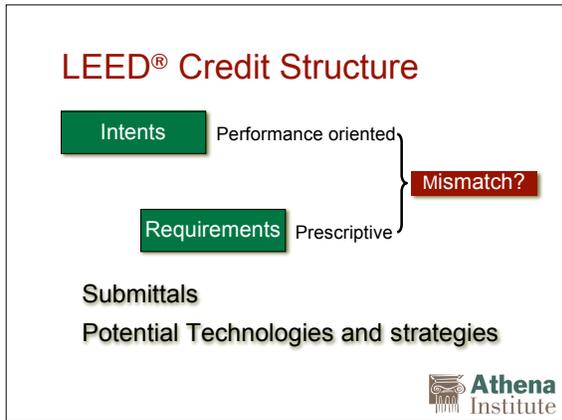


# A Practical Tool for Building Life Cycle Assessment:

Wayne Trusty  
 Ecobuild Fall, December 2008



- ### Presentation Outline
- ◆ LCA: Why? What? How?
  - ◆ LCA applied to buildings
    - » existing buildings
    - » limitations
  - ◆ The LCA toolkit
    - » picking the right tool for the task
  - ◆ Example of life cycle optimization
  - ◆ LCA in rating systems
    - » options
    - » LEED
    - » Green Globes
  - ◆ Introduction to the Athena EcoCalculator
- Athena Institute



**Materials and resources credits are especially weak in rating systems . . .**

**. . . and very controversial**

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### The use of wood is a good example

It's all about renewability!

No! It's about certification!

Actually, you're both wrong ...

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### Materials selection is all about trade-offs!

Abundant resources

High CO2

Resistant to pests

Water pollution

Recycled content

Locally available

CO2 neutral

Low energy

Harvesting issues

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### Weighing material options

By attribute?

Service life

regional

rapid renewability

recycled content

or...

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### By environmental performance → LCA

Acid rain damage

Air pollution

Resource depletion

Climate change

Water pollution

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### Life Cycle Assessment

resource use (depletion)

water use

transportation

energy use

resource extraction effects

emissions to water

solid wastes

emissions to air

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*A methodology for assessing the environmental performance of a product over its full life cycle*

### The ISO 14040 Framework

Life Cycle Assessment Framework

Goal & Scope Definition

Inventory Analysis

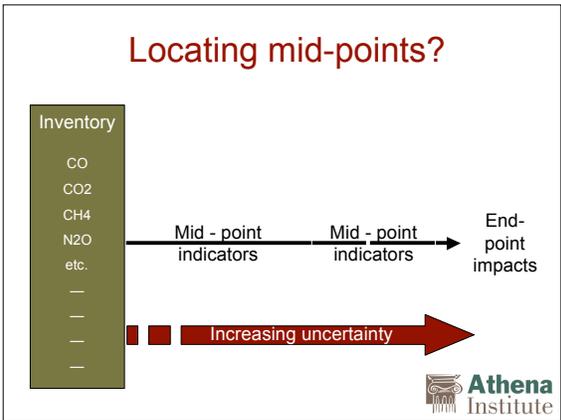
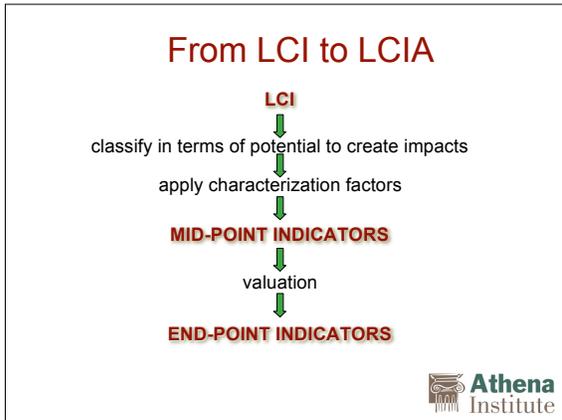
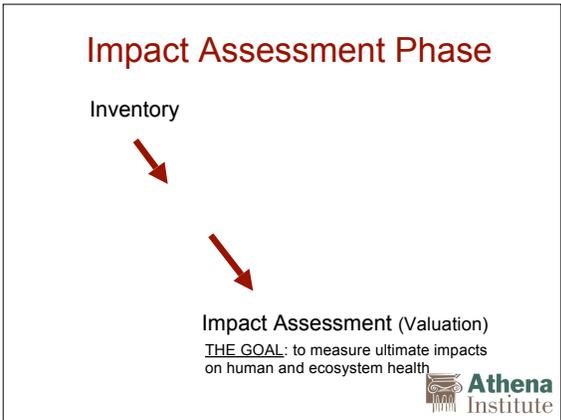
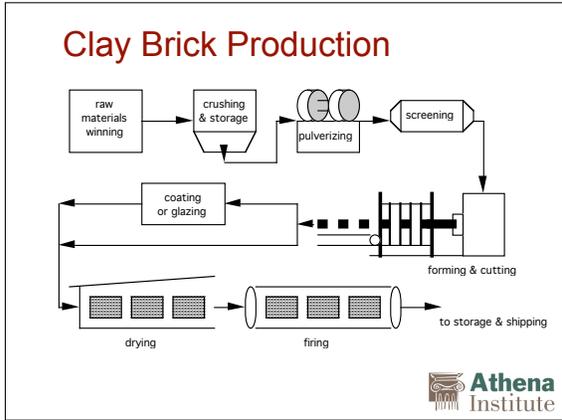
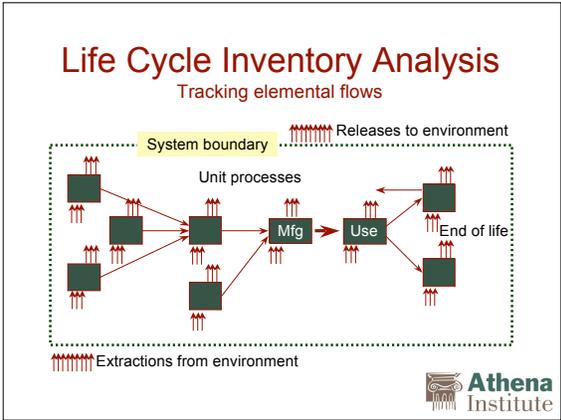
Impact Assessment

