WHOLE BUILDING LIFE CYCLE ASSESSMENT FOR THE B3 GUIDELINES

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Center for Sustainable Building Research

June 7, 2022

WEBINAR LOGISTICS & EDUCATION CREDITS

LOGISTICS

- A recording of this session will be posted on our training page at b3mn.org
- Architects needing AIA credit – please send your AIA # in the chat
- Others needing credit - you will be emailed a course certificate of completion
- Attendees will be muted until the end

Please send questions in the chat. We'll keep an eye out during each topic and leave time at the end of each to address questions.

WEBINAR LOGISTICS & EDUCATION CREDITS

LEARNING OBJECTIVES – TRAINING SESSION 1

1. Understand the purpose and define the meaning and scope of whole building life cycle analysis.
2. Understand the relative importance of embodied impacts in a building's life cycle.
3. Describe how the results of an LCA are measured and compared across different buildings.
4. Identify the currently available software tools for completing a whole-building LCA.
5. Understand the submission requirements and various compliance paths of B3 Guideline M.1A.

TODAY'S AGENDA

1. Overview of LCA
2. Whole Building LCA Tools
3. LCA Guideline M1A requirements
4. How to achieve compliance (workflow and examples)

Coming up on Wednesday: In-class exercises using Athena. Please come prepared with Athena Impact Estimator (free) installed on your computer.

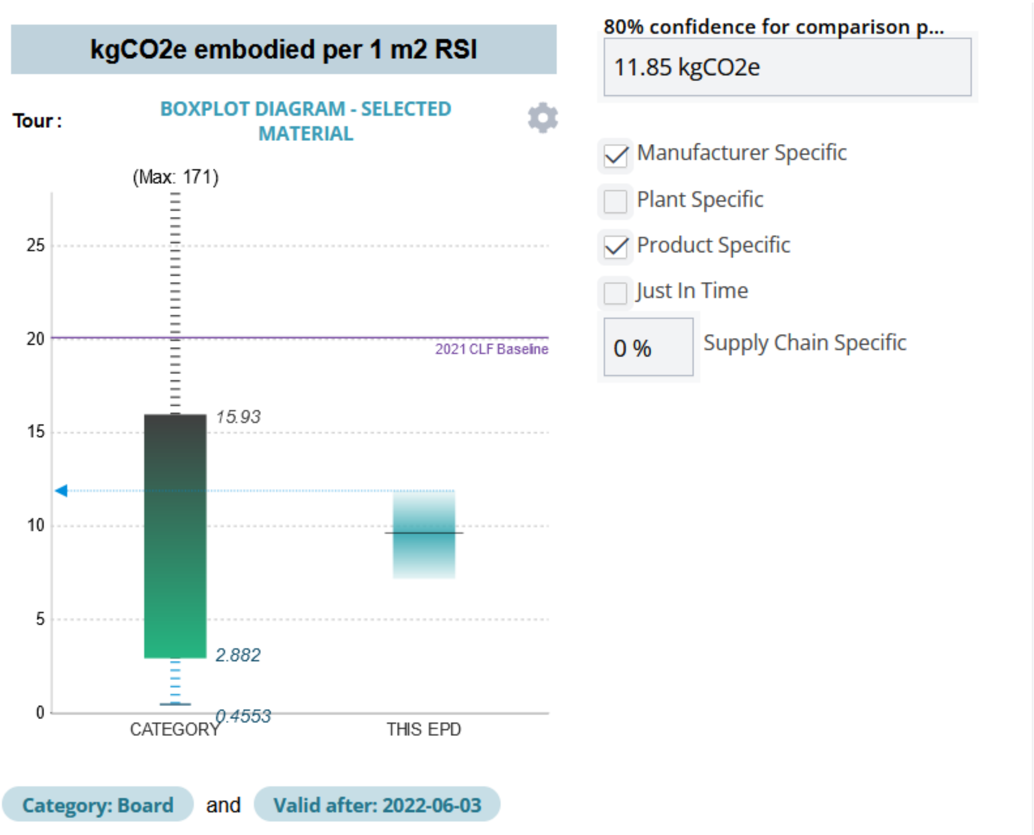
NOT EcoCalculator

OVERVIEW OF LCA

LCA LIMITATIONS

LCA may be most useful for *relative* impacts – for making decisions and comparing alternatives, ie – is option X better than option Y and by how much?

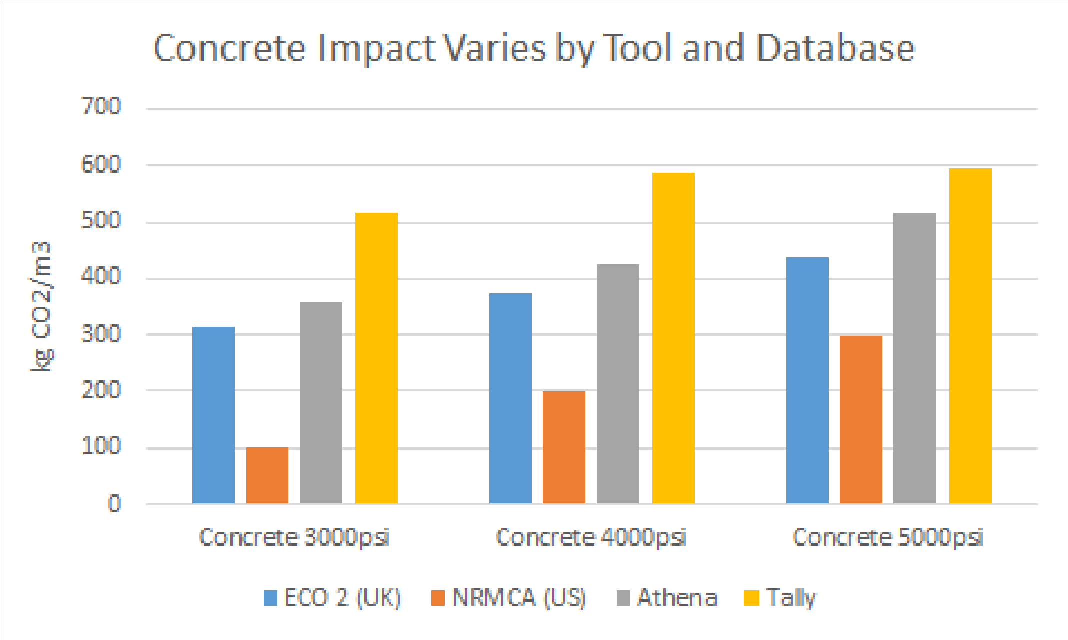
Less useful for determining *absolute* values. LCA practitioners have difficulty developing hard targets and benchmarks for building types. That's why a reference building of the same design is typically used for comparison.



LCA LIMITATIONS

Environmental impacts vary significantly from tool to tool and compared to standard benchmarks. This is due to variations in the material data sets – geographically where the data is coming from and how it is being calculated.

Comparison or tracking of results using two different tools or data sets is not valid in most cases.



LCA LIMITATIONS

WHY DO IMPACTS VARY SO MUCH?

LCA LIMITATIONS

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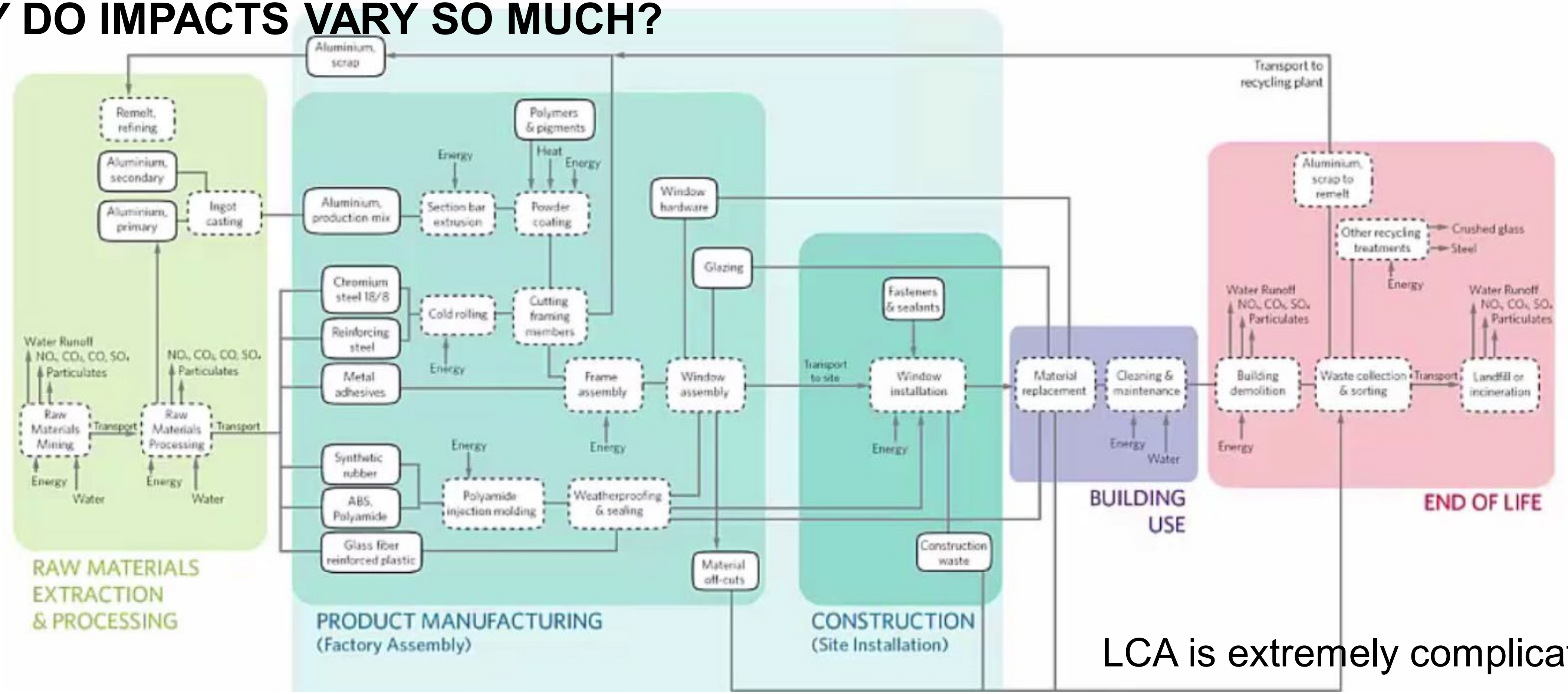


LCA is extremely complicated!

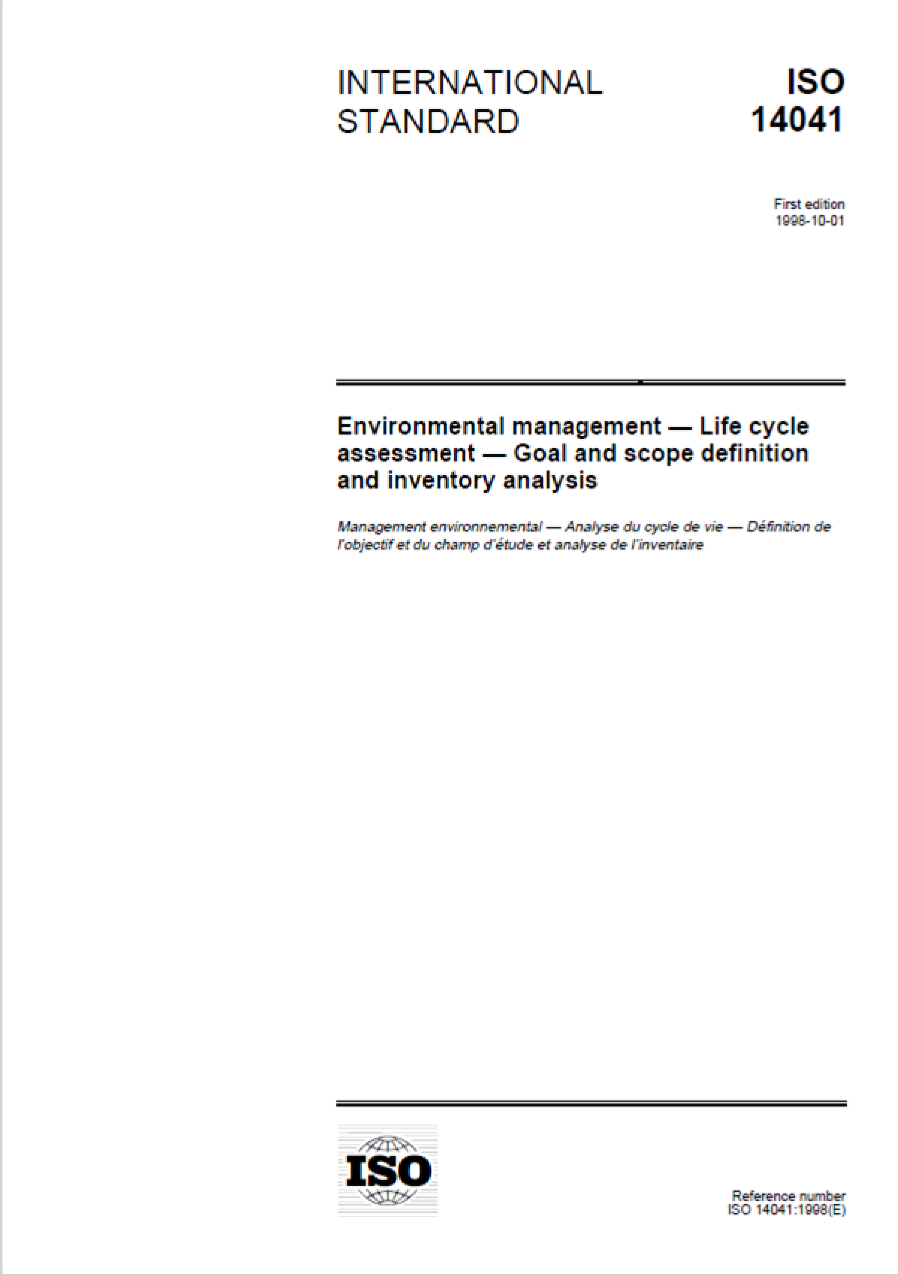
PROTOCOLS

HOW IS AN LCA DONE CONSISTENTLY?

ISO 14040 SERIES | Defines the mandatory elements of an LCA. How to...

- Set scope/boundaries
- Identify impact categories to be used
- Classify LCI results into impact categories
- Translate LCI results into environmental impact results

TRACI 2 | Methodology developed by EPA to translate LCI results into indicators (environmental impacts)



INTERNATIONAL STANDARD

ISO 14041

First edition
1998-10-01

Environmental management — Life cycle assessment — Goal and scope definition and inventory analysis

Management environnemental — Analyse du cycle de vie — Définition de l'objectif et du champ d'étude et analyse de l'inventaire

ISO

Reference number
ISO 14041:1998(E)

LCI VS. LCA

Life Cycle Inventory (LCI) - Identifies and quantifies all the *specific* chemicals or molecules (such as CFCs or C6H12) that are emitted during the relevant processes, as well as the raw material and energy inputs for these processes. This forms the data collection portion of the larger LCA process

Life Cycle Analysis (LCA) - Groups these emissions into categories and calculates environmental or human health impacts using a set of representative "indicator" molecules (CO2 for global warming, SO2 for acidification, O3 for smog, etc)

LCA RESULTS – “INDICATORS”

LCA results (environmental/human health impacts) are categorized by impact “indicators”. Taken together, the indicators are supposed to represent a comprehensive measure of impacts on the environment. Below, “e” stands for “equivalent”. Example set (there are more):

- Global warming potential (kg of CO_2e)
- Acidification potential (kg SO_2e)
- Human Health (particulates) (kg $PM_{2.5}e$)
- Eutrophication potential (kg N-e)
- Ozone Depletion potential (kg CFC-11-e)
- Smog potential (kg O_3e)
- Total primary energy

LCA RESULTS – “INDICATORS”

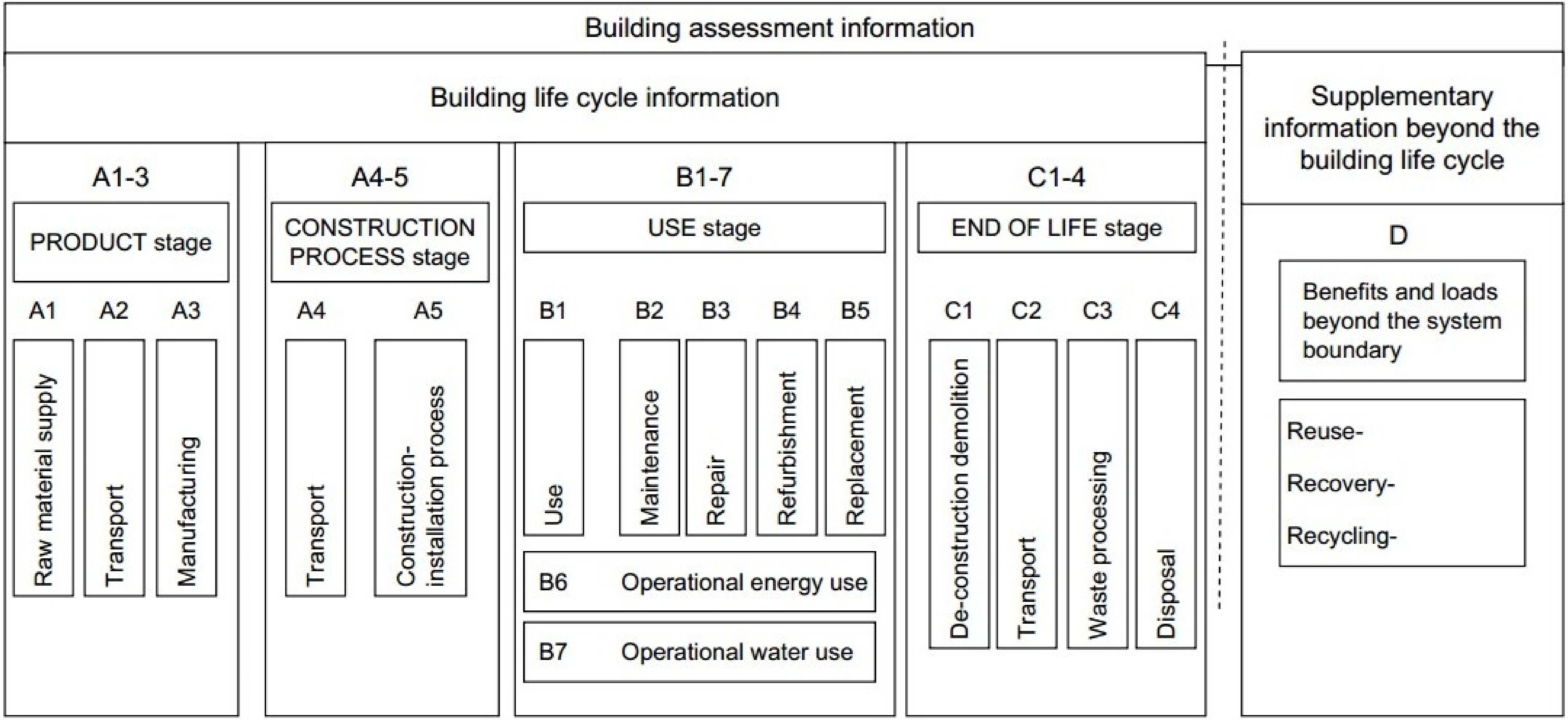
BENEFITS:

Use of indicators allows comparison of two products/materials that might result in the use or emission of very different sets of chemicals. You must have a common unit of measurement - which is the indicator molecule - to compare effects. However...

