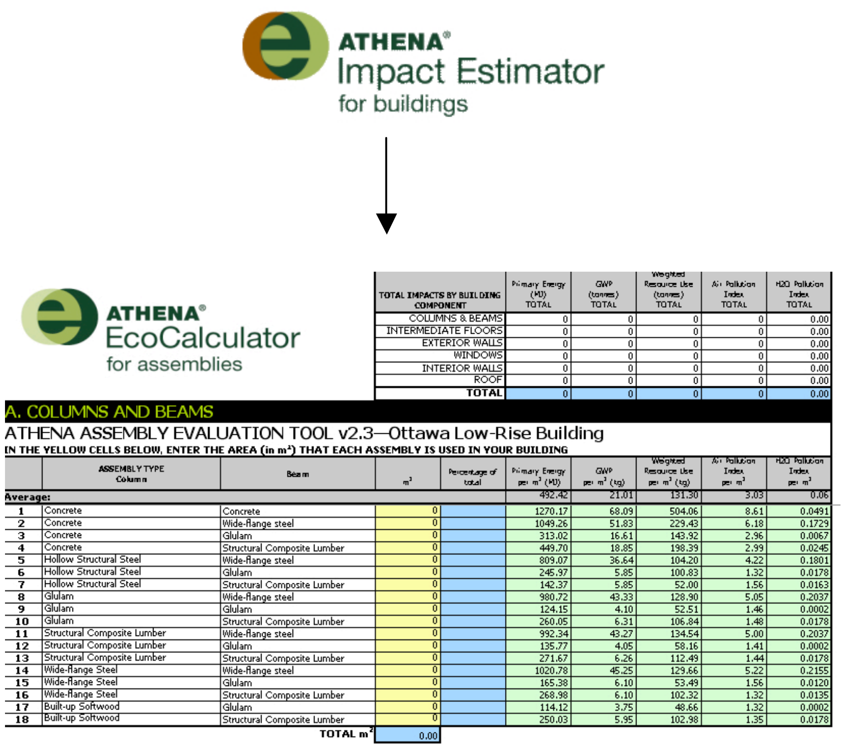
ATHENA® EcoCalculator for Assemblies Overview



TOTAL IMPACTS BY BUILDING COMPONENT	Primary Energy (MJ) TOTAL	GWP (tonnes) TOTAL	Weighted Resource Use (tonnes) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
COLUMNS & BEAMS	0	0	0	0	0.00
INTERMEDIATE FLOORS	0	0	0	0	0.00
EXTERIOR WALLS	0	0	0	0	0.00
WINDOWS	0	0	0	0	0.00
INTERIOR WALLS	0	0	0	0	0.00
ROOF	0	0	0	0	0.00
TOTAL	0	0	0	0	0.00