Interpretation

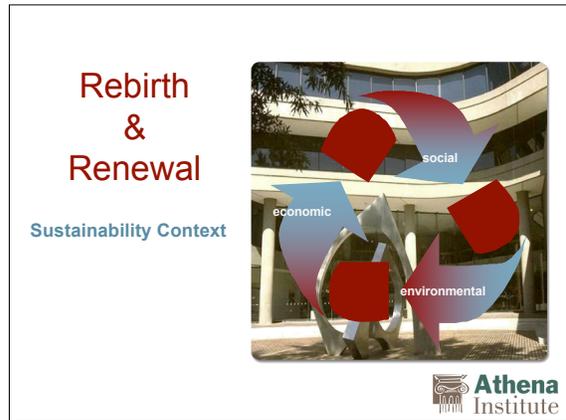
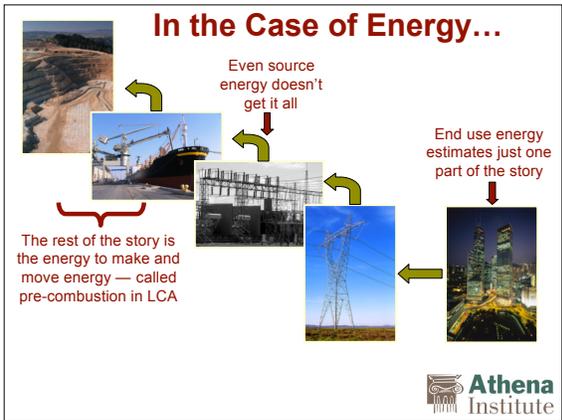
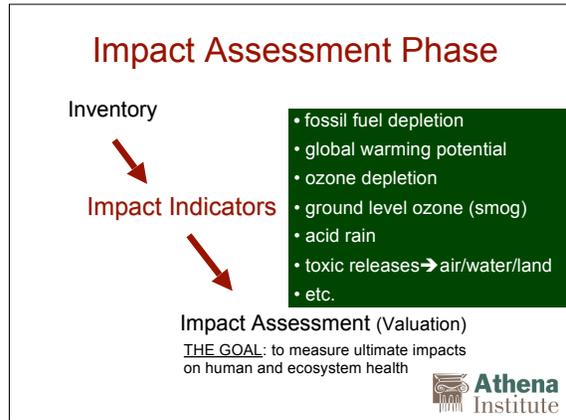
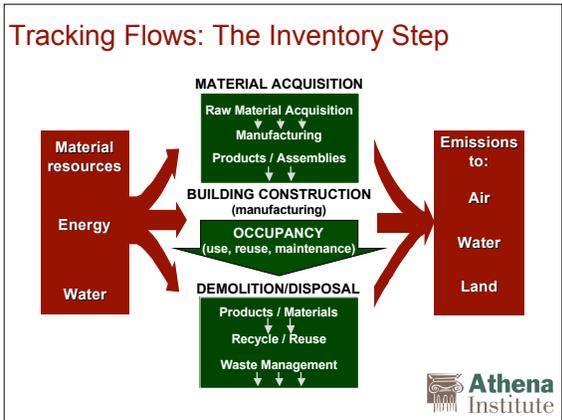
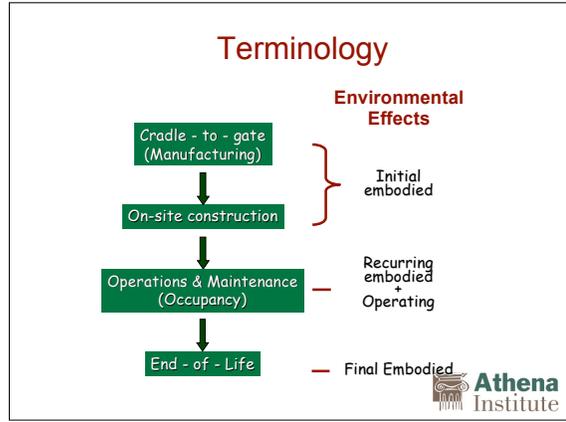
Direct Applications