DRAWBACKS:

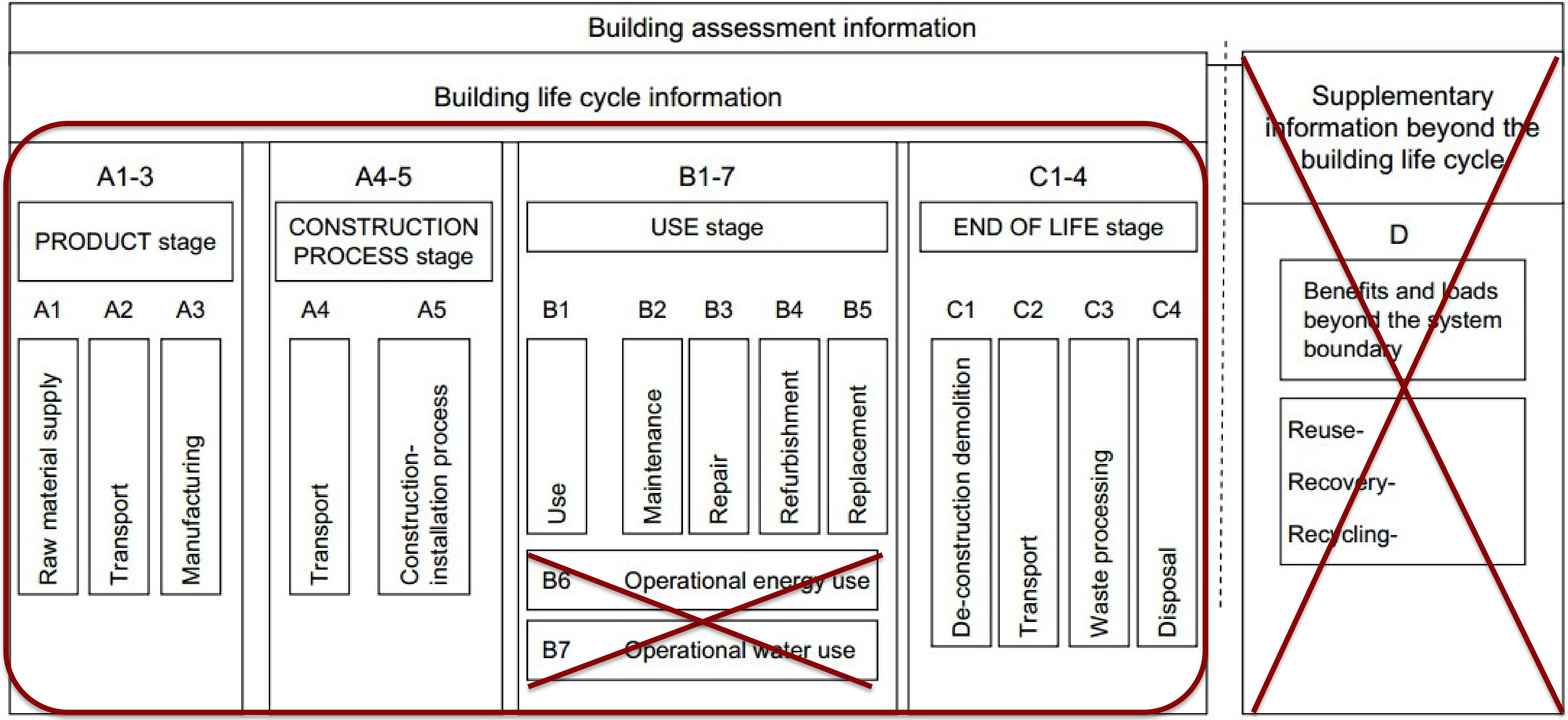
Indicators are just that. They “indicate” potential effects -- It is nearly impossible to definitively correlate emissions of specific chemicals to negative impacts on the environment or human health.

Typically, LCA falls especially short on human health impacts and habitat loss.



From EN 15978 - diagram from Construction sector views on low carbon building Materials, Jannik Giesekam, John R. Barrett & Peter Taylor

PHASES OF A TYPICAL BUILDING PRODUCT LCA



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PHASES OF A TYPICAL LCA

A NOTE ON BUILDING LIFE SPAN

Lifespan plays an important role in the results. Some materials look better than others considering different lifespans. However, the lifespan of a building can only be estimated.

EXAMPLE

Retail/commercial structures are often built of steel and concrete – more “durable” materials, but are also some of the shortest-lived. Houses and churches are often maintained to last for long periods of time, despite being made of wood.

Image credit – Ski Safari

Image credit – Montreal Gazette

A NOTE ON BUILDING LIFE SPAN

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Image credit – Ski Safari

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WHOLE BUILDING LCA TOOLS

TOOLS FOR LCA

SimaPRO, GaBi	• For LCA specialists and practitioners. • Requires knowledge of industrial processes. Specialists are hired by a company to perform an LCA on a particular product/material (such as a Huber OSB).
BEES, EcoConcept, EC3	• For consumers and designers. • Contains ready-made product-based LCA results, useful for finishing interiors, etc. Theoretically, results can be built up to evaluate whole assemblies.
Tally, One Click LCA, EC3, Athena Impact Estimator	• For architects and designers. • Can be used for whole building LCA analysis.

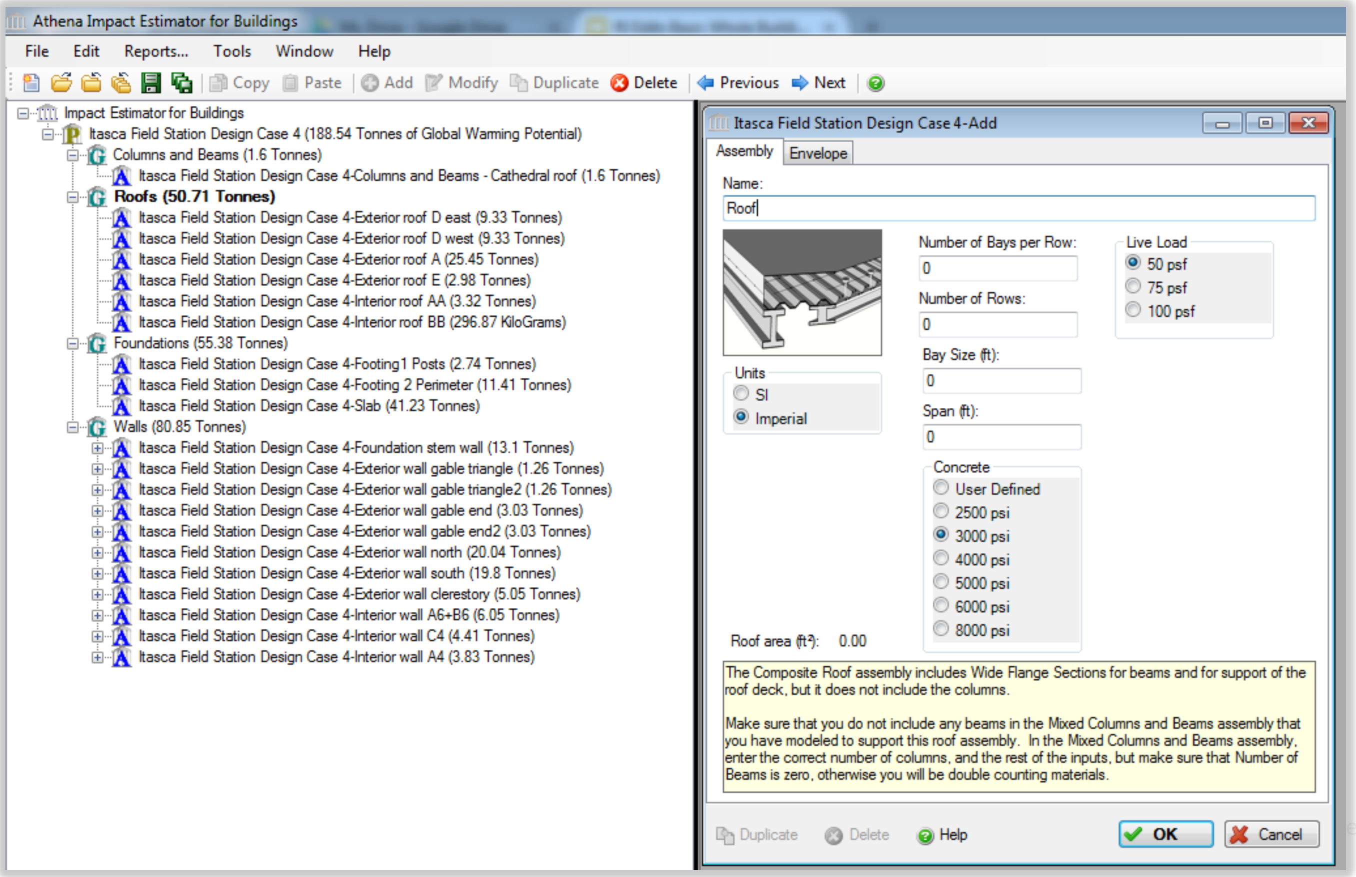
WHOLE-BUILDING LCA

- Attempts to quantify embodied impacts from the materials and process used to construct, maintain, and demolish the building.
- Typically, whole-building LCA includes: structure, enclosure, foundation, floors, maybe interior walls and maybe finishes
- Typically does not include: fixtures, furnishings, and equipment (plumbing, HVAC equipment, furniture, lighting, etc)
- May also include operational impacts (such energy use and associated emissions)

Image credit - ids-center.com

ATHENA IMPACT ESTIMATOR (IE)

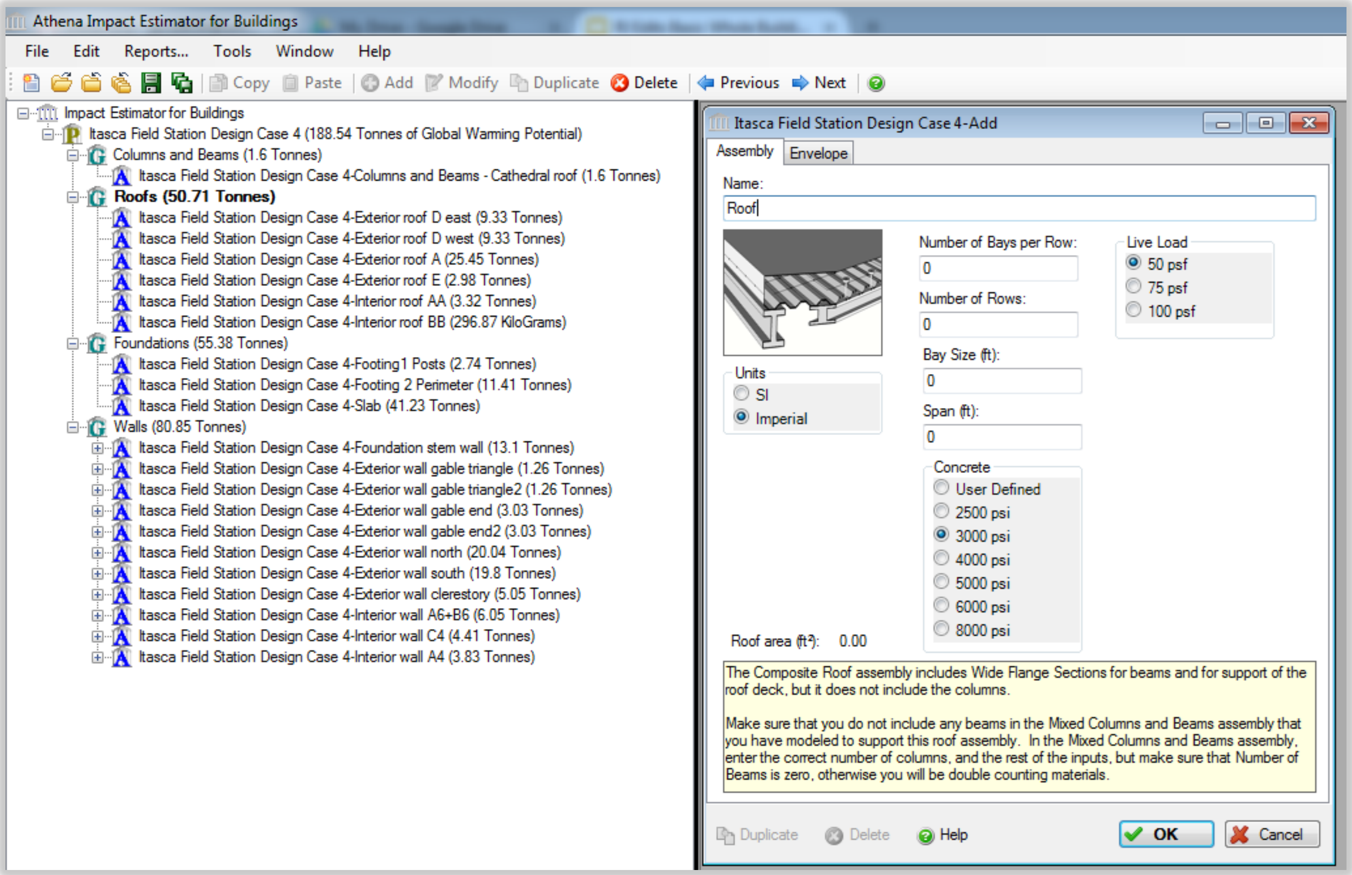
- Developed by Athena Institute
- Tree-based data structure based on area take-offs for building systems, no visual models
- Material impacts taken from USLCI Database - NREL database plus proprietary information developed by the Athena Institute with Morrison Hershfield



PROS & CONS OF ATHENA

PROS

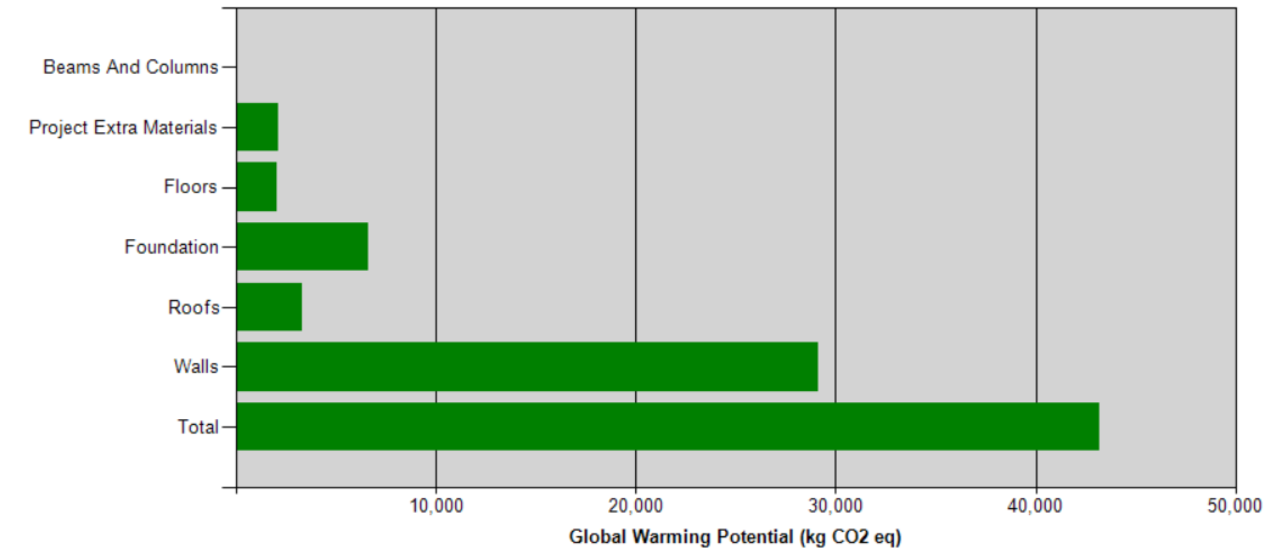
- Easy to use and navigate, and free!
- Basic building models can be generated quickly before complete plans are developed. Common assemblies (stud wall) are available
- Allows for comparisons early in the design process when changes can be made more easily and are more impactful
- Material database (USLCI Database) is based on North American industry and adjusted for location.



