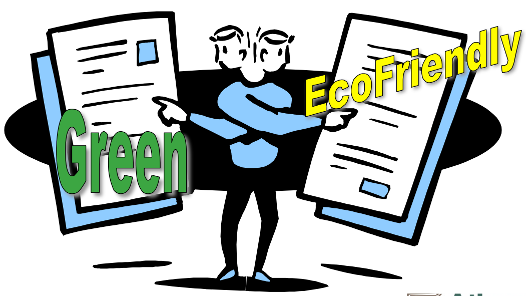
A Practical Tool for Building Life Cycle Assessment:

Wayne Trusty
Ecobuild Fall, December 2008



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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

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LEED® Credit Structure

Intents — Performance oriented

Requirements — Prescriptive

} Mismatch?

Submittals

Potential Technologies and strategies

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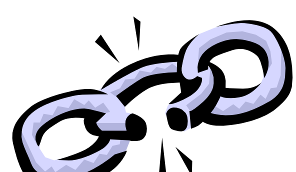
Materials and resources credits are especially weak in rating systems . . .



. . . and very controversial

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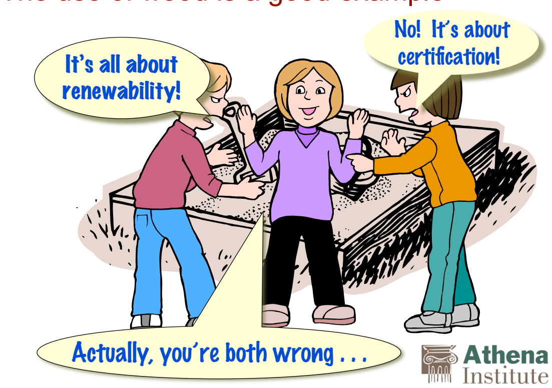
The use of wood is a good example



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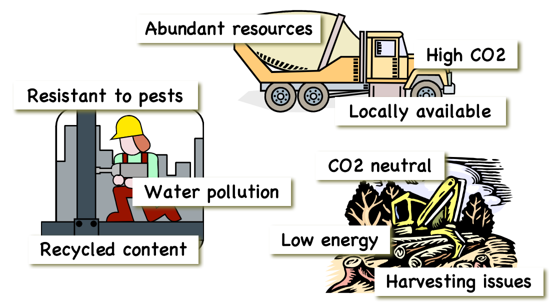
Materials selection is all about trade-offs!



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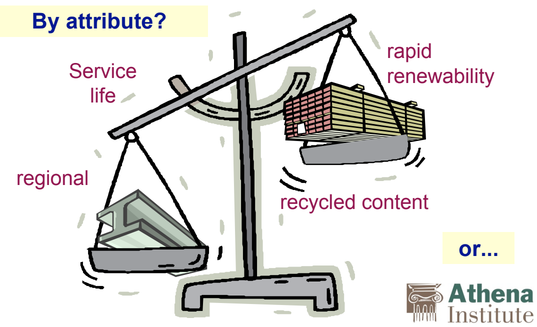
Weighing material options

By attribute?



or…

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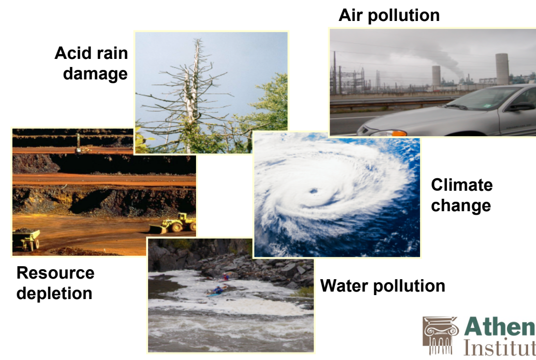
By environmental performance ➔ LCA



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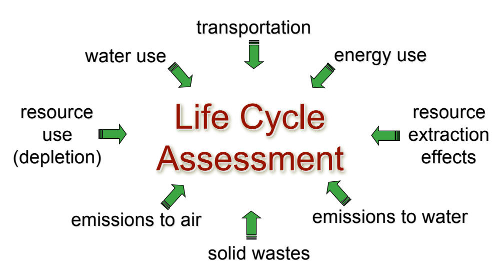