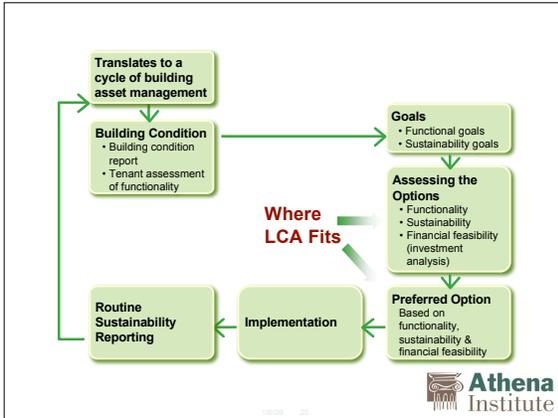
- Product Development & Improvement
- Strategic planning
- Public policy making
- Marketing
- Other

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- ## ISO 21930 on EPDs
- The following environmental information shall be included
- 8.2.2.1 Environmental impacts expressed with the impact categories of LCIA**
- climate change (CO<sub>2</sub>-equivalents)
  - destruction of the stratospheric ozone layer (CFC 11-equivalents)
  - acidification of land and water sources
  - eutrophication
  - formation of tropospheric ozone (photochemical oxidants)
  - depletion of non renewable energy resources
  - depletion of non renewable mineral resources
- Essentially the same list in ISO 21931 (in development) dealing with building assessment
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## Two Basic Approaches

1. Benchmarking to assess comparative effects for scoring or decision analysis
2. Avoided impacts to decide if environmental gains warrant extra costs/uncertainty

- The benchmarking approach is more rigorous
- The avoided impacts approach gives a quicker approximation
  - best for most projects
- Credit reuse by assigning zero manufacturing and transport burdens for reused elements
  - Renovation projects acquire floor space, wall areas, or other assemblies without the use of new materials

## Avoided Impacts Approach

Two scenarios define the range of potential effects

**Minimum Avoided Impacts equal the effects of:**

Demolishing a structural system  
+  
rebuilding a comparable structural system

**Maximum Avoided Impacts equal the effects of:**

Demolishing structure and envelope  
+  
rebuilding a comparable structure and envelope

## Heritage Building Issues

- ◆ Historic or heritage buildings pose special problems
  - » social/cultural significance may limit flexibility
  - » can't benchmark against conventional buildings
- ◆ Decide on the driver: heritage or sustainability
  - » may get both, but should have clear priorities
- ◆ Need to quantify environmental gains in any case
- ◆ Requires appropriate data and tools

## LCA Limitations

**LCA is not the answer to all problems**

E.g., does not readily handle such issues as:

- The timing of releases
- Indoor environmental quality
- Uncertainty and risk related to toxic releases
- Site specific resource extraction effects