PROS & CONS OF ATHENA

CONS

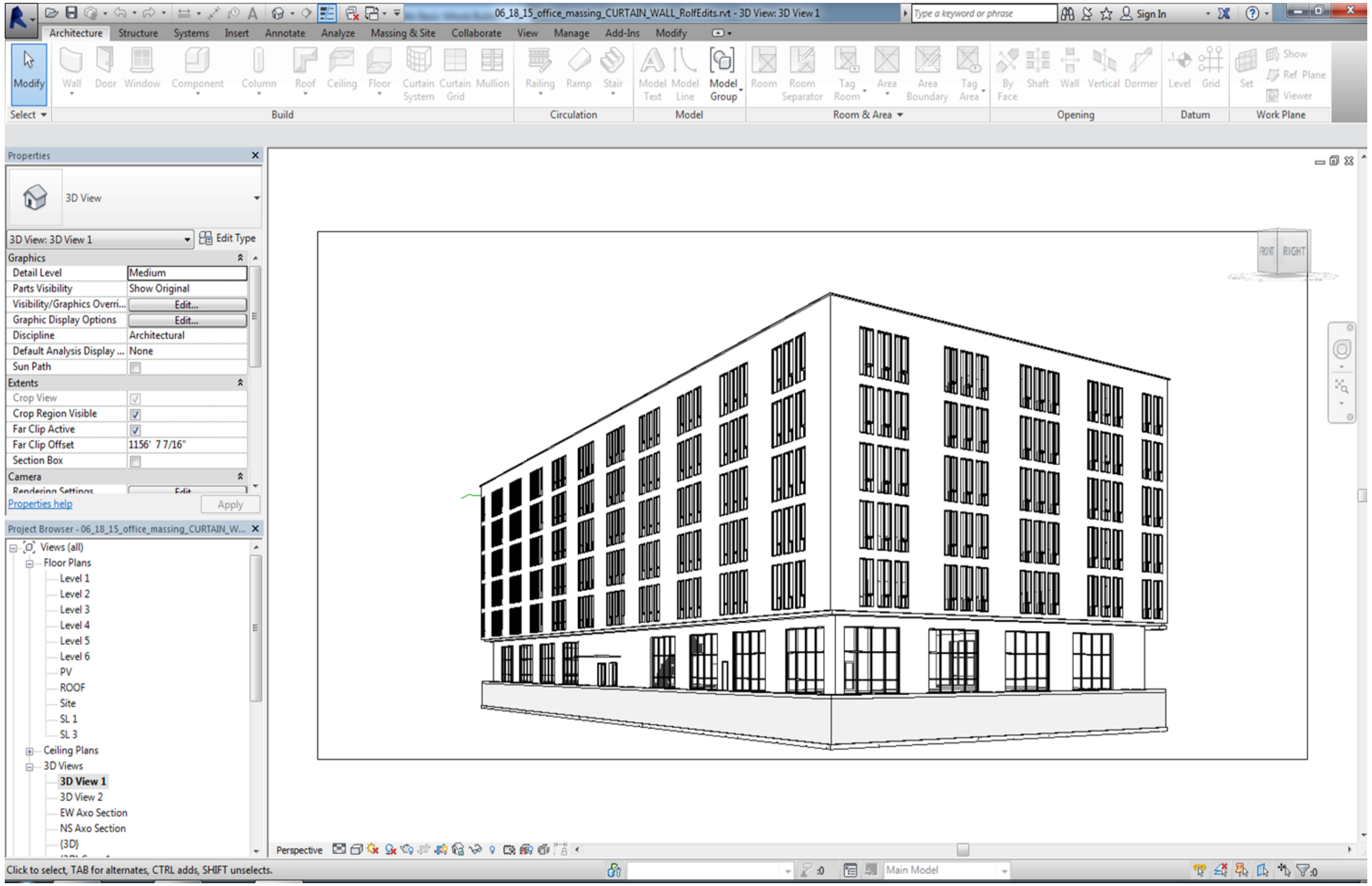
- No easy method to import material and takeoff data from BIM models
- No visual confirmation of modeled building components
- Database is a mix of public and proprietary information - consistency may suffer
- Reports and graphs are not presentation-ready
- Data sources and assumptions not always clearly documented



Assembly Group	Unit	Total
Beams And Columns	kg CO2 eq	0.00E+00
Floors	kg CO2 eq	2.02E+03
Foundation	kg CO2 eq	6.61E+03
Project Extra Materials	kg CO2 eq	2.12E+03
Roofs	kg CO2 eq	3.34E+03
Walls	kg CO2 eq	2.91E+04
Total	**kg CO2 eq**	**4.32E+04**

WHOLE BUILDING LCA TOOLS - TALLY

- Developed by Kieran Timberlake, moving to Building Transparency in 2021
- Uses Revit building model for takeoffs, quantities, and material information
- Materials not defined in Revit can be defined later in Tally
- Material impacts taken from GaBi database and customized for North American market

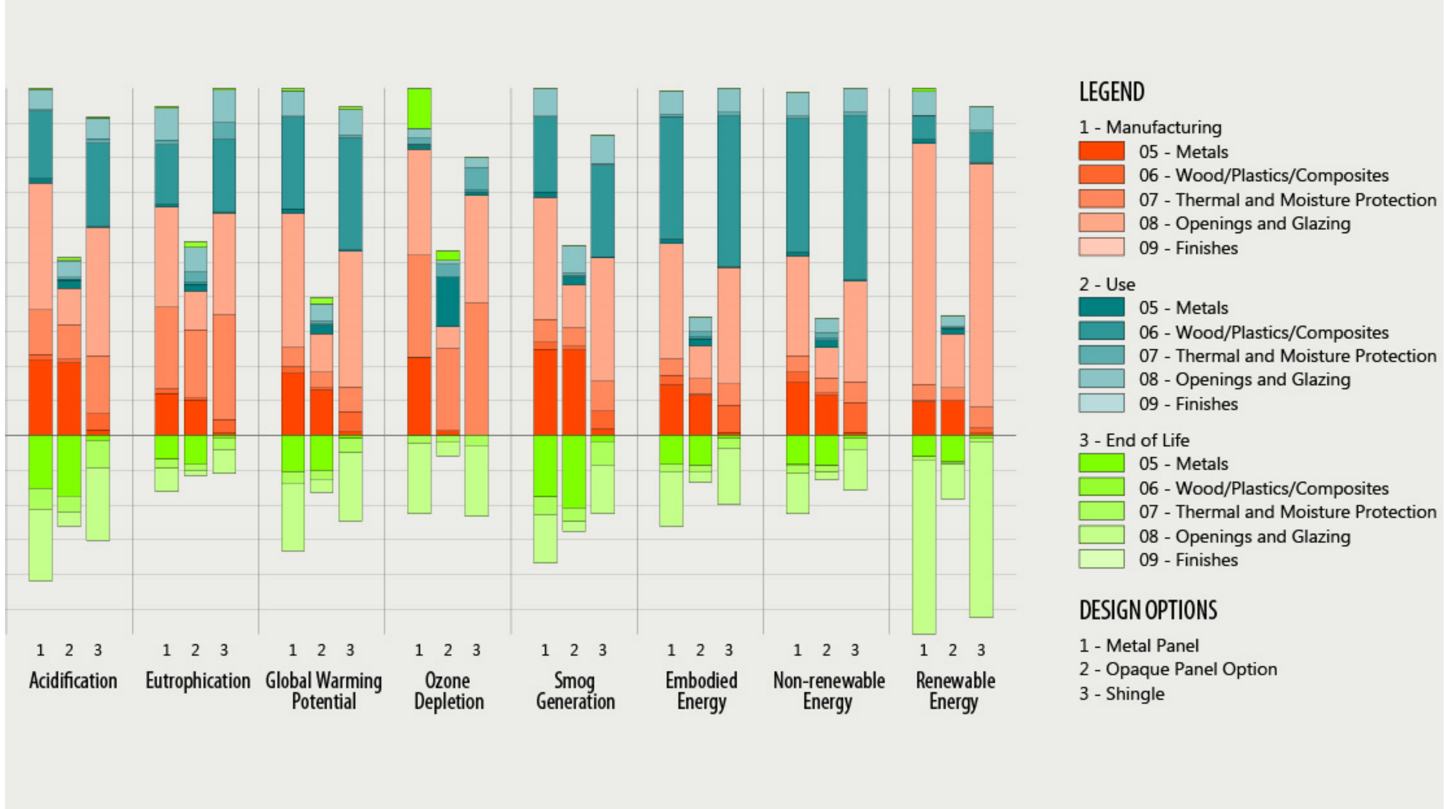


Screenshot - CSBR Revit model for Tally import

PROS & CONS OF TALLY

PROS

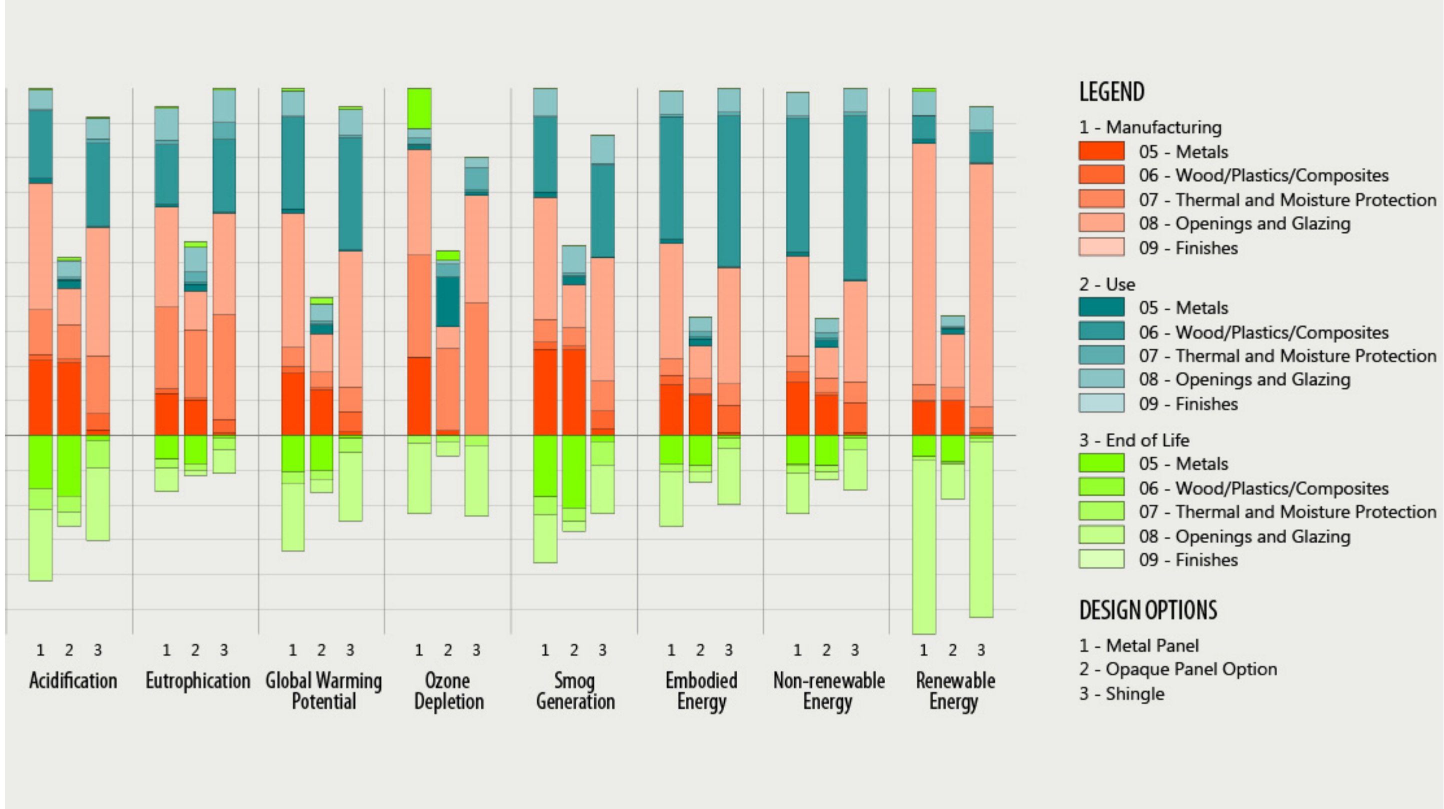
- Generates clear reports with documentation of data sources and assumptions for all materials
- Exports presentation-quality graphs
- Extensive database of materials
- Easy to use/navigate for Revit users
- Significantly eases LCA modeling since takeoffs and estimating are eliminated
- Coming soon – bill of materials import to EC3 with product specific EPD data



PROS & CONS OF TALLY

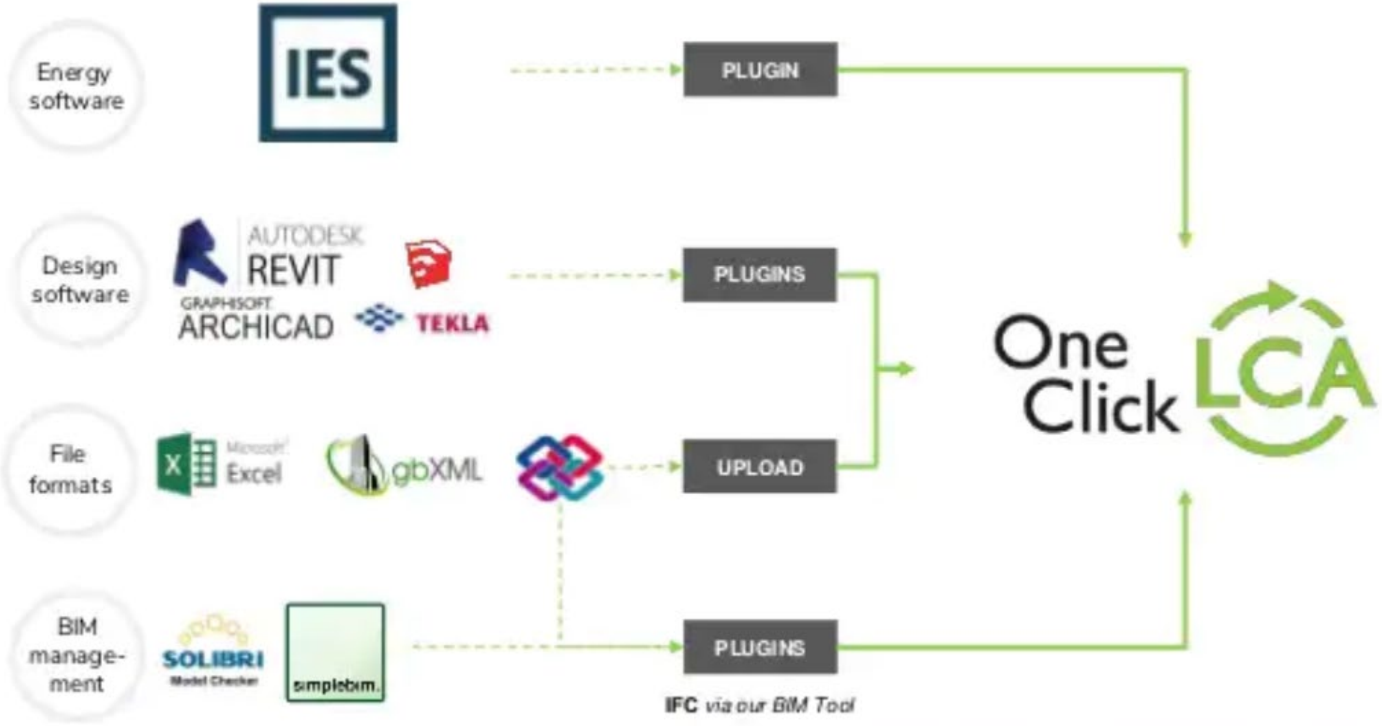
CONS

- Uses North American averages (does not adjust for location-specific factors)
- Revit model may not include all the components required to do a full building LCA, and some materials need to be removed (interior finishes, for example)
- Workflow - Revit model may not be ready in the early design phases when LCA analysis is most useful
- Expensive software



WHOLE BUILDING LCA TOOLS – ONE CLICK LCA

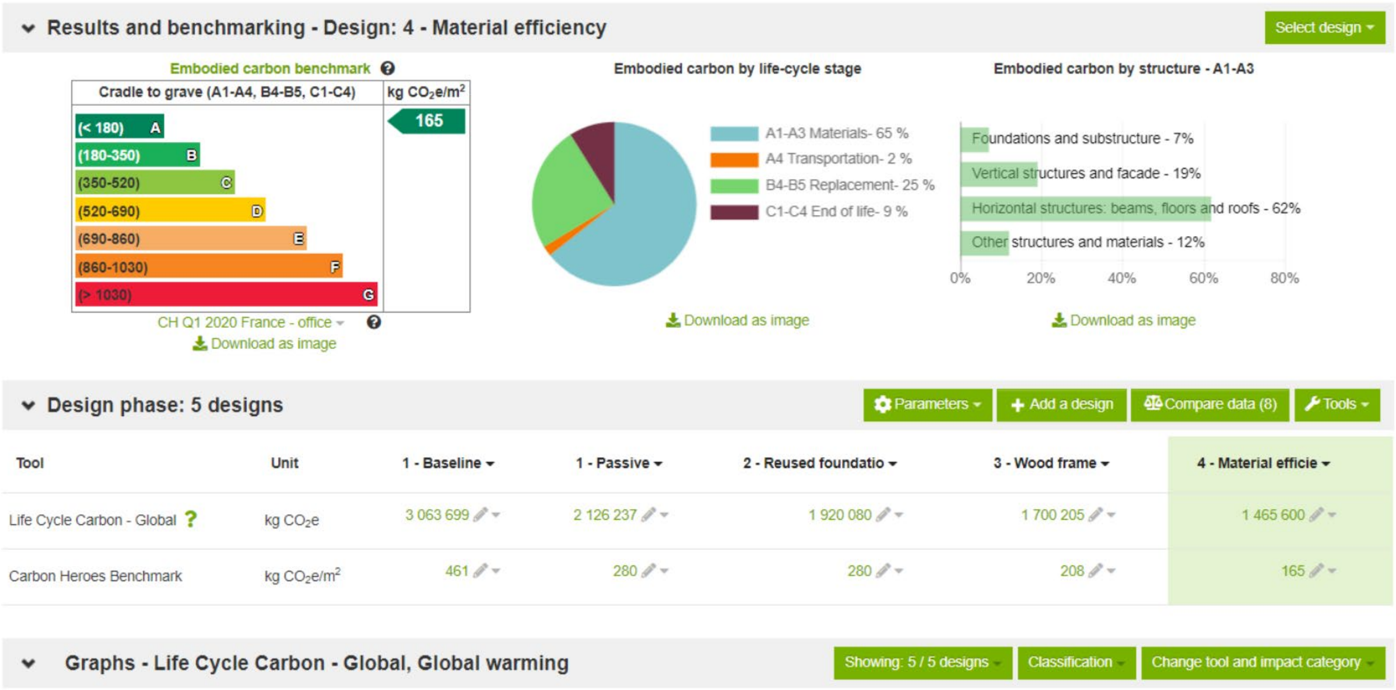
- Developed by Bionova
- Imports material and takeoff data from variety of outside software including Rhino, Grasshopper, Revit, IES, Excel
- Primarily used in Europe, but growing presence in North America
- Integrated with North American EPD database
- Integration with IES allows LCC as well as LCA



PROS & CONS OF ONE CLICK LCA

PROS

- Generates clear reports & presentation-ready graphs
- Integrates with large variety of other software
- Significantly eases LCA modeling since takeoffs and estimating are eliminated
- Add-on tool "Carbon Designer" allows LCA optimization to begin with very basic building info (floor area, # floors, etc) & generates ref. building



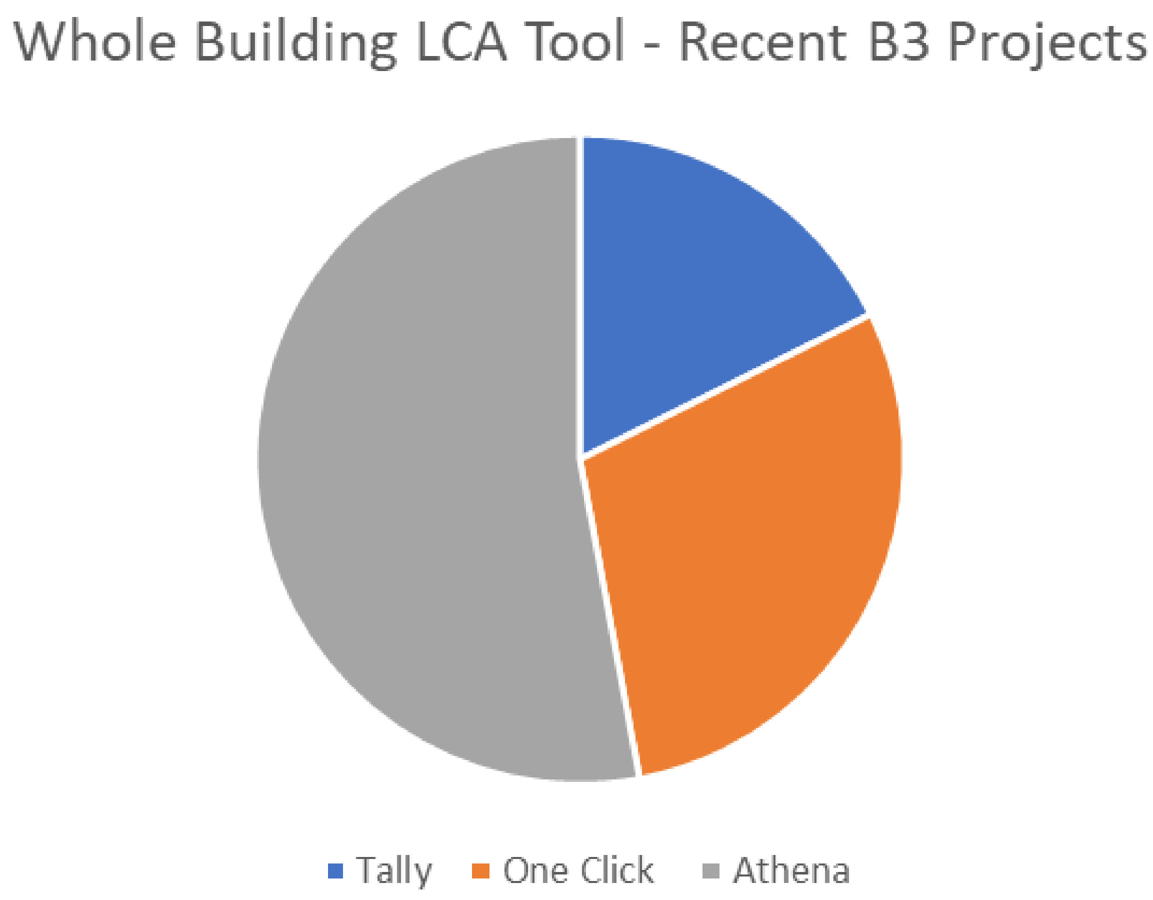
PROS & CONS OF ONE CLICK LCA

CONS:

- Reliance on EPDs for LCA database could generate some inconsistency
- Software models (Revit, IES, etc.) may not include all the components required to do a full building LCA, and some materials need to be removed (interior finishes, for example)
- Expensive software

WHOLE BUILDING LCA TOOLS – USE IN B3

- 53% of projects using Athena
- 29% of projects using One Click
- 18% of projects using Tally



WHOLE BUILDING LCA TOOLS – EC3

WHAT IS EC3?