A methodology for assessing the environmental performance of a product over its full life cycle

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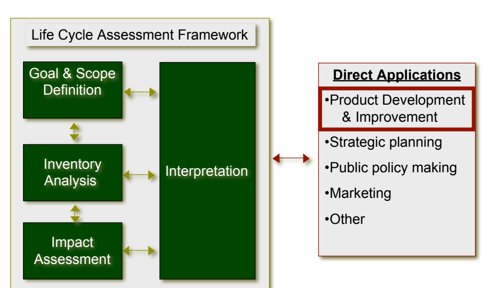
The ISO 14040 Framework



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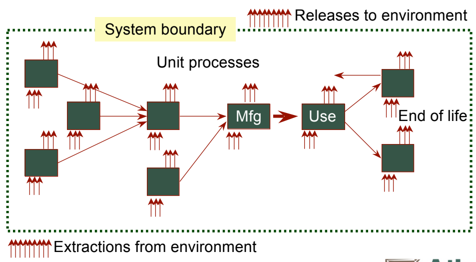
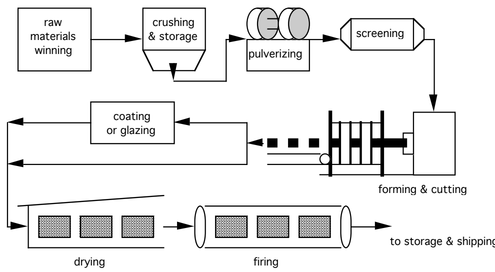
Life Cycle Inventory Analysis

Tracking elemental flows



Clay Brick Production



Impact Assessment Phase

Inventory

Impact Assessment (Valuation)

THE GOAL: to measure ultimate impacts on human and ecosystem health

From LCI to LCIA

LCI

classify in terms of potential to create impacts

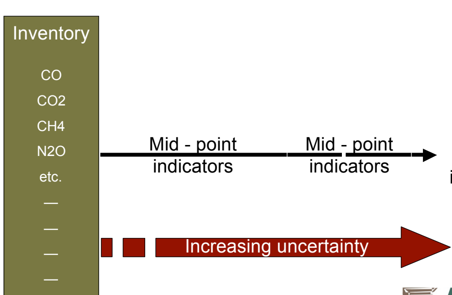
apply characterization factors

MID-POINT INDICATORS

valuation

END-POINT INDICATORS

Locating mid-points?



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_2-equivalents)
— destruction of the stratospheric ozone layer (CFC 11-eqvivalents)
— 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

Terminology

Environmental Effects

- Cradle - to - gate (Manufacturing) → On-site construction: Initial embodied
- Operations & Maintenance (Occupancy): Recurring embodied + Operating
- End - of - Life: Final Embodied

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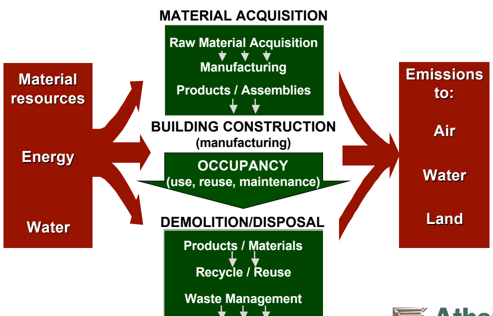
Tracking Flows: The Inventory Step



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Impact Assessment Phase

Inventory

Impact Indicators

- fossil fuel depletion
- global warming potential
- ozone depletion
- ground level ozone (smog)
- acid rain
- toxic releases→air/water/land
- etc.

Impact Assessment (Valuation)

THE GOAL: to measure ultimate impacts on human and ecosystem health

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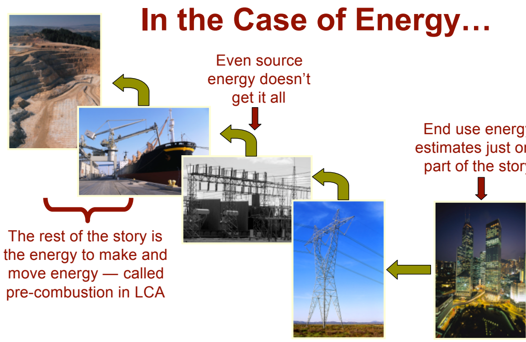
In the Case of Energy…



