# A LIFE CYCLE ASSESSMENT STUDY OF EMBODIED EFFECTS FOR EXISTING HISTORIC BUILDINGS

*Prepared for:*

**Parks Canada**

*by:*

**Athena Sustainable Materials Institute**

*in association with:*

**Morrison Hershfield Limited**

*July 14, 2009*

# DISCLAIMER

Although the Athena Sustainable Materials Institute has done its best to ensure accurate and reliable information in this report, the Institute does not warrant the accuracy thereof. If notified of any errors or omissions, the Institute will take reasonable steps to correct such errors or omissions.

This report was revised July 14, 2009 to reflect minor changes. There were labeling errors, resulting in a slight increase in estimated avoided impacts for all buildings. The error occurred in the units applied to the calculation for the demolition energy.

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*The Athena Institute – unparalleled excellence in fostering a sustainable built environment*

MORRISON HERSHFIELD


There is a tremendous impact to the environment when we construct something new, so avoiding new construction may be the most eco-conscious approach to our environment.

# Table of Contents

# Executive Summary

On behalf of Parks Canada, the Athena Institute, in association with Morrison Hershfield Consulting Engineers, has undertaken a Life Cycle Assessment study (LCA) of embodied effects of existing historic buildings. The underlying objective of the study is to develop a template that will allow decision makers to bring environmental considerations and data into the decision-making process when considering the environmental implications of demolishing historic buildings, or any existing building, compared to building new.

The project team applied the concept of LCA in assessing four separate buildings across Canada using the freely available ATHENA EcoCalculator for building assemblies to compare the effects of keeping historic buildings as opposed to building new structures in the same location. Case studies were developed for each of these buildings:

- **Ottawa,** *the Parkdale Fire Station*
- **Winnipeg,** *the Birks Building*
- **Calgary**, *the Lougheed Building*
- **Vancouver,** *the Chinese Freemasons Building*

The case studies involved obtaining architectural drawings, utility bills and renovation histories for each of the four buildings. Site visits were performed to confirm the accuracy of drawings and to verify the scope of the previous renovations. Morrison Hershfield then examined the existing buildings to judge whether improvements might be made in terms of operating energy performance. New buildings were designed in terms of common building assemblies that were inputted in the ATHENA® EcoCalculator. The results from the EcoCalculator were then used to demonstrate the environmental impacts avoided by preserving each building rather than demolishing and constructing new buildings of the same size to meet the current functions.

The Canadian Building Incentive Program (CBIP) Screening Tool from National Resources Canada's (NRCan) Office of Energy Efficiency was used to estimate the energy performance of the new buildings. This tool allows an estimate of the energy performance of a proposed building design relative to the Model National Energy Code for Buildings (MNECB) and the rules established by NRCan.

The comparative results of the screening tool are generally similar for all four buildings, indicating that the energy consumption of the existing renovated buildings is relatively similar to the energy consumption results expected for a typical new building. This is not surprising given the recent renovations at the buildings employed up to date construction practices, and it may also reflect the positive energy use implications of the high mass envelopes typical of historic buildings. As well, the relatively low window to wall ratios for historic buildings definitely have a positive impact on energy consumption.

The results of the screening tool for total energy consumption (GJ) of the existing renovated buildings are within 3 to 16% of the measured consumption from the utility bills. This is considered an acceptable margin, based on the limitations of the screening tool and utility bills. There was a larger variance for the Calgary building, however this may be explained by the variability of the actual utility bills and the fact that the utility bills may reflect energy use due to construction.

The whole building Global Warming Potential (GWP) results from each building were entered into the United States Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/solar/energy-resources/calculator.html) This free tool provides the user with more tangible, "humanized results". The resulting avoided impacts of the whole building for each of the four case studies is outlined below:

| Building | Whole Building Total Avoided Impacts Primary Energy MJ | Total Avoided GWP Impact CO2 equivalent tonnes | Equivalent CO2 Emissions From |
|---|---|---|---|
| Ottawa Parkdale Fire Station | 2,616,165 | 184.76 | Energy use of **85. 2** homes for one year |
| Winnipeg Birks Building | 27,913,070 | 1,561.6 | Energy use of **473** homes for one year |
| Calgary Lougheed Building | 43,093,628 | 3,449 | Energy use of **1,591** homes for one year |
| Vancouver Chinese Freemasons Building | 6,970,013 | 484.48 | Energy use of **224** homes for one year |

The above results demonstrate the significant environmental impacts that can be avoided by preserving an existing building instead of demolishing it and building new. The operating energy analysis supports a conclusion that such embodied effects are unlikely to be overshadowed by operating energy concerns if a building has been properly renovated.

Given the underlying objective of developing an approach that could be readily applied to existing buildings without recourse to specialized consulting services or tools that are not readily available, the results have to be considered as reasonable approximations as opposed to precise estimates. In particular, assumptions and adjustments have to be made to handle specifics such as situations where an existing building is attached or very close to another building, the interior configuration of a replacement building, and the effects of demolishing the existing building. In addition, while outside the scope of this study or the resulting template, the issue of useable air space above an existing building will often be a significant factor in the decision process.

# A LIFE CYCLE ASSESSMENT STUDY OF EMBODIED EFFECTS FOR EXISTING HISTORIC BUILDINGS

## 1.0 Introduction

### 1.1 Objectives

Too often, decisions about whether to keep or demolish a building revolve only around cost considerations without taking account of the environmental implications. As a result, justifying a major renovation may be difficult, as costs are often uncertain and may equal or even be greater than the cost of new construction. There is a need, therefore, to quantify the potential environmental gains available with keeping and renovating a building versus demolishing it and building new. Environmental impacts can then be brought into the decision process along with costs and other considerations.

Such quantification requires the use of appropriate data and tools, and to that end, this study is designed to:

- give Canadian citizens relevant information on the conservation of historic buildings based on precedent, i.e. completed conservation work that received funding through an HPI (Historic Places Initiative) tool – the Commercial Heritage Properties Incentive Fund (CHPIF)"; and
- create a methodology and a decision-support framework, with related tools, that will make it easier for Parks Canada and other provincial or federal agencies concerned with the preservation of historic buildings to readily examine the environmental implications of demolition versus building new.

### 1.2 Background

Eco-conscious individuals, groups and communities around the world are helping to shift popular thinking from a generally accepted concept of defined building lives to a concept of successive life cycles, where renewal and renovation are the start of a new service life for a structure. This shift in thinking leads us to take a closer look at the successive lives and evolving functions that a structure may serve over a longer time frame, and at the consequent environmental benefits. However, although the majority of Canadians agree that "it is important to preserve Canada's historic and heritage buildings" (Environics, April 2000), since 1975 more than 21% of the pre-1920 building stock has been demolished due to factors such as economic pressures, social and technological changes, and lack of public awareness. (<www.canadianheritage.gc.ca>).

