Smart Retrofits:
Pathway to a Low-Carbon World

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BUILDINGENERGY BOSTON
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CSHub

MIT CONCRETE SUSTAINABILITY HUB

Supporting building design decisions through life cycle assessment

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BuildingEnergy Boston

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What is a green building?

A life cycle perspective should be used to evaluate environmental impacts of building design strategies

Materials & Products

- Use recycled
- Reduce energy
- Improve material performance

Design & Construction

- Use less (i.e., stronger) material
- Create longer-lasting designs
- Reduce construction impacts

Operation

- Reduce building energy consumption
- Reduce maintenance
- Minimize damage due to hazards

End-of-Life

- Enable material recovery
- Enable component recovery

Trade-offs among strategies should be evaluated quantitatively

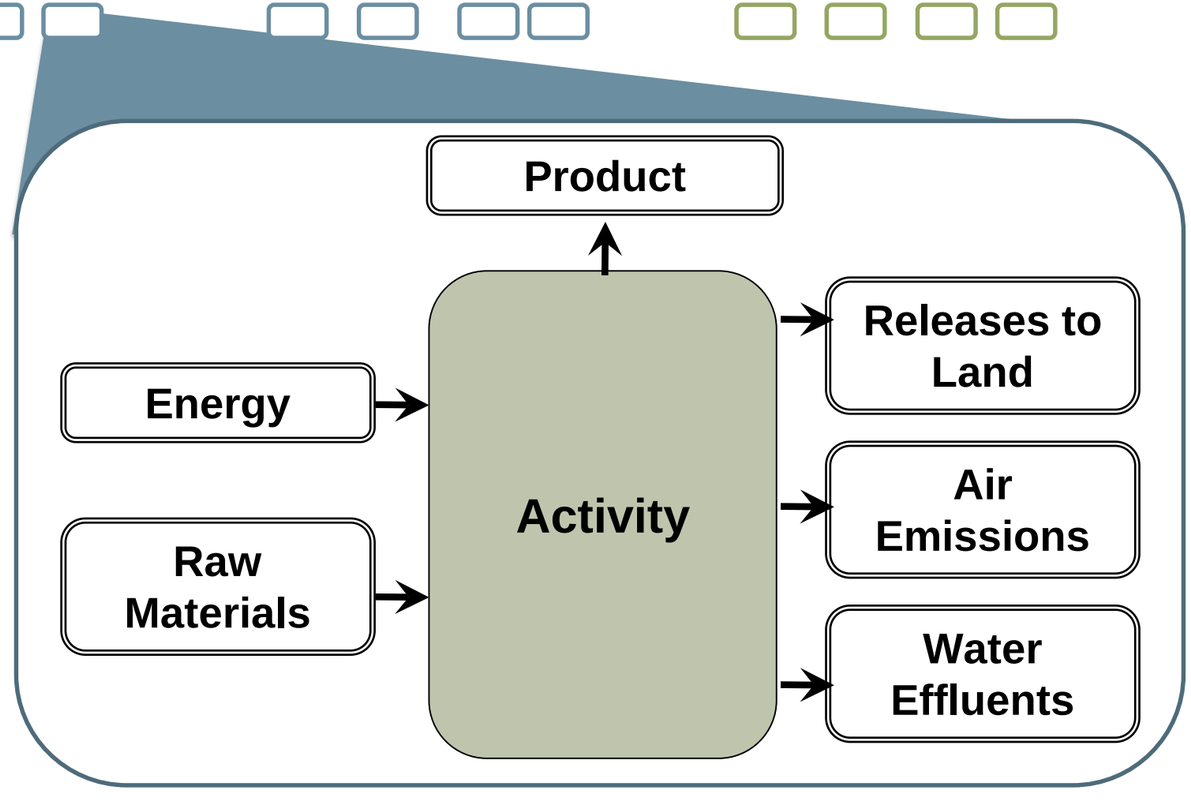
Life-cycle assessment:
Method for quantifying environmental impact

Materials & Production

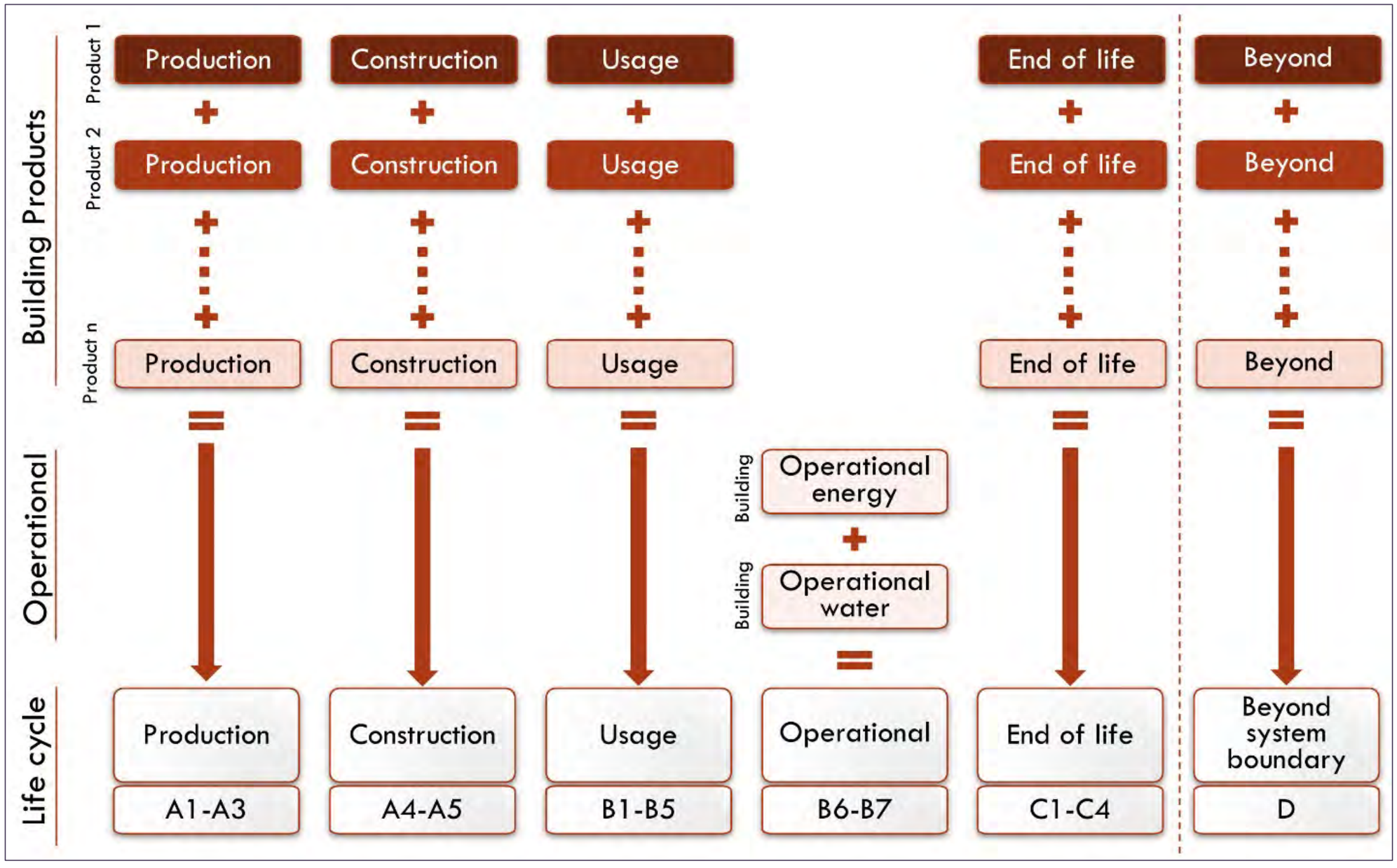
Design & Construction

Use

End-of-Life



Building LCA Scope from EN 15978

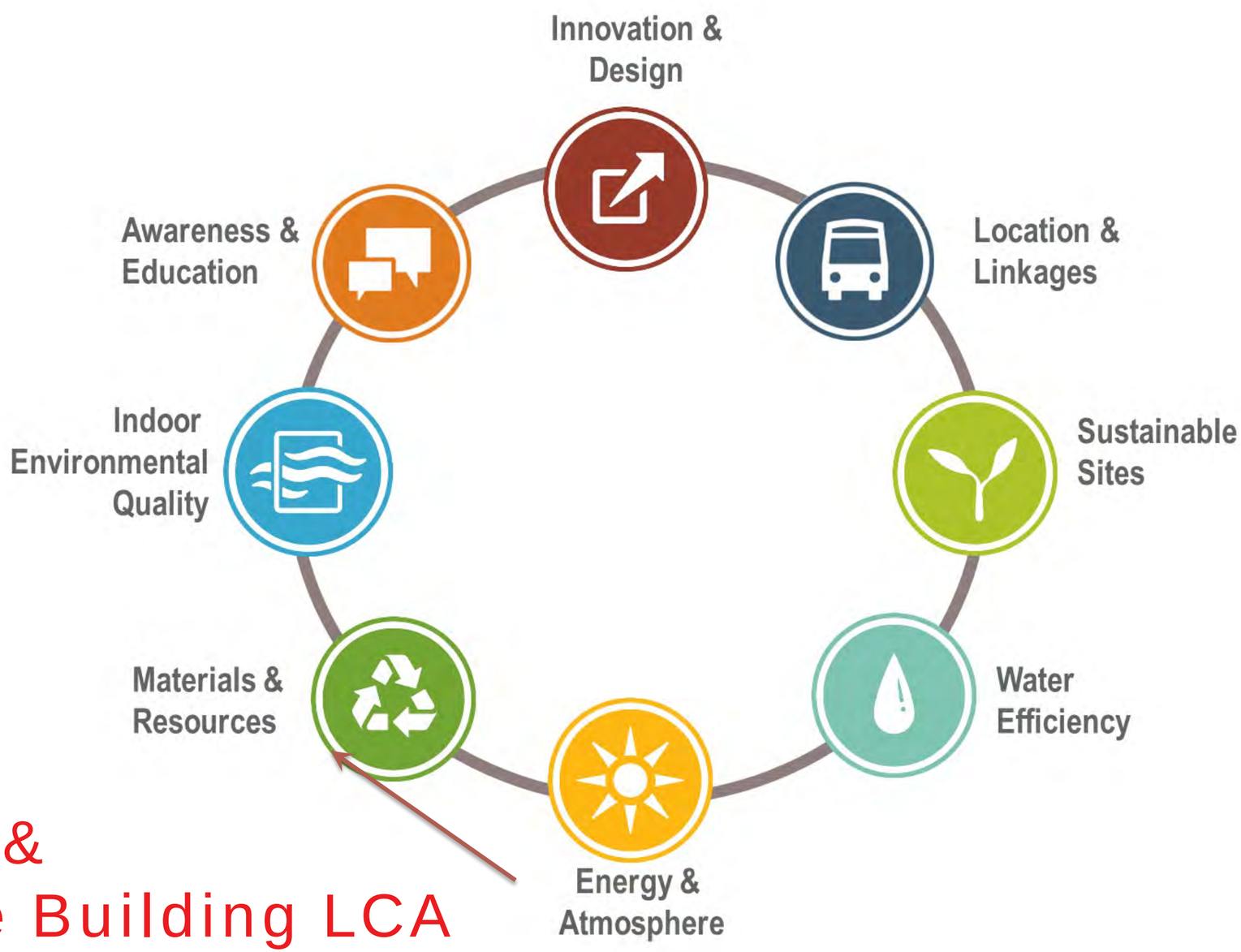


Scope of different building LCAs

	Materials & Production	Construction	Usage	Operational	End-of-Life
Building Product EPD*	✓				
Whole Building LCA	✓	✓	✓		✓
Whole Building & Whole Life LCA	✓	✓	✓	✓	✓

*EPD = Environmental Product Declaration

LEED has started to incorporate LCA



EPDs &
Whole Building LCA

EPDs and WBLCA Tools are meeting demand for LEED

Materials & Production

Construction

Usage

Operational

End-of-Life

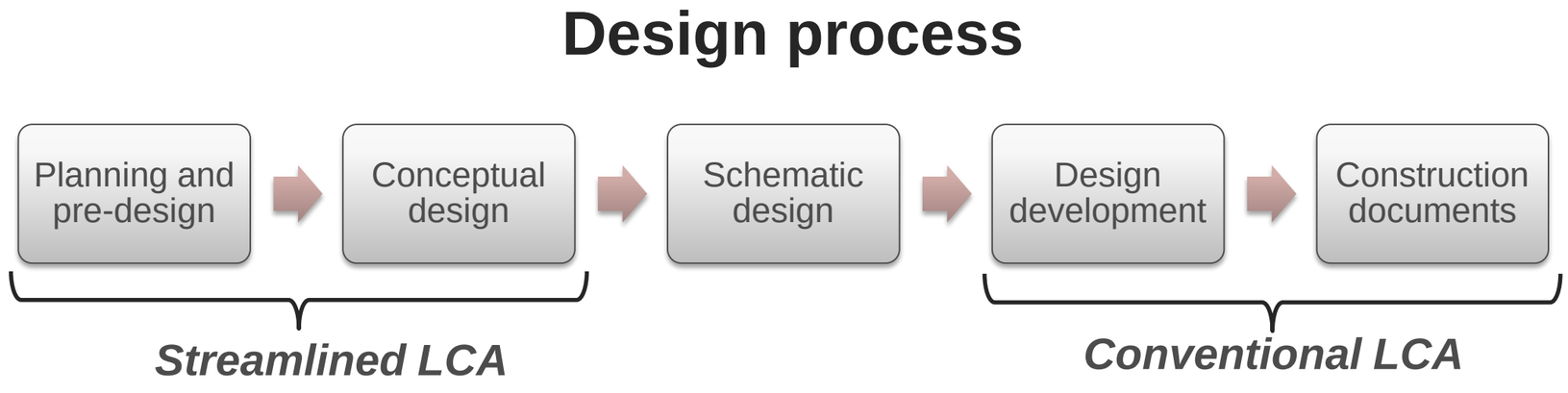
Building Product EPD	LEED M&R ✓				
Whole Building LCA	LEED M&R (Embodied Impacts) ✓	✓	✓		LEED M&R ✓
Whole Building & Whole Life LCA	✓	✓	✓	✓	✓

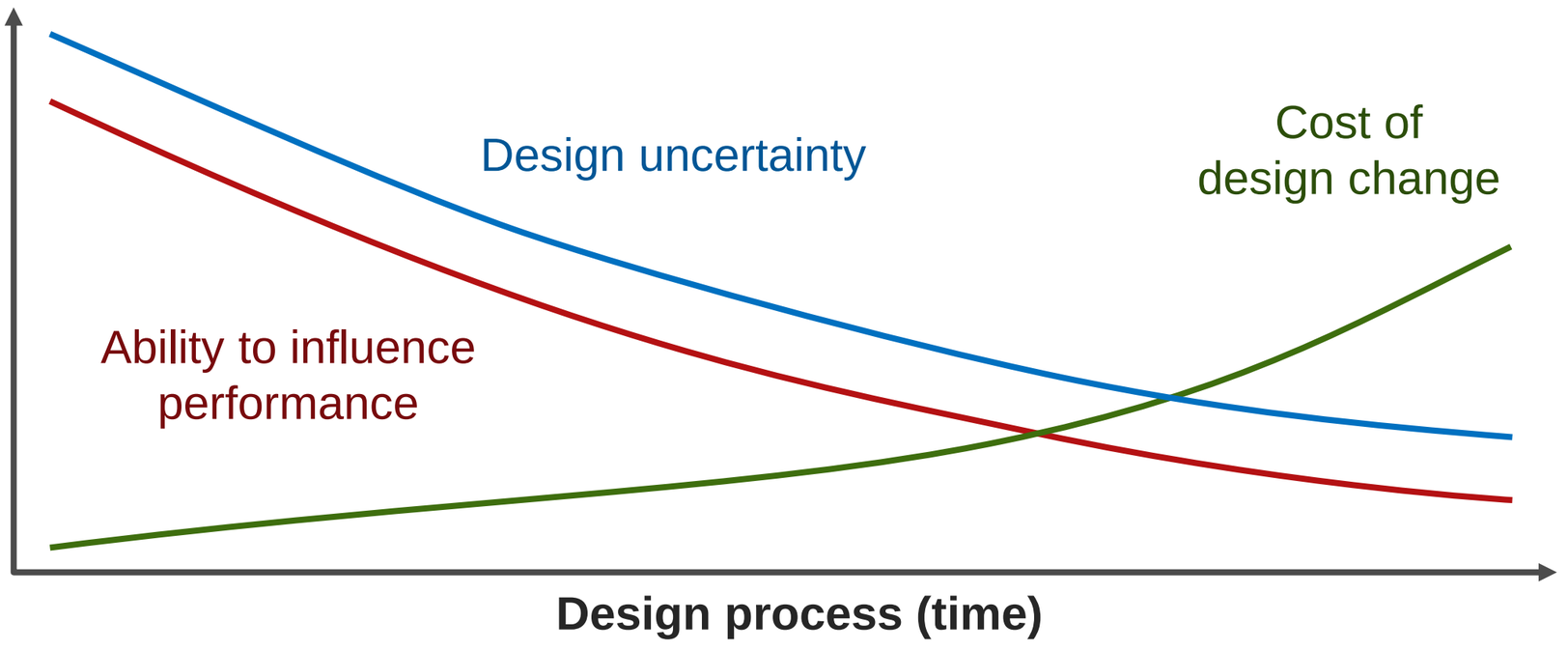
Potential objectives for building LCAs beyond LEED

	Materials & Production	Construction	Usage	Operational	End-of-Life
Building Product EPD	Vendor Decisions ✓				
Whole Building LCA	Design Decisions (Same Operational Performance) ✓	✓	✓		✓
Whole Building & Whole Life LCA	Design Decisions (Different Operational Performance) ✓	✓	✓	✓	✓

Challenge of supporting building design decisions

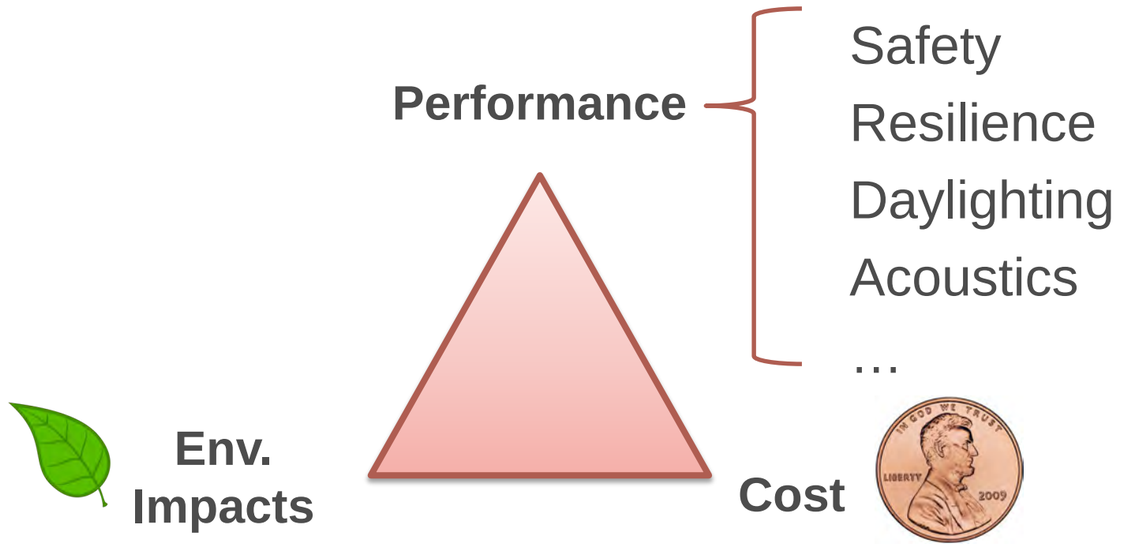
Design tension #1: Need for early guidance vs. uncertainty in early design





Challenge of supporting building design decisions

Design tension #2: Guidance vs. maintaining design flexibility

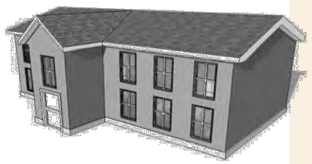


- Early design is about experimenting with potential solutions to variety of design objectives
- Pure optimization is too constraining
- More helpful to identify
  - Near-optimal region of design space
  - Flexible vs. critical aspects of design

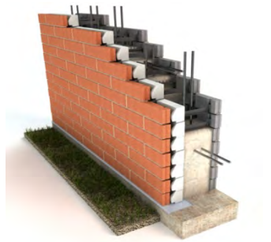
Early-design, probabilistic LCA model

Building Attribute to Impact Algorithm

ATTRIBUTES



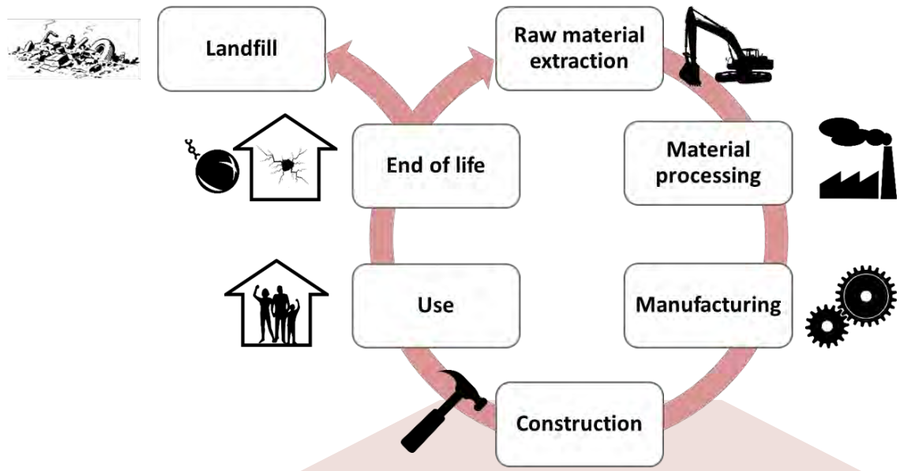
Building
Geometry and systems (mechanical, electrical and plumbing systems)



visualconstructionmarketing.com

Assemblies
Layers defined by material type and thickness

Materials
Each material can be specific or underspecified



Inputs

Under-specified design

(Building, assembly, & material attributes)

Building Attribute to Impact Algorithm

Energy model → Energy use

Material model → Material masses

Energy use × Impact factors → Life-cycle impacts

Material masses → **Cost model** → Life-cycle costs

Outputs

Life-cycle impacts

Life-cycle costs

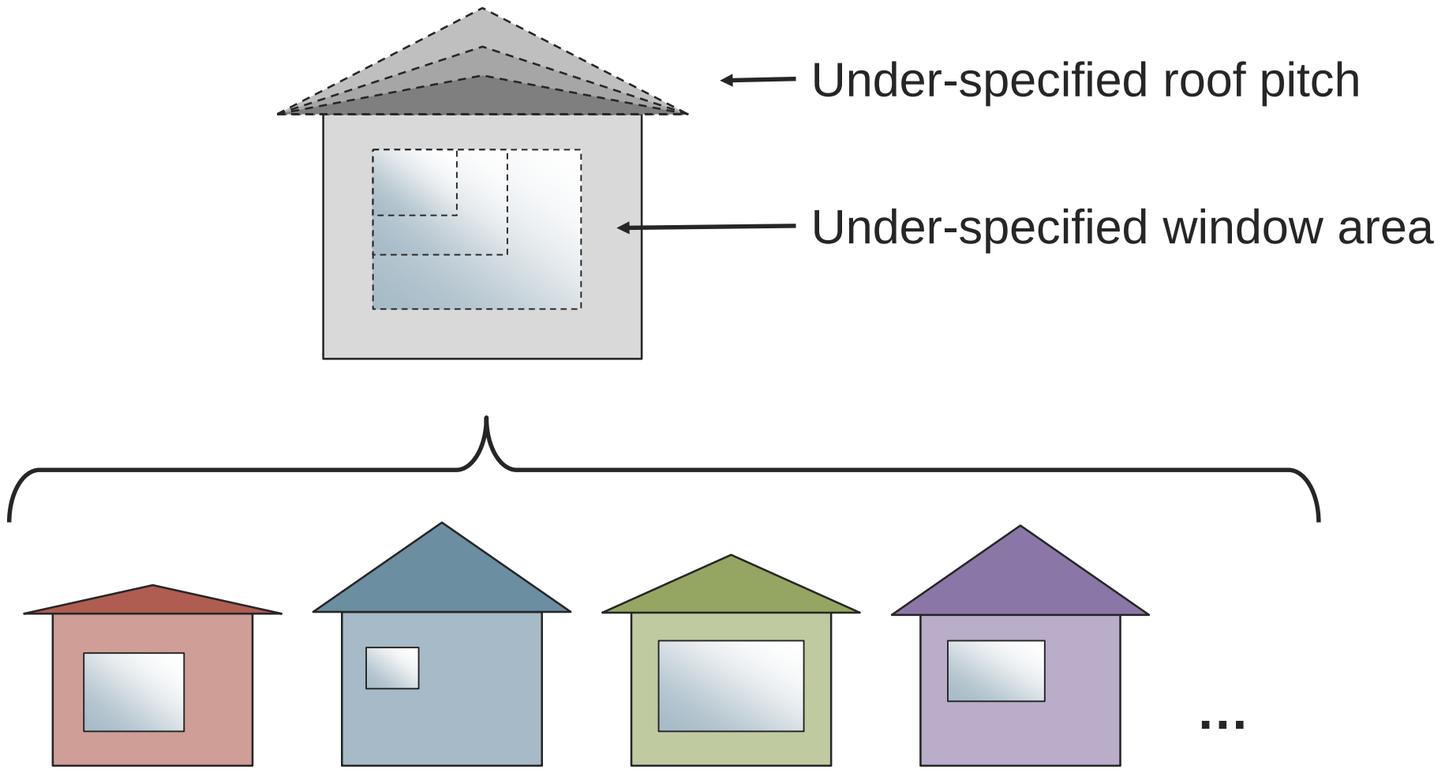
Design refinement

Hester, J., Gregory, J., Kirchain, R. "Actionable insights with less data: guiding early building design decisions with streamlined probabilistic life cycle assessment", The International Journal of Life Cycle Assessment (2018).

