unit kitchen;

(3) Some categories are scored subjectively. These categories are not compared against a reference and require a significant amount of judgement on the part of the assessor. In this case, an explanation of the rationale for the score is given. An example of this type of scoring is *Q5.1 - Level of building automation appropriate to system complexity*. The Performance Scale is reproduced in Table 2.3. It can be seen that the knowledge and beliefs of the assessor may affect the scoring.

Table 2.3: Performance Scale for Q5.1:
Level of building automation appropriate to system complexity

Score	Performance
-2	Non-applicable
-1	Non-applicable
0	The level of building automation for the case study building is overly complex and ineffective in meeting the operational requirements.
1	
2	
3	The level of building automation is consistent with the operational requirements of the case study building
4	
5	The level of control and automation of the building systems is the least technically and functionally complex while fully meeting the operational requirements of the case study building.

The GBC'98 framework is broken down into three levels: categories (Q1 Air Quality), criteria (Q1.1 Moisture Control), and sub-criteria (Q1.1.1 Control of moisture in building envelope that may affect IAQ). Sums of scores for criteria make up the total score for the category and similarly, sums of sub-criteria make up the scores for criteria. Sub-criteria are not presented separately within this report (for most categories). For each category, there is a discussion of the score given to each building. Following the discussion, a summary table is presented which lists the most important features followed by the score for each criteria (marked by a bullet point •).

2.2 Energy [Criteria R1]

This criteria assesses the measures taken to reduce energy consumption in the building. For a complete GBC'98 assessment, this category will include the life-cycle energy requirements which consists of the operating energy consumption, the embodied energy required for building materials and construction, and the embodied energy of replacement building components. For the purposes of this report, only operating energy consumption will be scored. Scores are based on actual energy usage (for Building A) or as determined using an hour-by-hour energy simulation (for Buildings B, C and D).

Building A

Building A was designed with some energy efficient measures because at the time there was a threat of another oil embargo. However, the availability and development of efficient technologies was far behind what it is today. A water-loop heat pump system was installed which is especially efficient for buildings which require simultaneous heating and cooling. The use of glazed sunrooms instead of balconies improved the heating performance of the building. Some retrofits such as envelope improvements, double glazed windows on atriums, and staged, high efficiency boilers were incorporated recently. An ESCO is being hired to improve energy use further.

An energy simulation was not available for Building A, but overall energy consumption was estimated from energy bills from a sample of 24 random units from the east phase. Energy bills from the common areas (recreation, parking, corridors etc.) of all three phases were obtained and used to determine the energy consumption given below. Suites in the east phase are representative of the rest of the development since there is exposure in all four directions (mainly east-west) which mitigates the extremes of north and south facing units.

The total energy consumption is approximately 29 ekWh per ft^2 per year. This value compares reasonably with estimates of 15-40 kWh/ft^2 for multi-residential buildings [2]. Building A receives a score of zero for this typical level of energy consumption.

Building B

Building B was designed specifically to be very energy efficient with the energy cost savings used to offset rents, the costs of higher quality building components, and the costs of a more luxurious design. Energy efficiency was achieved through an improved envelope, heat recovery in suites, and innovative mechanicals including cogeneration and an absorption chiller. The goal in this project was to reduce energy consumption to 50% of ASHRAE 90.1 standards. Compared to either Building A or to

ASHRAE, Building B's energy usage is 15 ekWh per ft^2 per year, which is half of that used in a reference building [3]. The score given for a 50% energy reduction is 2.7.

Building C

Building C was designed with energy efficiency in mind. A number of technologies were specifically included for their energy efficient features. This facility uses gas-fired centrally-heated DHW and hydronic heating with heat recovery on part of the exhaust air. Split-unit air-conditioning within suites was provided to the owners as an option. Recently a dehumidifying coil was installed on the fresh air supply to provide more comfortable conditions during the summer. Simulations of Building C have been carried out by energy consultants and reported on in [15]. The overall energy usage estimated by simulation was 11.2 ekWh/ft^2, and for the same building built to ASHRAE 90.1 standards (the reference), the energy consumption was 23 ekWh/ft^2, 51% less. However, actual bills are available which give the energy consumption as 17.8 ekWh/ft^2, only 23% less than the reference. Explanations are given as to why the energy simulation is 37% less than the actual consumption - design changes, unexpected behaviour by tenants (leaving windows open), and poor operating practices [15]. Regardless, Building C is scored using the simulated energy consumption of the actual building against the simulated consumption of the hypothetical reference building which is a 51% reduction.

Building D

Building D has a number of energy efficient features including: low E windows; high efficiency combination space and water heating system in each unit; HRV in each unit; low-flow water fixtures; high efficiency interior and exterior lamps; separate balcony and interior floor slab in each unit. Air conditioners were to be prohibited in the building. The overall energy consumption as estimated by energy simulation was 22.9 ekWh per ft^2, which was higher than the other advanced buildings in the comparison. Referenced to Building A, Building D's energy consumption is only 21 percent lower.

Table 2.4: Summary of Scoring of ENERGY Category

	Comments	Score	
Building A	• overall energy consumption: 29 ekWh/ft^2 per year		0
Building B	• overall energy consumption (simulation): 15 ekWh per ft^2		2.7
Building C	• energy consumption (simulation): 11.2 ekWh per ft^2, reference 23 ekWh per ft^2 based on simulation.		2.7
Building D	• energy consumption (simulation): 22.9 ekWh per ft^2		.8

2.3 Land [Criteria R2]

This category assesses the ecological significance of the land prior to building, and the measures taken to improve or maintain the site ecology. Three criteria are scored separately, and weighted equally for one combined score.

Building A
Building A was built on a site which was an industrial facility. This site was serviced and previously built upon prior to the development. Approximately 80% of the site area is covered by the building footprint, surface parking, and access roads. The remaining 20% is landscaped area. The landscaping is attractive and practical given the urban location of this site. Grass, as well as many trees and shrubs, have been planted.

Building B
Building B was developed on under-used land which was originally covered in brush, long grass and small trees. Although it was not previously built upon, the site was serviced. Approximately 55% of the site area is taken by the building footprint, surface parking and access roads. The remaining 45% is landscaped. The landscaping strategy is similar to Building A - mainly grass, trees and shrubs have been used. The strategy is acceptable for the suburban location, however, given the previous condition of the site, a more natural strategy could have been used.

Building C
Building C was built on a serviced lot having previously been used as a parking lot. There is no surface parking at Building C, with a portion of the site area taken up by a common courtyard. The landscaped area is approximately 9% of the total site area with rest made up of the building footprint and access roads. Some credit is given to this building for reintroducing some natural vegetation to this densely built area.

Building D
Building D was built on serviced land where the original two small apartment buildings were vacant and in dilapidated condition. They were demolished by the city before the project began. Fifty-five percent of the site area is building footprint, access roads and parking. Existing mature trees and shrubs were largely retained. Composters are located throughout the site for flowerbeds and gardens.

Table 2.5: Summary of Scoring of LAND Category

Building	Comments	Score*	
Building A	• built upon, serviced prior to construction • 80% of the site area is building footprint, access roads and parking • landscaped site with trees, grass, shrubs (previously industrial site)	(3) (1.5) (1)	1.8
Building B	• serviced, non-agricultural site prior to construction • 55% of site area is building footprint, access roads, and parking • landscaped site with trees, grass and shrubs (previously grassed field)	(1) (4) (1)	2
Building C	• serviced, non-agricultural, low-intensity site prior to construction • 90% of site area is building footprint, access roads and parking • reintroduced vegetation to previously-paved lot	(2) (0.75) (1)	1.3
Building D	• serviced, low-rental apartment buildings, demolished before project began • 55% of site area is building footprint, access roads and parking • existing mature trees and shrubs largely retained, others transplanted on site. Composters provided on site	(3) (4) (5)	4.

*scores in brackets ( ) indicate intermediate scores.

2.4 Water [Criteria R3]

This criteria assesses the water consumption in the building. Water consumption is assessed in three areas: building operation, landscape irrigation and dwelling unit use. Actual billing is not available for any of the buildings so water consumption is estimated using various methods (see Notes 1,2,3). For scoring the water requirements for landscaping, the Reference building is a building with the same site area using conventional landscaping and irrigation practices. Conventional landscaping for this type of building is assumed to be similar to Building A which has 25% shrubbery and 75% grass.

Building A

Water use for building operations includes the water for evaporative condensers, laundry facilities, and the indoor and outdoor pools (see Note 1 for explanation of assumptions). Building A has not incorporated any water-saving measures and may be considered as typical for most residential buildings. The total water use for the building operation is 26.2×10^6 litres per year which is 42.8 litres per ft^2 per year. Some over-estimation of water consumption may have resulted from the assumption that the entire cooling load requires evaporated water. The evaporative condensers can operate using air for cooling of the water loop, as well as by conventional water spray. Also, the nature of the water-loop is that during transition seasons, some units may be extracting heat and some rejecting heat to the same loop, negating the need for cooling of the loop.

Landscaping at Building A was not chosen to minimize water use and is considered to be equivalent to a reference building giving a score of zero. Water consumption for landscaping is 2.4×10^6 litres per year which 53.6 litres per ft^2 of landscaped area per year - (see Note 2 for explanation of calculation procedures).

Indoor water use with conventional appliances, fixtures, and usage is assumed to be approximately 220 litres per day per person [5], [9], [10] (water for laundry is included with building operation). See Note (3) for explanation of calculations. A reduction in water consumption of 15% over the reference was realized through the installation of toilet dams and shower and faucet aerators. It was assumed that they were installed in half the suites only. A score of 0.75 is awarded for a 15% reduction.

Building A will be the reference and will be the basis for comparison of building water consumption for Building B and Building C.

Building B

Water for the building operation is used for the HVAC evaporative condensers, and the laundry facilities. The total water use for building operation is 5.8×10^6 litres per year which is 24.5 litres per ft^2 per year. The 43% reduction over the reference building is primarily due to a reduced cooling load.

The landscaped area is approximately 45% of the site area, and is half grass and half shrubs and other small plants. Water use was calculated in the same way as for Building A and resulted in 1.9×10^6 litres per year. Neither Building B or Building A have incorporated water-saving strategies into the landscaping, however shrubs generally have lower water requirements than grass. Normalized for comparison, Building B uses 35.3 litres of water per ft^2 of landscaped area per year which is a reduction of 34% over the Reference.

Building B has reduced water consumption in dwellings by 53% over the Reference (see Notes for calculation) through the use of low-flush toilets, and shower and faucet aerators.

Building C

Water used for the building operation is laundry water and a small amount of makeup water for the outdoor fountain. Although the apartment size washers/driers are in each unit, this water consumption will be categorized as *building operation* as opposed to *dwelling* water use. There is no water consumption for cooling as there is in the other two buildings since cooling of the water loop is accomplished using heat exchangers instead of evaporation. The total water used for building operation is 1.59×10^6 litres per year which is 16 litres per ft^2 per year (see notes (1)) which is a reduction of 60% over the reference which scores 5.

There is not a lot of landscape irrigation requirements because this is a dense urban site with only 9% of the total site area landscaped. Approximately 22% of the landscaped area is shrubbery and 78% is gravel, with no irrigation conservation practices in place. The water consumption is estimated at 2.2 litres per ft^2 of landscaped area per year which is only 6% of that used by the reference building which scores 4.6. The reference building for Montreal uses 39.2 litres per ft^2 of landscaped area per year.

Water consumption in dwellings is reduced through the use of low-flow (6 lpf) toilets and aerators on faucets and showers. This results in a 53% reduction over the Reference (see Notes for calculation).

Of twenty-six owners responding to an occupant survey only 10 or 40% had installed water conserving showerheads and only 20% had installed aerators on their faucets.

Building D

There is no water use for building equipment operation as there are no central chillers or boilers. Water use measures include low-flow plumbing fixtures and an experimental grey water recycling installation in eight suites. Landscape water is by rain water collection by roof drains and a cistern. Plants have been selected to minimize watering.

Table 2.6: Summary of Scoring of WATER Category

Building	Comments	Score*	
Building A	• building operation - no measures for conservation 42.8 litres per ft^2 per year • landscaping - no measures for conservation 53.6 litres per ft^2 of landscaped area per year = reference • dwelling - toilet dams, faucet and shower aerators 220 litres per day per person	(0) (0) (0.75)	0.25
Building B	• building operation - reduced cooling load, reduced water requirement - 24.5 litres per ft^2 per year • landscaping - reduced consumption by using less grass - 35.3 litres of water per ft^2 of landscaped area per year • dwelling - low-flush toilets, toilet dams, faucet and shower aerators - 104 litres per day per person	(3.8) (1.2) (3.8)	2.9
Building C	• building operation - use heat exchanger instead of evaporative condenser - water for laundry - 16 litres per ft^2 per year • landscaping - 2.2 litres of water per ft^2 of landscaped area per year = reference • dwelling - low-flush toilets, faucet and shower aerators - 104 litres per day per person	(5) (4.6) (3.8)	4.5
Building D	• building operation - no measures - 23.4 litres/ ft^2/yr • landscaping - 100% by stored rain water - 0 litres/yr • dwelling - low-flows showerheads, sinks aerators, low-flush toilets	(5)	5

*scores in brackets ( ) indicate intermediate scores.