Even source energy doesn't get it all

End use energy estimates just one part of the story

The rest of the story is the energy to make and move energy — called pre-combustion in LCA

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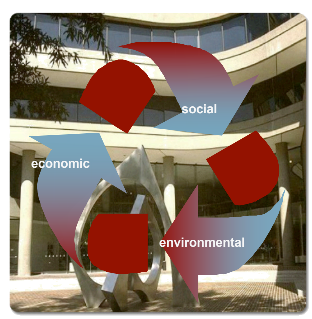
Rebirth & Renewal

Sustainability Context



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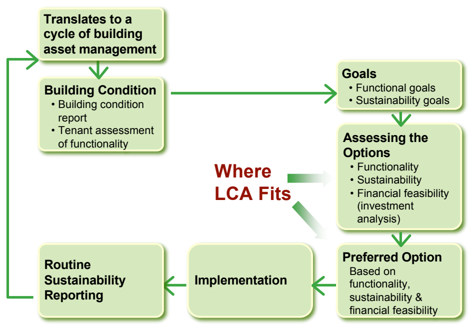


Two Basic Approaches

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:	Maximum Avoided Impacts equal the effects of:
Demolishing a structural system + rebuilding a comparable structural system	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

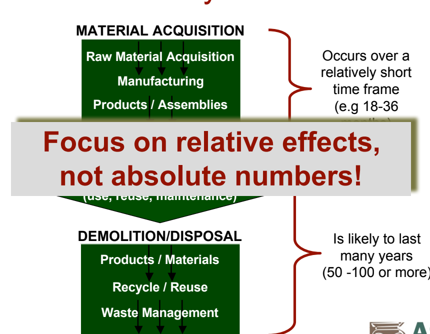
LCA Limitations

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



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

LCA ➔ physical units

LCC ➔ $

Complementary methods

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

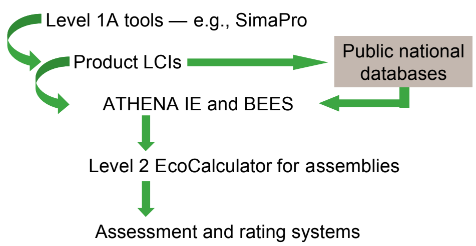
ATHENA® EcoCalculator
- Funded by GBI for use in Green Globes™ rating system
- General use version available

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

How the tools relate



NIST

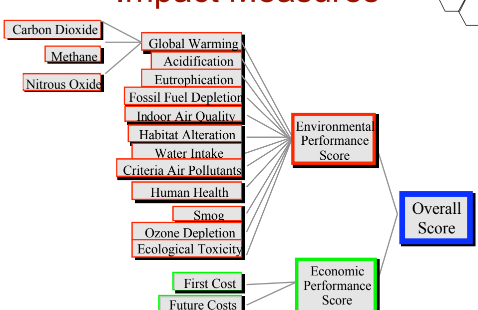
BEES Model (U.S.)

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)

NIST

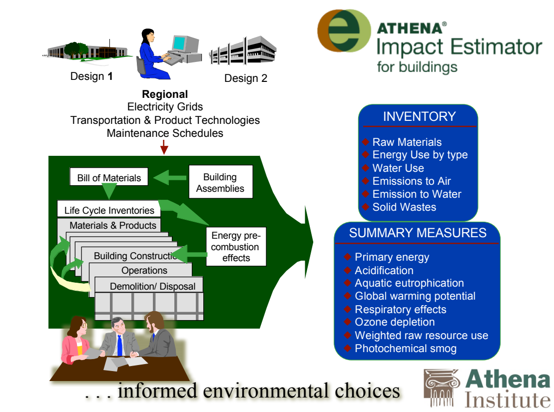
Impact Measures



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



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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

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Brand specific at procurement stage