Under-specified design

Represented by set of specific designs

Under-specified building



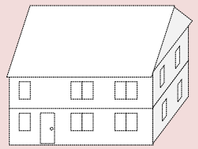
Set of 1,000 specific, randomly-generated designs
with varying roof pitches and window areas

Sequential specification

Design refinement method #1

Run BAIA
(Monte Carlo LCA)

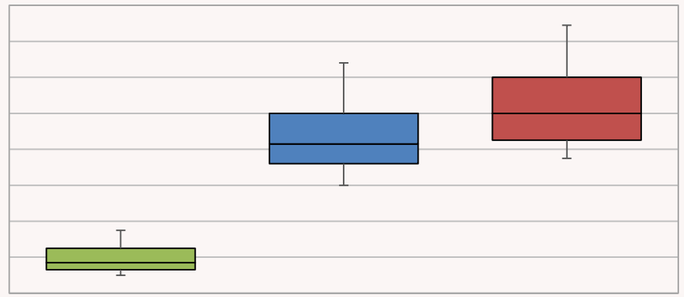
Input:



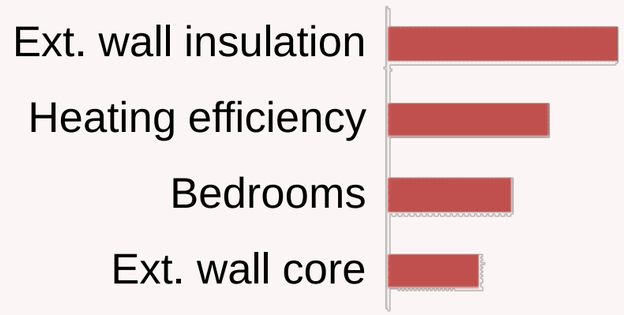
Under-specified design information

Key outputs:

Life cycle impacts and costs



Probabilistic triage: priority attributes



Refine design
Specify priority attribute(s)

Sequential specification example

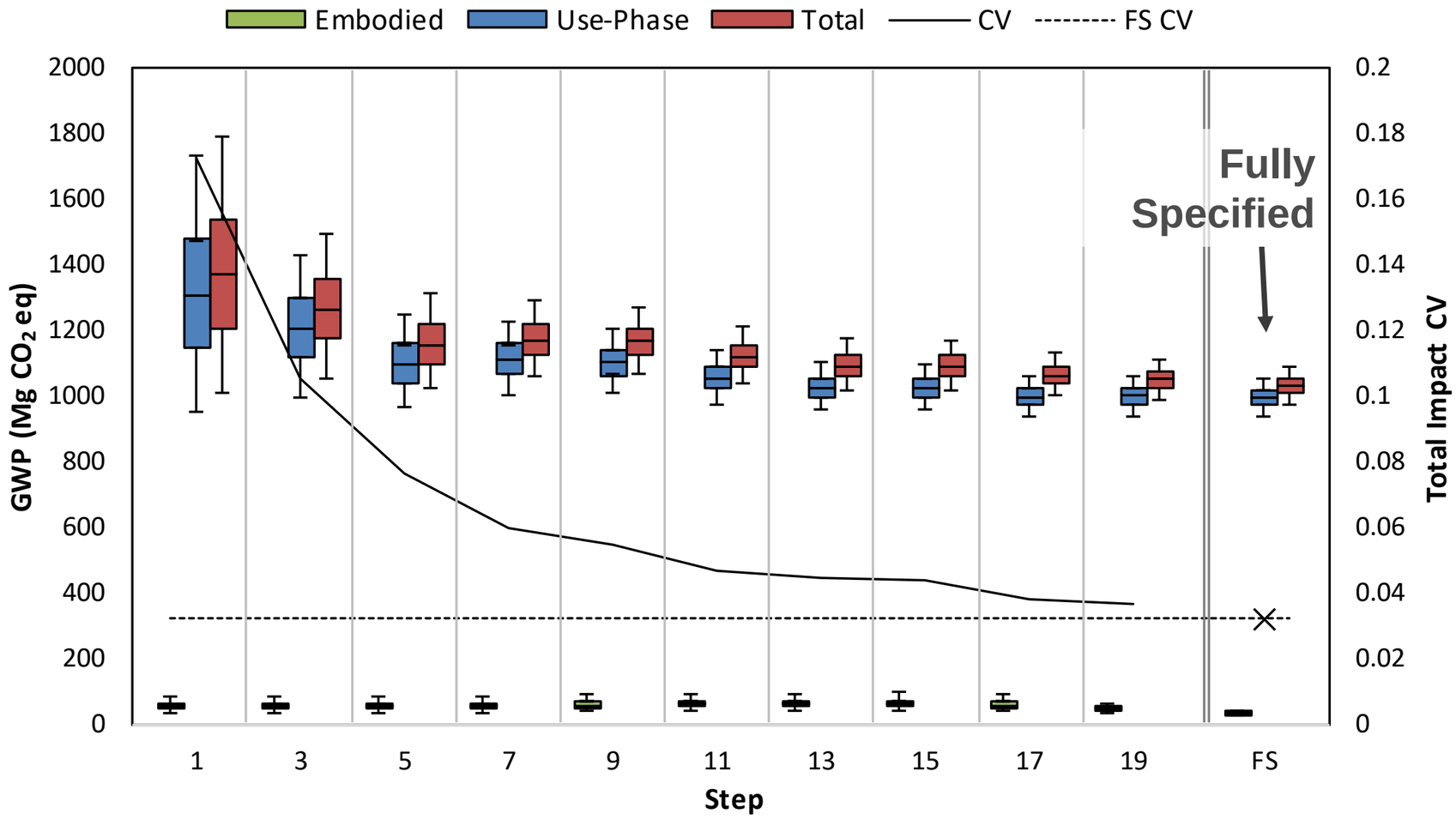
Selected attribute:
Air leakage

Selected attribute:
Window area

Boston **2400 sq. ft.** Any air leakage (0.5 - 7 ACH50) Any win. area (10-40% of wall area)	***Boston*** ***2400 sq. ft.*** **Low air leakage** **(≤ 3 ACH50)** Any win. area (10-40% of wall area)	***Boston*** ***2400 sq. ft.*** ***Low air leakage*** ***(≤ 3 ACH50)*** **Moderate win. area** **(20-30% of wall area)**
Step 1	**Step 2**	**Step 3**

Efficient increase in LCA precision

through sequential specification

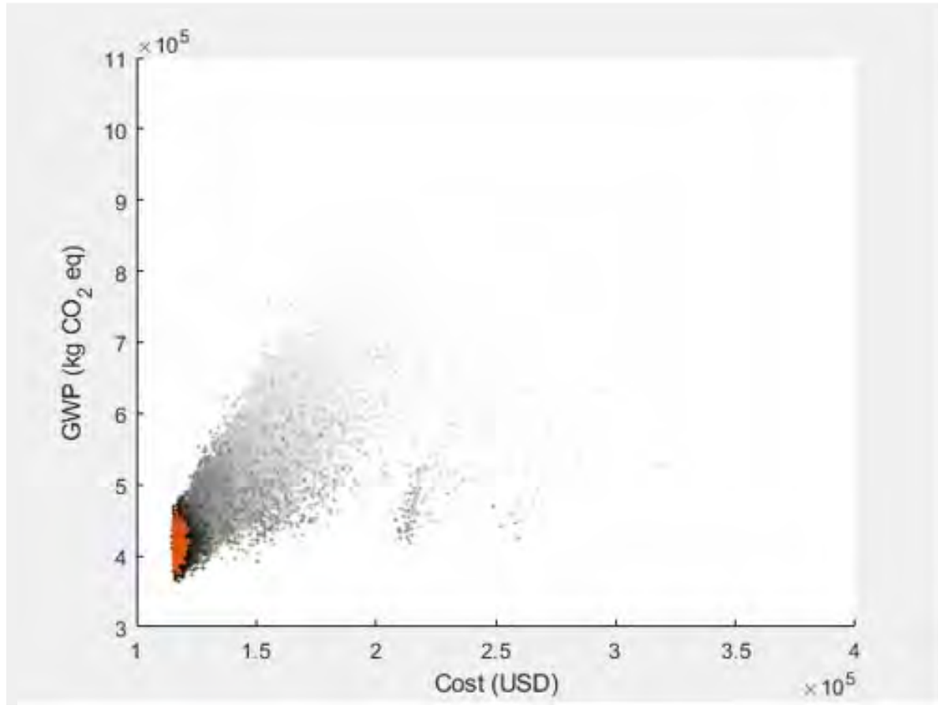


Variability (CV) quickly approaches value from a fully specified design.

Genetic optimization

Design refinement method #2

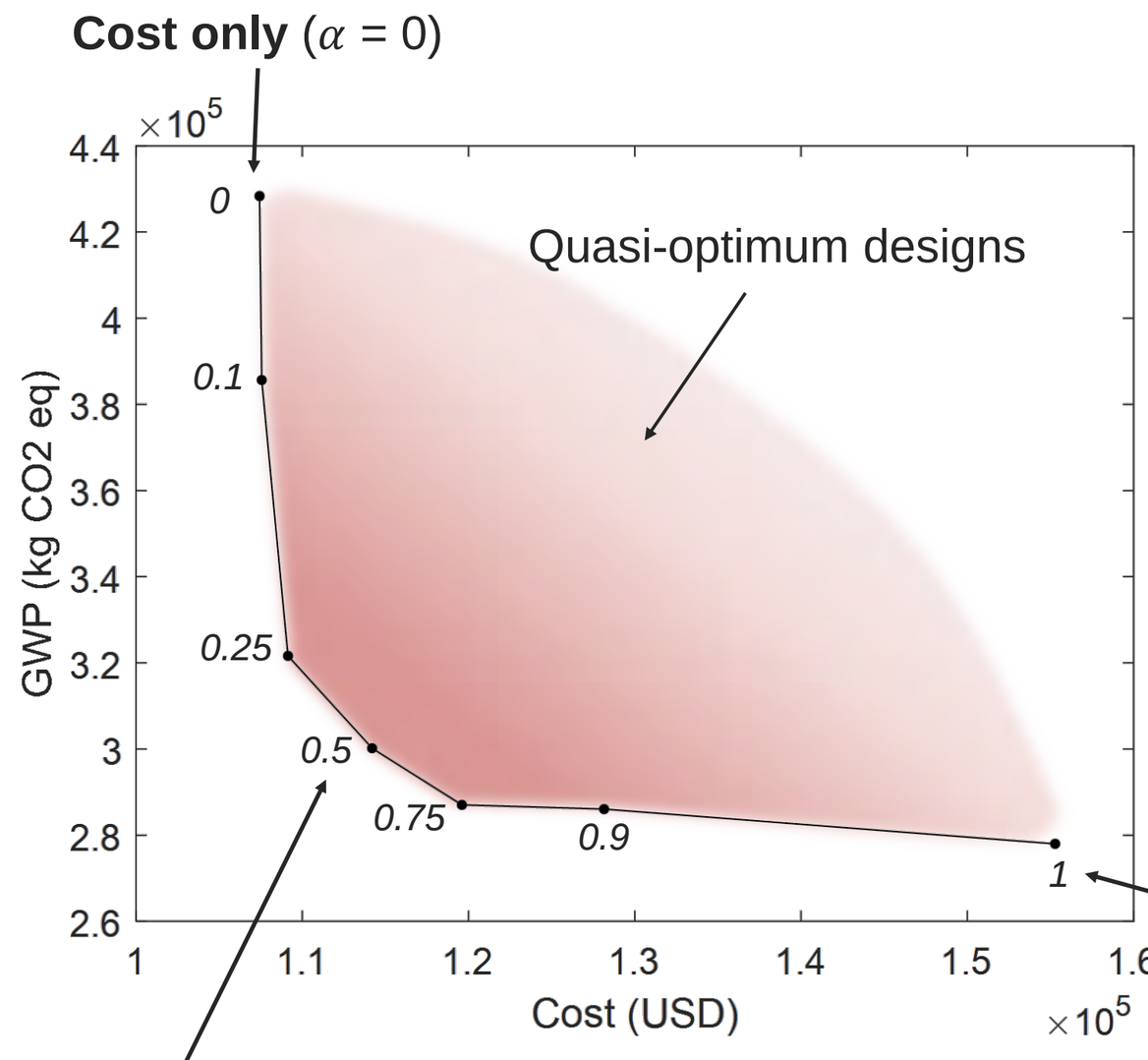
- Optimization method based on natural selection
- Each “generation” uses features from best designs in the previous generation
- Optimization continues until mean impacts and costs change by less than 0.1% over 5 steps
- A quasi-optimum region can be defined and used to determine which parameters are flexible



Black/grey = Intermediate generations
Orange = Final (optimized) generation

Impact/cost Pareto frontier

Determined by changing α, relative weight of impacts and costs



$$F_i = 1 - [\alpha I_i + (1 - \alpha) C_i]$$

F_i = Fitness of design i

I_i = Impacts* of design i

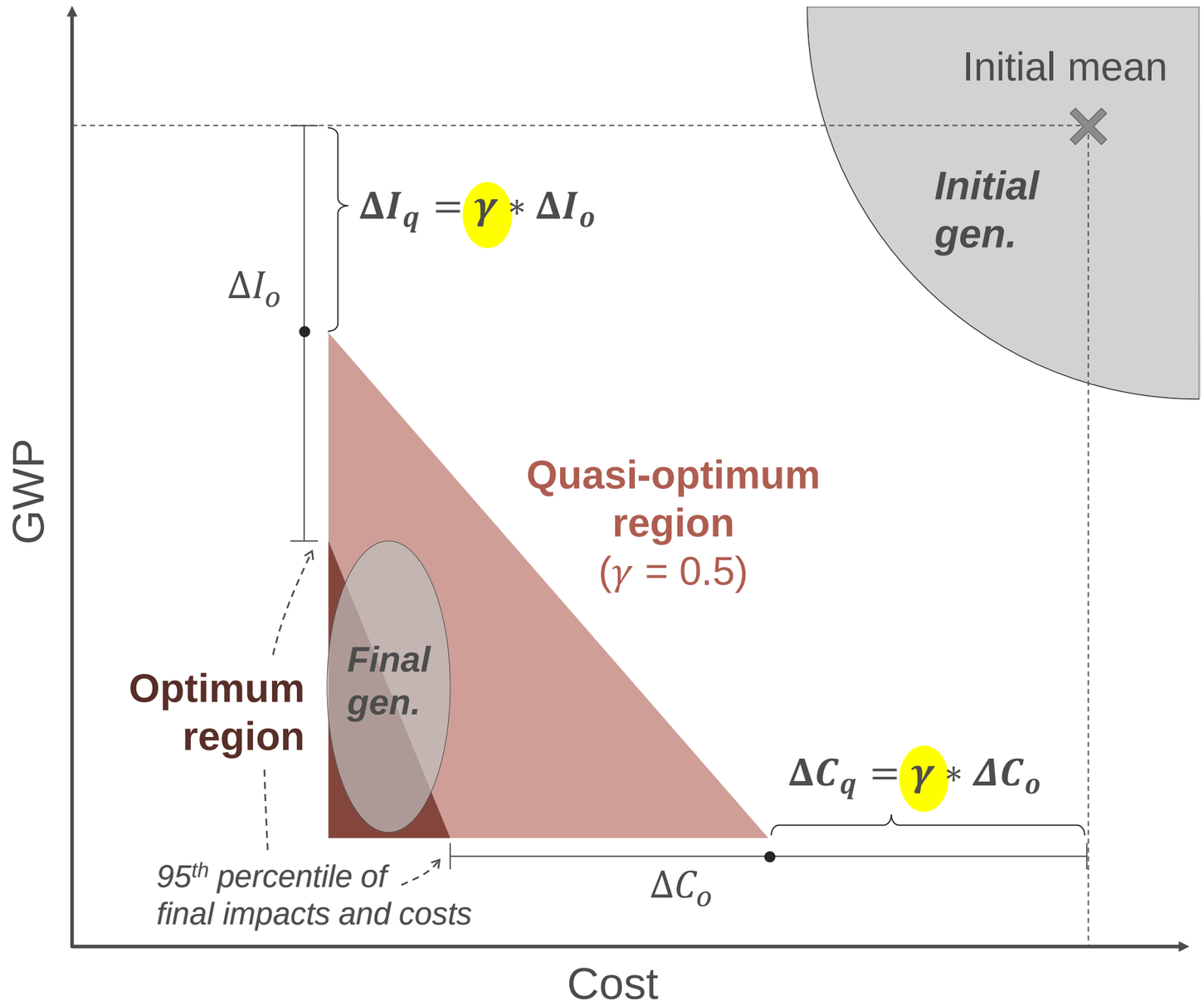
C_i = Cost* of design i

α = Weighting factor

*Normalized to [0,1] in each generation

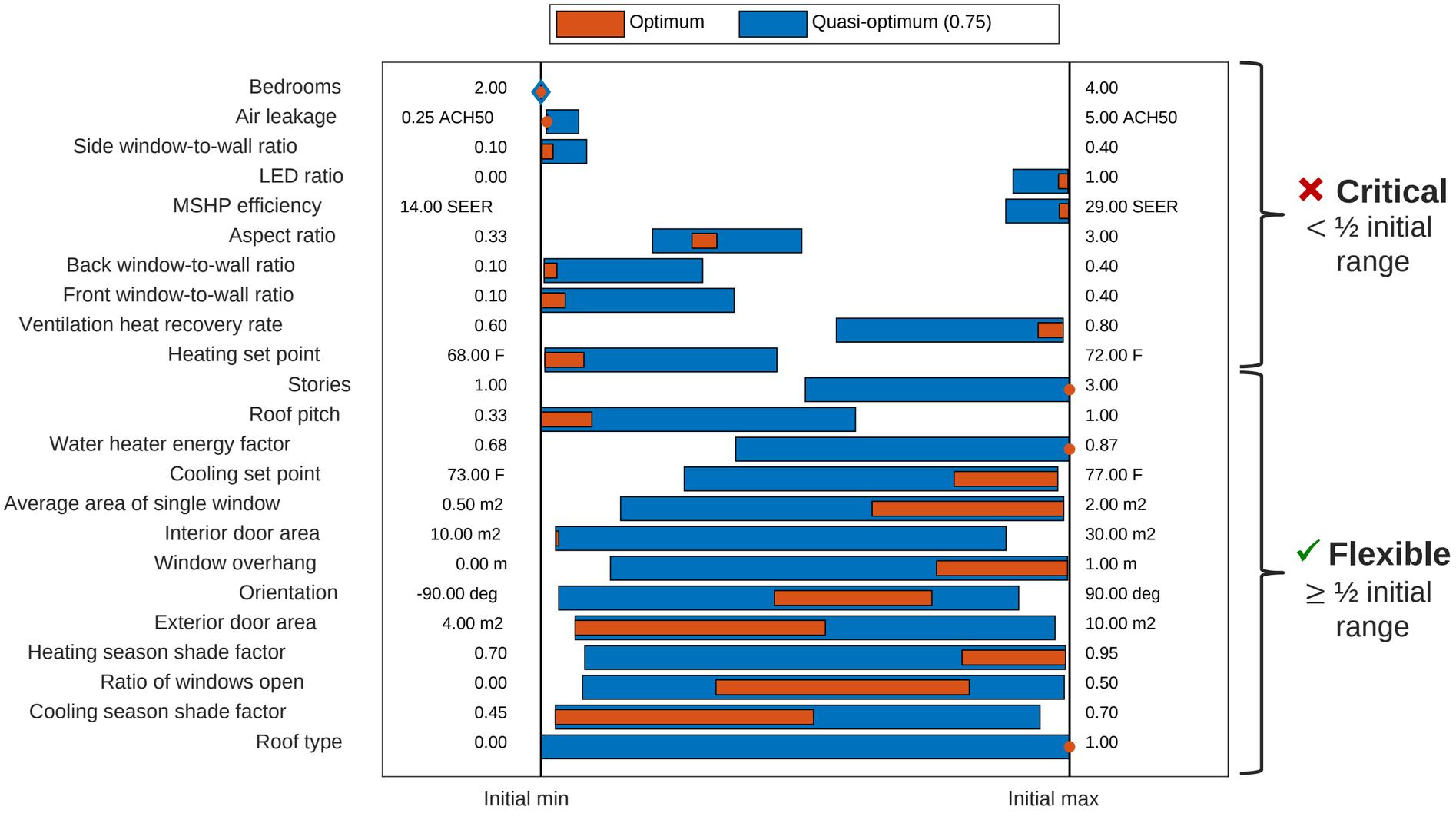
Definition of quasi-optimum regions

Based on % of optimum improvement in impacts and costs



Increased building attribute flexibility

From exploring quasi-optimum designs ($\gamma = 0.75$)



Larger blue bar indicates more flexibility gained

Case studies

Quasi-optimum designs in different contexts

Four sets of cases, each with three 2,400 square-foot buildings in Chicago (except for climate case):

1. **Climate**
   Chicago (cold), San Francisco (mild), and Phoenix (hot)
2. **Analysis period**
   25 years, 50 years, and 100 years
3. **Energy impact factor variability**
   Double, original, and half coefficient of variation
4. **Optimization weighting of impacts and costs (α)**
   0 (cost only), 0.5 (equal weighting), and 1 (impacts only)

Summary of cases

Flexibility of geometrical attributes, γ = 0.75

KEY: ✓ Flexible ✖ Critical ● Varies – NA		Climate			Weight of impacts vs. costs (α)		
Attribute	**Summary**	**Chicago**	**Phoenix**	**San F.**	**Cost only (0)**	**Equal (0.5)**	**Imp. only (1)**
GEOMETRY							
Orientation	✓						
Stories	✓						
Roof type	✓						
Roof pitch	✓						
Window overhang	✓						
Average area of single win.	✓						
Exterior door area	✓						
Interior door area	✓						
Front window-to-wall ratio	●	✖	✖	✓	✓	✓	✖
Back window-to-wall ratio	✖						
Side window-to-wall ratio	✖						
Building aspect ratio	✖						

Highlighting indicates sets of cases where flexibility changes

Summary of cases

Flexibility of occupant- and systems-related attributes, γ = 0.75

KEY: ✓ Flexible ✖ Critical ● Varies – NA		Climate			Weight of impacts vs. costs (α)		
Attribute	**Summary**	**Chic.**	**Phon.**	**San F.**	**Cost only (0)**	**Equal (0.5)**	**Imp. only (1)**
OCCUPANTS							
Ratio of windows open	✓						
Heating season shade factor	✓						
Cooling season shade factor	✓						
Cooling set point	✓						
Heating set point	●	✓	✓	✓	✓	✓	✖
Bedrooms (occupancy)	✖						
SYSTEMS							
Furnace efficiency*	✓	–	–	–	✓	–	–
AC efficiency*	✓	–	–	–	✓	–	–
MSHP efficiency*	●	✖	✖	✓	–	✖	✖
Water heater energy factor	●	✓	✓	✖	✓	✓	✓
Vent. heat recovery rate	●	✖	✓	✓	✓	✓	✖
Air leakage	●	✖	✓	✓	✖	✖	✖
LED ratio	✖						

**Mini-split heat pump preferred in majority of cases*

Highlighting indicates sets of cases where flexibility changes

Benefits of BAIA Approach

- Building design attributes are inputs
- Combined embodied and energy analysis
- Feedback provided on key parameters
- Details specified only when necessary
- Uncertainty quantified for impacts
- Quasi-optimization guides flexible design

The future of BAIA

- Expand to commercial structures
- Integrate with design software
- Evaluate potential to integrate with design process

CSHub

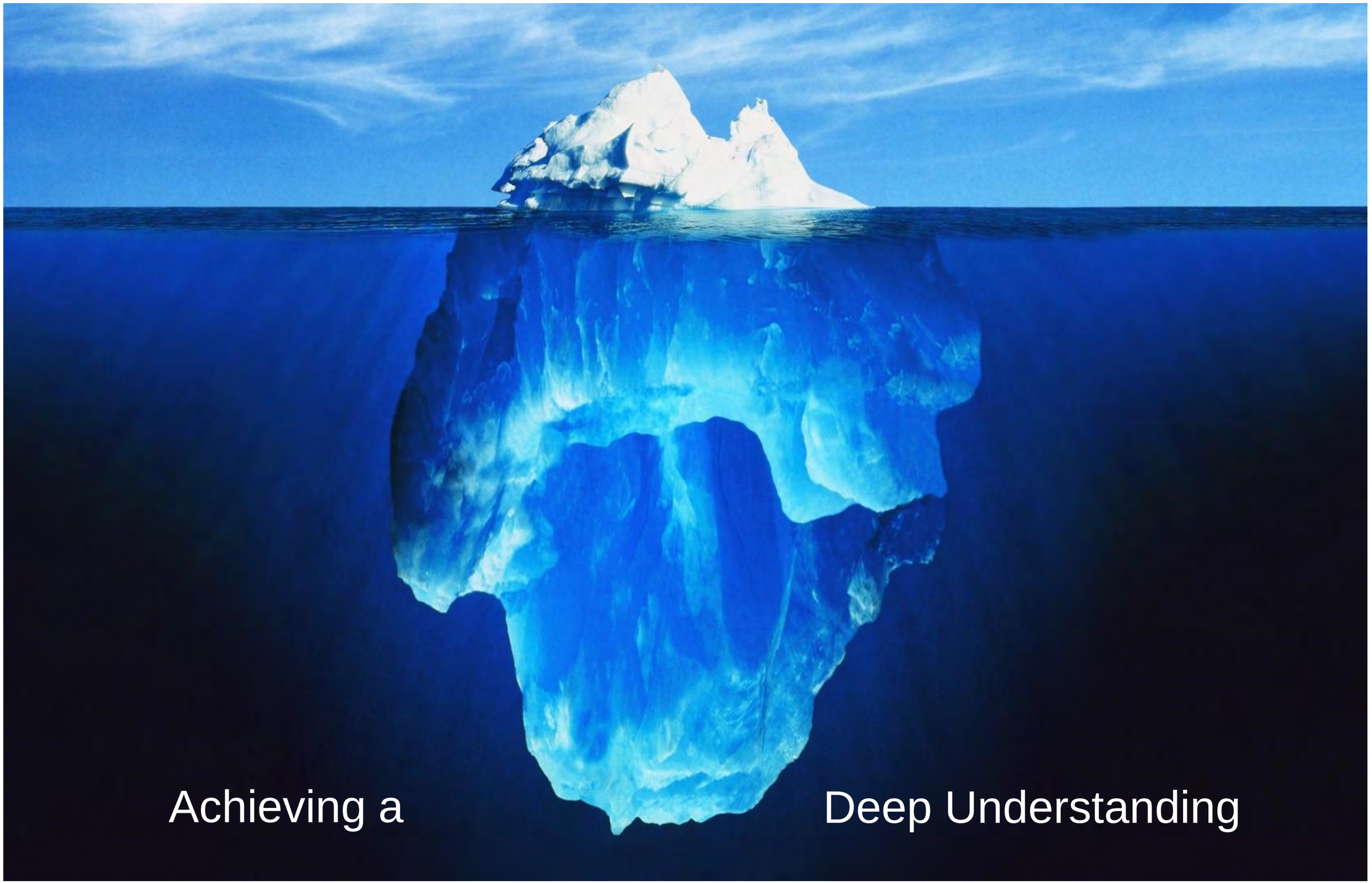
MIT CONCRETE SUSTAINABILITY HUB

More information available at:

http://cshub.mit.edu/

jgregory@mit.edu

Pathways to a Low Carbon World


Achieving a
Deep Understanding

Nutrition Facts

Serving Size 2 Tbsp (35g)

Amount per Serving

Calories 190
Calories from Fat 110

	% Daily Value*
Total Fat 12g	18%
Saturated Fat 2.5g	13%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 230mg	10%
Total Carbohydrate 13g	4%
Dietary Fiber 3g	12%
Sugars 4g	
Protein 7g	

Iron	4%	Calcium	2%
Vitamin B6	6%	Niacin	25%
Magnesium	15%	Folic Acid	6%
Copper	10%	Zinc	6%

Not a significant source of vitamin A and vitamin C.