Essentially, it is an EPD database developed by the Carbon Leadership Forum.

WHOLE BUILDING LCA TOOLS – EC3

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Two free, cloud-based tools have been built around the database:

1. **“Plan and Compare Buildings”** – Whole building embodied carbon analysis
2. **“Plan and Compare Materials”** – Material category and specific product carbon comparisons, including comparison to industry averages and ranges (low/high)

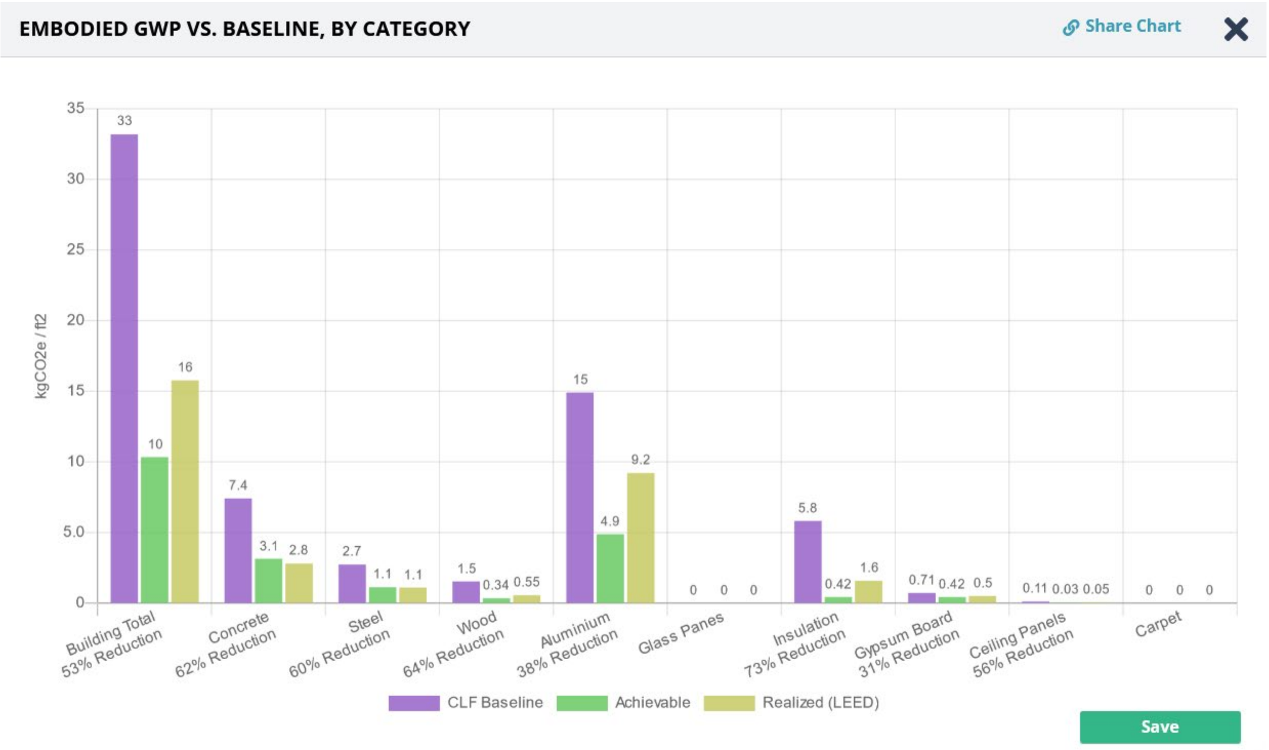
WHOLE BUILDING LCA TOOLS – EC3

“PLAN AND COMPARE BUILDINGS”

Whole building embodied carbon analysis

Pros:

- Works best with a BIM import
- Provides several carbon benchmarks for your building (“conservative”, “achievable”, and “realized/actual”) based on the same design and entered material quantities.
- Early use of the tool is possible using generic product category EPDs (before specific products are known).



WHOLE BUILDING LCA TOOLS – EC3

“PLAN AND COMPARE BUILDINGS”

Whole building embodied carbon analysis

Cons:

- Since the tool is based on EPD data, it does not include Construction, Maintenance, or Demolition phase impacts (Phases A3-5, B, C)
- Data entry without BIM import is clunky since materials must be entered by weight and volume, not length or surface area
- Some product categories have VERY few EPD entries. Therefore, the tool does not provide accurate estimates for these materials. Examples - cladding and roofing

WHOLE BUILDING LCA TOOLS – EC3

"PLAN AND COMPARE BUILDINGS"

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Currently, EC3 cannot be used to satisfy B3 whole-building LCA modeling requirements.

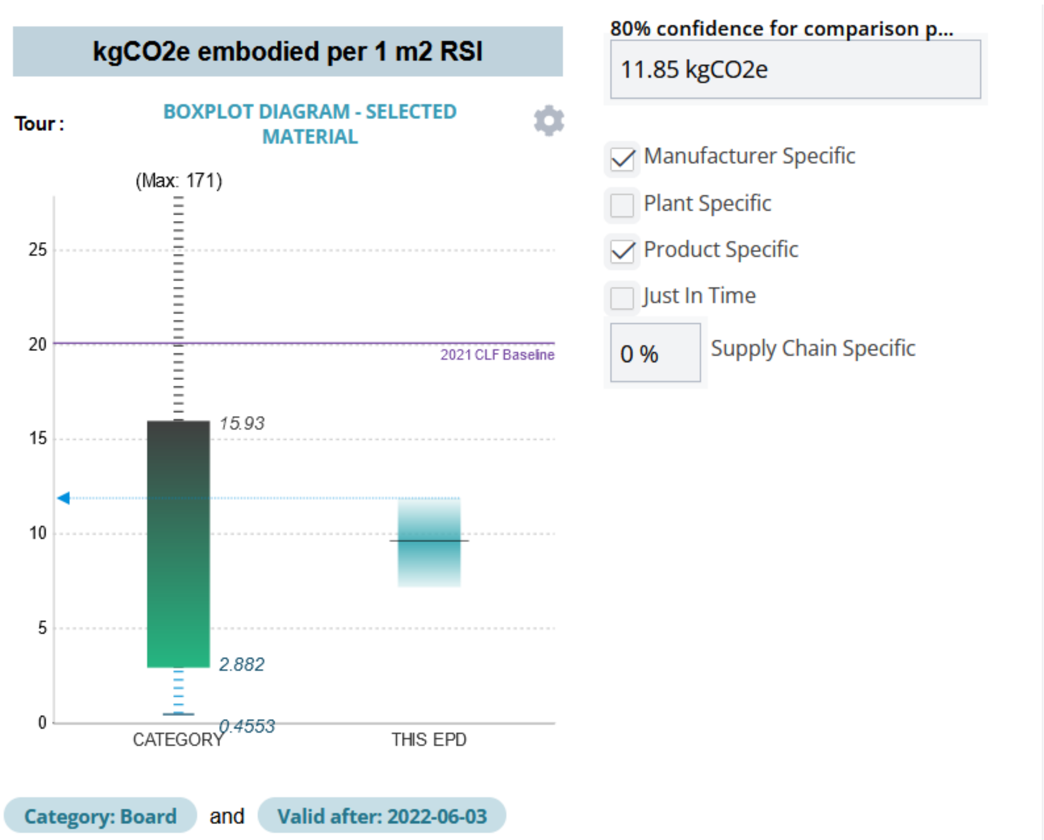
WHOLE BUILDING LCA TOOLS – EC3

“PLAN AND COMPARE MATERIALS”

Material-level analysis and comparison

Pros:

- Allows you to identify lower GWP material types (ie – EPS vs. XPS) or find the lowest GWP product in a material category (ie - Dupont Styrofoam vs. Owens Corning Foamular)
- Allows comparison of your product’s EPD to other product EPDs in the same product category, or to industry averages.



WHOLE BUILDING LCA TOOLS – EC3

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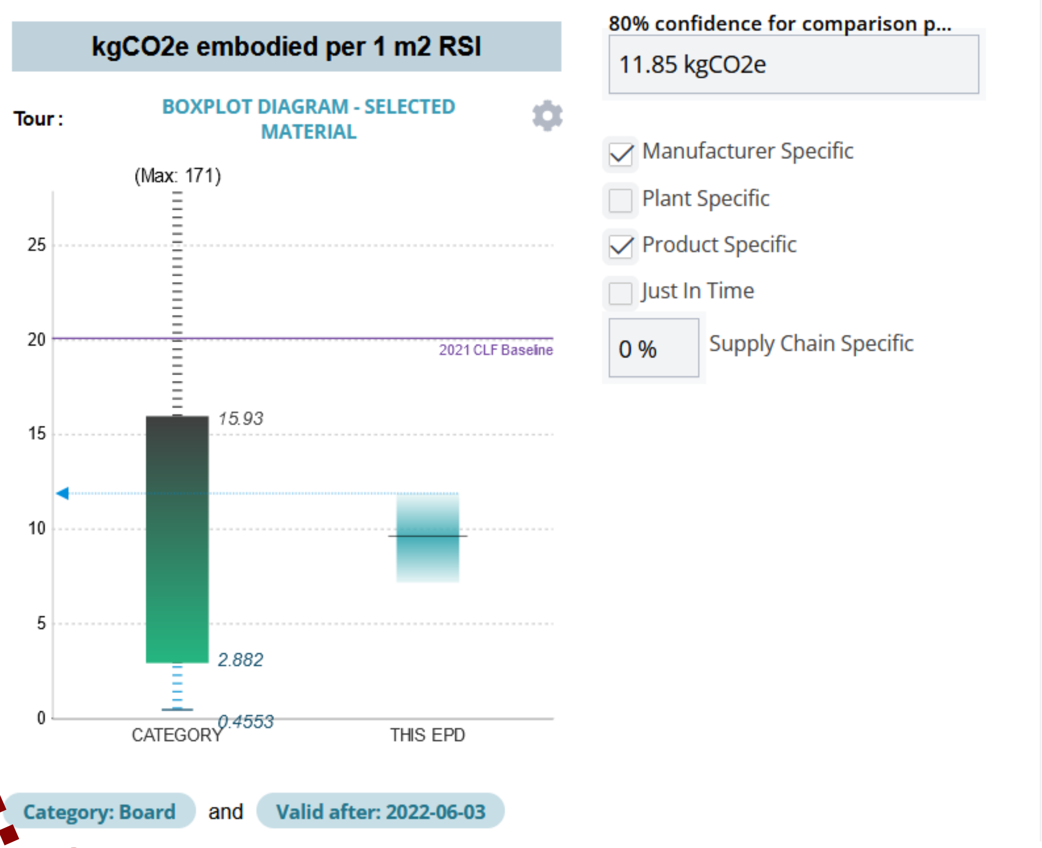


Currently, no other tool allows this.

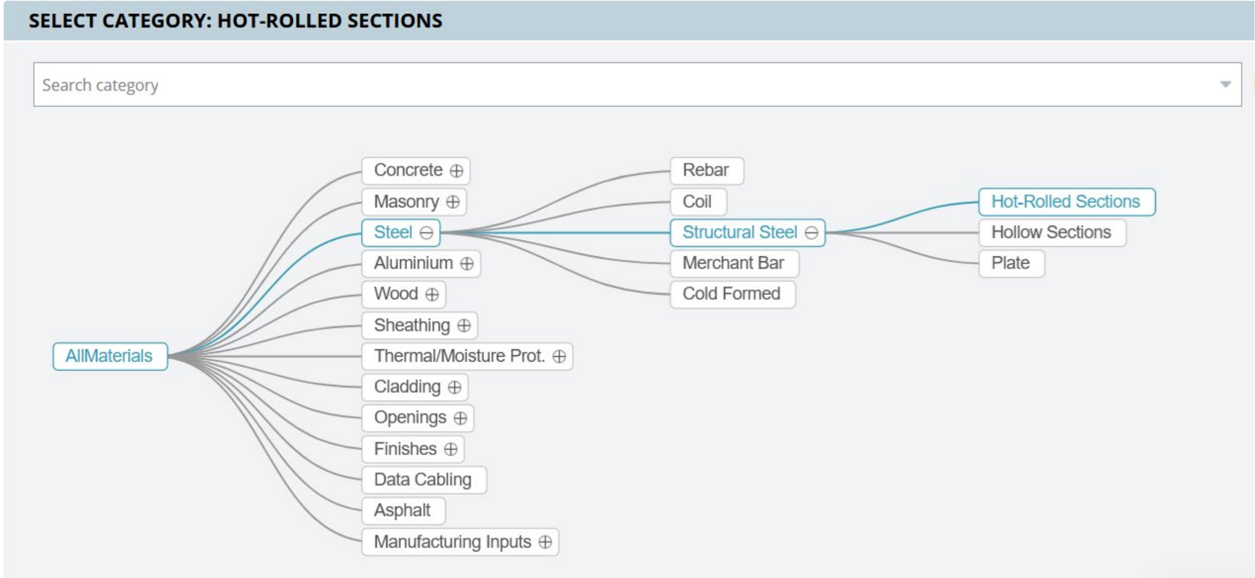
WHOLE BUILDING LCA TOOLS – EC3

"PLAN AND COMPARE MATERIALS"

Material-level analysis and comparison

Cons:

- Many product categories have low numbers of EPDs at this time making comparisons difficult. (Example - only 13 structural steel EPDs in all of USA at this time.)
- Most product categories do not contain enough EPDs to provide useful purchasing alternatives.



BREAK

GUIDELINE REQUIREMENTS

CREDIT M1A

OVERVIEW

1. Intent
2. Guideline Requirements
3. How to Achieve Compliance

CREDIT M1A

INTENT:

To use life cycle analysis to quantify and minimize the environmental impact of building materials, which have significant effects on global warming, air pollution, water pollution, energy consumption, and waste.

GOAL:

Reduce embodied global warming potential of the whole building.

CREDIT M1A

GUIDELINE REQUIREMENTS

3 paths to choose from…

1. Whole Building LCA Approach
2. Assembly Level LCA Approach (structural bays)
3. Material Level LCA Approach

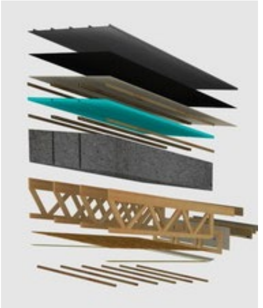
+ 1 whole building LCA model submitted for the final design, at the end of CD phase. (Note – whole building LCA model not required for B3 Small Projects ≤ 20,000sf)

Image credits
- ids-center.com
- greenbuildingassembly.com
- myhuberwood.com

CREDIT M1A

PATH 1: WHOLE-BUILDING LEVEL

PATH 2: ASSEMBLY LEVEL

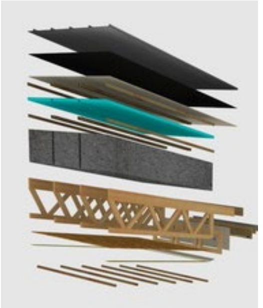


PATH 3: PRODUCT/MATERIAL LEVEL

CREDIT M1A

PATH 1: WHOLE-BUILDING LEVEL

PATH 2: ASSEMBLY LEVEL



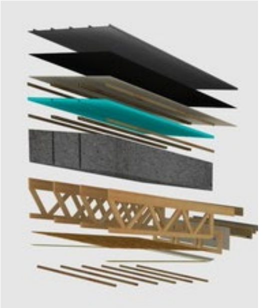
PATH 3: PRODUCT/MATERIAL LEVEL

Simplest, quickest approach. But limited. Can only compare materials that are functionally equivalent, for example – OSB vs. plywood sheathing. Not fair to compare ccSPF vs. fiberglass batts.

CREDIT M1A

PATH 1: WHOLE-BUILDING LEVEL

PATH 2: ASSEMBLY LEVEL



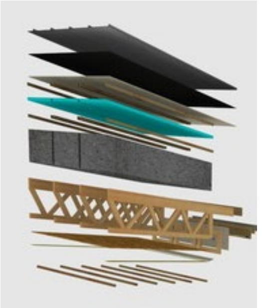
Easier to model than a whole building. But can only compare assemblies that are functionally equivalent. Not fair to compare R48 roof vs R20 roof, for example.

