Embodied Carbon & Life Cycle Considerations in Building Structures

WALSH Seminar

June 7th & 8th, 2016

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Energy + Resources Group

ARUP

Global Engineering Designer

Multi-disciplinary services

10,000+ Employees

Leader in sustainability

Established 1948

60+ Offices

33 Countries

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Course Summary

Embodied carbon is often neglected yet found to be critical to address for tackling climate change. Could the rise of mass timber as a construction alternative help us? Recent Arup carbon studies on the two USDA Tall Wood prize buildings offer some design and procurement lessons learned about the life cycle of wood products

Learning Objectives

- **Distinguish operational carbon from embodied carbon**
- **Identify how timber construction can be an effective strategy to lower embodied carbon**
- **Discover where the risks are to using timber as a means to lower embodied carbon**
- **Identify immediate actions designers and builders can take to producing lower carbon buildings for all types of construction**

FAQ's

- **Why care about embodied carbon?**
- **How about Timber?**
- **Is measuring Carbon enough?**
- **What can we do?**

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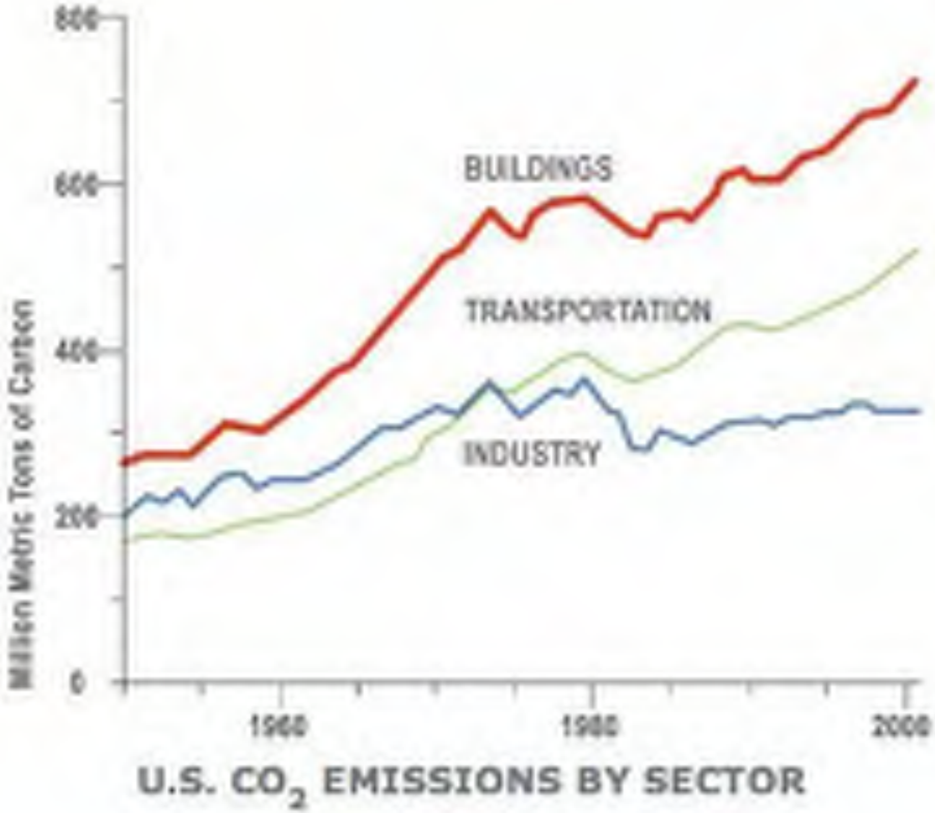
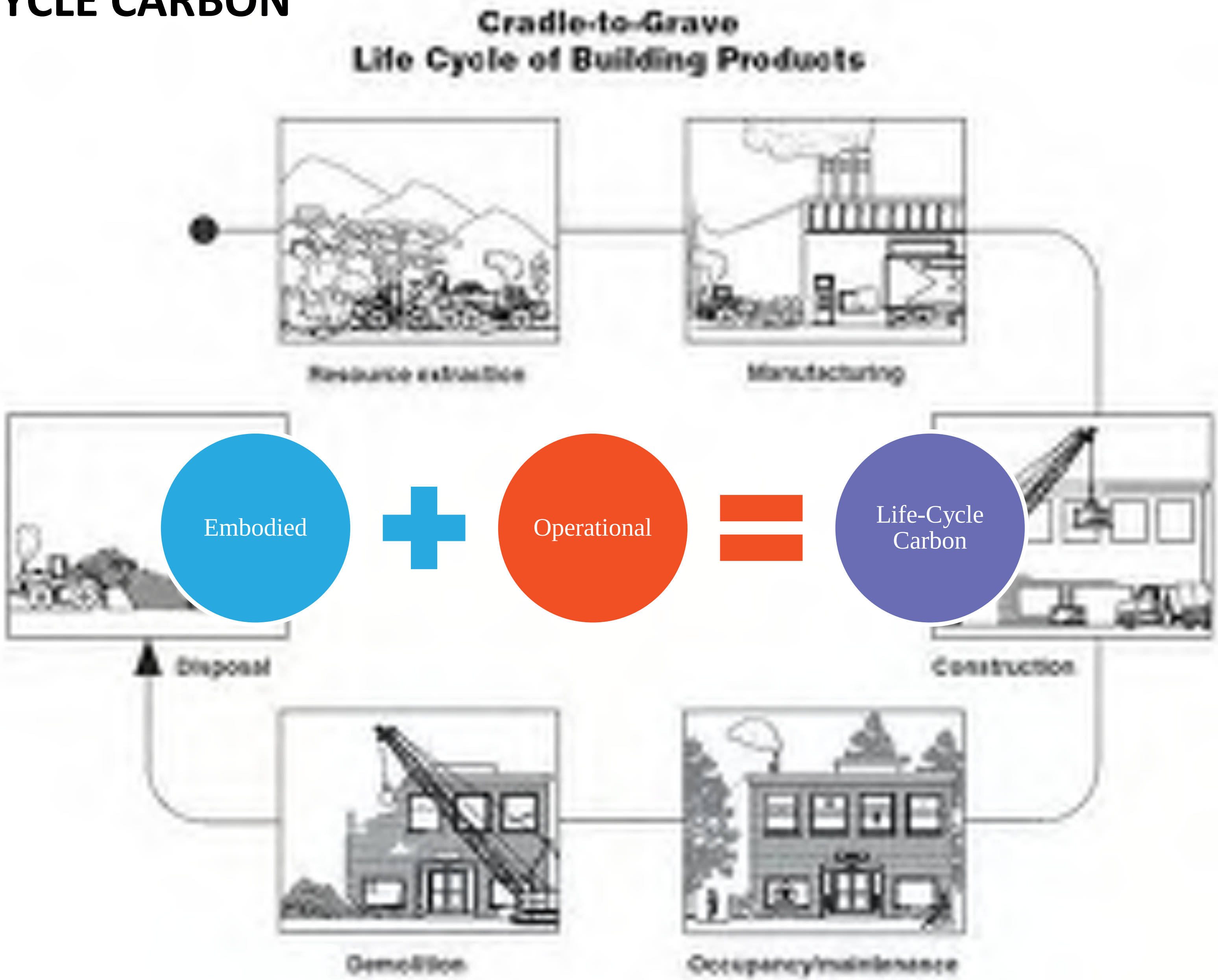
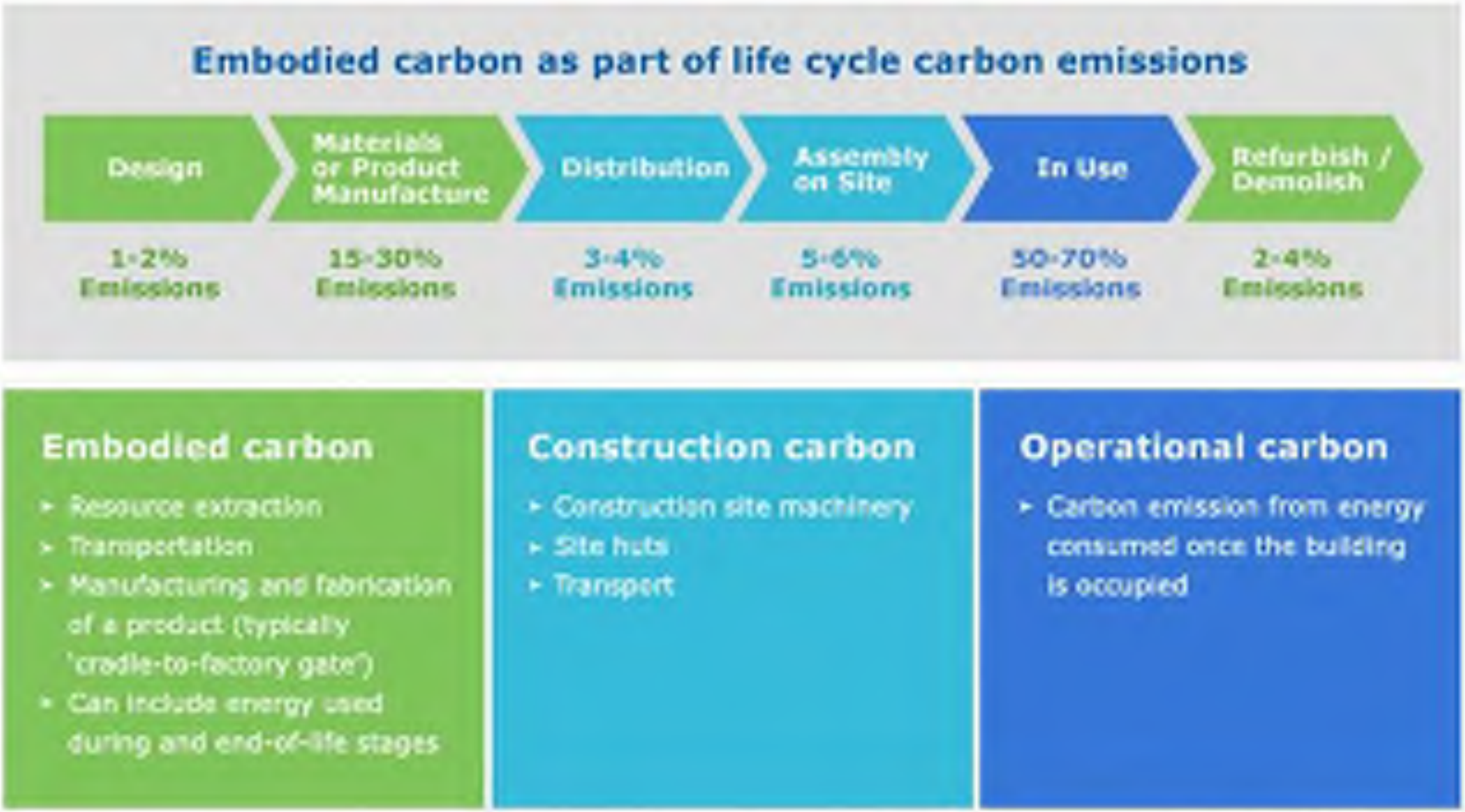
CARBON FROM BUILDINGS