Parks Canada therefore commissioned the Athena Institute, in association with Morrison Hershfield, to examine the environmental impacts avoided by renovating and giving new life to three historic buildings that had received funding through the *Commercial Heritage Properties Incentive Fund* (CHPIF). As noted above, CHPIF is a tool of the *Historic Places Initiative* (HPI), a Government of Canada program designed to bring governments, communities and the private sector together in conserving and celebrating historic places by actively engaging Canadians in their preservation.

CHPIF has provided financial incentives to the private sector to compensate Canadian corporations for preserving Canada's heritage properties to the benefit of Canadians and communities across Canada.

Shortly after this study was commissioned, the Government of Alberta approached the Athena Institute with an interest in undertaking very similar analysis for two historic buildings in that Province. Alberta subsequently decided to separately fund a study of one of those buildings, located in Calgary, and to have it included along with the three Parks Canada building in this report.

## 1.3 Project Scope

This study provides information regarding the environmental impacts of conserving and rehabilitating four historic buildings located in Ottawa, Winnipeg, Calgary and Vancouver versus demolition and building new. All four have been renovated as commercial or residential properties and are in use serving various functions. The project scope encompasses the following key elements:

- the use of Life Cycle Assessment (LCA) to estimate two key embodied environmental impacts, primary energy use, and global warming potential measured in terms of CO2 equivalence;

- estimated avoided impacts associated with demolition of the existing buildings and construction of new buildings of essentially the same size designed to serve the functions currently being served by the renovated buildings;

- differences, if any, in estimated operating energy use for the new versus existing buildings;

- identification of any significant impacts incurred to renovate the existing buildings; and

- a qualitative discussion of issues related to the overall ‘renovate versus build new‘ decision process.

As indicated under Objectives, this study is in the nature of a pilot study designed to investigate a process to examine the environmental side of the equation using readily available tools and to create a methodology, or template, that can be readily applied. The study is not intended to provide precise estimates with regard to either the embodied or operating energy aspects, but rather to provide reasonable approximations that can be developed without requiring specialized consulting services.

## 1.4 Report Outline

The remainder of this report is structured as follows:

**Section 2** provides an overview of the data collection and impact estimation procedures.
**Section 3** presents the case results for the four buildings.
**Section 4** deals with operating energy estimates and recommendations with suggested solutions.
**Section 5** focuses on issues that have been or may be encountered, with recommendations.
**Section 6** summarizes the approach developed here as a step-by-step process or template.

# 2.0 Data Collection and Impact Estimation Procedure

## 2.1 Case Studies

The study team developed specific case studies for each of the following four Canadian buildings that have been restored or renovated and are in use.

- The **Parkdale Fire Station** building in Ottawa
- The **Birks Building** in Winnipeg
- The **Lougheed Building** in Calgary
- The **Chinese Freemasons Building** in Vancouver

## 2.2 Data Collection

The following three types of data were required to compare the existing buildings with typical new designs:

- Information necessary to 'design' a typical new building to serve the current functions, with essentially the same useable square footage as the existing building. This includes floor area, exterior wall areas (based on a 3m height for a typical floor), window areas (based on 40% window/wall ratio)[1], interior wall area (based on the existing plan) and roof area.

- Information regarding renovations which may be needed for the evaluation of embodied effects incurred to renovate the heritage building.

- Utility bills and other information to assess the relative operating energy performance of the existing building versus a new building; .

The initial step to gathering the necessary data was to review available documentation. For the case studies, information regarding the conservation work that received funding from CHIF was provided by Parks Canada. This information generally included basic information regarding the conservation work, some floor plans and elevations, and in some instances, engineering reports.

Basic histories of the buildings were generally available on the internet. The owners of the buildings were contacted to arrange site visits and obtain additional information, especially information such as utility bills to assist in assessing building energy performance. The site visits also served to confirm data provided on drawings and to allow visual inspection of building up-grades related to operations.

## 2.3 New Building Designs

The new building designs were expressed in terms of common building assemblies — exterior walls, intermediate floors, columns and beams, roofs, interior partitions, and windows — that have been pre-studied using the ATHENA® Impact Estimator for buildings and are included in the freely available

[1] Window/wall ratio consistent with the assumption in the EcoCalculator, as discussed in Section 2.4.

ATHENA® EcoCalculator for building assemblies. The appropriate assemblies were chosen based on general construction practices for similar building types and sizes for the geographical location, with the new building designs intentionally kept to the same floor plates and number of floors as the existing buildings.

## 2.4 Embodied Environmental Effects Analysis

The Athena Institute used the design parameters provided by Morrison Hershfield from the site visits as inputs to the most recent version of the ATHENA® EcoCalculator to generate estimates of the effects of constructing new buildings — effects that were avoided by keeping the historic buildings.

The EcoCalculator comprises a set of Excel spreadsheets that contain environmental impact results for more than 400 common buildings assemblies grouped in the categories noted in Section 2.2, above. The user simply indicates the square metreage of a given assembly that will be used in a new building and the spreadsheet instantly shows the estimated total environmental effects associated with the choice. As more assemblies are selected, the EcoCalculator builds an estimate of the total building effects in a summary table.

When EcoCalculator results are generated using the Impact Estimator software, the analysis takes account of maintenance, replacement and related disposal effects for all assemblies as relevant (e.g., roofing materials), assuming a 60-year service life for new buildings. These effects are therefore included along with other life cycle effects associated with the extraction of resources, manufacturing, transportation and on-site construction. More detail on the inner workings of the Impact Estimator and EcoCalculator are available from the Athena Institute web site at <www.athenasmi.org>.

The environmental effects of building demolition also represent a critical avoided impact when a building is conserved and had to be taken into account in this study. On the other side of the ledger are those impacts incurred to renovate a building, effects that differ depending on the building and what was done. However, these aspects can be problematic for several reasons, as discussed in Section 5.0. Per square metre demolition factors were developed based on results of a previous Institute study as explained in that section, and applied to the buildings as relevant to generate the results shown in Section 3.0. Renovation effects are not included, but are also not considered critical in terms of the overall avoided impacts analysis (see Section 5.0).

The EcoCalculator provides estimates of a range of LCA measures consistent with international standards. For the purposes of this study, however, the focus is on two of those measures — embodied primary energy and global warming potential.