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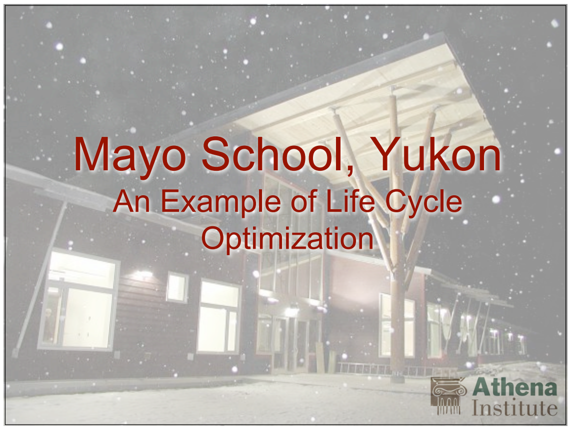

Comparative Design Elements

Building Component	Benchmark Design	Actual Design
Gross Floor Area	3220m^2	3220m^2
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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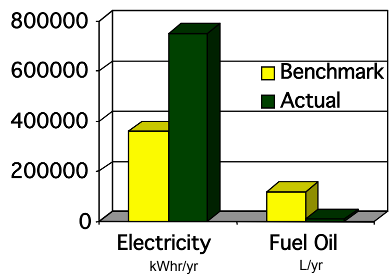
Direct Operating Energy



Source: S. Pope using CBIP estimating procedure

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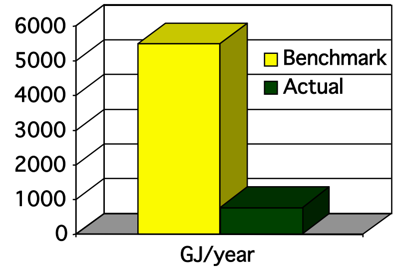
Fossil Fuel Use (Operations)



Source: Athena™ Environmental Impact Estimator

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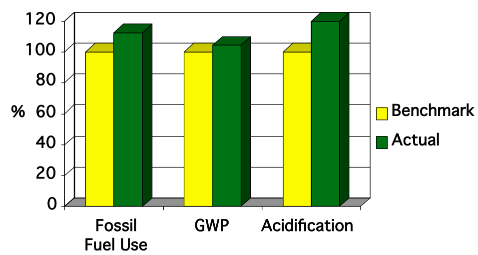
Life Cycle Embodied Effects



Source: Athena™ Environmental Impact Estimator

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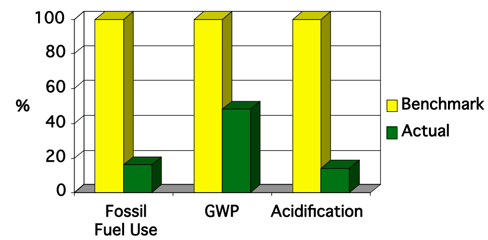
Total Life Cycle Effects: Embodied + Operating



Source: Athena™ Environmental Impact Estimator

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LCA in Assessment, Rating Systems and Standards

LEED — Leadership in Energy & Environmental Design

NAHB Model Green Home Building Guidelines

Green Globes

Buildings, Benchmarks & Beyond — The State of Minnesota Sustainable Building Guidelines

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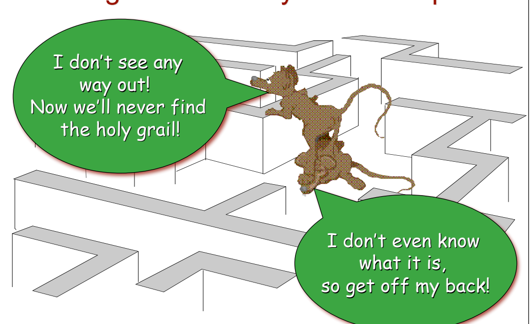
Building Sustainability is Not Simple



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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
- ✓LCA in background
- ✓limited demands on design teams
- ✓more demands on the rating organization
- ✓focus on materials
- ✓simplistic

Option 2
decisions based on LCA
- ✓design teams may use whole building LCA tool(s)
- ✓could combine embodied and operations effects
- ✓difficult to verify
- ✓high educational value

Option 3
whole building LCA
- ✓high demands on design teams
- ✓need benchmarks (onus on rating system orgs.)
- ✓combine embodied and operations effects
- ✓supports optimization of envelope vs. operations

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

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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