## The Uncertainty Factor

**MATERIAL ACQUISITION**

Raw Material Acquisition  
Manufacturing  
Products / Assemblies

}

Occurs over a relatively short time frame (e.g 18-36)

**Focus on relative effects, not absolute numbers!**

(use, reuse, maintenance)

}

**DEMOLITION/DISPOSAL**

Products / Materials  
Recycle / Reuse  
Waste Management

}

Is likely to last many years (50 -100 or more)

**Life Cycle Assessment is not the same as Life Cycle Costing!**

**LCA → physical units** } **Complementary methods**  
**LCC → \$**



### The LCA Tool Kit

**Level 1 — Product Focus**

- 1A - For LCA practitioners**
  - SimaPro, GaBi, Umberto
- 1B - LCA in the background**
  - BEES

**Level 2 — Assembly Focus**

**ATHENA® EcoCalculator**

- Funded by GBI for use in Green Globes™ rating system
- General use version available

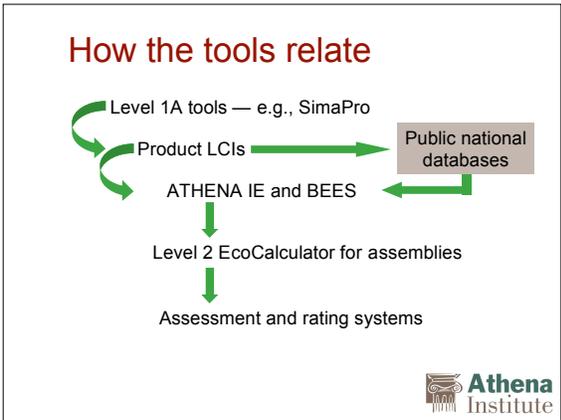
**Level 3 — Whole Building**

**ATHENA® Impact Estimator**

- LCA in the background

**Assessment and Rating Systems**

- Green Globes
- LEED
- Minnesota Design Guidelines
- NAHB Green Home Guidelines

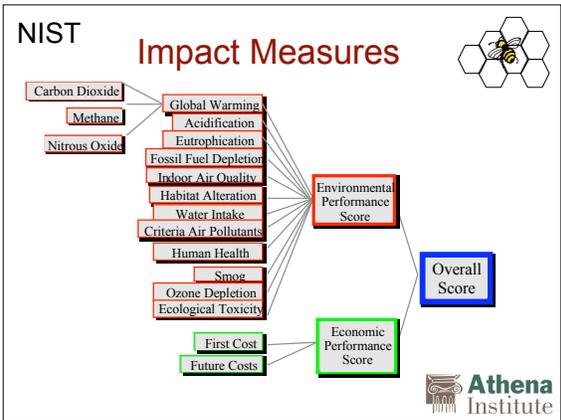



### NIST BEES Model (U.S.)



**LCA-based Level 1 product comparison tool for use at the specification/procurement stage**

- ◆ Provides detailed results for a wide range of impact indicators
- ◆ Uses weighting factors to generate environmental and economic scores
- ◆ Based on Consensus Standards
  - Life-Cycle Costing (ASTM E917)
  - Building Element Classification (ASTM E1557)
  - Environmental Life-Cycle Assessment (ISO 14040)
  - Multiattribute Decision Analysis (ASTM E1765)

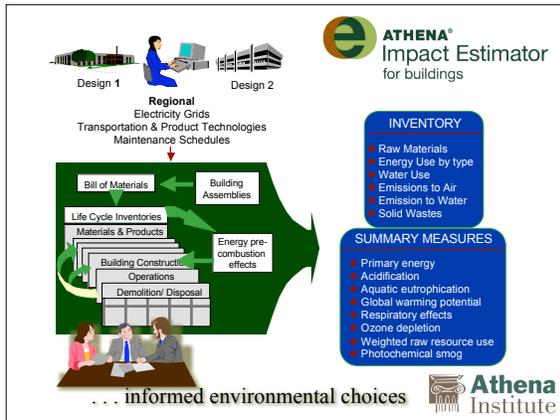




### ATHENA® Impact Estimator for buildings

**LCA-based level 3 whole building tool for use at the conceptual design stage**

- Shows environmental effects of changes in shape, design or material make-up of a building
- Allows designers to optimize operating+embodied energy effects over the complete building life cycle
- A range of indicators without weighting





## Picking the right tool

*fair comparisons!  
design stage?  
type of data?*

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## Functional equivalence . . .