A. COLUMNS AND BEAMS

ATHENA ASSEMBLY EVALUATION TOOL v2.3—Ottawa Low-Rise Building

IN THE YELLOW CELLS BELOW, ENTER THE AREA (in m²) THAT EACH ASSEMBLY IS USED IN YOUR BUILDING

	ASSEMBLY TYPE Column	Beam	m²	Percentage of total	Primary Energy per m² (MJ)	GWP per m² (kg)	Weighted Resource Use per m² (kg)	Air Pollution Index per m²	H2O Pollution Index per m²
Average:					492.42	21.01	131.30	3.03	0.06
1	Concrete	Concrete	0		1270.17	68.09	504.06	8.61	0.0491
2	Concrete	Wide-flange steel	0		1049.26	51.83	229.43	6.18	0.1729
3	Concrete	Glulam	0		313.02	16.61	143.92	2.96	0.0067
4	Concrete	Structural Composite Lumber	0		449.70	18.85	198.39	2.99	0.0245
5	Hollow Structural Steel	Wide-flange steel	0		809.07	36.64	104.20	4.22	0.1801
6	Hollow Structural Steel	Glulam	0		245.97	5.85	100.83	1.32	0.0178
7	Hollow Structural Steel	Structural Composite Lumber	0		142.37	5.85	52.00	1.56	0.0163
8	Glulam	Wide-flange steel	0		980.72	43.33	128.90	5.05	0.2037
9	Glulam	Glulam	0		124.15	4.10	52.51	1.46	0.0002
10	Glulam	Structural Composite Lumber	0		260.05	6.31	106.84	1.48	0.0178
11	Structural Composite Lumber	Wide-flange steel	0		992.34	43.27	134.54	5.00	0.2037
12	Structural Composite Lumber	Glulam	0		135.77	4.05	58.16	1.41	0.0002
13	Structural Composite Lumber	Structural Composite Lumber	0		271.67	6.26	112.49	1.44	0.0178
14	Wide-flange Steel	Wide-flange steel	0		1020.78	45.25	129.66	5.22	0.2155
15	Wide-flange Steel	Glulam	0		165.38	6.10	53.49	1.56	0.0120
16	Wide-flange Steel	Structural Composite Lumber	0		268.98	6.10	102.32	1.32	0.0135
17	Built-up Softwood	Glulam	0		114.12	3.75	48.66	1.32	0.0002
18	Built-up Softwood	Structural Composite Lumber	0		250.03	5.95	102.98	1.35	0.0178
		TOTAL m²	0.00						

June 2008

1.0 Introduction

The goal of this document is to present an overview of the ATHENA® EcoCalculator for Assemblies by providing an indication of the inner workings of the tool – what it does and how it does it. The EcoCalculator is a free Life Cycle Assessment (LCA) tool that provides environmental impacts for common building assemblies. It was originally commissioned by the Green Building Initiative for use in its Green Globes assessment and rating system, where it is provided in the form of a credit calculator. The tool was developed by the Athena Sustainable Materials Institute in association with the University of Minnesota and Morrison Hershfield Consulting Engineers.

The free generic version of the EcoCalculator, without credit calculation functions, can generate instant LCA results because each pre-defined assembly has already been assessed using the ATHENA® Impact Estimator for Buildings – the parent software. The Estimator, in turn, uses Athena's datasets as well as data from the U.S. Life Cycle Inventory Database (please see www.nrel.gov/lci).

A similar transparency document available on the Athena Institute website (www.athenaSMI.org), "The Impact Estimator for Buildings Software and Database Overview", provides an understanding of the inner workings of the Impact Estimator. That document is fundamental to a full understanding of the EcoCalculator in view of the Impact Estimator's parent software role, and should be referenced for more detailed background information on key factors and considerations underlying the calculations.

It is important to note that certain assemblies within the EcoCalculator are still being worked on (highlighted in red type in the tool), and others may be changed somewhat in the near future in terms of their specific definitions. As data for other assemblies becomes available, they will be added to the EcoCalculator.

2.0 High Level Description

The EcoCalculator (EC) is a decision support tool, not a scoring or rating system. The software indicates the environmental implications of pre-defined assemblies that have been assessed using the Impact Estimator.

The EcoCalculator can be used for new construction projects, retrofits and major renovations, and for industrial, institutional, and office designs, either to compare specific assemblies or to assess all of the assemblies in a structure. Low-rise residential buildings are handled in a separate residential version that works in the same way as the commercial versions, but with different assemblies.

The results take into account all life cycle stages: resource extraction and processing; product manufacturing; on-site construction of assemblies; all related transportation; maintenance and replacement cycles over an assumed building service life of 60 years; and structural system demolition and transportation to landfill.

There are six types of building assemblies included in the EC:

- columns and beams
- intermediate floors
- exterior walls
- windows
- interior walls
- roofs

Foundations and footings were omitted because the overwhelming range of possible types based on local codes and geomorphology makes it difficult and potentially misleading to pre-define assemblies.

The list of assemblies represents common practices based on existing references and consultation with industry representatives and other stakeholders. The number of assemblies available is limited by two factors:

1. LCA data is not available for some materials; and
2. the desire to make the EcoCalculator easy to use means not showing every possible variation within each assembly type (e.g., instead of showing LCA results and ratings for every type of rigid insulation on roof and wall assemblies, a generic representative “rigid insulation” is shown).