2.5 Airborne Emissions [Criteria E1]

Airbone emissions are based on simulated energy performance in buildings B, C and D. This category assesses the amount of emissions associated with the building operation. Emissions are affected by the choice of fuel and the quantity of energy consumed. Some factors, such as geographical location, will affect fuel availability and emissions due to electricity generation. This category inherently assesses the choice made in regard to fuel mix for the building (i.e. direct fossil fuel combustion vs. electricity from hydro grid) and thus, it is important to choose a relevant reference building - Building B has been compared against Building A, since they are both located in Ontario, but Building C is compared against both a hypothetical reference building which has been simulated in accordance with ASHRAE 90.1 and Building A. ASHRAE 90.1 requires that both buildings use natural gas for space heating. Furthermore, Building C has incorporated a low NO_x direct-contact water heater which will reduce NO_x emissions by approximately 60% over conventional combustion [16]. Building D can be compared to Building A in regard to emissions as both are located in Ontario. CO_2 emissions are higher in Building D than Building B or Building C, primarily due to higher electrical energy use. SO_2 emissions are about 40% higher than Building B and C. Both NO_x and TPM emissions are much lower than Building A but significantly higher than Building B and C. This is largely due to the Ontario electrical generation mix which has limited impact in Building B because of the co-generation system and in the case of Building C, electrical generation is almost entirely hydro-electric. (While the co-generation system has had little effect in practice, the simualtion results show potential for significant purchased electricity reductions). The ozone depleting index for Building D is zero as there are no air conditioners in the building. See Note 4 for the emissions factors that have been used in this category. The value for natural gas has been reduced by 60% to account for the low-NO_x generation in Building C. E1.5.2 (Halon Emissions) -has not been assessed since halons have been banned for a number of years. Tables 2.7 through 2.12 summarize the sub-criteria.

Table 2.7: CO_2 Emissions [Criteria E1.1]

Category E1.1 CO_2 Emissions	Purchased Electrical Energy Consumption (kWh/ft²)	Emissions due to Electrical Energy [mg/ft²/yr]	Natural Gas Consumption (MJ/ft²)	Emissions due to Natural Gas [mg/ft²/yr]	Total Emissions [kg/ft²/yr]
Building A	13.7	1,723,734	55.1	2,738,470	4.5
Building B	0.46	57,877	60.4	3,001,880	3.1
Building C *reference for C*	4.88 7.82	2568 4116	22.9 55.5	1,138,130 2,758,350	1.1 2.8
Building D	8.55	1,075,761	51.9	2,579,430	3.6

Table 2.8: SO_2 Emissions [Criteria E1.2]

Category E1.2 SO_2 Emissions	Purchased Electrical Energy Consumption (kWh/ft²)	Emissions due to Electrical Energy [mg/ft²/yr]	Natural Gas Consumption (MJ/ft²)	Emissions due to Natural Gas [mg/ft²/yr]	Total Emissions [mg/ft²/yr]
Building A	13.7	18,199	55.1	11	18,210
Building B	0.46	611	60.4	12	623
Building C	4.88 7.82	3.6 5.8	22.9 55.5	4.7 11.1	8.3 16.9
Building D	8.55	11,357	51.9	10.4	11,367

Table 2.9: NO_x Emissions [Criteria E1.3]

Category E1.3 NO_x Emissions	Purchased Electrical Energy Consumption (kWh/ft^2)	Emissions due to Electrical Energy [$mg/ft^2/yr$]	Natural Gas Consumption (MJ/ft^2)	Emissions due to Natural Gas [$mg/ft^2/yr$]	Total Emissions [$mg/ft^2/yr$]
Building A	13.7	3551	55.1	2314	5865
Building B	0.46	119	60.4	2537	2656
Building C	4.88 7.82	2.1 3.4	22.9 55.5	385 2331	387 2334
Building D	8.55	2216	51.9	2180	4396

Table 2.10: TPM Emissions [Criteria E1.4]

Category E1.4 TPM Emissions	Purchased Electrical Energy Consumption (kWh/ft^2)	Emissions due to Electrical Energy [$mg/ft^2/yr$]	Natural Gas Consumption (MJ/ft^2)	Emissions due to Natural Gas [$mg/ft^2/yr$]	Total Emissions [$mg/ft^2/yr$]
Building A	13.7	572	55.1	71	643
Building B	0.46	19	60.4	78	97
Building C	4.88 7.82	5.4 8.7	22.9 55.5	29.5 71.6	35 80
Building D	8.55	357	51.9	67	424

Table 2.11: Ozone Depleting Potential [Criteria E1.5]

Category E1.5 Ozone Depleting Potential (ODPI)	Comments	Ozone Depleting Potential Index (ODPI) [kg equiv. CFC-11/ft^2]
Building A	Building A does not have a central chiller but each unit has its own heat pump. There is an estimated 1.25 lbs of R-22 refrigerant in each heat pump.	34.3×10^{-6}
Building B	Building B has both an absorption chiller, which does not use CFCs or HCFCs, and a reciprocating chiller which is charged with 70 lbs of R-22. This results in a total ODPI that is only 20% of that found in Building A.	6.7×10^{-6}
Building C	Air conditioning is chosen as an option when purchasing a unit. A/C systems are split with HFC's as the refrigerant (HFC has ODP =0)	0
Building D	No air conditioning systems are installed in the building.	0

Table 2.12: Summary of Scoring of AIRBORNE EMISSIONS Category

Building	Comments			Score*	
Building A	• CO_2 - 4.5 kg/ft^2/yr. • SO_2 - 18,210 mg/ft^2/yr. • NO_x - 5865 mg/ft^2/yr. • TPM - 643 mg/ft^2/yr. • ODPI - 34.3x10^{-6} kg equiv. CFC-11 per ft^2			(0) (0) (0) (0) (0)	0
Building B	• CO_2 - 3.1 kg/ft^2/yr. • SO_2 - 623 mg/ft^2/yr. • NO_x - 2856 mg/ft^2/yr. • TPM - 97 mg/ft^2/yr. • ODPI - 6.7x10^{-6} kg equiv. CFC-11 per ft^2			(1.4) (5) (3) (5) (3.7)	3.6
Building C	• CO_2 - 1.1 kg/ft^2/yr. - ref - 2.8 kg/ft^2/yr. • SO_2 - 8.3 mg/ft^2/yr. - ref - 16.9 mg/ft^2/yr. • NO_x - 387 mg/ft^2/yr. - ref - 2334 mg/ft^2/yr. • TPM - 35 mg/ft^2/yr. - ref - 80 mg/ft^2/yr. • ODPI -0 kg equiv. CFC-11 per ft^2	(5) (5) (5) (5) (5)	5.0	ref. (3.6) (2.4) (5) (3.1) (5)	3.8
Building D	• CO_2 - 3.6 kg/ft^2/yr. • SO_2 - 11367 mg/ft^2/yr. • NO_x - 4396 mg/ft^2/yr. • TPM - 424 mg/ft^2/yr. • ODPI -0 kg equiv. CFC-11 per ft^2			(.8) (1.8) (1.0) (1.6) (5)	2.0

*scores in brackets ( ) indicate intermediate scores. The first score on right for Building C is based on comparison with Building A. The second column on right for Building C is based on score against reference from simulation.

2.6 Solid Waste [Criteria E2]

This category assesses the systems that are in place to deal with averting solid waste from landfills. This category is important for residential building since they tend to produce more solid waste than other building types. Both general household waste, and wastes due to future decommissioning of the building are considered. The latter category is advanced and has not been considered part of the building design process until recently.

Building A

Two portions of Building A have a recycling room located on the bottom floor and tenants must bring their recyclables to the room. The other phase of Building A has a RecycleTech automatic system so that tenants can drop the recyclables through the garbage chute on their floor. The RecycleTech system works reasonably well although some complaints have been heard regarding items getting stuck in the chute. GBC'98 scores this category based on the area dedicated to recycling in each unit, on each floor, and centrally. Building A has provided 1 m^2 per 1000 m^2 of floor area which is considered to be typical. There is no consideration of wastes generated during the decommissioning of the building.

Building B

Building B has a significant central storage space for recyclables. They have also incorporated RecycleTech systems to simplify sorting and recycling for staff and tenants. The system has operated reasonably, although there has been instances of misuse. There is approximately 0.6m^2 of space dedicated to central recycling, and 0.5 m^2 per floor. Although the 0.6 m^2 is less than the 0.75 m^2 required for a score of three, the space is ample and thus, Building B receives a score of three. There is no allowance for organic separation or recycling or for wastes from future decommissioning.

Building C

Building C has a large space in the garage dedicated to the storage of recyclables. Recyclables are only sorted into two streams: paper/boxboard and glass /metal /plastic /aluminum, and not a lot of space is required. Each unit has kitchen storage, however tenants are required to carry recycling to the bins in the garage which reduces participation. There is no organic separation or recycling. The design did not consider wastes from future decommissioning.

Building D

Building D has four recycling rooms on each floor. There are large composters on the site for organic waste separation. Under each kitchen counter is space for 'blue boxes' for recycling. There has not been consideration of future recycling of building components.

Table 2.13: Summary of Scoring of SOLID WASTE Category

Building	Comments	Score*	
Building A	• 1m^2 per 1000m^2 of floor space; no organic waste separation • future recycling of building components has not been considered	(0) (0)	0
Building B	• 0.75m^2 of central recycling space per unit and 0.5 m^2 per floor (3); no organic waste separation (0) • future recycling of building components has not been considered	(1.5) (0)	0.75
Building C	• 0.5m^2 (approx.) of central recycling space per unit and storage space in units, no on-floor space (2); no organic waste separation (0) • future recycling of building components has not been considered	(1) (0)	0.5
Building D	• 97.8 m^2 of space dedicated to storage and handling of recyclable material. One recycling room on each floor and 4 depots for organic waste separation • future recycling of building components has not been considered	(3) (0)	1.5

*scores in brackets ( ) indicate intermediate scores.

2.7 Other Loadings [Criteria E4]

This category assesses environmental loadings not covered in any of the previous categories. The two items that are assessed are: the measures that have been taken to minimize automobile usage and the amount of nuclear waste generated by the building energy use (see Note 5). The reference building for the nuclear waste category will be the same as that for the energy section and the building will have the same location (i.e. use the same electricity grid). The score for nuclear waste production represents the reduction in electricity production as well as measures to offset nuclear-generated electricity.

Building A
Building A has provided 668 resident parking spots and 54 visitor spots for the 740 units. The number required by local bylaws is 483 and 54, respectively. Building A receives a score of –1.6 for this sub-criteria. There are two bicycle rooms with approximately 125 spaces. Tenants may have a bicycle rack erected at the back of their automobile parking space for free (it is estimated that there is 100 of these). There are approximately 40 spaces provided outside for visitor bicycle parking. This results in one resident space per three units and one visitor space per twenty units (score: 0.5).

There is an estimated 7.2×10^{-4} dm^3 of radioactive waste per ft^2 of floor area produced due to electricity consumption by Building A. There has been no attempt to reduce nuclear waste.

Building B
There has been no attempt to reduce parking levels beyond the minimum required by bylaws in Building B. There are 159 resident spaces and 47 visitor spaces. There are two bicycle rooms offering approximately one space per 3 apartments. There is only one visitor bicycle parking space per 18 apartments.

There is an estimated 0.24×10^{-4} dm^3 of radioactive waste produced per ft^2 of floor area by Building B. This is 5% of that produced by the reference. Building B was predicted to achieve this enormous reduction by producing its own electricity using co-generation (natural gas). In practice, the reduction has been between 60 and 70 percent. Waste heat from co-generation is used for heating, cooling and hot water production which reduces the energy load further .

Building C
Building C provides 40 parking spots for the building and no on-site visitor parking. The reference / minimum parking requirement is 50 spaces. Building C has provided 20% less than the reference and receives a score of 0.8.

No visitor bicycle parking is available but the bicycle storage room is secure and located in the garage. The room has sufficient space to store one bicycle per unit (80 spaces). A score of four is awarded. The highest score (5) would have been awarded had there been some allowances for visitor bicycle parking.

Building C is connected to the Quebec Hydro grid which uses almost exclusively hydroelectric energy. Nuclear energy accounts for only 3.1% of all electricity generated [17]. Le Clos produces 1.48 dm^3 of nuclear waste per year due to its electricity consumption. The reference building produces 2.38 dm^3 per year. Le Clos achieved a reduction of 37% which gives a score of 1.3.

Building D
Building D has fewer parking spaces than normally required by the City of Ottawa and in addition provides for one bicycle parking space for each occupant.

Building D is connected to the Ontario Hydro electric power grid, but relative to reference Building A (also in Ontario) produces 60% less nuclear waste.