> **Primary energy** is measured in Mega-joules (MJ), and includes all non-renewable energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources — for example, natural gas used as a raw material in the production of various plastic (polymer) resins. In addition, the measure captures the pre-combustion (indirect) energy use associated with processing, transporting, converting and delivering fuel and energy. This measures provides a close approximation of the fossil fuel use.

**Global Warming Potential (GWP)** is a reference measure. Carbon dioxide is the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a “CO2 equivalence effect” which is simply a multiple of the greenhouse potential (heat trapping capability) of carbon dioxide. This effect has a time horizon due to the atmospheric reactivity or stability of the various contributing gases over time. The International Panel on Climate Change (2001) 100-year time horizon figures have been used here as a basis for the equivalence index:

$CO_2$ Equivalent kg = $CO_2$ kg + ($CH_4$ kg x 23) + ($N_2O$ kg x 296)

## 2.5 Operating Energy Use

Whether an existing building can perform at an acceptable level in terms of operating energy can be a key consideration in the decision process from both an environmental and an economic perspective. To investigate this aspect, Morrison Hershfield used the Canadian Building Incentive Program (CBIP) screening tool to compare energy consumption of the existing building and a typical new building, assuming that a typical new building would meet the minimum requirements of the Model National Energy Code for Buildings (MNECB).

As noted previously, Morrison Hershfield examined the existing buildings to judge whether improvements might be made in terms of operating energy performance. Given the project scope and budget, this task could not be undertaken at the level of a full energy audit and report, but is intended as an overview on the efficacy of whatever upgrades have been incorporated.

The operating energy analysis is dealt with separately in section 4.0.

# 3.0 Case Studies: Embodied Effects

## 3.1 Case Study 1 - Parkdale Fire Station (#11)

*424 Parkdale Avenue, Ottawa*

**Tenants:**

Communications firm (second floor)

Cooking school (first floor)

Massage therapist's offices (first floor)

**Leasable Area:** Upper floor is 245 $m^2$
Lower retail is 217 $m^2$

**The Parkdale Fire Station** (also known as Fire Station No. 11) was designated as a municipal heritage site in 1996 and formally recognized by the province because it was one of three surviving pre-1930 fire stations in Ottawa. It is a rare surviving example in Ottawa of a fire station that incorporates pre-1930 fire-fighting technology. Built in 1923, the building was used as a fire station until 1986, after which it housed a food bank and artists' studios and galleries. The building, which had been vacant for approximately two and a half months prior to the renovations, reflects the pre-1930 period when the Ottawa fire department evolved from a poorly equipped fire fighting force to a professional fire department.

**New Use**

Fire Station 11 Ltd., the owner of the site, has rehabilitated the vacant building for multipurpose use, including a catering service, communications firm and massage clinic. The building is part of the collective memory of the Hintonburg Community and is included in historical walking tours of the area.

**Building Summary**

The building construction includes a concrete structure and load bearing brick masonry walls and wood framed windows. The building is roughly square in plan and has two floors, with a partial basement. The building is situated very close to the north property line and adjacent building. Parking is available at the front and rear of the building, with an access lane along the south elevation.

**Heritage Restoration Summary of Work:**

- New Insulating Glass (IG) units installed in existing frames for most windows;
- North elevation windows cleaned, painted and exterior storms installed.
- New windows and doors on east elevation ("garage doors" – not the main entrance door, which was cleaned and repainted);
- New mechanical system (old boiler, storage tanks and ducting removed);
- Upgraded electrical system, wiring and new fixtures;

- Some new interior wall partitions, some were maintained; and
- No major renovations to structure, exterior wall cladding, tower or roof.

**Considerations:**

1. The tower is “lost” space that is not used, and not heated. Existing building only has a partial basement; a new building would have a full basement that could be useable space;
2. Lost useable space due to thick, load-bearing brick masonry walls.

**Proposed Typical Replacement Building:**

- Two storey with full basement;
- Same 236 $m^2$ footprint as the existing building;
- Height of 6.6m (3.6m ground floor; 3m second floor);
- Similar interior configuration;
- 40% window to wall ratio consistent with EcoCalculator assumptions for exterior walls; and
- Two cladding materials due to the general size and site specific components — brick masonry cladding on elevations visible from the street (the front of the building and the south side, which is visible from the main street) and metal siding for the remainder.

## Athena EcoCalculator Results
### *Parkdale Fire Station*

| Building Component | Assembly | Primary Energy per $m^2$ (MJ) | GWP per $m^2$ (kg) | Total Primary Energy | Total GWP (tonnes) |
|---|---|---|---|---|---|
| Columns & Beams | Wide flange steel columns & beams – 236 $m^2$ x 2 floors | 1020.78 | 45.25 | 481807 | 21 |
| Intermediate Floors | OWSJ w/ steel decking system and concrete topping – 236 $m^2$ x 2 floors | 853.65 | 56.48 | 402922 | 27 |
| Exterior Walls | 2x6 steel stud 16” oc, brick cladding, 2” rigid insulation, sheathing, batt insulation, vapour barrier, gypsum board, latex paint – 103.2 $m^2$ | 1750.86 | 77.91 | 318657 | 14 |
| Exterior Walls | 2x6 steel stud, 16” oc, steel cladding (26ga), 2” rigid insulation, sheathing, batt insulation, vapour barrier, gypsum board, latex paint – 197.4 $m^2$ | 1968.17 | 172.47 | 596356 | 52 |
| Windows | Aluminum – 40 $m^2$ | 6521.32 | 312.53 | 260853 | 13 |
| Interior Walls | Steel stud (16” oc), gypsum board + latex paint each side – 280 $m^2$ | 382.64 | 15.32 | 107139 | 4 |
| Roofs | OWSJ w/ steel decking, modified bitumen membrane, vapour barrier, rigid insulation, gypsum board, latex paint – 236 $m^2$ | 1620.13 | 68.63 | 382351 | 16 |
| | | | **Whole Building** | **2550085** | **147** |

## Total Avoided Impacts Summary
### *Parkdale Fire Station*

| Building Component | Total Primary Energy (MJ) | Total GWP (Eq. CO2 tonnes) |
|---|---|---|
| Columns & Beams | 481807 | 21 |
| Intermediate Floors | 402922 | 27 |
| Exterior Walls | 915013 | 66 |
| Windows | 260853 | 13 |
| Interior Walls | 107139 | 4 |
| Roofs | 382351 | 16 |
| Whole Building Demolition | 66080 | 37.76 |
| **Total Avoided Impacts (Whole Building)** | **2,616,165** | **184.76** |

The Whole Building GWP results from the above table were entered into the United States Environmental Protection Agency’s Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/solar/energy-resources/calculator.html) This free tool provides the user with more tangible, “humanized” results. The avoided GWP impact of the Parkdale Fire Station is equivalent to the CO2 emissions from the electricity use of **85.2** homes for one year.