Sensitivity studies were done to ensure the variation between products that fall under a generic definition does not vary significantly.

The number of assemblies in each category varies widely depending on the possible combinations of layers and materials. Within the exterior wall category, for example, there are eight basic wall types, seven cladding types, three sheathing types, five insulation types and two interior finish options. The number of assemblies for exterior walls represents all viable combinations of these options.

Assemblies are currently assessed in terms of a limited range of performance measures: global warming potential, embodied primary energy (fossil fuel depletion), pollution to air and water, and weighted resource use.

To develop results, the user indicates the square footage (or metreage for Canadian regions) represented by selected assemblies. Users can evaluate multiple assembly types within a category (e.g., exterior walls), in which case their impact measurements will be combined to arrive at a total environmental impact for that category. The EC calculates and shows the percentages accounted for by selected assemblies within a category to assist the user.

Design results are presented in tabular form and show real time changes as the inputs are adjusted by the user. This allows different assembly options to be considered in light of their environmental impacts and provides the information necessary to make informed, scientifically based choices.

3.0 Inner Workings

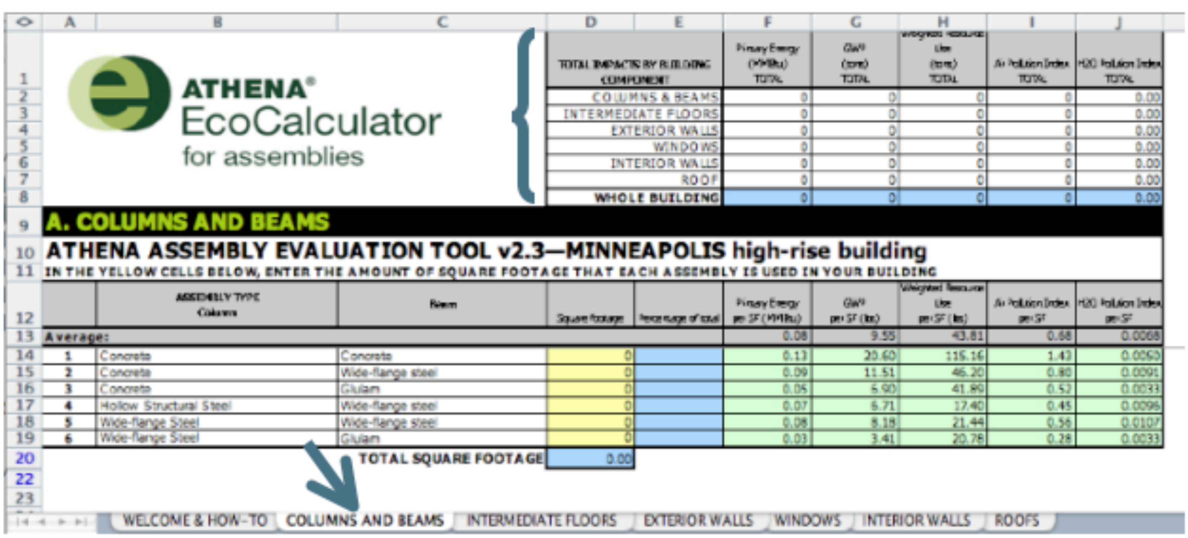
3.1 Overview

The spreadsheet displays a selection of assembly category tabs along the bottom of the page (columns and beams, roofs, windows, exterior walls, etc.). As can be seen in Figure 1 below, the sheet is divided into colour coded cells.

Colour-coding

- Yellow denotes cells where users input the areas for selected assemblies as noted above.
- Blue cells in the lower table show automatically calculated percentages of an assembly category accounted for by each selected assembly in that category.
- Blue cells in the upper small table show the automatically calculated total impacts by individual measure for all selected assemblies across all categories.
- Green cells show per square or per square metre impact results from the IE by individual measure for each assembly.
- White cells in the upper small table show the total impact by individual measure for each assembly category, automatically calculated by multiplying square footages times per square foot impact results for all selected assemblies.

Directly above the column of green cells for each measure (e.g., for global warming potential), there is a cell that shows the average performance for that assembly category (e.g., for all low rise exterior walls in a warmer climate zone). This allows different assemblies to be compared to the typical average assembly at a glance, with results lower than the average preferred.