*Percent Daily Values (DV) are based on a 2,000 calorie diet.

Ingredients:
PEANUTS, CORN SYRUP SOLIDS, SUGAR, SOY PROTEIN, CONTAINS 2% OR LESS OF: SALT, FULLY HYDROGENATED VEGETABLE OILS (RAPESEED AND SOYBEAN), MONO AND DIGLYCERIDES, MOLASSES, MAGNESIUM OXIDE, NIACINAMIDE, FERRIC ORTHOPHOSPHATE, ZINC OXIDE, COPPER SULFATE, FOLIC ACID, PYRIDOXINE HYDROCHLORIDE.

Environmental Impacts →

Health Impacts →

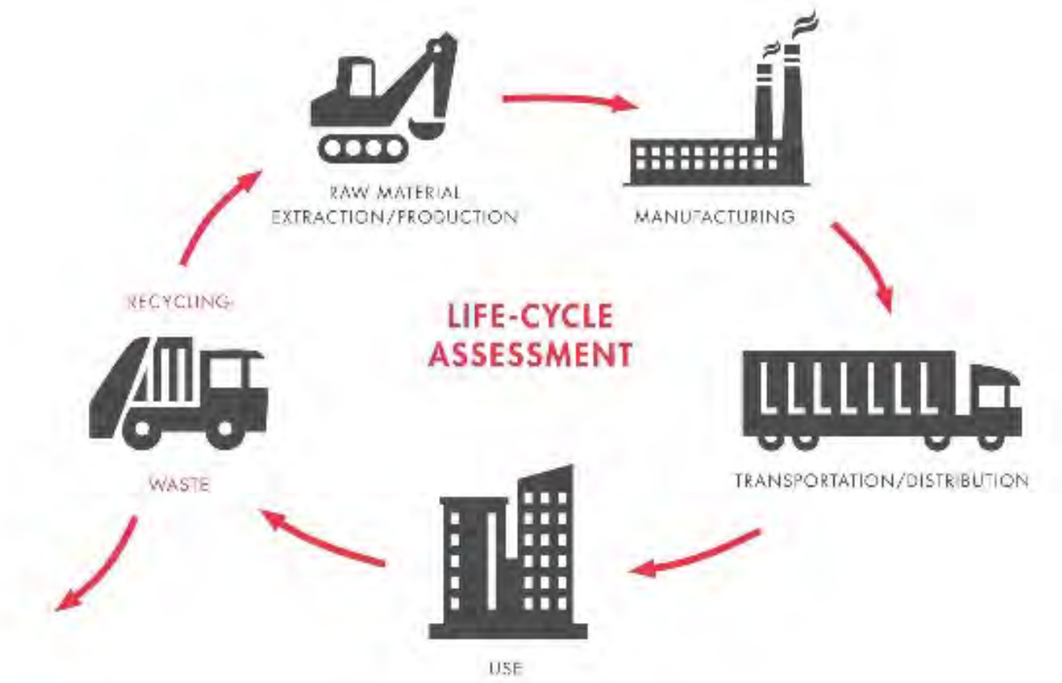
Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC- 11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N- eq)	6.43E-04
Photo-Oxidant Creation Potential (kg 03 eq)	0.121

Your Product's Ingredients: Listed Here

Environmental Product Declaration



GLOBAL WARMING POTENTIAL (GWP) Carbon footprint. Quantification of greenhouse gas and other types of emissions which contribute to global warming/climate change.

ACIDIFICATION POTENTIAL When emissions (especially sulfur dioxide from coal-burning) contribute to acid rain, which leads to the build-up of acidity in soil and bodies of water.

OZONE DEPLETION The thinning of the earth's stratospheric ozone layer due to widespread production and release of halogens (notably CFCs, HCFCs, freons and halons), which also contributes to global warming/climate change.

EUTROPHICATION The potential increase in chemical nutrients, such as nitrogen and phosphorus often found in fertilizers, in aquatic ecosystems. The added nutrients stimulate excessive plant growth and algal blooms, depleting oxygen and light leading to large scale fish kills.

SMOG/PHOTOCHEMICAL OZONE CREATION POTENTIAL Potential contribution of a substance towards creating "ground level ozone." POCP is formed by reactions of VOCs and nitrogen oxides in the presence
of heat and sunlight.

Global Warming Potential

Ozone Depletion Potential

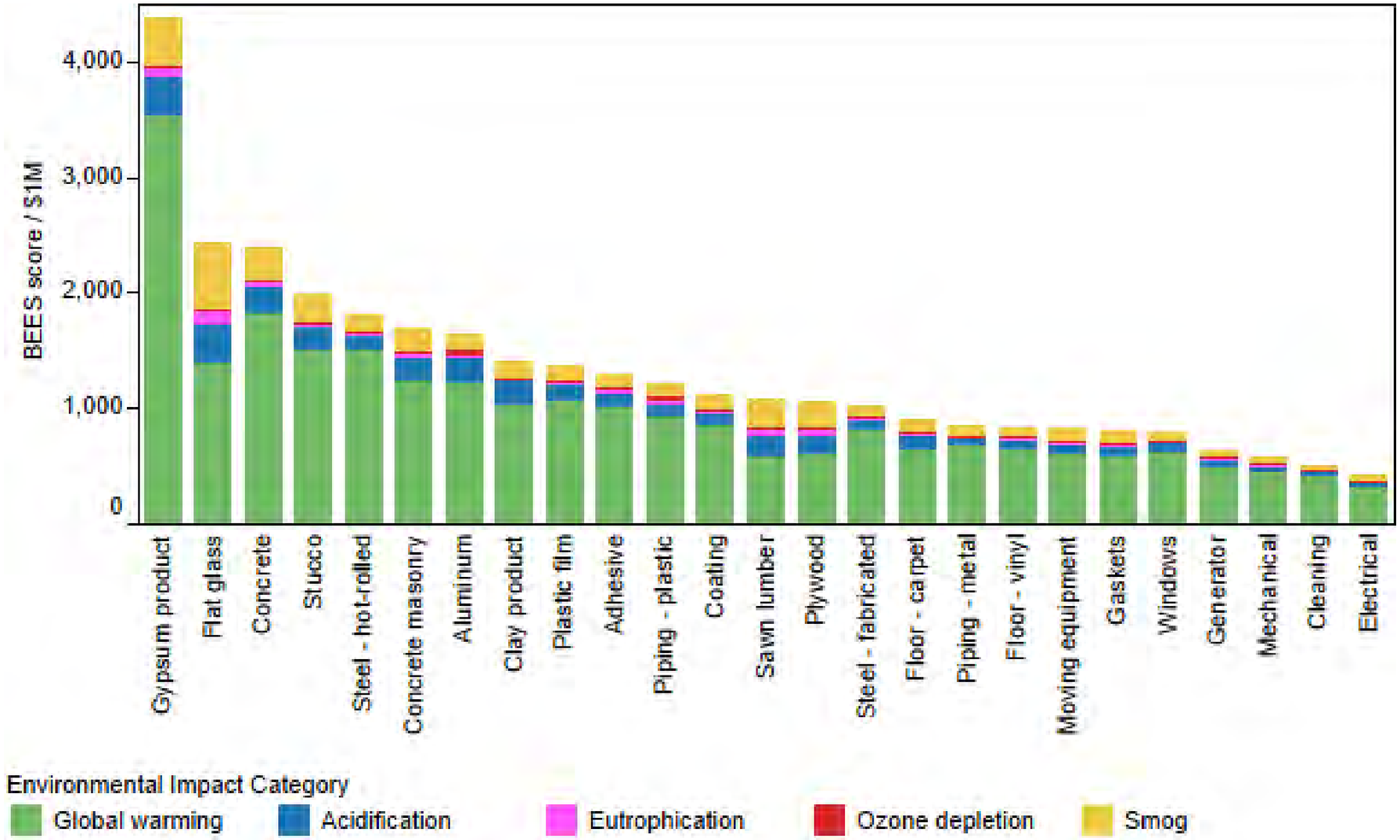
Photochemical Ozone Creation Potential - Smog

Acidification

Eutrophication

Abiotic (Resource) Depletion

Carbon as a Proxy for Other Environmental Impacts



Environmental Impact per Dollar Spent in Sector

How do we use the tools

Environmental Impacts

Building Product Disclosure & Optimization

ENVIRONMENTAL PRODUCT DECLARATIONS - Disclosure

- Option 1: Use at least 20 different permanent products from at least 5 manufacturer's that have an EPD (1 point)
  - Product-specific LCA from cradle to gate following ISO 14044 = 1 product
  - Industry-wide EPD = 1 product
  - Product-specific EPD = 1.5 product

Gypsum Board

ASTM INTERNATIONAL

Environmental Product Declaration

According to ISO 14025 and ISO 21930

An industry average cradle-to-gate EPD for Glass Mat Gypsum Panels produced by Gypsum Association member companies for the USA and Canadian Markets.

Declaration Number: EPD- 038
Date of Issue: 09/13/2016
Period of Validity: 5 years

EPD Summary Results - 1 MSF of $^{1}/_{2}$" and $^{5}/_{8}$" Glass Mat Gypsum Panels

Environmental Product Declaration

Typical (5/8" Type X)

North American Gypsum Boards

ENVIRONMENTAL PRODUCT DECLARATION

JOINT COMPOUND

DRYWALL FINISHING COUNCIL

ENVIRONMENTAL PRODUCT DECLARATION

CERTAINTEED TYPE X GYPSUM BOARD

FOR CERTAINTEED GYPSUM MANUFACTURING FACILITIES BASED AT:
CARROLLTON, KENTUCKY
MOUNDSVILLE, WEST VIRGINIA
ROXBORO, NORTH CAROLINA

ENVIRONMENTAL PRODUCT DECLARATION

AIRRENEW ESSENTIAL TYPE X GYPSUM BOARD 5/8" (15.9MM)

FOR CERTAINTEED GYPSUM MANUFACTURING FACILITIES BASED AT:
MOUNDSVILLE, WEST VIRGINIA, USA

CertainTeed
SAINT-GOBAIN
Gypsum

ENVIRONMENTAL PRODUCT DECLARATION

USG Sheetrock® Brand EcoSmart Panels Firecode 30®

UNITED STATES GYPSUM COMPANY
ALIQUIPPA, PA

ENVIRONMENTAL PRODUCT DECLARATION

USG Sheetrock® Brand EcoSmart Panels Mold Tough® Firecode® X

UNITED STATES GYPSUM COMPANY
BRIDGEPORT, AL; PLASTER CITY, CA; RAINIER, OR; SPERRY, IA; WASHINGTONVILLE, PA

Metal Stud

Environmental Product Declaration | Steel Recycling Institute

Steel Recycling Institute

VERIFIED by PCR GLOBAL SERVICES
ENVIRONMENTAL PRODUCT DECLARATION
BASED ON LCA

Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220 USA

A complete list of manufacturers represented by this EPD can be found here: www.recycle-steel.org/epd-companies

Product

Industry-wide Cold-Formed Steel Studs and Track manufactured in U.S. and Canada.

Product Description

The [redacted]® steel framing & metal lath products covered by this EPD are:

Material & Coa[redacted]

[redacted]

galvanized s[redacted]

Structural Stud and Track (ICC-ES ESR 3016)

- Manufactured for the use in curtain wall, load-bearing, rough-opening & ceiling/floor/roof applications
- Available in typical c-shaped sections ranging in thickness from 33 mils to 118 mils

ViperStud® Interior Framing (ICC-ES ESR 2620 & ATI-ES 0154)

- Proprietary interior framing system using high-strength steel to increase overall performance
- Available in c-shaped sections ranging in thickness from 15 mils to 33 mils

ProX Header® (IAPMO ER-0286)

- Proprietary header/rough-opening system designed to use less material and incre safety
- Available in sections ranging in thickness from 33 mils to 68 mils

SureBoard® for Shear panels (IAPMO ER-0126)

- Steel sheet/gypsum sheathing product designed specifically for wall shear applications

Sure-Span® Floor Joist Framing System (ESR PENDING)

- Proprietary steel floor joist/roof rafter framing system with extra-large flared punch-outs for greater access of HVAC, MEP, and TELCOM conduits
- Available in proprietary c-shaped sections ranging in thickness from 43 mils to 97 mils

CST, SLP-TRK®, and FAS Track® 1000 Brand Slotted Tracks (ICC-ES ESR 2012)

- Head of Wall top tracks designed for seismic and fire-abatement assemblies
- Available in c-shaped sections in thicknesses ranging from 33 mils to 68 mils

USG SHAFTWALL Brand CH and H-Stud Studs and Track (AER 09038)

- USG's CH studs and J-Runners for shaftwall and stairwell applications
- USG's H-Stud and C-Runner for area separation wall assemblies

Expanded Metal Lath Products (ICC-ES ESR 1623)

- Manufactured for the use in exterior and interior applications for 3-coat stucco assemblies
- Available in various flat, self-furred, ribbed, and paper-backed versions

Plastering Accessories (ICC-ES ESR 1623*)

- Various profiles used in conjunction with expanded metal lath products
- Products designed and manufactured for casing, corners, control joints, expansion joints, screeds, and weeps

Drywall/Interior Accessories (ICC-ES ESR 3016*)

- Product designed for use with interior non-load bearing stud framing systems
- Products include angles, drywall finishing trims, flat straps, furring channels, and resilient channels

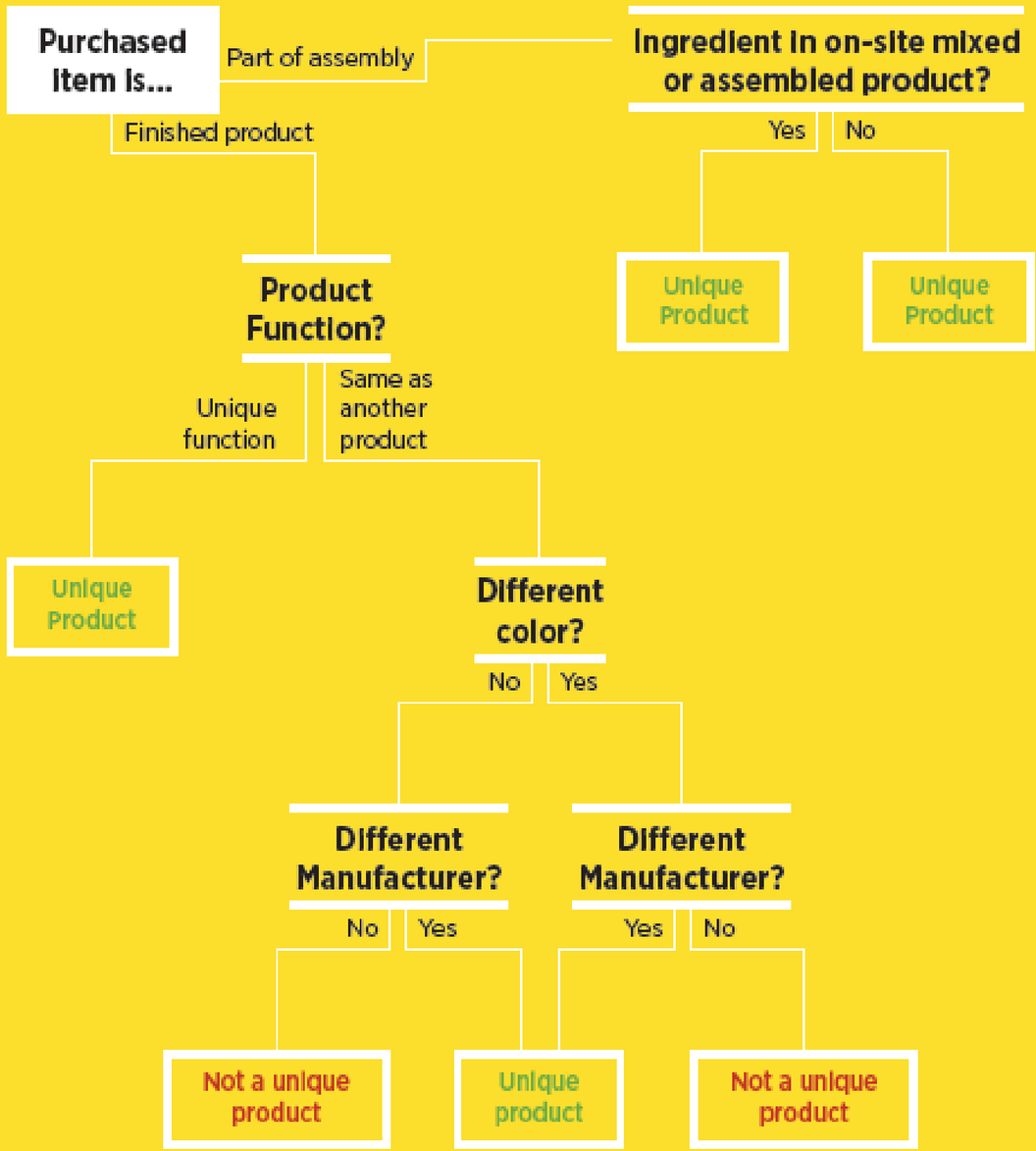
Connectors, Clips, and Channels (ICC-ES ESR 3016*)

- Various connectors and clips used for connecting structural and non-structural steel framing components
- Products included are clip angles, corner angles/ledgers, diagonal tension strapping, gusset plates, slide clips, and u-shaped channels

Environment

DOES THIS ITEM COUNT AS A PRODUCT?

MR Building Product Disclosure and Optimization Credits



Insulation

Table 3: Life-cycle Impact Category Results for the Functional Unit of FOAMULAR® XPS Insulation

FOAMULAR® XPS Insulation, 1 m^2, R_{SI}=1			Raw materials acquisition			Manufacturing	Distribution	Installation, Maintenance & Use	End of life
Impact category	Unit	Total	Raw Materials	Packaging	Transportation RM and PKG				
Global warming	kg CO2 eq	6.08E+1	5.70E+0	2.50E-2	1.33E-1	1.95E+1	7.58E-2	2.93E+1	6.05E+0
Acidification	mol H+ eq	1.78E+0	1.45E+0	5.05E-3	4.43E-2	2.53E-1	2.52E-2	0.00E+0	3.83E-3
Eutrophication	kg N eq	9.85E-4	8.42E-4	4.66E-6	4.23E-5	6.83E-5	2.41E-5	0.00E+0	3.66E-6
Smog	kg O3 eq	2.08E-1	1.35E-1	1.05E-3	2.17E-2	3.55E-2	1.23E-2	3.25E-4	1.88E-3
Ozone depletion	kg CFC-11 eq	3.63E-4	3.63E-4	4.12E-10	5.82E-12	2.16E-10	3.31E-12	0.00E+0	5.03E-13
Waste to Landfill	kg	8.57E-1	8.57E-2	4.91E-4	0.00E+0	1.09E-4	0.00E+0	0.00E+0	7.71E-1
Metered Water	kg	3.79E+1	3.54E+1	1.76E+0	0.00E+0	7.31E-1	0.00E+0	0.00E+0	0.00E+0

ENVIRONMENTAL PRODUCT DECLARATION

STYROFOAM™ INSULATION

Life Cycle Assessment – Product

Impact category	Unit	Total	Raw materials	Manufacturing	Transport	Installation, maintenance	End of life
Ozone depletion	kg CFC-11 eq	6.71E-04	6.71E-04	0	0	0	0
Global warming	kg CO2 eq	9.53E+01	9.03E+00	2.54E+01	1.90E-01	2.72E+01	3.33E+01
Smog	kg O3 eq	1.98E-01	3.38E-01	2.30E-02	3.50E-02	0	2.00E-03
Acidification	mol H+ eq	9.98E-01	7.48E-01	1.72E-01	6.50E-02	0	3.00E-03
Eutrophication	kg N eq	2.72E-03	1.85E-03	6.70E-04	1.10E-04	0	7.00E-05
Water use	kg	5.45E+00	1.45E+00	4.00E+00	0	0	0
Non-hazardous waste	kg	7.99E-01	1.60E-02	6.00E-03	0	0	7.77E-01
Hazardous waste	kg	2.70E-03	2.70E-03	0	0	0	0
Waste to energy	kg	7.80E-05	0	7.80E-05	0	0	0
Primary Energy	MJ	8.88E+01	7.48E+01	1.06E+01	3.20E+00	0	2.20E-01

ENVIRONMENTAL PRODUCT DECLARATION

TUFF-R™ AND THERMAX™ INSULATION

W CHEMICAL COMPANY

THERMAX™

Impact category	Unit	Total	Raw materials	Raw Material Transport	Manufacturing	Gate to Grave Transport	End of life
Ozone depletion	kg CFC-11 eq	6.62E-07	6.02E-07	2.05E-08	8.02E-09	2.96E-08	1.85E-09
Global warming	kg CO2 eq	6.11E+00	5.62E+00	1.24E-01	2.13E-01	1.47E-01	4.96E-03
Smog	kg O3 eq	4.14E-01	2.46E-01	3.22E-02	9.87E-03	2.87E-02	9.76E-02
Acidification	mol H+ eq	1.66E+00	1.47E+00	6.30E-02	6.30E-02	5.75E-02	2.07E-03
Eutrophication	kg N eq	1.33E-02	1.23E-02	1.94E-04	6.55E-04	1.98E-04	6.37E-06
Primary Energy	MJ	9.97E+01	9.24E+01	1.89E+00	2.86E+00	2.38E+00	1.31E-01
Water	M3	4.56E-02	4.41E-02	4.35E-04	4.86E-04	5.00E-04	1.10E-04
Waste to Landfill	kg	7.23E-01	0.00E+00	0.00E+00	7.08E-02	0.00E+00	6.52E-01

Building Product Disclosure & Optimization

ENVIRONMENTAL PRODUCT DECLARATIONS - Optimization

- Option 2: Use products that comply with one of the criteria below for 10%, by cost, of the total value of permanently installed products in the project, or use at least 10 permanently installed products sourced from at least three different manufacturers:
  - Any product with a “Life Cycle Impact Reduction Action Plan” is valued at 50% or ½ product
  - Any product with third-party verified, published EPD or LCA showing reductions in GWP:
    - Any reduction = 1 product or 100% of cost
    - >10% reduction = 1.5 products or 150% of cost

Metal Stud

Impact Category	Category Indicator	Indicator Description	Unit	PRODUCT STAGE: Raw Material Extraction / Processing — A1	PRODUCT STAGE: Transport to the Manufacturer — A2	PRODUCT STAGE: Manufacturing — A3	CREDITS AND BURDENS BEYOND THE SYSTEM BOUNDARY: Reuse, Recovery, Recycling Potential — D
Global warming [a]	Global Warming Potential	Global Warming Potential (GWP)	ton CO_2 eq/ ton [d]	2.2	$3.6x10^{-2}$	$4.4x10^{-2}$	-0.76
				Negligible [f]	Negligible [f]	Negligible [f]	Negligible [f]
				$1.0x10^{-2}$	$3.4x10^{-4}$	$2.8x10^{-4}$	$-1.7x10^{-3}$
				$.7x10^{-4}$	$1.9x10^{-5}$	$1.3x10^{-4}$	$-9.0x10^{-5}$
				0.18	$1.0x10^{-2}$	$2.1x10^{-3}$	$-1.8x10^{-2}$
			q/	$5.4x10^{-5}$	Negligible	$7.6x10^{-8}$	$2.1x10^{-9}$
Depletion of abiotic resources (fossil) [b]	Fossil fuel consumption	Abiotic depletion potential (ADP-fossil fuels) for fossil resources	BTU/short ton (MJ/metric ton) [e]	$3.0x10^{7}$ (29,000)	$5.1x10^{5}$ (490)	$5.8x10^{5}$ (560)	$-9.3x10^{6}$ (-8,900)

Life Cycle Impact Assessment

Parameter	Unit	Value
Impact Assessment Method: TRACI 2.1		
Global warming potential (GWP)	metric ton CO_2 eq	2.25
Depletion potential of the stratospheric ozone layer (ODP)	metric ton CFC-11 eq	5.04E-08
Acidification potential of soil and water (AP)	metric ton SO_2 eq	1.21E-02
Eutrophication potential (EP)	metric ton N eq	5.25E-04
Formation potential of tropospheric ozone (POCP)	metric ton O_3 eq	0.181

Parameter	Unit	LCIA Method	A1 – A3
GWP	[metric ton CO_2-eq.]	TRACI (version 2.1)	2.39
ODP	[metric ton CFC11-eq.]	TRACI (version 2.1)	5.07E-08
AP	[metric ton SO_2-eq.]	TRACI (version 2.1)	0.0134
EP	[metric ton N eq.]	TRACI (version 2.1)	5.55E-04
POCP	[metric ton O_3 eq.]	TRACI (version 2.1)	0.185

Life Cycle Impact Assessment

Parameter	Unit	Magnitude
Impact Assessment Method: TRACI 2.1		
Global warming potential (GWP)	metric ton CO_2 eq	2.41
Depletion potential of the stratospheric ozone layer (ODP)	metric ton CFC-11 eq	5.69E-04
Acidification potential of soil and water (AP)	metric ton SO_2 eq	1.29E-02
Eutrophication potential (EP)	metric ton N eq	5.27E-08
Formation potential of tropospheric ozone (POCP)	metric ton O_3 eq	0.194

Created on July 1, 2015

LEED Interpretation

ID# 10415

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Rating System

LEED BD+C: New Construction, LEED BD+C: Core and Shell, LEED BD+C: Schools, LEED BD+C: Retail, LEED BD+C: Healthcare, LEED BD+C: Data Centers, LEED BD+C: Hospitality, LEED BD+C: Warehouses and Distribution Centers, LEED ID+C: Commercial Interiors, LEED ID+C: Retail, LEED ID+C: Hospitality

Rating System Version

v4 - LEED v4

Inquiry

How can products contribute to earning Option 2 of the LEED v4 MR credit BPDO – Environmental Product Declarations?