- ◆ Want to compare functionally equivalent products
- ◆ Choice of one product → other choices
- ◆ Differences in O & M implications
- ◆ Misleading comparisons more likely for structure and envelope products

**. . . be cautious about product comparisons**

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## The right data and tool for the task

Generic at conceptual design

Brand specific at procurement stage

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## Mayo School, Yukon

### An Example of Life Cycle Optimization

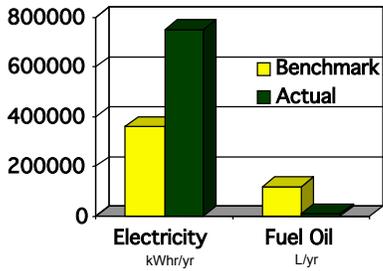
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## Comparative Design Elements

Building Component	Benchmark Design	Actual Design
Gross Floor Area	3220m <sup>2</sup>	3220m <sup>2</sup>
Design Life	80 years	80 years
Primary Structure	Single storey, traditional light frame wood	Single storey, light frame engineered wood
Envelope	2x6 wood studs, 140 mm fibreglass insulation	Double wood stud wall, 280 mm fibreglass
Cladding/fenestration	Wood shiplap siding, aluminum fixed frame windows, Low E argon	Wood shiplap siding, PVC operable frame windows, Low E argon
Roofing system/insulation	Conventional 2-ply Mod. Bit., 100 mm XPS	Conventional 2-ply Mod. Bit., 250 mm cellulose

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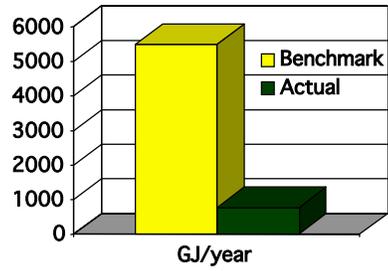
### Direct Operating Energy



Source: S. Pope using CBIP estimating procedure



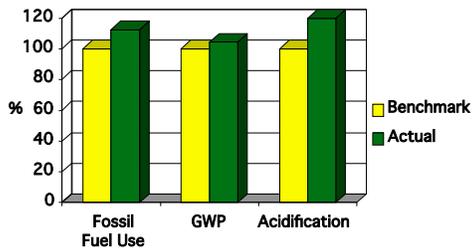
### Fossil Fuel Use (Operations)



Source: Athena™ Environmental Impact Estimator



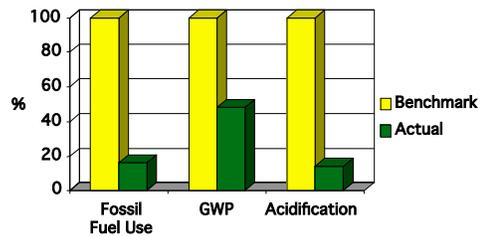
### Life Cycle Embodied Effects



Source: Athena™ Environmental Impact Estimator



### Total Life Cycle Effects: Embodied + Operating



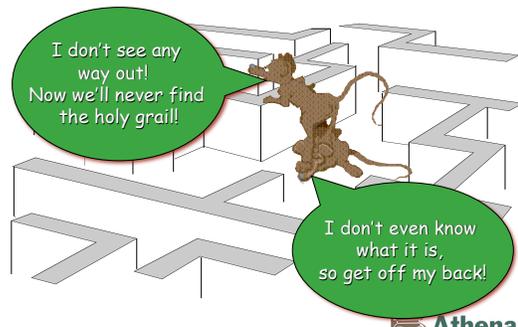
Source: Athena™ Environmental Impact Estimator



### LCA in Assessment, Rating Systems and Standards



### Building Sustainability is Not Simple



## Green Building Standards (all with an LCA component)

- ◆ GBI/ANSI Standard 01-2007P: **Green Building Assessment Protocol for Commercial Buildings**
- ◆ ASTM: **Standard Specification for the Minimum Attributes of a Building that Promotes Sustainability**
- ◆ NAHB: **National Green Building Standard™**
- ◆ ASHRAE/USGBC/IESNA Std 189: **High-Performance Green Buildings**