Two main sections:

1. **The top table shows the aggregate results as assemblies are added and appears on every sheet**
2. **The bottom table lists all the assemblies in the selected category and shows the results by assembly**

Figure 1

The user chooses the combination of elements that most closely approximates the proposed assembly or assemblies of the building and enters the area (in square metres as indicated by the diagram in Figure 2) of each type of assembly in the yellow cell next to that assembly. Note that in the case of the columns and beams category, the square footage relates to the area of supported floor plate. Results immediately appear in the green cells, as well as in the top table.

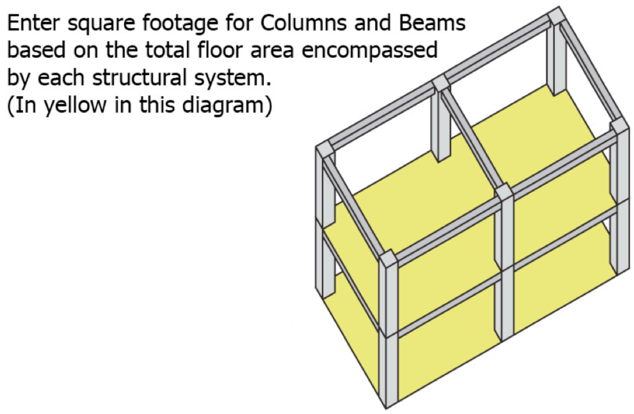


Figure 2

3.2 Regional Considerations

In the software, cities are used to designate regions because material or product flows, energy use and other considerations are not readily defined by strict political boundaries. The user selects the city that best represents the location of the building site.

This regionalization means that lists of assemblies reflect appropriate insulation values in different parts of the country. For example, the exterior walls in a northern version have a nominal R-value of 20 and in the southern version it is approximately R-10. Similarly, the roofs in the north have a nominal R-value of 40 and in the south it is approximately R-20.

The current version of the EcoCalculator supports the following regions;

- Northern USA averages
- Southern USA averages
- 8 Canadian regions: Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, Québec, Halifax
- 4 US regions: Atlanta, Minneapolis, Orlando, Pittsburgh

The following regions will be added in the near future;

- Los Angeles
- New York

- Seattle
- Other SW and central regions

The environmental impacts of a building assembly will vary in different locations for several reasons; for example:

- code requirements for insulation in wall and roof assemblies vary by region, as do building practices;
- material sources and transportation distances vary by location; and
- maintenance and replacement cycles can also vary.

The user selects the version that best reflects the R-values and height of the building:

EcoCalculator version	Roof	Wall	Building Height
Northern climate/high-rise construction	R-40	R-20	Over 4 stories
Northern climate/low-rise construction	R-40	R-20	1–4 stories
Southern climate/high-rise construction	R-20	R-10	Over 4 stories
Southern climate/low-rise construction	R-20	R-10	1–4 stories

R-values have been included to clarify functional equivalence. They are calculated using an additive method with component R-values derived from the *ASHRAE Handbook of Fundamentals* (ASHRAE, Atlanta, GA, 1981). They are not meant to indicate actual thermal performance. Steel stud walls assume the ASHRAE correction factor to account for convective thermal transmission.

The LCA impact of a given assembly in a particular location does not vary by building type. For example, a square foot of a concrete masonry interior wall has essentially the same LCA results whether that wall is used in a one-storey house or a 20-storey high-rise office building. For this reason, there is no need for separate versions of the EcoCalculator for different building types.

For every region, the EcoCalculator has both low-rise (four stories and less) and high-rise versions so that impact averages reflect appropriate assemblies within each category.

4.0 Considerations, Assumptions and Impact Measure Definitions

4.1 Considerations

In the development of specific LCA results using the IE, one must define assembly geometry and other structural characteristics, such as the length of an exterior wall or the live load on an intermediate floor. For example, exterior walls are run using 1,000 linear feet, 10 feet in height and a 40% window to wall ratio. The results are presented on a per square foot or per square meter basis in the EcoCalculator to make it easy for users to make visual comparisons among assemblies and with the averages for a category.