Table 2.14: Summary of scoring of OTHER LOADINGS Category

Building	Comments	Score*	
Building A	• automobile use - more parking. spaces than required - minimal number of bicycle spaces (-1.6+0.5)/2 • nuclear waste - same as reference	(-0.5) (0)	-0.25
Building B	• automobile use - supplied the minimum number of parking spaces - minimal bicycle spaces - score ➞ (0+0.5)/2 • nuclear waste - 95% less than reference	(0.25) (4.7)	2.5
Building C	• automobile use - 15% less parking than reference with maximum bicycle storage except for visitors (0.6+4)/2 • nuclear waste - not applicable in Quebec	(2.3) (1.3)	1.8
Building D	• automobile use - 83% fewer spaces than normally required (5) Bicycle spaces - 1 per occupant (5) • nuclear waste - 60% less than reference	(5) (2.5)	3.7

*scores in brackets ( ) indicate intermediate scores.

2.8 Air Quality [Criteria Q1]

This category assesses a wide variety of features of the building and its operation which affects the building indoor air quality. There are a number of criteria and sub-criteria, so to simplify and present the scoring clearly, the table below provides more detail than the previous summary tables. Note that in section *Q1.2 Pollutant Source Control*, a new sub-criterion *Control of Pollutants within Dwellings* has been added. This sub-criterion assesses measures in place to control bathroom and kitchen pollution within the dwelling. Q1.1.2 does not apply to Building C. GBC'98 does not credit a building for absence of cooling towers.

Table 2.15: Summary of AIR QUALITY scoring [Criteria Q1]

		Building A		Building B		Building C		Building D	
Q1.1 Moisture Control	Q1.1.1 Control of Moisture in Building Envelope	Used rainscreen design principals - vapour barrier - thermally broken window frames help avoid condensation	1	Used rainscreen design principals - vapour barrier applied to strict performance standard.	3	Pressure-equalized rainscreen design - quality control during construction to control moisture and air-tightness - some defects noted during assessment - some attention given to drying of wet construction materials	3	Exterior wall is rain screen design. Continuous air vapour barrier designed to avoid thermal bridging	3
	Q1.1.2 Control of Spray from Cooling Towers	Follows recommended guidelines	5	Spray observed during assessment	0	No cooling towers - air-source split-system air conditioners	n/a	No cooling towers	n/a
	Q1.1.3 Standing Water in HVAC Distribution	No risk of standing water in HVAC system	3	Some risk of condensation on fin-tube convectors within suites	1	No risk of standing water in HVAC system	3	No risk of standing water	3
Q1.2 Pollutant Source Control	Q1.2.1 Mineral Fibre Control	No mineral fibres used in building	3	Mineral fibres used in suspended ceilings but not used as plenums	3	Mineral fibres used in suspended ceilings but not used as plenums	3	Mineral fibres used in duct liner	3
	Q1.2.2 VOC Emissions Control	No consideration of IAQ for material selection - materials are likely to emit VOCs	0	Materials specifically chosen to minimize offgassing	3	intent to minimize VOCs through low VOC paints, wood/tile flooring - however, use of unsealed particleboard and stippling negates intent	2	Water-based paints and adhesives have been used with low VOC content. No chemical cleaners used in public areas	3
	Q1.2.3 Pollution Migration between occupancies	Pressurized hallway provides some migration control (although this type of ventilation system is historically poor)	1	Each unit has a balanced HRV - suites are sealed from the corridors - design is not completely effective (assessment revealed failing gaskets and evidence of cooking pollution in corridor)	4	Some design measures were ineffective (e.g. pressurized suites observed defective due to gaskets and caulking missing at some joints; elevator draws air from parking garage although the garage was designed to be under negative pressure; difficult to balance properly)	2	Each suite under negative pressure. Garbage/recycling areas have separate exhausts as do washrooms and kitchens. Suites sealed at party walls	3

Table 2.15: Summary of AIR QUALITY scoring [Criteria Q1] (continued)

	Q1.2.4 Radon Control	Not applicable to building location	-	Not applicable to building location	-	Not applicable to building location	-	Not applicable to building location	n/a
	Control of Pollution within Dwelling	Kitchen and bathroom exhaust outside	3	Bathroom exhausts through HRV; kitchen recirculates	0	Kitchen and bathroom exhaust outside	3	Kitchen and bathroom exhaust outside	3
Q1.3 Ventilation and Fresh Air Delivery	Q1.3.1 Quality of Supply of Outdoor Air	Fresh air intakes are located near parking garage entrance and adjacent to busy street (evidence of birds nest in intake grill)	0	Individual intakes and exhaust for each suite - there is a risk of re-entrainment of air from other suites or from rooftop equipment	3	Located on rooftop but separated substantially from exhaust; bird and insect screens installed	5	HRV supply air taken from roof. Plumbing vents extended to avoid reingestion	5
	Q1.3.2 Quantity of Outdoor Air	Quantity of ventilation is constant and provides minimum requirements	0	HRV's can supply minimum (25 cfm) but can also be manually changed to supply more (40 cfm - +60%)	5	HRV is designed to allow 45 cfm per suite without increasing energy use but is still being commissioned.	5	HRVs can supply minimum but can also supply more	3
	Q1.3.3 Filtration Performance	No special filters	0	No special filters	0	Filtration efficiency 60% (typical 30%)	5	No special filters	0
	Q1.3.4 Cross Ventilation	30% of units can have cross-ventilation; reference is 60%	-1.	30% of units can have cross-ventilation; reference is 60%	-1.	30% of units can have cross-ventilation; reference is 60%	-1.	50% of units have cross-ventilation; reference is 60%	-0.3
	Q1.3.5 Adequate amount of operable windows	Operable windows are in all rooms except the bathroom - operable portion in living area is fairly small	1	Operable windows are in all rooms except the bathroom - fairly small - some complaints from tenants due to size of operable portion	1	Operable windows have been provided in all rooms. There are also large sliding patio doors	3	All windows are operable in suites. Suite doors to exterior are operable	3
	Overall Scoring	**1.6**		**1.8**		**3**		**2.6**	

2.9 Thermal Quality [Criteria Q2]

This category assesses the thermal comfort of occupants due to the humidity levels and temperature levels. Scoring for this category is based on design features, however, tenants were consulted, or in the case of Building C surveyed, as to the conditions of their dwellings and their testimonies will be incorporated into the assessment.

Building A

Based on discussions with building personnel, there were few complaints about indoor thermal conditions. Tenants have control over the heat pump in their unit and windows are operable, although this portion is small. There is some solar overheating of south-facing units due to large windows but for the most part, the water-loop heat pump system is adequate to handle this. Also, blinds can be used to mitigate overheating. Relative humidity levels were not noted as a problem, although there are no measures in place to deal with them. This is considered typical of most buildings

Building B

Tenants indicated that the cooling system was not entirely adequate after a sudden onset of hot weather. Otherwise, tenants have individual control over heating and have operable windows. There are no measures in place to control humidity levels.

Building C

Air conditioning was provided as an option at Building C. As such, some south-facing suites are overheating. Tenants with air conditioning have individual units in their suites and all tenants have individual control over heating. Recently a dehumidifier has been installed on central ventilation air.

Eight of the twenty-six owners responding to an occupant survey were satisfied with their thermal comfort. Another eleven felt it was okay but could be improved. There were complaints of excessive heat in summer from some occupants and about 30% admitted to opening their windows in winter.

Building D

Air conditioners are prohibited. Balconies were designed to provide shading of the windows in each unit. Mature deciduous trees provide additional shading of the building in summer. There are no humidifiers in the building.

Table 2.16: Summary of Scoring of THERMAL QUALITY Category

Building	Comments	Score*	
Building A	• individual control of temperature • no humidity-control measures in winter	(3) (0)	1.5
Building B	• cooling system inadequate (slow) during very hot summer only • no humidity-control measures	(0) (0)	0
Building C	• summer overheating in suites without air conditioning (optional) • recent installation of central dehumidification	(0) (2)	1
Building D	• individual control of temperature - no cooling - balconies designed to provide shading in summer • no humidity control measures	(2) (0)	1

*scores in brackets ( ) indicate intermediate scores. Scores reflect design intent only.

2.10 Visual Quality [Criteria Q3]

This criteria assesses the quality of natural light that enters the dwelling unit, how much contact with the exterior the inhabitants have (measured by quality of view), and the degree of privacy in the dwelling. Note that daylighting factors were not specifically measured in the buildings. However, this category can be scored subjectively.

Building A

Suites are very well lit, with open interiors, centred around the large atrium. The exterior of Building A is almost entirely glazed allowing windows in bedrooms also. Other areas of the building such as the pool area, meeting room, fitness area, etc. do not have windows at all. The score for this category is weighted towards the daylighting of the dwelling unit rather than the common areas (70/30). One third of the units are oriented east-west, while two thirds are north-south. This results in approximately 65% of inhabitants able to receive direct sunlight. Illumination levels within common areas of the building are consistent with industry regulations and norms.

Visual contact with the exterior is very good in Building A. The development is surrounded by residential or low-rise industrial on three sides and one higher seven story office building on the north side. Lower stories on the north side do not have a distant view but all other units do, which is about 85% of the units. Privacy within dwellings is good since there are very few neighbours with direct views. The office building to the north is within approximately 20m of Building A and may sacrifice daytime privacy (it is an office) of approximately 15% of the tenants.

Building B

As with Building A, Building B's dwelling units have been designed in an open format with large glazed areas in the central living area. Due to the thin profile of the buildings, common areas are well lit also. There are ample windows in the laundry room, the end of each corridor, the lobbies and the recreation rooms.

Illumination levels within common areas are consistent with industry norms, however, the considerable use of daylight, makes the lighting system superior to the norm. Building B has had a good amount of attention paid to lighting and may be considered to be best-practice.

An estimated 20% of units are facing north and may not receive direct sunlight.

Approximately 10% of units do not have adequate contact with the exterior. These units are on the bottom floor of one of the buildings where the property line is demarked by a tall hedge. However, these units have direct walk-outs onto grass backyards (which is not accounted for in GBC'98).

None of the dwelling units within Building B have had their privacy compromised by the proximity of an adjacent building. This may be attributed to good design, however, development is not very dense within the region and there is very little chance of any two large buildings being closely located.

Building C

Due to the U-shape of the building, many of the units experience daylight throughout the day from the south, or the east and west. Although all common areas have been designed with windows, they are on the lower floors and tend to be located in spaces which are shadowed. The score for the dwellings is 4. The score for the common areas including the lobby and gathering areas, is 1.

Illumination levels are sufficient in most areas but seems excessive in the parking area. More attention could have been paid to achieving a lower lighting power density. The score for this building is 4.

This building is only blocked on the east side but this does little to eliminate Spring solstice sun from the southeast. Approximately 95% of the units would receive a minimum of two hours of direct sunlight per day; 85% of all the units have unrestricted sunlight. There are no bedrooms or living rooms which face an adjacent building that may compromise privacy.

Building D

Dwelling unit daylighting varies with suite location and size. Windows are in different locations and of different sizes. All but 11 suites receive direct sunlight. All units have private outdoor space. Ten percent of the units face a school on the north side. Windows on that elevation are smaller and balcony doors are single rather than double.

Table 2.17: Summary of Scoring of VISUAL QUALITY Category

Building	Comments	Score*	
Building A	• very good daylighting in units (.7x4), poor in common areas (.3x-1)	(2.5)	
	• illumination levels normal in common areas	(0)	
	• 65% of units receive direct sunlight	(1)	
	• 85% of units have adequate contact with exterior / views	(3)	
	• 15% of units have poor privacy due to proximity of office bldg.	(3)	1.9
Building B	• very good daylighting in units (4), and in common areas (4)	(4)	
	• illumination levels considered best-practice due to natural light	(5)	
	• 80% of units receive direct sunlight	(2.5)	
	• 90% of units have adequate contact with exterior / views	(3.5)	
	• no adjacent buildings, all units have privacy	(5)	4.0
Building C	• very good daylighting in units (.7x4), poor in common areas (.3x1)	(3.1)	
	• illumination levels considered best-practice due to natural light	(4)	
	• 95% of units receive direct sunlight	(4)	
	• 85% of units have adequate contact with exterior / views	(3)	
	• all of the suites have access to satisfactory views	(5)	3.8
Building D	• dwelling unit daylighting levels will vary with suite location. Designed as much as possible to allow maximum daylighting. Atrium in common area provides good daylighting	(4)	
	• illumination levels considered good practice in suites and common areas	(3)	
	• 73% of units receive direct sunlight	(1.8)	
	• 90% of units have adequate contact with exterior views	(3.5)	
	• 10% of units have poor privacy due to proximity of school	(3.5)	3.2

*scores in brackets ( ) indicate intermediate scores.

2.11 Noise and Acoustics [Criteria Q4]

This category assesses the measures taken to isolate occupants from outside, between dwelling units, and from potential noise sources within the building.

Building A
Information for this category was unavailable due to the age of the building.

Building B
The lower floors of one of the buildings are very close to a busy street. This was a design consideration for these units and so the sound transmission levels were increased to STC 55.

Although the actual NC (noise criteria) levels for building equipment is unknown, there is increased sound insulation levels specified for units adjacent to the elevator. Most mechanical noise would probably come from the HRV located within the unit, however, these were tested and found to be very quiet.

Sound transmission between occupancies is good with an STC rating of 50 which corresponds to typical practice. Tenants have noted that some noise comes from suites above. This propagation is primarily due to the use of wood flooring rather than a damping material such as carpet.

Building C
All exterior walls have been designed with sound-proofing of STC 60 which is above the norm.