Ruling

In addition to the option outlined in the credit language, products that meet any of the following requirements can also contribute towards Option 2:

1. Demonstrate reduced impact with a product-specific EPD against an industry-wide generic EPD, provided the manufacturer was part of the study and the two conform to the same PCR.

2. Demonstrate reduced impact of the same product, over time, with two product-specific EPDs.

Credit Name	Building product disclosure and optimization - environmental product declarations
Credit Category	Material & resources
International Applicable	Internationally applicable
Campus Applicable	Not campus applicable

Products Catalog

3 results

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Certification

EPD - Optimization

Manufacturer / Brands

Product Type

EcoTouch® Unfaced Insulation

Highcliff™

Kohler Co.

Interface Americas GlasBac, Type 66 Nylon

3. Life Cycle Impact Assessment Results

Table 2. TRACI Optimized EPD Impact Assessment Results

4. Interpretation of Optimization Results

The environmental impact reductions were due to improved efficiencies in raw materials, inbound transportation, manufacturing, outbound transportation and end of life transportation. Improved manufacturing capabilities allow for less waste and fewer raw materials needed to manufacture an equivalent product. Numerous energy efficiency programs have also lowered the energy intensity of our products. More details of the company-wide efforts can be found on our website http://sustainability.owenscorning.com.

The additional plant which was included in the optimized EPD makes the EPD more representative of the product being produced. The use of primary calulcated emissions for natural gas combustion, rather than the emissions included in a secondary database process, are more representative in the overall model. The type of primary calculated emissions used for the 2016 data set were not available for the 2011 data set.

Using the comparability criteria, the comparison can be termed a robust comparison. Eight of the criteria were identical or equivalent. Four of the criteria required additional interpretation for comparison. For Scope, the validity periods are different since this summary is comparing an earlier version of the same product. For Data Quality, the number of plants was increased and level of primary emission data included in the analysis was more detailed for the optimized version of the EPD. The Cut-off Rules varied only by the inclusion of packaging end of life in the optimized EPD which was shown to be insignificant. The EPDs were originally created under different versions of the reference PCR. The LCA model from the reference EPD was updated and re-analyzed to provide a robust comparison

Big Moves

Generic EPD's

Environmental
Product
Declaration

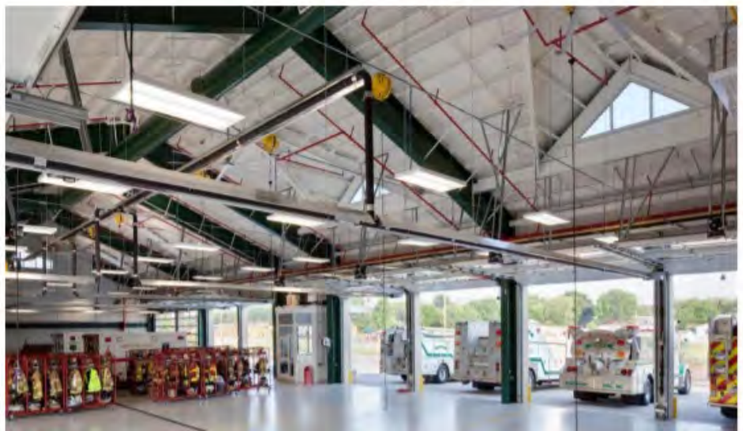
NRMCA
NATIONAL READY MIXED CONCRETE ASSOCIATION

NRMCA MEMBER INDUSTRY-WIDE EPD FOR READY MIXED CONCRETE

ENVIRONMENTAL PRODUCT DECLARATION

PRIMARY STRUCTURAL STEEL FRAME COMPONENTS

METAL BUILDING MANUFACTURERS ASSOCIATION
INDUSTRY-WIDE EPD



MBMA
METAL BUILDING MANUFACTURERS ASSOCIATION®

The Metal Building Manufacturers Association (MBMA), Cleveland, Ohio, was founded in 1956. Since that time, MBMA and its manufacturer members have worked together as partners to further its mission: to conduct research, to help advance building codes and standards, and to educate the construction community. MBMA's passion is to support a strong, sustainable metal building systems industry that meets the needs of building owners and society.

ENVIRONMENTAL PRODUCT DECLARATION

NORTH AMERICAN GLUED LAMINATED TIMBERS

AMERICAN WOOD COUNCIL
CANADIAN WOOD COUNCIL

Table 8. Summary Results (A1-A3): 3001-4000 psi (20.69-27.58 MPa) RMC product, per cubic meter															
Indicator/LCI Metric	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
Unit (equivalent)	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	251.8	7.30E-6	0.99	0.32	20.63	1918	1880	36	2011	2.01	0.13	0.12	0.29	0.42	4.32
Maximum	416.9	1.00E-5	1.31	0.50	26.87	2642	2591	51	2327	3.05	0.13	0.12	0.29	0.47	5.95
4000-00-FA/SL	416.9	1.00E-5	1.31	0.50	26.87	2642	2591	51	2327	3.05	0.13	0.12	0.29	0.43	5.95
4000-20-FA	356.3	8.90E-6	1.15	0.43	23.91	2304	2260	44	2182	2.61	0.13	0.12	0.29	0.43	5.44
4000-30-FA	323.6	8.10E-6	1.07	0.39	22.31	2121	2081	40	2104	2.37	0.13	0.12	0.29	0.43	5.15
4000-40-FA	289.2	7.30E-6	0.99	0.35	20.63	1930	1894	36	2021	2.11	0.13	0.12	0.29	0.42	4.86
4000-30-SL	317.8	9.50E-6	1.24	0.39	24.00	2273	2227	46	2165	2.49	0.13	0.12	0.29	0.46	4.97
4000-40-SL	284.8	9.10E-6	1.22	0.36	23.05	2152	2108	44	2110	2.30	0.13	0.12	0.29	0.47	4.64
4000-50-SL	251.8	8.80E-6	1.20	0.32	22.10	2029	1987	42	2056	2.11	0.13	0.12	0.29	0.47	4.32
4000-50-FA/SL	252.2	7.90E-6	1.09	0.32	20.90	1918	1880	38	2011	2.01	0.13	0.12	0.29	0.46	4.40

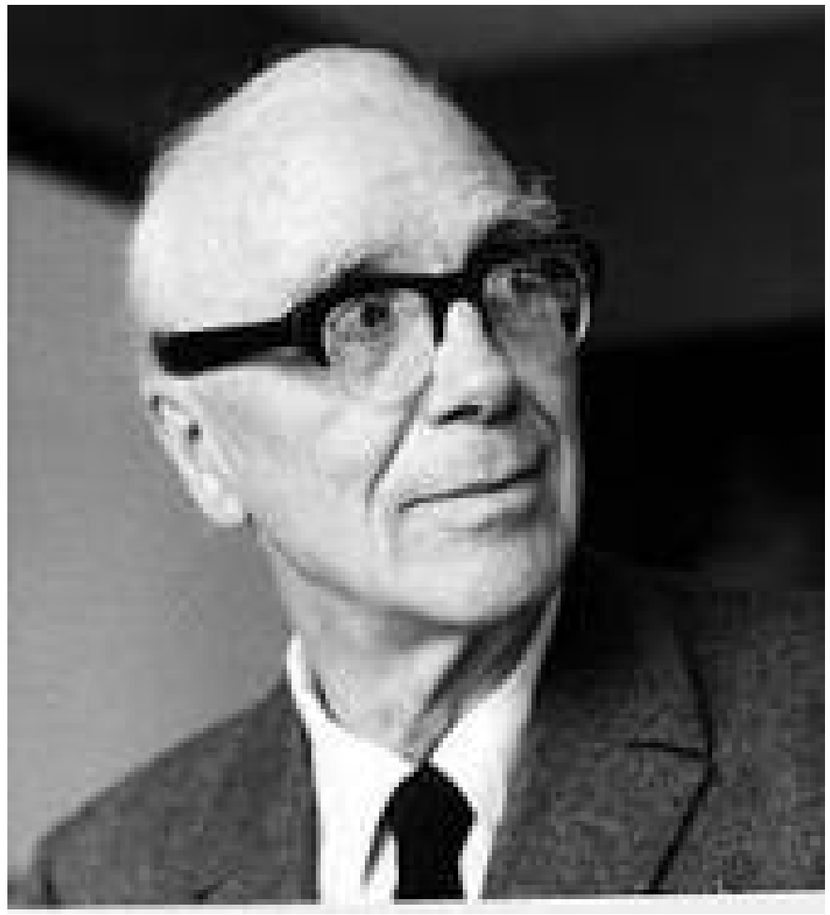
Table 2: Cradle-to-Gate Impact Assessment Results - 1m³ North American Glulam				
Impact category indicator	**Unit**	**Total**	**Forestry operations**	**Glulam production**
Global warming potential	kg CO_2 eq.	197.97	11.37	186.59
Acidification potential	H+ moles eq.	102.67	8.33	67.55
Eutrophication potential	kg N eq.	0.1198	0.0228	0.0970
Ozone depletion potential	kg CFC-11 eq.	0.0000	0.0000	0.0000
Smog potential	kg O_3 eq.	26.12	4.27	21.86
Total primary energy consumption	**Unit**	**Total**	**Forestry operations**	**Glulam production**
Non-renewable fossil	MJ	3211.72	173.32	3038.40
Non-renewable nuclear	MJ	338.86	1.71	337.15
Renewable, biomass	MJ	2201.18	0.00	2201.18
Renewable, other	MJ	82.40	0.22	83.16
Material resources consumption	**Unit**	**Total**	**Forestry operations**	**Glulam production**
Non-renewable materials	kg	4.10	0.00	4.10
Renewable materials	kg	553.80	30.44	523.37
Fresh water	L	963.21	4.42	958.79
Non-hazardous waste generated	**Unit**	**Total**	**Forestry operations**	**Glulam production**
Solid waste	kg	36.83	0.17	36.67

Parameters Describing Environmental Impacts		Per Metric Tonne		Per Short Ton	
Abbreviation	**Product Stage**	**A1 to A3**	**Unit**	**A1 to A3**	**Unit**
GWP	Global warming potential	1489	kg CO_2 eq	1350.8	kg CO_2 eq
ODP	Depletion potential of the stratospheric ozone layer	5E-06	kg CFC-11 eq	4.5E-06	kg CFC-11 eq
AP	Acidification potential	5.8	kg SO_2 eq	5.2	kg SO_2 eq
EP	Eutrophication potential	0.259	kg N eq	0.235	kg N eq
POCP	Photochemical ozone creation potential	81.8	kg O_3 eq	74.2	kg O_3 eq
ADP-elements	Abiotic depletion potential for non-fossil resources[1]	1.96E-04	kg Sb eq	1.78E-04	kg Sb eq
ADP- fossil fuels	Abiotic depletion potential for fossil resources	19,769	MJ, LHV	1.7E+07	BTU, LHV

Structural Systems - Concrete

- Reduce Cement Content:
  - Lower quantity of Portland Cement with SCM's
    - Fly Ash
    - Granulated Blast Slag
    - Metakaolin
  - Specify Higher quality Aggregate
  - Reduce water content
- High Strength Concrete = Less Cement

Consult your Structural Engineer

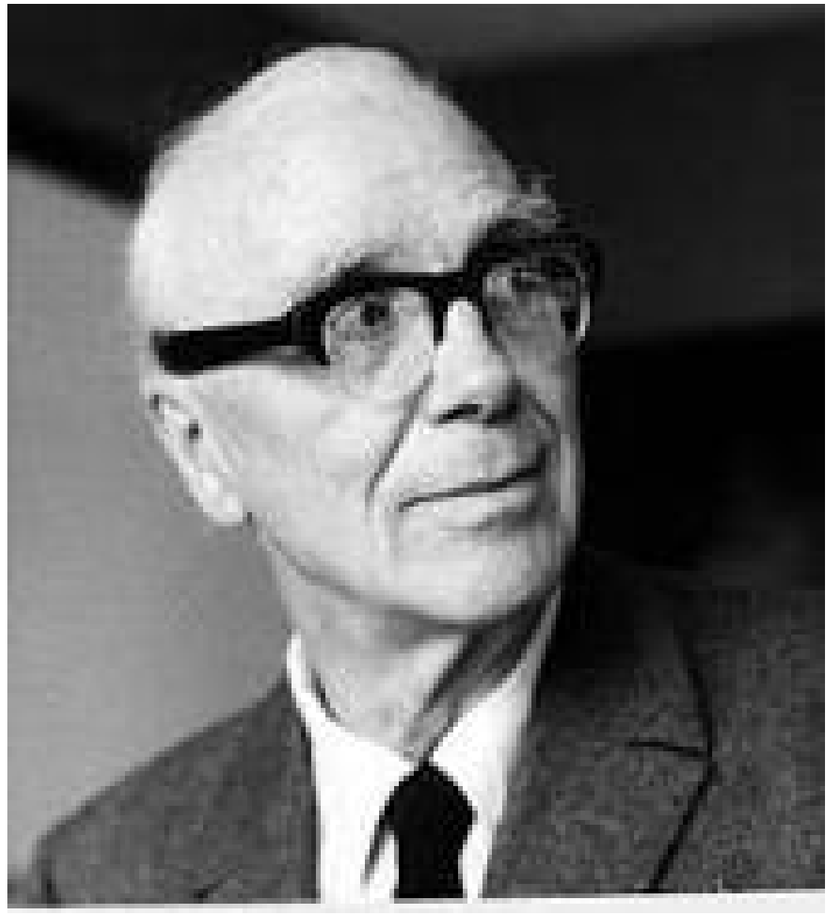


Ove Arup

Structural Systems - Steel

- Clean up the steel
  - North American steel is cleaner, higher recycled content.
- Use Less Steel
- Efficient Design

Consult your Structural Engineer



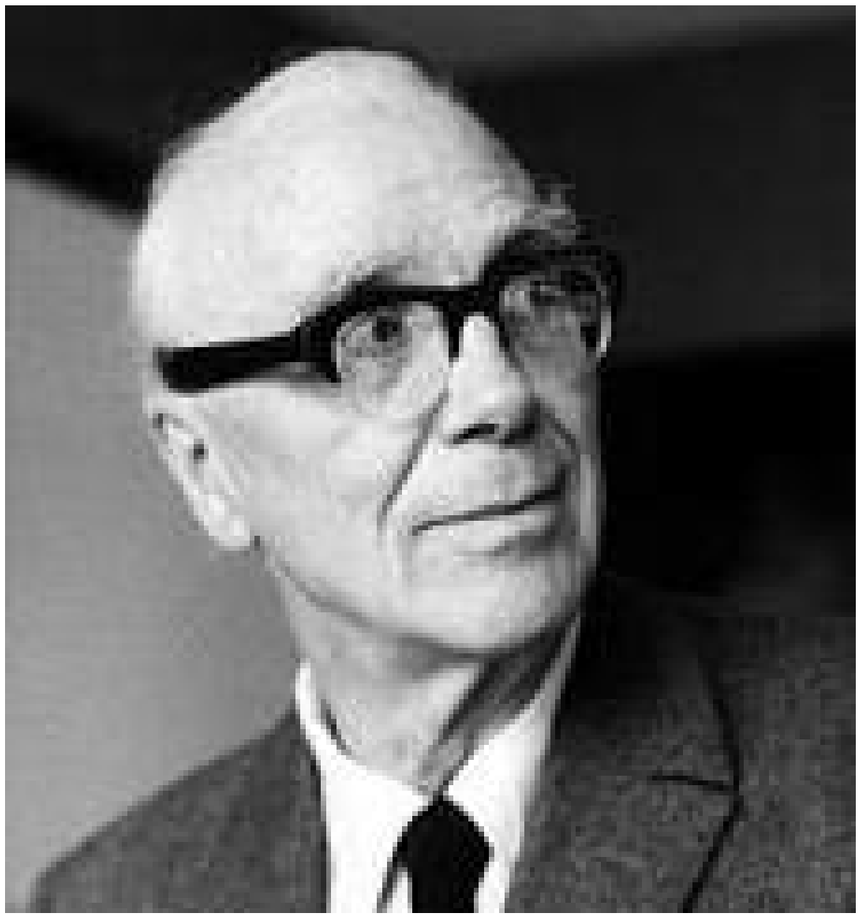
Ove Arup

Gustave Eiffel

Structural Systems - Wood

- Complicated Topic
- Use only FSC and salvaged wood
- Use only what you need - efficiency

Consult your Structural Engineer



Ove Arup

Gustave Eiffel

Stephanie Kwolek

Focus on the materials you use the most of, and the energy and carbon intensive materials.

Where to focus:

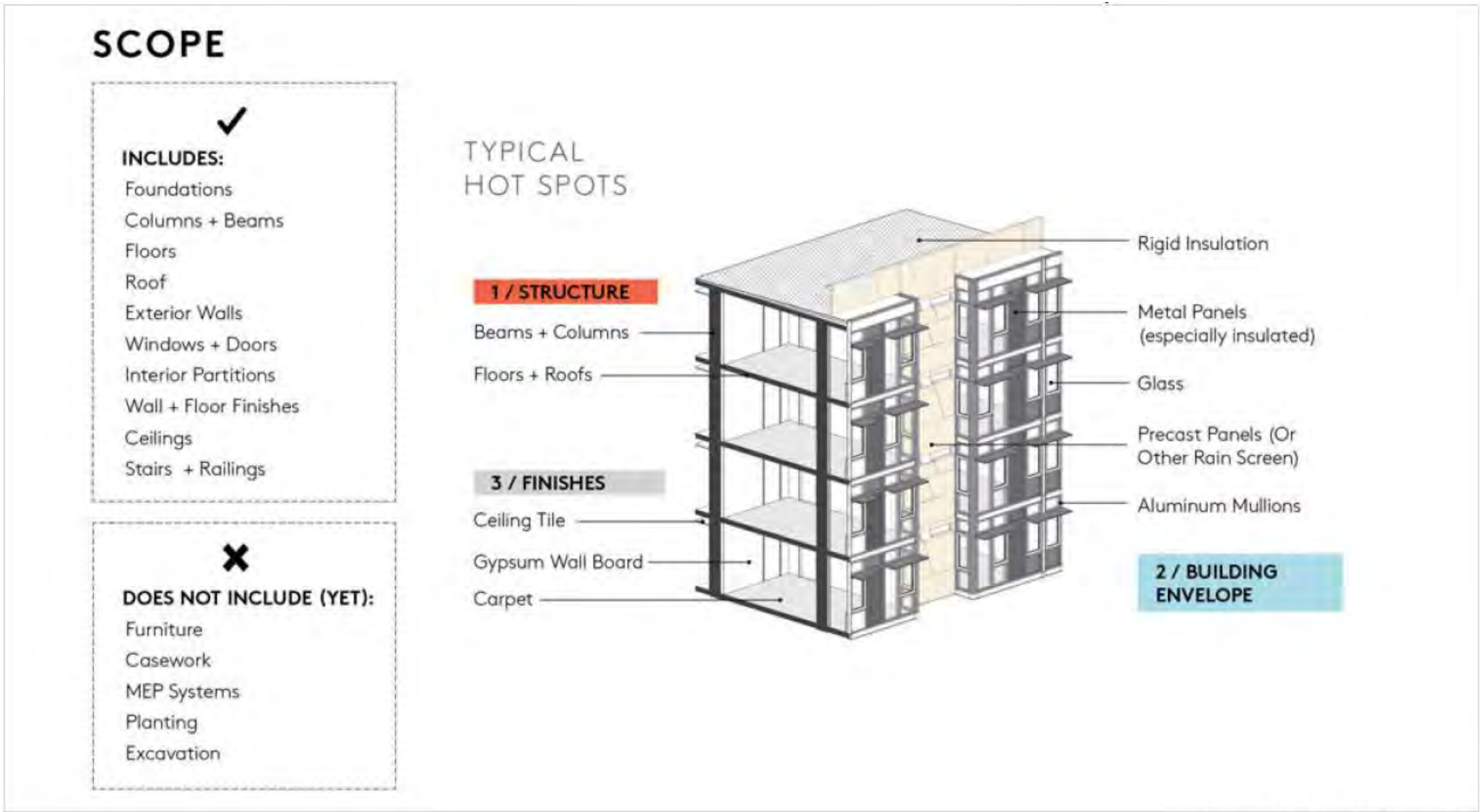
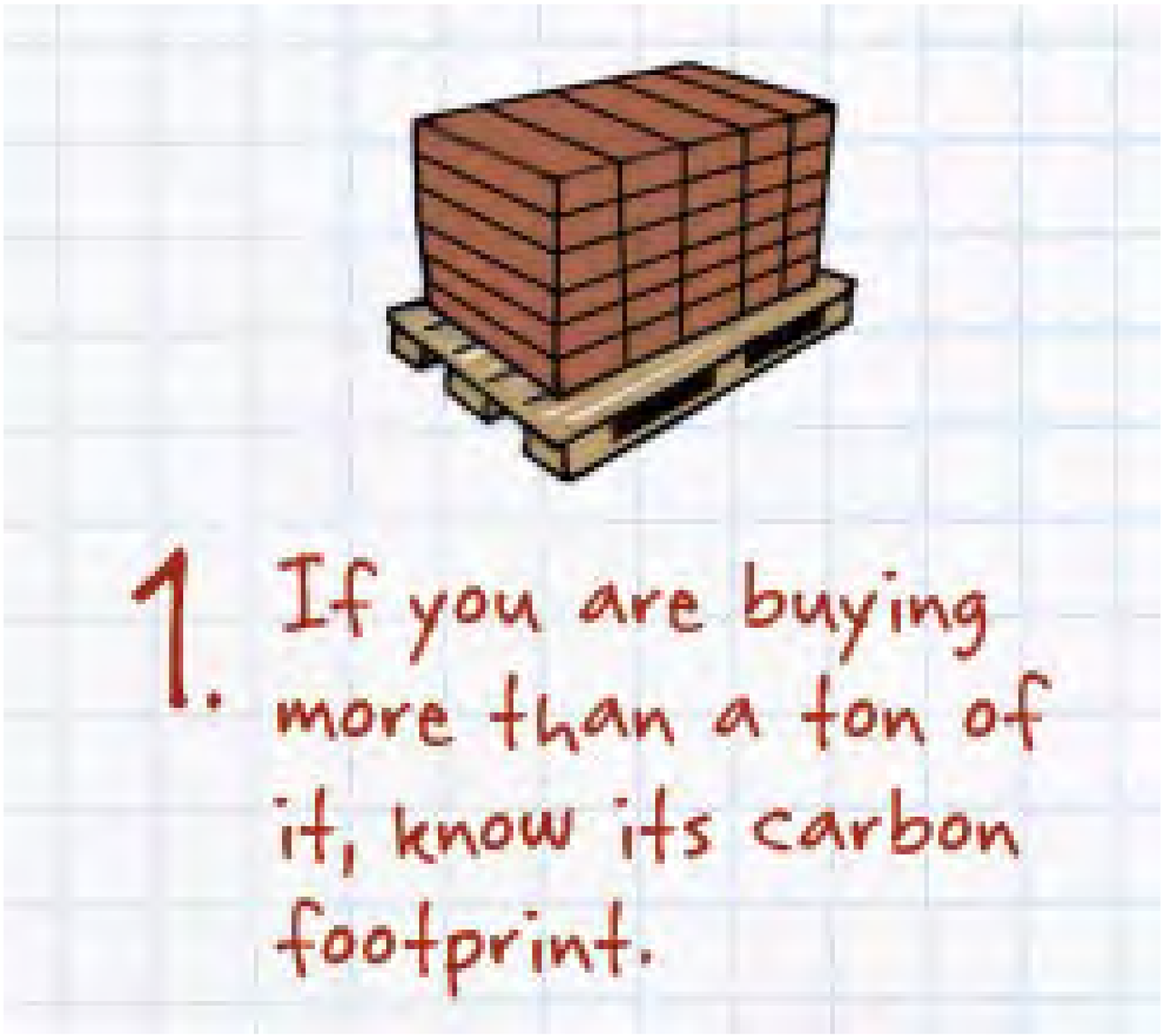


Image: Mithun (Meghan Lewis)

Fully Disclosed...



