LUNCH & LEARN

Thursday, April 19, 2018

Life Cycle and Evaluation

Life Cycle Assessment (LCA) in the Design Workflow

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AIA Continuing Education

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This course has been registered with the AIA's CES program.

Course #: ZGFAPR1918
Provider #: C181

Course Description

The purpose of this presentation is to discuss Life Cycle Assessment (LCA) tools, benefits of analysis, and potential workflows that allow architects and designers to engage with the embodied environmental impacts of building materials. This includes the optimization of higher performance materials and reduction of higher impact material early in the design process through the evaluation of multiple options as well as the overall evaluation of the whole building prior to construction.

Learning Objectives

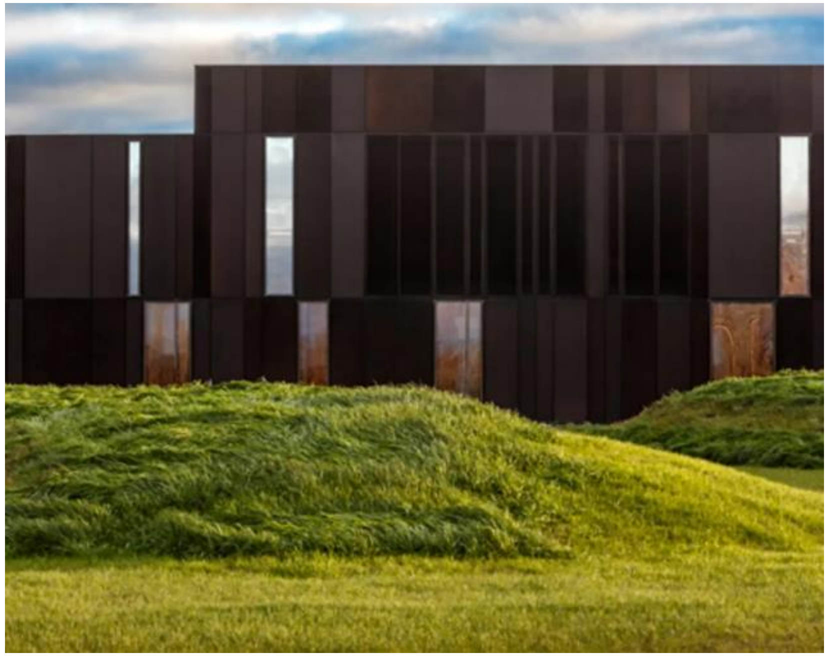
1. Learn to make the argument for LCA with clients and project teams and understand how to present LCA data to support decision making.
2. Learn effective methods for integrating LCA into every phase of the design process, from pre-design through construction documentation.
3. Understand the required methods and standards for the LEED v4 Whole Building Life Cycle Reduction Credit and proper method for submitting credit documentation.
4. Understand how LCA can influence material choices and specification writing.

1. The Argument for LCA

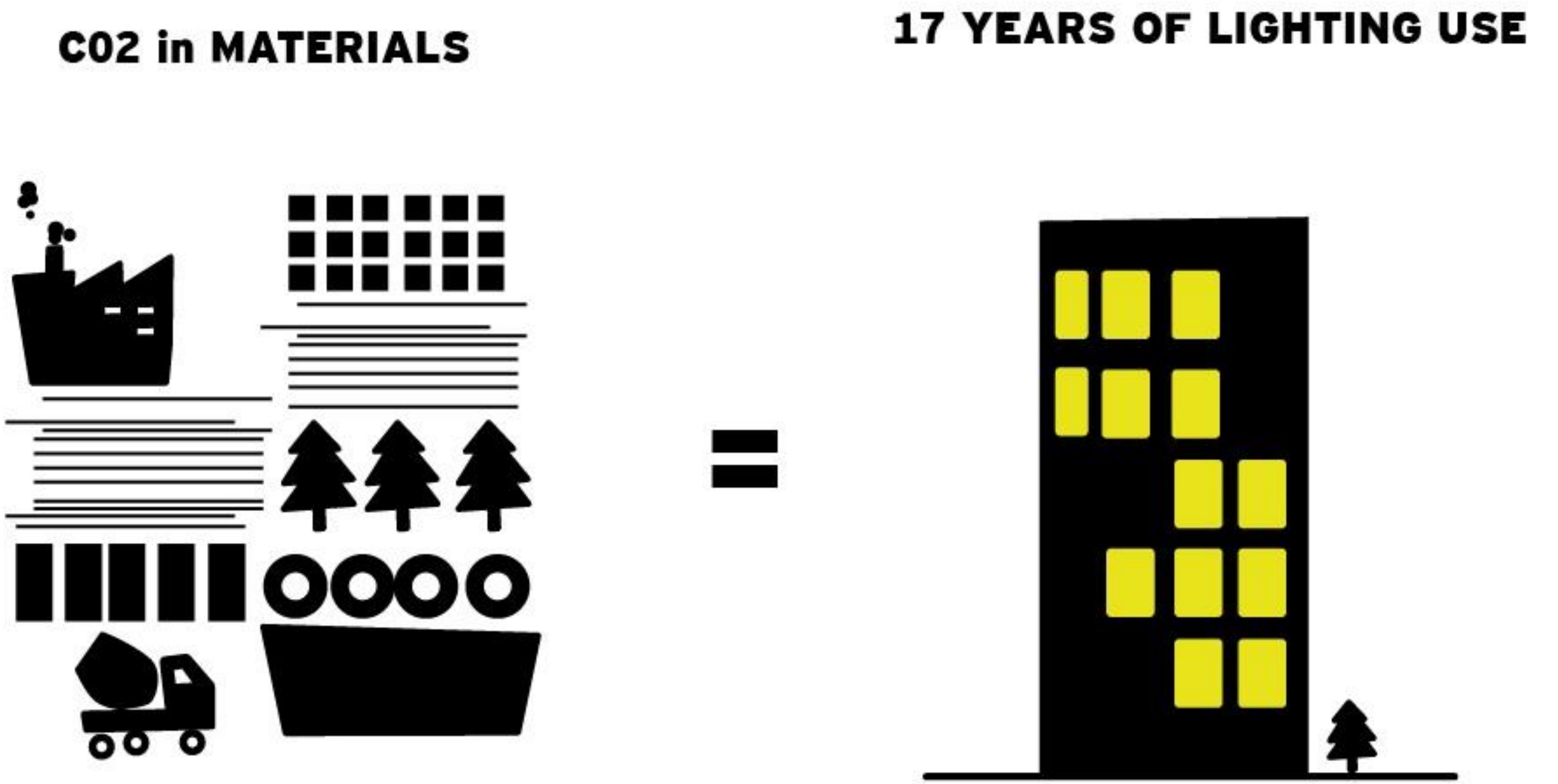
2016 AIA Institute Award Winners





Daylight Timelapse of KieranTimberlake’s Studio


C02 in MATERIALS
17 YEARS OF LIGHTING USE

Mineral extraction

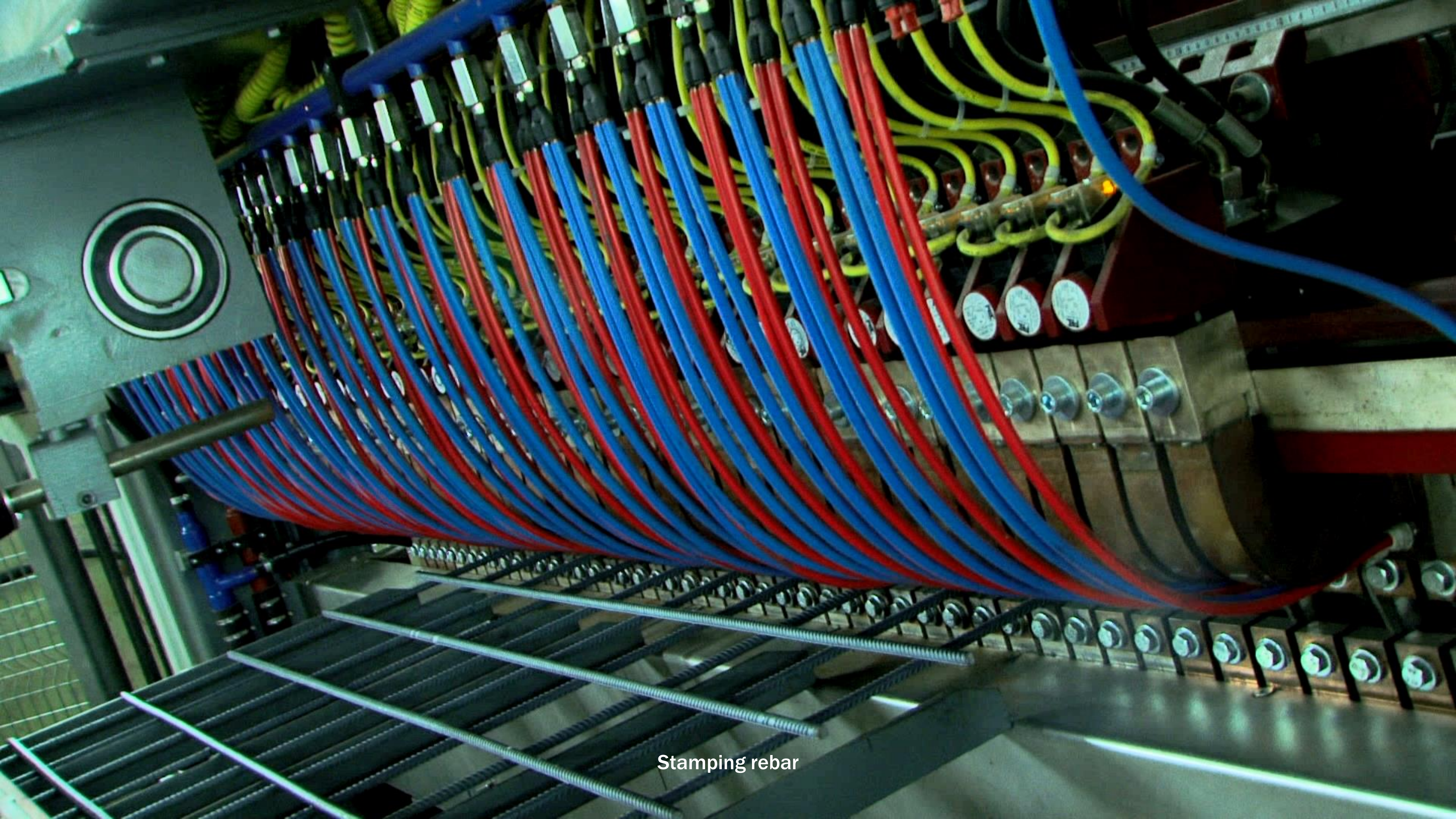
Dynamite, drills, and dump trucks

Hot-rolled steel manufacturing process

Steel refinement

Pouring concrete masonry units

Heat insulation formation



Stamping rebar

Site preparation

Resource and energy usage in the formation of a foundation

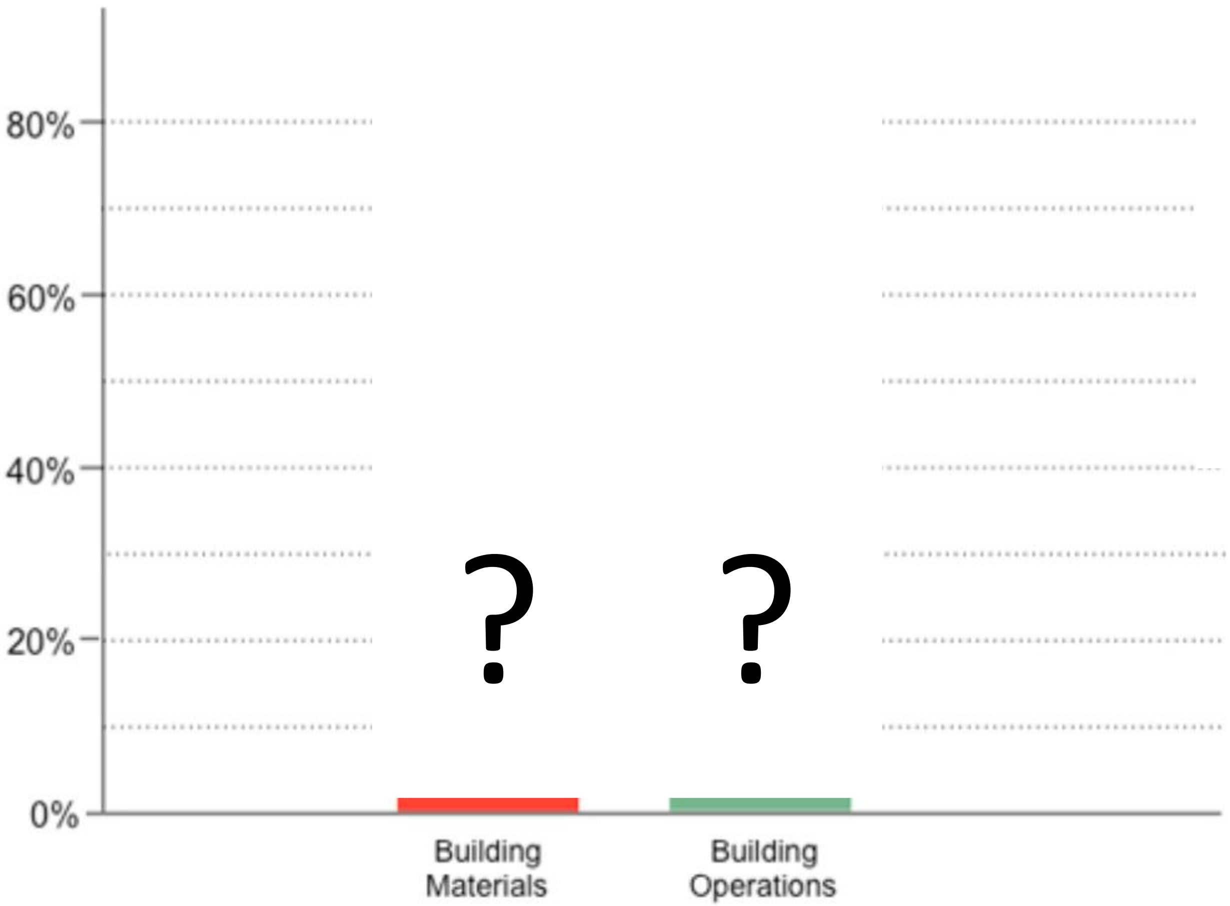

Energy use from building operations

End of life

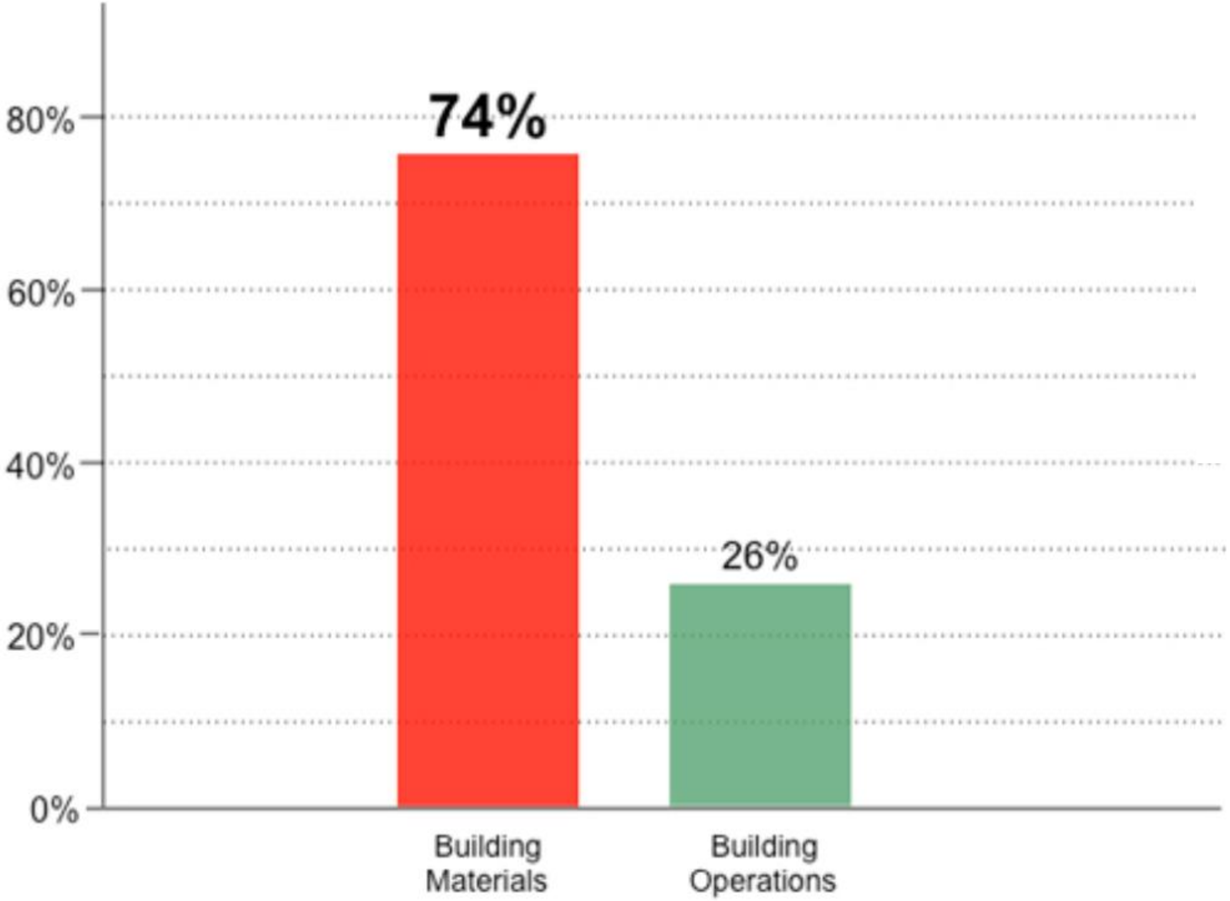

Building demolition

Sorting for recycling, reuse and disposal


How can we track all of this?



2030 Energy Consumption Footprint of All Buildings Constructed Between 2015 - 2030 (900 Billion Sq. Ft).



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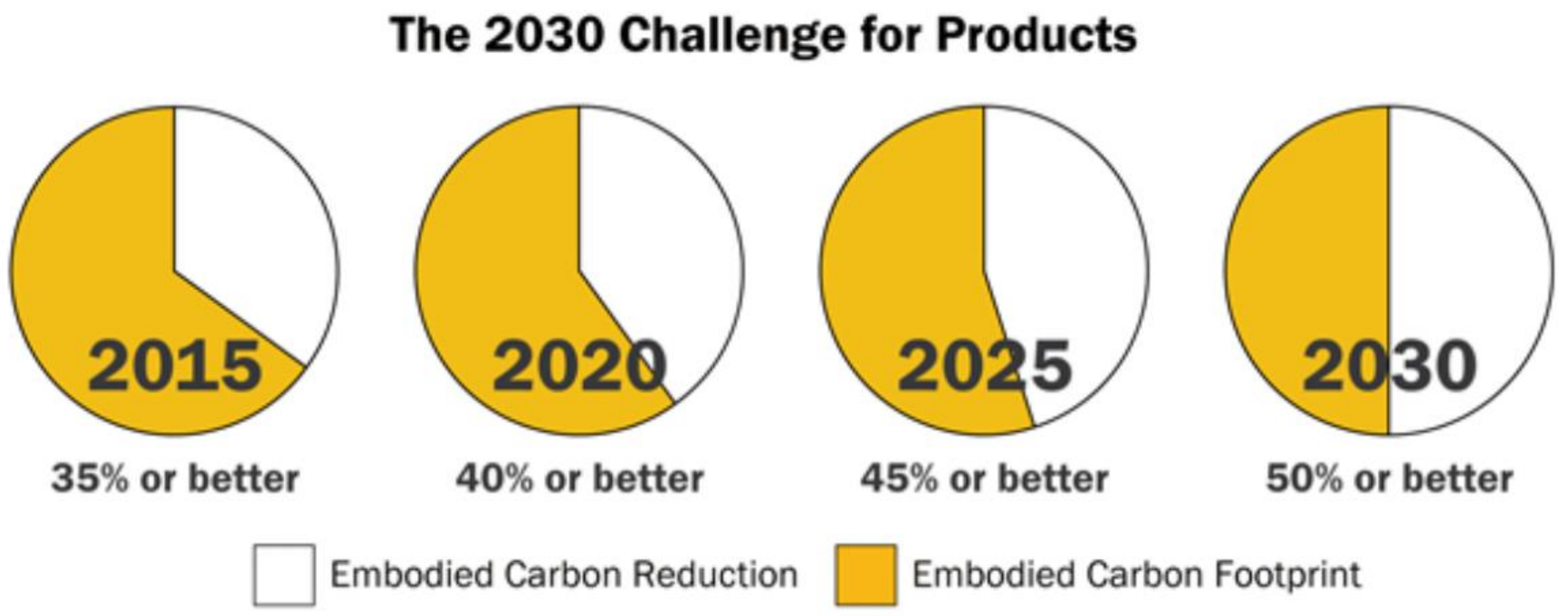
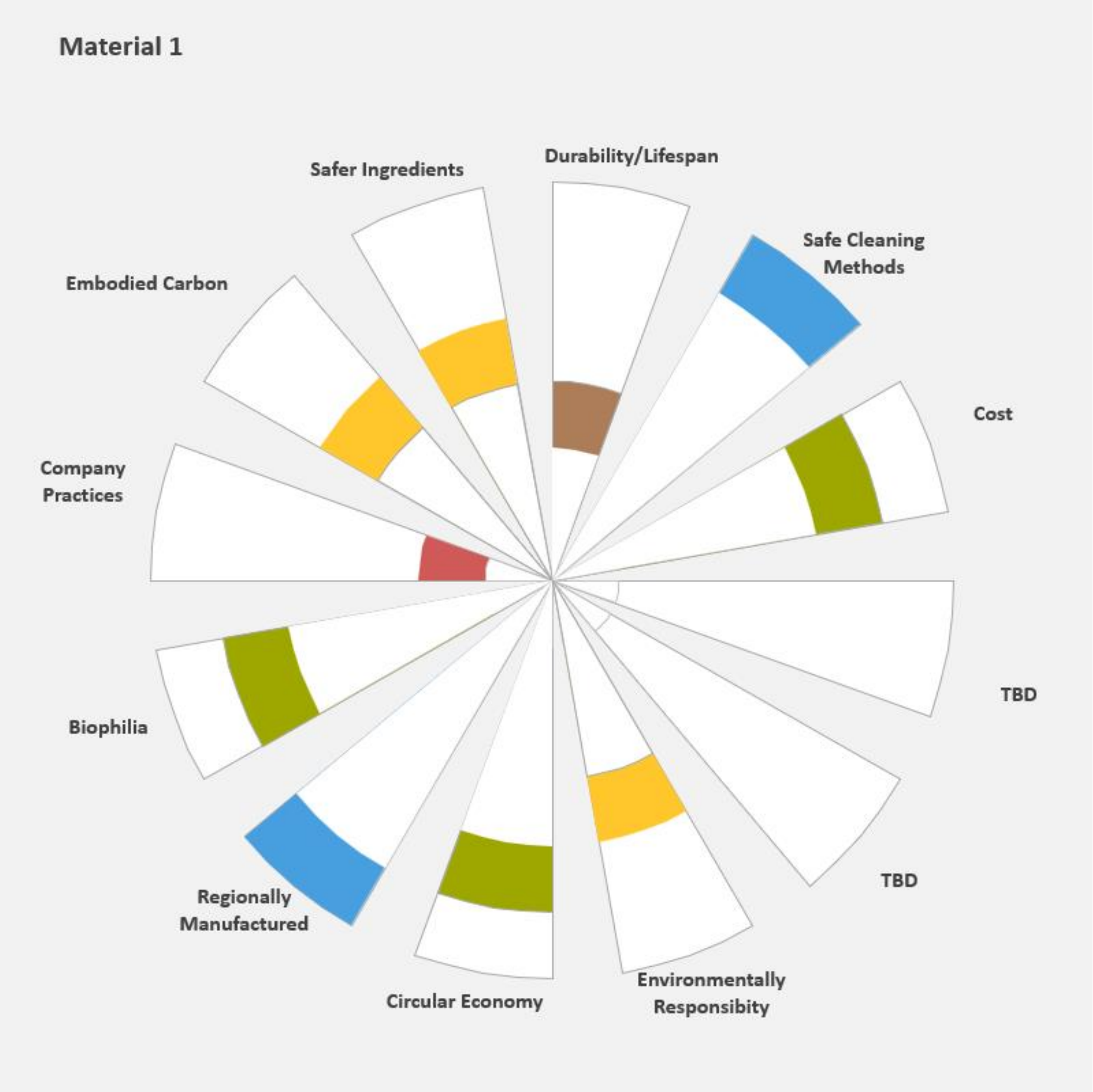


The 2030 Challenge for Products calls on the global architecture, planning, design, and building community, to specify, design, and manufacture products for new developments, buildings, and renovations to meet a maximum carbon-equivalent footprint of 30% below the product category average through 2014 – increasing to 50% by 2030.




MATERIALS TRANSPARENCY

WHY IS THIS IMPORTANT?

THE SITUATION

Today there are 80,000+ chemicals in use

- 85% Have no health data
- 67% Have no environmental data at all

HUMAN HEALTH IMPACTS

In 1976 there were 62,000 chemicals in use in the US. The Toxic Substances Control Act grandfathered all of them. Fewer than 200 have been tested for human safety. Only 5 of them have been banned in the United States.

PRODUCT-RELATED CHEMICAL HUMAN HEALTH CONCERNS INCLUDE:

ENDOCRINE DISRUPTION
REPRODUCTIVE
MULTI-GENERATIONAL GENETIC MUTATIONS
IMMUNE RESPONSE
VASCULAR DISEASE
NEURODEVELOPMENT
CANCER
PERSISTENT BIO ACCUMULATIVE TOXINS

WANT TO LEARN MORE?

"SIX CLASSES: A Webinar Series on Chemicals of Concern"

ENVIRONMENTAL IMPACTS

CHALLENGE FOR PRODUCTS

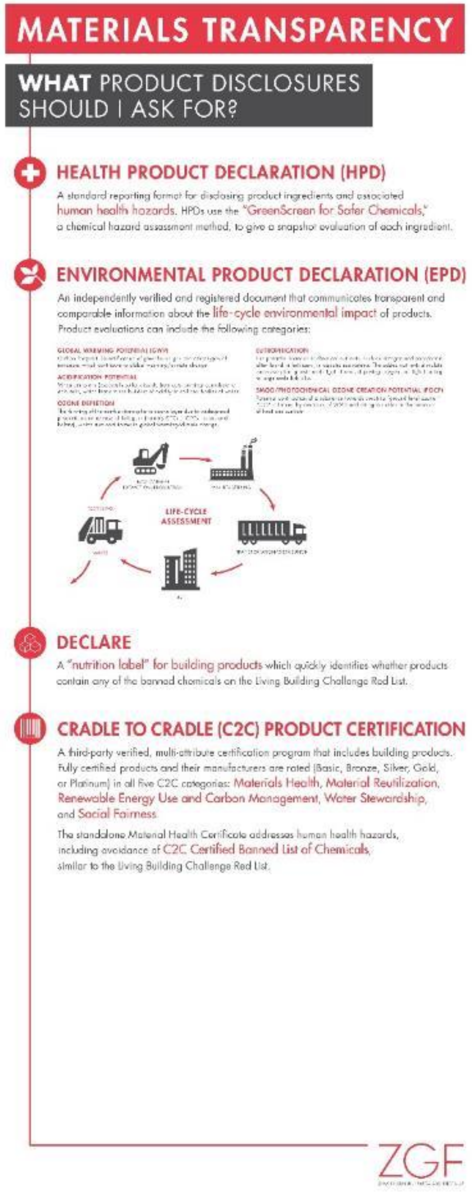
Over the first 20 years of the life of a building, 45% of total energy consumption is attributed to the embodied energy of building products and the rest is attributed to building operations.

BUILDING STANDARDS

Sustainability rating systems like LEED v4, Living Building Challenge, and The Well Building Standard are requiring or rewarding projects for efforts to select healthy, low-impact materials with transparency standards.

ZGF'S CALL TO ACTION

ZGF


MATERIALS TRANSPARENCY

WHAT PRODUCT DISCLOSURES SHOULD I ASK FOR?

HEALTH PRODUCT DECLARATION (HPD)

A standard reporting format for disclosing product ingredients and associated human health hazards. HPDs use the "GreenScreen for Safer Chemicals," a chemical hazard assessment method, to give a snapshot evaluation of each ingredient.