PATH 3: PRODUCT/MATERIAL LEVEL

CREDIT M1A

PATH 1: WHOLE-BUILDING LEVEL

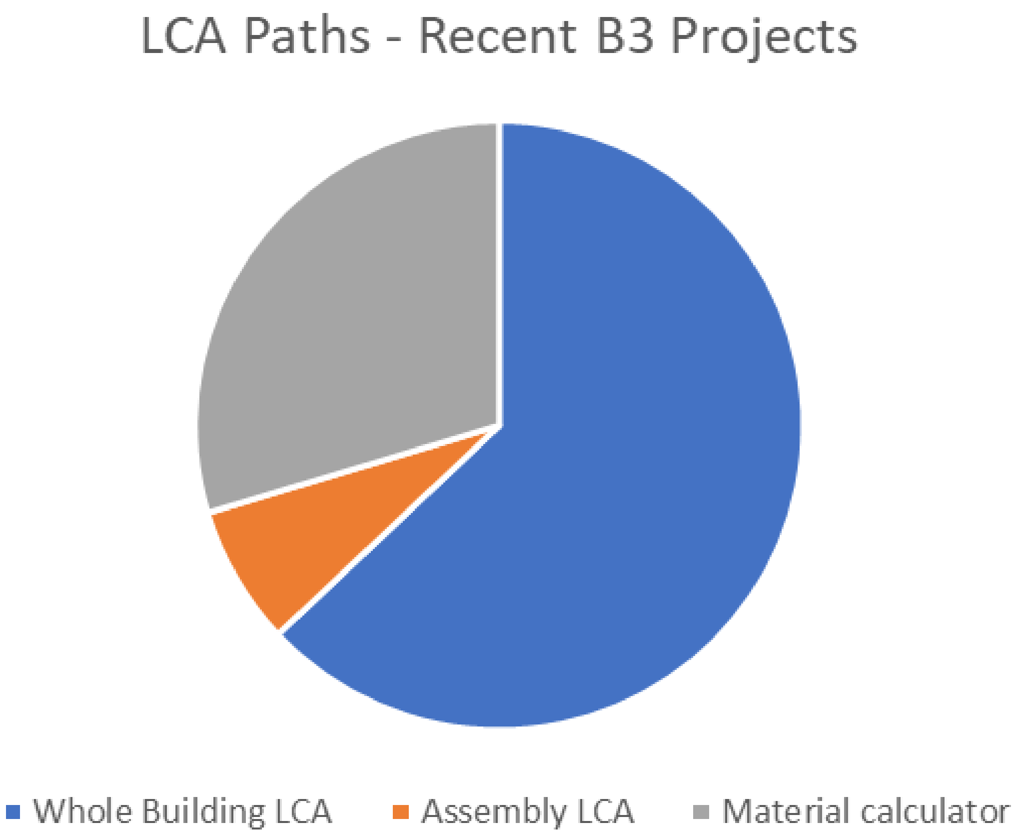
Most complex to model. But now we can compare buildings that are functional equivalents. Allows for investigations of building shape and surface area, and tradeoffs between different types of structural systems.

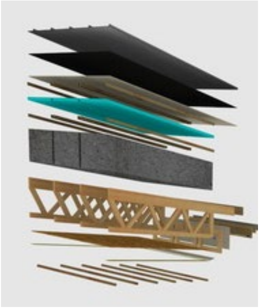


PATH 2: ASSEMBLY LEVEL

PATH 3: PRODUCT/MATERIAL LEVEL

CREDIT M1A


LCA Paths - Recent B3 Projects
Whole Building LCA
Assembly LCA
Material calculator




AdvanTech
FLOORING

CREDIT M1A

GUIDELINE REQUIREMENTS | PATH 1 – WHOLE BUILDING LCA APPROACH

Closely follows *LEED v4 BD+C MR Credit - Building Life Cycle Impact Reduction*

Document at least a 10% reduction in whole building global warming potential as compared to a Reference Building through life cycle assessment using approved software. Compare the Selected Design (the design of the building at the end of the CD phase) to the Reference Building, developed by the end of the SD phase.

CREDIT M1A

GUIDELINE REQUIREMENTS | PATH 2 – ASSEMBLY LEVEL LCA APPROACH (STRUCTURAL BAYS)

Document at least a 10% reduction in global warming potential as compared to a Reference Case structural bay model (or similar functional unit) using approved software. Compare the Selected Design Case (representing the design of the building at the end of the CD phase) to the Reference Case, developed by the end of the SD phase.

CREDIT M1A

GUIDELINE REQUIREMENTS | PATH 3 – MATERIAL LEVEL LCA APPROACH

Achieve GWP savings by substituting lower GWP materials for higher GWP materials. Document savings by using the B3 LCA Material Selection Calculator and achieving an Impact Score of < 1.65 (or < 1.75 for B3 Small Buildings)

This compliance path is limited to building projects that utilize one dominant structural and enclosure type, which must make up at least 60% of the building's structural volume and exterior surface area respectively. In addition, the project's assemblies and materials must be well-approximated by those contained in the Material Selection Calculator.

HOW TO ACHIEVE COMPLIANCE

CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

Modeling requirements:

1. Approved software: Tally, Athena Impact Estimator, One Click LCA - (No EC3)
2. Building service life: 60 years
3. Assessment scope: A-C (cradle to grave), omit D (beyond building life)
4. The Reference Building (SD) and the Selected Design (CD) must be functionally equivalent. They must both meet the Owner's Project Requirements, as established in P1. They must have the same function and floor area. They must both meet the minimum performance requirements of the B3/SB2030 program (such as energy use).

CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

What to include in the model:

1. Complete building enclosure including glazing from the interior finish to the exterior cladding
2. Structural elements (posts, beams, bearing walls)
3. Foundation, basement, roof, and all intermediate floors
4. Attached or unattached parking structures on site

CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

What to omit:

1. All non-load bearing interior walls and assemblies
2. All interior finishes with the exception of the exterior walls
3. All furnishings and equipment
4. All building electrical and mechanical equipment
5. All site improvements (landscaping, parking lots) with the exception of parking ramps

CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

Key Differences from *LEED v4 BD+C MR Credit - Building Life Cycle Impact Reduction*:

1. A 10% impact reduction is required for GWP only
2. LEED Options 1,2, and 3 (building and material reuse) will not be considered as a compliance path for this credit (though they may help meet other B3 reqs.)
3. Interior non-structural walls and assemblies should be omitted from LCA models

CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

Allowable impact reduction strategies:

Impact Reduction Strategies	Path 1 Whole Building	Path 2 Assembly Level	Path 3 Material Level
Building Size (floor area)	no	no	no
Building Service Life	no	no	no
Building shape (layout, surface area)	yes	no	no
Building structural spacing (grid layout)	yes	no	no
Assembly substitutions (swap types)	yes	yes	no
Assembly design changes (thicknesses and layers of materials)	yes	yes	no
Window-to-wall area ratio changes	yes	yes	no
Floor to Floor height changes	yes	yes	no
Structure design changes (type and sizing of beams + columns)	yes	yes	no
Material substitutions	yes	yes	yes

WHOLE BUILDING LCA MODELS

ITASCA BIOLOGICAL STATION – wood frame, super-insulated, single story, slab on grade

Image credit - MSR

WHOLE BUILDING LCA MODELS

ITASCA BIOLOGICAL STATION – wood frame, super-insulated, single story, slab on grade

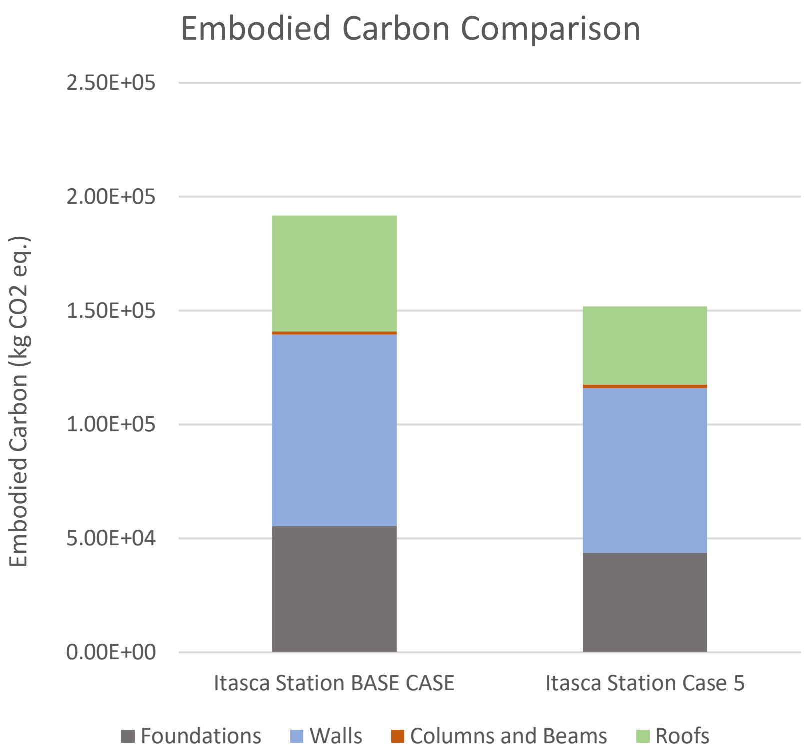
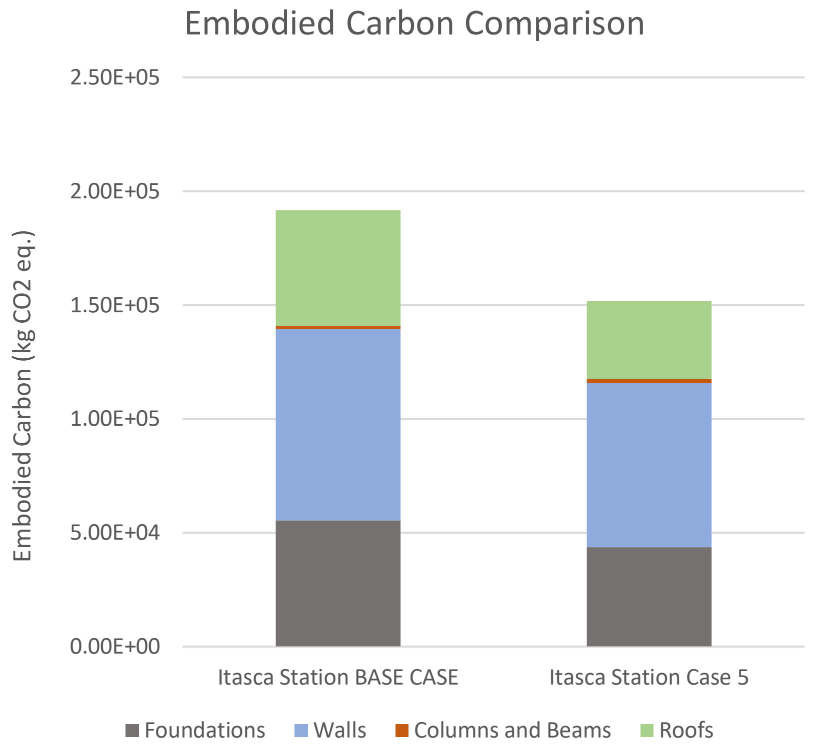


Image credit - MSR

WHOLE BUILDING LCA MODELS

ITASCA BIOLOGICAL STATION – wood frame, super-insulated, single story, slab on grade



Base case foundation - perimeter and post footings, 5" concrete floor slab w 2" XPS

Base case walls - foundation stem wall w 2" XPS, 2x8 stud wall w ccSPF + mineral wool in cavities, and 3" EPS exterior foam

Base case C+Bs - glulam columns and LVL beams for cathedral roof

Base case roofs - wood truss roof w 20" blown cellulose, peel & stick membrane, glass felt shingles

Case 5 foundation - 4" concrete slab replacing 5", EPS foam replacing XPS below grade

Case 5 walls - cedar bevel siding replacing fiber cement, cellulose + air barrier replacing closed cell spray foam

Case 5 C+B's - same as base case

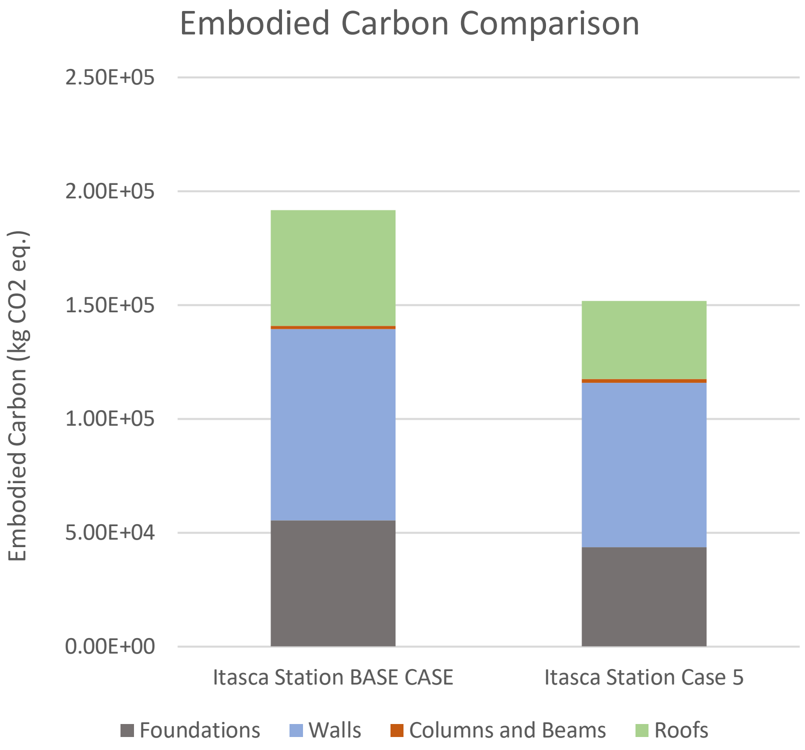
Case 5 roofs - roofing felt (2 layers) replacing peel & stick membrane

20.8% savings

275 kg CO_2e/m^2 - base case

WHOLE BUILDING LCA MODELS

ITASCA BIOLOGICAL STATION – wood frame, super-insulated, single story, slab on grade



Base case foundation - perimeter and post footings, 5" concrete floor slab w 2" XPS

Base case walls - foundation stem wall w 2" XPS, 2x8 stud wall w ccSPF + mineral wool in cavities, and 3" EPS exterior foam

Base case C+Bs - glulam columns and LVL beams for cathedral roof

…glass felt shingles

Majority of savings comes from 2 strategies:

- "Dematerializing" – reducing thickness of concrete slab
- Material substitutions – replacing bitumen membrane on roof w 2 layers roofing felt, replacing spray foam w cellulose + air/vapor barrier

Case 5 foundation - 4" concrete slab replacing 5", EPS foam replacing XPS below grade

Case 5 C+B's - same as base case

Case 5 roofs - roofing felt (2 layers) replacing peel & stick membrane

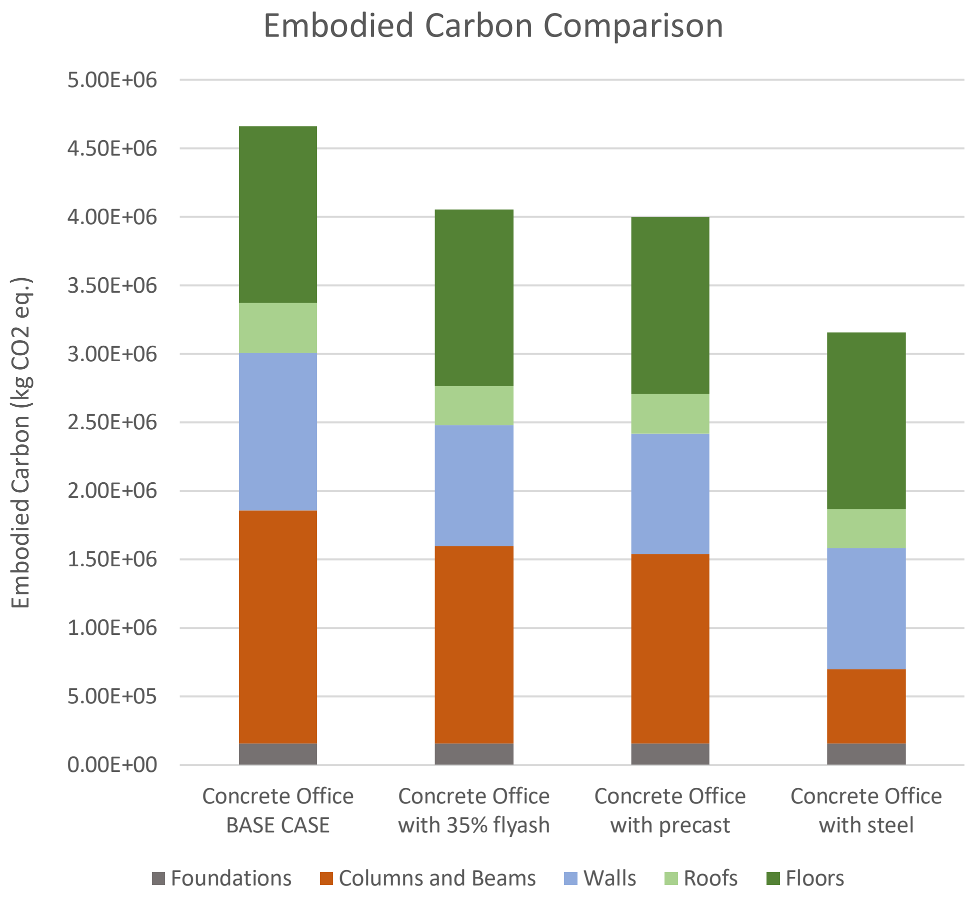
20.8% savings

275 kg CO2e/m2 - base case

WHOLE BUILDING LCA MODELS

WELLS FARGO OFFICE BUILDING – 6-story office building, concrete frame (site-cast concrete posts & beams with precast concrete plank floors

WHOLE BUILDING LCA MODELS



Base case foundation - perimeter and post footings, 4" concrete floor slab
Base case walls - CMU basement wall w 1.5" XPS + fib batt, CMU and steel stud exterior wall w fib batt + 1.5" XPS, brick and metal panel cladding
Base case C+Bs - site-cast concrete posts and beams
Base case roofs - concrete hollow core roof, 4" XPS, bitumen roofing membrane
Base case floors - concrete hollow core floors