The HVAC and HRV systems are equipped with silencers at the inlets and outlets on air-intakes and exhausts. Mechanicals are isolated on pads and hangars, however drains are in contact with building negating some isolation efforts. The boilers are variable which makes them seem louder than conventional units. Only one of the boilers is isolated. An equivalent score of 2 is awarded for Building C noise control measures.

Noise attenuation between units (ceiling and floor) is STC 55 which again is above the norm. The ceiling is rated at Impact Isolation Class 65 with carpet.

Eighteen of twenty-six owners responding to an occupant survey complained of some form of noise from outside or between units. Outside noise was a problem in summer with open windows and noise from adjacent suites was also noted.

Building D
Building located in a residential neighbourhood that is fairly quiet.

Boiler and mechanical room located well away from suites. STC 52 construction for this space.

Between suites, the STC rating was 50. Suite doors were solid core wood. Party walls have 92 mm of sound batt insulation with metal studs.

Table 2.18: Summary of Scoring of NOISE AND ACOUSTICS Category

Building	Comments	Score*	
Building A	• information unavailable		n/a
Building B	• STC 55 on lower floors • STC 55 for elevators and other mechanical. equipment - adequate • same as reference - STC 50 between occupancies - some attenuation through ceiling due to wood flooring and concrete • no IIC specification	(4) (3) (-0.5)	2.2
Building C	• all exterior walls are built with STC 60 • silencers on mechanical equipment near suites • STC-55 (ceiling and floor); IIC 65 with carpet	(5) (2) (3)	3.3
Building D	• STC for windows-unspecified • STC 52 for HVAC and mechanical. Boiler and mechanical equipment located well away from suites • STC 50 between dwelling units • No IIC rating for floor	n/a (1) (0) (0)	0.3

*scores in brackets ( ) indicate intermediate scores.

2.12 Controllability [Criteria Q5]

This category assesses whether the control strategies that have been implemented to save energy are too complex too maintain and result in the systems not meeting the desired objective. Maximum scores are given for simple, yet effective, control strategies. Also, assessed is the ability of HVAC system to meet different temperature and ventilation requirements within different rooms of the same occupancy.

Building A

The control strategy on Building A's central system is simple with little attempt to optimize performance. In fact, control of the system is performed by an office in Winnipeg and is usually left at seasonal settings. A new control strategy will be implemented soon to improve energy efficiency. Some retrofitting has been done to improve energy efficiency of boilers but these have not been overcomplicated. Within dwelling units, occupants can control their environment using a simple thermostat. There is no capability to adjust heating, cooling or ventilation within different rooms of an occupancy, however, there are adjustable registers to control air flow from the heat pump.

Building B

Building B has installed a co-generation system which provides cooling through an absorption chiller, DHW heating and hydronic heating. The system is complex and requires outside experts to operate it. There have been problems with the system but, following commissioning, the system should become more dependable. However, the system will require significant service and maintenance on an on-going basis. Within suites, occupants can control comfort levels using a simple thermostat. There is no capability to adjust heating, or cooling within different rooms. There are registers which can be used to adjust the distribution of the fresh air supply.

Building C
Building C has installed a sophisticated system which is remotely controlled by outdoor temperature. Tenants can control their comfort with a simple thermostat. Room-by-room control of heat is possible. Registers allow control of ventilation within different rooms of the suite. There is some indirect control of cooling possible as a cooling coil has been installed in the ventilation air stream to provide dehumidification.

Building D
Building D uses programmable thermostats in each suite and local thermostatic controls in common areas. There is no central building control system. Occupants can adjust suite temperatures to match their requirements. Ventilation units in each suite have a timed override. There are no occupancy sensors used in the building HVAC or lighting systems.

Table 2.19: Summary of Scoring of CONTROLLABILITY Category

Building	Comments	Score*	
Building A	• simple system, minimal control strategy • single zone control within dwelling units; registers for ventilation control	(4) (1)	2.5
Building B	• complicated co-generation system • single zone control within dwelling units; registers for ventilation control	(0) (1)	0.5
Building C	• sophisticated system, remotely controlled • multi-zone control of ventilation and heat; cooling incorporated into ventilation	(2) (3)	2.5
Building D	• programmable thermostats in individual suites and local thermostatic controls in common areas – thermostat programming to be explained. • individual suite control of temperature, ventilation and lighting – no occupancy sensors.	(2) (1)	1.5

*scores in brackets ( ) indicate intermediate scores.

2.13 Design and Construction Process [Criteria P1]

This category assesses the environmental measures that were taken during the design and construction processes. These measures challenge existing norms and help put environmental issues as guiding principles alongside technical, financial, creative and other accepted criteria. There are seven criteria under this one category; in order to make the information clear, it is presented in a table rather than paragraph form. For Buildings A and B information was not available in categories P1.3 through P1.6. Scores are based on only those categories with information.

2.14 Building and Operations Planning [Criteria P2]

This category assesses the measures in place to ensure that the building is well managed and that the design objectives are implemented practically. As with the previous category, the information is presented in a table.

Table 2.20: Summary of Scoring of Design and Construction [Criteria P1]

		Building A		Building B		Building C		Building D	
P1.1	Provision of an interdisciplinary design team	Knowledge of the design process has been lost. It has been assumed that, as with most buildings of the time, the design process was linear with financiers leading the process. Industry norms for design are linear.	0	Building B was designed with the cooperation of energy /environmental engineers, architects and the developers.	4	A multi-disciplinary design team was involved from the concept stage; members included energy, IAQ, and environmental specialists	5		
P1.2	Development of explicit targets for performance parameters	Early brochures indicated that the design goals set were good urban design, increased market value, and reduced environmental impacts. Building A aimed to revitalize an underused part of downtown Toronto, and capitalize on an impending fuel shortage by minimizing automobile transport.	3	Building B set goals prior to design: energy 50% of *ASHRAE 90.1*; superior indoor air quality; provide a pedestrian-oriented street edge; and provide economical and quality housing for less fortunate families. Also, a high level of quality was specified so that some units could be rented at full market value to achieve a mixed economic profile of tenants. Building B won a World Habitat Award for its design.	5	Targets were set to create a healthy, energy efficient project and goals were quantified. Building C was a winner of a national design challenge which required clear goals on energy and resource use, IAQ, ventilation, quality, envelope durability, adaptability and accessibility.	5		
P1.3	Environmentally-sensitive construction procedures	Unknown	-	Unknown	-	None	0	Contractor given instructions to protect existing mature trees and where and how to store materials and supplies. Spec. called for contractor to prepare waste reduction plan.	3
P1.4	Construction and demolition waste strategy	Unknown	-	Unknown	-	Had intended to do but not done.	-2.	Contractor was required to prepare and follow plan on reducing, revising, recycling wood, cardboard, drywall, metal, [portland cement.	3
P1.5	Appointment of commissioning agent and development of protocols	Unknown	-	Unknown	-	Some systems underwent commissioning.	2	None	0
P1.6	Post construction/ renovation flush out	Unknown	-	Unknown	-	on-going construction during occupancy	0	Not done	0
	Total	**1.5**		**4.5**		**1.7**			

Table 2.21: Summary of Scoring of Building and Operations Planning [Criteria P2]

		Building A		Building B		Building C		Building D	
P2.1	Provision of building and technical systems documentation	All HVAC maintenance is performed by an on-site Honeywell employee; all HVAC manuals are kept in his office. As-built drawings are in main office. HVAC maintenance records are clearly marked on equipment. Unsure of other systems.	4	Some HVAC manuals kept on-site although not all were there. EMS manuals kept by the energy services company that operates the system. The as-built drawings and maintenance records are kept in the office and in mechanical room.	3	HVAC manuals and emergency numbers available beside equipment with maintenance logs. Drawings are available.	4	Manuals were prepared by contractors for HVAC, controls, lighting and other systems. These were reviewed by design professionals.	3
P2.2	Provision of building operational logs	The extent of this activity is unknown.	-	Maintenance records to all systems are kept by property manager. May not be formal protocol.	2	Logs and records kept for all equipment in a reasonable manner.	3	For HVAC major components, otherwise not provided.	1
P2.3	Plans for training of operating and maintenance staff	Honeywell employee retained to maintain and operate all HVAC systems.	3	Maintenance staff receive training on operation of building systems. Outside expert retained to operate central HVAC systems.	3	No special training of operations staff. Outside control of system by trained personnel	2	Manuals with written instructions, in-depth walk-around tour, with explanation go systems and their operation. maintenance. Captured on video-tape for staff reference.	2
P2.4	Specification of preventative maintenance program	Honeywell employee is paid for, among things, preventative maintenance to all equipment.	4	A full monthly preventative maintenance program is implemented by an outside expert.	4	No special programs.	0	Preventative maintenance specified on HRVs, generator, elevators, DHW systems.	3
P2.5	Plans for occupant environmental awareness program	There is no occupant environmental awareness program.	0	New tenants are trained in operation of their HVAC systems.	2	Little or no communication with occupants.	0	Tenants received manual. How to for thermostat, combo-water heater, low-flow toilets, sorting recyclable material, use of composter/rain barrel.	4
P2.6	Provision of tenant performance incentives in leases	Occupants pay for electricity only. Water-loop and hot water is communally paid.	0	Energy and water bills are included with rent. No stipulation on energy use.	-2	Occupants are billed individually for electricity. Heating is communally paid	2	Individual suite metering for gas and electricity, but not for water.	3
	Total	**2.2**		**2**		**1.8**		**2.7**	

2.15 Location and Transportation [Criteria C1]

This category assesses the features in the case studybuilding which directly and indirectly reduce the number of automobile trips. Factors which help to reduce trips are: the proximity to public transportation, amenities and services within or nearby, and the reduction of commercial transport requirements.

Building A

Building A is located on two major streetcar routes and the subway is 500 m away. A full range of shops, and services are located within approximately 200 m of the building. Basic requirements are met by the retail area on the ground floor.

Building B

Building B was intentionally located on a major bus route to eliminate the usual necessity of automobile ownership for its low-income tenants. The building is located 500 m from a full range of shops. Basic requirements are met by the retail area on the ground floor.

Building C

Building C is within 300 m of the nearest public transit, 400 m of the bus terminal and within 750 m of the train station. Shops and services are within 300m of the building. There is a medical clinic on the first floor for critical service.

Building D

Building D has a bus stop in front of building and the transit way is within 800 metres, for connections to the entire city.

The building is within walking distance of downtown and a host of amenities. A local university is within walking distance and offers recreational and cultural facilities to the public.

Table 2.22: Summary of Scoring of LOCATION AND TRANSPORTATION Category

Building	Comments	Score*	
Building A	• located on two bus routes and near subway • located very near shops; basic requirements on ground floor	(5) (5)	5
Building B	• located on major bus routes • located near shops; some basic requirements on ground floor	(5) (4)	4.5
Building C	• located near subway, bus and train terminals • located very near shops; commercial/retail on ground floor	(5) (5)	5
Building D	• Bus stop in front of building. Within 800 meters of transit way which connects to all areas of city. • Within walking distance of downtown near University and major shopping centre.	(3) (5)	4

*scores in brackets ( ) indicate intermediate scores.

Table 2.23: Summary of Scoring of Loadings on Immediate Surroundings [Criteria C2]

		Building A		Building B		Building C		Building D	
C2.1	Interference with access to daylight of adjacent property	There is some blockage of daylight on adjacent properties. The morning sun is blocked on a number of residences, an office to the north is shaded a large portion of the day.	0	There is very little blockage of the sun from adjacent properties, efforts have been made to step down to surroundings. An adjacent trailer park is shaded in late afternoon.	2	There are two three storey apartment blocks to the north of Bldg. C which have not been shaded.	0	There is shading of buildings to the north in winter. School on east shaded in winter, as well. Solar shading studies provided to city.	0
C2.2	Interference with access to winter sun of adjacent property	Estimated - 60% of a building facade on the building line is shaded on Feb. 21, 12 noon.	1	There is no shading. Buildings have access to winter sun	2	No shading; there is a common wall with the adjacent building.	3	There is shading of buildings to the north in winter. School on east shaded in winter, as well. Solar shading studies provided to city.	1
C2.3	Solar heat absorption and re-radiation from building surfaces (see Note (6))	Area-weighted solar absorptivity of horizontal. bldg. surfaces and hard-landscaping is 49% (very little asphalt, mostly brick paths, concrete sidewalks and gravel roof)	3	Area-weighted solar absorptivity of horizontal. bldg. surfaces and hard-landscaping is 63% (asphalt parking lots, brick paths, gravel roof)	2	Hard landscaping consists of gravel cover, light-colour roof and shrubbery - little to no asphalt. Solar absorptivity is 40%.	4	Reflective surfaces not used. Glass shaded by overhangs and balconies - not considered reflective problem.	1.5
C2.4	Reflected glare from building surfaces	not assessed for MUR	n/a	not assessed for MUR	n/a	not assessed for MUR	n/a	Reflective surfaces not used. Glass shaded by overhangs and balconies - not considered reflective problem.	n/a
C2.5	Adverse wind conditions at grade	Height of building is 35m which is similar to some surrounding buildings and taller than neighbouring residential. No measures to minimize wind.	0	Height of building is 46m for tallest building. Smaller building is stepped down to height of surroundings. Tall building set on a podium to mitigate gustiness.	2	The building is stepped down to within 10% of the adjacent properties and is approx 30m high. Setback from road prevents gustiness for pedestrians.	3	No. Buildings shape and orientation protect its courtyard and playground from winds. Shields other buildings, as well.	3
C2.6	Waste heat rejection from building equipment to outdoor public spaces	not assessed in GBC '98	n/a	not assessed in GBC'98	n/a	not assessed in GBC '98	n/a	Not assessed in GBC'98.	n/a
C2.7	Noise from building affecting adjacent properties	Penthouse mechanical rooms are enclosed and sound-proofed. Air handling unit is inside building.	2	Penthouse mechanical rooms are enclosed and sound-proofed. Some fans located outside but do not seem to be overly loud.	2	Exhaust air is silenced. Little effect with adjacent street noise.	4	Noise from boilers in mechanical room, adjacent to school.	2
	Total	1		2		3.7		1.5	

2.16 Loadings on Immediate Surroundings [Criteria C2]

This category assesses the design measures which reduce potentially adverse impacts on neighbouring buildings or outdoor spaces. Some of the following criteria are scored using quantitative measures which are difficult to obtain without very detailed analysis. These criteria have been scored subjectively instead.