ENVIRONMENTAL PRODUCT DECLARATION (EPD)

An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products. Product evaluations can include the following categories:

GLOBAL WARMING POTENTIAL (GWP)
ACIDIFICATION POTENTIAL
OZONE DEPLETION
EUTROPHICATION
SMOG/PHOTOCHEMICAL OZONE CREATION POTENTIAL (POCP)

LIFE-CYCLE ASSESSMENT

DECLARE

A "nutrition label" for building products which quickly identifies whether products contain any of the banned chemicals on the Living Building Challenge Red List.

CRADLE TO CRADLE (C2C) PRODUCT CERTIFICATION

A third-party verified, multi-attribute certification program that includes building products. Fully certified products and their manufacturers are rated (Basic, Bronze, Silver, Gold, or Platinum) in all five C2C categories: Materials Health, Material Reutilization, Renewable Energy Use and Carbon Management, Water Stewardship, and Social Fairness.

The standalone Material Health Certificate addresses human health hazards, including avoidance of C2C Certified Banned List of Chemicals, similar to the Living Building Challenge Red List.

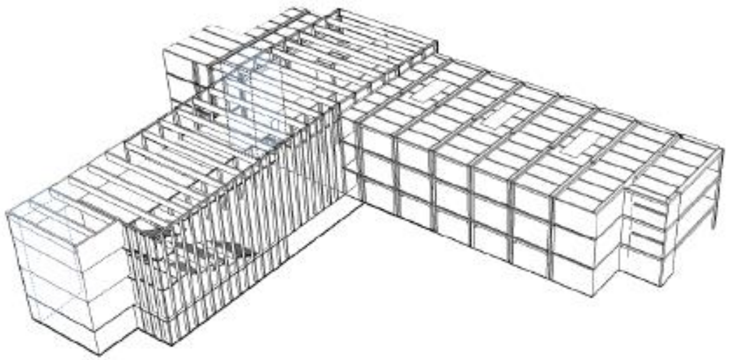
ZGF

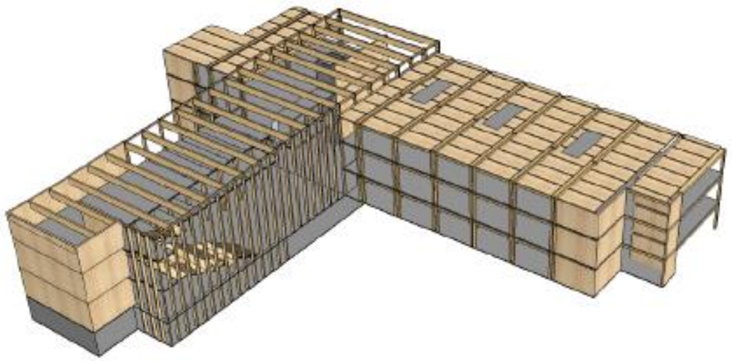
2. What’s in a Building?

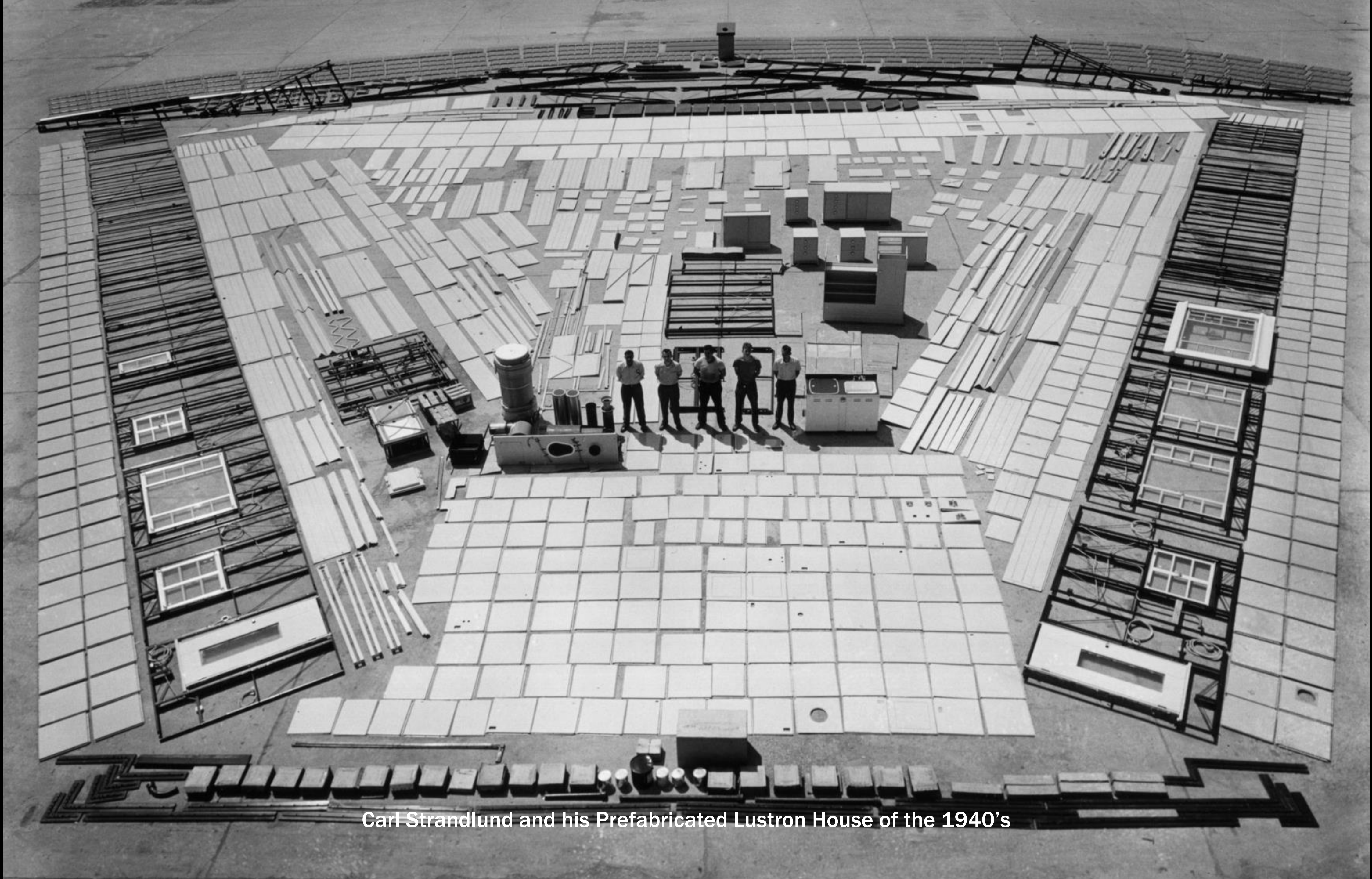
Do Less Harm – Reducing Impact

Proposed Building
44,000 - 620,000 MT CO2e

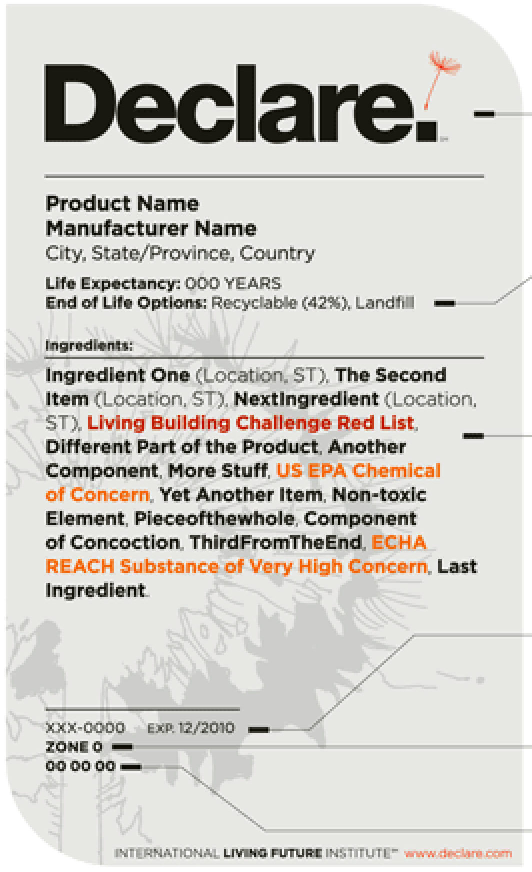
78% to 98% Reduction







Carl Strandlund and his Prefabricated Lustron House of the 1940’s



Intentionally simple in scope. By focusing on product ingredients, we hope to 'level the playing field' and create a platform for constructive conversations about the human health and ecological impacts of the decisions we make.

Options: Take back program; Salvageable or reusable in its entirety; Recyclable (%); Landfill; Hazardous waste (%).

All constituent parts of a product, including trace elements, whether directly added or otherwise present – even if 'naturally occurring'. Items are color coded to communicate potential hazards:

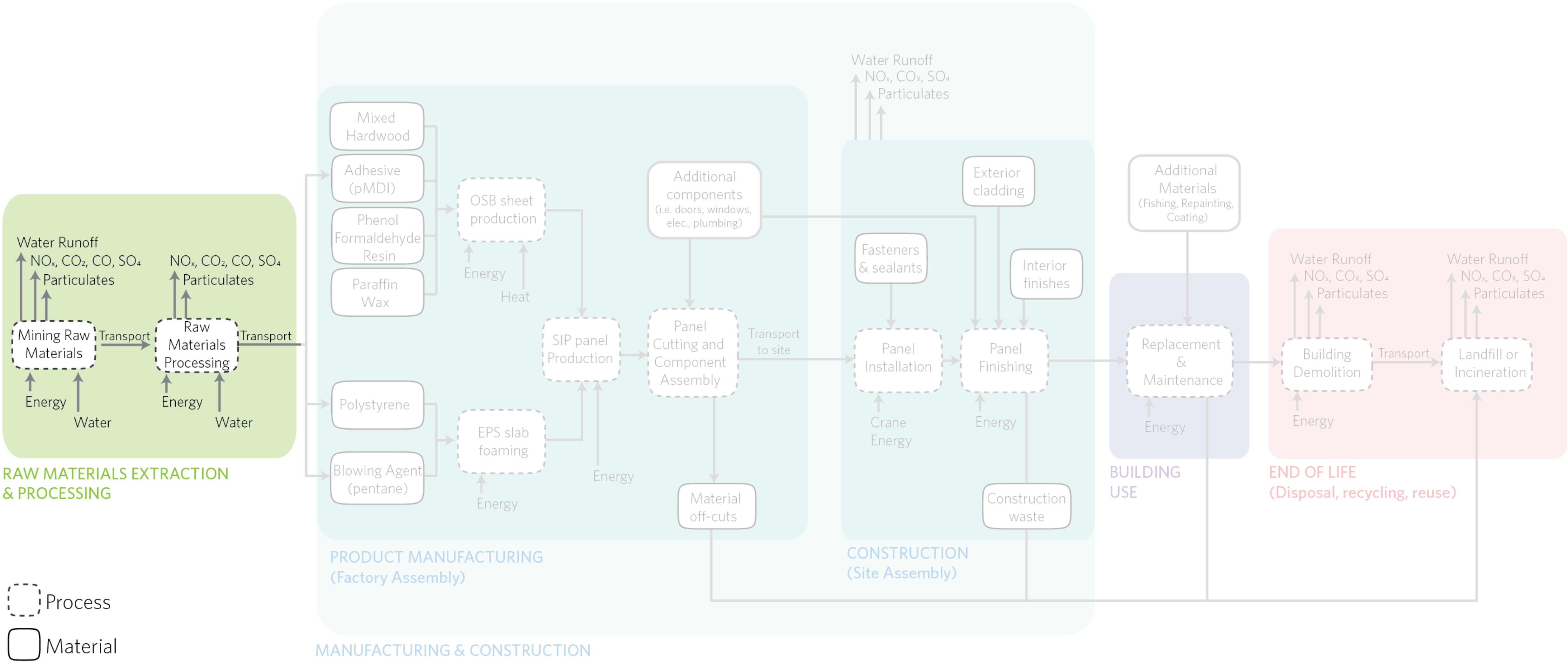
Living Building Challenge Red List
US EPA Pollution Prevention + Toxics Existing Chemicals Program or European Chemicals Agency REACH Substances of Very High Concern
Not referenced in any of the three programs noted above

Declare identifier for company + product
Valid for 12 months, starting with the date of issue

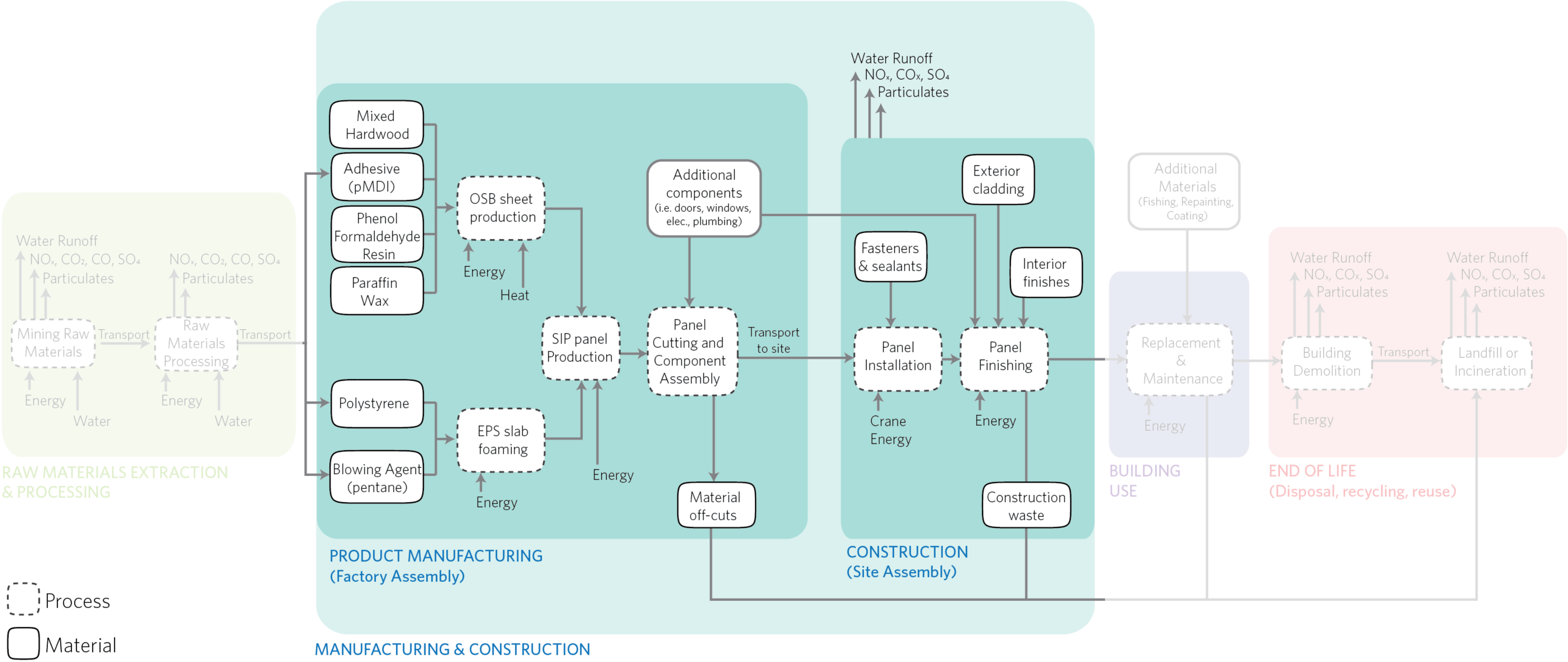
Designation per the Appropriate Sourcing Imperative in the Living Building Challenge, intended to support the growth of regional economies rooted in sustainable practices, products and services.

CSI MasterFormat 2010 classification

1. Raw Material Extraction and Processing



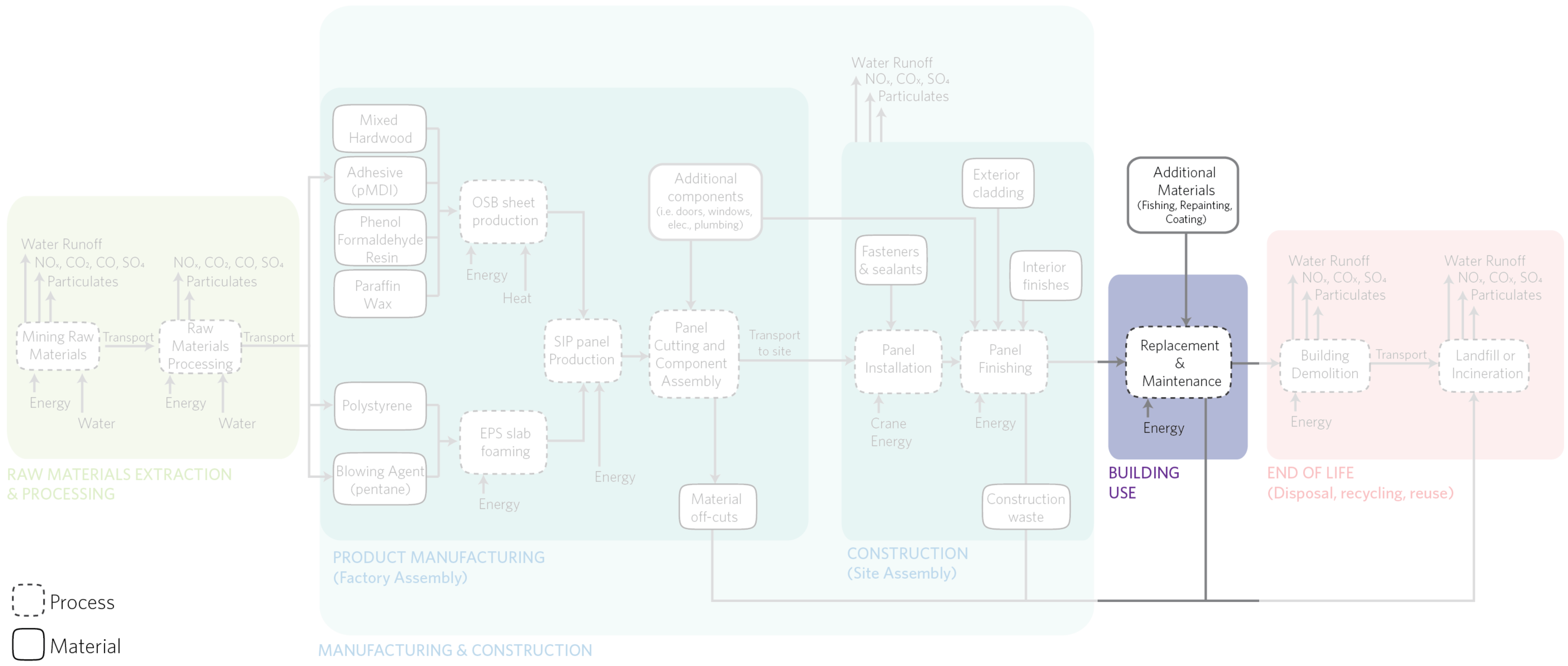
2. Manufacturing and Construction



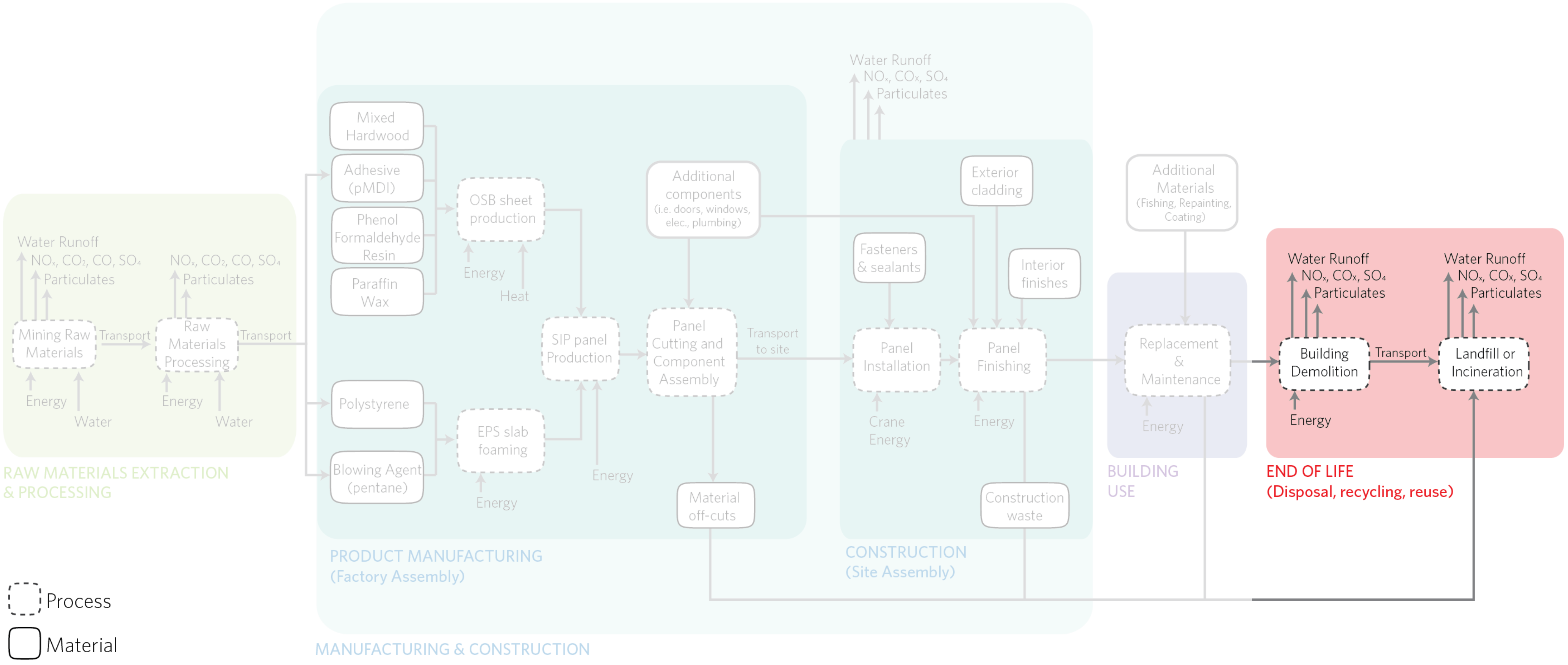
Process

Material

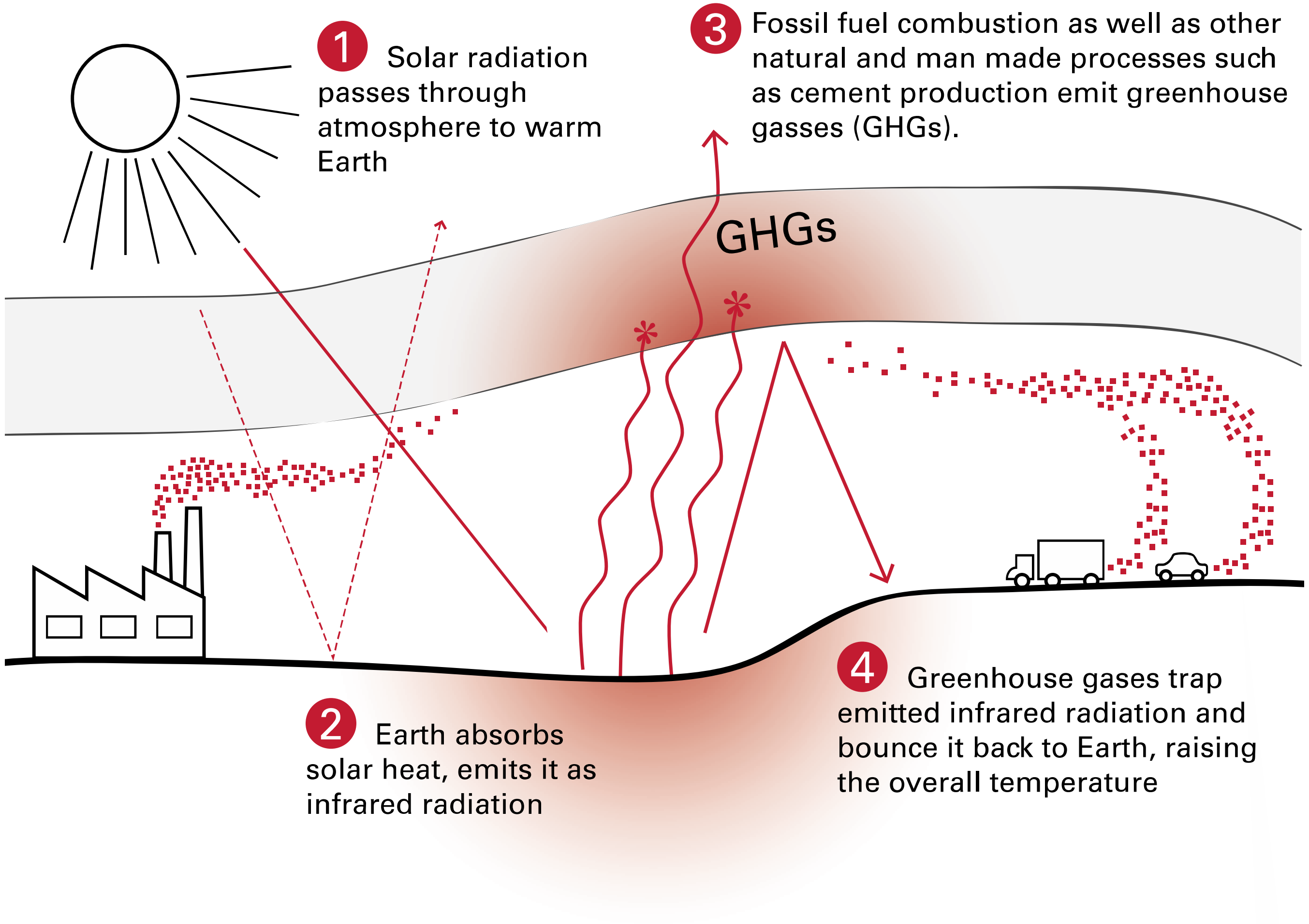
3. Building Use



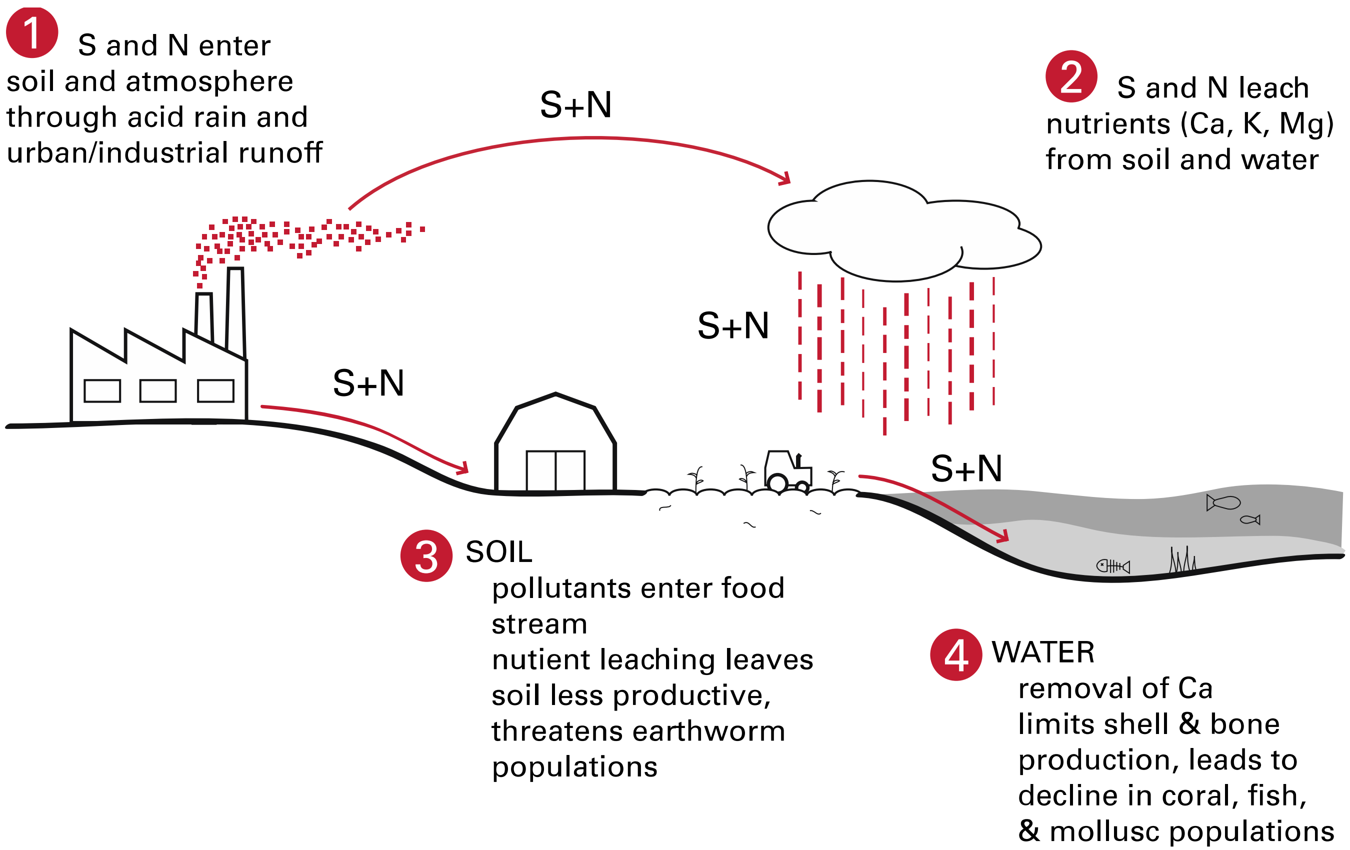
4. End of Life


Water Runoff
NOx, CO2, CO, SO4
Particulates
Mining Raw Materials
Transport
Raw Materials Processing
Transport
Energy
Water
RAW MATERIALS EXTRACTION & PROCESSING
Mixed Hardwood
Adhesive (pMDI)
Phenol Formaldehyde Resin
Paraffin Wax
OSB sheet production
Energy
Heat
Polystyrene
Blowing Agent (pentane)
EPS slab foaming
SIP panel Production
Additional components (i.e. doors, windows, elec., plumbing)
Panel Cutting and Component Assembly
Material off-cuts
Transport to site
PRODUCT MANUFACTURING (Factory Assembly)
Water Runoff
NOx, COx, SO4
Particulates
Exterior cladding
Fasteners & sealants
Interior finishes
Panel Installation
Panel Finishing
Crane Energy
Construction waste
CONSTRUCTION (Site Assembly)
MANUFACTURING & CONSTRUCTION
Additional Materials (Fishing, Repainting, Coating)
Replacement & Maintenance
BUILDING USE
Building Demolition
Landfill or Incineration
END OF LIFE (Disposal, recycling, reuse)
Process
Material