## 3.2 Case Study 2 - The Birks Building

*276 Portage Avenue, Winnipeg*


**Tenants:**

Government offices – Land Titles Office

**Area:** 3,030 $m^2$ of office space; 855$m^2$ footprint

**The Birks Building** was Winnipeg's first 'permanent' facility for the Young Men's Christian Association (YMCA). The YMCA obtained the Portage property in 1890, opening one of the best outfitted YMCAs in Canada in early 1901. Henry Birks and Sons, a jeweler, moved into the premises in 1909 and had the exterior transformed architecturally in 1910, while the interior was renovated into one of the city's most functional and exclusive shops in 1914. Major alterations were made in 1928, 1951-52, the late 1960s and mid-1970s. The 1951 work included installation of a granite base and Tyndall stone facings around solid bronze show windows on the ground floor. Corner columns and vestibule walls were lined with Travertine marble. In 2006 a major renovation was undertaken and the building is now entirely office space.

**Building Summary**

The building construction includes cast metal, steel and wood structural elements, load bearing brick masonry walls and wood and metal framed windows. The building is rectangular in plan and has four floors, with a full basement. The East wall of the building butts up against the adjacent building. The north and west elevations face main streets, and the south elevation faces a laneway.

**Heritage Restoration Summary of Work:**

- Minimal exterior cladding repair work (done prior to CHIF project – in good condition);
- New insulation (to achieve R20 – reported spray polyurethane), air barrier, vapour barrier and interior finish;
- All mechanical systems removed, new plumbing air handling, air conditioning and heating (LEED and CBIP);
- Significant structural upgrades, including repair/replacement of structural steel columns, beams and joists, and new piles for electrical transformer;
- New windows (with IG units) installed on the interior (wood frame, IG units in most locations, triple glazing on south elevation), leaving older exterior windows intact (includes original metal frame windows with single glazed, wired glass; newer wood frame windows with IG units; and original wood framed windows with single glazing)
- Windows at grade — from renovation circa the 1990's — include aluminum framed windows with IG units, which appear to have warm edge spacer;

- Enclosed an area to create an atrium – existing window frames (which became interior) refurbished, new glazing (aluminum frame with IG units) to exterior;
- New transformer and electrical system;
- New roofing membrane, insulation and vapour barrier;
- New passenger and freight elevator; and
- New interior finishes, one new stairwell, while maintaining one in original layout.

**Considerations:**

1. Only a partial fourth floor and lost space in the 'atrium';
2. Numerous interior partitions, appears to be primarily due to the existing structure; and
3. Built immediately adjacent to building on the east elevation (no cladding on lower 2 floors).

**Proposed Typical Replacement Building:**

- Four storeys with full basement;
- Same 855 $m^2$ floor plate as existing, height of 12m (3m per floor, which is less than existing);
- Similar interior configuration and 40% window to wall ratio;
- Assumed a full footprint for fourth floor; and
- Two cladding materials due to the general size and site specific components — precast concrete cladding on elevations visible from the street (North, West and South elevations), EIFS cladding for the East elevation, which is not visible from the street.

## Athena EcoCalculator Results
### *Birks Building*

| Building Component | Assembly | Primary Energy per m² (MJ) | GWP per m² (kg) | Total Primary Energy | Total GWP (tonnes) |
|---|---|---|---|---|---|
| Columns & Beams | Wide flange steel columns & beams - 855m² x 4 floors | 1019.5 | 45.18 | 3485140 | 155 |
| Intermediate Floors | OWSJ w/steel decking system and concrete topping - 855m² x 4 floors | 807.46 | 50.06 | 2761529 | 171 |
| Exterior Walls | 2x6 steel stud 16" oc, precast, 2" rigid insulation sheathing, batt insulation, vapour barrier, gypsum board, latex paint - 914m² | 907.18 | 53.54 | 8957312 | 496 |
| Exterior Walls | 2x6 steel stud 16"oc, EIFS, gypsum board sheathing, batt insulation, vapour barrier, gypsum board, latex paint - 451m² | 865.66 | 43.90 | | |
| Windows | Aluminium - 546m² | 5780.56 | 286.99 | 3156184 | 157 |
| Interior Walls | Steel stud (16" oc), gypsum board & latex paint each side - 3600m² | 405.70 | 14.29 | 1460511 | 51 |
| Roofs | OWSJ w/steel decking, 4-play built-up roofing, vapour barrier, rigid insulation, gypsum board, latex paint - 855m² | 8904.79 | 301.31 | 7613594 | 258 |
| | | | **Whole Building** | **27434270** | **1287** |

## Total Avoided Impacts Summary
### *Birks Building*

| Building Component | Total Primary Energy (MJ) | Total GWP (Eq. CO2 tonnes) |
|---|---|---|
| Columns & Beams | 3485140 | 155 |
| Intermediate Floors | 2761529 | 171 |
| Exterior Walls | 8957312 | 496 |
| Windows | 3156184 | 157 |
| Interior Walls | 1460511 | 51 |
| Roofs | 7613594 | 258 |
| Whole Building Demolition | 478800 | 273.6 |
| **Total Avoided Impacts (Whole Building)** | **27,913,070** | **1561.6** |

The avoided GWP impact of the Birks building is equivalent to the CO2 emissions from the electricity use of **473** homes for one year.

## 3.3 Case Study 3 - The Lougheed Building

*604 1st Street SW, Calgary Alberta*


**Tenants:**

Retail, Restaurant, Cafe (ground floor)

Entry to Theatre (ground floor)

Offices (2nd through 6th floors)

**Floor Area:** Basement - 1,421 m$^2$
Ground floor - 1,003 m$^2$
Second floor - 1,208 m$^2$
Third floor - 1,068 m$^2$
Fourth - Sixth floors - 1,394 m$^2$ (per floor)

**The Lougheed Building** was designed as a multi-purpose commercial building by civic leader and real estate mogul, James Lougheed during the pre-war building boom. Built in the Chicago Commercial style, it was the city's first large reinforced concrete structure, notable for its horizontal mass, giant pilasters at every second bay, and large decorative tin cornice (since removed). Construction materials were Medicine Hat brick, sandstone and concrete. Most of the original décor in the building was missing or badly aging, prior to recent renovations.