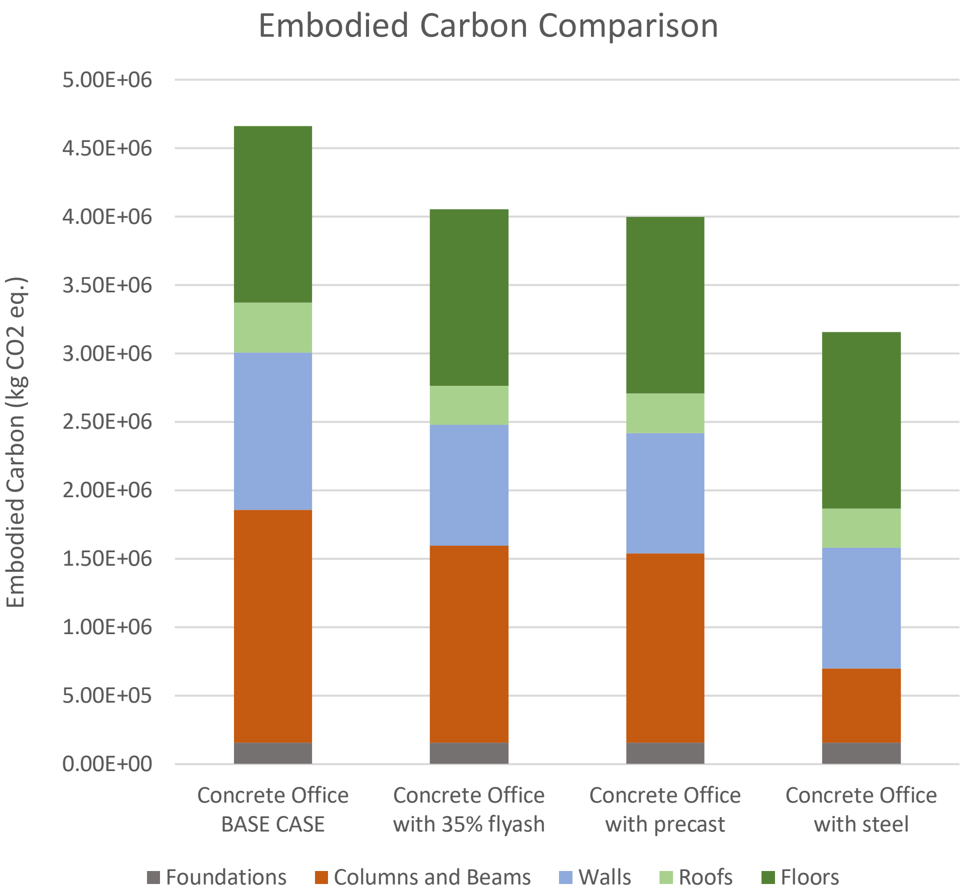
Flyash case foundation - same as base case
Flyash case walls - EPS replacing XPS, stucco and fiber cement replacing brick and metal panel cladding, respectively
Flyash case C+B's - concrete columns and beams poured with 35% flyash content
Flyash case roofs - EPS replacing XPS insulation, EPDM replacing bitumen membrane
Flyash case floors - same as base case

Precast case – same as Flyash case, but precast concrete columns and beams replacing site cast, flyash removed

Steel frame case – same as Flyash case, but steel frame replacing concrete columns and beams, flyash removed

12.9%, 14.2%, 32.2% savings
242 kg CO2e/m2 - base case

WHOLE BUILDING LCA MODELS



Base case foundation - perimeter and post footings, 4" concrete floor slab
Base case walls - CMU basement wall w 1.5" XPS + fib batt, CMU and steel stud exterior wall w fib batt + 1.5" XPS, brick and metal panel cladding
Base case C+Bs - site-cast concrete posts and beams
Base case roofs - concrete hollow core roof, 4" XPS, bitumen roofing membrane
Base case floors - concrete hollow core floors

Majority of savings comes from 2 strategies:

Flyash case foundation - same as base case
Flyash case walls - EPS replacing XPS, stucco and fiber cement replacing brick and metal panel cladding, respectively
Flyash case C+B's - concrete columns and beams poured with 35% flyash content
Flyash case floors - same as base case

- Structure design change – swap site-poured concrete for steel or precast concrete columns and beams

Steel frame case – same as Flyash case, but steel frame replacing concrete columns and beams, flyash removed

12.9%, 14.2%, 32.2% savings
242 kg CO2e/m2 - base case

- Material substitutions – replacing metal panel and brick cladding with stucco and fiber cement

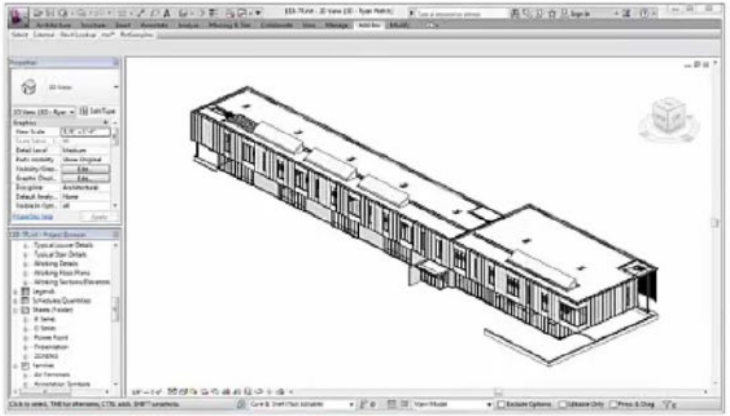
CREDIT M1A

HOW TO ACHIEVE COMPLIANCE | PATH 1 – WHOLE BUILDING LCA APPROACH

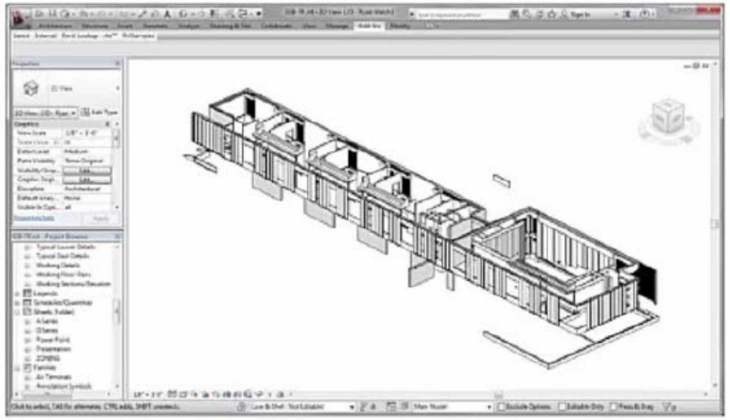
Workflow:

- Start early (SD phase)
- Keep a record
- Include the whole team (structural engineers, etc)

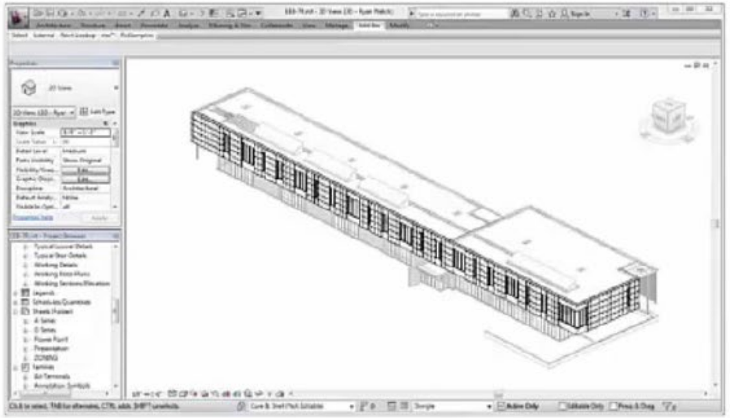
BUILDING INFORMATION MODEL



DEFINE SCOPE OF STUDY



ISOLATE AND STUDY



COMPARE OPTIONS

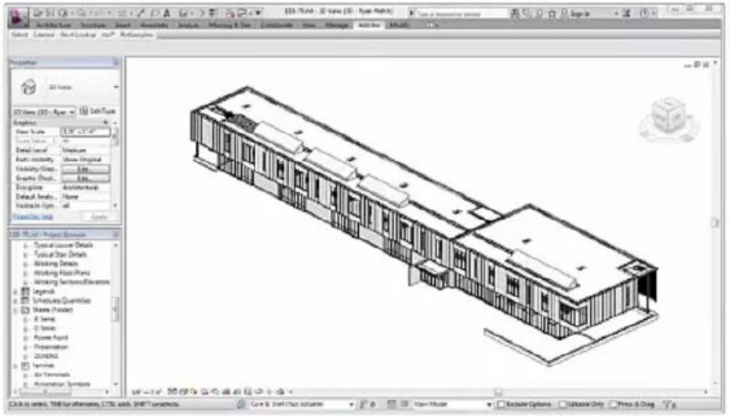
CREDIT M1A

How to Achieve Compliance
Path 1 – Whole Building LCA Approach

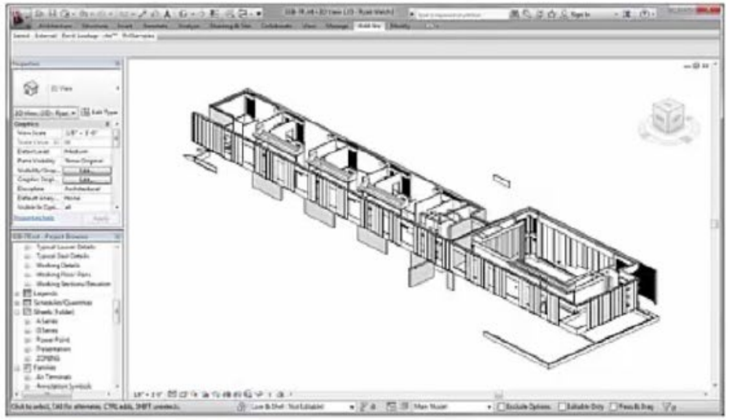
Workflow:

- *Don’t forget to remove site elements, interior assemblies and finishes from model*

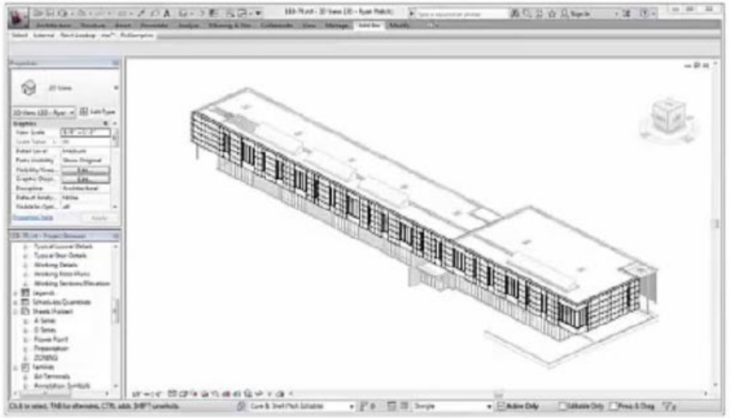
BUILDING INFORMATION MODEL



DEFINE SCOPE OF STUDY



ISOLATE AND STUDY



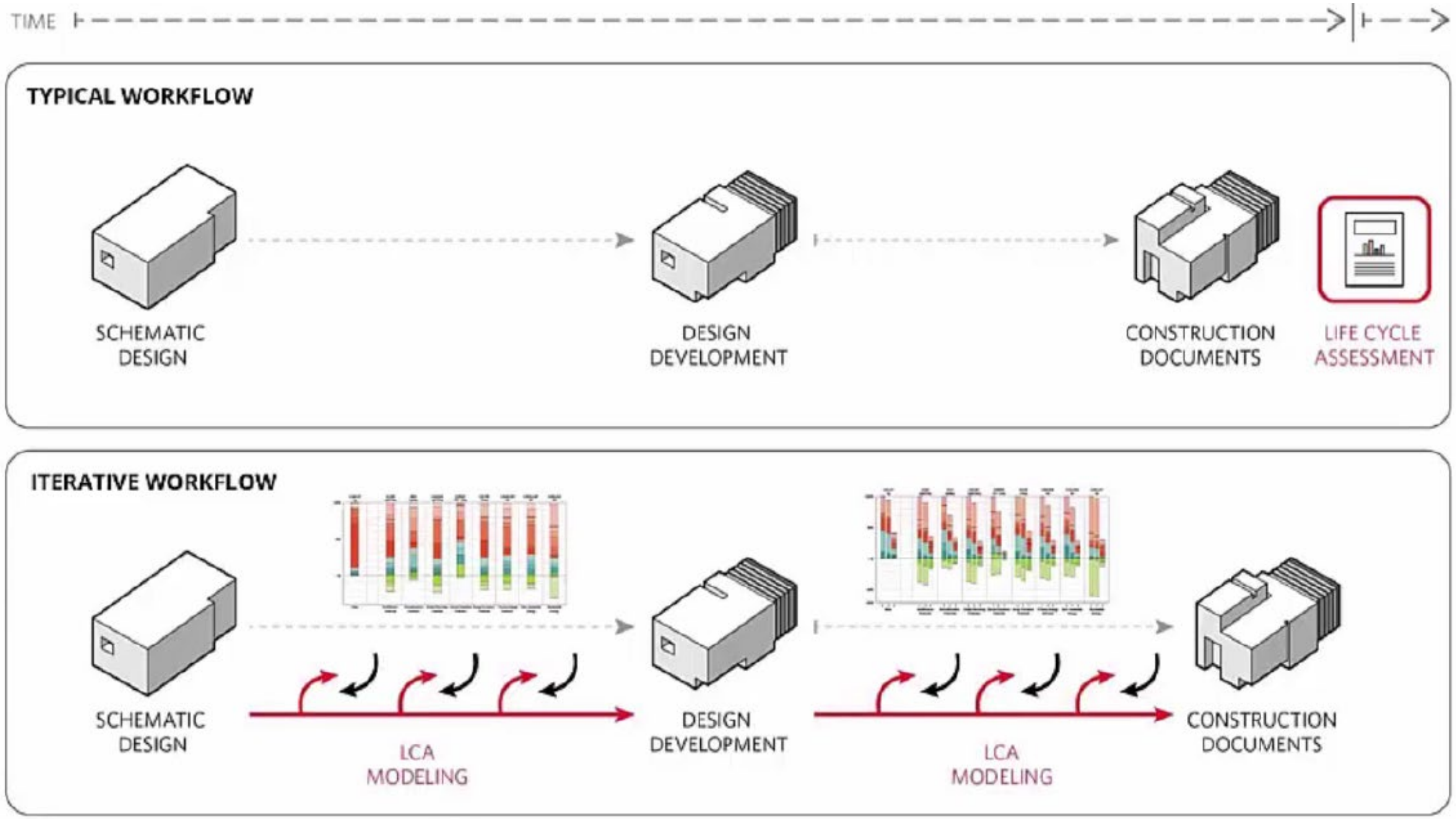
COMPARE OPTIONS

CREDIT M1A

How to Achieve Compliance Path 1 – Whole Building LCA Approach

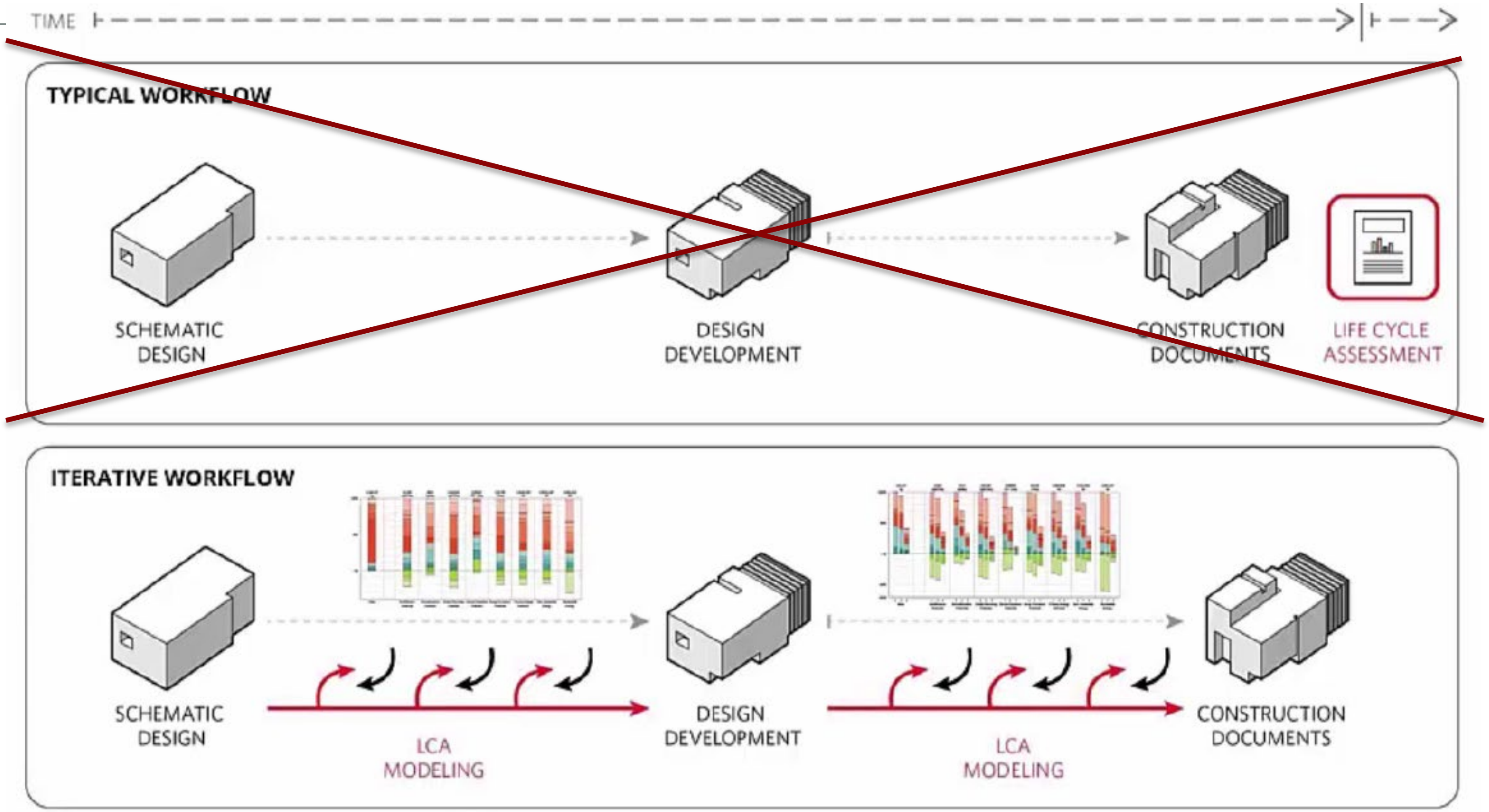
Workflow:

- *Significant savings requires an iterative workflow.*



CREDIT M1A

How to Achieve Compliance Path 1 – Whole Building LCA Approach



Workflow:

- *Significant savings requires an iterative workflow. Is this difficult?*

CREDIT M1A

PRE-DESIGN		EARLY SD		50% SD		100% SD	EARLY DD		50% DD		100% DD	
Overall budget, program, and pro-forma set	*Draft of overall schedule set for project planning*	*OPR complete*	*Building siting (orientation + massing) set*	*Building type/ code set*	*Major systems set*	*Structural + envelope performance criteria set*	*Draft construction schedule set*	*Secondary structural systems set (curtain wall, etc.)*	*Outline specifications*	*Exterior elevations set*	*D-B: Manufacturer/ vendor chosen*	*Exterior assemblies set*

WHOLE BUILDING

SET GOALS
- Operational carbon: Set energy use intensity (EUI) goals + fuel source
- Embodied carbon: Set carbon intensity limits ($kgCO_2eq/sf$), % reduction targets, and/or limits
- Rating system metrics

LCA: MASSING COMPARISON
Study massing options

Establish relevant regulations and rating systems (Buy Clean CA, LEED, LBC, etc.)