2.17 Accessibility

This category assesses the measures taken to ensure that the building is habitable by all persons. This category was not deemed important in the GBC'98 assessment methodology because it is not directly related to environmental design. However, it has been included in this assessment because it is considered to be an important aspect of building functionality. This category is scored in two separate parts: accessibility in common areas and outside, and accessibility within the dwelling units. Lower scores will be given for designs that allow handicapped individuals use of the building, maximum scores will be given for full accessibility and ease of use by blind or deaf persons, and seniors.

Building A
The outside area of Building A has been designed with accessibility in mind. Sidewalks are cut, there are no steps, and doors are reasonably wide. The common areas of Building A were designed specifically to allow easy access to all recreational facilities. Although there are no stairs, there are many doorways, some of which are close together which would be difficult for wheelchair access. For security reasons all doors lock which may worsen the problem. There are no dwelling units specifically designed for handicapped or senior's use. All units are privately owned and could be modified by the owner. This is typical of most multi-unit residential buildings.

Building B
The outside of Building B is wheelchair accessible. All sidewalks are cut and doors have automatic openers. Common areas are also accessible. There are a number of dwelling units at Building B that have been designed specifically for wheelchair use. Counters are adjustable in height and are free of cupboards below. Doors and corridors through the unit have been widened.

Building C
Building C was designed to be accessible and exceed the requirements of the building code. Doorways, and corridors throughout the building have allowed additional space for the manoeuvrability of wheelchairs. Some minor exceptions were noted in the garage. Emergency response requirements have been exceeded through the design of barrier-free refuge on each floor and protected elevator and exterior egress. Dwellings have had extra space allotted to allow for wheelchairs, nailing backing for the installation of grab bars, electric outlets for cupboard level ovens and electric outlets for electronic door openers. One observed hindrance to accessibility is the step barring access to the balcony.

Building D

Building D has several handicapped accessible units. In addition, both the common areas and outdoor areas are accessible to handicapped individuals.

Table 2.24: Summary of Scoring of ACCESSIBILITY Category

Building	Comments	Score*	
Building A	• outdoor and common areas reasonably accessible- too many doorways inside • no accessible dwelling units	(2) (0)	1
Building B	• outdoor and common areas accessible • several units designed specifically for wheelchair access	(3) (3)	3
Building C	• outdoor and common space accessible, emergency egress provided • extra space; potential for grab-bars, appliances, door openers	(4) (3)	3.5
Building D	• several handicapped accessible units. • outdoor and common areas accessible.	(3) (3)	3

*scores in brackets ( ) indicate intermediate scores.

3. SUMMARY OF THE GBC'98 COMPARISON RESULTS

Figures 3.1, 3.2, 3.3, and 3.4 summarize the scores from the assessments. The scores are grouped into major categories to allow analysis of the results. Figure 3.5 presents an overall summary of the scoring for all categories evaluated. It is apparent that Building B, Building C and Building D have fared well in many categories.

In the area of Resource Consumption (Figure 3.1), all three advanced buildings have received very good scores in most categories. Reductions in resource consumption is a fundamental goal of advanced buildings and these results were expected. Building A has done well in the Land category reflecting its urban location.

In the area of Environmental Loadings, Building B and Building C have scored well in most categories, while Building A has been found to be typical (zero score). The relatively poor scores received in the Solid Waste category may be an indication that the measure may be difficult to achieve.

For Indoor Environmental Quality, Building C has done well in four of the categories, but it is evident that some tradeoffs, such as air-conditioning for summer comfort, at the expense of increased energy use, were necessary in the Thermal Quality category to achieve the other goals of the building. Building B has done well in three categories but scores are similarly low for Building B in the Thermal Quality category. This section represents categories which are as related to health and 'green performance' as they are to luxury and quality of a building. For this reason, Building A has fared consistently well in all the categories in Indoor Environmental Quality.

For Process Performance, the three advanced buildings scored well for the design process. However, they did not score as well as Building A for the operations of the building, probably because of the scale of the developments and the complexity of the systems. Building A is very large and is able to properly maintain equipment with full time staff.

For Contextual Performance, which assesses the effects of the building on its immediate surroundings, all four buildings scored well in location and transportation, mainly because all buildings are high density and subscribe to the same goals of good urban design.

All three advanced buildings (B, C, D) have been designed to be accessible and scored well in this category. It would be interesting to score the three advanced buildings against a new 'market-ready' development to closer examine what is typical today.