Commercial tenants at this prestigious address have included the United Farmers of Alberta, major players in the early days of Alberta's oil industry, and the city's leading professionals.

**Building Summary**

The building construction includes concrete and steel structural elements, load bearing brick masonry walls and wood framed windows. The building is an L-shape around the Sherman Grand Theatre (considered a separate building, and not included in this project). The building has six storeys and a full basement. The ground floor is commercial space, including a restaurant, cafe, retail stores and the entrance to the theatre. The upper floors are office space. The building is situated on two main street, and connected to the Theatre with two enclosed lightwells.

**Heritage Restoration Summary of Work:**

- New ground floor windows - wood frame with IG units;
- Refurbished original window frames, installed new IG units, second and third floor windows;
- New aluminum inserts for wood frames with IG units, upper floors (fourth through sixth);
- Refurbished single pane metal frame windows, south elevation;

- Enclosed air wells with aluminum frame windows with IG units;
- Insulation added to exterior walls, minimal work completed on exterior cladding;
- New roofing membrane and insulation;
- New mechanical system (new boilers, condensing towers and make-up air units;
- Upgraded electrical system, wiring, new fixtures;
- Maintained interior finishes on second floor (or replicated materials). Third through sixth floor are almost entirely new finishes;
- Structural upgrades for two new stairwells, new freight elevator and supports for cornice.

**Considerations:**

1. Lost useable space due to thick, load bearing brick masonry walls;
2. Lost space due to the lightwells - also additional heating costs because these are now heated spaces;
3. L-shaped building;
4. Connected to the Theatre;
5. Part of basement is not renovated yet - consideration is being give to return it to its historic character when area was used as a restaurant. Would need to install new stairs for access, which would impact useable space;
6. Attempted to maintain much of the original character of the building, especially on the lower floors, which introduces constraints associated with layout, lighting, fixtures, etc.;
7. Energy efficient items were incorporated in renovation, including low flush toilets, grey water storage and lights on motion sensors.

**Proposed Typical Replacement Building:**

- Six storeys;
- Same 1,555 m2 footprint as existing;
- Height of 3m per floor;
- Similar interior configuration and 40% window to wall ratio;
- Assumed no adjacent buildings.

## Athena EcoCalculator Results

### *Lougheed Building*

| Building Component | Assembly | Primary Energy per $m^2$ (MJ) | GWP per $m^2$ (kg) | Total Primary Energy | Total GWP (tonnes) |
|---|---|---|---|---|---|
| Columns & Beams | Concrete – 1,555 $m^2$ x 6 floors | 1460.97 | 83.14 | 13630810 | 776 |
| Intermediate Floors | Concrete flat plate and slab column system, 25% flyash – 1,555 x 6 floors | 1653.58 | 116.73 | 15427864 | 1089 |
| Exterior Walls | Curtainwall: Spandrel Panel (with insulated backpan) – 2200 $m^2$ | 1161.65 | 46.44 | 2555633 | 102 |
| Windows | Curtainwall viewable glazing – 880m2 | 3051.74 | 324.68 | 2685530 | 286 |
| Interior Walls | Steel stud (16" oc), gypsum board + latex paint each side – 2,800 $m^2$ | 1176.94 | 71.94 | 3295437 | 201 |
| Roofs | Concrete flat plate slab and column, Modified Bitumen membrane, vapour barrier, rigid insulation, latex paint – 1,550 $m^2$ | 2707.33 | 162.21 | 4196354 | 251 |
| | | | **Whole Building** | **41791629** | **2706** |

## Total Avoided Impacts Summary

### *Lougheed Building*

| Building Component | Total Primary Energy (MJ) | Total GWP (Eq. CO2 tonnes) |
|---|---|---|
| Columns & Beams | 13630810 | 776 |
| Intermediate Floors | 15427864 | 1089 |
| Exterior Walls | 2555633 | 102 |
| Windows | 2685530 | 286 |
| Interior Walls | 3295437 | 201 |
| Roofs | 4196354 | 251 |
| Whole Building Demolition | 1,302,000 | 744 |
| **Total Avoided Impacts (Whole Building)** | **43,093,628** | **3449** |

The avoided GWP impact of the Lougheed building is equivalent to the CO2 emissions from the electricity use of **1,591** homes for one year.


## 3.4 Case Study 4 - Chinese Freemason Building

*5 West Pender St., Chinatown, Vancouver*

**Tenants:**

Ground floor –office

Second to Fourth floors – residential units

**Area:** 340 $m^2$ per floor

**The Chinese Freemasons Building**, originally named The Cheekungton was completed in 1901. The buildings incorporate the traditional Chinese style with the Victorian Italian-style. Two completely different facades distinguish this building on the northwest corner of Pender and Carrall streets in Vancouver. The side facing Pender represents a fine example of Cantonese recessed balconies. The Carrall Street side displays the standard Victorian style common throughout the British Empire.

**Building Summary**

This building originally housed ground floor retail and a restaurant on the upper floors. The building underwent major renovations in 1913 and again in 1975 when the building was re-built for office space. In 2005 a major renovation was undertaken at the building, and the building now offers office space on the ground floor and the upper floors are residential units. The building construction includes steel and reinforced concrete structural elements (dating from 1974), load bearing brick masonry walls and aluminum framed windows. The building is roughly square in plan and has four floors, with a full basement. There is a mezzanine on the first floor.

**Heritage Restoration Summary of Work:**

- Restored brick cladding by replacing cracked bricks and repointing deteriorated mortar joints;

- Replaced ground floor windows with aluminum clad windows with IG units and low E;
- Replaced upper floor windows with aluminum windows with IG units;
- Structure upgraded to meet seismic requirements;
- Completed significant below grade structural work, including adding strip footings and walls, elevator pit, underpinning existing foundation, and new stairs;
- New flat roof construction;
- Interior completed, gutted and new finishes, mechanical and electrical installed.

**Considerations:**

1. Mezzanine on ground floor;
2. No windows on north and west elevations, fourth floor light well provides daylight on East elevation;
3. Energy efficient items incorporated in the renovation, including low flush toilets;
4. Tight to adjacent building on West elevation.

**Proposed Typical Replacement Building:**

- Four storeys with full basement;
- Same 364m$^2$ footprint;
- Height of 3m per floor;
- Assumed similar interior configuration and 40% window to wall ratio;
- Assumed no adjacent buildings.