Could progress over time, from short to long term ideal approach

Option 1 pre-rate assemblies	Option 2 decisions based on LCA	Option 3 whole building LCA
<ul style="list-style-type: none"> <li>✓ LCA in background</li> <li>✓ limited demands on design teams</li> <li>✓ more demands on the rating organization</li> <li>✓ focus on materials</li> <li>✓ simplistic</li> </ul>	<ul style="list-style-type: none"> <li>✓ design teams may use whole building LCA tool(s)</li> <li>✓ could combine embodied and operations effects</li> <li>✓ difficult to verify</li> <li>✓ high educational value</li> </ul>	<ul style="list-style-type: none"> <li>✓ high demands on design teams</li> <li>✓ need benchmarks (onus on rating system orgs.)</li> <li>✓ combine embodied and operations effects</li> <li>✓ supports optimization of envelope vs. operations</li> </ul>



## LCA into LEED (US)

- ◆ September 2004 kick-off meeting
- ◆ Working Groups
  - » recommend how best to implement LCA-based credits
    - goal and scope
    - technical LCA issues
    - weighting of impact measures
- ◆ Goal and scope WG recommended assembly ranking approach
- ◆ Accepted by USGBC board
- ◆ Decision made to use the ATHENA EcoCalculator
  - » Work underway to develop specific LEED credit calculator



## LCA in Green Globes (US)

- ◆ Basically LCA education credits at present
  - » encourage selecting materials with the lowest life cycle environmental burden
  - » but no firm benchmarks or measures
- ◆ Work completed on the assembly ranking approach
  - » GBI funded prototype tool
  - » reviewed by the ANSI committee, BRE, NIST
  - » ATHENA Impact Estimator used for basic LCA of assemblies
  - » points based on performance relative to benchmarks for each of several measures (e.g., global warming potential)
- ◆ Included in public comment process under ANSI



 **ATHENA®**  
Impact Estimator  
for buildings



 **ATHENA®**  
EcoCalculator  
for assemblies



 **ATHENA®**  
EcoCalculator  
for assemblies

LCA-based tool for evaluating and comparing the environmental effects of assemblies

- Currently includes about 400 assemblies
- Uses mid-point impact indicators
- In rating system, credit better than average performance
  - ✓ for each indicator within an assembly category
- Generic version, without credit links, is freely available
  - ✓ various regional versions



## ATHENA<sup>®</sup> EcoCalculator for assemblies

# Simple to Use

results in spreadsheet form

Users only fill in yellow cells

Instant answers

## The First Worksheet

**Welcome to the Athena EcoCalculator**

This easy-to-use interface is designed to calculate the environmental impacts associated with the assemblies used in your building. The environmental impact measures are:

- Primary Energy** - The amount of energy used in the production, processing, transportation, installation, and disposal of each material, measured in terms of its weight.
- Global Warming Potential** - The amount of global warming caused by the emissions, primarily, transportation, installation, and disposal of each material, measured in terms of its weight and Global Warming Potential (GWP) factor.
- Regional Resource Use** - The amount of resources used in the production, processing, transportation, installation, and disposal of each material, measured in terms of its weight and regional resource use factor.
- Water Pollution** - The amount of water pollution caused by the emissions, primarily, transportation, installation, and disposal of each material, measured in terms of its weight and water pollution factor.
- Air Pollution** - The amount of air pollution caused by the emissions, primarily, transportation, installation, and disposal of each material, measured in terms of its weight and air pollution factor.

To use the calculator:

- Click on the desired assembly tab at the bottom of the spreadsheet.
- In the yellow cells, enter the square footage of each type of assembly that you plan to use in your building.
- The table at the top of the page shows the total impacts of each assembly type, as well as the entire building.

For further information go to:  
<http://www.athenaeco.com/athenaeco/>

- Brief definitions of the measures
- A quick user's guide

## Go to the first assembly tab...

**A. COLUMNS AND BEAMS**  
ATHENA ASSEMBLY EVALUATION TOOL v2.3—MINNEAPOLIS high-rise building

Two main sections:

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

## Identifying the cells...

- Yellow cells are for entering the amount of an assembly in ft<sup>2</sup> or m<sup>2</sup>
- Blue cells show the % of the category total accounted for by a selected assembly
- Column headings name the impact indicator
- Grey cells right below show the average performance for assemblies in this category
- Green cells show the impacts per ft<sup>2</sup> or m<sup>2</sup>

## Some categories have a lot of assemblies...

Exterior Walls

Roofs

2,941 tons CO<sub>2</sub>e  
cradle to grave  
60 year life

Open web steel joist with steel decking system and concrete topping, gypsum board, latex paint