Figure 3.1: Resource Consumption

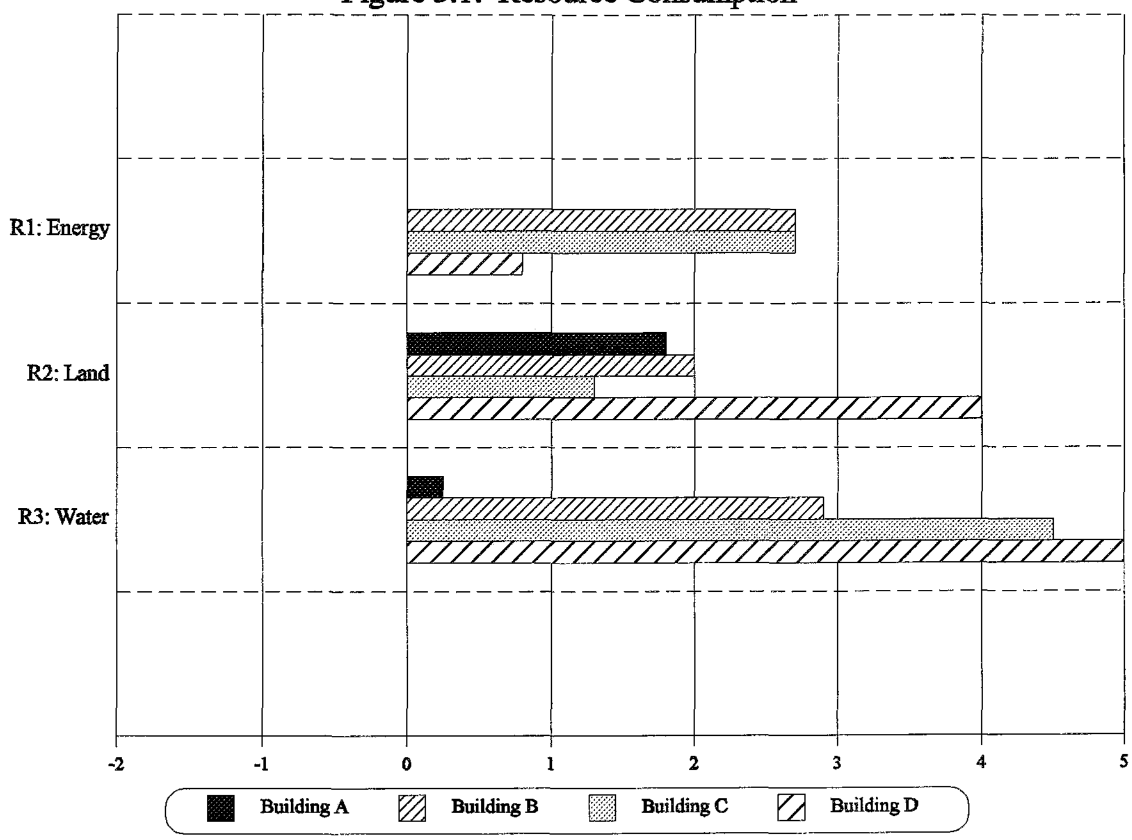


Figure 3.2: Environmental Loadings

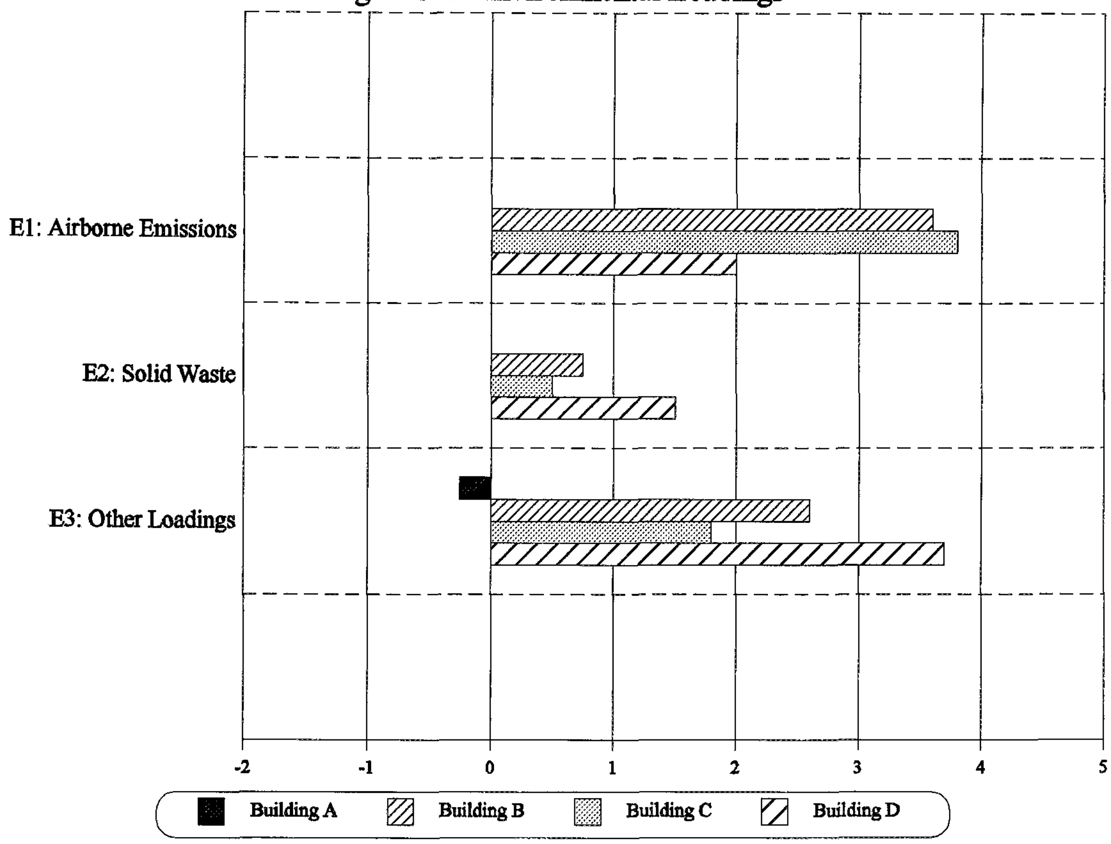


Figure 3.3 Indoor Environmental Quality

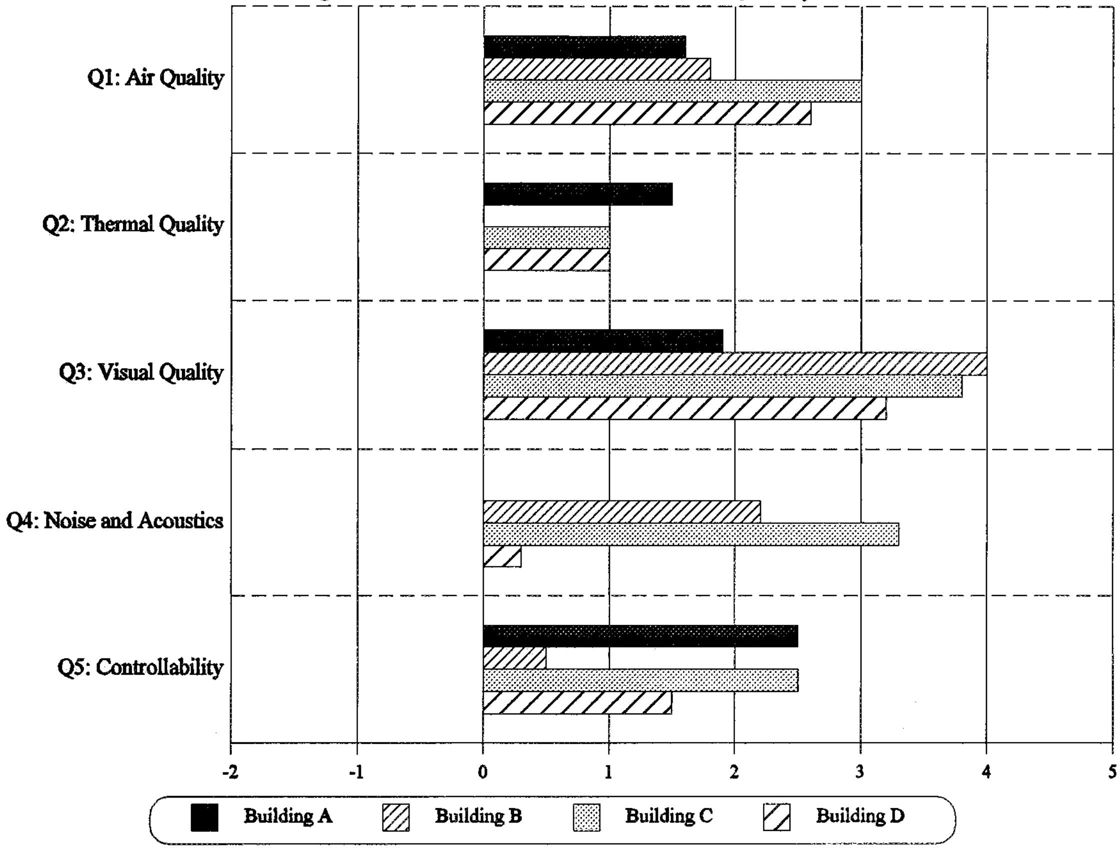


Figure 3.4: Process Performance, Contextual Performance, Accessibility

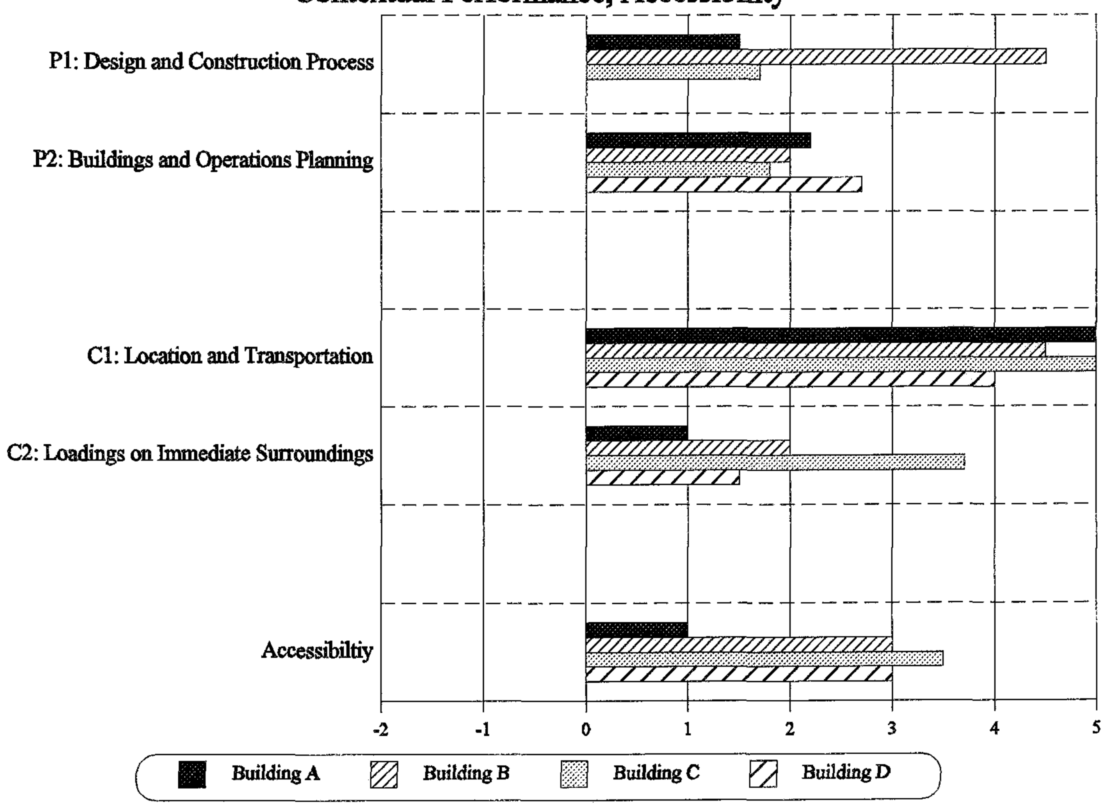
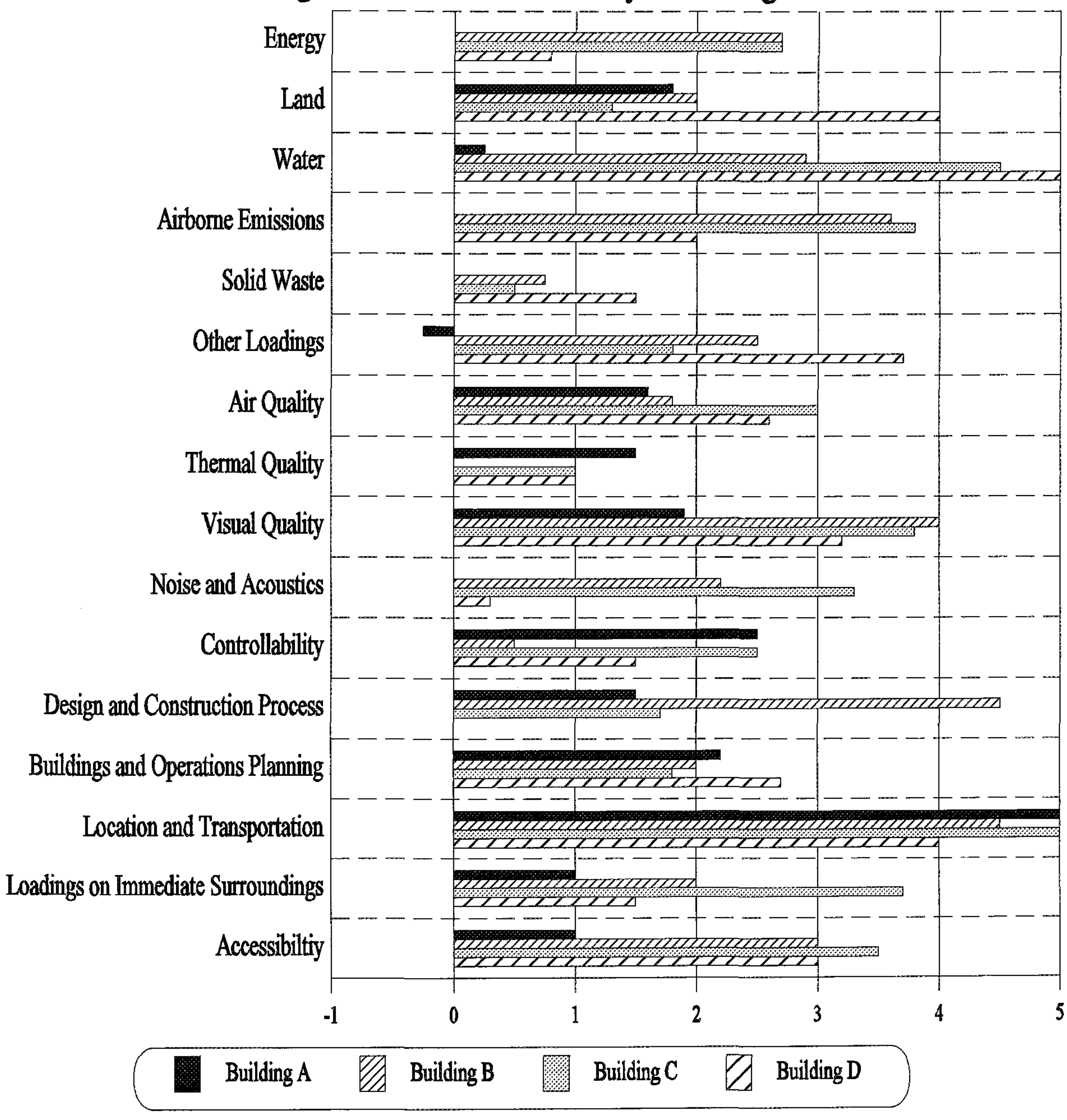


Figure 3.5: Overall Summary of Scoring



4. CONCLUSIONS

Phase III was to utilize an existing environmental assessment tool to evaluate the green performance of four existing multi-family buildings. GBC'98 [1] was chosen as the assessment methodology. Three of the buildings (B, C and D) were recently constructed advanced buildings, while building A was a market-ready condominium built in the early 1980's with a number of advanced features and amenities for the times.

The GBC'98 methodology [1] attempted to provide an organized, objective way of evaluating the four buildings and comparing them to each other. Sixteen performance criteria from GBC'98 were evaluated and scores developed in each category. Building A was the *reference* building for the purposes of scoring in many of the criteria. Otherwise, the Team employed reference values developed for GBC'98 [8].

GBC'98 is deficient in that scores are on the basis of simulated as opposed to actual energy use. This is the case in other performance criteria, as well, where design intent and actual experience are quite different, but scores are based on design intent. The information presented in this report is based on a walk-through of the buildings and detailed review of design documents. Observations from the walk-throughs are included but do not influence the GBC'98 scores which are based on design information.

4.1 Results of the Assessment

As expected, the advanced buildings scored significantly better than the older building in terms of predicted energy consumption. The advanced buildings, however, are generally using more energy than had originally been predicted through simulation. This was often due to commissioning problems, occupancy effects and departures from original design intent. This discrepancy is observed in other performance categories, as well.

In many criteria, the old building scored competitively with the advanced buildings. For example, in land use, indoor environmental quality, process performance, contextual performance the 1980's building scored close to one or more of the advanced buildings. This result also suggests that some sustainable principles are already incorporated into some conventional buildings. This is an important observation because designers and purchasers should recognize that some elements of sustainable design are not much different than good urban design.

Subsidized housing is usually thought to be drab and cramped. Instead, through the application of sustainable design principles, Buildings B and D have some durable, high quality components with lower maintenance costs, large windows and good ventilation to improve aesthetics and comfort and reduced utility bills. This is reflected in the high scores which these two buildings received in these areas and others in the GBC'98 assessment.

GBC'98 needs to take into consideration the service and maintenance required particularly for advanced systems.

4.2 How Assessments will Help Buildings

The process as represented by GBC'98 in its current form is unrealistic to impose on the building industry. It needs to fit in a tight schedule/tight budget design process. It is too time consuming at present and needs development to better meet the needs of the industry.

Having gone through this multi-phase evaluation of assessment methods one can speculate about how assessments can help the building industry. Assessment tools can:

- provide a level playing field and common reference. At present, owners, operators, tenants and others don't have a general tool to assess building design or performance.
- raise awareness of environmental issues and the data gathered can be used to develop benchmarks to compare designs and performance trends, identify where trade offs can be made.
- provide data needed to develop cost effective environmental strategies to address the Kyoto commitments.
- illustrate that code compliance (essentially '0' scores) which generally dominate the design process is inadequate and that the industry must strive to go well beyond minimum compliance in sustainable design.
- provide insurance companies with data to develop requirements for appropriate responses to environmental liabilities, for risk analysis and for interventions. Owners at the same time can benefit from having documented conditions.
- eventually, as they develop more sophistication in a broad range of issues, become valuable education and design tools, as well as a tool for "as-built" evaluations.
- provide impartial, third party performance data on an existing building to be used in the owner's marketing efforts.
- provide data that equipment/product/service suppliers and providers can use to improve their product/service and use in sales and promotion.

Appendix B contains opinions of one of the project team members on the problems with and improvement options for the current environmental assessment methods which were reviewed by the team in earlier phases of this project.

5. REFERENCES

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APPENDIX A
Assessment Notes

Assessment Notes

(1) Calculating water consumption for building operation

The assumptions given below allow calculation of the operational water needs of both the reference building and the subject buildings.

Because an energy simulation or sub-metering has not been done for Building A, Ontario Hydro's estimates of cooling energy consumption [1] were used to estimate the amount of water evaporated in the evaporative condenser. By assuming an EER, the heat rejected can be calculated. It is generally assumed that all heat rejected evaporates water. Using the latent heat of water, the amount of water evaporated can be calculated.

Estimates of typical residential water usage are given in [4], and [5]. Fifty five litres per day per unit are assumed for laundry water consumption.