The IE does not yet include all the required information for all materials or assemblies within the defined list. For assemblies that are not currently fully supported by the IE, estimates were made to approximate their environmental impact from first principles. In the current version, estimated embodied effects were developed for EIFS cladding, precast concrete cladding, welded wide flange (WWF) steel columns, structural insulated panel walls (SIPS), and Glulam and LVL columns.

4.2 Assumptions

Global Assumptions

- An assumption was made that all assemblies would be installed in either low or high-rise office buildings, using components and loadings typical for central areas of the United States (i.e., no unique seismic loadings were considered), but with a differentiation between northern and southern climates for the purposes of properly defining assemblies in terms of thermal performance and related code requirements.
- The IE requires a definition of building type, ownership and expected life. This affects the maintenance schedule and repair/replacement of certain building assemblies. For the purposes of the EcoCalculator, we assumed an "owner occupied office" building type with a 60-year life for both high and low-rise buildings.
- The life cycle stages included in the LCA results include resource extraction, resource transportation, building product manufacturing and component manufacturing (components incorporate two or more building products), transportation from manufacturing plant to building site by various modes, on-site construction, maintenance and replacement of components over a 60-year period and end of life (demolition) effects.
- The building exterior walls were assumed to have 40% windows by area.
- All windows were assumed to be inoperable.
- All window glazing assumed double-glazing with low-E silver coating and argon filled cavity. Viewable curtainwall assumed two panes of 6mm glazing.
- All concrete (except floor topping) was assumed to be 4000 psi (30 Mpa).
- All cast-in-place concrete was assumed to contain 25% fly ash in place of Portland cement; although this is not necessarily typical, it was considered more appropriate to use an environmentally beneficial formulation.
- All concrete masonry was assumed to contain 0% flyash, while precast concrete was assumed to contain 10% silica fume in place of Portland cement.
- All gypsum board was assumed to be 5/8" thick regular gypsum board, taped and finished with latex paint.
- All wood structural panels (WSP) used data for oriented strand board (OSB). This will change to source data from plywood in the next version.
- All structural composite lumber (SCL) used data from laminated veneer lumber.
- All vapor barriers were assumed to be 6 mil PET.

- Rigid insulation used data from closed-cell extruded polystyrene.
- Batt insulation used data from fiberglass batt.

Column and Beam Assumptions

- Live load for structural systems was assumed to be 75 psf/ 3.6 kPa.
- Bay sizes were set at 30 feet by 30 feet for the purpose of assessing columns and beams.
- Floor-to-floor heights were set at 10 feet.
- Glulam beams assumed 24F grade (2400 psi allowable bending stress) beams.
- Steel columns assumed 5” x 5” steel tube, ¼” tube thickness. Connector materials were not included in steel column-based column and beam assemblies.
- Softwood columns assumed 6” x 6” (nom.) built-up columns.
- Wide flange steel column and beams used approximated volumes modeled as extra basic material.

Intermediate Floor and Roof Assumptions

- The live load for roofs was set at 45 psf (2.4 kPa).
- The live load for intermediate floors was set at 75 psf (3.6 kPa).
- Glulam beams were assumed to be at 24F glulam 4ft./1200mm spacing, supporting 2x (nom.)/38mm S/P/F tongue-and-groove decking.
- Wood trusses were assumed to be 2x6 or 2x10 (nom.)/38x89mm or 38x140mm solid lumber fastened with galvanized steel nail plates. Trusses were spaced at 24in./600mm o.c. and bridging was included at 6’-6”/2000mm o.c.
- Open web steel joists were assumed to be 4ft./1200mm o.c.
- Precast double-T assemblies were assumed to be 8ft./2400mm wide.
- Steel joists were assumed to be light gauge steel “C” joists, intended for residential use only.
- Composite wood and steel joists (TJM, TJL, TJW and TJH type) were assumed at 4ft./1200mm o.c. Joist chords were assumed to consist of one or two 2x8 (nom.)/38mm x 89mm wood members with tubular steel webs. Nails and other steel connectors except bridging were assumed to be included.
- Wood I-joists were assumed to be ½” OSB web with 2 x 3 (nom.) LVL flanges.
- Solid wood joists were assumed to be 2x (nom.)/38mm wood joists (SPF #2 grade) at 16”/400mm o.c. and included solid lumber bridging at 6’-6”/2000mm o.c.
- Steel decking was assumed to be 22 ga. 1.56”/39mm metal deck.
- Concrete topping was assumed to be 3 ½”/89mm thick concrete reinforced with 6”x6”/150mm x 150mm no. 10 metal mesh.
- EPDM roofing membrane assumed ethylene-propylene-diene monomer used as roofing membrane application density of 4.5 kg/m2 or 92lbs/square (100 sq.ft.).
- Modified bitumen roofing membrane assumed 2-ply roofing application density of 34 kg/m2 or 695lbs/square (100 sq. ft.).