EcoCalc v2.3 Minneapolis High-Rise.xls

**ATHENA® EcoCalculator for assemblies**

**1,156 tons CO<sub>2</sub>e cradle to grave 60 year life**

**ATHENA ASSEMBLY EVALUATION TOOL**  
IN THE YELLOW CELLS BELOW, ENTER THE AMOUNT OF SQFT

**High-rise building (AS USED IN YOUR BUILDING)**

Assembly	Area (sq ft)	Primary Energy (kWh/ft²)	CO <sub>2</sub> e (lb/ft²)	Embodied Energy (kWh/ft²)	CO <sub>2</sub> e (lb/ft²)	Embodied Energy (kWh/ft²)	CO <sub>2</sub> e (lb/ft²)
17 CIP Concrete, EIFS, latex paint	0.48	0.17	10.04	135.17	1.33	0.0077	
18 CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint	20.48	0.13	25.35	147.35	1.94	0.0040	
19 Rigid insulation, vapor barrier, gypsum board, latex paint	21.94	0.22	24.44	143.12	3.45	0.0098	
20 CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint	0.48	0.17	10.04	135.17	1.33	0.0077	
21 Rigid insulation, vapor barrier, gypsum board, latex paint	0.14	0.14	23.81	128.42	1.98	0.0014	
22 CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint	0.11	0.11	20.98	113.95	1.74	0.0027	
23 Rigid insulation, vapor barrier, gypsum board, latex paint	0.14	0.14	26.31	151.02	2.13	0.0040	
24 CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint	21.04	0.11	19.35	107.94	1.43	0.0027	
25 Rigid insulation, vapor barrier, gypsum board, latex paint	0.11	0.11	20.75	115.31	1.73	0.0022	
26 CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint	0.13	0.13	33.40	116.76	1.89	0.0023	
27 Rigid insulation, vapor barrier, gypsum board, latex paint	0.17	0.17	22.38	49.63	2.48	0.0113	
28 Rigid insulation, vapor barrier, gypsum board, latex paint	13.06	0.16	21.53	49.05	2.40	0.0110	
29 Rigid insulation, vapor barrier, gypsum board, latex paint	13.27	0.18	32.82	29.34	3.23	0.0064	

**Annotations:**

- Assembly 17: CIP Concrete, brick cladding, rigid insulation, vapor barrier, gypsum board, latex paint
- Assembly 26: CIP Concrete, rigid insulation, vapor barrier, gypsum board, latex paint

**ATHENA® EcoCalculator Whole Building Context for assemblies**

- Results on a per unit area basis (e.g., per ft<sup>2</sup>)
  - Estimates based on much larger areas, e.g., 1000 linear feet of wall
- Components and loadings typical for central U.S.
- Owner occupied office buildings, 60-year lifespan
  - Affects maintenance and repair/replacement schedules
- Other specific assumptions:
  - Window to wall ratio
  - Concrete strength and fly ash content
  - Gypsum board type and thickness with latex paint
  - Live load for all intermediate floors, columns & beams, roofs
  - Bay sizes and column heights
  - External wall thicknesses depending on construction system
  - Stud size/strength and spacing
  - Sheathing and decking materials

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**EcoCalc Versions**

- Current
  - USA averages — colder climate, hi insulation
  - USA averages — warmer, low insulation
  - 8 Canadian regions
    - Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, Québec, Halifax
  - 4 US regions
    - Atlanta, Minneapolis, Orlando, Pittsburgh
- Coming 2008/09
  - Los Angeles, New York, Phoenix, Seattle

**All with hi-rise and low-rise versions**

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**WELCOME**

At the Athena Institute, we believe that better information and tools are critical to achieving a sustainable built environment. We also believe that a life cycle assessment (LCA) approach to sustainability is the only way to create a level playing field for the vast array of building materials in use.

From our Canadian offices, and through our US offices, Athena Institute International, the not-for-profit Athena organization undertakes and directs innovative

**www.athenaSMI.org**

**NEW! Now downloading Version 2.3 of the FREE EcoCalculator**

Now Included: Ontario, British Columbia, Quebec, Ontario, Quebec, Ontario, Toronto, Winnipeg

Please check the previous version of the EcoCalculator for more information.

**ATHENA Impact Estimator for energy**

**ATHENA EcoCalculator for assemblies**

Allows users to evaluate whole buildings and assemblies based on internationally recognized LCA methodology

Provides instant LCA results for more than 400 common building assemblies (list of changes)

Click the images above for more information.