Set baseline if tracking relative improvements (% reduction)

HOT SPOT ANALYSIS
- Perform whole building LCA
- Identify top material impacts
- Establish strategies for reducing or optimizing materials with the biggest impact

Identify optimization opportunities (see "Materials" section below)

Update LCA model + track change in life cycle impacts over DD

STRUCTURE

REVIEW GOALS
- Architect and engineer discuss carbon reduction + goals
- Discuss schedule + budget implications with contractor (D-B)
- Work with geotechnical engineer + structural to optimize foundations

LCA: STRUCTURAL COMPARISON
- Study structural concepts + alternatives
- Confirm most appropriate system (P.T. vs. mild, steel, wood, etc.)

STRUCTURE FIXED
- Structural performance criteria is fixed (loads, design strength, serviceability)
- Incorporate embodied carbon reduction targets

STRUCTURAL HOT SPOTS
- Push for cement reductions if using concrete (topping slab, mat foundations, and other low-hanging fruit at a minimum!)
- Consider schedule implications

Architect/engineers collaborate to reduce volume of structural materials as possible

Finalize reduction strategies in structure (e.g. cement reduction in concrete, sourcing goals for steel, etc.)

ENVELOPE

Envelope constraints set through code analysis, daylighting + energy modeling studies

LCA: ENVELOPE STUDIES
- Compare facade + assembly design options
- Test assemblies - insulation layers, etc.

ENVELOPE HOT SPOTS
- Identify target item reductions
- Push for low carbon insulation + other hot spots

Identify optimization opportunities (see "Materials" section below)

Establish reduction strategies for envelope (e.g. insulation preference, window type, etc.)

CREDIT M1A

How to Achieve Compliance

Path 2 – Assembly Level LCA Approach (structural bays)

Document at least a 10% reduction in global warming potential as compared to a *Reference Case* structural bay model (or similar functional unit) using approved software. Compare the *Selected Design Case* (representing the design of the building at the end of the CD phase) to the *Reference Case*, developed by the end of the SD phase.

Coming Wednesday – in class exercise

CREDIT M1A

How to Achieve Compliance
Path 2 – Assembly Level LCA Approach (structural bays)

Modeling requirements:

1) Same as Path 1

CREDIT M1A

How to Achieve Compliance
Path 2 – Assembly Level LCA Approach (structural bays)

What to include in the model:

1) A typical “slice” through the building, 1 or 2 bays wide
2) The slice must extend from the front to the back of the building
3) It must include the complete building enclosure including glazing from the interior finish to the exterior cladding
4) Structural elements (posts, beams, bearing walls)
5) Full building height: foundation, basement, all intermediate floors, roof

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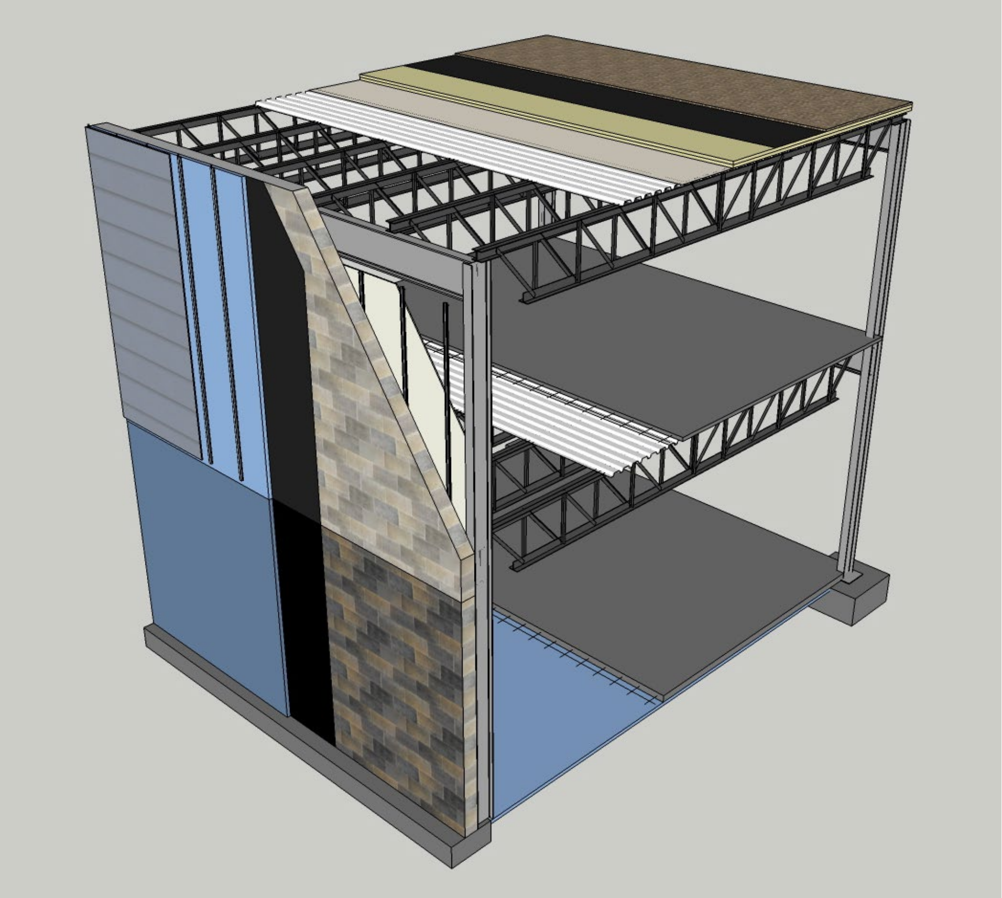
How to Achieve Compliance
Path 2 – Assembly Level LCA

What to include in the model:

Similar to this picture, foundation to roof, but include enclosure on the back side of the building as well.



CREDIT M1A

How to Achieve Compliance
Path 2 – Assembly Level LCA Approach (structural bays)

What to omit:

1) Same as Path 1, plus…
2) Unattached parking garages

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How to Achieve Compliance
Path 2 –
Assembly Level
LCA Approach

Allowable impact reduction strategies:

Impact Reduction Strategies	Path 1 Whole Building	Path 2 Assembly Level	Path 3 Material Level
Building Size (floor area)	no	no	no
Building Service Life	no	no	no
Building shape (layout, surface area)	yes	no	no
Building structural spacing (grid layout)	yes	no	no
Assembly substitutions (swap types)	yes	yes	no
Assembly design changes (thicknesses and layers of materials)	yes	yes	no
Window-to-wall area ratio changes	yes	yes	no
Floor to Floor height changes	yes	yes	no
Structure design changes (type and sizing of beams + columns)	yes	yes	no
Material substitutions	yes	yes	yes

CREDIT M1A

How to Achieve Compliance
Path 2 – Assembly Level LCA Approach (structural bays)

Steps:

1) *As early as possible, begin developing a structural bay LCA model (a representative slice) of the proposed building.*
2) *Once the SD phase design is relatively complete (and projected to achieve the owner's project requirements and B3/SB2030 performance targets), create a structural bay model that defines the "Reference Case".*
3) *Through the remainder of SD, DD, and CD phases, work to achieve a 10% reduction in GWP compared to the "Reference Case" .*
4) *Submit a "Selected Design Case" representing the final building design at the end of the CD phase, which achieves a 10% reduction compared to the "Reference Case".*

BREAK

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Achieve GWP savings by substituting lower GWP materials for higher GWP materials. Document savings by using the **B3 LCA Material Selection Calculator** and achieving an Impact Score of < 1.65 (or < 1.75 for B3 Small Buildings)

This compliance path is limited to building projects that utilize one dominant structural and enclosure type, which must make up at least 60% of the building's structural volume and exterior surface area respectively. In addition, the project's assemblies and materials must be well-approximated by those contained in the Material Selection Calculator.

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Allowable impact reduction strategies:

Impact Reduction Strategies	Path 1 Whole Building	Path 2 Assembly Level	Path 3 Material Level
Building Size (floor area)	no	no	no
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Floor to Floor height changes	yes	yes	no
Structure design changes (type and sizing of beams + columns)	yes	yes	no
Material substitutions	yes	yes	yes

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Modeling requirements:

1) There is no modeling! Use the B3 Material Selection Calculator. (But don't forget a final whole-building LCA model is due at the end of CD phase unless your building qualifies for the B3 Small Buildings approach.)

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Steps:

1) *As early as possible in the SD phase, identify the proposed building's most common material type in each of the following 10 categories:*

- cladding
- low-slope roofing
- pitched roofing
- columns & beams structural material
- exterior wall structural material
- cavity insulation (for wall)
- cavity insulation (for roof)
- board insulation (for wall)
- board insulation (for roof)
- board insulation (for foundation)

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Steps:

1) *As early as possible in the SD phase, identify the proposed building's most common material type in each of the following 10 categories:*

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- columns & beams structural material
- exterior wall structural material
- cavity insulation (for wall)
- cavity insulation (for roof)
- board insulation (for wall)
- board insulation (for roof)
- board insulation (for foundation)

But it must account for at least 60% of the total surface area in its respective category.

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Steps:

1) *As early as possible in the SD phase, identify the proposed building's most common material type in each of the following 10 categories:*

- *- cladding*
- *- low-slope roofing*
- *- pitched roofing*
- *- columns & beams structural material*
- *- exterior wall structural material*
- *- cavity insulation (for wall)*
- *- cavity insulation (for roof)*
- *- board insulation (for wall)*
- *- board insulation (for roof)*
- *- board insulation (for foundation)*

If there is no material in a category, that category is removed from consideration.

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

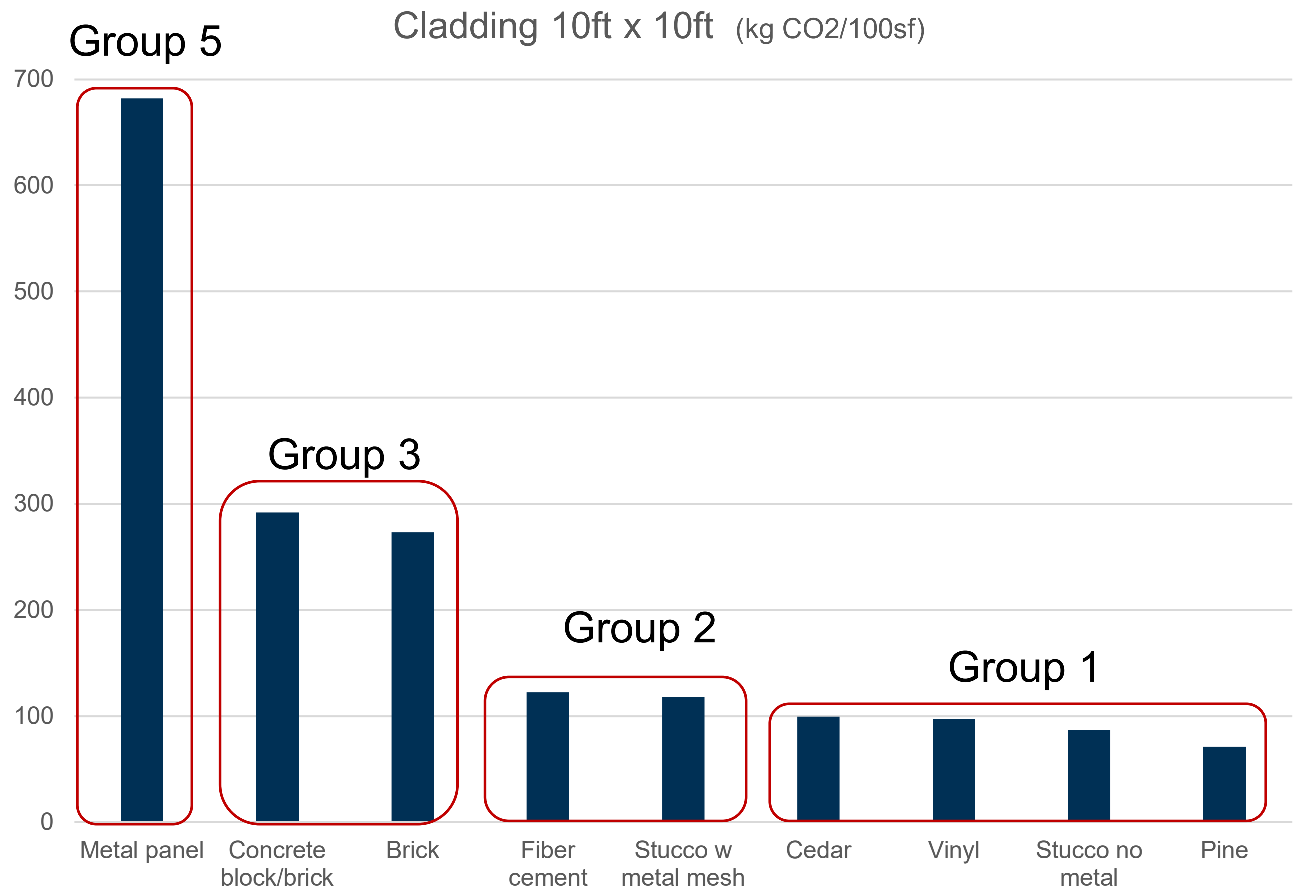
Steps:

2) Enter these materials in the B3 Material Selection Calculator. As the design progresses, work to substitute lower GWP materials for the original selections to achieve a score of < 1.65 and incorporate those changes in the building plans and specs.

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

GWP charts



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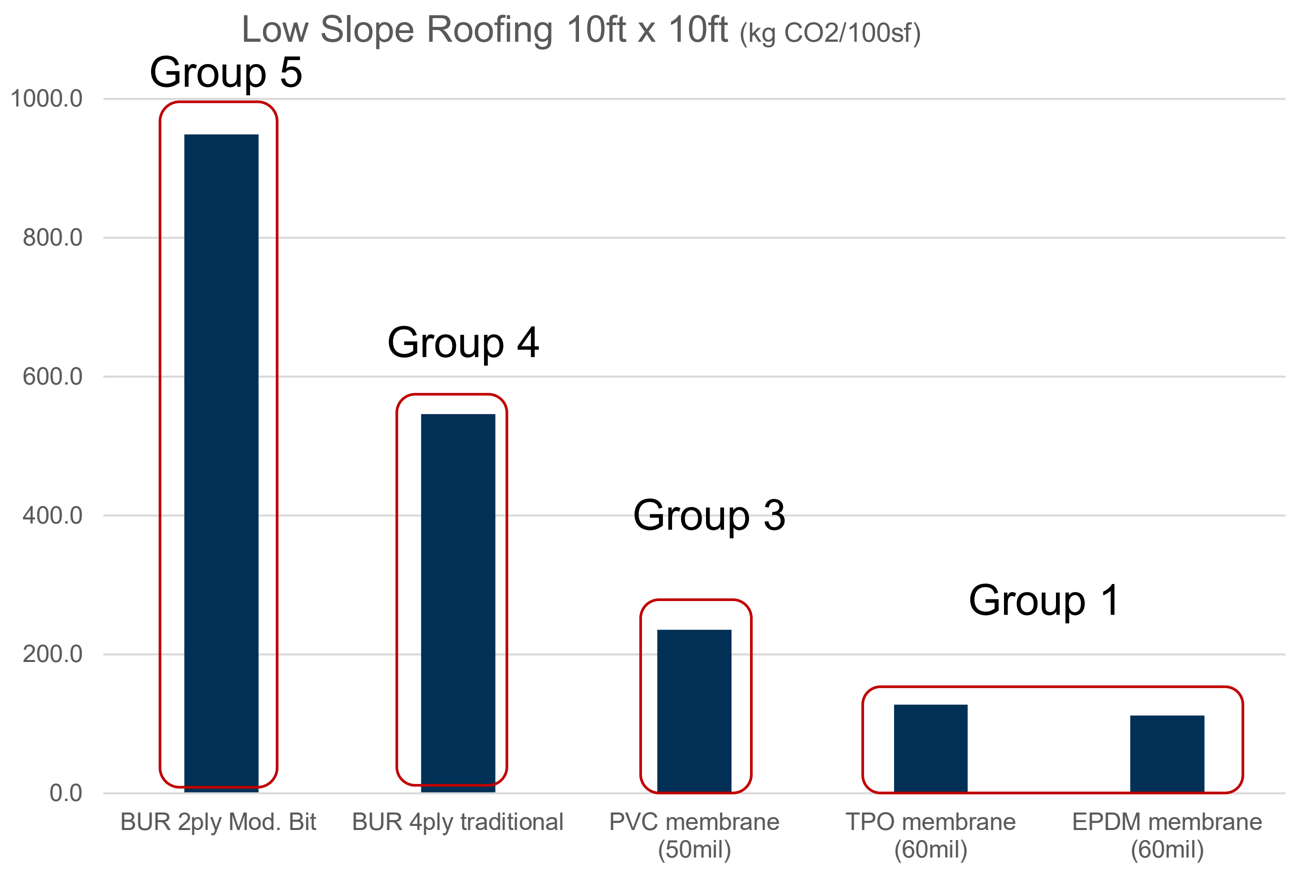
How to Achieve Compliance
Path 3 – Material Level LCA Approach