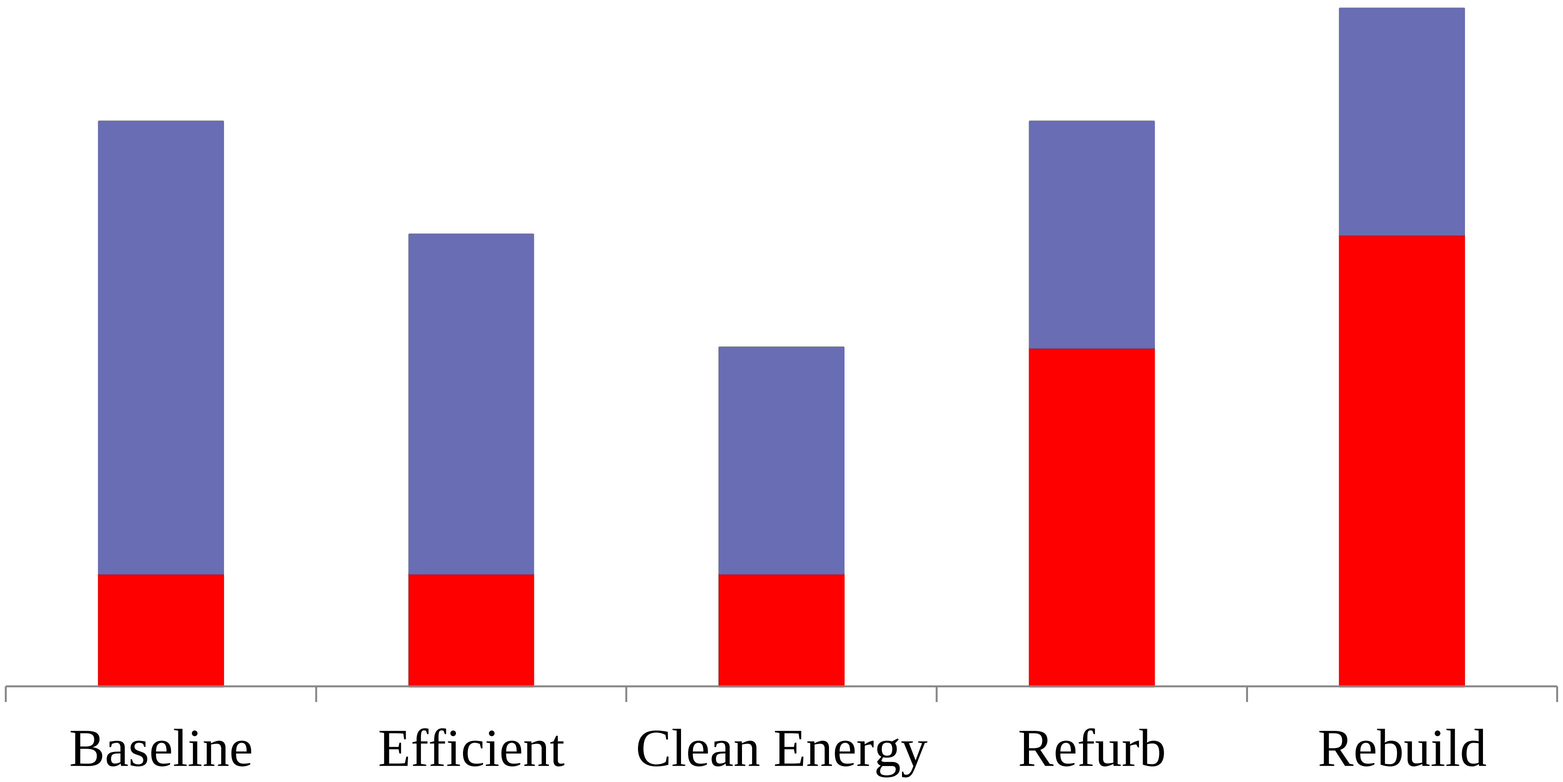
LIFE CYCLE CARBON



LIFE CYCLE CARBON



Operational Carbon vs. Embodied



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It's the NOW that matters