Impact Categories



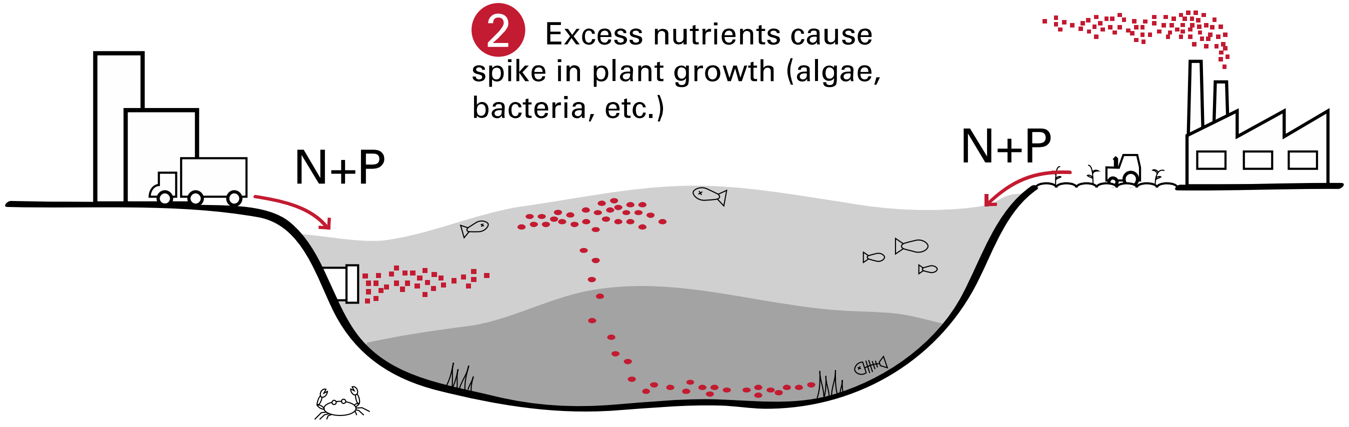
Source: K. Simonen, *Life Cycle Assessment*, 2014



Source: K. Simonen, *Life Cycle Assessment*, 2014

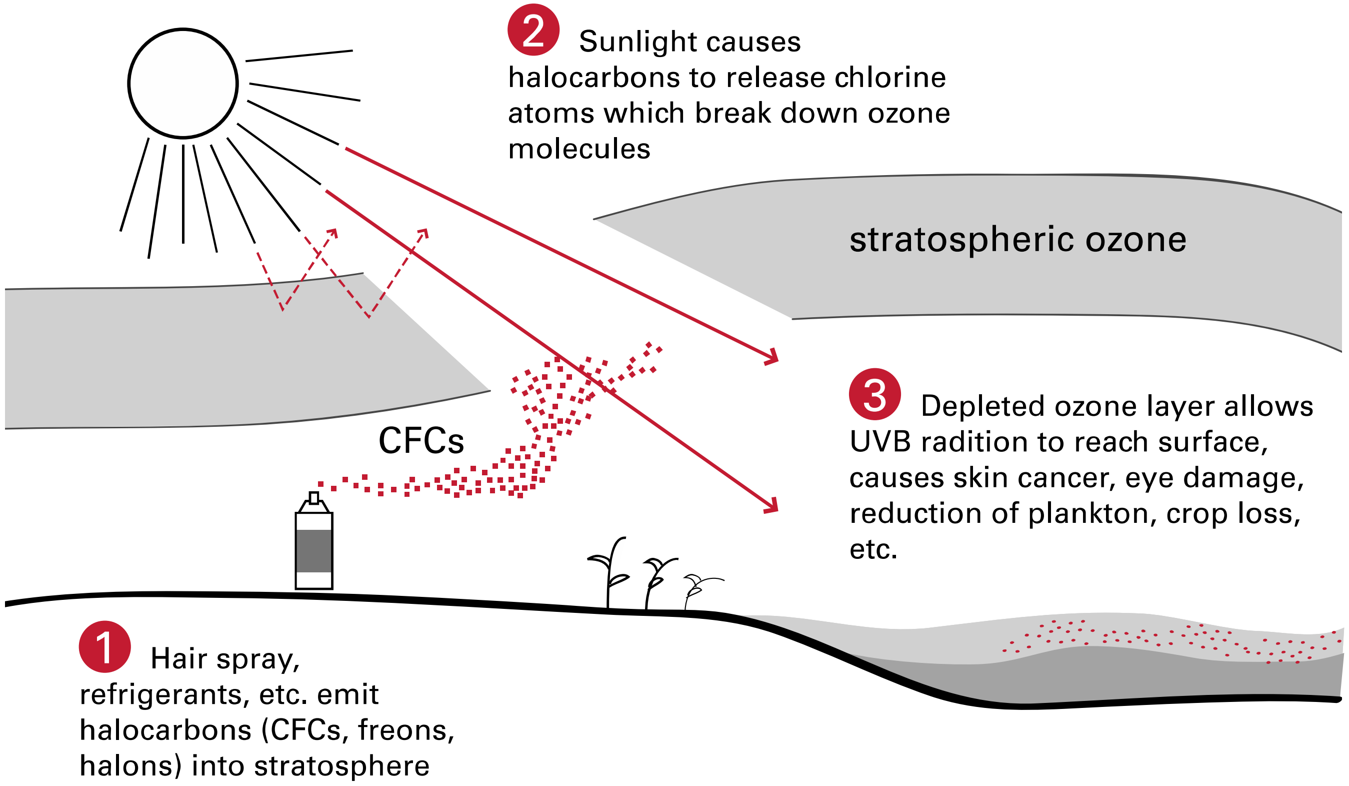
1 Agricultural, urban, and industrial runoff adds excess nutrients (N + P) to water systems

2 Excess nutrients cause spike in plant growth (algae, bacteria, etc.)



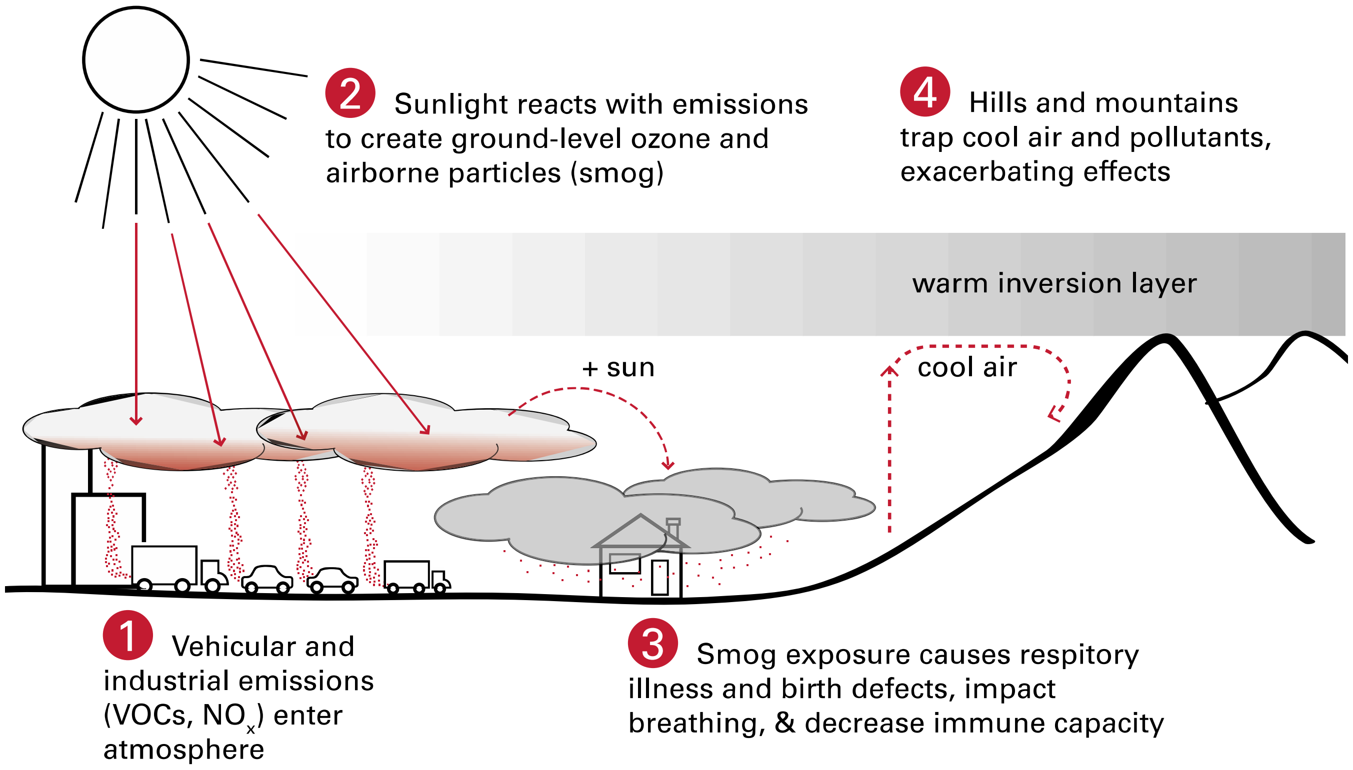
3 New plant population consumes all available oxygen, creating dead (hypoxic) zones and causing other species to flee or die

Source: K. Simonen, *Life Cycle Assessment*, 2014



Source: K. Simonen, *Life Cycle Assessment*, 2014

Smog



Source: K. Simonen, *Life Cycle Assessment*, 2014

	Type	Example	Unit
Non-Renewable	Energy	Coal combustion for electricity	MJ
	Material	Crude oil as material input to plastic	MJ
Renewable	Energy	Bio-fuel	MJ
	Material	Wood burned in a furnace	MJ

Source: K. Simonen, *Life Cycle Assessment*, 2014

3. LCA Design Workflow

MATERIALS AND RESOURCES CREDIT

Building Life-Cycle Impact Reduction

STEP 1: CALCULATE BUILDING MATERIALS

STEP 2: SELECT APPROPRIATE TOOLS AND DATA SETS FOR LCA ASSESSMENT

STEP 3: CREATE AND MODEL BASELINE BUILDING

STEP 4: SELECT RELEVANT IMPACT MEASUREMENT SYSTEMS

STEP 5: USE LCA TO MAKE DESIGN DECISIONS THAT REDUCE ENVIRONMENTAL IMPACTS

STEP 6: INCORPORATE FINAL LCA RESULTS

MATERIALS AND RESOURCES CREDIT

Building Life-Cycle Impact Reduction

STEP 2: SELECT APPROPRIATE TOOLS AND DATA SETS FOR LCA ASSESSMENT

STEP 3: CREATE AND MODEL BASELINE BUILDING

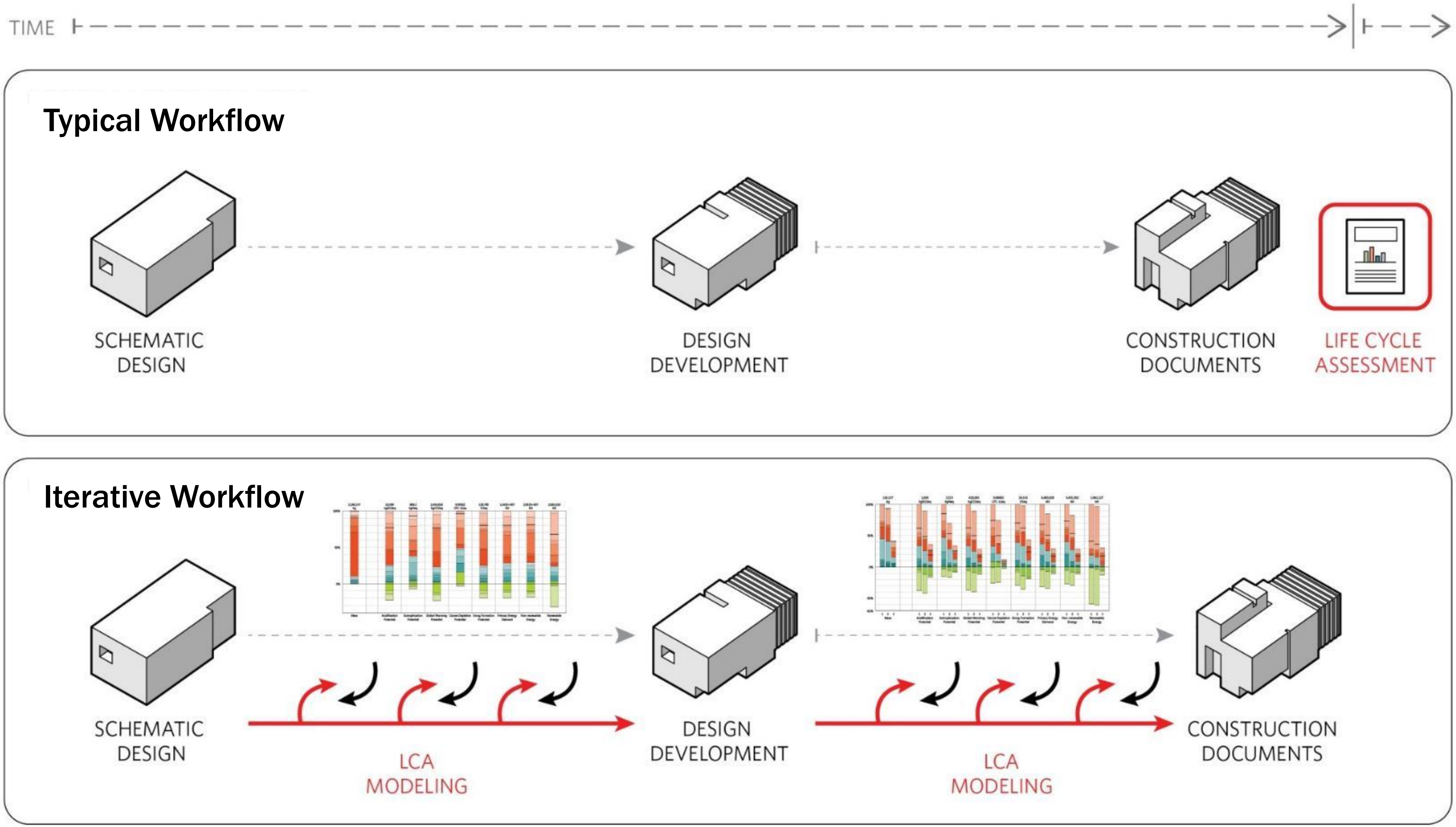
STEP 1: CALCULATE BUILDING MATERIALS

STEP 5: USE LCA TO MAKE DESIGN DECISIONS THAT REDUCE ENVIRONMENTAL IMPACTS

STEP 6: INCORPORATE ITERATIVE LCA RESULTS

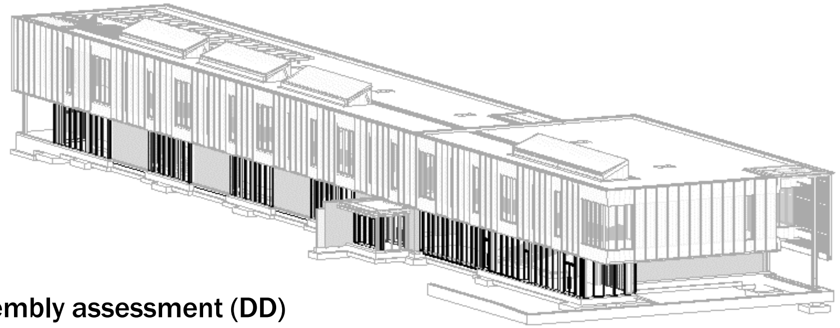
STEP 4: SELECT RELEVANT IMPACT MEASUREMENT SYSTEMS

Typical vs. Iterative LCA Workflow

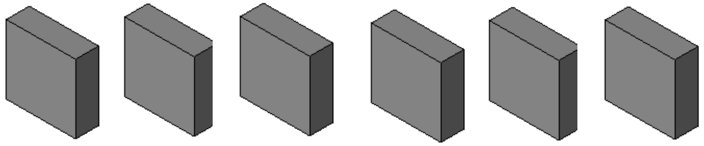


Select Appropriate Scope for Design Phase

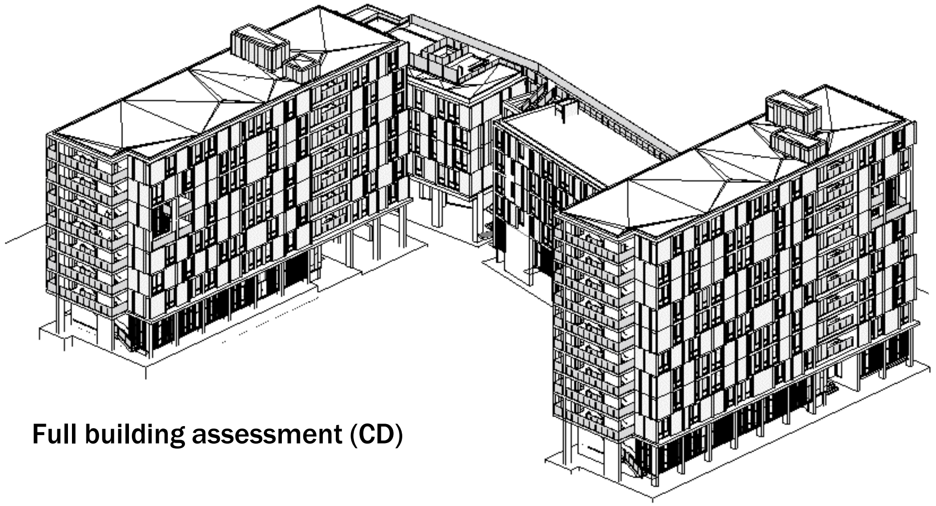
- Single material (product) assessment
- Material or assembly comparison
- Design options
  (multiple materials and assemblies)
- Full building assessment



Assembly assessment (DD)

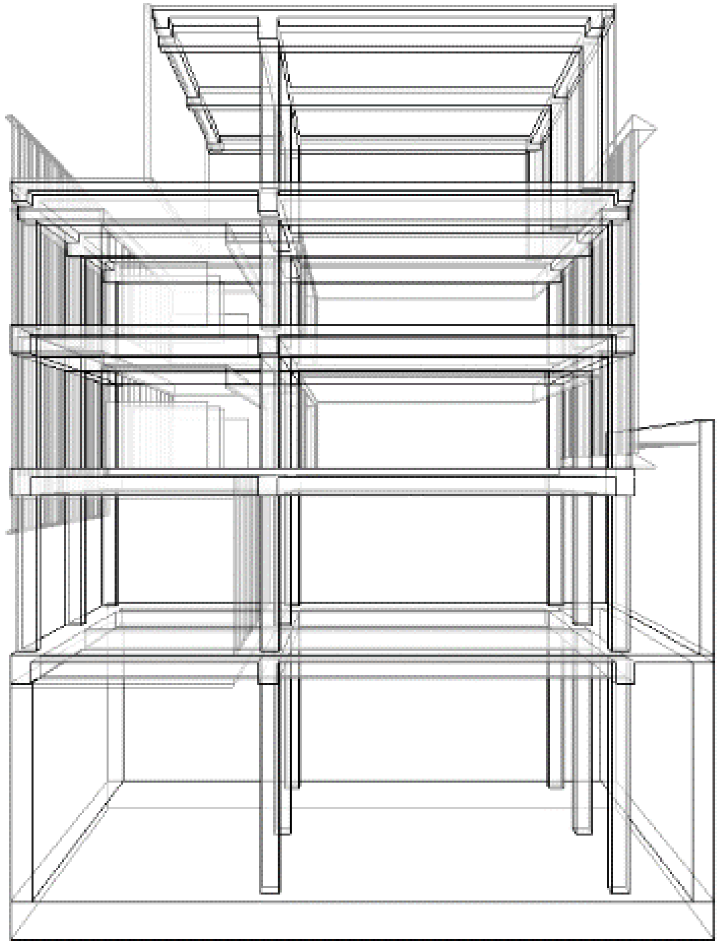


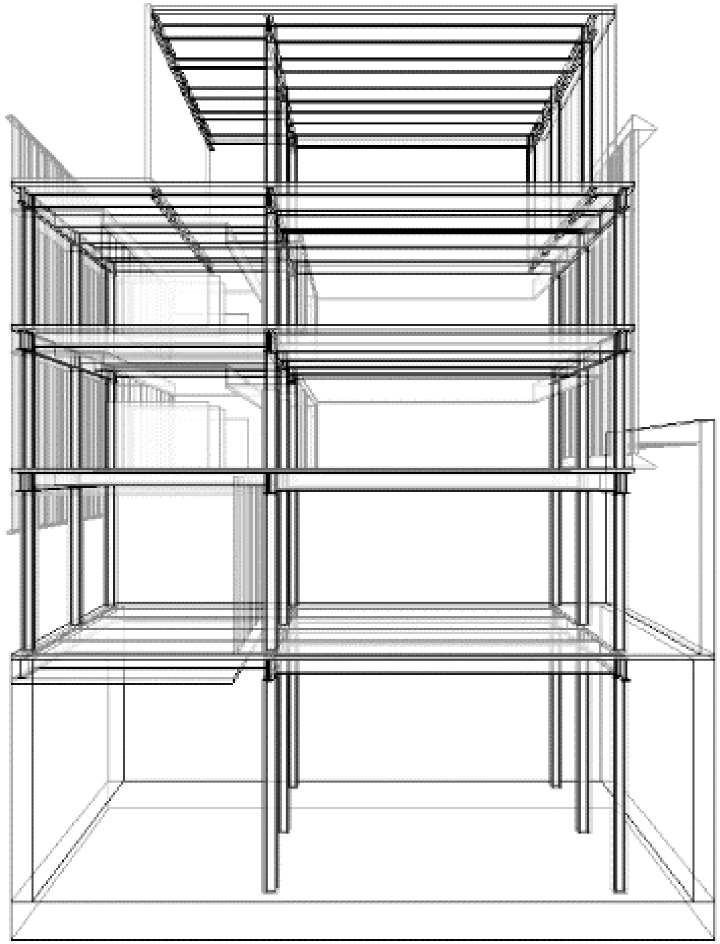
Component assessment (SD)



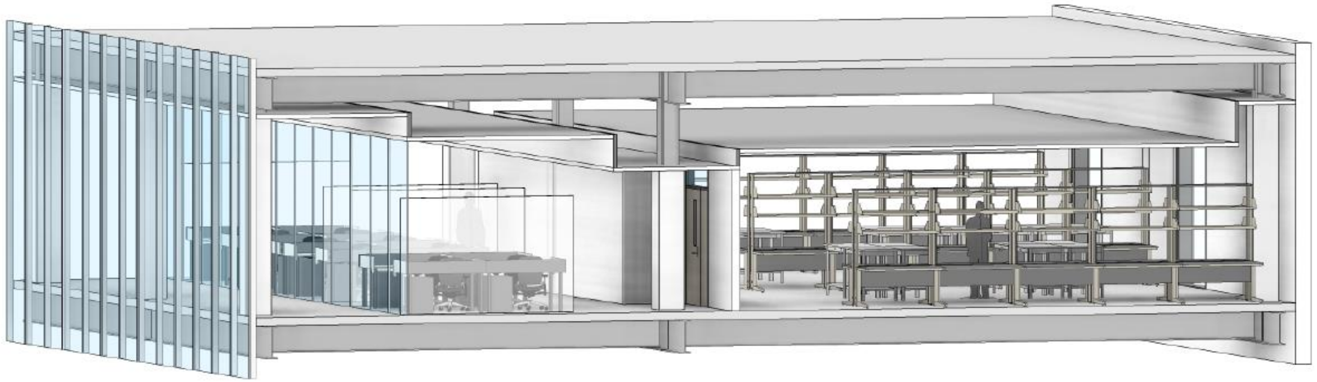
Full building assessment (CD)

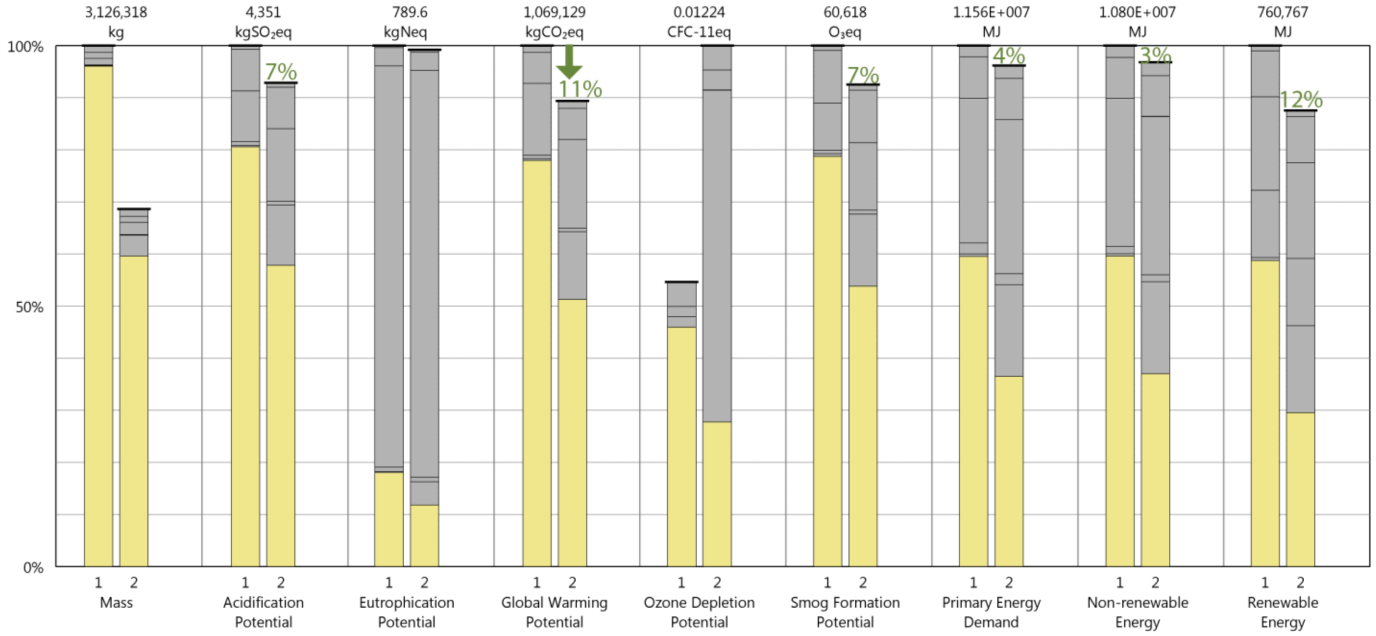
Can we reduce the impact of a building before structural selection?