Exterior Wall Assumptions

- Concrete masonry exterior walls were assumed to be standard weight, 8"x8"x16" hollow concrete blocks; every third vertical core was assumed to be grouted and reinforced with one steel bar.

- ICF exterior walls were assumed to be 8" in total thickness with a finished R-value of 20. 4000psi concrete with average (9%) flyash content was assumed; steel reinforcement included; wood sill plates and rough opening framing included.
- Cast-in-place concrete walls were assumed to be 6" thick, with 4000psi concrete with average (9%) flyash content; #5 rebar reinforcement included; allowance for form-ties, wire, etc.
- Concrete tilt-up walls were assumed to be 6" thick, with 4000psi concrete with average (25%) flyash content; #5 rebar reinforcement included; allowance made for CIP steel angle, lifting inserts/accessories, etc.
- Curtainwall assemblies assumed a self-supporting grid comprising most of the exterior wall envelope area. Grid system was assumed to be aluminum (100mm deep mullions) on 2m centers vertically and 1.5m horizontally. Provided take-off assumed every vertical mullion in the curtainwall to be structurally connected via structural steel at every floor.
- Wood studs were assumed to be kiln dried, 2x4 or 2x6 (nom.) thick depending on the climate zone. Double top plates and a single top plate included; fasteners included.
- Steel studs were assumed to be 1 5/8" x 3 5/8" or 1 5/8" x 6" 20 ga. Studs; top and bottom tracks included; fasteners included.
- Brick cladding was assumed to be standard 7.6"x 3.5"x 2.3" cored clay brick; flashing and mortar included.
- Steel cladding was assumed to be 26 ga. galvanized steel siding with one coat of latex paint.
- Precast cladding was assumed to be 4" thick, with 5,000 psi concrete.
- Stucco was assumed to be Portland cement based traditional stucco with steel mesh reinforcement. Galvanized flashing and #15 felt moisture barrier included.
- Vinyl cladding was assumed to include aluminum flashing and #15 felt moisture barrier.
- Wood siding used data from beveled pine lap siding; one coat of latex paint included.
- All exterior wall rigid insulation was assumed to be extruded polystyrene, 4" thick in the northern climate zone and 2" in the southern region.
- All batt insulation in exterior walls was assumed to be fiberglass, 8" thick in the northern climate zone and 4" thick in the southern region.

Interior Wall Assumptions

- Interior concrete masonry walls were assumed to be 6" thick.
- Wood studs were assumed to be 2x4, kiln dried; single top and bottom plates included; fasteners included.
- Steel studs were assumed to be 25 ga, 1 5/8" x 3 5/8"; top and bottom tracks included; fasteners included.

4.3 Impact Measure Definitions

Embodied primary energy is reported in Giga-joules (GJ) or millions of Btu's (MMBtu). Embodied energy 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 is included. In addition, the measure captures the pre-combustion (indirect) energy use associated with processing, transporting, converting and delivering fuel and energy.