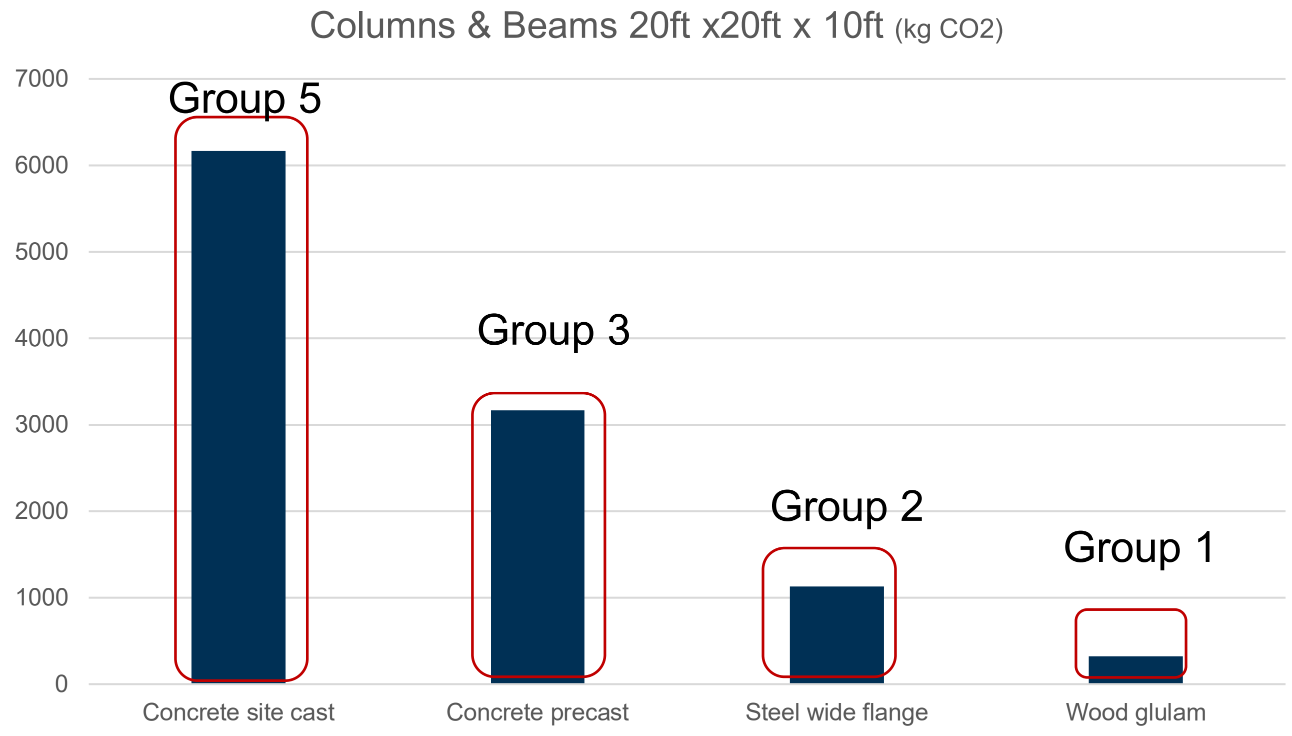
GWP charts



CREDIT M1A

How to Achieve Compliance Path 3 – Material Level LCA Approach

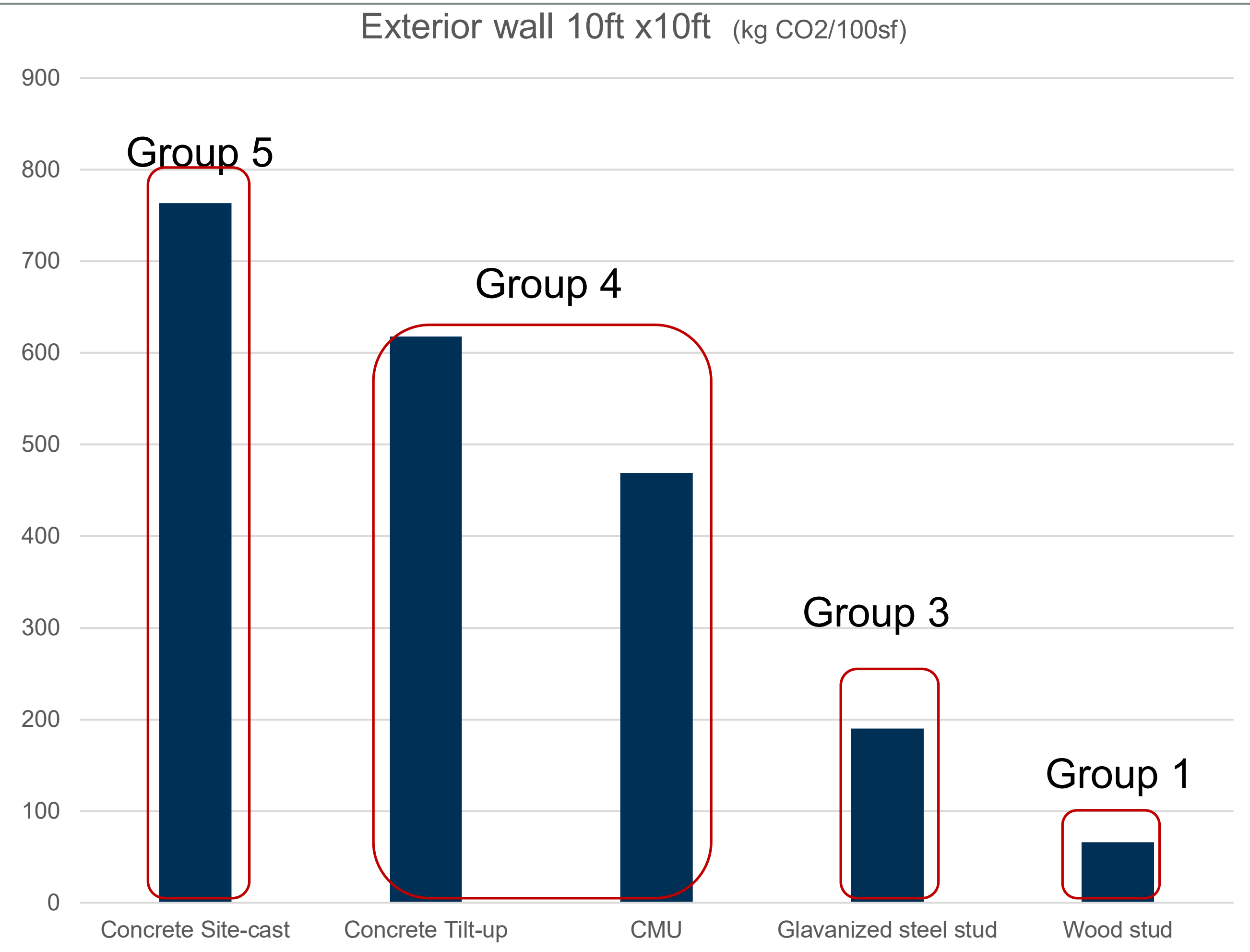
GWP charts



CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

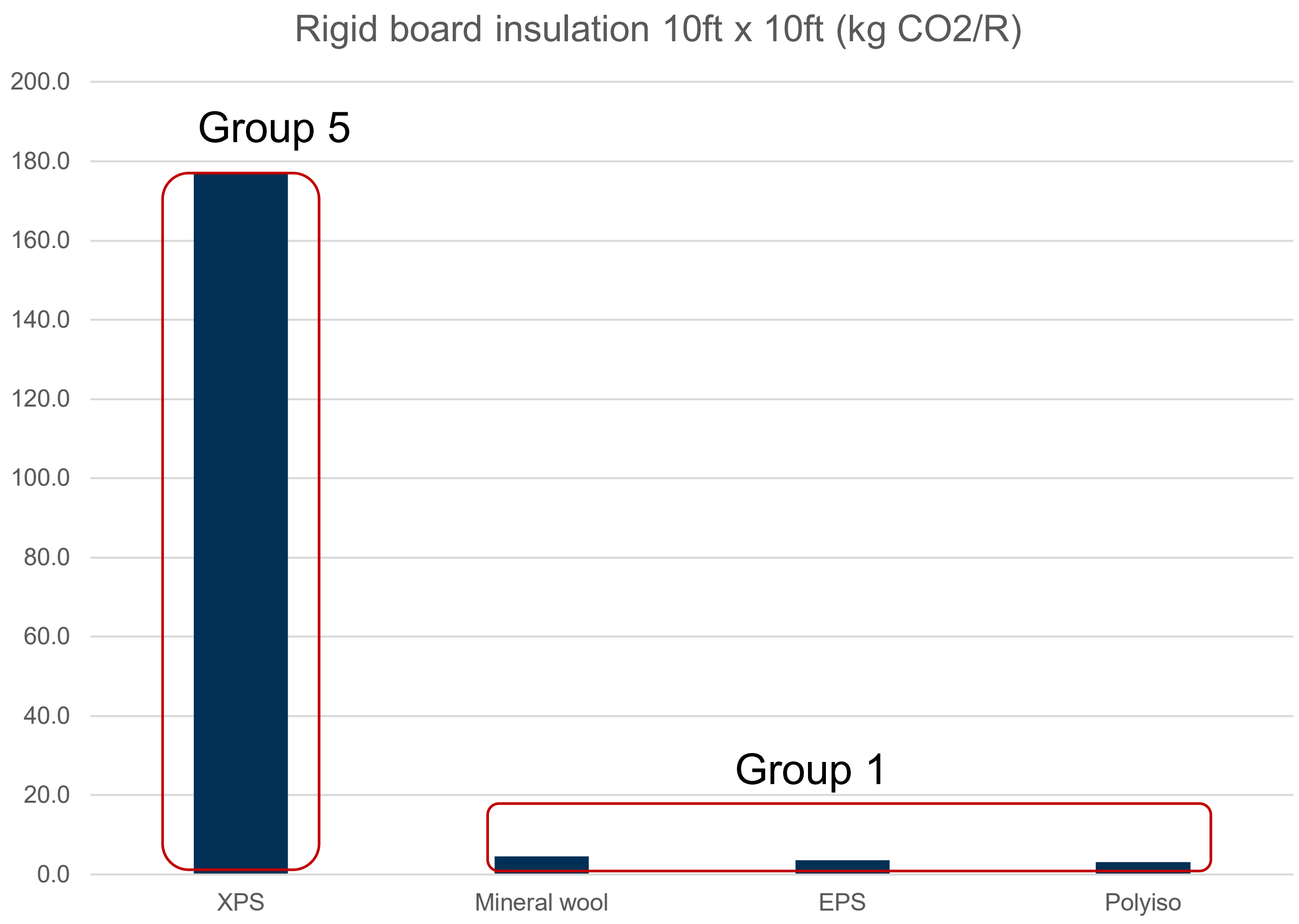
GWP charts



CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

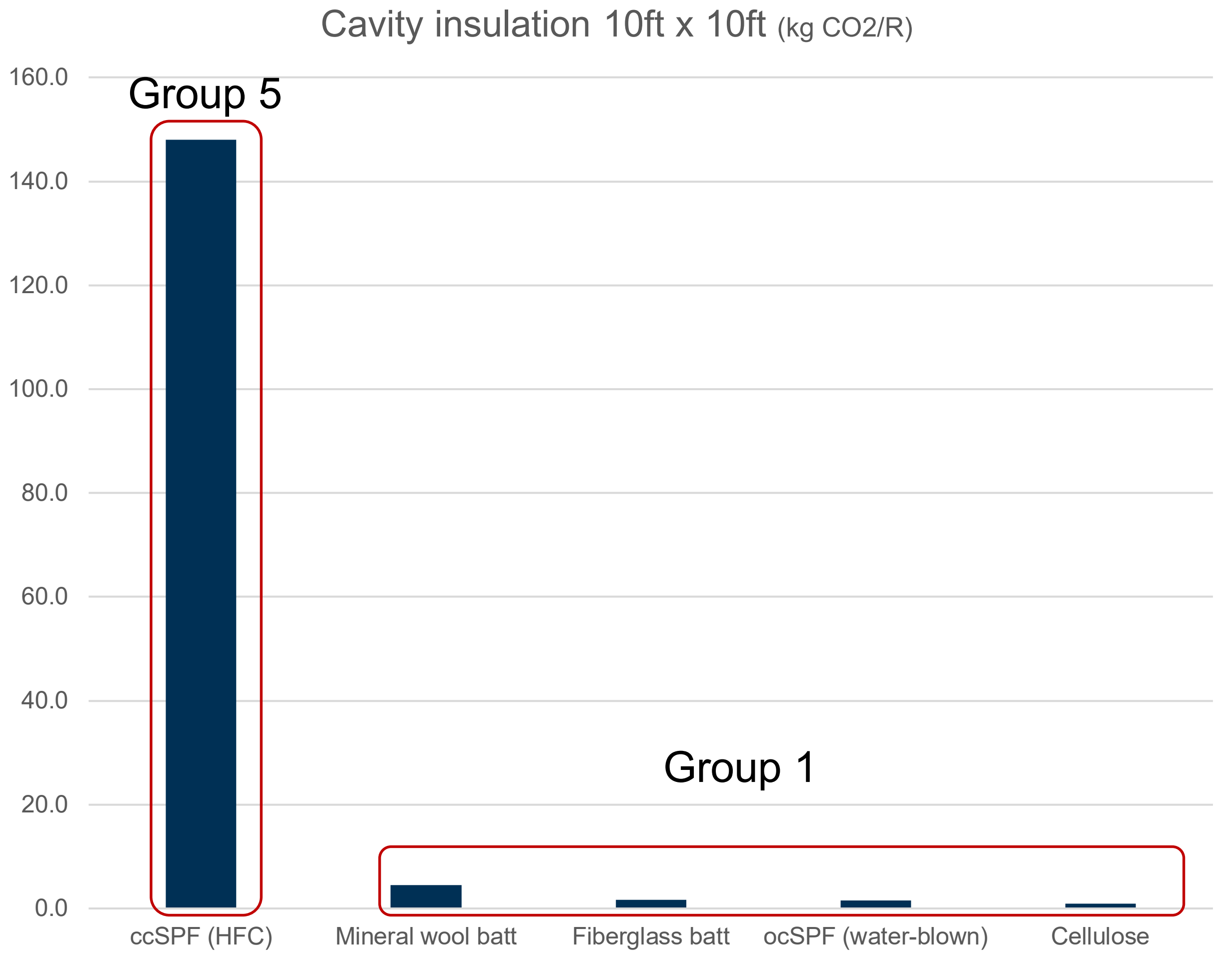
GWP charts



CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

GWP charts



A NOTE ON BLOWING AGENTS

Chart from Building Green Guide to Insulation, 2017

XPS and closed cell SPF have historically had extremely high embodied GWP due to their blowing agents.

Type of Insulation	Blowing Agent	Atmospheric Lifetime (yr)	ODP[1]	GWP[2]
Polyisocyanurate				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141b	9.3	0.11	725
3rd Generation	Pentane, cyclopentane	–	0	7[3]
Spray Polyurethane				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141b	9.3	0.11	725
3rd Generation	HFC-245fa	7.2	0	1,030
3rd Generation	CO_2	–	0	1
4th Generation (2017)	HFO-1233zd	< 0.1	0	7
Extruded Polystyrene (XPS)				
Original	CFC-12	100	1	10,900
2nd Generation	HCFC-142b	17.9	0.065	2,310
3rd Generation	HFC-134a	13.8	0	1,430
4th Generation (TBD)	HFO-1234ze[4]	< 0.1	0	7

A NOTE ON BLOWING AGENTS

Chart from Building Green Guide to Insulation, 2017

In the last year or two, manufacturers have begun to introduce products with vastly lower GWP, but availability is still limited, state to state, depending on regulations.

Type of Insulation	Blowing Agent	Atmospheric Lifetime (yr)	ODP[1]	GWP[2]
Polyisocyanurate				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141b	9.3	0.11	725
3rd Generation	Pentane, cyclopentane	–	0	7[3]
Spray Polyurethane				
Original	CFC-11	45	1	4,750
2nd Generation	HCFC-141b	9.3	0.11	725
3rd Generation	HFC-245fa	7.2	0	1,030
3rd Generation	CO_2	–	0	1
4th Generation (2017)	HFO-1233zd	< 0.1	0	7
Extruded Polystyrene (XPS)				
Original	CFC-12	100	1	10,900
2nd Generation	HCFC-142b	17.9	0.065	2,310
3rd Generation	HFC-134a	13.8	0	1,430
4th Generation (TBD)	HFO-1234ze[4]	< 0.1	0	7

A NOTE ON BLOWING AGENTS

XPS products with low GWP:
- Owens Corning – Foamular NGX (still pink)
- Dupont – Reduced GWP Styrofoam (new look – grey instead of blue)
- Kingspan – Greenguard XPS LG (still green)

Closed cell SPF products with low GWP:
- Specify a ccSPF blown with Solstice LBA blowing agent (GWP = 1)
    - Demilic – Heatlok XT HFO
    - Lapolla – Foam-Lok 2000-4G
    - others…

A NOTE ON BLOWING AGENTS

XPS products with low GWP:

- Owens Corning – Foamular NGX (still pink)
- Dupont – Reduced GWP Styrofoam (new look – grey instead of blue)
- Kingspan – Greenguard XPS LG (still green)

Closed cell SPF products with low GWP:

- Specify a ccSPF blown with Solstice LBA blowing agent (GWP = 1)
  - Demilic – Heatlok XT HFO
  - Lapolla – FoamLok 2000-4G
  - others…

If these products are specified in the building plans and truly available for purchase, substitutions are allowed in the B3 Material Selection Calculator:

- ocSPF (water blown) for the low GWP ccSPF
- EPS for the low GWP XPS

Some states (not MN) have banned HFCs in the production of foam. Low GWP product may be more available in these states.
https://www.hfcbans.com/bans-by-region.html

CREDIT M1A

How to Achieve Compliance
Path 3 – Material Level LCA Approach

Example – Wells Fargo Office Building

Appendix M-1a: Material Selection Calculator

B3 Guidelines - Version 3.2r01

KEY:		
		Blue highlighted areas show
		Yellow highlighted areas sho

Is this Project pursuing the B3 Guidelines Small Building Method?	No

Category	Primary Material	Impact #
Cladding	Metal Panel	5
Low Slope Roofing	BUR 2-ply modified bitumen	5
Pitched Roofing	NA	0
Exterior wall material (above grade)	Galvanized steel stud	3
Columns & Beams material	Concrete site cast	5
Cavity insulation (wall)	Fiberglass batt/blown	1
Cavity insulation (roof)	NA	0
Board insulation (wall)	XPS	5
Board insulation (roof)	XPS	5
Board insulation (below grade)	XPS	5
		4.25 **Impact Score**
		FAIL

Path 3 – Material Level LCA Approach

BASE CASE

NOTES:

1. An Impact Score of < 1.75 is required for compliance with GWP Reduction Path 3 for projects pursuing the E
2. An Impact Score of < 1.65 is required for compliance with GWP Reduction Path 3 for all other projects

Appendix M-1a: Material Selection Calculator

B3 Guidelines - Version 3.2r01

KEY:		
	(blue)	Blue highlighted areas show
	(yellow)	Yellow highlighted areas sho

Is this Project pursuing the B3 Guidelines Small Building Method?	Yes

Category	Primary Material	Impact #
Cladding	Fiber cement	2
Low Slope Roofing	EPDM membrane (60mil)	1
Pitched Roofing	NA	0
Exterior wall material (above grade)	Galvanized steel stud	3
Columns & Beams material	Concrete precast	3
Cavity insulation (wall)	Mineral wool batt	1
Cavity insulation (roof)	NA	0
Board insulation (wall)	EPS	1
Board insulation (roof)	Polyiso	1
Board insulation (below grade)	EPS	1
		1.63 **Impact Score**
		PASS

Path 3 – Material Level LCA Approach

BASE CASE

NOTES:

1. An Impact Score of < 1.75 is required for compliance with GWP Reduction Path 3 for projects pursuing the E
2. An Impact Score of < 1.65 is required for compliance with GWP Reduction Path 3 for all other projects

END OF SESSION 1 – QUESTIONS?