Schematic Design: Evaluating Concrete vs. Steel in a Lab Bay Study





Option 1: Concrete

Option 2: Steel

Concrete with 25% Fly Ash Content

Other Materials

11% reduction in GWP

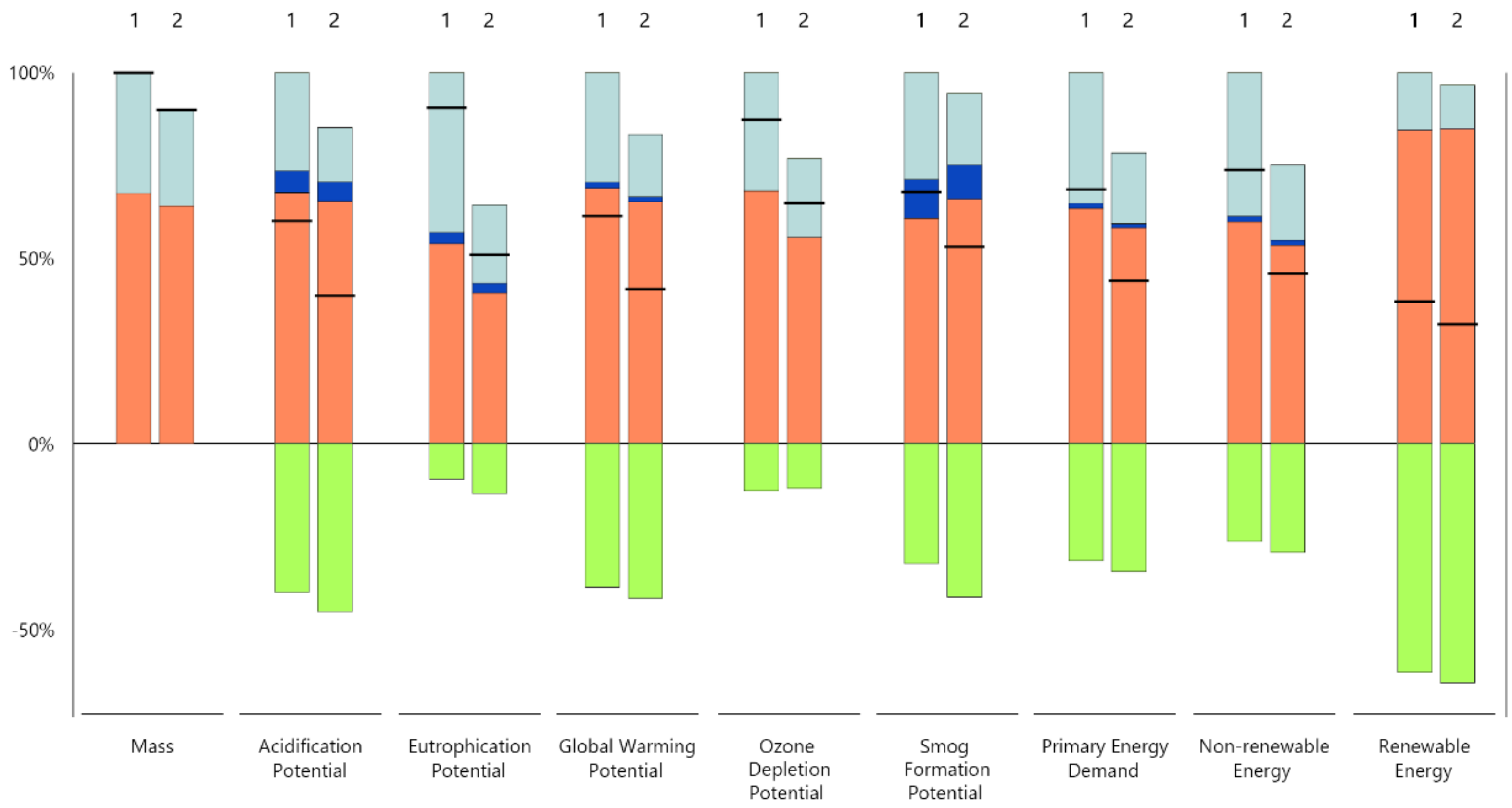
Annual emissions of ~25 passenger vehicles

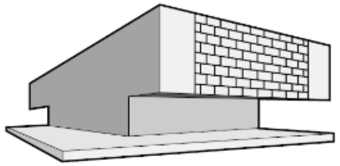
Carbon sequestered by 96.4 acres of forest

Even though steel is better, still has a lot of concrete.

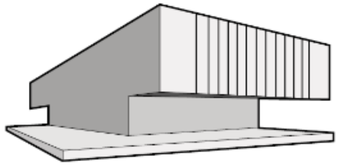
Design Development: Comparing Curtain Wall with Insulated Metal Panel Shingles

Design Development: Comparing Curtain Wall with Insulated Metal Panel Shingles





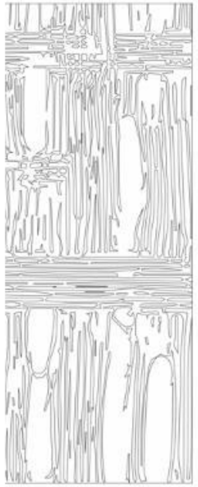
Option 1



Option 2

Design Development: Optimizing Material Usage in Panel Patterning

GREAT MAPLE
TANGENTIAL



GREAT MAPLE
RADIAL

SOLID

WILLOW
TANGENTIAL

WILLOW
RADIAL

WILLOW
TRANSVERSAL

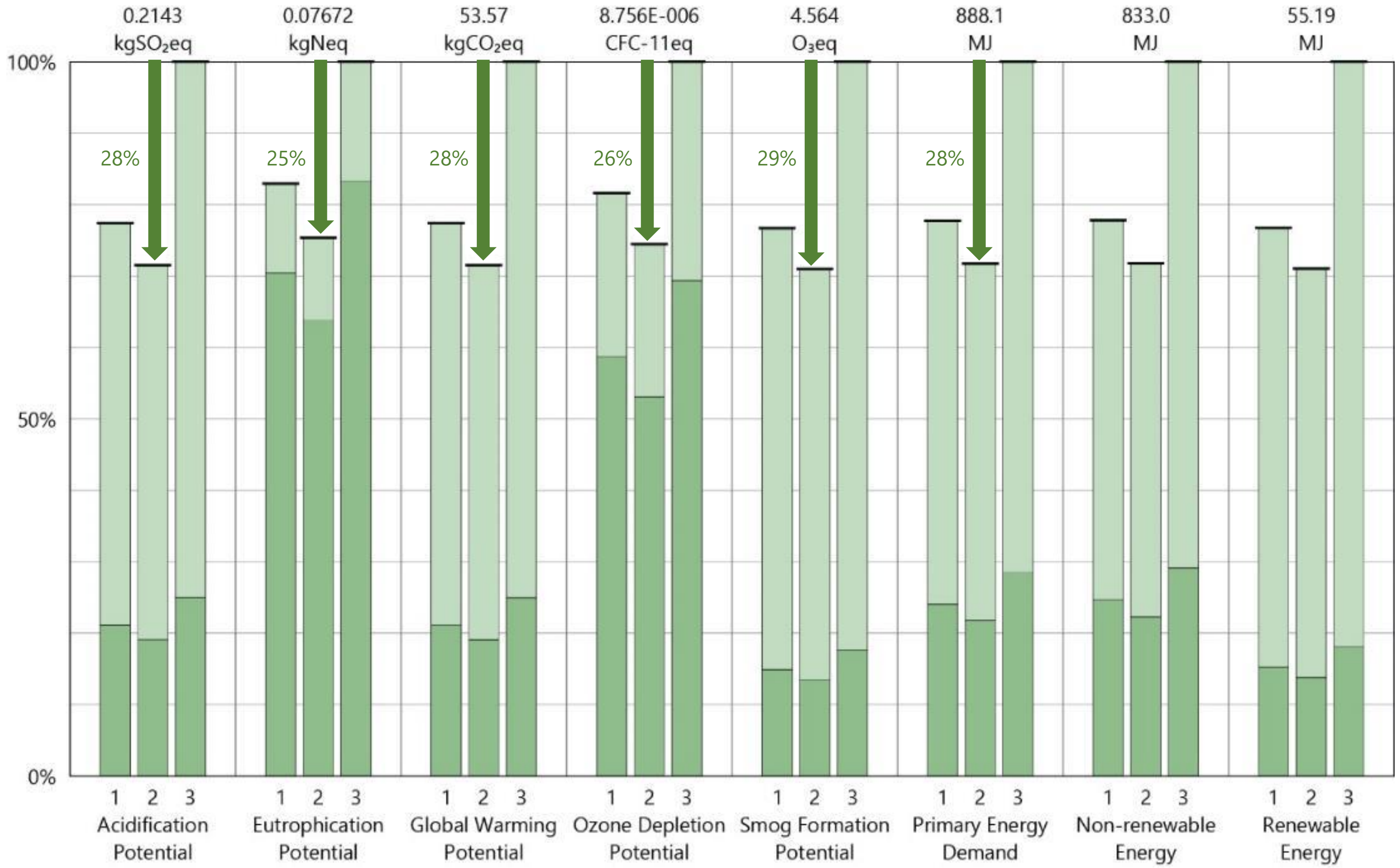
Comparative Results

Design Options

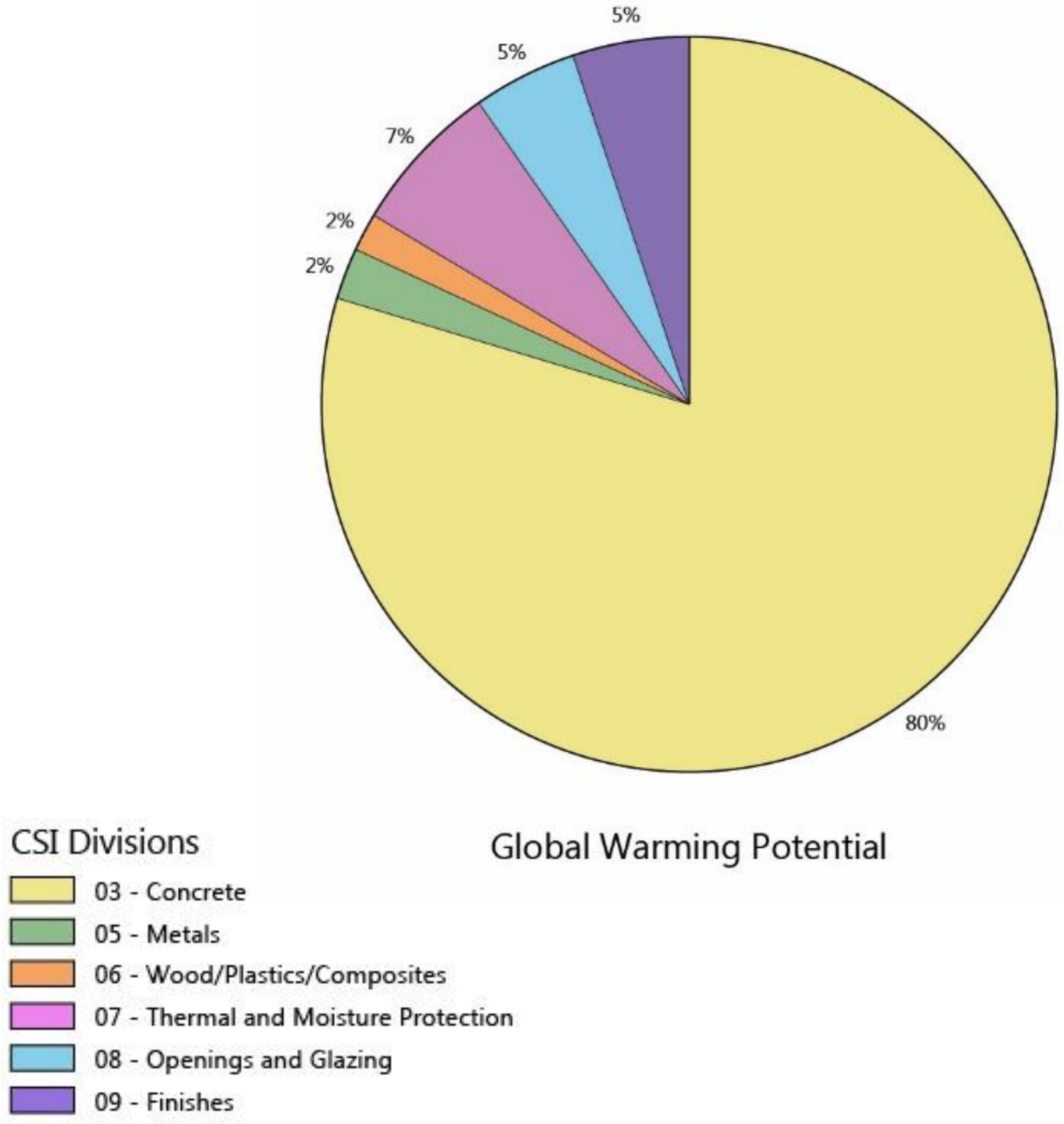
Option 1 - Maple Radial (primary)
Option 2 - Willow Tangential
Option 3 - Solid

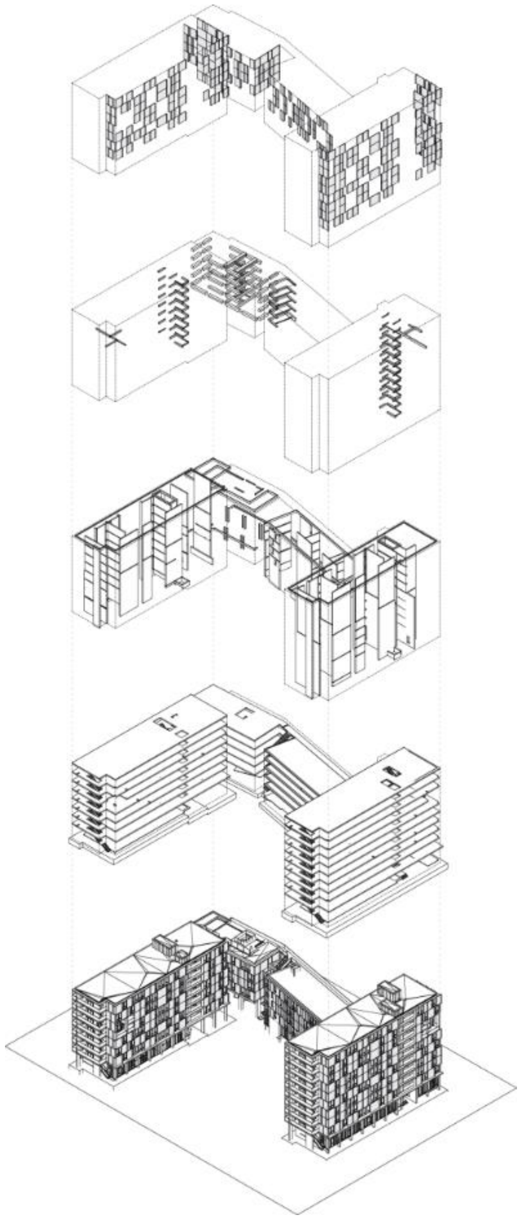
Materials

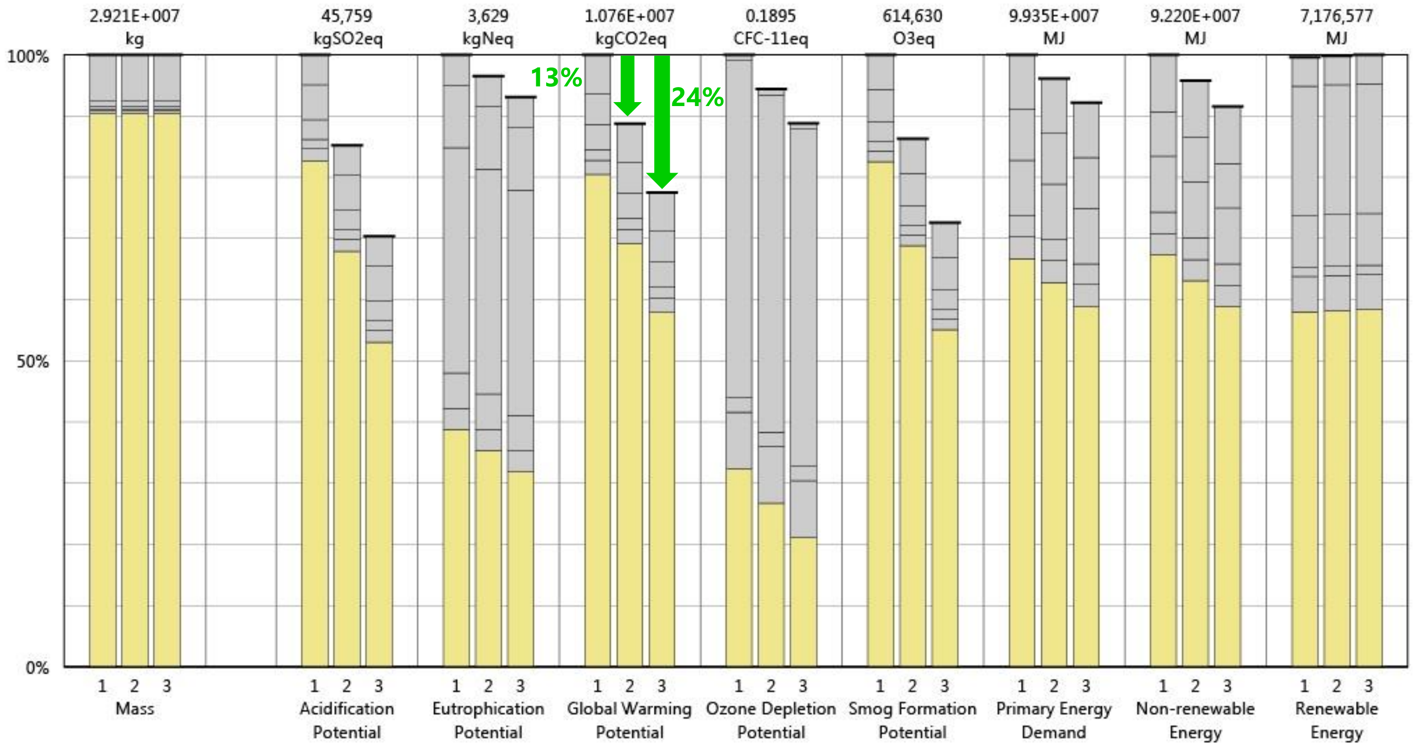
Fluoropolymer coating, metal stock
Steel, sheet




3
1
2
3
2


5%
5%
7%
2%
2%
80%
CSI Divisions
03 - Concrete
05 - Metals
06 - Wood/Plastics/Composites
07 - Thermal and Moisture Protection
08 - Openings and Glazing
09 - Finishes
Global Warming Potential





Results per CSI Division

Design Options

Option 1 - Concrete, 00% Fly Ash

Option 2 - Concrete, 25% Fly Ash

Option 3 - Concrete, 50% Fly Ash

CSI Divisions

03 - Concrete

05 - Metals

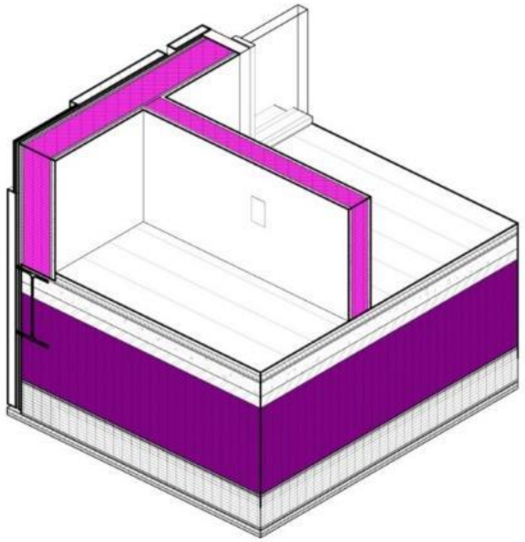
06 - Wood/Plastics/Composites

07 - Thermal and Moisture Protection

08 - Openings and Glazing

09 - Finishes

Construction Administration: Environmental Impacts by Substitutions

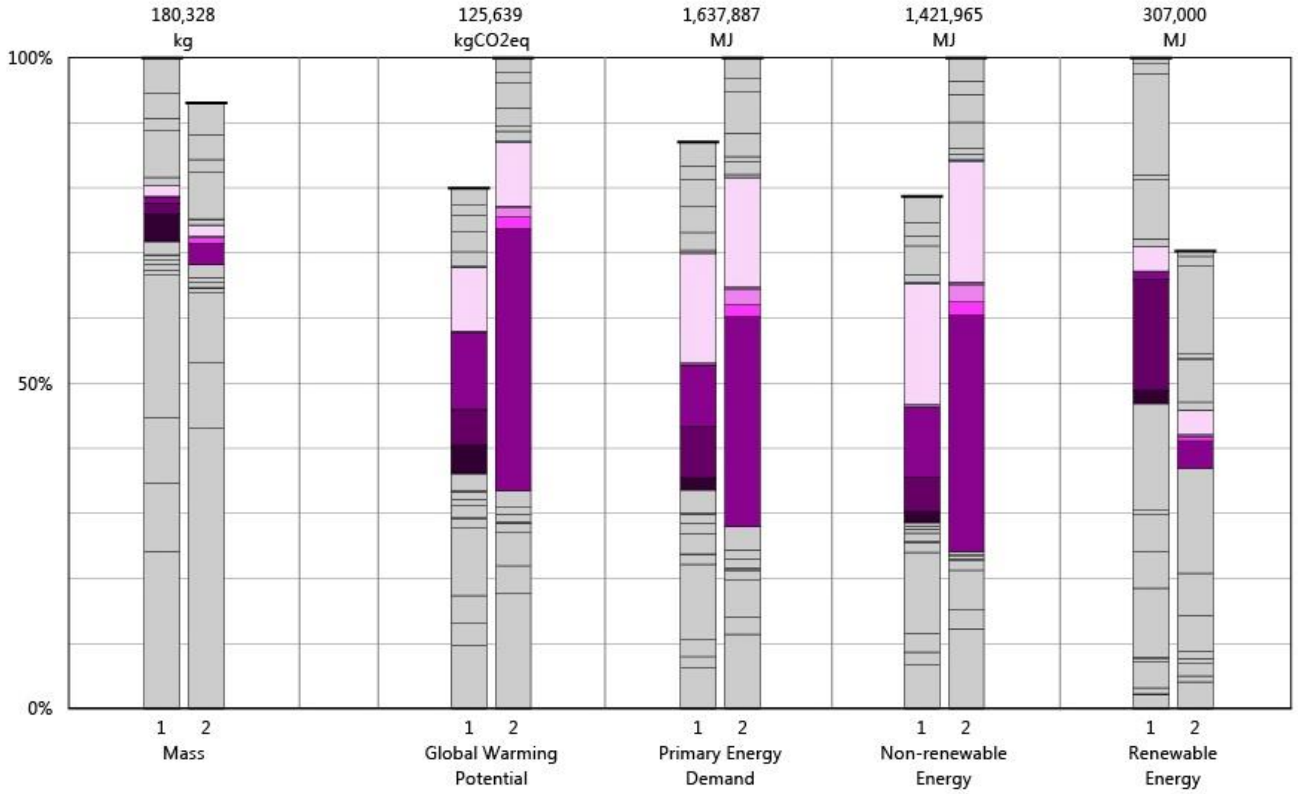


Changes between project phases

How do changes made during construction affect building performance and embodied impacts?

What are the trade offs between material choices (embodied impacts, cost, performance, constructability)?

Results per CSI Division, itemized by material



Option 1 - As Designed

07 - Thermal and Moisture Protection

- Cellulose insulation, blown
- Cellulose insulation, board
- Closed cell, polyurethane foam
- Mineral wool, board, generic
- Open cell, polyurethane foam
- Polyisocyanurate (PIR), board
- Polyethelene sheet vapor barrier
- PVC roofing membrane, sheet

Option 2 - As Built

07 - Thermal and Moisture Protection

- Cellulose insulation, blown
- Cellulose insulation, board
- Closed cell, polyurethane foam
- Mineral wool, board, generic
- Open cell, polyurethane foam
- Polyisocyanurate (PIR), board
- Polyethelene sheet vapor barrier
- PVC roofing membrane, sheet

START EARLY

Conduct continuous and iterative assessments at every stage of the design and construction process.

KEEP A RECORD

Keep all your output reports and track performance over the entire design process to demonstrate and document your baseline performance and track the achievement of the requisite reductions for the LEED reviewers.

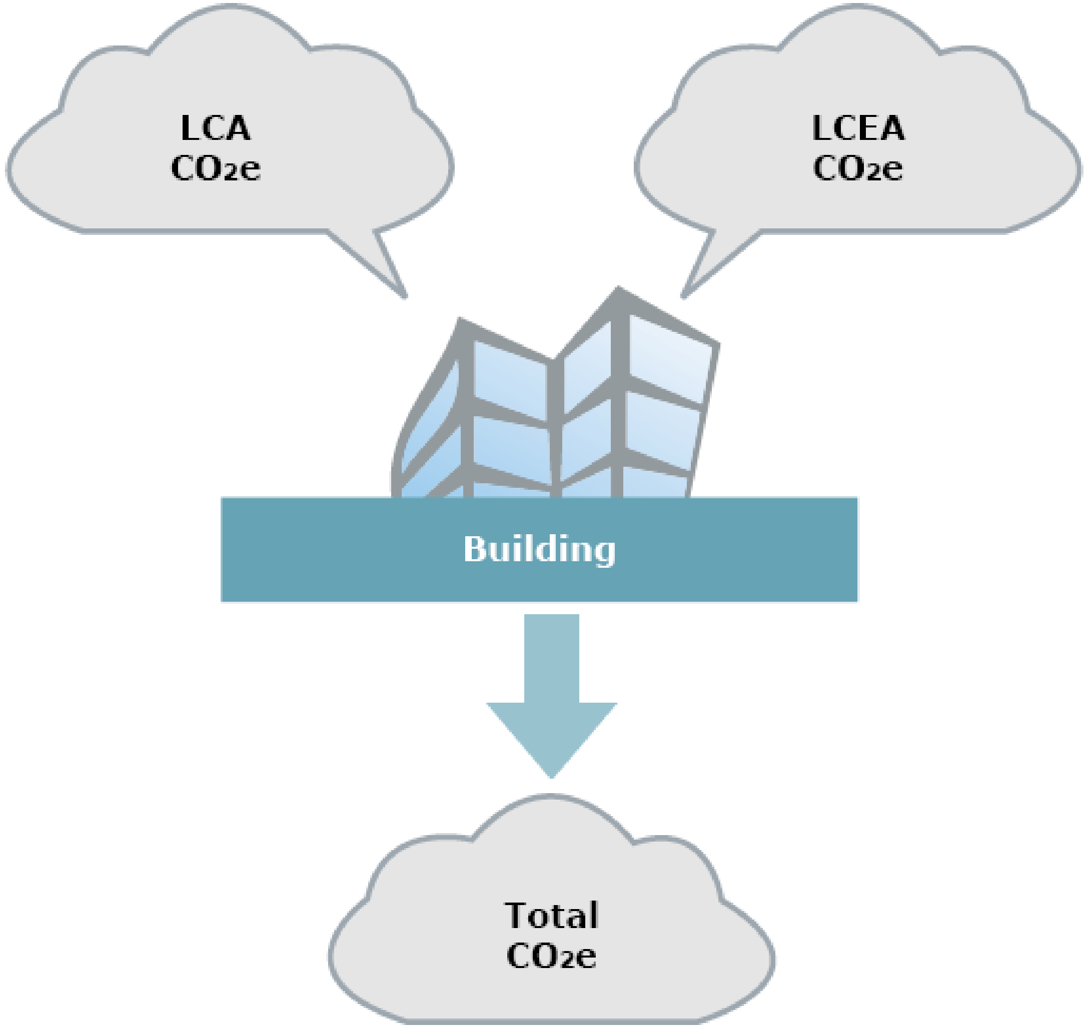
EXPERIMENT EARLY AND OFTEN

Using the smallest appropriate functional unit, test different materials and design options to determine the potential for impact reduction through material substitutions, design options and modifications before integrating the new design into the whole building model.