Industry-accepted correlations [6], [7] have been used to determine water requirements for indoor and outdoor swimming pools. The correlations are presented in graphical form and are dependant on wind speed and the difference between the saturation vapour pressure at the pool water temperature and the saturation vapour pressure at the air temperature and humidity. An approximation to the graphical data is: $W = \frac{(95+357V)(P_W - P_a)}{Y}$; W is the evaporation in lb per hr per ft² of surface area; where V is in MPH, assumed equal to 2 MPH for this work; Y is the latent heat of vaporization of water which equals 1050 Btu/lb; the pressure term represents the difference between the saturation pressure at the water temperature and the saturation pressure at the dewpoint temperature of the air (P_w is taken at 79°F; P_a is taken at 85°F and 60% RH; the pressure difference is 0.25 inches of Hg). Indoor pools operate year round, outdoor pools operate 3.5 months of the year, fountains operate 6 months of the year.

use	**amount**
HVAC	18.3 litres/ft²/year
laundry	55 litres/day/unit
indoor pool	135,000 litres per year
outdoor pool	13,000 litres per year
Total	**26.2 x10⁶ litres per year**
Normalized	**42.8 litres per ft² per yr**

The subject building total water use is calculated by using the above values depending on the features available in the building. Scoring for this category is based on the value normalized per square foot.

(2) Calculating water consumption for landscaping

Water consumption for landscaping is estimated using the calculation outlined in [8]. This calculation assumes a certain water requirement for a number of coverings depending on location. An overwatering of about two times is also assumed.

(3) Typical water usage is given in [8] and is reproduced in the table below. The effect of installing shower and faucet aerators and toilet dams can be estimated. Reductions in water flows are estimated in [4].

For Building A, it is assumed that 50% of the apartments participated in installing toilet dams and shower and faucet aerators, a 15% reduction in dwelling water consumption is realized.

	Reference	**Building A**	**Building B**	**Building C**
Toilets	5.5 flushes @ 20 litres per flush	(with dam) 5.5 flushes @ 15 litres per flush	(low flow) 5.5 flushes @ 6 litres per flush	(low flow) 5.5 flushes @ 6 litres per flush
Shower/Bath	6.4 min. @ 15 litres per min.	(with aerator) 6.4 min. @ 10 litres per min.	(with aerator) 6.4 min. @ 10 litres per min.	(with aerator) 6.4 min. @ 10 litres per min.
Cooking/Drinking	tap 1.4 min. @ 10 litres per min.	(with aerator) tap 1.4 min. @ 5 litres per min.	(with aerator) tap 1.4 min. @ 5 litres per min.	(with aerator) tap 1.4 min. @ 5 litres per min.
Total	220 litres per person per day	153.5 litres per person per day	104 litres per person per day	104 litres per person per day

(4) Calculating airborne emissions

The following table contains airborne emissions factors which can be used to calculate the emissions produced from the building.

	Electricity			**Fossil Fuel Combustion**		
	Ontario [mg/MJ]	**British Columbia [mg/MJ]**	**Quebec [mg/MJ]**	**Natural Gas [mg/MJ]**	**Propane or LPGs [mg/MJ]**	**Fuel Oil [mg/MJ]**
CO2	34950	14500	146.2	49700	59800	73100
SO2	369	16	0.205	0.2	0.2	102.3
NO_x	72	9	0.12	42	43	60
TPM	11.6	3.7	0.308	1.29	1.29	154

(5) Calculating nuclear waste generation

The GBC'98 assessment manual proposes that 9.55x10-5 dm3 of radioactive material is generated per kWh of electricity produced in a nuclear plant. In Ontario, (until recently) 55% of electricity generated was through nuclear. In Quebec, 0.2% of electricity is generated using fuel oil and the rest, 99.8% is generated using hydroelectric.

(6) Calculating area-weighted solar absorptivity

Criteria C2 - Solar heat absorption and re-radiation from building surfaces - This category requires the calculation of the area-weighted solar absorptivity of unshaded, horizontal, exterior building surfaces and hard landscaping. This is taken to mean the roof of the building and all parking, walkways, and other landscaping besides grass and gardens. The area that is unshaded must be estimated. The following table contains solar absorption coefficients of common materials [11, [12].

Material	**Solar Absorption Coefficient**
Asphalt/ tar/ black oil	0.9
Concrete (sidewalks)	0.40
Brick (red, light coloured)	0.75
Gravel	0.29

APPENDIX B

Problems with Programs and Tools
and Improvement Options

Prepared by Ed Lowans
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Problems With Programs and Tools and Improvement Options

Context

This report was developed outside the CMHC contract in response to requests by tool and program developers and end users for additional generic **non comparative** comments regarding existing programs, their further development and marketability. A **comparative** assessment of individual tools and programs was completed in the CMHC report "Environmental Assessment Tool For Multifamily Buildings".

Responses to this appendix from the developers have not yet been solicited and it is anticipated that this report could be substantially altered in response to their comments.

Some of the tools and programs were provided in confidence and therefore the comments are generic in nature and do not refer to any specific program or tool. Advanced versions of several of the tools and programs have been released since this analysis was done. Advanced versions contain many self and project initiated corrections which are not accounted for in this report.

Most of the assessed tools and programs were not designed for multi residential application, but were applied to this building format to test their appropriateness. Many comments relate to adapting the commercial format to residential applications, not to perceived problems in the original programs.

The programs and tools assessed are works in progress, most are first generation and have not been independently vetted or market tested. The following comments are intended to provide an outside perspective of where they are relative to each other, the state of the art and the needs of market place. To view these comments as criticism of the programs or their developers would be grossly unfair and taken completely out of context to the purpose of the exercise.

Some of the comments are made in the context of what would be ideal, not necessarily what is easy to achieve, while others are made in the context of generally available knowledge.

A complete discussion of the art and science of building evaluations is beyond the scope of this report. The following comments are intended to provide a snapshot of a range of issues and is not intended to be a complete evaluation.

Bias

Anthropocentric Bias

The tools and programs were developed within the context of relatively conservative concepts of environmental appropriateness and practice. The programs and tools can not reasonably accommodate leading edge environmental developments in the built environment at their current level of sophistication, and none of them pretend to do so.

Professional Bias

The programs reflect the professional focus of the developers rather than the stated focus of the program, therefore they tend to be dominated by academic architectural perceptions of building life cycles and environmental issues, and to focus predominantly on the life cycle periods most familiar to architects, specifically the design/build period.

Procedural Bias

Linear methods are used to develop programs aimed at integrated assessments. For instance integration is discussed as a primary element of advanced buildings but is not assessed as a parallel requirement. Lighting and HVAC are scored separately but not the efficiency of their integration under Light Harvesting. This phenomenon is common to other assessment categories, and is a primary driver of Advanced Building Syndrome; the failure of most advanced buildings to perform as intended.

Language Bias

Past paradigm terms are used to define next generation ideas. For instance conservation is the focus rather than regeneration and demolition rather than deconstruction.

Temporal Bias

Temporal issues need to be adjusted for. In addition to regional variations, the difference between construction dates can substantially bias the score. For instance the design component of a building that was state of the art ten years ago would score equally well with a mediocre current design effort. Some elements have to be scored in the context of the time when they occurred, just as some future issues like recyclability have to be assessed in the context of an estimated future.

Innovation Bias

There is no mechanism to account for the unique costs and problems associated with innovation. An innovative new building could score low based on it's start up costs and problems. The ability to score non standard and innovative elements is poorly developed significantly limiting their appropriate evaluation.

Contextual Bias

The programs would assign a point for an operable window on the first floor of a building facing a crime ridden, polluted and noisy street, at the same time they would provide a point in the same place for a triple glazed acoustic window. The window assemblies but not their installation would be assessed. The degree to which issues are contextually dependent can never be fully covered by the programs regardless of how much improvement takes place. The knowledge and observation skills of the assessor and the degree to which secondary and tertiary issues can be incorporated will determine the long range value of the programs. The assessor may be far more important than the program.

Category Bias

Secondary subject areas are often presented as primary ones due to their familiarity rather than to their actual relative position. For instance Indoor Air Quality is often presented as the lead subject area when it is actually a sub section of Indoor Environment. Similarly individual substances of concern are discussed as independent subject areas. For instance mineral fibres are scored as a lead category rather than as a sub section of fibres, and material VOC's are listed but not VOC's or SVOC's in general. Embodied Energy is included as if it were a master subject rather than just one of many Embodied Characteristics.

Part of a formula is often presented as if it were a complete formula. For instance surface area is presented as an indicator of sink capacity without qualification regarding porosity, temperature, air movement, and moisture level. Air distribution is measured at the main intake fan rather than at the diffuser or in the individual breathing zone where it is most relevant. The rated efficiency of filter cartridges is used rather than the actual performance efficiency of the filter unit.

Geographic Bias

The programs were developed in different countries and climates and consequently include elements that are unique to the originating locations geographic, cultural, linguistic and building practice norms. Program development must include careful adaptation to the local context to avoid significant value, environmental and legal liabilities.

Focus

The majority of the environmental impact is determined at the pre-conception, conception and design stages which are not significantly addressed by the programs. The programs do not clearly define, differentiate between or address major issues such as Advanced Design, Environmental Design, Social Design, Dematerialization, Industrial Ecology, Sustainable Design, Environmental Psychology and Sociology, or a complete set of major steps in the design/build life-cycle including commissioning, recommissioning, decommissioning, and end fate.

The programs assessment categories and weightings are biased in favour of easiest to identify and measure hard indicators rather than more difficult to identify or measure and often more important soft issues. Therefore categories are not necessarily ranked by relative importance to the environment or society. The programs primarily address marginal improvements within a limited range of relatively traditional issues.

Using the programs as design guidelines would result in buildings with relatively conservative marginal improvements, not "advanced" buildings. The inability to apply integration in the development and application of the tools and programs limits their appropriateness for assessing advanced issues.

The programs are focussed primarily on the building, in the architectural tradition, as if it were an isolated entity. Although infrastructure is casually included it's importance is grossly under represented. The environmental impact of the building includes the environmental impact of the infrastructure that serves it. Suburban buildings using extensive new infrastructure are scored equally with urban redevelopment using intensive existing infrastructure.

Infrastructural impacts may exceed building impacts therefore this factor alone can result in gross misinterpretation of the building's actual environmental impact. For example credit is given for location adjacent to public transportation regardless of how appropriate it is in the context of the occupants needs, or the relative impact of the infrastructure itself. Water, sewers, and roads etc. are similarly considered as if their impacts were equivalent.

As in most LCA type impact assessment programs, building assessment programs do not consider demographic impacts, which like infrastructure impacts might exceed those of the building itself.

The programs are focussed on conventional new single use construction when the majority of impacts may be associated with existing built environment issues including renovation, mixed use, flexible use, adaptive reuse, and deconstruction.

Graphics

The programs and tools tend to use written lists and grouped comparisons without graphically demonstrating the bigger picture. Environmental spreadsheets would provide context for forest vs. trees comparisons, and help ensure that all evaluations are performed in a more comprehensive or equivalent manner.

Universal Tools

Dealing with different issues and sections in different ways does not encourage a level playing field, or comprehensive understanding of the issues and evaluation techniques. The methodogy of the programs and the LCA programs from which they draw inspiration are at an early stage of development and they have not yet figured out how to manage diverse issues with a common set of tools; to describe a complete set of issues and their relative importance; or to score them with a simple transparent value.

Education

The focus on the design and build stages, on the needs of the program over those of the assessment, and the limited breadth and depth of issues considered substantially limits the value of the program as an educational tool, as a design guide and particularly as a tool for developing or evaluating advanced design projects, methods or broad based environmental issues. As the programs expand their coverage of environmental issues into areas where they have less understanding they lose corresponding credibility both as assessment and as educational tools. The inability to address integration internally and externally prevents their use as educational tools for advanced buildings. The programs use and therefore teach an incremental method.

Scoring and Weighting

Scoring is more important to the academic than to the commercial client, and represents a barrier to commercialization, particularly given the inconsistency with which any building could be assessed.

Scoring and weighting need to be simpler and more straight forward. Questions need to be divided into clear categories including Level I, II, III corresponding to primary, secondary and tertiary levels of importance and assessment. In other words how important is this question, at what level was it rated and assessed, and what is the level of confidence for the data generated. The programs and tools focus almost exclusively on a narrow range of level one issues, mostly within the realm of conventional practice, and issues familiar to the developers.

Scoring and weighting must be adjustable since they reflect the bias of the developer, which may be inappropriate to the value system of the user. For instance energy issues take clear precedence over other environmental impacts in the programs, while people designing a building for Indoor Environment may legitimately see energy as an equally or less important issue for their needs.

Both scoring and weighting need to be transparent, not dealt with in complicated formulas. Simple comparisons using percentages, scales of 1 to 5 or 1 to 10, and yes/no answers are more manageable and meaningful outside the academic context. Impact comparisons should be done on gross or site building dimensions, volumes and numbers against tenant/space equivalents. Building impacts should be expressed as a function of population, not number of dwelling units. Single occupancy luxury units can score well against high occupancy units under the programs. The building, it's infrastructure share, and occupant impacts are the three legs of the equation. Integration tools such as Environmental Footprint analysis, Secondary and Tertiary impacts need to be incorporated.

Weight, volume, and price are used as measures of convenience even when their use does not provide an accurate indication of their impact. Comparisons must be between equivalent entities. The programs frequently compare apples to oranges.

The programs and tools experience substantial difficulty in evaluating and scoring soft (social/ environmental) issues. Some of these issues are not well enough understood internally, or in the broader context to be articulated or evaluated meaningfully and therefore should be included as unscored elements until evaluation confidence is robust enough to justify inclusion. Developers should have external experts in each subject help determine how to incorporate assessment criteria rather than have architecturally focussed individuals interpret environmental subjects. Outside experts should be familiar with built environment, design and integration issues and not just isolated subject areas.