## Athena EcoCalculator Results

***Chinese Freemasons Building***

| Building Component | Assembly | Primary Energy per m² (MJ) | GWP per m² (kg) | Total Primary Energy | Total GWP (tonnes) |
|---|---|---|---|---|---|
| Columns & Beams | Wide flange steel columns & beams – 1456 m² | 1033.77 | 45.18 | 1505172 | 66 |
| Intermediate Floors | OWSJ w/steel decking system and concrete topping – 1456 m² | 820.99 | 52.08 | 1195360 | 76 |
| Exterior Walls | 2x6 steel stud 16” oc, steel cladding (26ga), 2” rigid insulation, sheathing, batt insulation, vapour barrier, gypsum board, late paint – 534 m² | 2184.66 | 190.05 | 1166611 | 101 |
| Windows | Aluminum – 213.6 m² | 6215.82 | 301.25 | 1327700 | 64 |
| Interior Walls | Steel stud (16” oc), gypsum board & latex paint each side – 2300 m² | 377.09 | 14.23 | 867302 | 33 |
| Roofs | Open-web steel joinst w/steel decking, PVC membrane, vapour barrier, rigid insulation, gypsum board, latex paint – 364 m² | 1934.14 | 77.18 | 704028 | 28 |
| | | | **Whole Building** | **6766172** | **368** |

## Total Avoided Impacts Summary

***Chinese Freemasons Building***

| Building Component | Total Primary Energy (MJ) | Total GWP (Eq. CO2 tonnes) |
|---|---|---|
| Columns & Beams | 1505172 | 66 |
| Intermediate Floors | 1195360 | 76 |
| Exterior Walls | 1166611 | 101 |
| Windows | 1327700 | 64 |
| Interior Walls | 867302 | 33 |
| Roofs | 704028 | 28 |
| Whole Building Demolition | 203840 | 116.48 |
| **Total Avoided Impacts (Whole Building)** | **6,970,013** | **484.48** |

The avoided GWP impact of the Chinese Freemasons Building is equivalent to the CO2 emissions from the electricity use of **224** homes for one year.

# 4.0 Operating Energy

## 4.1 Approach

Whether or not an existing, renovated building can perform as well as a new building in terms of operating energy can be a key consideration in the decision to keep or demolish the existing building. As noted in Section 2.5, Morrison Hershfield used the 'Screening Tool for New Building Design' from the Office of Energy Efficiency to estimate the energy performance of the new buildings, assuming that a typical new building would meet the minimum requirements of the Model National Energy Code for Buildings (MNECB). The MNECB was published by the National Research Council of Canada in 1998. The code contains a set of 'prescriptive' energy-efficiency measures that should be included in new commercial buildings.

The screening tool works by comparing a new building design to a reference building, with the latter defined as a building designed to the prescriptive requirements of the MNECB. The reference building is architecturally identical to the proposed design, having the same areas, window-to-wall ratio, fuel types, appliance and electrical usage and process equipment, and insulated to the MNECB prescriptive levels applicable to the climatic region and space heating fuel for the location.

The purpose of the screening is not to develop an accurate prediction of annual energy use. Rather, the purpose is to conduct a high-level comparison to the reference building. Many simplifying assumptions are therefore incorporated within the tool, and it assumes typical building use patterns and standards of construction.

The intent for this project was to model the new building and compare the performance to utility bills for the existing building. Although the intent was to provide reasonable approximations not precise estimates, the variables and limitations inherent to the screening tool and EcoCalculator necessitated additional analysis to confirm the reasonableness of the proposed approach. MH modeled four scenarios for each building using the screening tool:

1. Existing Renovated Building: A model for the existing building was developed and compared with existing utility bills. The model was then fine-tuned to ensure that it matched actual energy use as close as possible. This step was added to obtain an indication of how significant the assumptions and limitations of the model are, and how these may impact the results.

2. Best Renovated Building: A 'best renovation scenario' was then modeled, maintaining the fundamentals of the existing building – floor plate area, building height, window-to-wall ratio, and HVAC distribution system – but encompassing available energy saving options, such as more efficient lights and more efficient boilers, within the constraints and limitations implemented in the model. We have not considered the impacts these types of renovations would have on the historic characteristic of the buildings or the cost implications of implementing these upgrades. This scenario was included to determine if the fundamental structure of a historic building imposes limitations on the energy performance of the building.

3. Typical New Building: The new building design was modeled as originally planned. This model incorporates the new building height and new window-to-wall ratio. The model is based

on the "reference building" within the screening tool, with minor alterations that are typically observed within new construction (such as the use of variable speed fans).

4. Best New Building: The new building design was also modeled assuming the best available energy saving options. This model encompasses the same fundamentals as the typical new building – floor plate area, building height, window-to-wall ratio, etc. – but encompasses available energy saving options. This model represents the best energy performance that could be achieved in a new building. This scenario was included to allow a comparison between the energy consumption of a typical building and one that attempts to achieve energy conservation, and this comparison shows a potential range of energy usage in new buildings. A comparison of the potential improvements for a new building to the potential improvements of the existing building also allows an analysis of the limiting factors of the existing historic building.

## 4.2 Data Gathering

A significant amount of detailed information and knowledge of building construction is necessary to accurately analyze operating energy usage. Obtaining detailed data for the existing buildings takes time and commitment from all parties, including the building owners and designers of record for the renovation (architectural, mechanical and electrical). We experienced challenges in contacting the correct individuals to obtain the data, constraints associated with the time and expense necessary to locate and copy the information, and the motivation for the owners and designers to provide this information. While much of the data was eventually obtained, a significant number of assumptions and averages were necessary to obtain results from the screening tool. The next sub-section highlights some of the key limitations and assumptions that were necessary to run the CBIP screening tool for the four buildings in the pilot study.

## 4.3 Data Limitations/Assumptions

The following data limitations and related assumptions deal primarily with energy modeling for existing buildings. As noted, this was not a required step but deemed useful. Numerous assumptions, based on good engineering judgment, were made during the modeling of the four scenarios for each building. The following summarizes some of the most significant and typical assumptions for the four buildings within the pilot study.

### Utility Bills

Utility bills for all four buildings were obtained, although of varying completeness. Because the renovations were completed recently, typically, the utility bills for the operating buildings were only available for a few years at the most. The average annual consumption values used for the comparisons likely include construction equipment or unusual weather conditions, which could be averaged out if utility bills for a longer period (approximately 5 years would be optimal) could be obtained. Analyzing the utility bills so that an accurate comparison of results can be achieved requires a general understanding of energy use.

### Windows

In renovated historic buildings, the original window style and the actual window frames are considered of high heritage value, and significant attempts are undertaken to retain the windows. In the four buildings reviewed for this project, the renovations/upgrades to the windows included everything from minimal intervention (retaining the metal frames and single glazed wired glass) to complete replacement. Determining the U-value for heritage restored windows is complicated, as published or measured values are not available. Printed publications, such as ASHRAE, as well as experience with the performance of historic window types were referenced to approximate the value for the heritage windows.