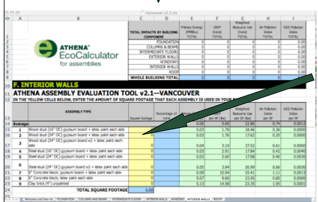
ATHENA® EcoCalculator for assemblies

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

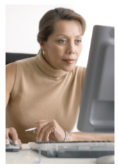
- Currently includes about 400 assemblies
- Uses mid-point impact indicators
- In rating system, credit better than average performance
  - ✓ for each indicator within an assembly category
- Generic version, without credit links, is freely available
  - ✓ various regional versions

Simple to Use

results in spreadsheet form



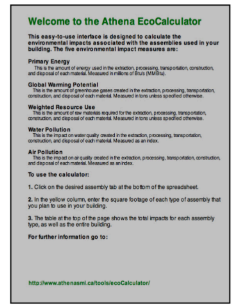
Users only fill in yellow cells



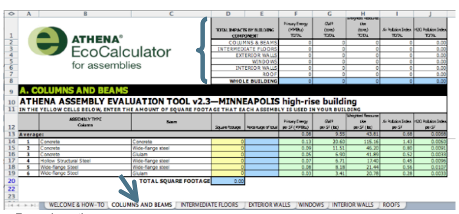
Instant answers

The First Worksheet

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



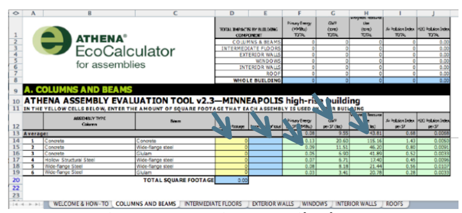
Go to the first assembly tab…



Two main sections:

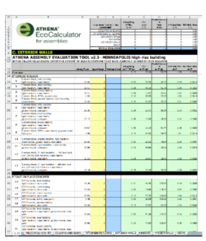
1. The top table shows the aggregate results as assembly are added and appears on every sheet
2. The bottom table lists all the assemblies in the selected category and shows the results by assembly

Identifying the cells…

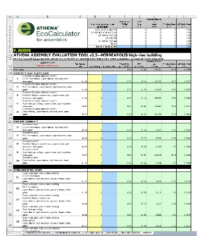


1. Yellow cells are for entering the amount of an assembly in ft² or m²
2. Blue cells show the % of the category total accounted for by a selected assembly
3. Column headings name the impact indicator
4. Gray cells right below show the average performance for assemblies in this category
5. Green cells show the impacts per ft² or m²

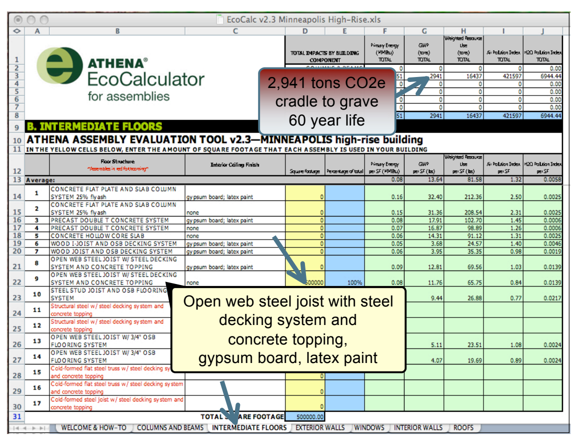
Some categories have a lot of assemblies…

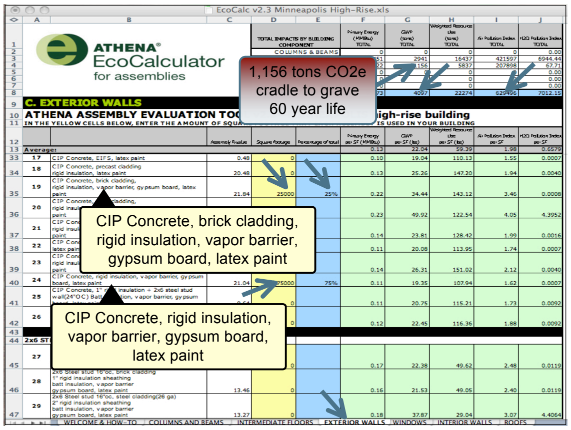


Exterior Walls



Roofs





ATHENA EcoCalculator for assemblies

Whole Building Context

- Results on a per unit area basis (e.g., per ft^2)
  - ✓ 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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