Understand the formula

$$\frac{\text{Kg } CO_2 \text{ eq}}{\text{metric tonne}}$$

CO_2 eq is Carbon Dioxide Equivalent

Ready Mixed Concrete (Straight Mix) (NWC 3000-4000psi)

Declared unit: 1 kg

Cradle-to-gate LCA Results (per declared unit)

Acidification Potential	Eutrophication Potential	Global Warming Potential	Ozone Depletion Potential	Smog Formation Potential	Primary Energy Demand
1.19E-03 kg SO_2 eq	3.39E-05 kg N eq	2.42E-01 kg CO_2 eq	7.81E-10 kg CFC-11 eq	1.69E-02 kg O_3 eq	1.39E+00 MJ

24.2 Carbon Dioxide Equivalent
1 yard of concrete = 4000 lbs
1 yard of concrete = 48.4 CO_2 eq

Type X Drywall

Declared unit: 1 kg

Cradle-to-gate LCA Results (per declared unit)

Acidification Potential	Eutrophication Potential	Global Warming Potential	Ozone Depletion Potential	Smog Formation Potential	Primary Energy Demand
1.01E-03 kg SO_2 eq	6.63E-05 kg N eq	3.60E-01 kg CO_2 eq	2.00E-11 kg CFC-11 eq	1.86E-02 kg O_3 eq	5.91E+00 MJ

36 x metric tons
1 gypsum board sheet = 51 lbs
1 gypsum board sheet = 0.918 CO_2 eq

Carpet Tile

Declared unit: 1 kg

Cradle-to-gate LCA Results (per declared unit)

Acidification Potential	Eutrophication Potential	Global Warming Potential	Ozone Depletion Potential	Smog Formation Potential	Primary Energy Demand
2.21E-02 kg SO_2 eq	1.75E-03 kg N eq	8.78E+00 kg CO_2 eq	1.03E-09 kg CFC-11 eq	3.32E-01 kg O_3 eq	1.59E+02 MJ

8.78 x metric tons
1 yard of carpet = 5-20 lbs
1 yard of carpet = 0.066 CO_2 eq

ALWAYS REMEMBER

And Never forget

ONE

You need a Tracking Tool

Environmental Product Declaration

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	Continuous Dyed Nylon 6,6 with Milliken ES ComfortPlus® Backing	Milliken	Continuous Dyed Nylon 6,6 with Milliken ES ComforPlus® Backing
	Coral Brush	Forbo Flooring Systems B.V.	Coral Brush
	Corporate - Commercial Broadloom Carpet with Nylon 6,6 Face Fiber	Shaw Industries, Inc.	Commercial Broadloom Carpet
	Corporate - Commercial Broadloom Carpet with Solution Q® or Solution Q Extreme® Face Fiber	Shaw Industries, Inc.	Commercial Broadloom Carpet

Environmental Product Declaration

programoperators.com

Program Operator Consortium EPD / Transparency Report Catalog

Last updated: Mar 1, 2017

Contact us to include a new or updated EPD.

CSI MasterFormat® division / # EPDs	Manufacturer	Product name	Ind. avg.	LCA scope	Program operator	Expiration date
09 00 00 Finishes 100						
09 20 00 Plaster and Gypsum Board	**Gypsum Association members**	Industry Average for Glass Mat Gypsum Panels		C2Gate	**ASTM**	Aug 17, 2021
09 65 00 Resilient Flooring	**DINOFLEX**	Evolution Tile		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**DINOFLEX**	Next Step		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**DINOFLEX**	Sport Mat Flooring		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**ECORE**	ECOsurfaces		C2Grave	**SCS**	Mar 31, 2020
09 65 00 Resilient Flooring	**ECORE**	Everlast		C2Grave	**SCS**	Mar 31, 2020
09 65 00 Resilient Flooring	**ECORE**	Forest Rx/Terrain Rx		C2Grave	**SCS**	Mar 31, 2020
09 65 00 Resilient Flooring	**Mats Inc**	Domination		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**Mats Inc**	Duo Tile		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**Mats Inc**	Panorama Eco		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**Mats Inc**	Panorama Tile		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**Mats Inc**	Panorama Stance		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**To Market**	Atmosphere Recycled Rubber Flooring		C2Grave	**SCS**	Dec 7, 2020
09 65 00 Resilient Flooring	**To Market**	Strata Performance		C2Grave	**SCS**	Dec 7, 2020
09 65 16.23 Vinyl Sheet Flooring	**Armstrong**	Heterogeneous Vinyl Sheet		C2Grave	**ASTM**	Dec 11, 2019
09 65 16.23 Vinyl Sheet Flooring	**Armstrong**	Homogeneous Vinyl Sheet		C2Grave	**ASTM**	Oct 30, 2019
09 65 16.23 Vinyl Sheet Flooring	**KCC Corporation**	ECOSENSE (2.2mm)		C2Grave	**SCS**	Oct 6, 2020
09 65 16.23 Vinyl Sheet Flooring	**Raskin Industries**	Transformations™		C2Grave	**SCS**	Oct 5, 2020
09 65 16.23 Vinyl Sheet Flooring	**To Market**	OzoTec		C2Grave	**SCS**	Sep 22, 2021
09 65 16.33 Rubber Sheet Flooring	**ECORE**	ECOfit		C2Grave	**SCS**	Mar 31, 2020
09 65 16.33 Rubber Sheet Flooring	**ECORE**	ECOrx		C2Grave	**SCS**	Mar 31, 2020
09 65 16.33 Rubber Sheet Flooring	**ECORE**	ECOsilence		C2Grave	**SCS**	Mar 31, 2020
09 65 16.33 Rubber Sheet Flooring	**ECORE**	Galaxy rx		C2Grave	**SCS**	Jun 5, 2021
09 65 16.33 Rubber Sheet Flooring	**ECORE**	Performance		C2Grave	**SCS**	Mar 31, 2020
09 65 16.33 Rubber Sheet Flooring	**ECORE**	Performance/Monster/ECOfit/ECOrx		C2Grave	**SCS**	Mar 31, 2020

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ORIGIN

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Lona Rerick

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Novalis Innovative Flooring

Novalis Rural

Novalis Innovative Flooring

Novalis Stone

Novalis Innovative Flooring

Novalis Urban

Novalis Innovative Flooring

Novalis Wood

Novalis Innovative Flooring

Novalis Impression

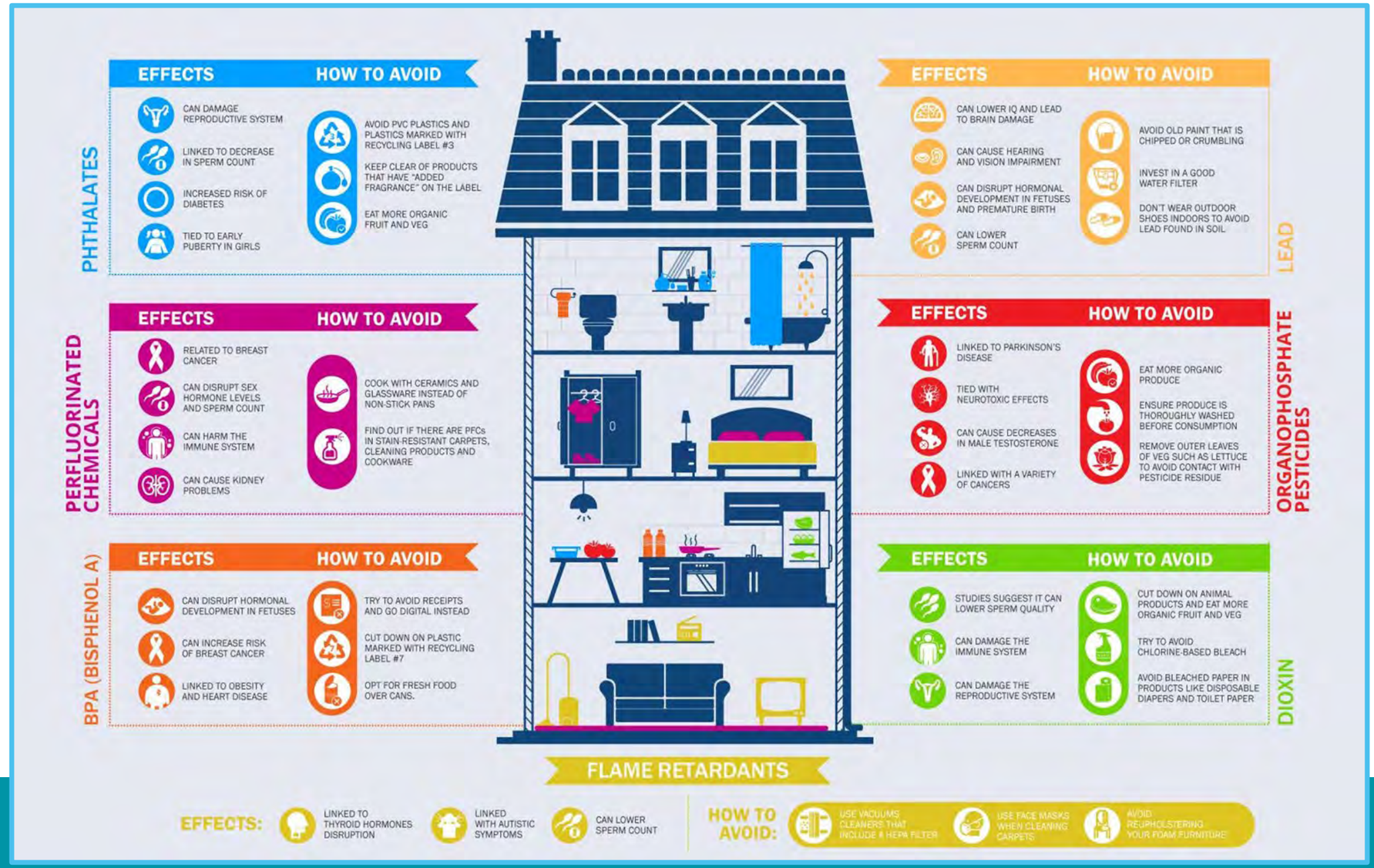
Novalis Innovative Flooring

Marmoleum Decibel

Forbo Flooring Systems

TWO

Don't forget about Health



THREE

If you don't spec it, you won't get it

SECTION 07 2726

FLUID-APPLIED MEMBRANE AIR BARRIERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes fluid-applied, **[vapor-retarding] [and] [vapor-permeable]** membrane air barriers.

B. Related Requirements:
1. Section 061600 "Sheathing" for wall sheathings and wall sheathing joint-and-penetration treatments.
2. Section 07 2500 "Weather Barriers" for weather barriers, including building paper, flexible flashing, and building wraps.

1.3 DEFINITIONS

A. Air-Barrier Material: A primary element that provides a continuous barrier to the movement of air.

B. Air-Barrier Accessory: A transitional component of the air barrier that provides continuity.

Division 1

B. Sustainable Design Submittals: For building products sourced from manufacturers documenting efforts to minimize environmental and health impacts, provide the following information to the extent available:

1. Product Data: For recycled content, indicating postconsumer and preconsumer recycled content and cost.
2. Product Certificates: For regional materials, indicating location of material manufacturer and point of extraction, harvest, or recovery for each raw material. Include distance to Project and cost for each regional material.
3. Building Product Disclosure Requirements: [**To encourage the use of building products that are working to minimize their environmental and health impacts,**]provide the following information [**when available**]:
   a. Environmental Product Declarations:
   b. Material Ingredients Documentation demonstrating the chemical inventory of the product to at least 0.1% (1000ppm).

Division 2-14

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Building Product Disclosure Requirements: Provide Building Product Disclosure documentation for products used in this section when available.
   1. Environmental product Declarations:
   2. Material Ingredients –Documentation demonstrating the chemical inventory of the product to at least 0.1% (1000ppm).

Getting our Way

SECTION 01 2900

PAYMENT PROCEDURES

1.4 Application Preparation: Complete every entry on form. Notarize and execute by a person authorized to sign legal documents on behalf of Contractor. Architect will return incomplete applications without action.

A. Entries shall match data on the schedule of values and Contractor's construction schedule. Use updated schedules if revisions were made.

B. Include amounts for work completed following previous Application for Payment, whether or not payment has been received.

C. Include only amounts for work completed at time of Application for Payment.

D. Provide updated Environmental product data submittal form to assure proper accounting of environmental metrics with each application for payment.

THIS FORM IS REQUIRED TO BE SUBMITTED *WITH Product Data Submittals*

You must include backup documentation such as *SPECIFIC* Product Data Sheets, Cut Sheets, Product Specific Letter from Manufacturer, etc. DO NOT INCLUDE GENERIC MARKETING MATERIAL

LEED PROJECT NAME: _____

SUBCONTRACTOR: _____

Specification Section: _____ Submittal Number: _____

Project Product Data					***Materials and Resources LEED Credits***													
					MR EPD	***Leadership Extraction***					***Material Ingredient***							
	Spec Section[1]	Product	Manufacturer	Product Costs[1] (only exclude install labor) ($)	Product Specific (PS) or Industry Wide (IW) Env. Product Declaration (EPD)[2]?	FSC Certified[3] Wood Products? (%)	Post-Consumer Recycled Content[4] (%)	Pre-Consumer Recycled Content[5] (%)	Extended Producer Responsibility[6] Program Name?	Extracted, Manufactured, & Purchased within[7] 100 miles?	Manufacturer Inventory[8]	Fully Declared HPD to 1000 ppm Declaration[9] included?	C2C version (2.1.1 or 3.0) Level of Certification [10]	Declare Label[11] with ingredient disclosure greater than 1000 ppm?	ANSI/BIFMA e3 Furniture Sustainability Standard[12]	Cradle to Cradle Material Health Certificate[13]	Product Lens[14]	Facts – NSF/ANSI 336
Ex.		ABC Product	ABC, Inc.	$ XX,XXX	PS / IW	%	%	%	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
1																		
2																		
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9																		

FOUR

Just Ask

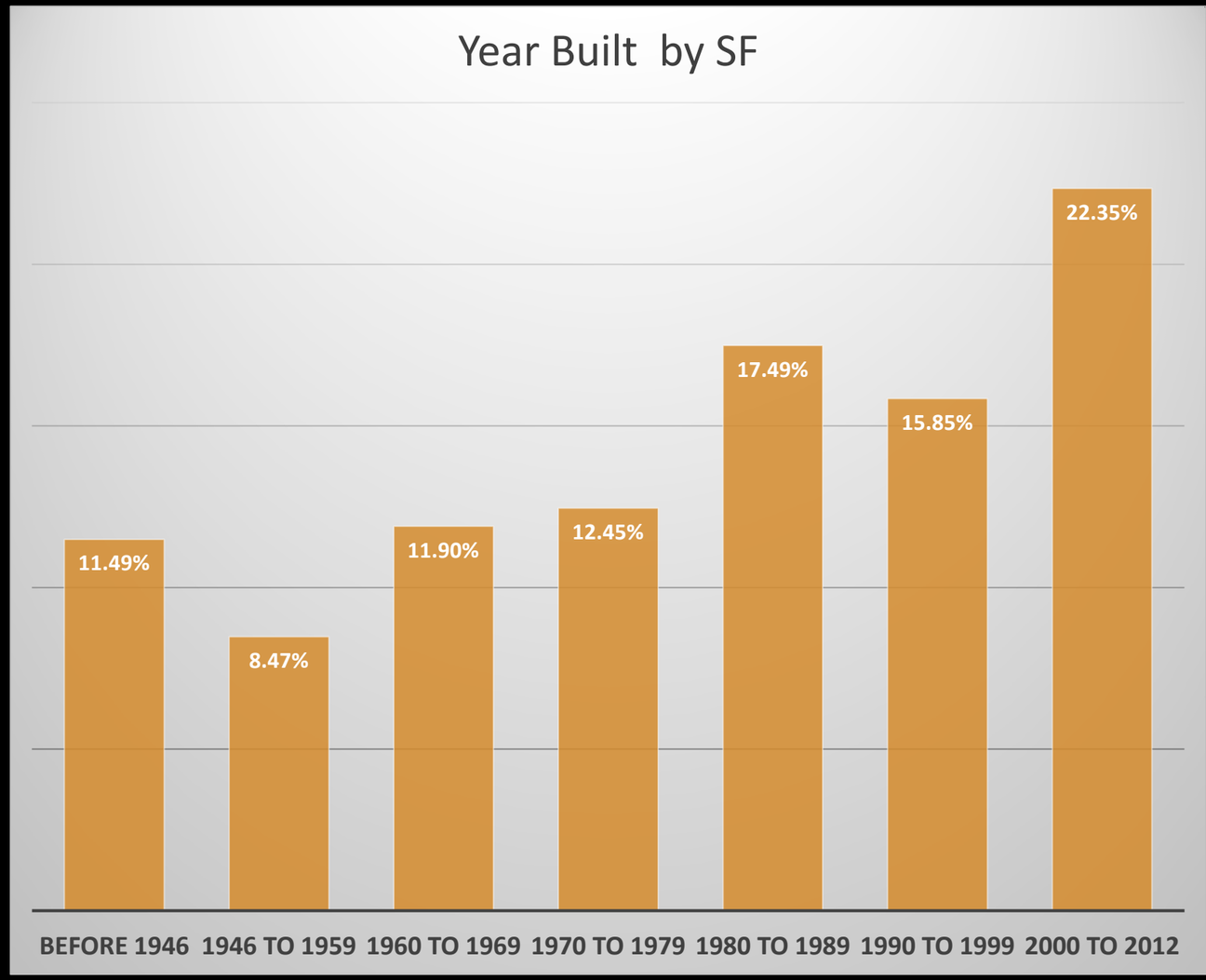
Reuse: measure what we value

15 March 2019

Brad Guy, Assoc AIA
ISO/TC 59/SC 17/WG1 Design for A/D
AIA Materials Knowledge Working Group
USGBC LEED Social Equity Working Group

Building stock available for reuse

- 60% older than 25 years
- 22% older than 50 years
- 2.2% vacant as of 2012 (NGO)
- = 2 billion SF (NGO)



CBECS, 2016

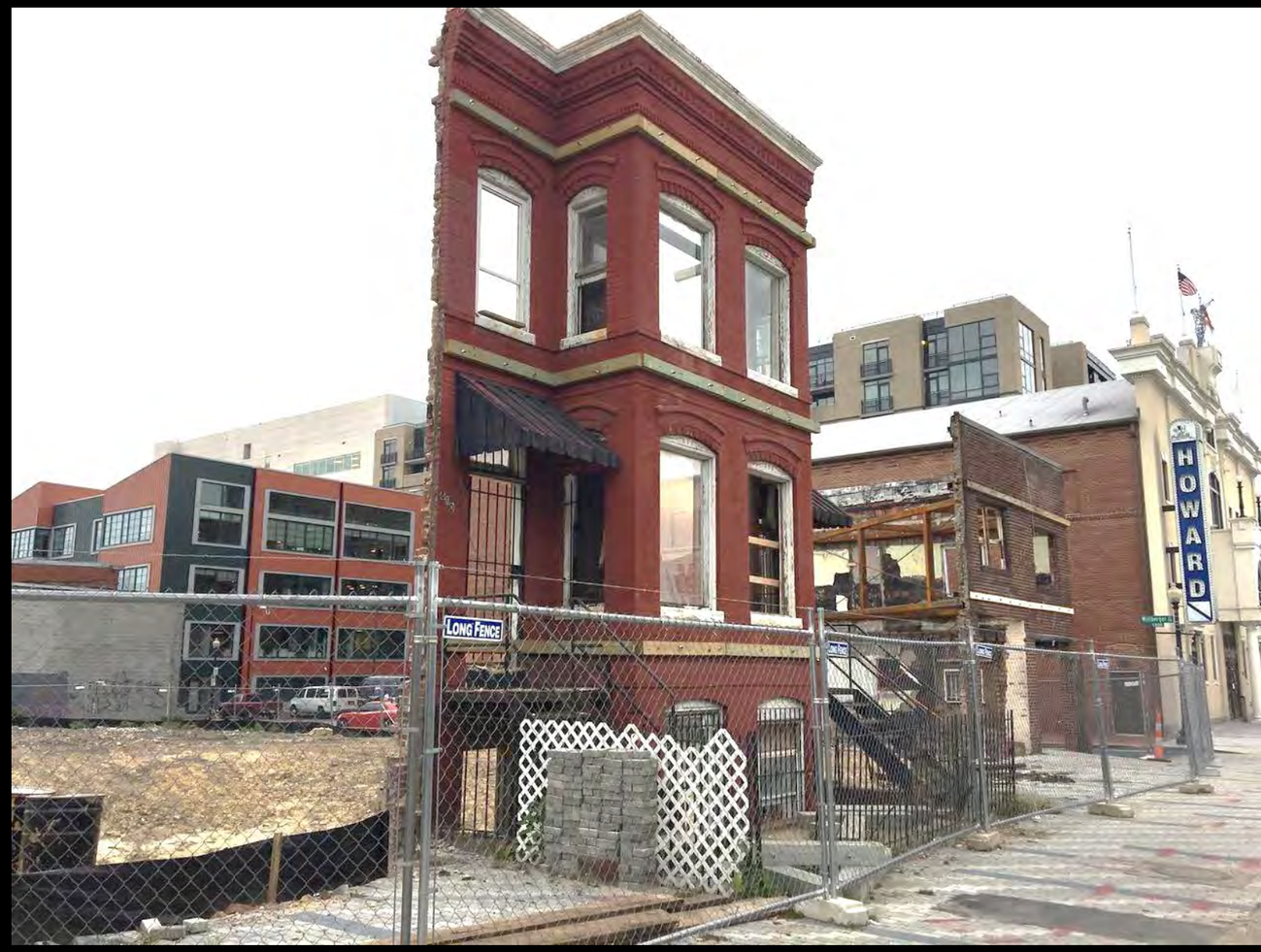
Retrofit trend

- Adaptive reuse (AdRu) ~ 1-2% of all commercial space annually.
- Estimated to be 4% by 2023 – due to mall and store closings and rise of e-commerce and A.I.
- “AdRu now competes effectively against new construction. **It can be 15-20 percent cheaper and faster for projects without environmental issues in cities that have sufficiently evolved their zoning and building codes to accommodate it.** The wild card is the permitting, engineering, and approval costs for AdRu.”

“Adaptive Reuse: Turning Blight into Bright”, Alabama Center for Real Estate, University of Alabama, 2018.

Scale-jumping

1. Salvage materials from renovation and demolition.
2. Substitute reclaimed materials for new in renovation and construction.
3. Retrofit existing buildings, reuse in situ.
4. Reuse buildings on Brownfields and within urban fabric.



Four studies of reuse (different scales)

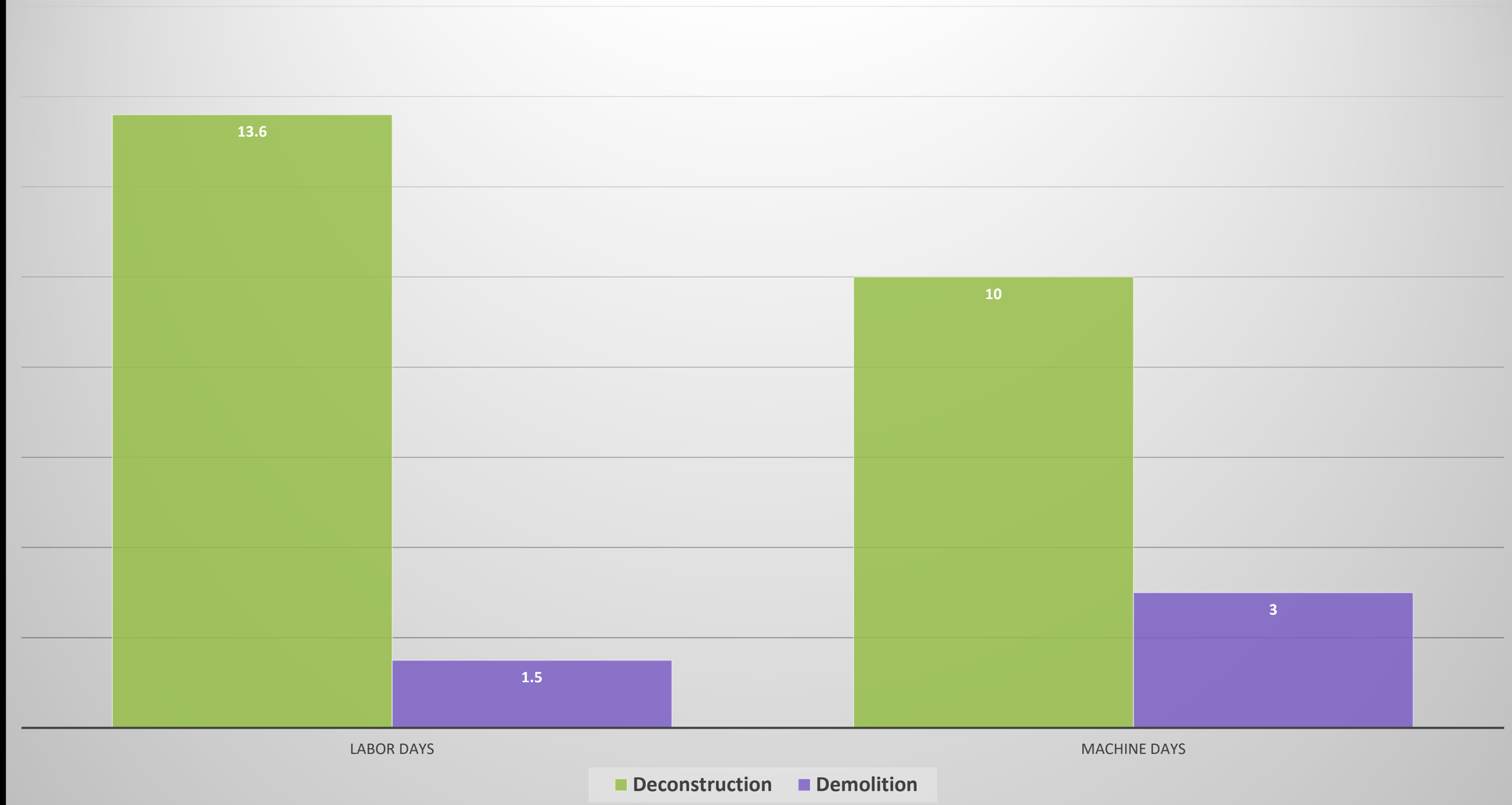
- GWP of demolition versus deconstruction.
- GWP footprint (Scope III) of reuse system for materials.
- Whole building GWP impact reduction for net-zero retrofit.
- Building reuse vs non-reuse via LEED site, energy and IEQ metrics.