In addition to rating the question, the answer must also be rated; what level of certainty accompanies the rating? Many answers reflect best guesses while others reflect actual metered quantities, yet both are weighted as if they were equally meaningful. Simulation is used on an equal footing with hard measurements even though field results consistently show simulations to have poor accuracy. Simulation should be tempered with feedback from actual case study results until they are consistent.

Using only one auditor for a complex range of questions precludes the possibility of scoring all issues equally well. Engineer assessors will score the same building substantially differently from an architect or environmental assessor. The ability of the programs to ask foolproof questions will lag behind the ability of a highly experienced assessor for the foreseeable future.

Efficiency (ie. how much energy does it take per unit of water pumped) is often scored when appropriateness (ie. can you avoid the need) is the more relevant question.

Although credits can be assigned for a mix of materials and efficiencies applied at the individual building level they can not necessarily be used at the aggregate level since **at economic capacity or at less than operating unit quantities (all) material is used regardless of it's environmental profile.** In other words just because you did not use it on your building did not mean that it did not get used. Below capacity discretionary actions may therefore have a greater influence on reducing net impacts.

Gross impact reduction may occur if a fundamental shift can be induced such as a paradigm shift or critical mass is reached for adoption of an idea, product or technique. No net environmental impact reduction occurs from incremental actions governed by scale of production units such as a generator operating unit. Reducing energy demand from one building does not result in shutting down a generator therefore the portion of the impact assigned to the generator and related infrastructure is not affected. Most if not all environmental assessment programs score internal (site) reductions as if they resulted in actual equivalent off site reductions in environmental impacts. Site specific and aggregated use reductions are not equivalent to actual impact reductions.

Context

The programs and tools focus predominantly on static, single issue (isolated) questions, applied to a dynamic, integrated problem. The programs need to develop a clear understanding of the difference between the individual elements and the interactive cause and effect relationships, and between design intent and performance. Prescriptive, performance, objective and subjective, linear and integrated elements must be clearly differentiated.

For example the programs need to focus more on answering individual questions where confidence is significant rather than trying to define categories and relationships which have low relative confidence. It is more important and practical to focus on a wide range of individually assessable elements than to try to come to an aggregate assessment of an artificial category. In a fully integrated model each individual element must be optimized independently (incremental effects) as well as in relation to cross affected elements (synergistic effects). These two issues should be dealt with both independently, and in parallel.

The assessment format should follow a logical comparison of related issues. For instance Design Intent should always be scored next to Performance, otherwise it is impossible to gauge the effectiveness of the design element. Similarly hard indicators such as meter readings should always be compared to equivalent soft indicators such as simulations to gauge the effectiveness of the simulation. Each pair of related elements should be compared on a line by line basis, preferably on an environmental spreadsheet.

Related issues should be evaluated together on a checklist even if they are scored within their own specific categories. For instance swimming pools should not be assessed under water but under swimming pools, with water, operating and embodied energy, accessibility, safety and chlorine etc. all listed on a pool checklist. The assessor is physically assessing a pool and the pool has to be visible to the client and design team as an independent impact for decision making purposes.

Assessors are under severe time constraints and will tend to use whatever indicator is handy, complicating any pre existing bias in the program. For instance verbal evidence of management performance will be accepted when physical evidence should be confirmed, and the presence of physical evidence will be scored rather than it's actual relevance to the intent of the question. Programs and assessors tend to score positively the word of the operator, or the presence of a binder marked operating procedures, regardless of the age or content of the binder or the obvious or recorded state of maintenance.

Content

The content of the programs is heavily weighted around traditional elements of the design/ construction phase of the buildings life cycle, and does not substantially address a complete life cycle - pre design, commissioning or subsequent life cycles, renovation, adaptive reuse, recommissioning, decommissioning, end fate, or advanced design and advanced construction issues.

The programs and tools are primarily energy focussed following the post oil embargo tradition. Secondary and tertiary energy impacts, social and environmental issues are not well developed. Even within the energy category secondary and tertiary impacts are not well developed, with combustion emissions being the primary focus. Many less familiar issues are included at random rather than as a thorough and logically organized higherarchical list.

Lists of substances of concern and the discussion of their relevance tend to be short and often out of date. Some are indefensibly generated internally from scratch when substantive outside scientific material is readily available and defensible. There is a lack of reference to known sources of impact assessment data.

There is a tendency to pick a formula of convenience rather than a more defensible formula. This is best illustrated by the use of nationally aggregated data for evaluating the LCA impact of primary building materials, which produces information which can not be used to determine the actual impact of these materials at the site specific level. For instance the average embodied energy of steel has no relationship to the actual embodied energy of steel used in a particular building. Therefore comparisons between assessed buildings using nationally or industry wide aggregated input data will give little if any indication of actual impacts. Both quantity and aggregate impact data are very poor indicators of actual impacts at the site level and are essentially used as convenient surrogates for actual impact assessment. Using them together compounds the problem.

There are many instances of inconsistency, where some elements are applied in some places but not in others, some things are scored twice or appear in different sections at different times. This problem is compounded by the wide range of interpretation allowed the auditor.

Many fundamental issues are not covered - eg. thermal emissions, albido (solar reflection), fatal light attraction (avian impacts), most accessibility (non wheelchair) categories etc.

Most regulated issues are covered to the point of compliance but not beyond, while equivalent non regulated issues are not covered, giving the false impression that compliance is a significant environmental or social achievement. The programs could benefit from increased use of benchmarking, model codes, model specifications, and advanced checklists. This would help shift the focus from simulation, regulation, prescription and marginal improvement to advanced elements and real world performance.

The use of simulated base case buildings should be abandoned in favour of regional average models as data from individual assessments is collected. It is more productive in the long run to compare using real world benchmarks than theoretical ones. It is more consistent, manageable and meaningful to continuously update an average than to generate a base case model for each simulation or assessment exercise. Commercial clients are interested in a pragmatic level playing field, and are not interested in the onerous task of generating a theoretical base case building.

The differentiation between green field, redevelopment and brown field, as well as urban and suburban sites needs to be improved. The current scoring would not realistically reflect the substantial differences in actual impacts. This also applies to the comparison of new, retrofit and adaptive reuse categories.

The need for building management plans is articulated but not for traffic reduction or other infrastructure related management plans. Advanced permitting processes already require traffic and water management plans that go well beyond the current scope of the programs. The programs need to benchmark themselves against actual leading edge developments in the marketplace.

Scientific Validity

Myths and spiritual belief systems are ingrained in both the hard and soft element of the programs. The same level of scientific rigor is not applied to the new/soft elements as is to the more familiar/ hard elements. For example many environmental issues such as durability and recycled content are envisioned and presented as automatic attributes when they are clearly contextually dependent variables.

Estimates of building and component life vary substantially between programs and do not take escalating building obsolescence into account. Many buildings now become obsolescent or damaged enough to require reconstruction or substantial repair in as little as five to ten years, with 30 years being the average anticipated "economic or market" life. Unanticipated repair and retrofit issues are major market place realities which are not addressed by programs focussed on new design and construction. Advanced elements can have elevated direct and indirect performance risk, particularly in the break in phase. These unaccounted for impacts can be a large portion of the actual impact profile.

Software Tools

The programs do not take advantage of existing information regarding accessory tools such as advanced design/build/manage software, source lists, texts etc. Reorganizing the programs into modules and formatting them to accommodate more plug and play options could substantially improve their marketability and development potential. There are many integrated tools such as FRAME software for window evaluation which could easily provide enhanced performance.

The software tools are more important as development efforts, than as indicators of actual impacts. The results that they generate at this point in time are valuable as indicators of progress in software design. In other words the value is in the development phase, not practical applications. Using the tools as if they gave meaningful practical results is often counter productive. Like the programs they require substantially improved understanding and interpretation of environmental implications. The inability to input custom data or adjust weighting substantially lowers the value of the tools, and locks in the bias of the development team.

The time required to learn to use, input data and run programs represents a formidable barrier to market adoption, independent of the low level of output value. Either problem would independently prevent market adoption at this time.

Investigative Technique

Checklist formats are inflexible and focus the assessor on the listed rather than on appropriate open investigative techniques. This is counter intuitive for programs that ostensibly intend to have intrinsic value as educational tools used to spawn original thinkers grounded in first principles.

The lack of attention paid to investigative techniques and safeguards is a major problem, precluding the possibility of arriving at consistent results amongst buildings, programs, tools or assessors.

The assessors knowledge, experience and bias substantially affect the outcome of the assessment, indicating that the programs need to develop much stronger safeguards for objectivity. Rigorous assessor training may be more important than rigorous program development. Reference checklists and guidelines would be essential for meaningful field application, particularly if self assessment techniques are to be viable.

Transparency

The programs and tools lack transparency. The logic or method behind many conclusions is not presented and therefore can not be challenged, understood or improved. The lack of transparency is a major barrier to comprehension, evaluation, development and market acceptance.

Client Needs

In many cases the client needs more information about what problems were discovered and what remedial options are available and less about scoring. This would require a different format for the program and a different skill set for the assessor. The programs tend to reveal isolated deficiencies without supplying corresponding isolated or integrated solutions beyond those needed to improve simple scores.

As the client base moves toward active CAD building and facility management and smart building systems, they will require that programs have plug and play compatibility with master software. They will also require compatibility with multiple facilities and real time interaction. Programs must be designed to work with a wide range of emerging building design, operation and management software. The tendency to develop several independent commercial or national tools and programs is counter productive given that it would take the equivalent of a combined effort at current levels to develop just one reasonably effective and comprehensive first generation effort. The paradigm within which the tools and programs are being developed is a generation behind leading edge elements already operating in the marketplace.

Future Considerations

Many elements which form the foundations of tools and programs are entering a period of rapid change. The programs make no provision for this acceleration in the rate of change. For instance deregulation will change many of the formulas used to calculate impacts. It will be increasingly difficult to determine where energy came from and therefore what it's upstream impacts are.

The concepts of offsetting actions such as tree planting, issuing free transit passes and environmental credit trading are rapidly developing therefore the programs must be able to accommodate these new market realities. Tools and programs should use model code or code ready language where appropriate in order to facilitate rapid adaptation of advanced specifications in the marketplace. The programs do not adequately address intelligent technologies. They must be modified to accommodate the rapid development and adoption of these technologies within the marketplace.

The appropriateness of built environments under disaster scenarios is an imminent issue which is not addressed. Program modules should be developed dealing with issues such as floods, fires, droughts, tornadoes, hurricanes and earth quakes. These issues are already substantially affecting the environmental impact of built environments. It is not enough to consider Global Warming prevention issues, the impacts have already begun and must be accounted for and dealt with as present not future issues.

Standardization and harmonization issues will also rapidly impact program development. There are many national variations already, most of which are not regionally appropriate adaptations of core programs. For instance programs will have to consider compatibility with international initiatives such as the ISO 14000 environmental program, or general developments such as Home Energy Rating Systems and national model codes such as the National Building Code. A common format will also discourage the use of programs as non tariff barriers to trade.

Collaboration on the internet will produce generic programs and components which will be living documents, changing faster than proprietary ones and providing self evaluation options. This will put competitive pressure on commercial tools and programs, and expose the academic and commercial communities to open market, non price driven competition and criticism. The demand for more robust and defensible programs will progress faster than will the current program developer's ability to deliver.

Development of individual areas of concern will progress at different speeds and will be demanded both separately and as integral modules by the marketplace. This development will put pressure on the programs to modify their format to a modular arrangement.

There will be considerable demand for flexibility as the number of market interests and subject areas continues to expand and their development accelerates. Product stewardship and continuous quality improvement for instance are major areas of concern in the marketplace which are not addressed.

Each of the programs and tools address a different basket of issues to different degrees, using different criteria, indicating that they may be focussing more on developing proprietary vehicles than on developing the state of the art, and a common language etc. It will take considerable resources, well beyond the capability of a single country to develop a significant and comprehensive level one program. It will take considerably more effort and time to develop flexible, integrated, multi level and multi attribute analysis techniques. International integration is increasingly important given the rapid development of globally integrated products and development.

The programs assess buildings against each other at the level of current practice, in developed countries with no accommodation for appropriateness in the global, alternative, or under privileged context. Therefore there is little differentiation between the impact assigned to a luxury building or a low income building, or between developed and undeveloped sites and infrastructures. The programs tend to teach and reward marginal improvements within conventional practice and therefore act as a barrier to appropriate development.

The difference between a positive checklist which lists all options and a negative one which lists only key or indicator options should be emphasized in future development. The trend toward adding endless questions is self defeating at the development, marketing and application levels.

The programs should have as a base case no less than the prevailing legal or practice standard, preferably at the international or most stringent level, and should compare the building to the known range of markers, not just to a single chosen one.

Comparing buildings with elemental net consumption data of measurable commodities such as water, equivalent fuel etc. divided by the number of occupants may often be more useful than comparing individual design and building elements. The end result, is often more important than the means used to achieve it. Formulating an estimate of environmental impact by evaluating the means is often inappropriate for evaluating existing buildings and particularly for teaching purposes.