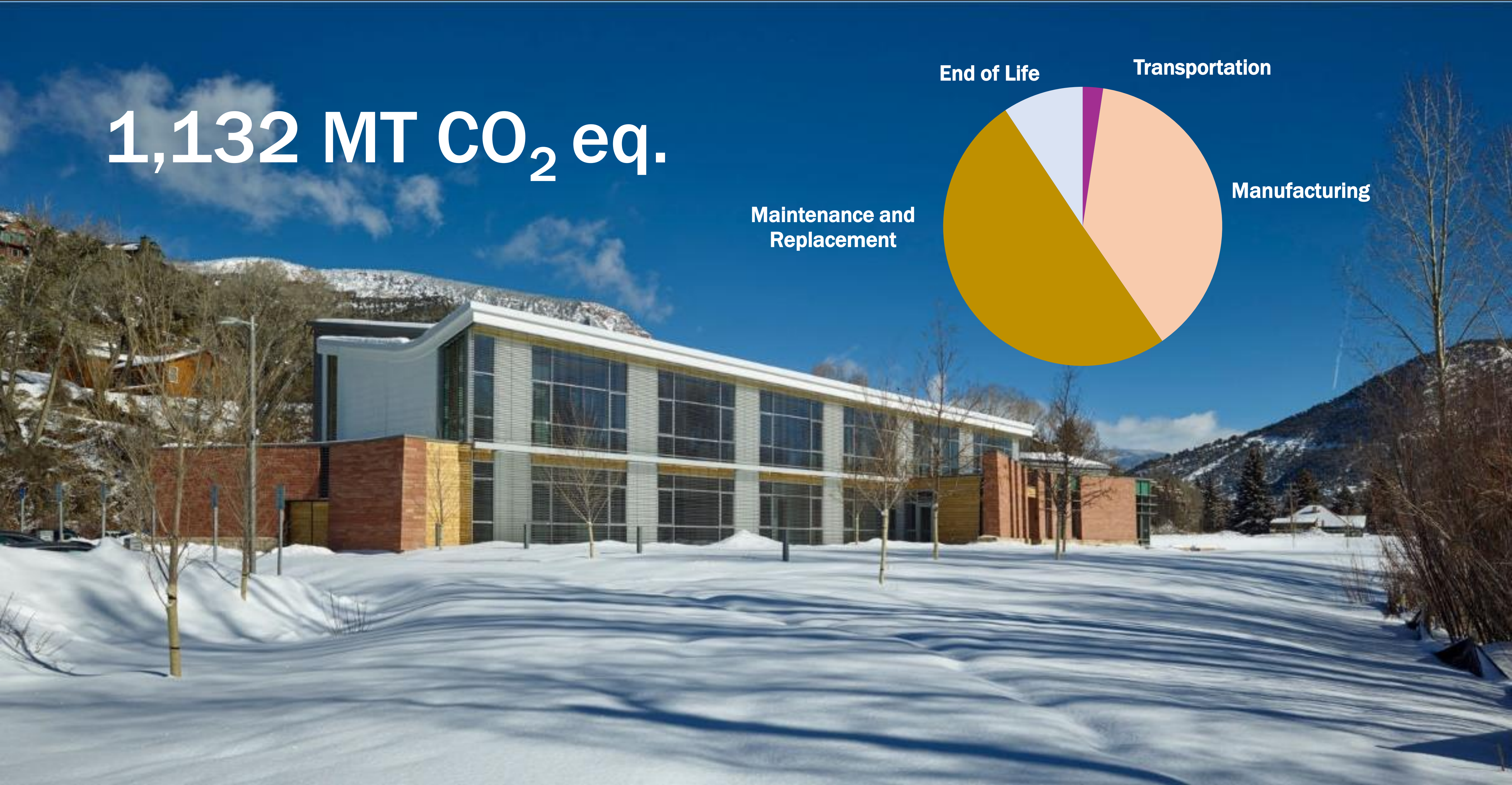
INCLUDE THE WHOLE TEAM

Effectively using the data generated by LCA requires the entire design team, from the client, to the architect, to the construction manager. Just because a design team proposes a better performing material doesn't mean it's feasible. Involving the whole design team in the LCA process ensures everyone understands the information and the implications of selecting particular materials.

4. Impact Through Intuition: RMI Case Study

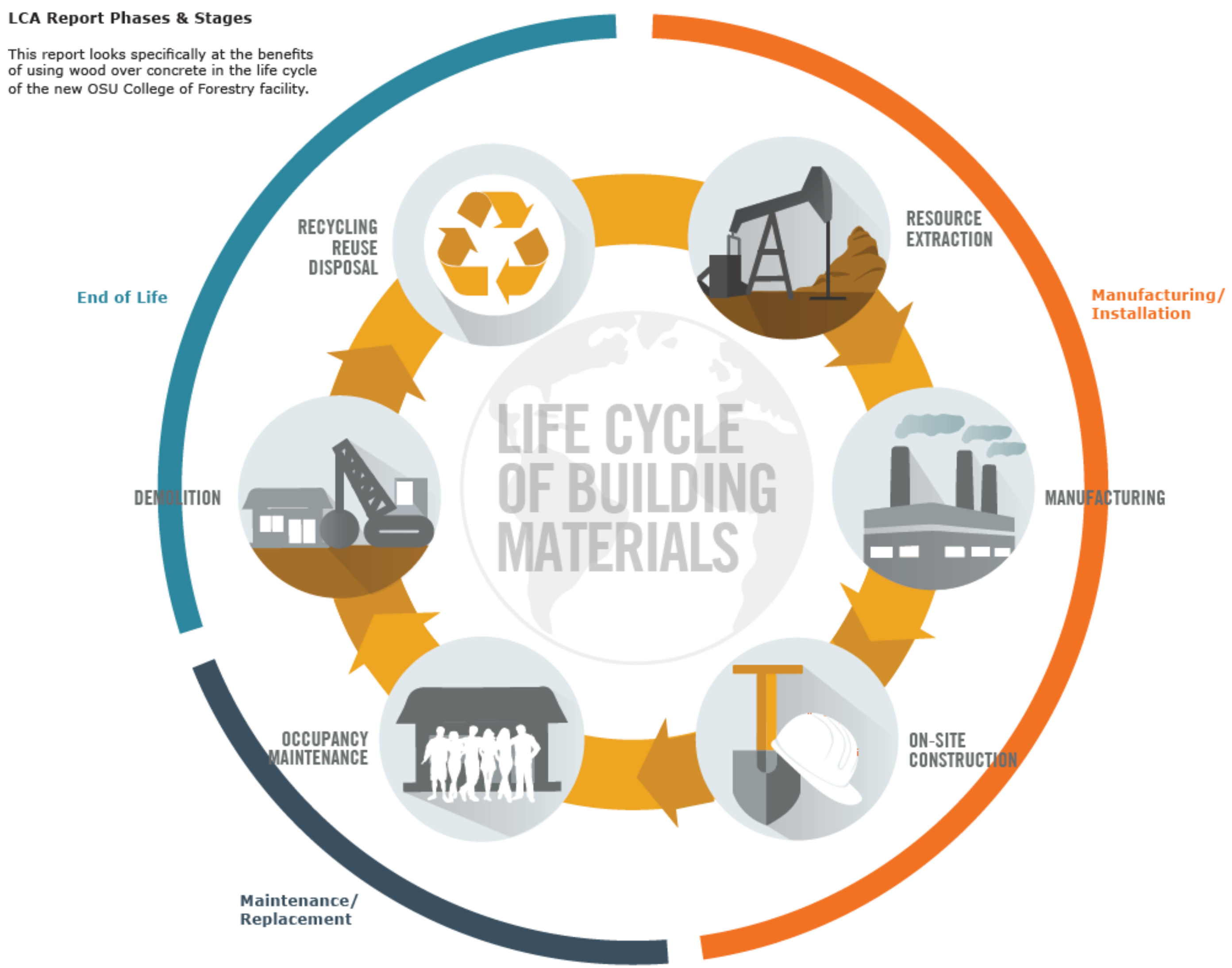

LCA
CO_2e
LCEA
CO_2e
Building
Total
CO_2e

1,132 MT CO_2 eq.

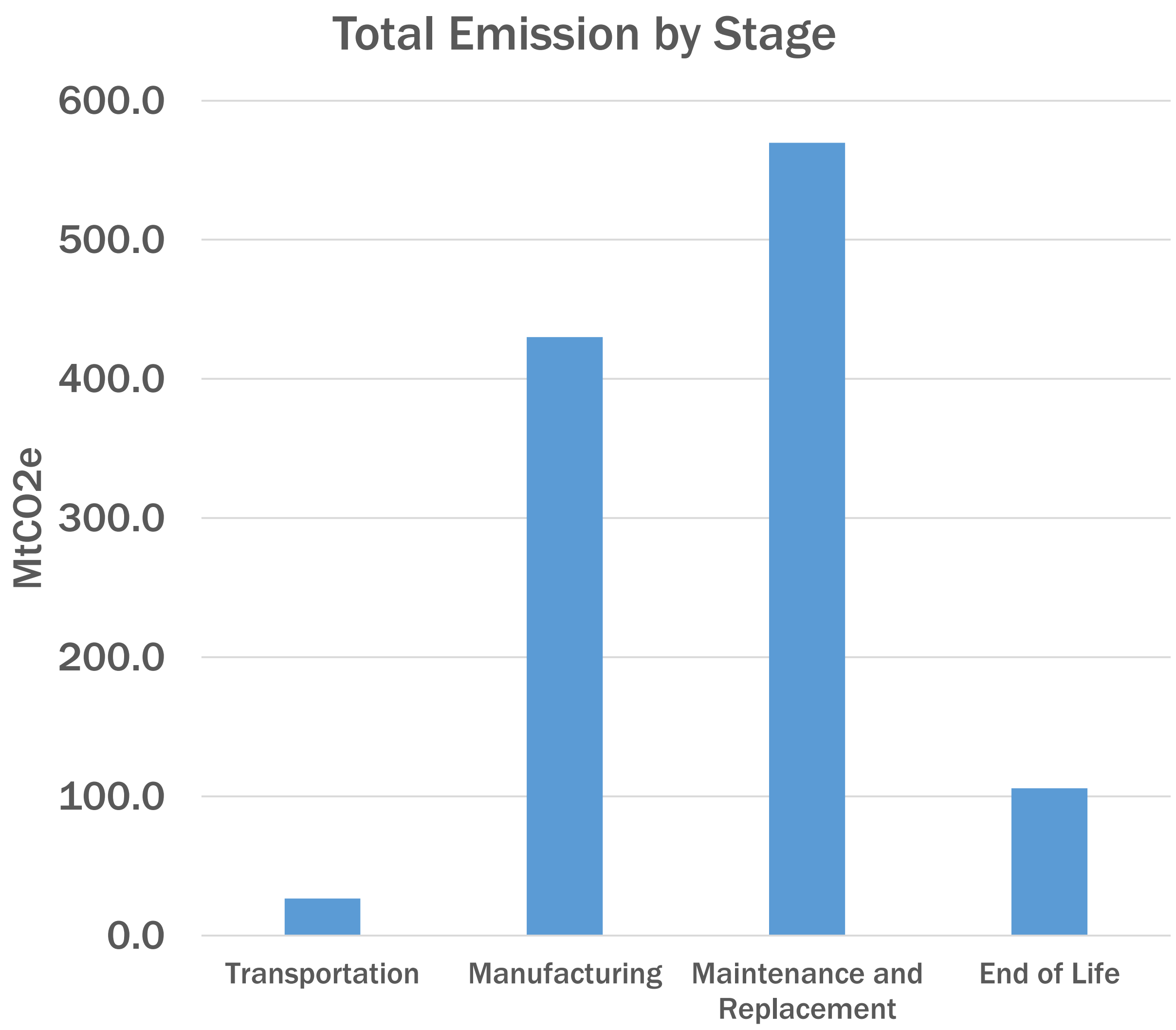


RMI by LCA Stage

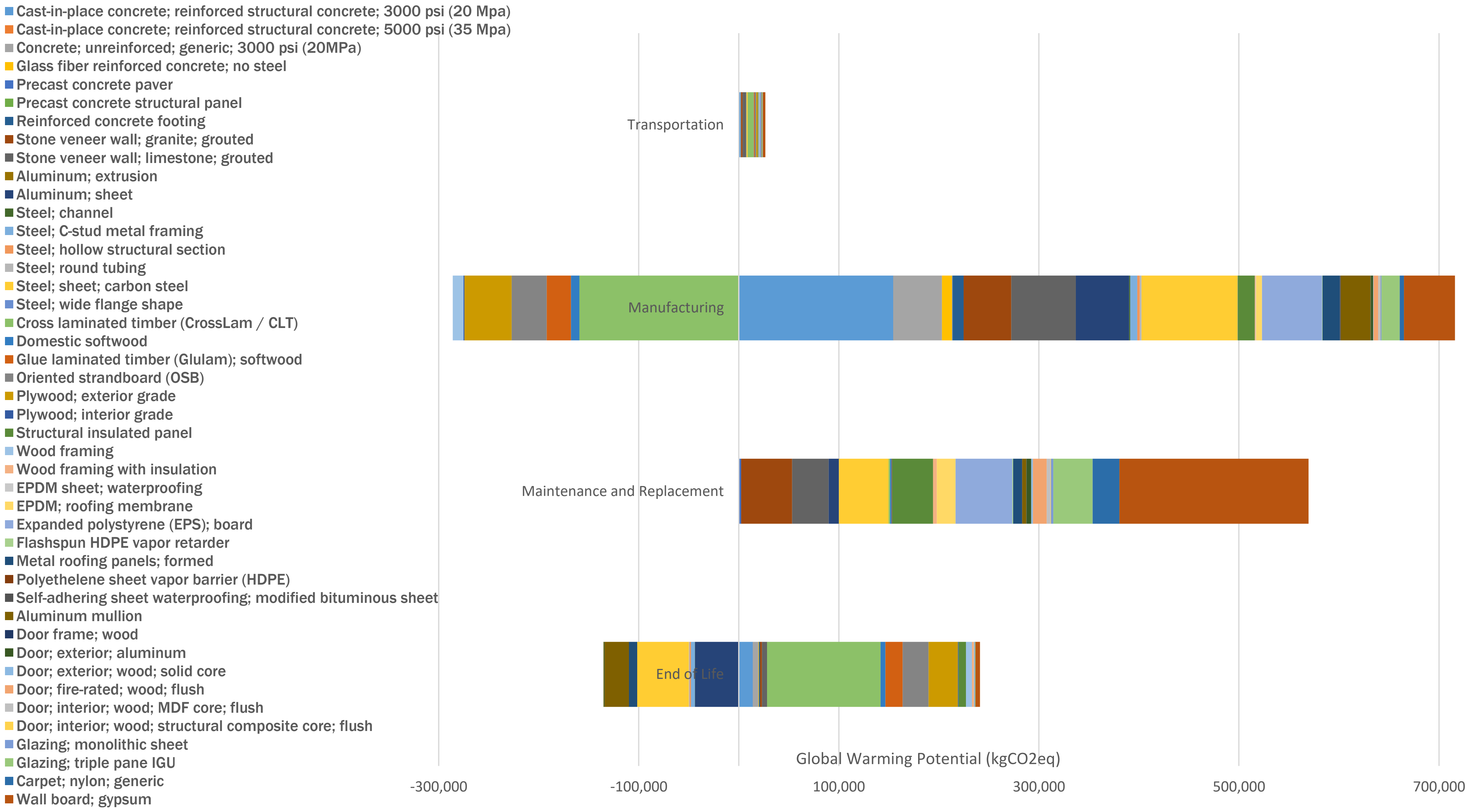
1. Transportation
2. Manufacturing
3. Maintenance and Replacement
4. End of Life

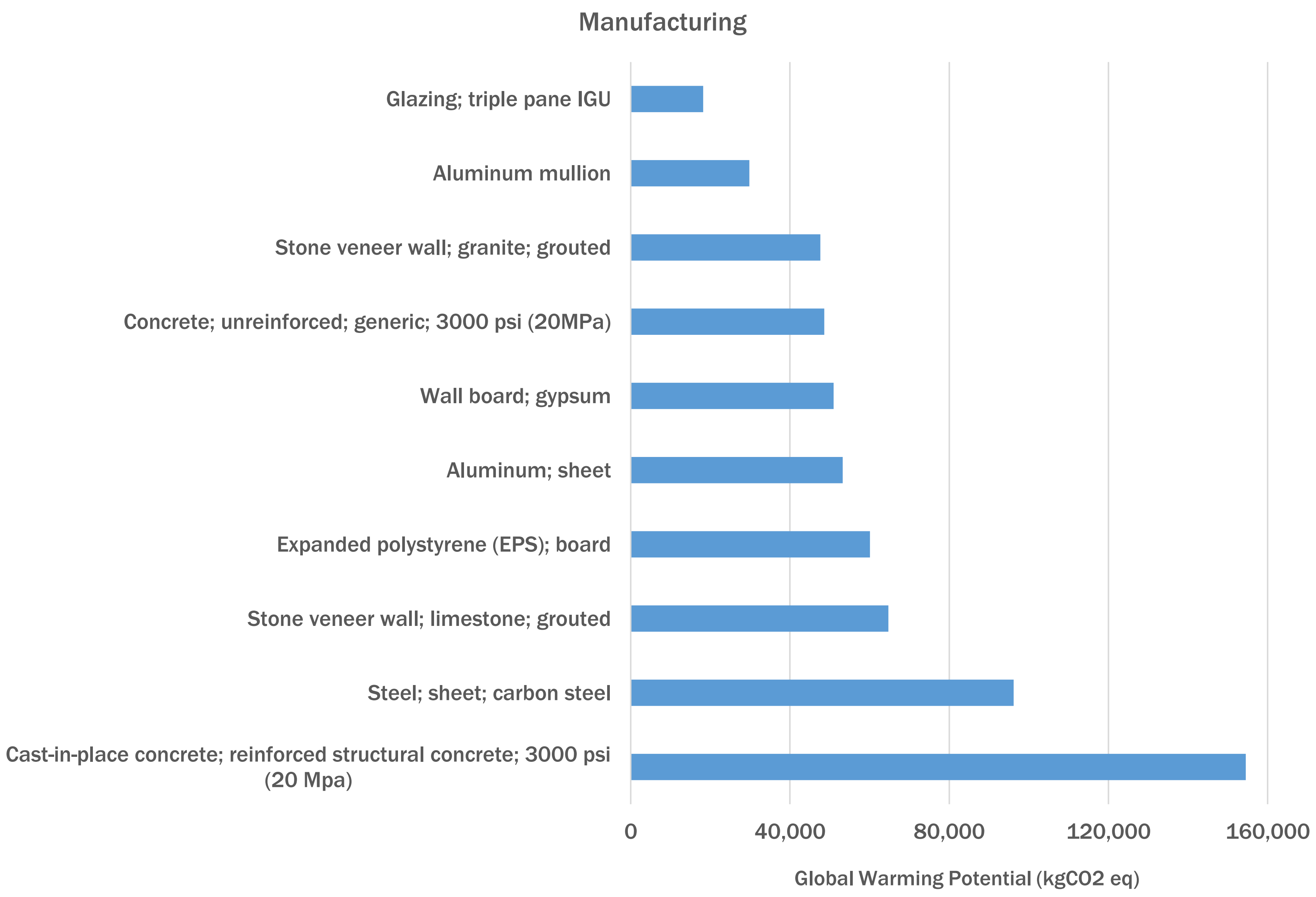


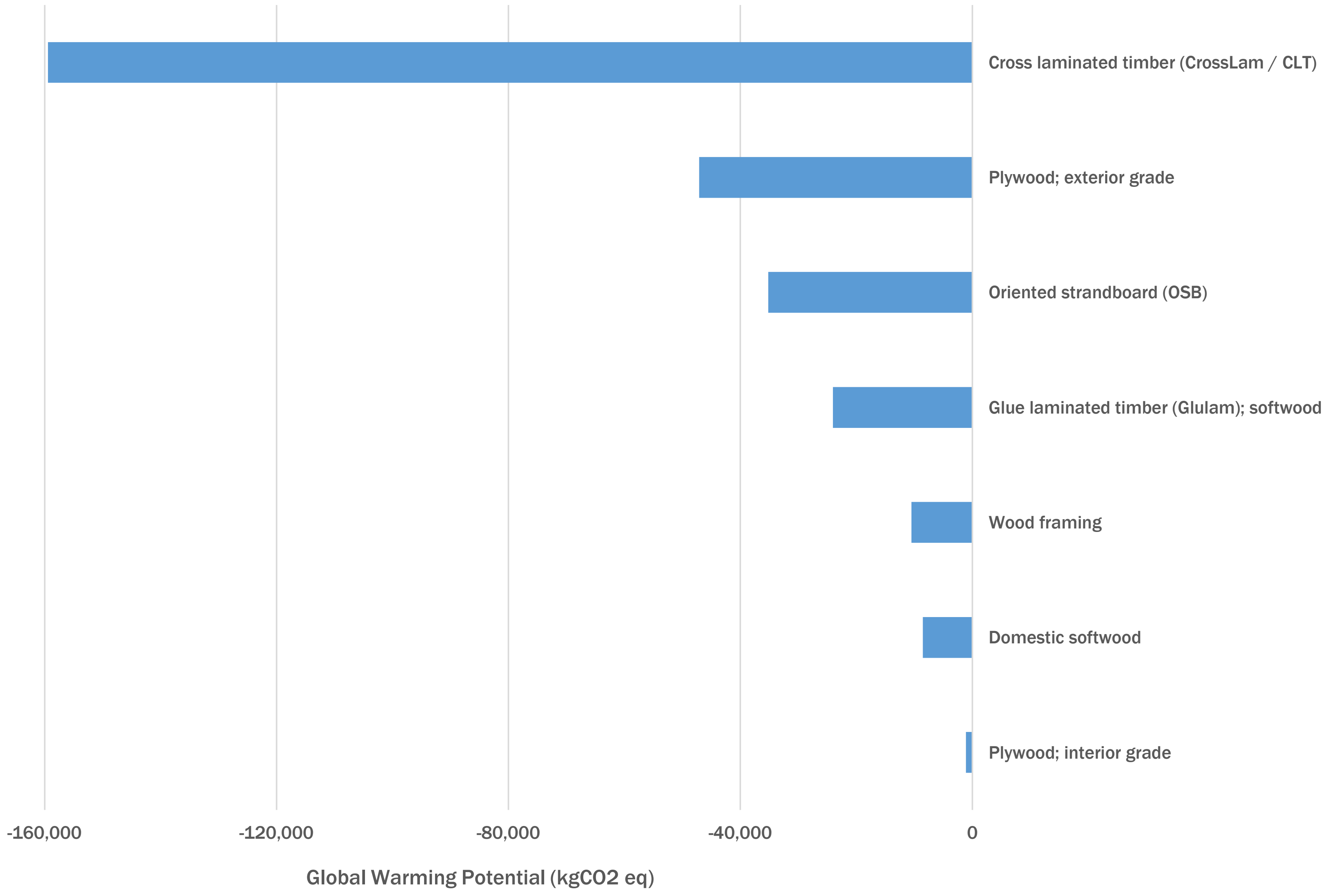
1. Transportation
2. Manufacturing
3. Maintenance and Replacement
4. End of Life

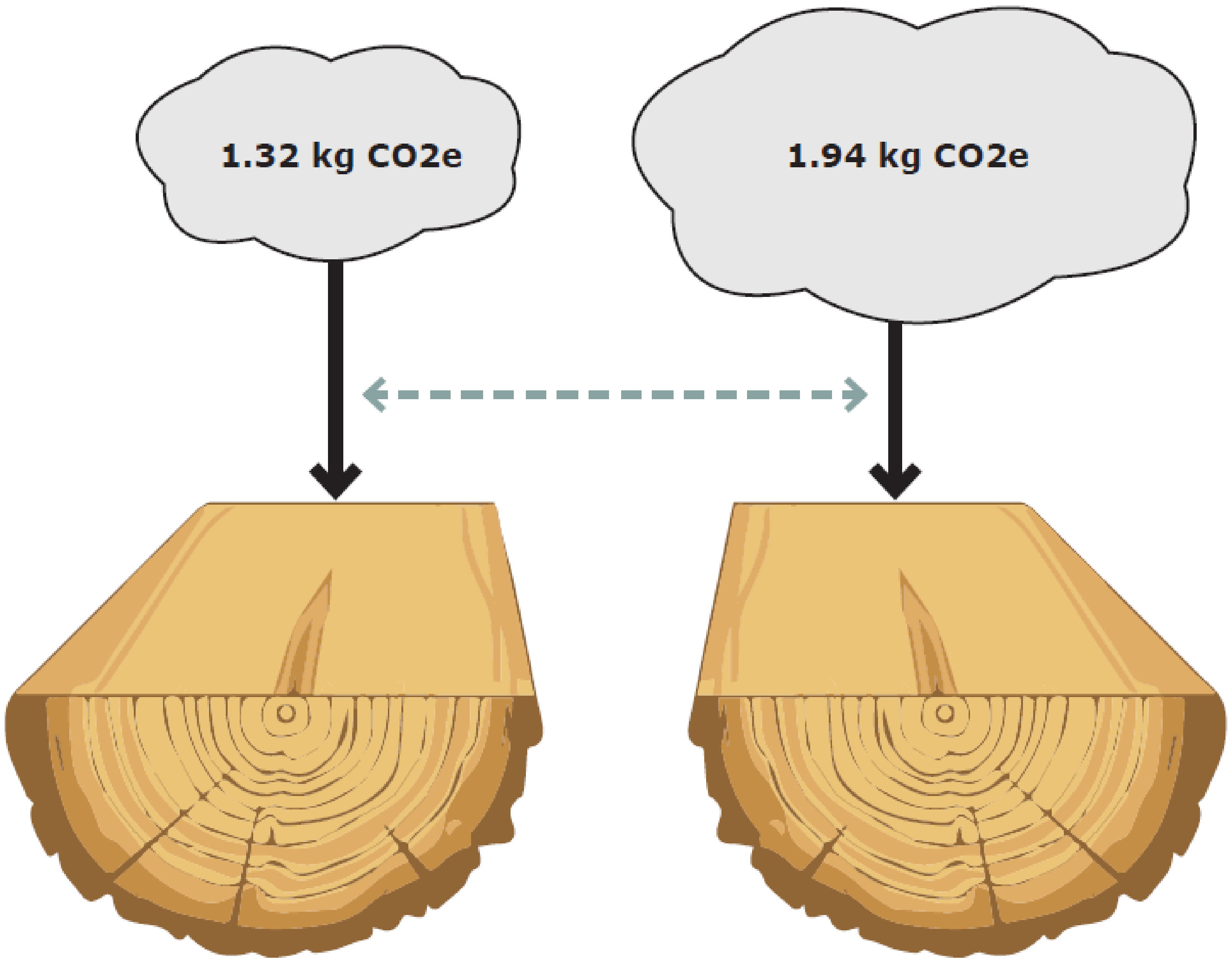


RMI Whole Building Breakdown

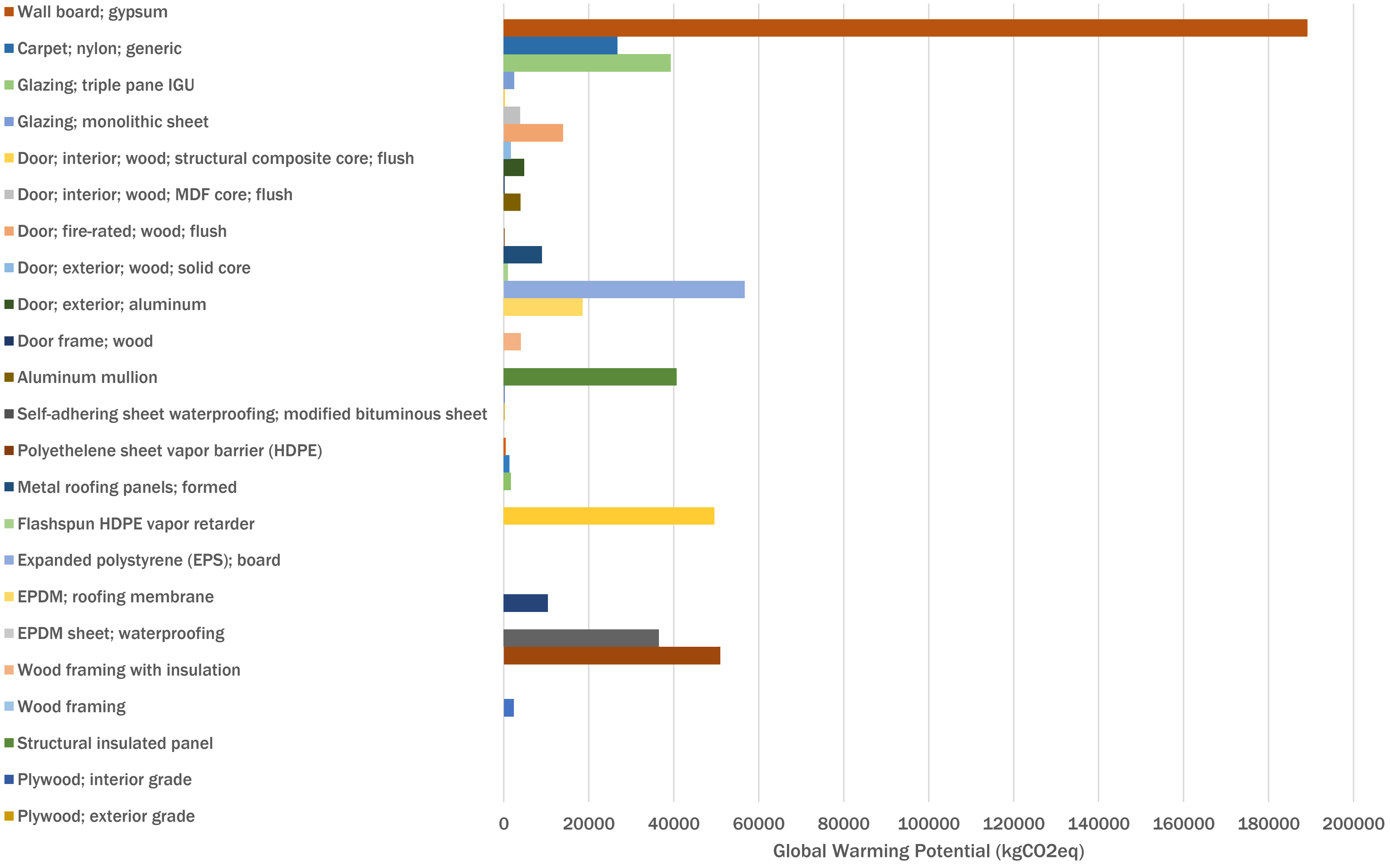



Manufacturing
Glazing; triple pane IGU
Aluminum mullion
Stone veneer wall; granite; grouted
Concrete; unreinforced; generic; 3000 psi (20MPa)
Wall board; gypsum
Aluminum; sheet
Expanded polystyrene (EPS); board
Stone veneer wall; limestone; grouted
Steel; sheet; carbon steel
Cast-in-place concrete; reinforced structural concrete; 3000 psi (20 Mpa)
0
40,000
80,000
120,000
160,000
Global Warming Potential (kgCO2 eq)