LCA of deconstruction vs demolition

- Impacts of process via time, mass, environmental effects?
- Trade-offs between deconstruction and demolition?
- Greenhouse gas (GHG) impacts of deconstruction vs demolition?
- Environmental “break-even” for deconstruction?

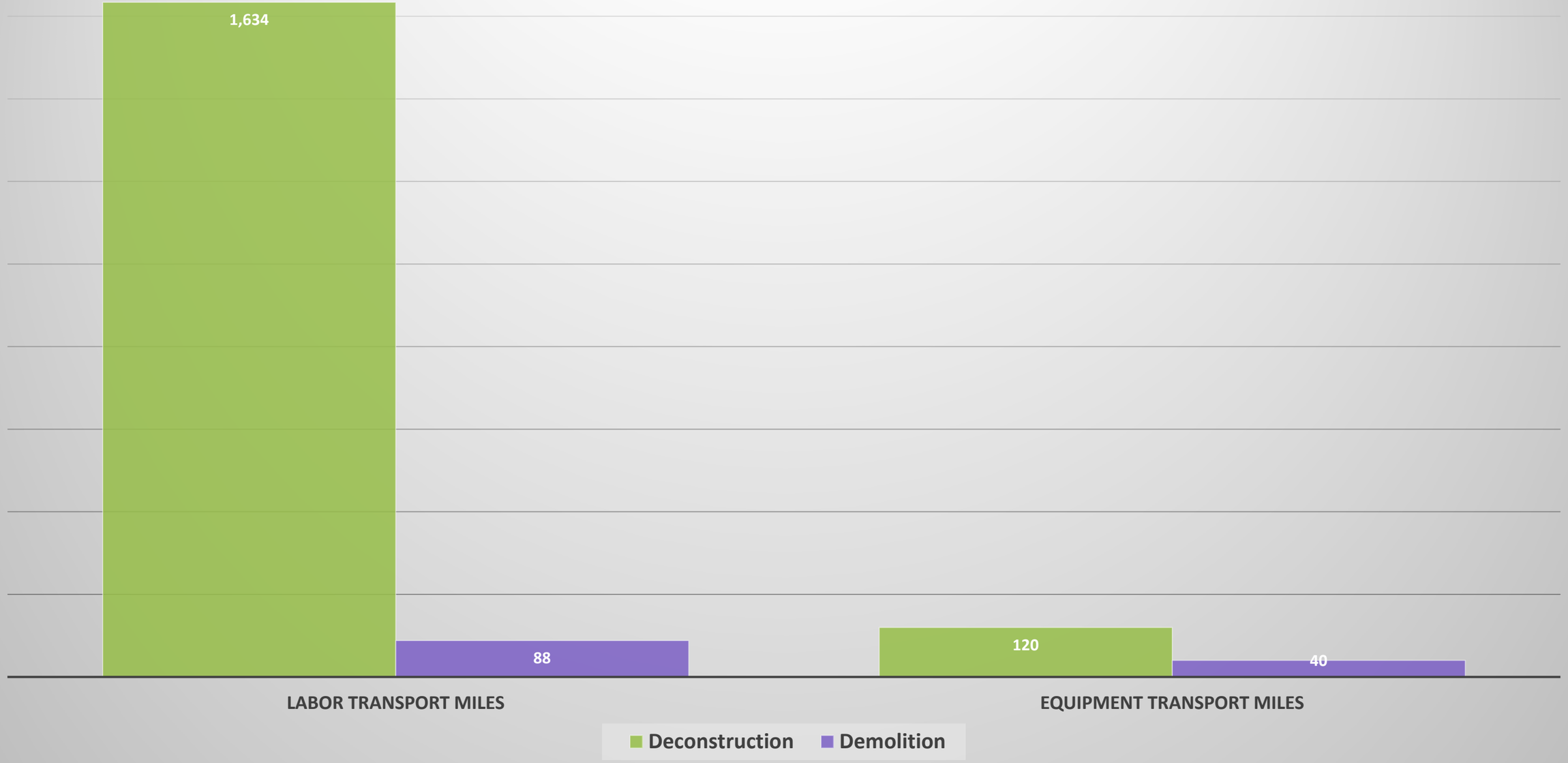
Ft. McClellan LCA

Time



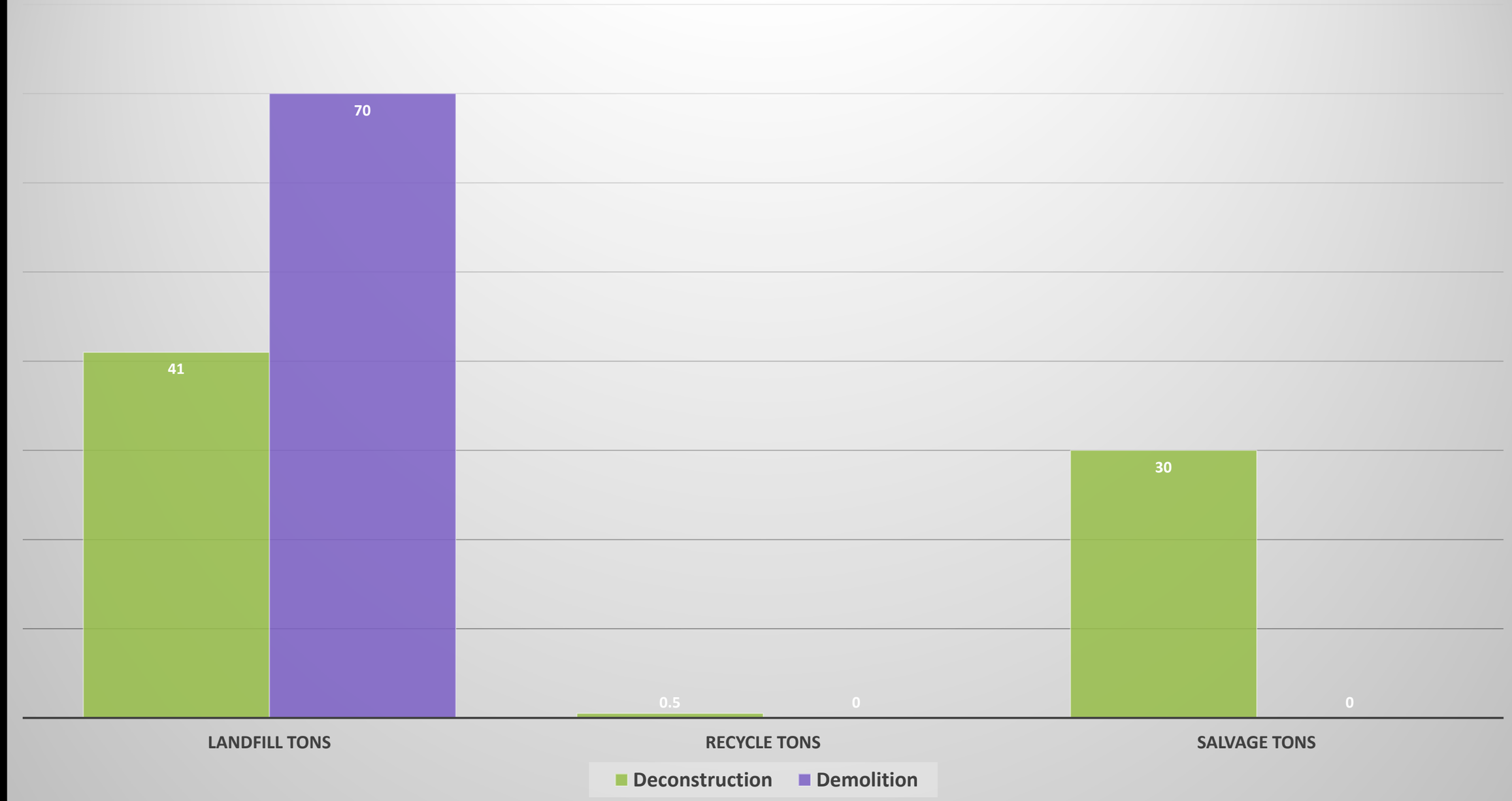
Ft. McClellan LCA

Transport (CO2-e)



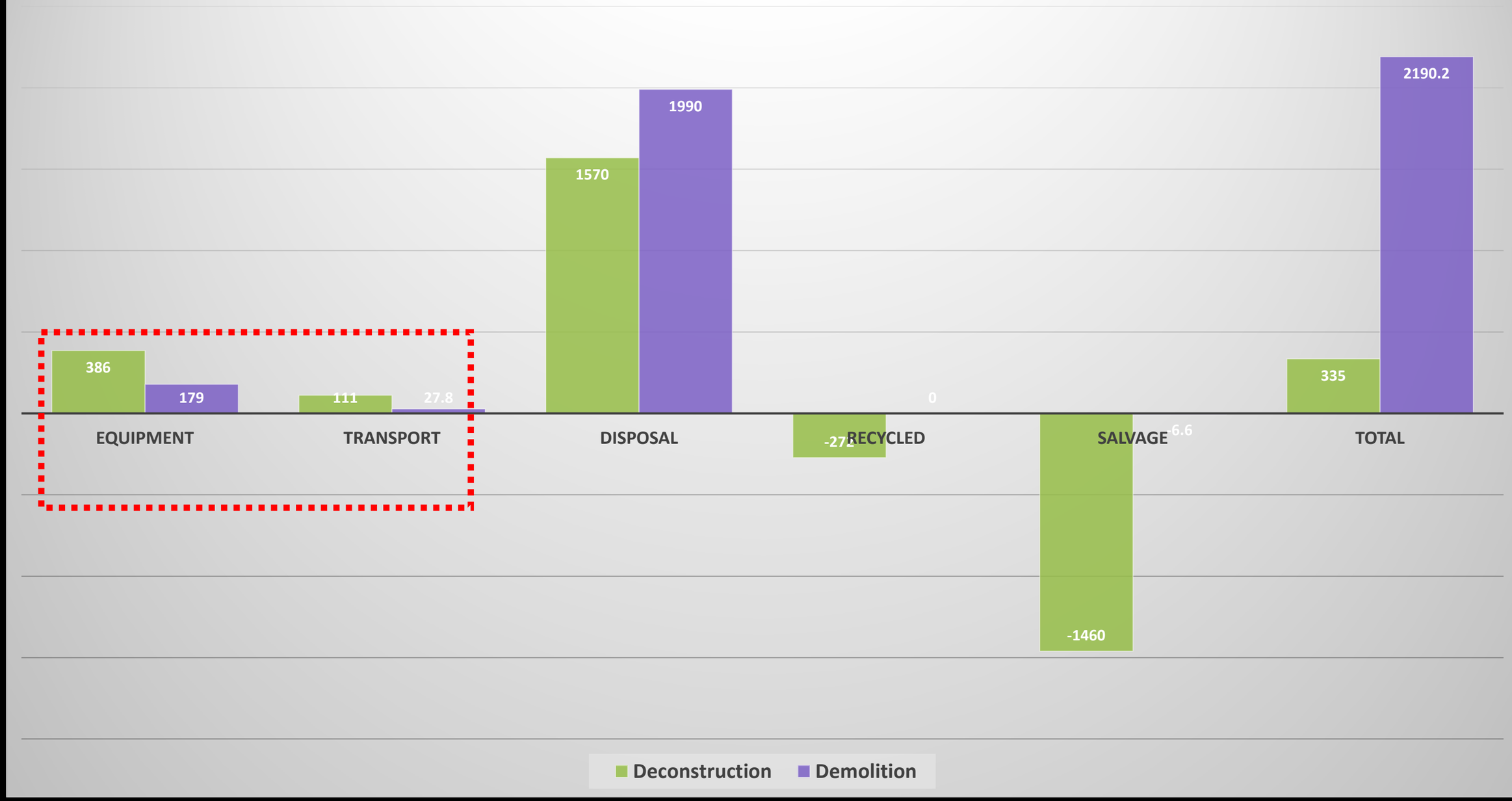
Ft. McClellan LCA

Mass (43% reuse)



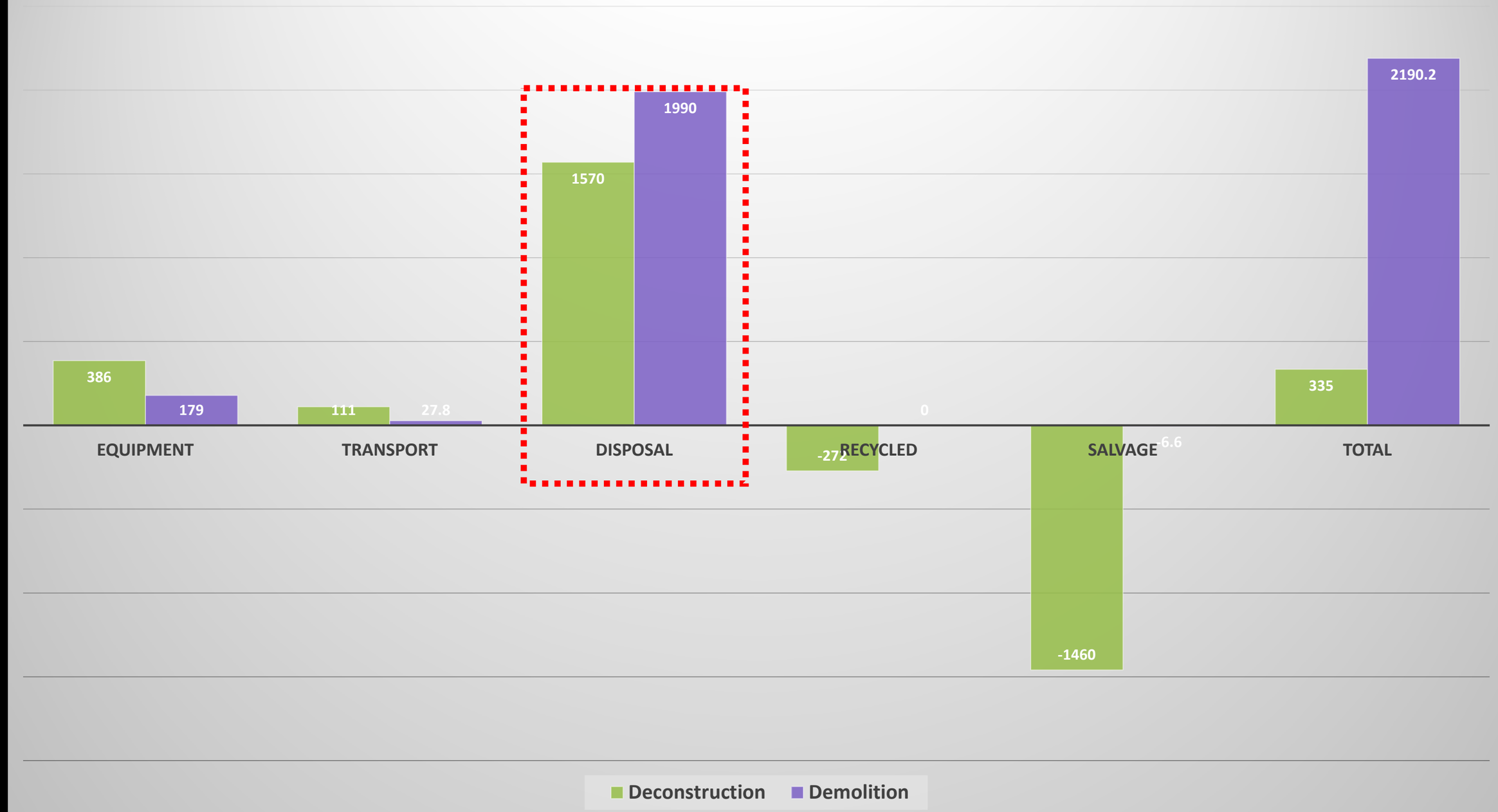
Ft. McClellan LCA

CO2-e g/per SF



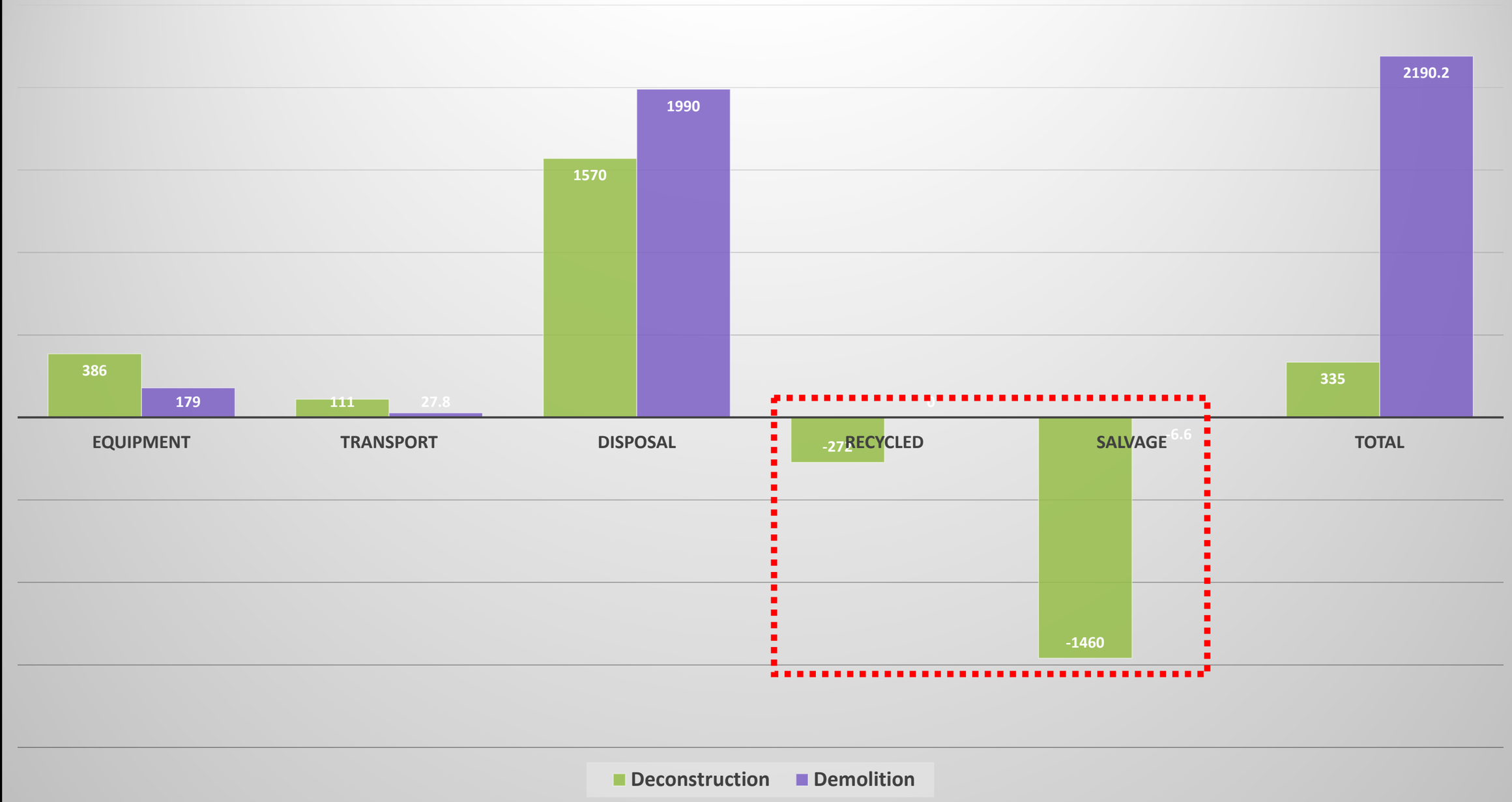
Ft. McClellan LCA

CO2-e g/per SF



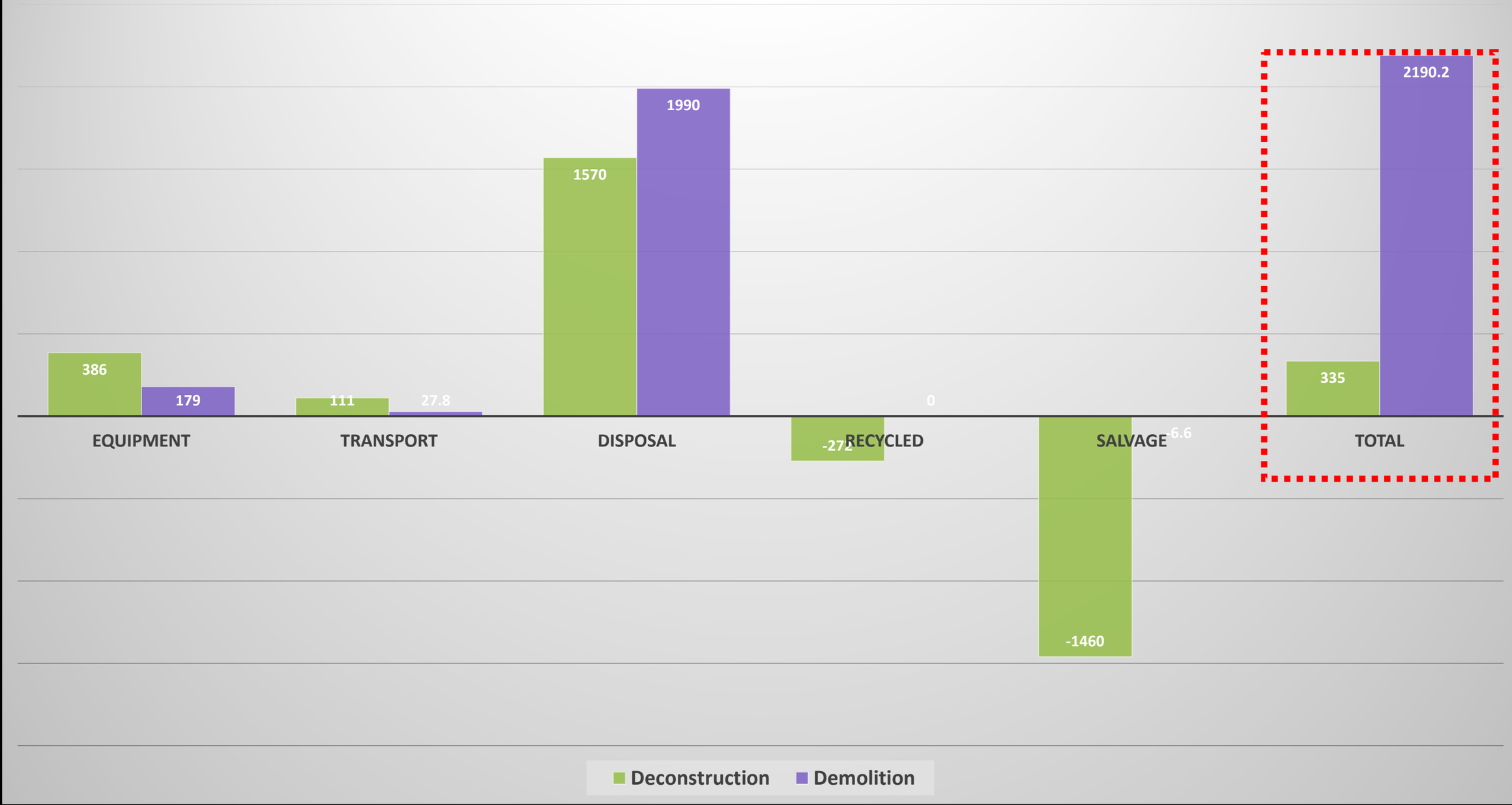
Ft. McClellan LCA

CO2-e g/per SF



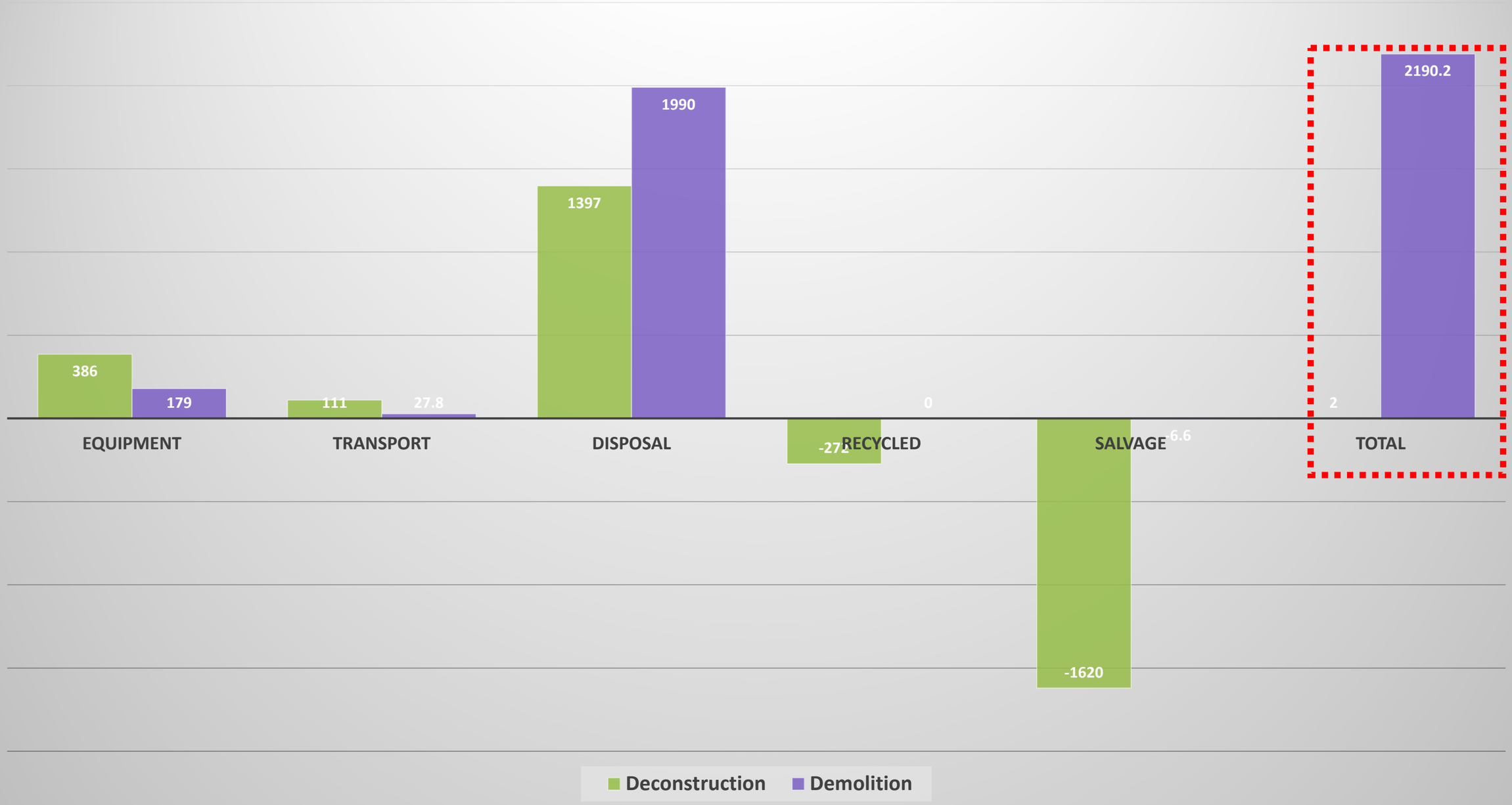
Ft. McClellan LCA

CO2-e g/per SF (43% REUSE)