In addition, the value for the windows is an average for the entire building. In reality, it is common in renovated buildings to find a different window approach applied in different parts of the building. Renovated buildings typically include both new frames and glazing (which generally include sealed, insulated glazing units, low-e coatings and argon gas) and renovated windows (which may include original elements, new elements, or elements installed at some time in the history of the building).

The screening tool assumes typical air infiltration rates for new construction, which are generally more air tight than historic buildings. Therefore, the window U value was adjusted to emulate the effect of increased infiltration and uncertainties in the actual envelope construction until the results were similar to the actual utility bills.

### Wall/Roof Construction

Determining the construction of these elements is generally not possible based on a visual review of the building. Depending on the level of intervention at the building, details may be available on the design drawings. This aspect was handled by bringing to bear a basic understanding of construction practices, both current and historical.

### Lighting

In many of the buildings the lighting was installed by the tenants and the layout and details of fixtures was not available. Lighting loads were based on available documents, our on-site review, and general experience and understanding of typical lighting practices in renovated buildings. The lighting loads were adjusted to emulate the electricity utility bills.

## 4.4 Results of the Screening Tool

The four building models outlined in section 4.1 were completed for the four buildings. Where limited information was available, including incomplete utility bills or design drawings, good engineering judgment and experience was used to make assumptions to complete the analysis. The screening tool results for the existing renovated building was used as the benchmark for comparison with the best renovation, typical new building and best new building scenarios.

It is important to emphasize that numerous assumptions that affect the reliability of the results had to be made at several stages of the modeling procedure, including for the new buildings and analysis of actual energy consumption for the existing buildings. Although this affects the reliability of the figures, trends in the increase and decrease of energy consumption between the different scenarios are consistent with expectations based on our knowledge of the facilities.

Total Energy Consumption (GJ)

| | Existing Renovated Building | Best Renovated Building | Typical New Building | Best New Building |
|---|---|---|---|---|
| Ottawa | 570 | 335 | 554 | 390 |
| Winnipeg | 2790 | 1506 | 2982 | 1631 |
| Calgary | 7860 | 4345 | 6991 | 4300 |
| Vancouver | 1872 | 580 | 1332 | 614 |

Percent Difference from Existing Building

| | Best Renovated Building | Typical New Building | Best New Building |
|---|---|---|---|
| Ottawa | 41% less | 3% less | 31% less |
| Winnipeg | 46% less | 7% more | 42% less |
| Calgary | 45% less | 11% less | 45% less |
| Vancouver | 69% less | 29% less | 67% less |

The comparative results of the screening tool are generally similar for all four buildings, indicating that the energy consumption of the existing renovated buildings is relatively similar to the energy consumption results expected for  a typical new building. This is not surprising given the recent renovations at the buildings employed up to date construction practices, and it may also reflect the positive energy use implications of the high mass envelopes typical of historic buildings. As well, the relatively low window to wall ratios for historic buildings definitely have a positive impact on energy consumption.

The poorer performance of the best new building appears to be due to the higher glazing ratio assumed for the typical new building.  In general, the historic buildings have glazing ratios between 8 and 26%, whereas the new building was assigned a glazing ratio of 40% (to maintain consistency with the EcoCalculator).  This change in the amount of glazing has a significant impact on energy use.

The results also indicate that there are still areas for improvement in the existing buildings to reduce energy consumption.  The results also show that there can be a wide range of consumption in new buildings.

The results of the screening tool for total energy consumption (GJ) of the existing renovated buildings are within 3 to 16% of the measured consumption from the utility bills. This is considered an acceptable margin, based on the limitations of the screening tool and utility bills.

The existing renovated building appears to consume less energy than the typical new building for the Winnipeg location. This is consistent with expectations as some energy saving initiatives were included in the renovations.

The potential reduction in total energy consumption that can be achieved by implementing energy saving initiatives for the Vancouver building is notably higher than for the other buildings modeled in this report. This is consistent with expectations as the boiler installed at the existing Vancouver building is not a high efficiency boiler and the mechanical system over ventilates the building (using more energy). Therefore, there is a higher potential for improvement in the existing building.

The most notable finding appears to be that the physical constraints of a heritage building do not appear to limit the potential for energy performance of a building. The biggest limitation may be the level of intervention for the renovations of the historic building. In this analysis, one of the primary limiting factors to energy savings for the typical new building may be the applied 40% window-to-wall ratio.

We caution that these conclusions are based on data that contains inherent assumptions and limitations that may be significant enough to skew the data. For example, the model for the existing Calgary building was 16% different from the actual energy consumption. If we consider this variable in the comparison of energy use between the existing building and the new building, the potential difference in energy use could range from a 5% increase in energy to a 27% decrease (instead of the 11% decrease noted from the direct comparison).

Although the conclusions appear reasonable based on our experience and knowledge of the buildings, the limitations of the CBIP screening tool introduces significant variables. It appears that these variables may be significant enough to impact conclusions that are based on the results of the screening tool. The impact these variables have on the results should be corroborated. Completing full energy modeling may be warranted to determine the accuracy of the results of the screening tool with respect to the objective of this project. A full energy model could provide potentially more accurate results, but would be considerably more time consuming and would still be subject to the limitations imposed by not knowing actual infiltration rates, envelope construction and profiles of use.

# 5.0 Issues and Special Considerations

In addition to assessing the environmental implications of preserving the four case study buildings, a fundamental objective of this project is to develop a basic approach or template that can be readily applied to other historic buildings. As might be expected in a pilot study of this nature, we had to address specific unforeseen issues by making assumptions or adopting specific analysis procedures. In this section, we want to focus on key issues or considerations that will have to be dealt with in future studies by applying common approaches.

The recommendations that follow are just that, recommendations. They flow from intense study team discussions about how to deal with specific situations and are premised on the need to keep the process as simple and straightforward as possible.

## 5.1 Avoided Demolition Impacts

To avoid having to undertake detailed studies of the impacts from demolition of an existing building, we drew on an earlier study, “An Environmental Life Cycle Assessment of a Typical Office Building”, undertaken for Public Works and Government Services Canada in the 1990s. The study estimated the energy associated with demolishing structural office systems in two geographic regions of the country for various material recycling and reuse scenarios. The resulting per square metre estimates reflect the use of diesel fuel by trucks, heavy machinery and on-site electricity generators during demolition activities.