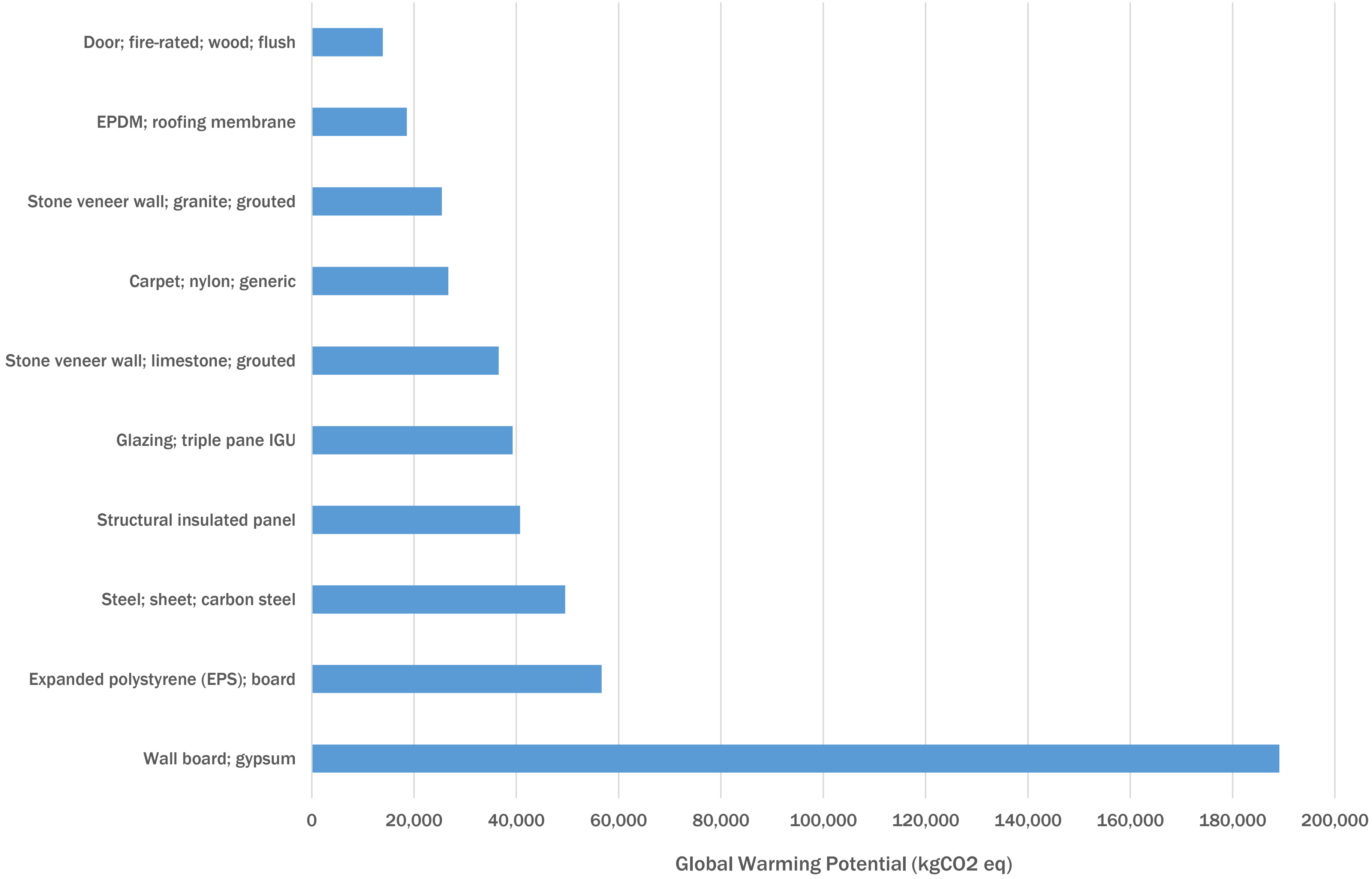

Cross laminated timber (CrossLam / CLT)
Plywood; exterior grade
Oriented strandboard (OSB)
Glue laminated timber (Glulam); softwood
Wood framing
Domestic softwood
Plywood; interior grade
-160,000
-120,000
-80,000
-40,000
0
Global Warming Potential (kgCO2 eq)


1.32 kg CO2e
1.94 kg CO2e

RMI Stage Assessment: Maintenance and Replacement

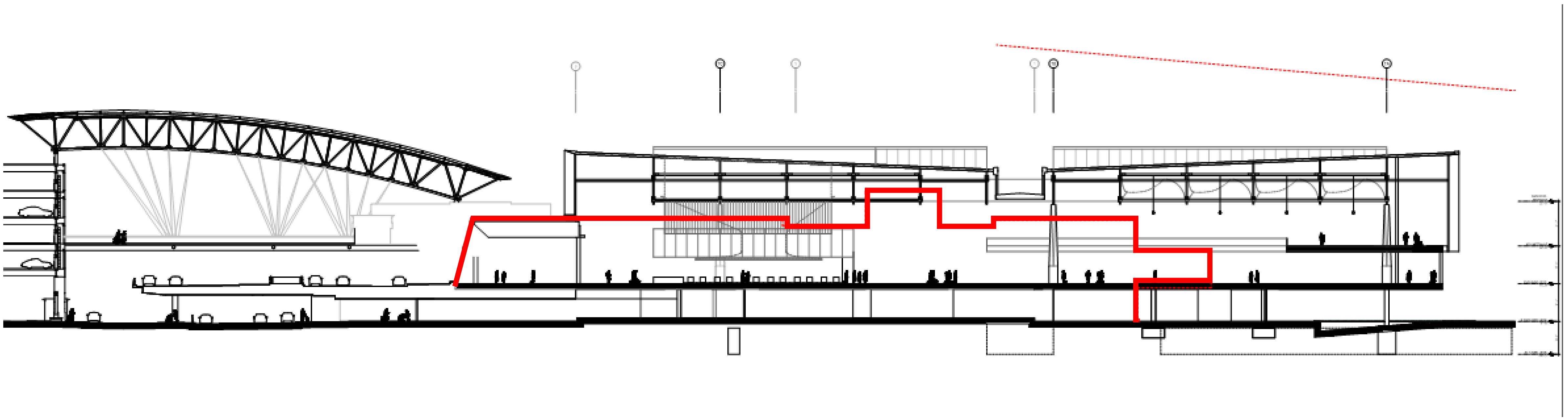


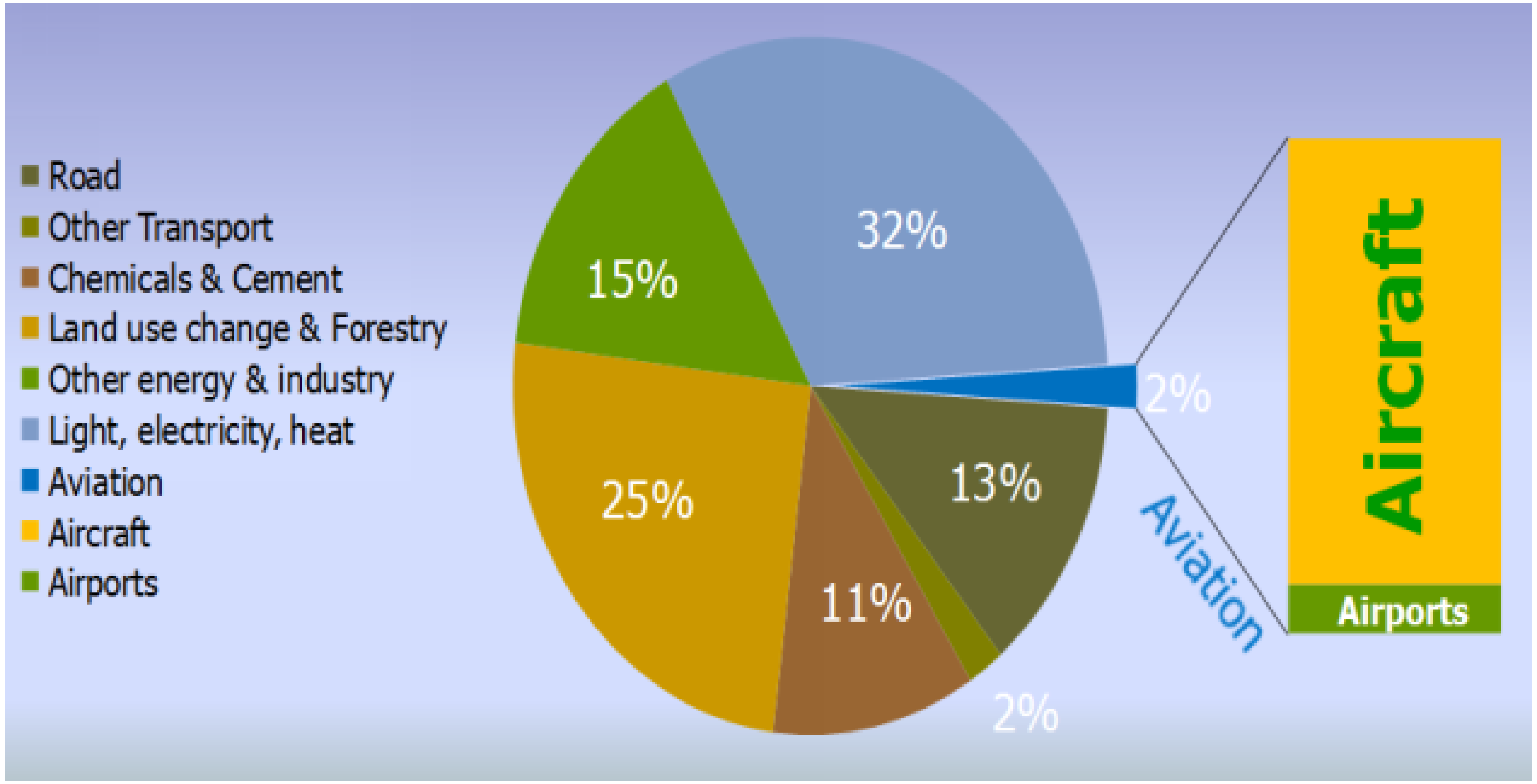
RMI Top Ten: Manufacturing and Installation

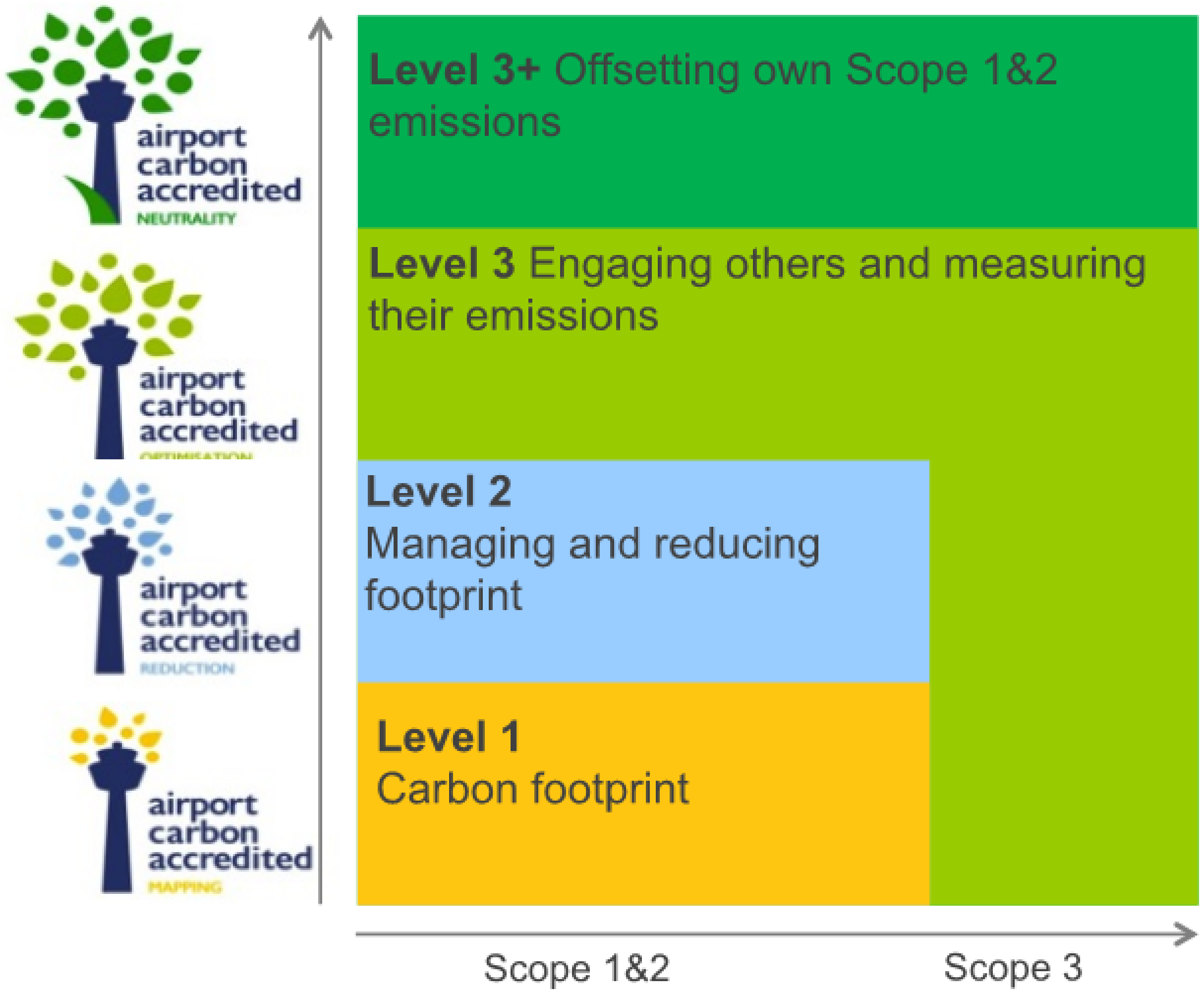


5. LCA at PDX: Airport TCORE Case Study

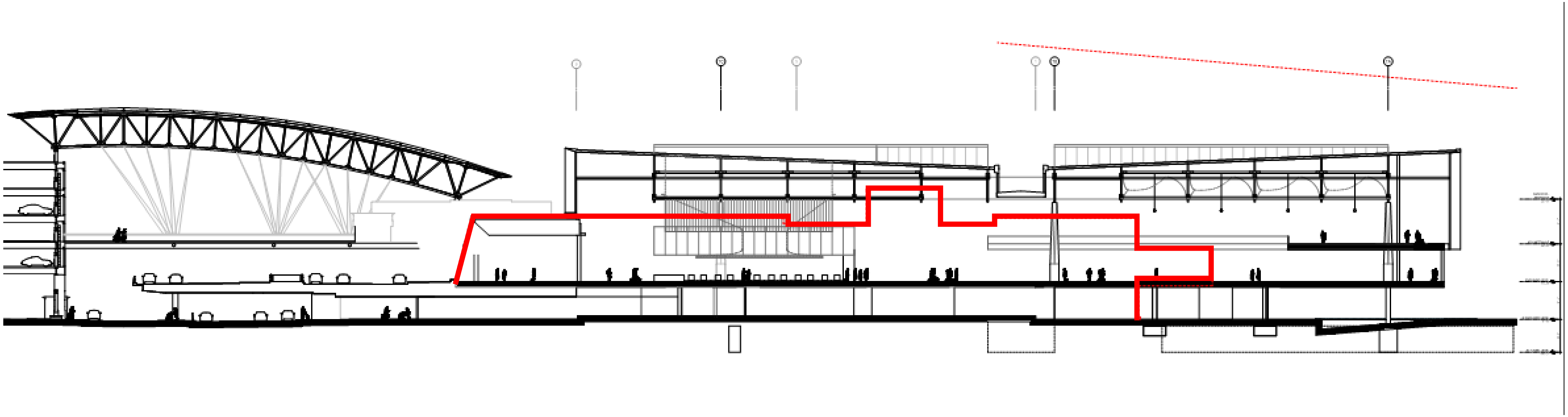
Airport Scope

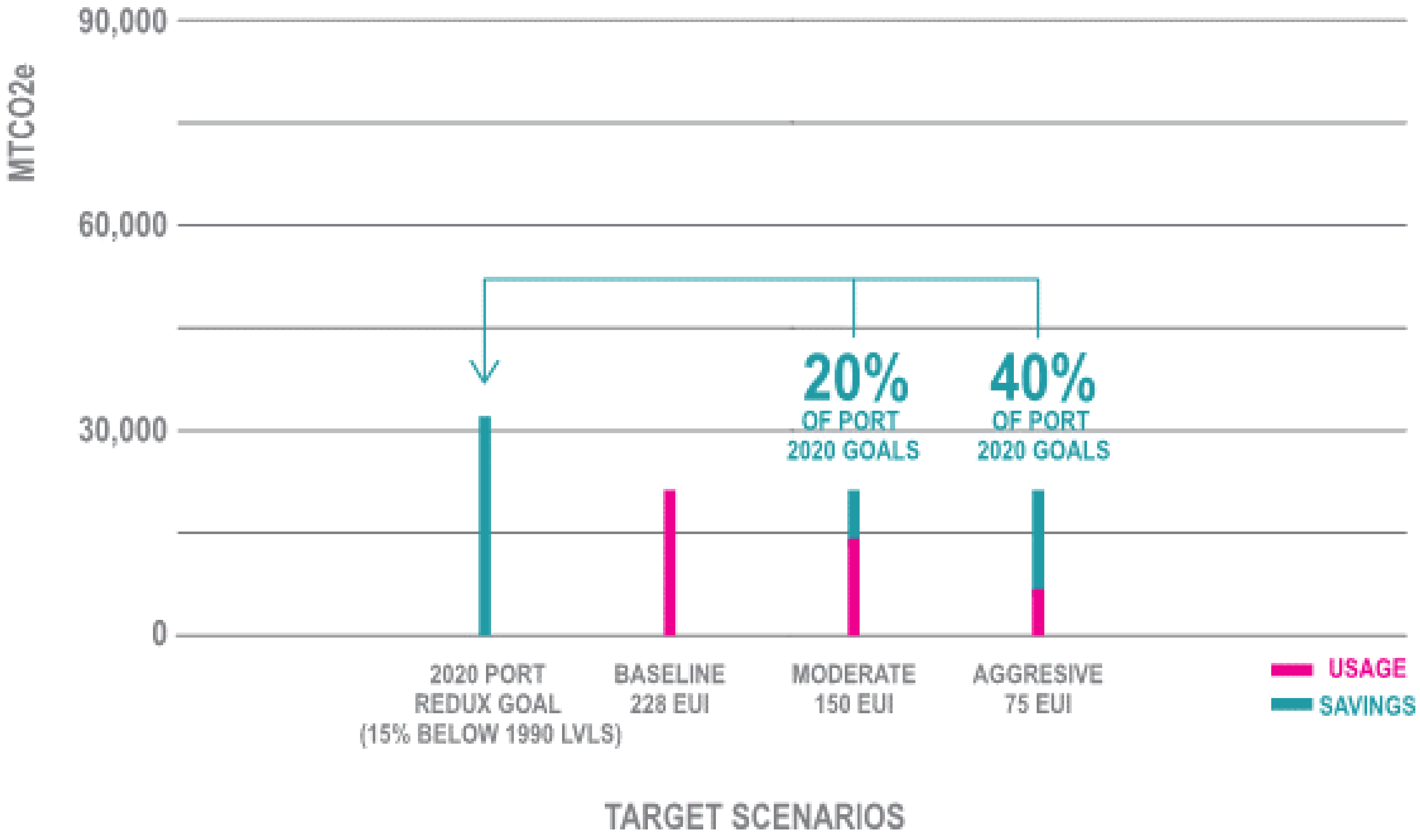



Road
Other Transport
Chemicals & Cement
Land use change & Forestry
Other energy & industry
Light, electricity, heat
Aviation
Aircraft
Airports
32%
15%
25%
11%
13%
2%
2%
Aviation
Aircraft
Airports

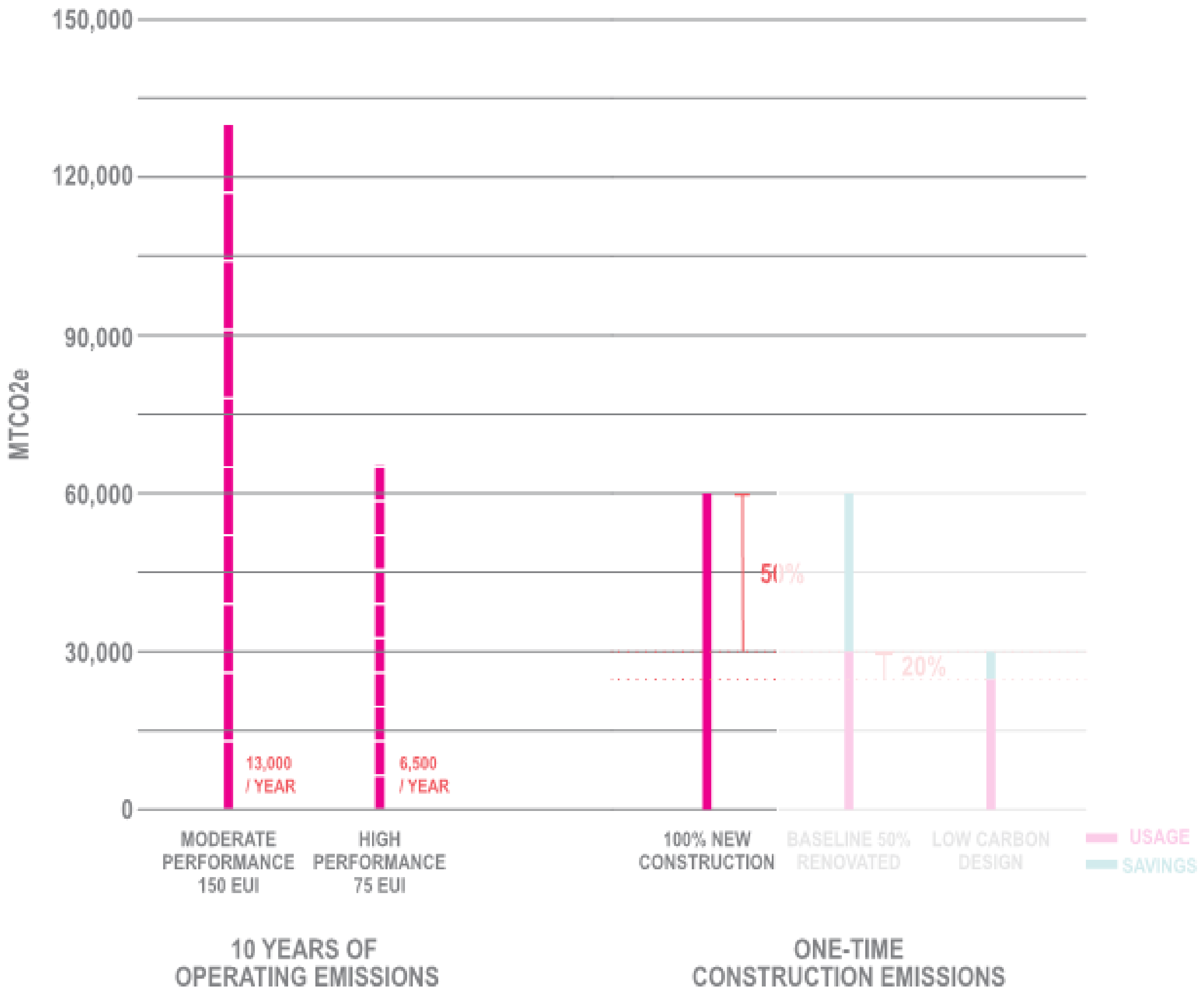

airport carbon accredited
NEUTRALITY
airport carbon accredited
airport carbon accredited
REDUCTION
airport carbon accredited
MAPPING
Level 3+ Offsetting own Scope 1&2 emissions
Level 3 Engaging others and measuring their emissions
Level 2
Managing and reducing footprint
Level 1
Carbon footprint
Scope 1&2
Scope 3

Airport Scope

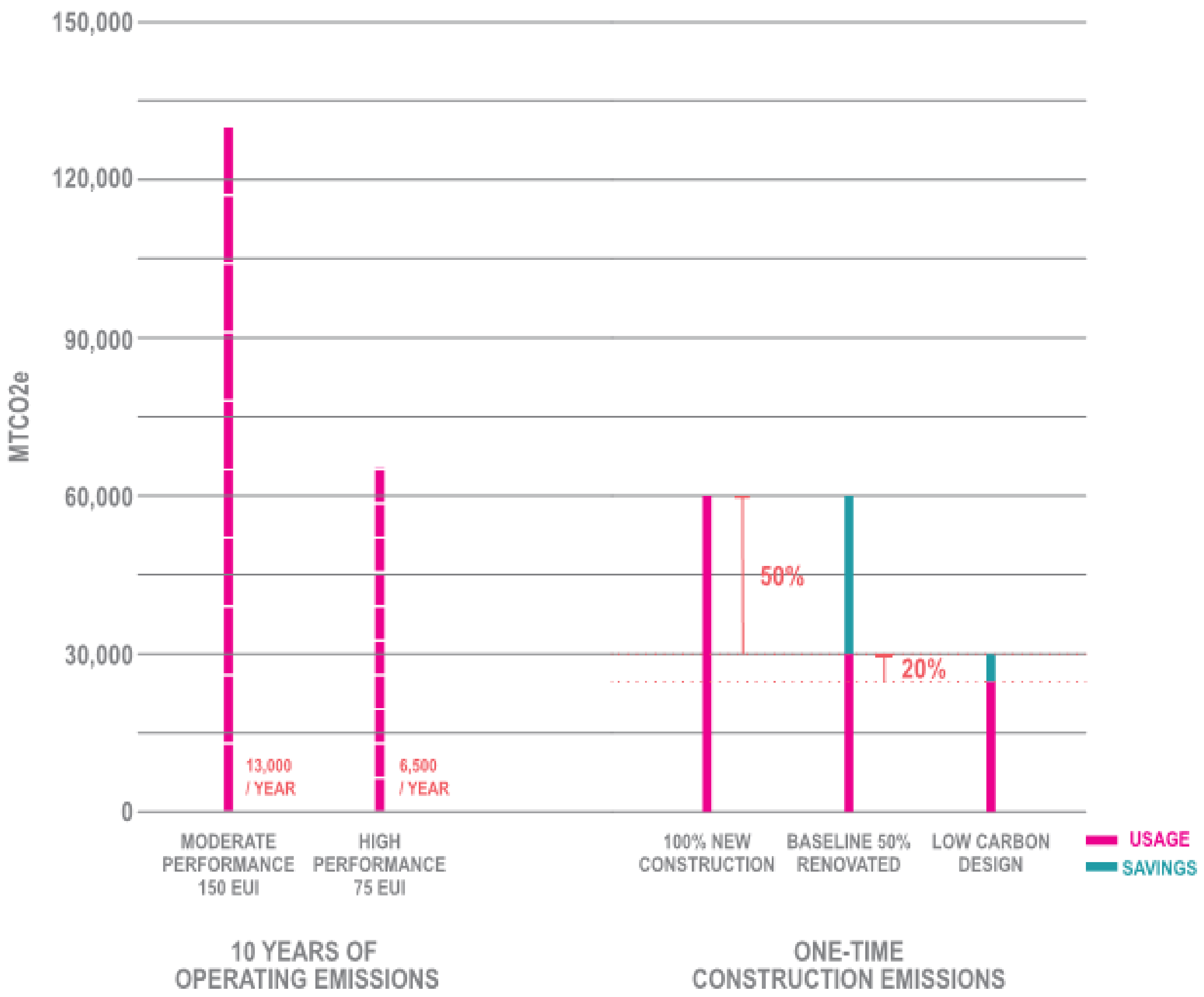



90,000
60,000
30,000
0
MTCO2e
20%
OF PORT
2020 GOALS
40%
OF PORT
2020 GOALS
2020 PORT
REDUX GOAL
(15% BELOW 1990 LVLS)
BASELINE
228 EUI
MODERATE
150 EUI
AGGRESIVE
75 EUI
USAGE
SAVINGS
TARGET SCENARIOS