Global Warming Potential (GWP) is an equivalence measure with carbon dioxide as the common reference standard for global warming or greenhouse gas effects. All other greenhouse gases are referred to as having a "CO_2 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 difference in 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 + (GH4 kg x 23) = (N2O kg x 296)

The air and water pollution measures are similarly intended to capture the pollution effects of groups of substances emitted at various life cycle stages. In this case we used the critical volume method to estimate the volume of ambient air or water that would be required to dilute contaminants to acceptable levels, where acceptability is defined by the most stringent standards (e.g., drinking water standards). The IE software calculates and reports these critical volume measures based on the worst offender – that is, the substance requiring the largest volume of air and water to achieve dilution to acceptable levels. The hypothesis is that the same volume of air or water can contain a number of pollutants.

Water Pollution Index = maximum of the following divided by 1,000,000:
i) DISSOLVED SOLIDS (mg) / 5000.0
ii) POLYNUCLEAR AROMATIC HYDROCARBONS (mg)
iii) CYANIDE (mg) / 0.05
iv) PHENOLS (mg) / 0.01
v) AMMONIA/AMMONIUM (mg) / 20.0
vi) NITRATE NITRITE (mg) / 20.0
vii) HALOGENATED ORGANICS (mg) / 0.2
viii) CHLORIDES (mg) / 2500.0
ix) ALUMINUM (mg) / 1.0
x) OIL and GREASE (mg) / 10.0
xi) SULPHATES (mg) / 5000
xii) SULPHIDES (mg) / 0.5
xiii) IRON and other HEAVY METALS (mg) / 3.0v

Air Pollution Index = maximum of the following, divided by 1000:
i) SULPHUR OXIDES (g) / 0.03
ii) PARTICULATES (g) / 0.06
iii) CARBON MONOXIDE (g) / 6
iv) NITROGEN OXIDES (g) / 0.06
v) VOLATILE ORGANICS (NMHC) (g) / 6
vi) PHENOLS (g) / 2

Raw resource use can be measured in common units such as tonnes, but a unit of one resource like iron ore is not at all comparable to a unit of another resource like timber or coal when it comes to the environmental implications of extracting resources. Since the varied effects of resource extraction, (e.g., effects on biodiversity, ground water quality and wildlife habitat, etc.) are of primary concern, it is important to ensure that they are taken into account. However, some of these effects are much more difficult to quantify than others, such as the effects on wildlife habitat, water quality and biodiversity; we call these ecological carrying capacity effects, defining ecological carrying capacity as the ability of an ecosystem to absorb the varied effects of resource extraction. While these effects are as important as other more readily quantified resource inputs and waste outputs, ecological carrying capacity effects are much more difficult to incorporate for a number of reasons, especially their highly site-specific nature.

The approach adopted was to survey a number of resource extraction and environmental specialists across Canada to develop subjective scores of the relative effects of different resource extraction activities. The scores reflect the expert panel ranking of the effects of extraction activities relative to each other for each of several impact dimensions. The scores were combined into a set of resource-specific index numbers, which are applied in the ATHENA® Impact Estimator as weights to the amounts of raw resources used to manufacture each building product. The Weighted Resource Use values reported by the Impact Estimator are the sum of the weighted resource requirements for all products used in each of the designs. They can be thought of as "ecologically weighted pounds or kilograms", where the weights reflect expert opinion about the relative ecological carrying capacity effects of extracting resources. Excluded from this measure are energy feedstocks used as raw materials. Except for coal, no scoring survey has been conducted on the effects of extracting fossil fuels; as a result, they have been assigned a score of one to account only for their mass. The weighting factor for each raw material is set out below:

Resource	Weighting factor
Aggregate	1
Limestone	1.5
Iron ore	2.25
Coal	2.25
Boreal timber	2.5
Coastal timber	3.25

The final sum measure is an ecologically weighted measure of resource use.

5.0 In Conclusion

This document was intended to present an overview of the ATHENA® EcoCalculator for Assemblies by providing an indication of the inner workings of the tool. As was noted in section 1.0, Introduction, there is a close relationship between the EcoCalculator and ATHENA® Impact Estimator for Buildings, the Impact Estimator being described as the 'parent' software. As the Impact Estimator continues to be modified, the EcoCalculator will be correspondingly changed; significant changes to both tools will result in updates to this document.