The estimated values taken from that study and applied in this project are as follows:

Primary Energy .14 $GJ/m^2$
Global Warming Potential .08 Eq. $CO2$ $tonnes/m^2$

While not precise, these demolition energy values can be applied with reasonable confidence to any cast-in-place structure, are probably acceptable for steel structures, and undoubtedly overstate the impacts for wood structural systems. At some point, it would be useful to undertake a more detailed assessment of demolition impacts going beyond the structural systems to include all envelope components, intermediate floors and transport to land fill, etc. The results will undoubtedly show that the above estimates understate this aspect of avoided impacts and are therefore conservative from a preservation decision perspective.

## 5.2 Renovation Impacts

The impacts of existing renovation are not included in this study. Again, this category poses problems because different buildings will undergo renovation to different degrees and only a detailed building-by-building analysis will provide reasonable estimates. The problem is complicated by the fact that historic buildings will typically have undergone renovation over a period of many years, with the latest work building on what came before. The Birks Building is a prime example, as indicated in the case study description (Section 3.2). In other cases, such as the Parkdale Fire Station, renovation may not be as extensive. In either situation, the estimate of renovation required when a decision is made to preserve a building is unlikely to be so extensive as to significantly change the avoided environmental impacts aspect of the decision process.

## 5.3 Attached or Adjacent Building Issues

Some historic buildings are either attached to other buildings are have other buildings very close to them. For example, the Loughheed building is attached to a theatre and to another building. In such situations some exterior walls in a replacement building would not have 40% windows as is assumed in the EcoCalculator assemblies. In other cases, an existing building may be separated from its neighbours by sufficient distances that all walls would have windows at, or approaching, the 40% level. For the purposes of this study, we have assumed the same floor plate for the new buildings as for the existing buildings, and that the new buildings would not be attached to, or even be too close to a neighbour. Applying the EcoCalculator external wall assembly data assumes the 40% window-to-wall ratio in all exterior walls. Since windows typically have a higher per square metre embodied energy and global warming potential compared to opaque walls, this approach overstates the avoided impacts for any situation where the window-to-wall ratio would be significantly less than assumed.

Workarounds, or compensating factors, can be developed to minimize this problem in cases where it could pose more significant overstatement of the avoided impacts, but that step is beyond the current scope.

## 5.4 New Building Interior Configuration

In the case studies, the interior configuration of the new buildings has been assumed to be essentially similar to the existing buildings. This might not always be realistic; for example, the second floor of the Lougheed building. This assumption effects the number of interior partitions included in the new building energy and global warming potential estimates. The problem is how to determine what would be built if there is a marked departure from the existing configuration for an office building. Would it be an open plan with minimal private office space, a series of fixed private offices, or moveable floor to ceiling partitions? We recommend the path chosen for the case studies unless there is clear direction to the contrary. In that case, the square metreage assumed for the interior partition entry in the EcoCalculator can be adjusted. And in any case, this is not a highly significant number relative to the total avoided impacts estimate.

## 5.5 The Air Space Issue

The last issue we want to at least mention here is the treatment of the air space above an existing building, especially in a dense urban area. This aspect of the decision process is well beyond the scope of this work and is not something that can be taken into account using the EcoCalculator or other available tools. At the same time, it can be a critical aspect of the debate about whether to keep an historic building.

Historic buildings typically fall toward the low-rise end of the height spectrum, with the highest of our case study buildings at six storeys. In urban areas, the air space above such buildings is very valuable and, indeed, using that space and increasing densification is often cited as a sustainability justification for building new. For example, it helps prevent urban sprawl with attendant reduced transportation and underground infrastructure construction. And if we look at the per square metre environmental effects of replacing a five storey building with a thirty-five storey office tower, we will see quite different numbers compared to the estimates we've presented here using the avoided impacts approach.

There is no easy answer to this part of the decision process unless a municipality has regulations in place that allow a transfer of air space from a historic to a new development on a different site. But this aspect should not be forgotten or ignored, and the real answer may be to ensure that municipalities do indeed provide for transfer. In addition, the air space issue and its resolution has broader social, aesthetic and cultural implications that should be taken into account.

# 6.0 Analysis Template

Following is a summary of the basic analysis steps for estimating embodied avoided impacts. The operational energy aspects are not included for the reasons explained in Section 4.

1) Obtain floor plans, elevations and information regarding the history of the building, specifically repairs and renovations completed.

2) Visit the site to confirm the accuracy of drawings and verify the scope of the renovations. Review the site and building location for constraints or limitations that may impact the design of the new building, such as buildings immediately adjacent to the existing. Review typical construction assemblies for the geographical area (i.e., prevalent construction practices and assemblies that are being used in new buildings).

3) Determine assembly areas for the replacement building: structural (footprint by number of floors); exterior wall areas (based on existing wall lengths and new building height (3m per floor)); window areas (based on 40% window to wall ratio); area of interior walls; roof area (based on footprint).

4) Download the free version of the Athena EcoCalculator for Assemblies from the website <www.athenasmi.org> for the relevant geographic region and building height: low-rise (under 4 storeys) or high-rise (5 storeys and above)

5) Select assemblies from the EcoCalculator for the new building based on constructions used in the geographical location, size of building, type of building, site, etc. The following assembly categories are available: Columns and Beams, Intermediate Floors, Exterior Walls, Windows, Interior Walls, Roofs.

6) After selecting a major category (e.g., Exterior Walls), enter the square metreage of each type of exterior wall assembly for the new building in the yellow column. More than one assembly type may be entered in each category. The impact totals will indicate their combined environmental impact.

7) Due to underlying assumptions inherent within the EcoCalculator, a 40% window to wall ratio must be used. To do so, take 40% of the total exterior wall area of the new building. The result becomes the square metreage to be entered in the yellow column of the Windows assembly category.

8) After entering assemblies for each category, the small chart at the top of the screen will indicate the environmental impacts by building component within each category as well as for the whole building.

9) In order to calculate demolition effect factors, determine the functional square footage of the new building by multiplying the number of floors in the building by the total roof area. The functional square footage of the building should then be multiplied by the following factors:

**Primary Energy related to demolition** = functional square footage of building x .14 GJ/m2 (140 MJ/m2)

**Global Warming Potential related to demolition** = functional square footage of building x 0.08 Eq. CO2 tonnes/$m^2$

10) The GWP results from the new building can then be entered into the United States Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator http://www.epa.gov/solar/energy-resources/calculator.html. This free tool provides the user with more tangible, "humanized results" such as the number of homes for which emissions from electricity use would be equivalent to the avoided CO2 emissions for a given building.