Airport Scope – Construction vs. Operating Emissions

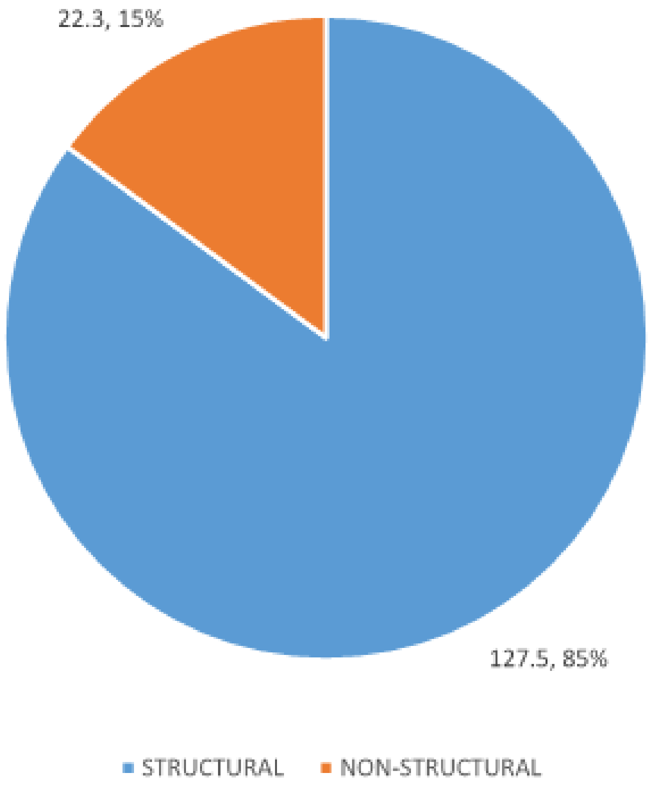


Airport Scope – Construction vs. Operating Emissions



CARBON
PROJECT EMBODIED CARBON

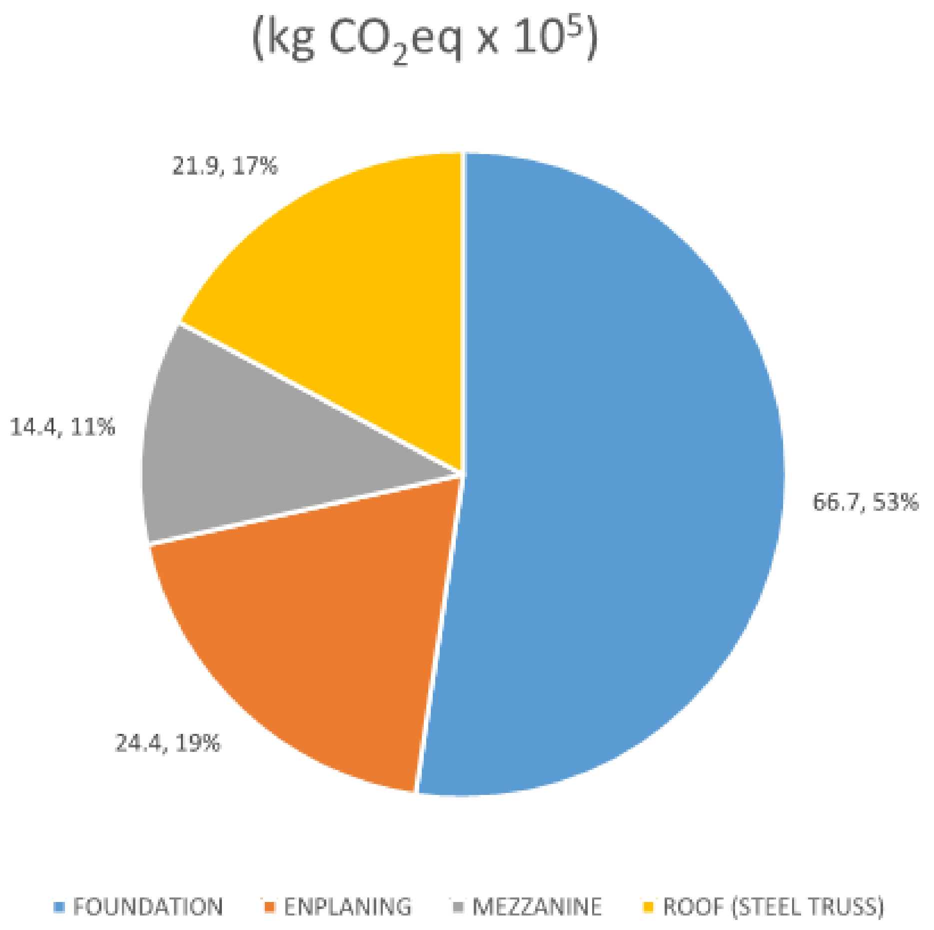
(kg CO_2eq x 10^5)



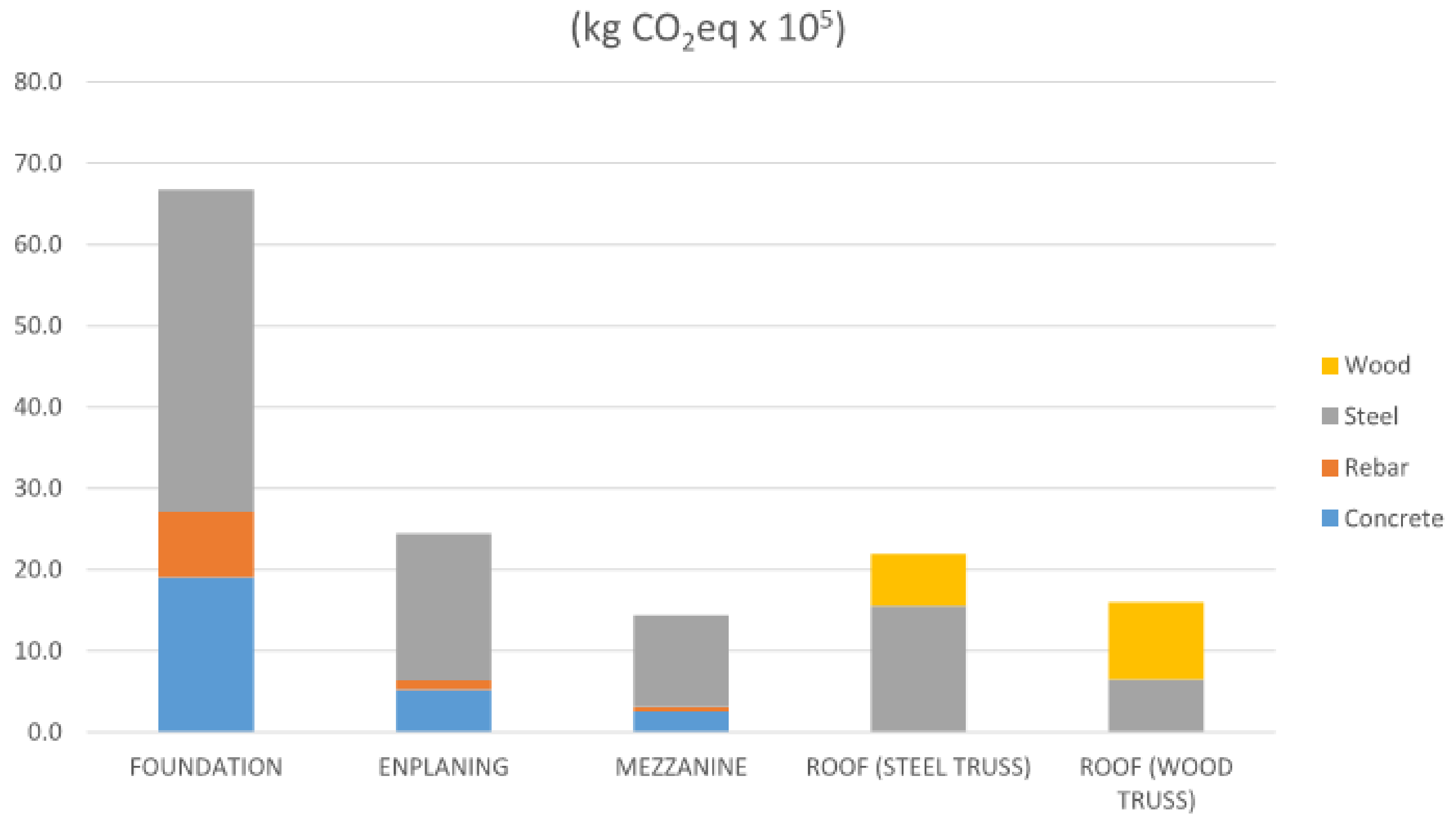
(does not include interior partitions)

CARBON

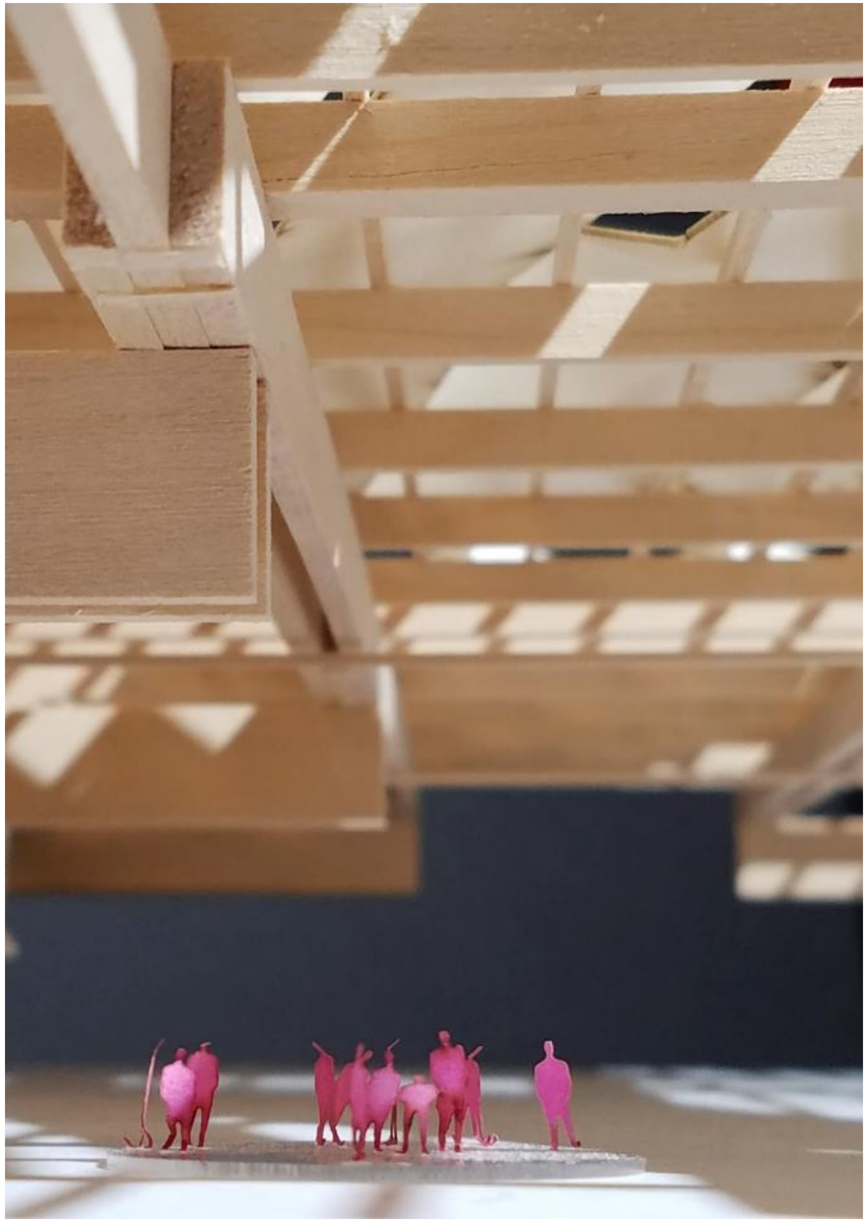
STRUCTURE EMBODIED CARBON

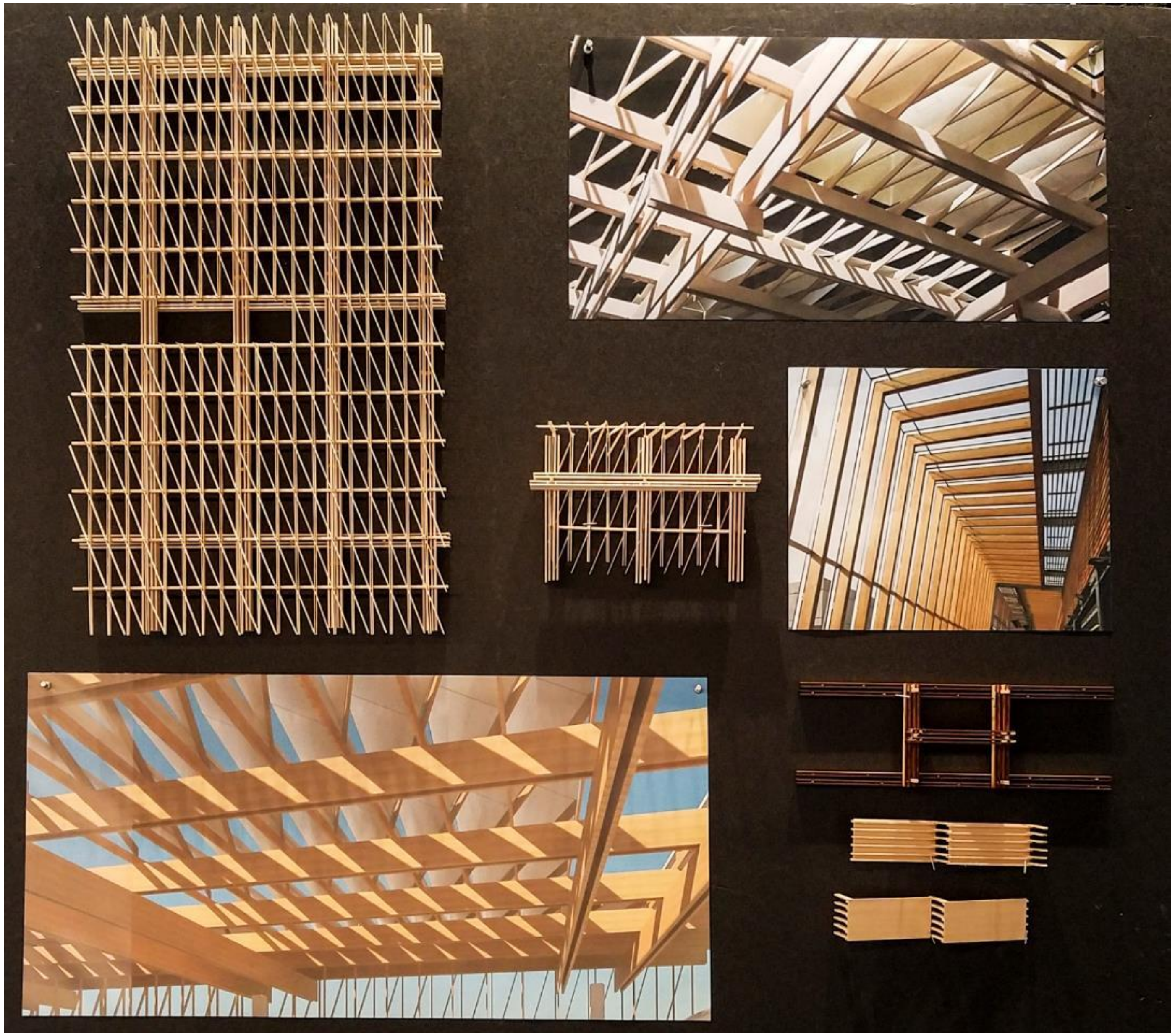


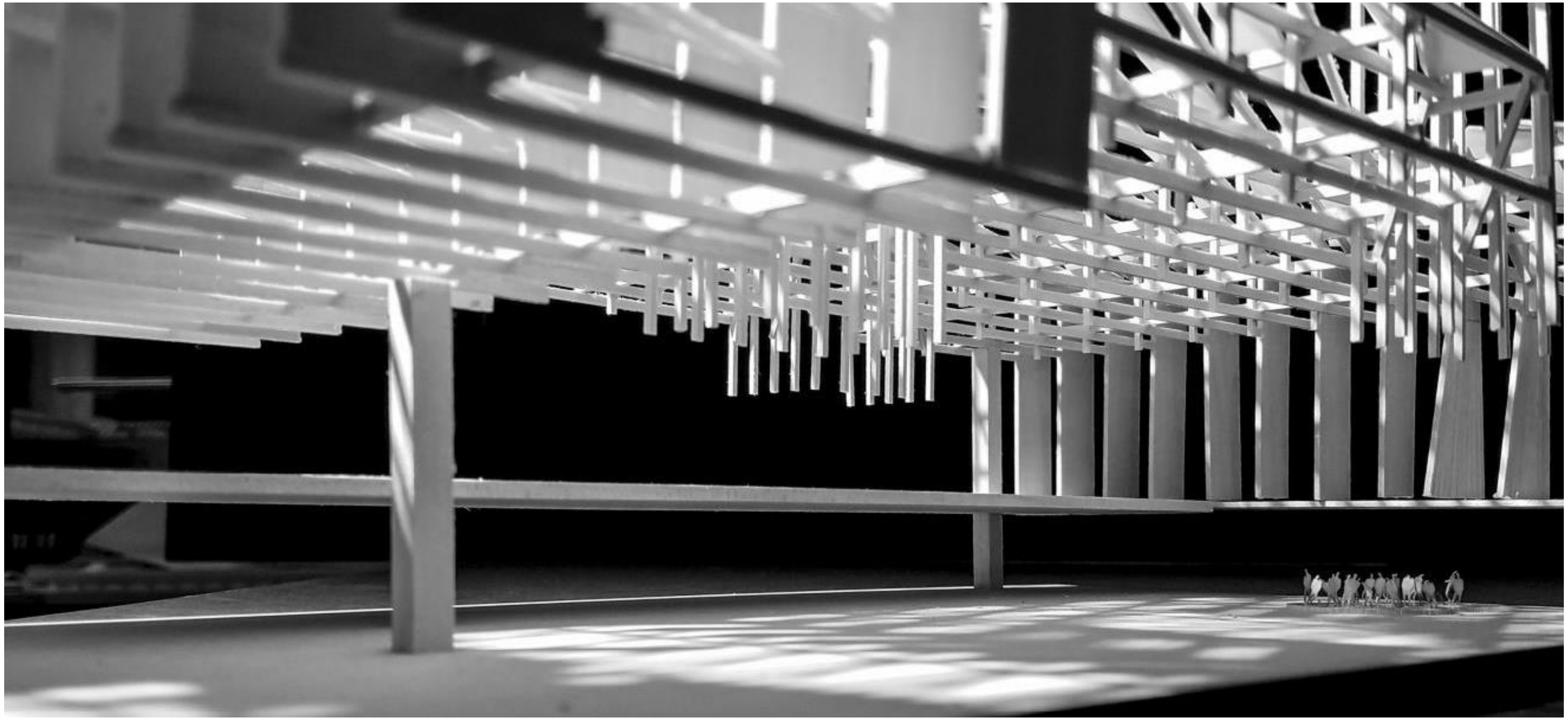
CARBON
STRUCTURE EMBODIED CARBON

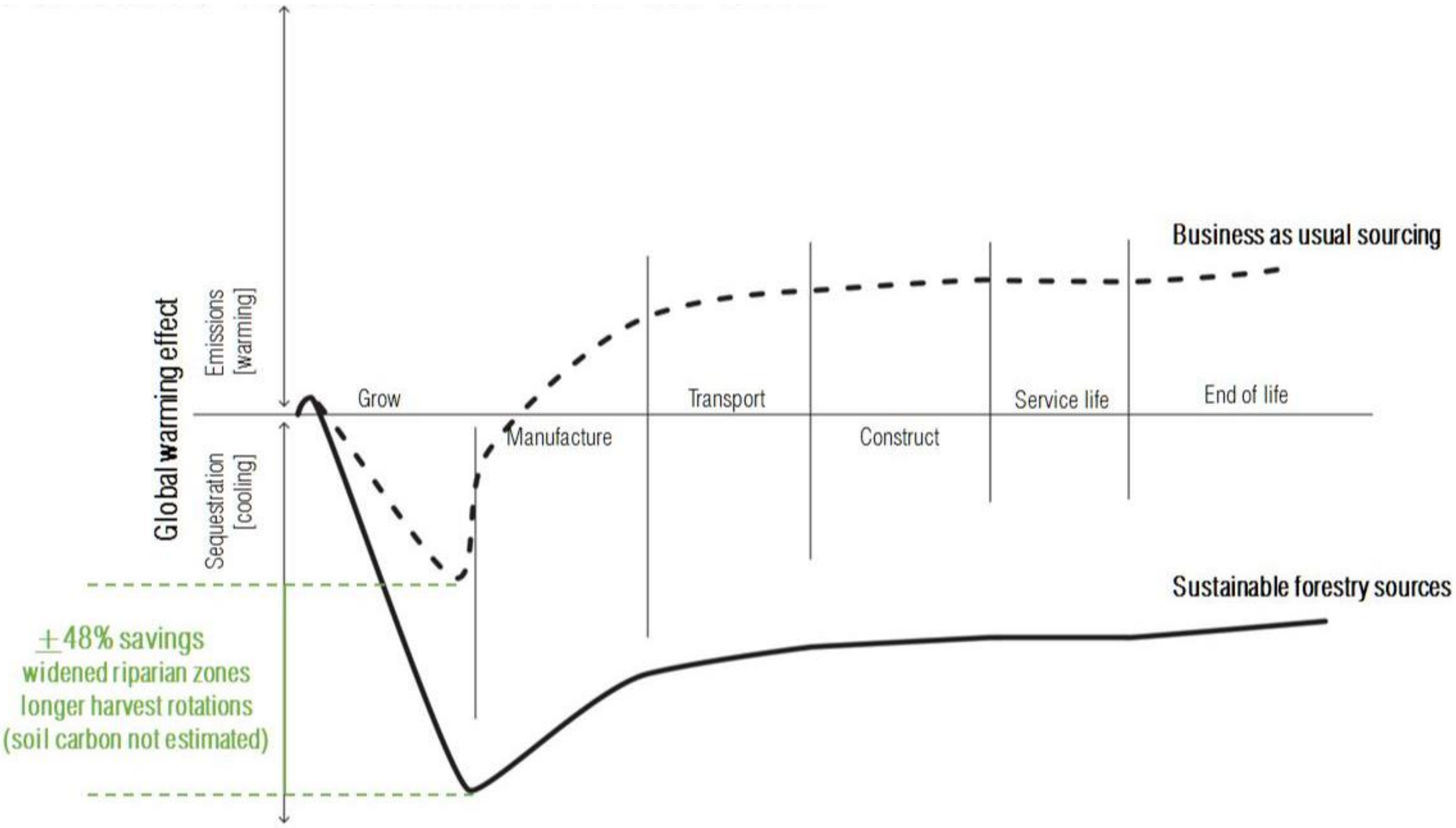


Airport Scope – Construction vs. Operating Emissions



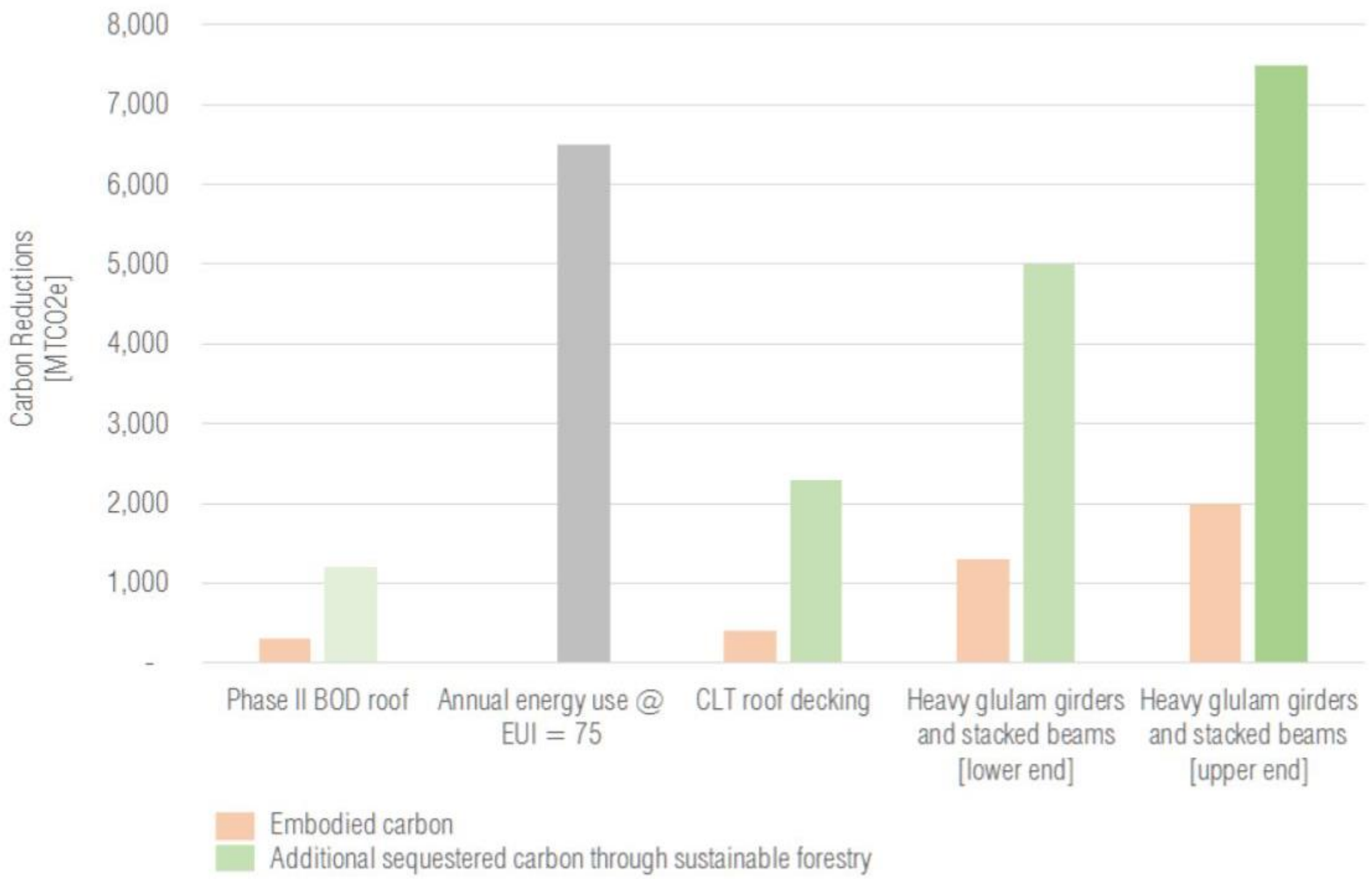


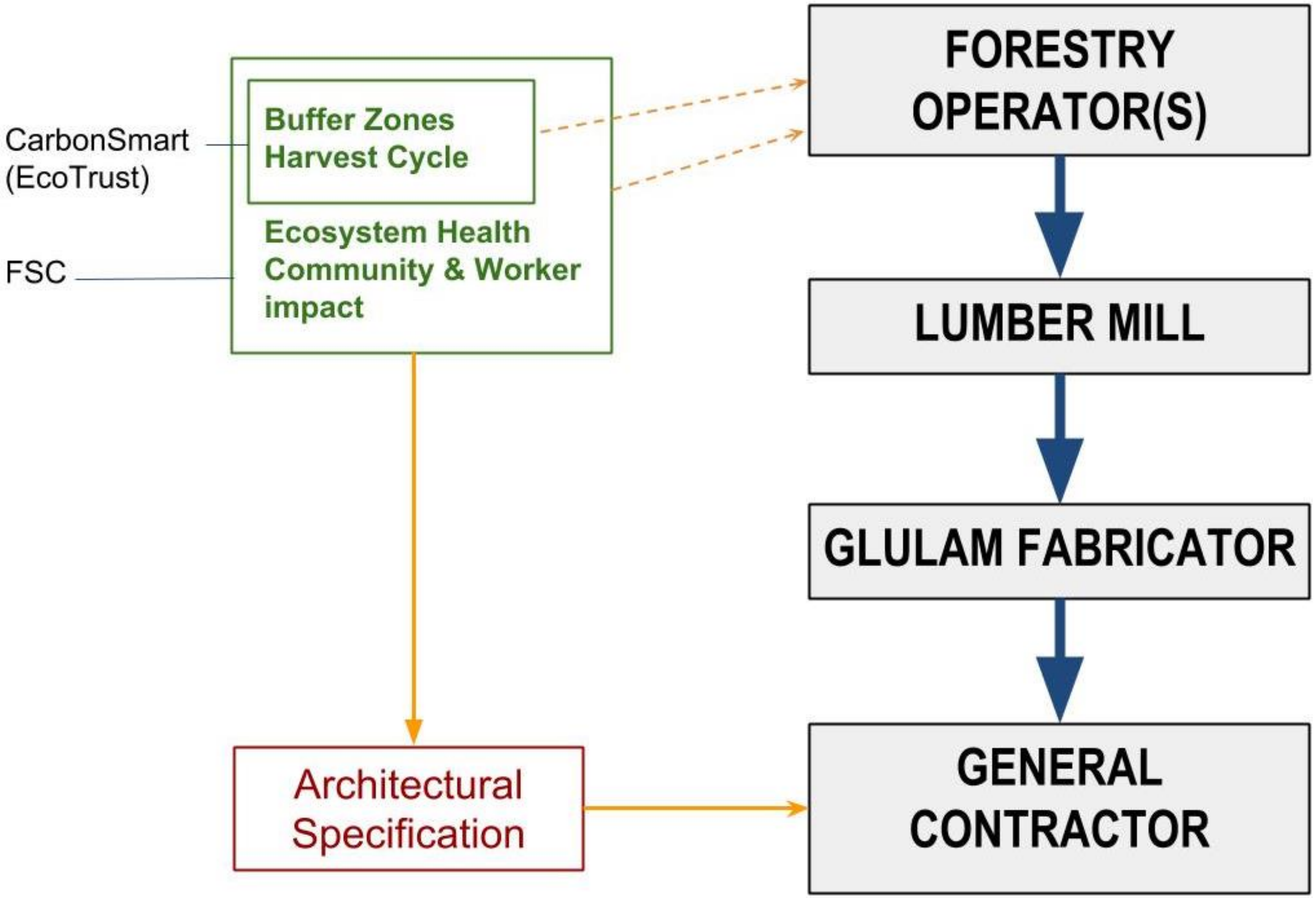




Graphic adapted from *The New Carbon Architecture*. Bruce King, 2018.
Climate Smart Forestry for a Carbon-Constrained World. Ecotrust, 2017.