Ft. McClellan LCA

CO2-e g/sf (what if 55% REUSE)



Ft. McClellan LCA

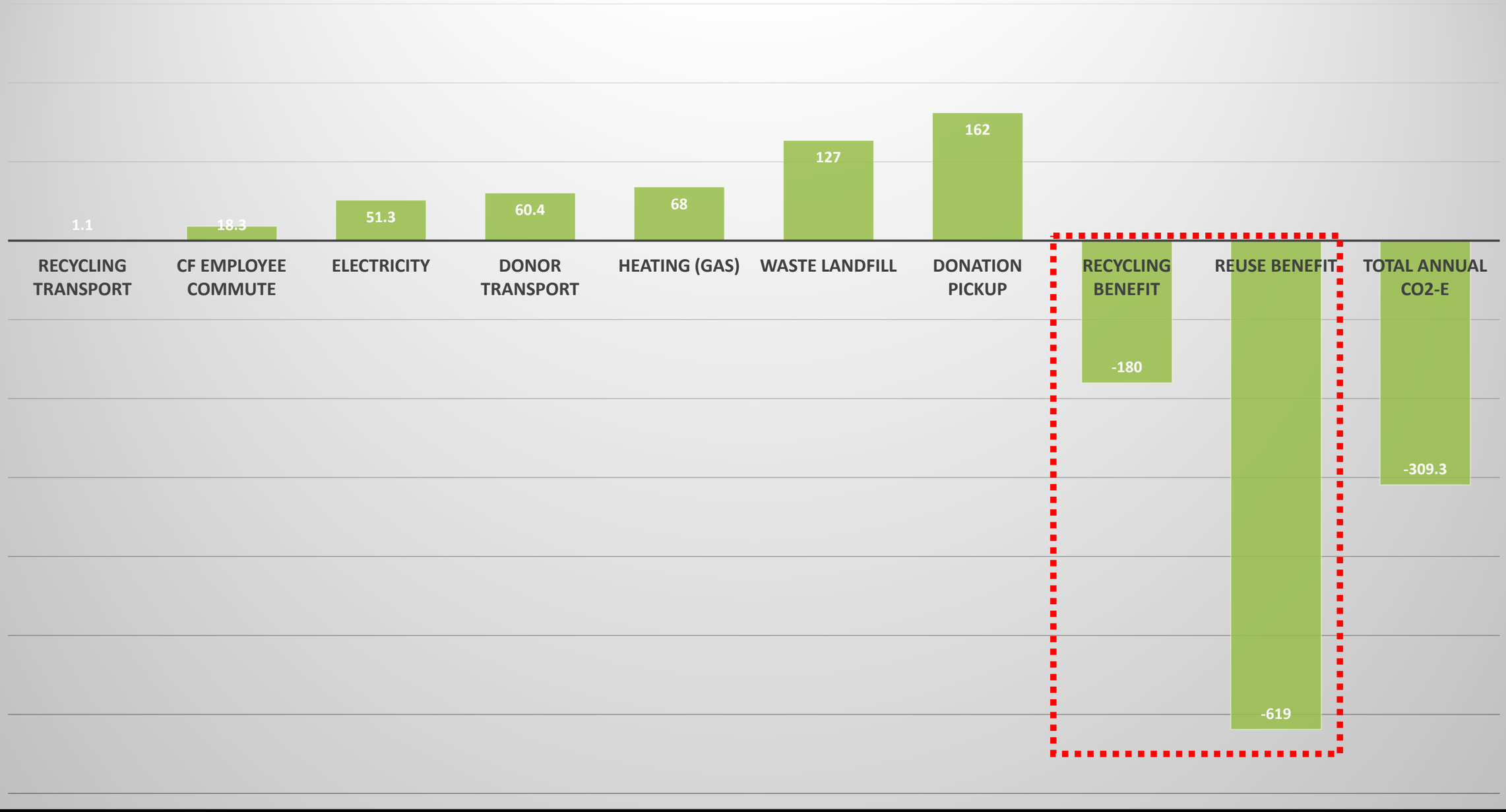
Carbon footprint (scope III) of reuse operation

- Environmental (GHG) benefit to reuse facilities?
- GHG consumer marketing message?
- Internal knowledge of environmental impacts?
- Regional building materials reuse facility, ~55,000 SF, Washington, DC.

Annual MT CO2-e

CF Carbon Footprint

Annual MT CO2-e

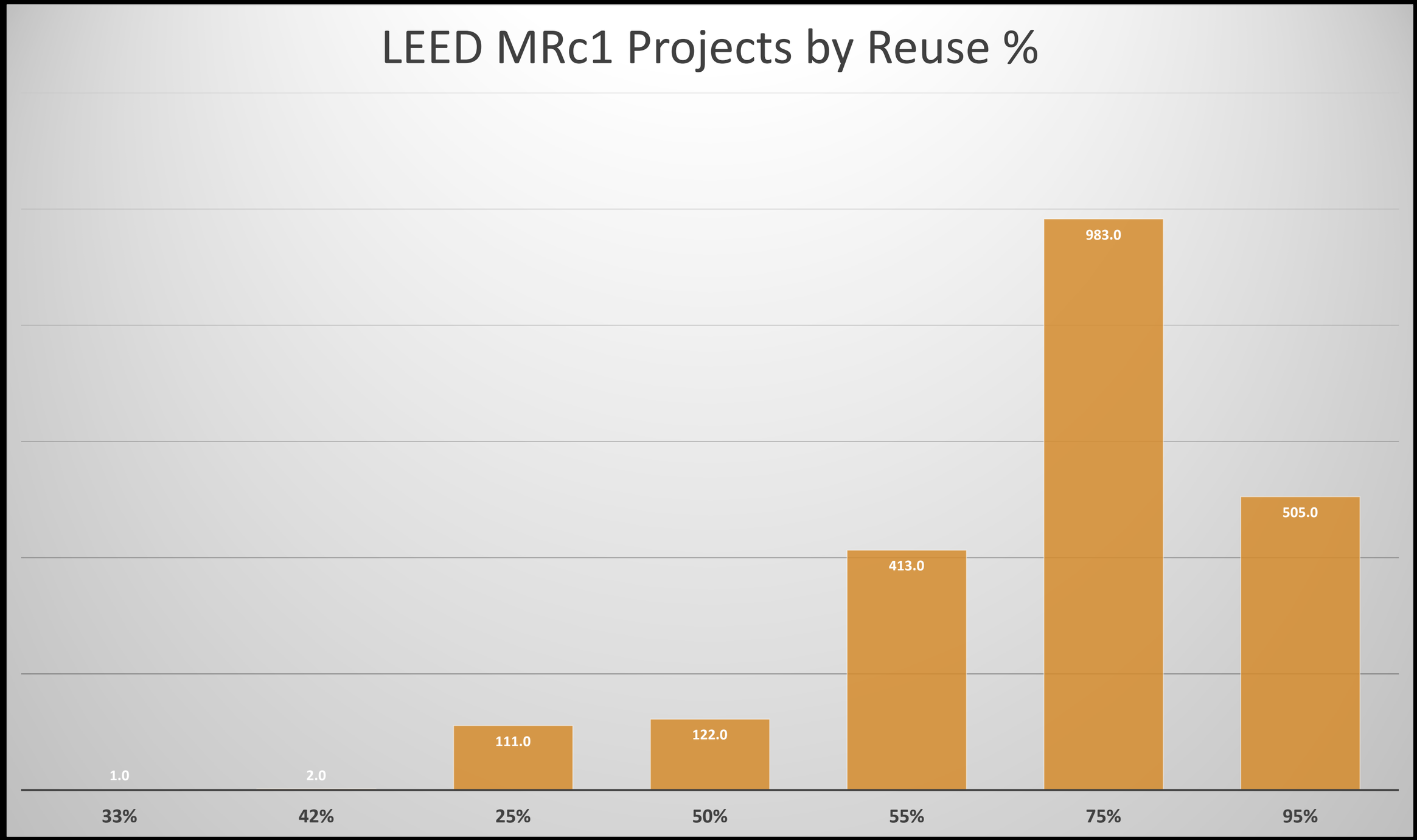


Annual MT CO2-e

CF Carbon Footprint

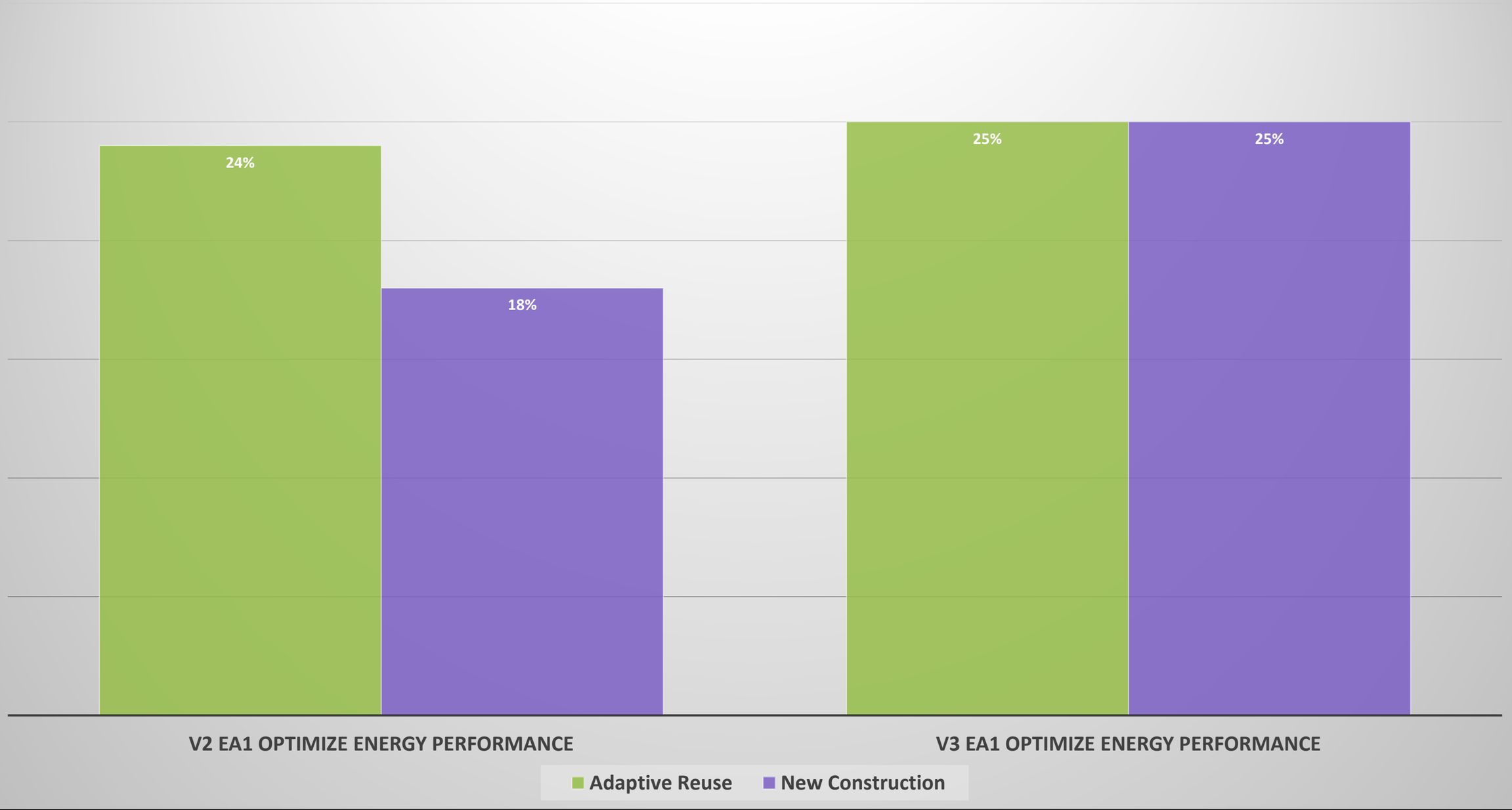
LEED v2 & 3 building reuse vs new

- Energy performance of building reuse vs new construction?
- Is building reuse “sustainable design”?
- Holistic comparison between building reuse and new construction?

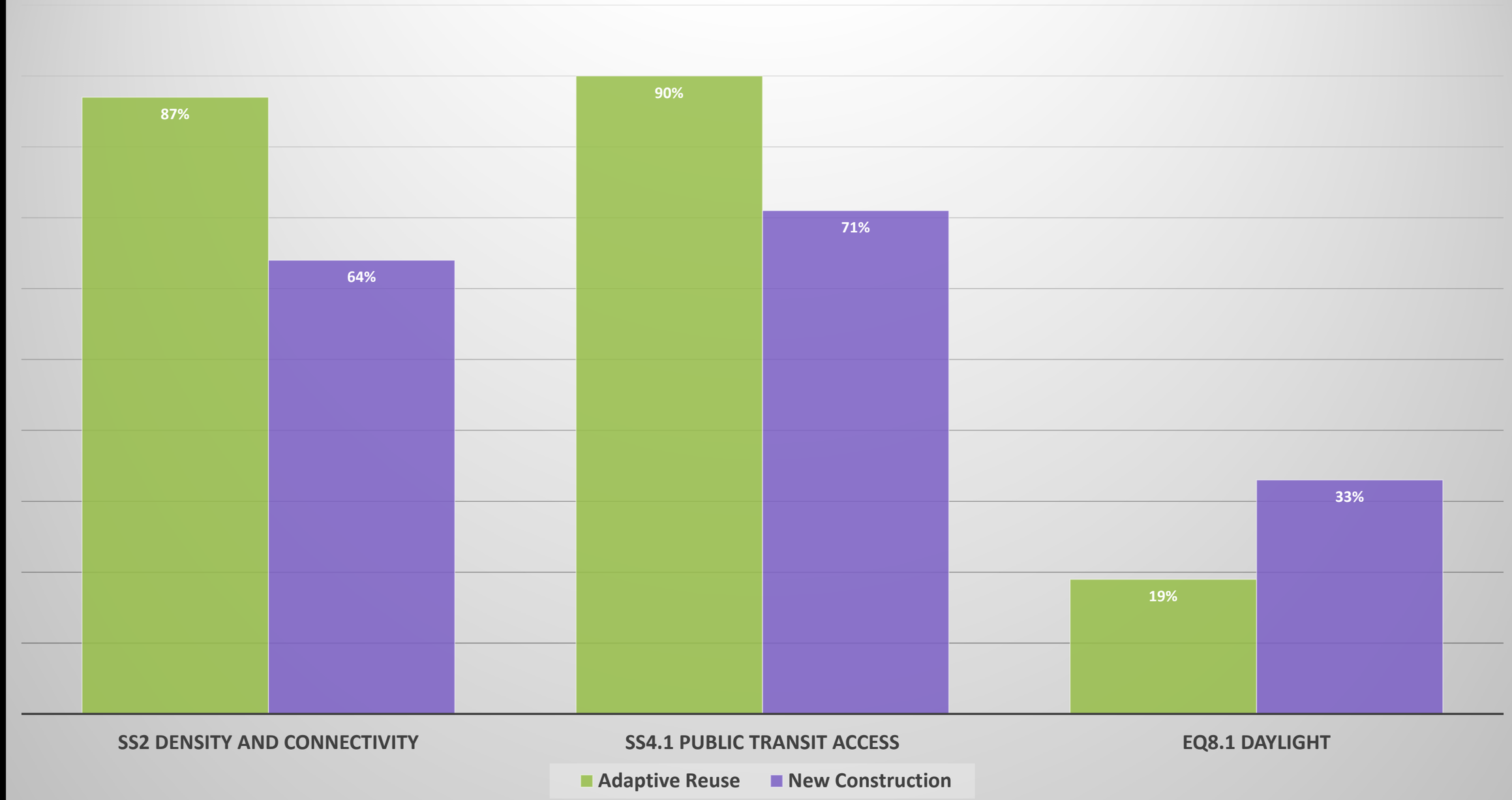


LEED Building Reuse

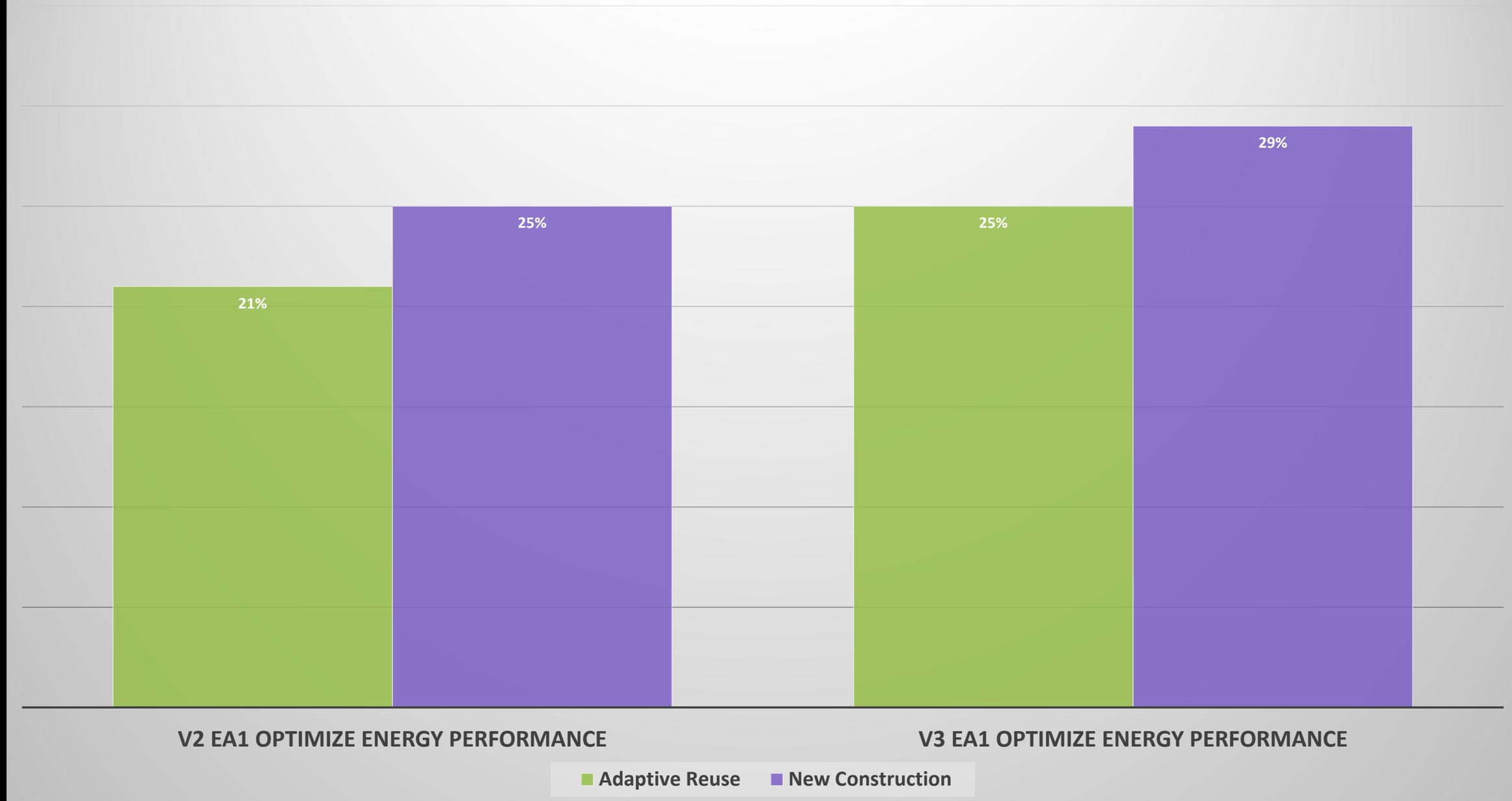
Core & Shell EA Energy-use Reduction



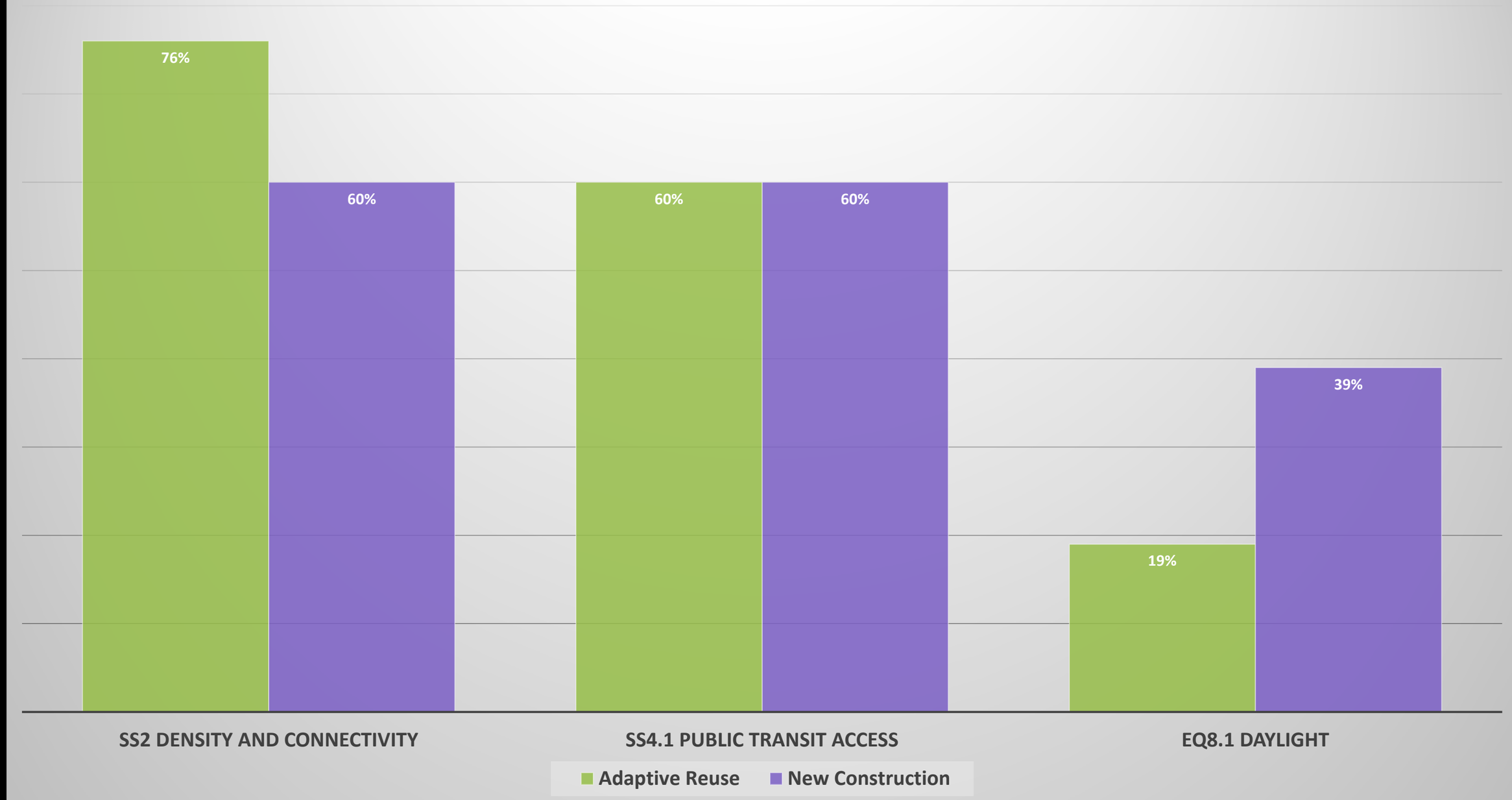
Core & Shell SS and IEQ Credits



NC & MR EA Energy-use Reduction



NC & MR SS and IEQ Credits

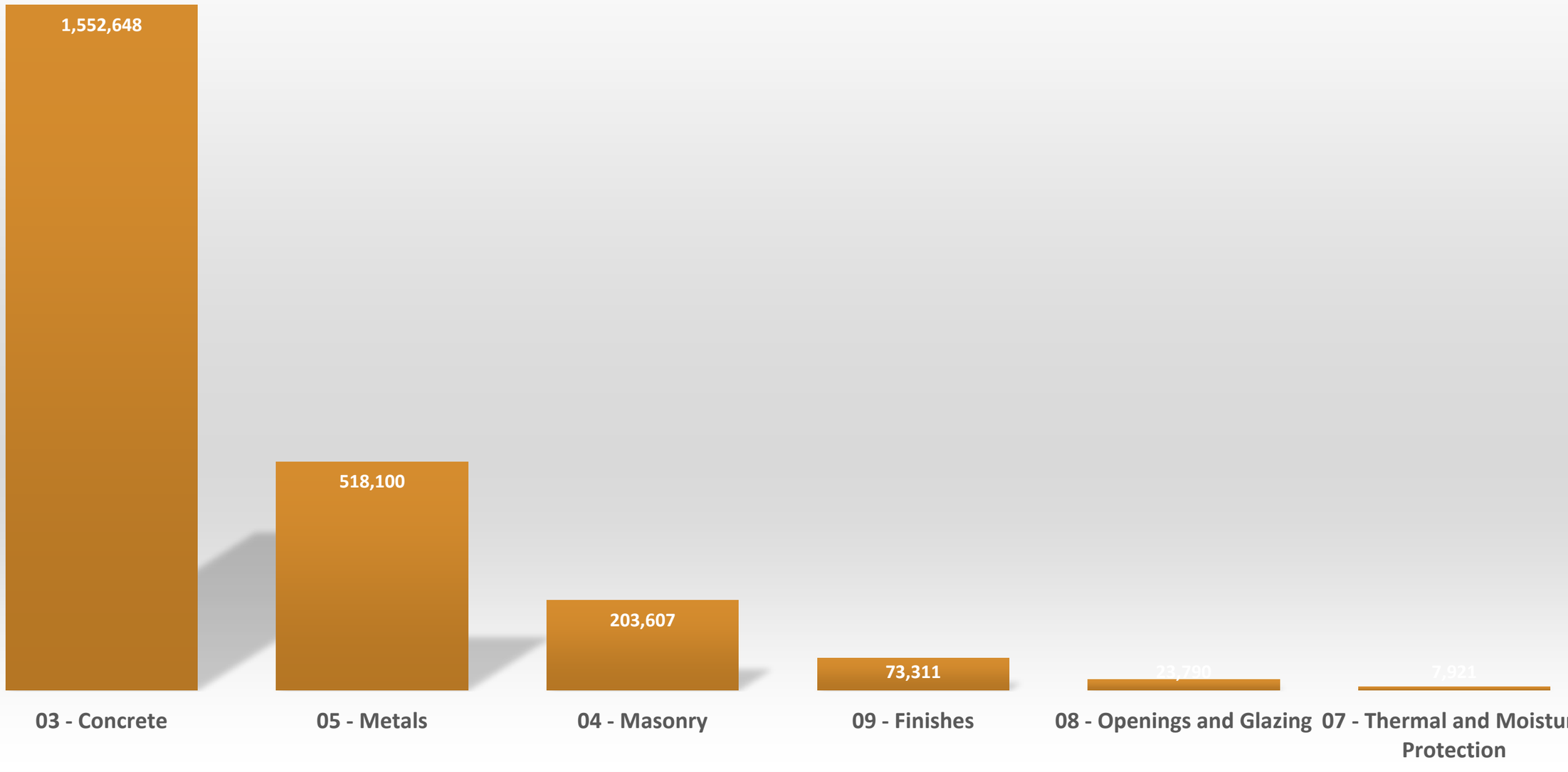


Whole building net-zero retrofit

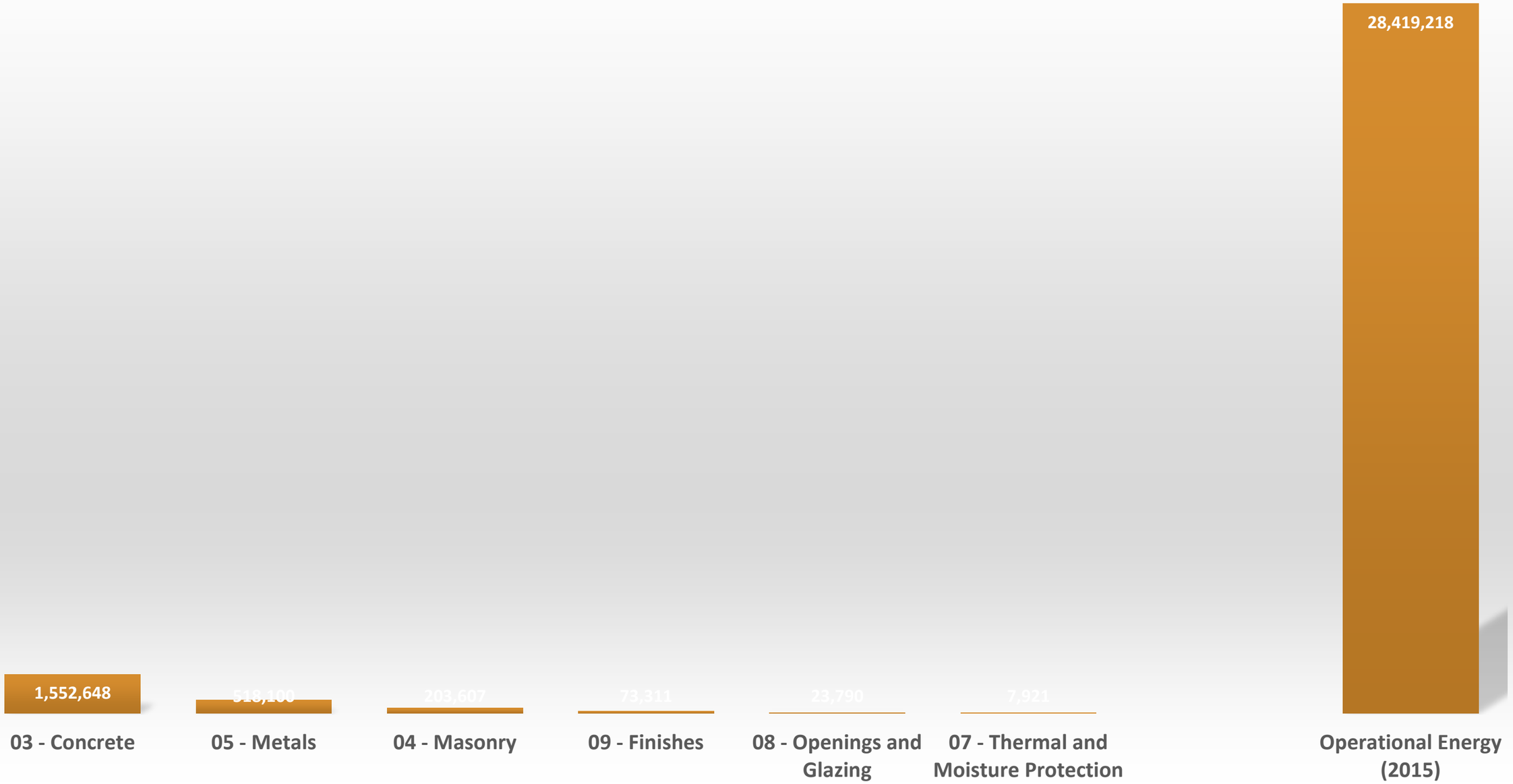
- GWP “benefits” between replacement and retrofit?
- Impacts of PV panels for net-zero?
- Hotspots for embodied impacts?
- Building lifecycle (60-year) effects?

AGU Net-Zero

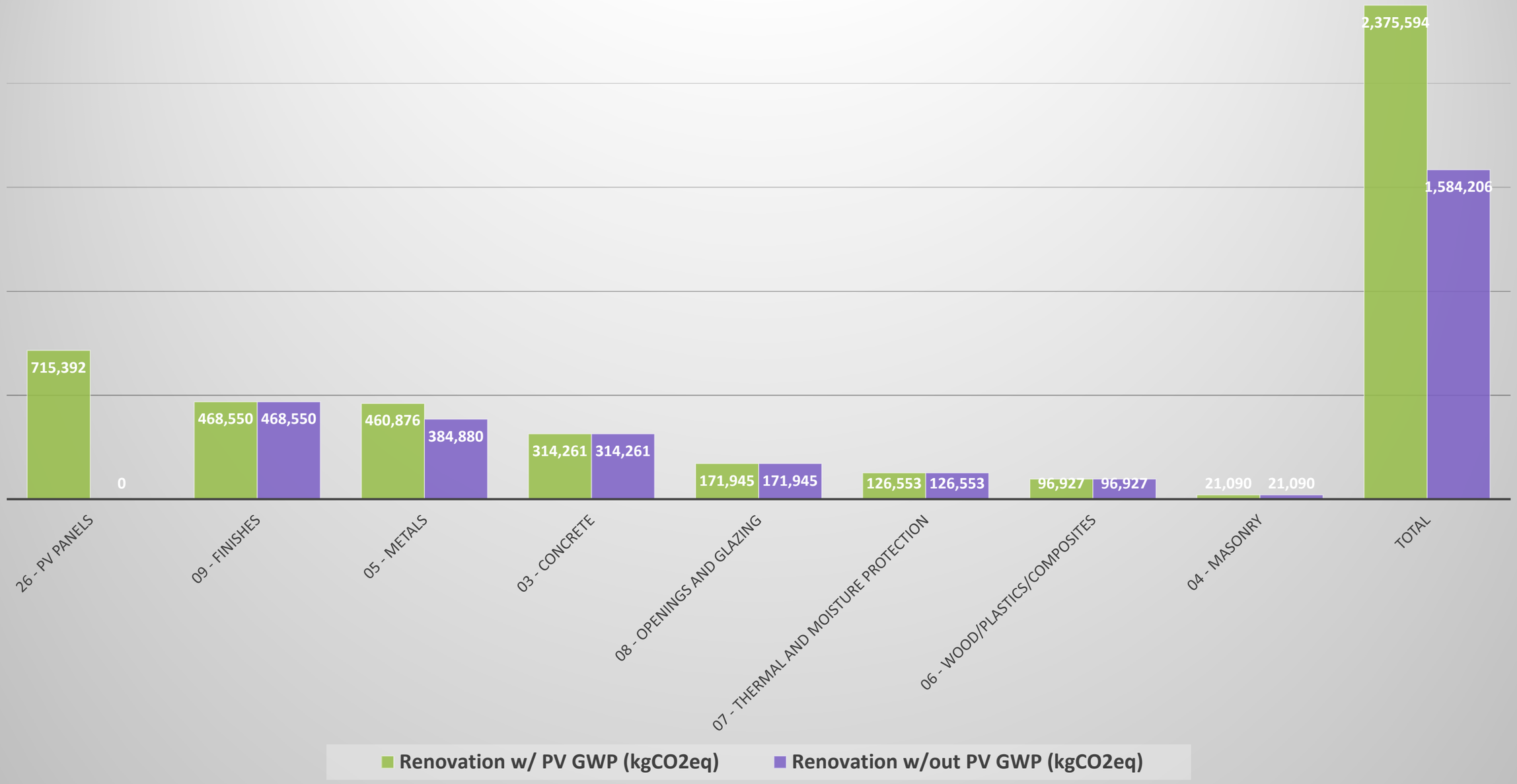
Existing Embodied (EM) GWP (kgCO2eq)



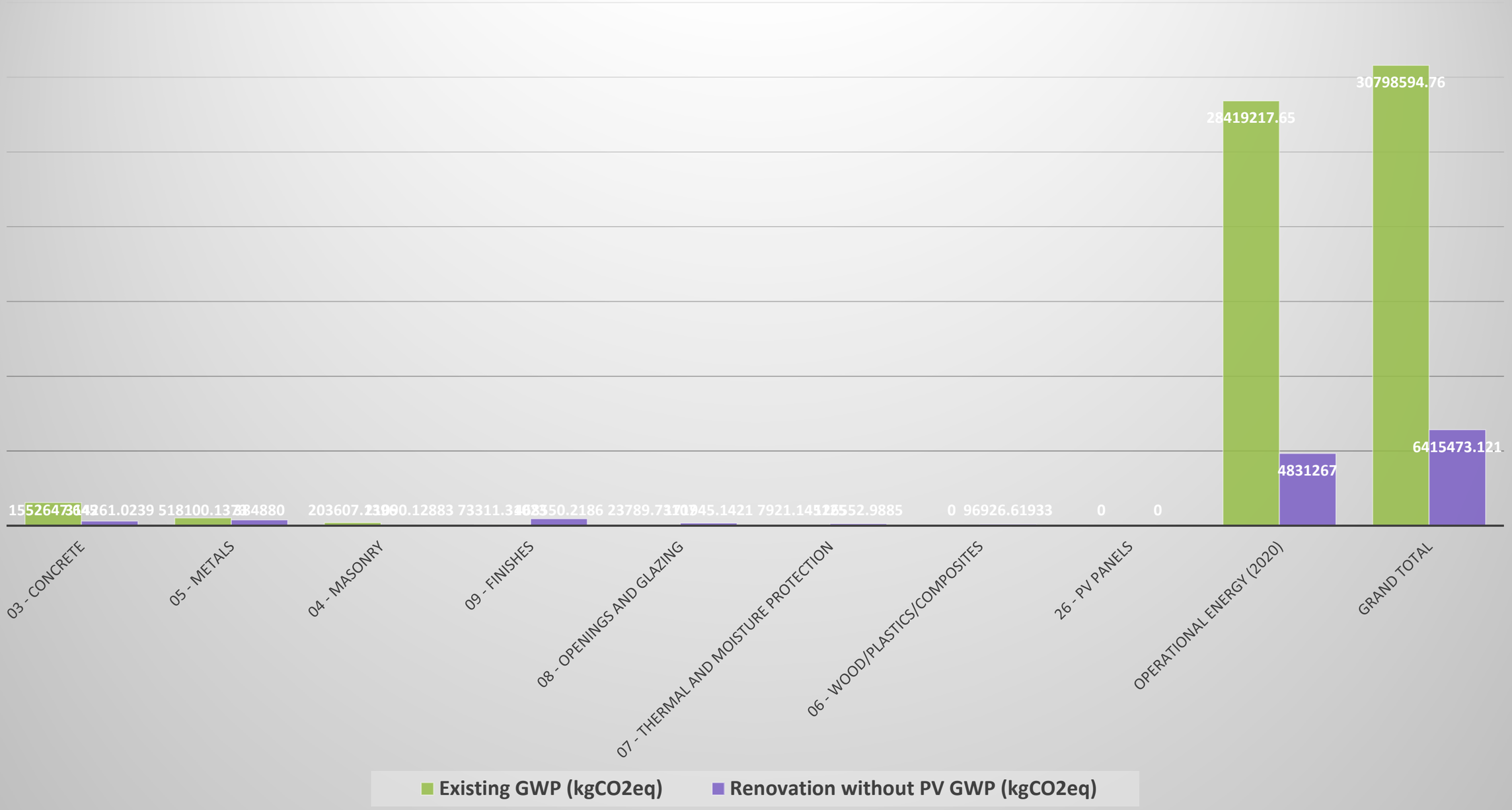
Existing EM + OP GWP (kgCO2eq)



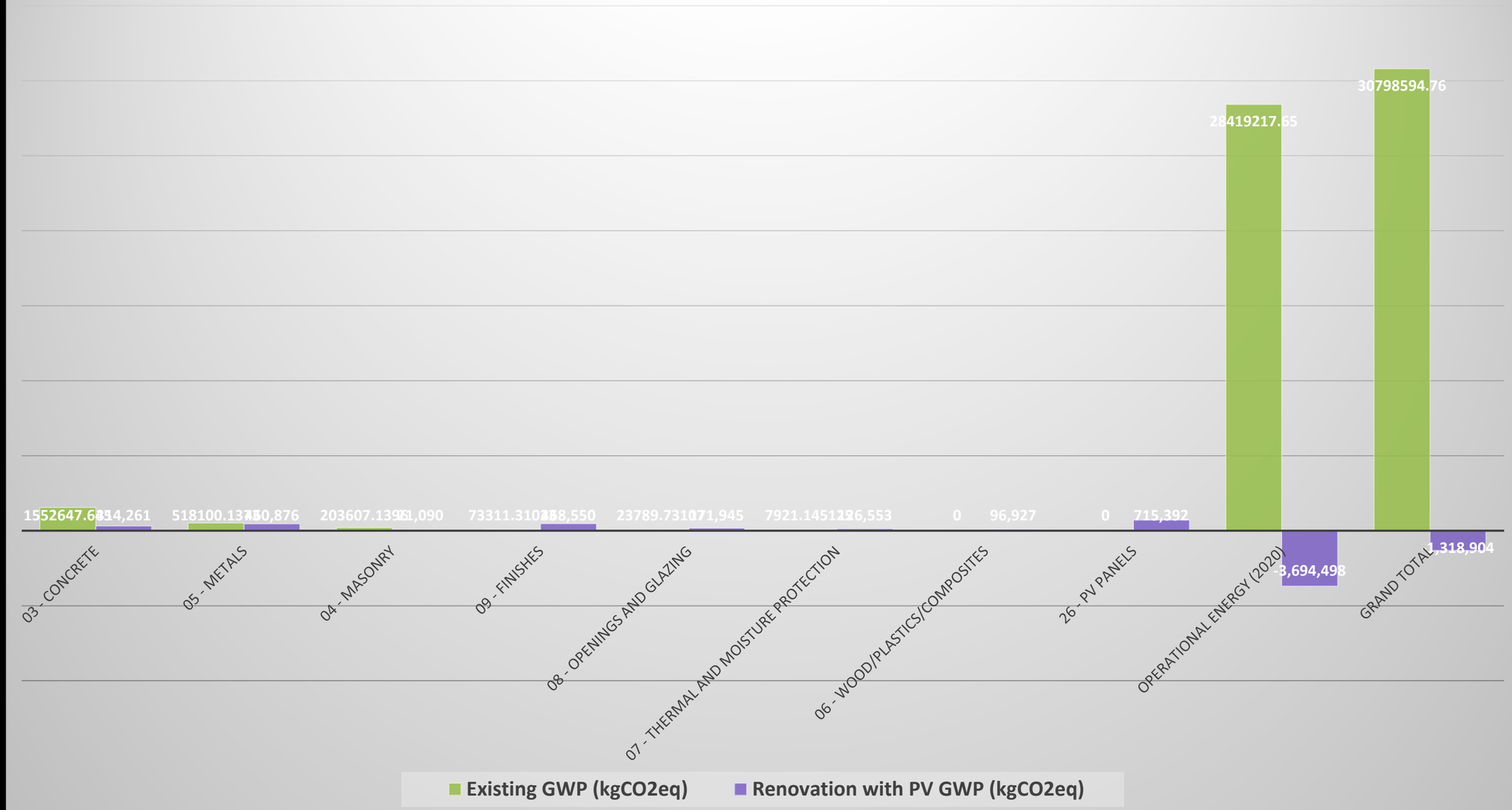
Renovation EM w/ vs w/out PV



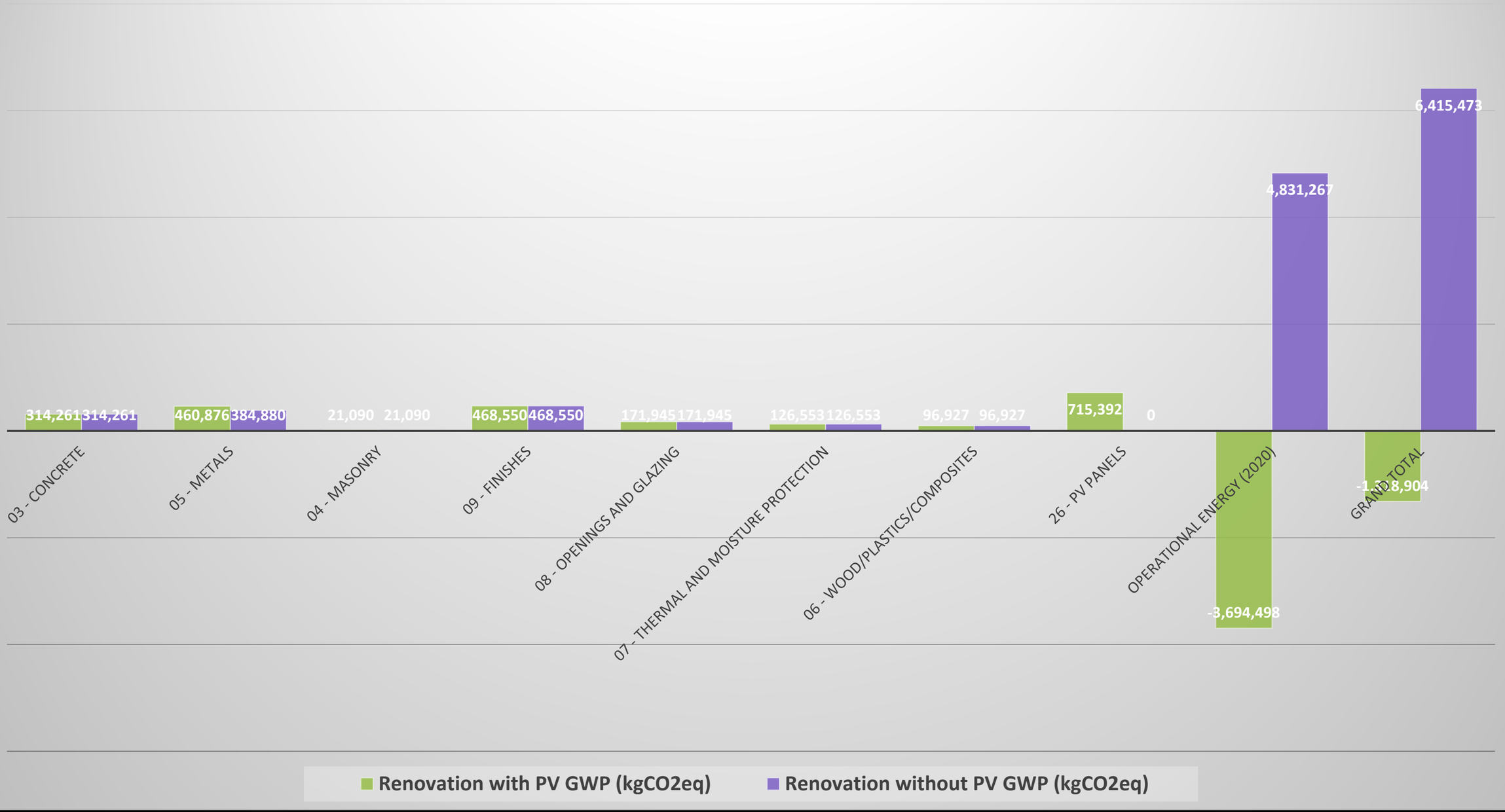
Existing vs Renovation **w/out PV**



Existing vs Renovation **w/ PV**



Renovation **w/ vs w/out PV**



Building Lifecycle Impact Reduction (GWP)

- **Embodied energy** reduction from existing (i.e. build new) to retrofit.
- **Without PV = 33% reduction in GWP**
- *Expenditure of high GWP materials – finishes, metals, electrochromic glazing, etc.*
- **With PV = 1% reduction GWP**
- *Additional expenditure of high GWP metals for PV frame and PV panels.*
- Net-zero retrofit “PV payback” of EM of renovation, i.e. **building is net-positive both EM and OP over 60-year lifespan.**

Themes and findings

- Salvaging reduces GWP impacts of renovation and demolition.
- Reuse substitutes for new materials – **CARBON SINK.**
- Location-related values and GWP are major benefits of reuse.
- More to reuse than just the building (context).

- **Building reuse energy-performance comparable or better than new construction (some limitations).**
- **Renewable-energy buildings' additional impacts can be offset by starting with existing and vice-versa.**

Future

- Carbon offsets for reuse of materials and buildings.
- Scope of reuse in US – more information.
- PCRs and EPDs for reclaimed materials.
- Buildings as invested materials banks for the future (return).
- DESIGN FOR ADAPTABILITY AND DISASSEMBLY (ISO 20887).

- **Only two choices for buildings: <u>existing</u> or <u>net production</u> of – materials, energy, ecosystem services, etc.**

Thank you !

Brad Guy
materialreuse@gmail.com