Carbon Savings of Sustainable Forestry




CarbonSmart
(EcoTrust)
FSC
Buffer Zones
Harvest Cycle
Ecosystem Health
Community & Worker impact
FORESTRY OPERATOR(S)
LUMBER MILL
GLULAM FABRICATOR
GENERAL CONTRACTOR
Architectural Specification

LUNCH & LEARN

Thursday, April 19, 2018

Thanks for listening!

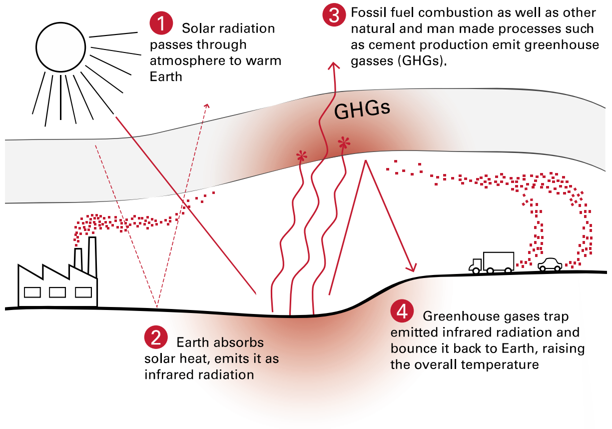
Life Cycle and Evaluation
April PPT Lunch & Learn

Sean Wittmeyer | ZGF Architects

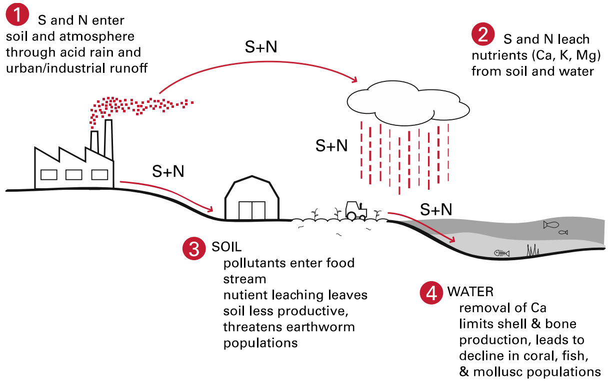
Jacob Dunn | ZGF Architects

Garage

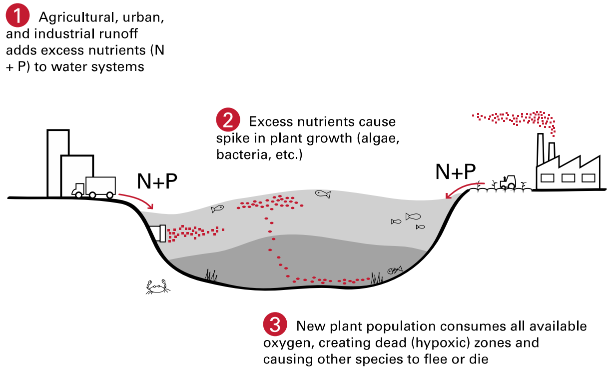
[Chart about impact of embodied vs operational carbon – check w/jake]



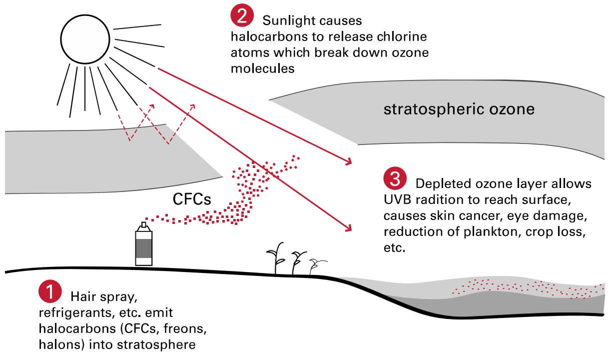
GLOBAL WARMING



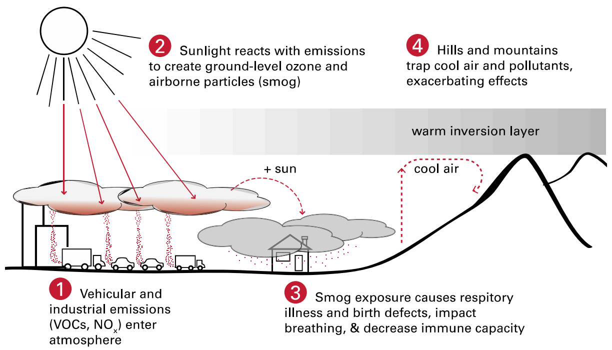
ACIDIFICATION



EUTROPHICATION



OZONE DEPLETION



SMOG

	Type	Example	Unit
Non-Renewable	Energy	Coal combustion for electricity	MJ
	Material	Crude oil as material input to plastic	MJ
Renewable	Energy	Bio-fuel	MJ
	Material	Wood burned in a furnace	MJ

PRIMARY ENERGY DEMAND

Source: K. Simonen, *Life Cycle Assessment*, 2014

MATERIALS AND RESOURCES CREDIT

Building Life-Cycle Impact Reduction

STEP 1: CALCULATE BUILDING MATERIALS

STEP 2: SELECT APPROPRIATE TOOLS AND DATA SETS FOR LCA ASSESSMENT

STEP 3: CREATE AND MODEL BASELINE BUILDING

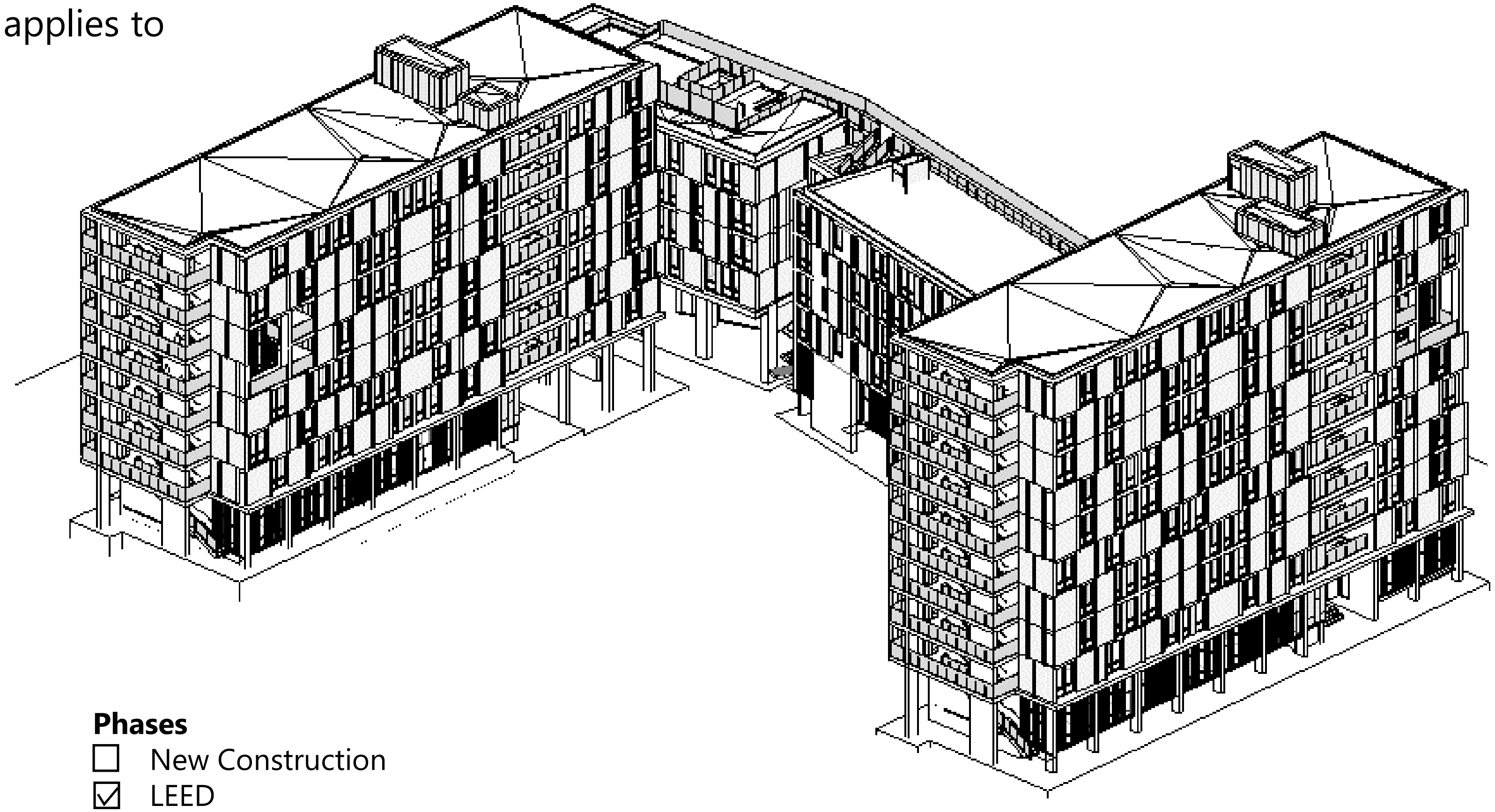
STEP 4: SELECT RELEVANT IMPACT MEASUREMENT SYSTEMS

STEP 5: USE LCA TO MAKE DESIGN DECISIONS THAT REDUCE ENVIRONMENTAL IMPACTS

STEP 6: INCORPORATE FINAL LCA RESULTS

ISOLATE CORE AND SHELL

Allows for reduced scope that covers those elements that the LEED credit applies to



Phases

☐ New Construction

☑ LEED

KEEP TRACK OF ITERATIVE DECISIONS

Helps when working backwards to create a "baseline" model for comparison

Research Questions, full-building:

- What materials contribute the most (proportionately) to the environmental impact of the buildings as of the end of DD?
- How does the final building (as specified at 100% CDs) compare to earlier designed options? To a "baseline building"?

Research Questions, façade:

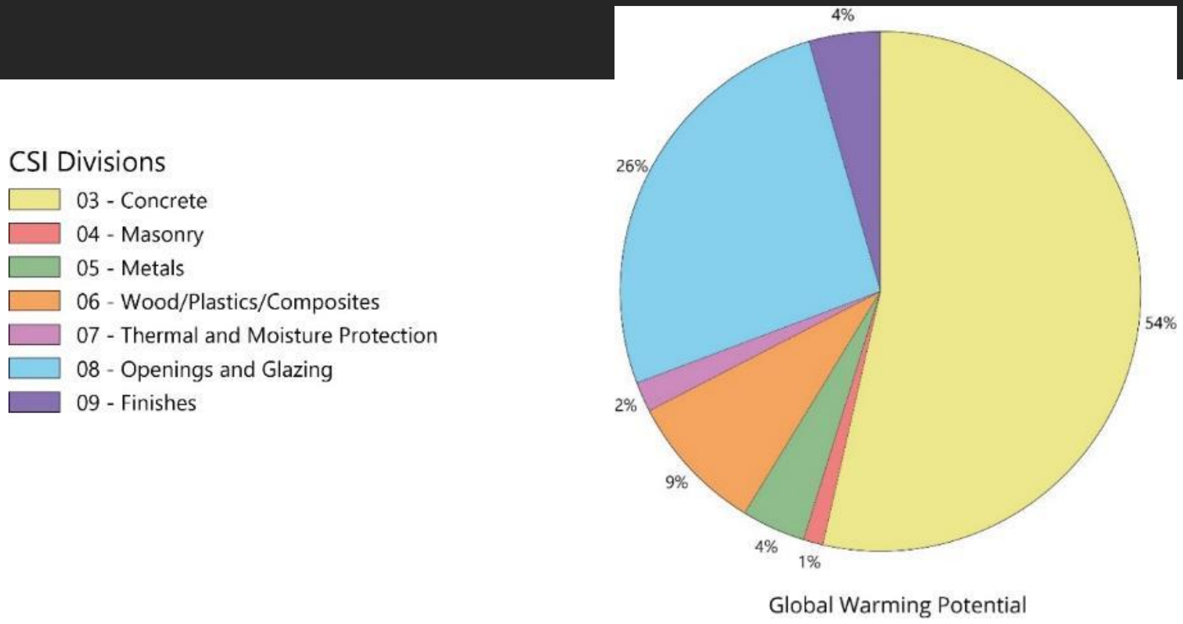
- What is the impact of the metal gauge specified for the structural battens and corrugated metal panel?
- How much of the total wood amount is reduced when changing open joint dimension from 3/8" to ½" gap?
- What is the impact of changing the North façade of Building C from a wood clad system to a metal clad system?
- How much does service life of the wood (influenced by wood finishing product) contribute to the environmental impacts of the façade?
- What are the differences in environmental impact between the corrugated backup system and the previously specified system (Vaproshield)?
- Are there measurable differences in environmental impact based on differences in durability in wood species (Western Red Cedar, Knotty Western Red Cedar, Kebony)?
- What is the resulting impact in the change in façade from wood to metal assembly based on the biogrowth risk study?
- What are the differences in material quantity for iterations of perforated panel based on opening size?
- What is the impact of the backup insulation as a proportion of the building life cycle impacts?
- How do the environmental impacts of a brick exterior on the base compare to those of a concrete exterior finish on the base?
- How do the environmental impacts of the banded and frieze design options compare to each other?
- How do the environmental impacts of a storefront system compare to those of curtainwall construction?

Research Questions, structure:

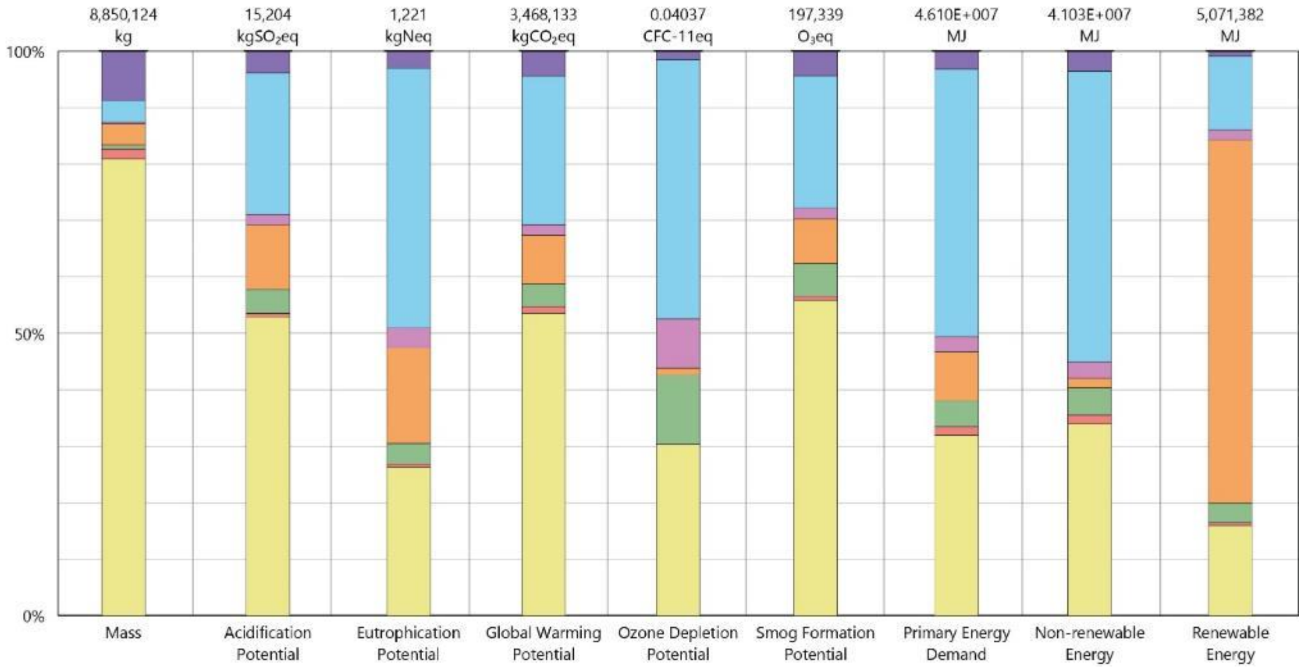
- What percentage overall reductions can be made by increasing the percent of SCMs used in the concrete mix?
- What are the savings made through dematerialization (increased spacing) of the wood stud system?
- How do the environmental impacts of wood stud compare to those of metal stud?
- What are the overall reductions that can be made to the structural components when compared against the highest impact base case?

FULL BUILDING ASSESSMENT

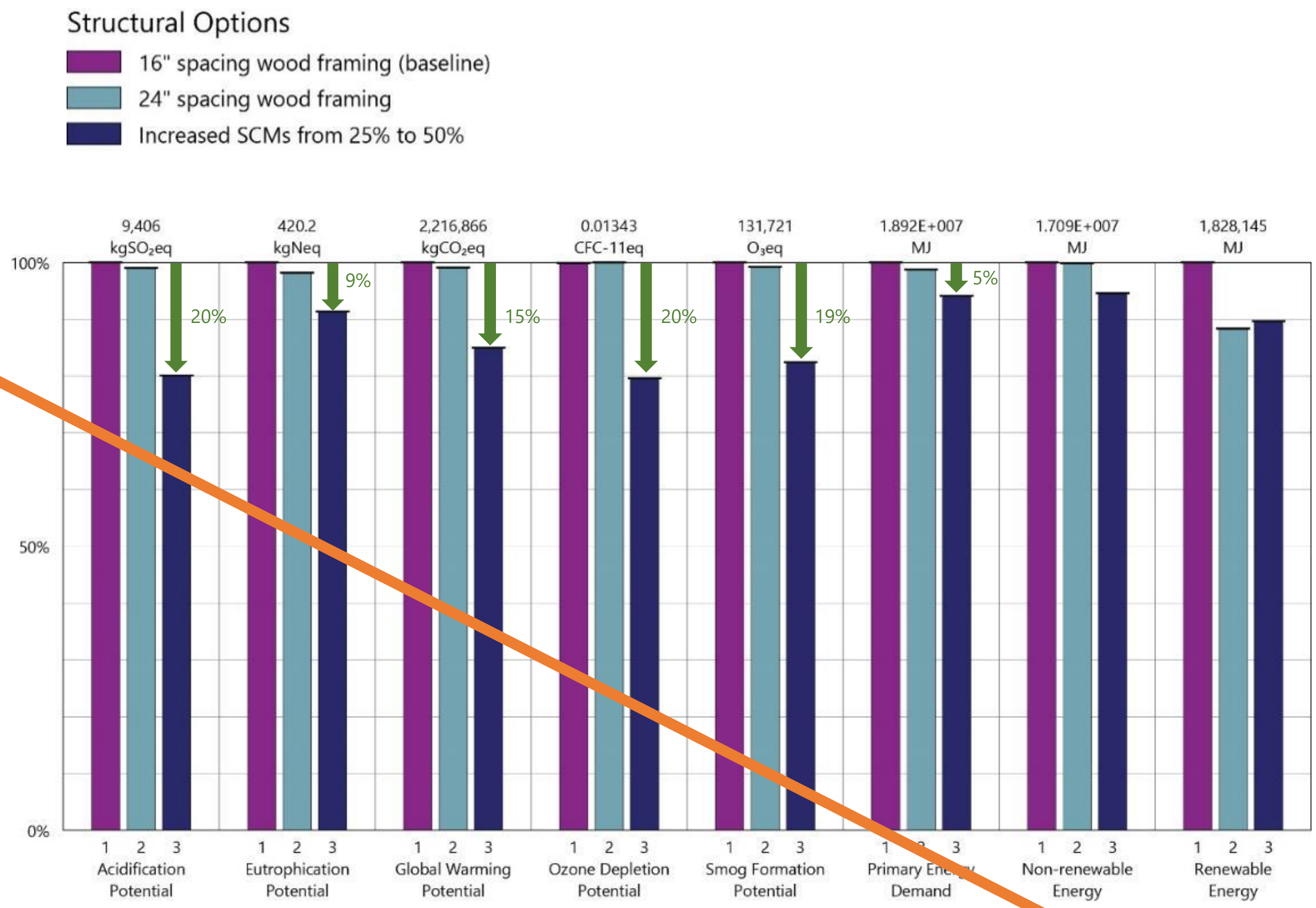
Where do the majority of building environmental impacts occur?



Results per CSI Division



I think you could cut the next 6 slides



Structural Options
16" spacing wood framing (baseline)
24" spacing wood framing
Increased SCMs from 25% to 50%
100%
50%
0%
9,406 kgSO₂eq
420.2 kgNeq
2,216,866 kgCO₂eq
0.01343 CFC-11eq
131,721 O₃eq
1.892E+007 MJ
1.709E+007 MJ
1,828,145 MJ
20%
9%
15%
20%
19%
5%
1 2 3
Acidification Potential
Eutrophication Potential
Global Warming Potential
Ozone Depletion Potential
Smog Formation Potential
Primary Energy Demand
Non-renewable Energy
Renewable Energy

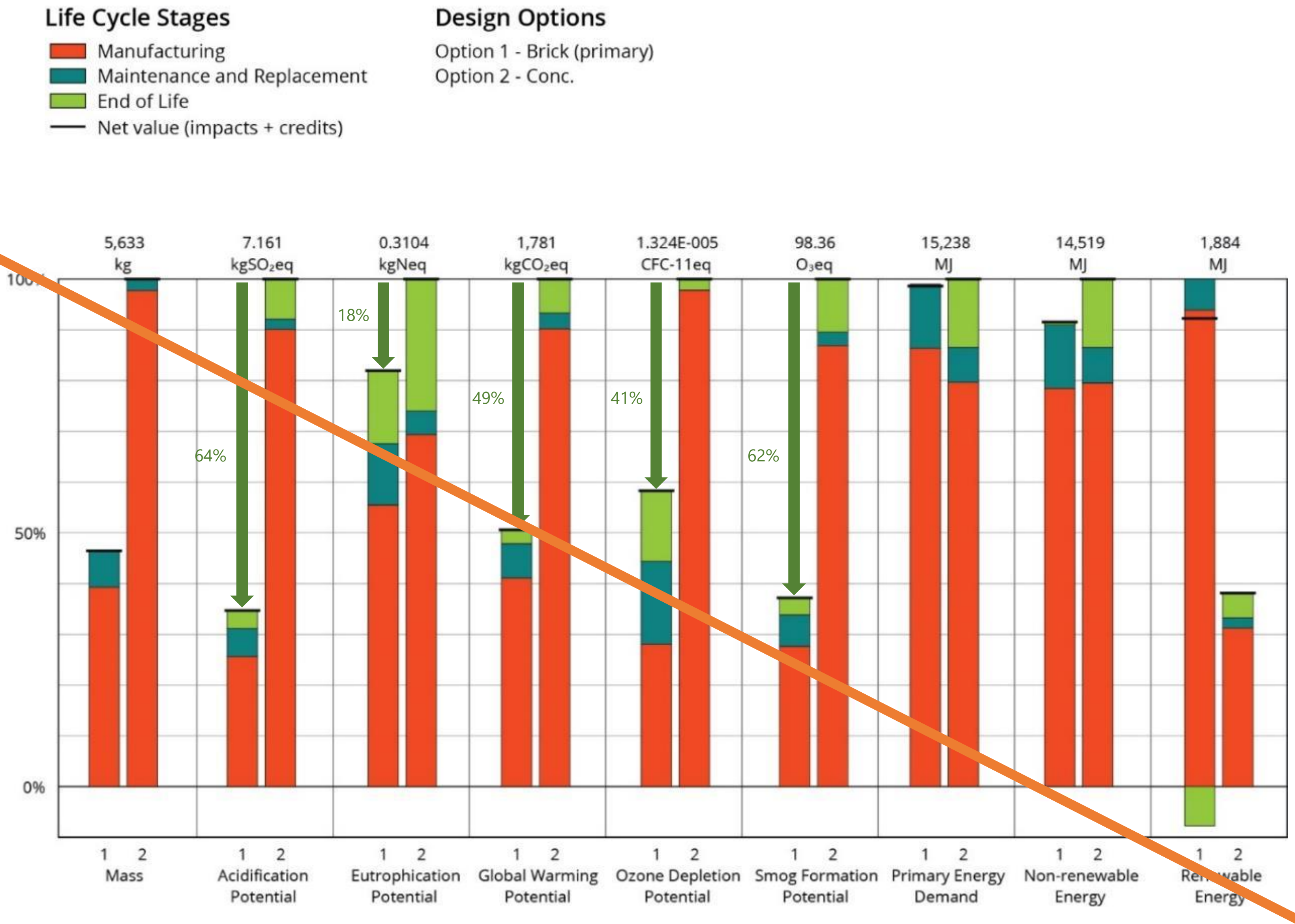
DESIGN DEVELOPMENT

How can I reduce the impacts associated with the facade system?

Option 1 - Brick

Option 2 - Concrete

Comparative Results



SCHEMATIC DESIGN

It is important to conduct Life Cycle Assessments as a part of the early decision-making process because many of the largest contributing factors to environmental impacts are determined early in the design process.

DESIGN DEVELOPMENT

Incremental changes to environmental impacts can be included as a part of the feedback process throughout design to achieve exemplary performance. It is important to conduct Life Cycle Assessment throughout this phase as a part of the evaluation process for design options.

CONSTRUCTION DOCUMENTS

Performing Life Cycle Assessments throughout the process of detailing assemblies can make a big difference to overall environmental impacts of a building. This is the time to go after those last few percentage points of improvement!

POST CONSTRUCTION

The evaluation of proposed changes during the construction process can help avoid unintentionally increasing embodied environmental impacts.

Methodology