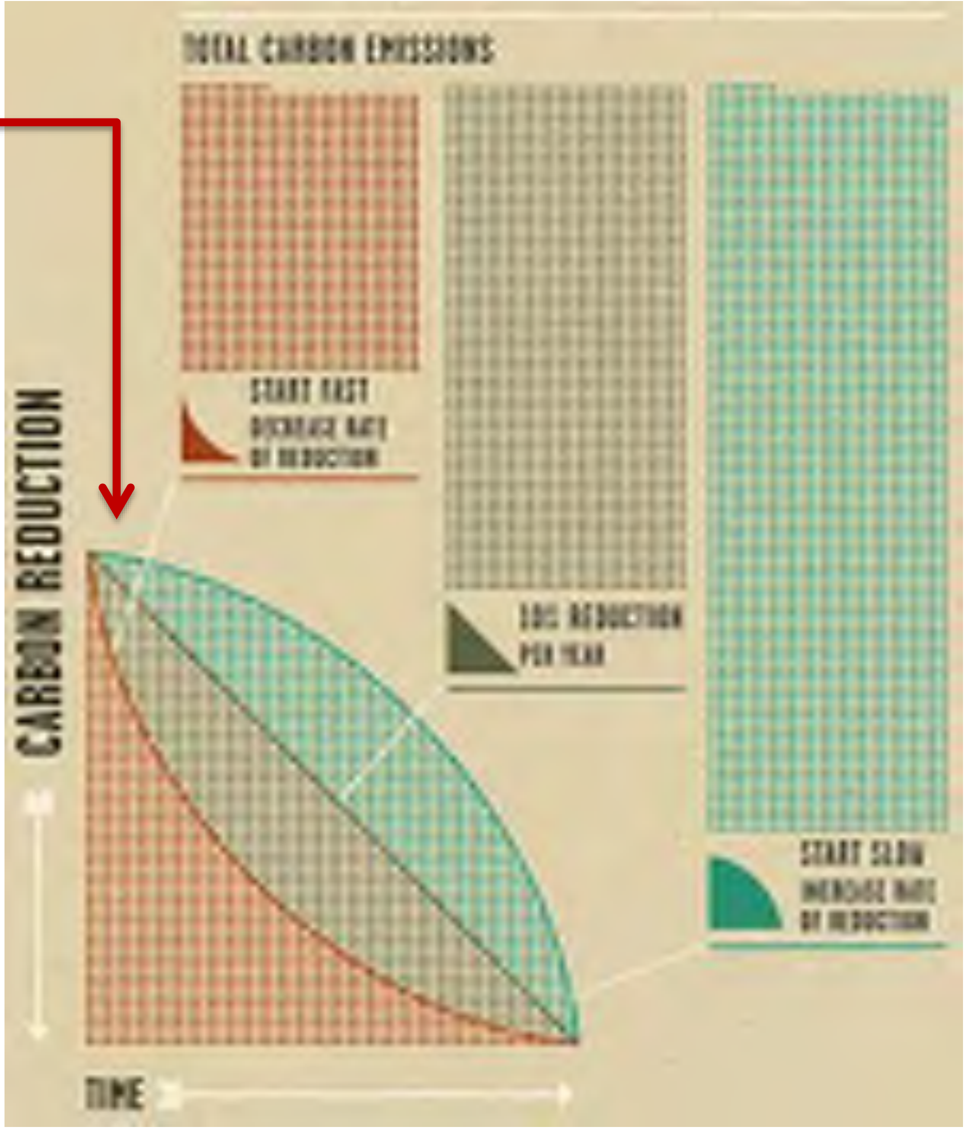

Illustration by Ed Nacional
From book by George Monbiot
Heat: How to Stop the Planet from Burning

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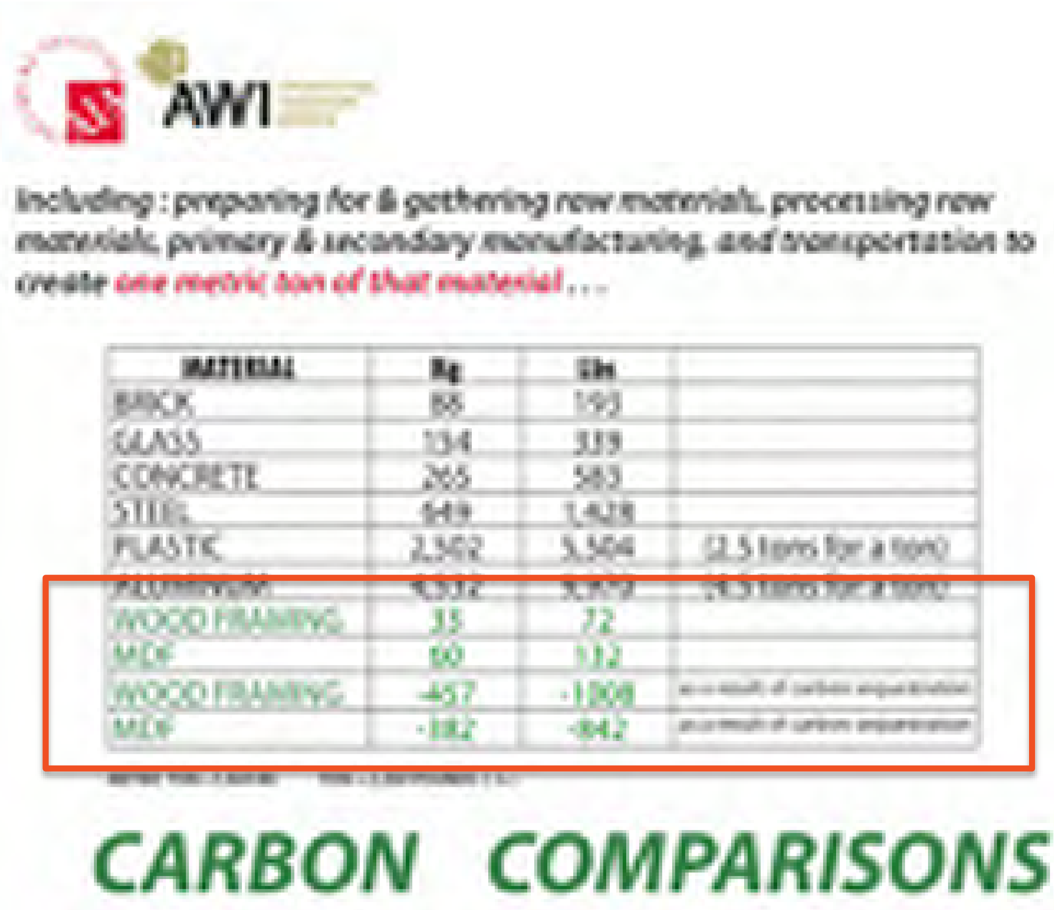
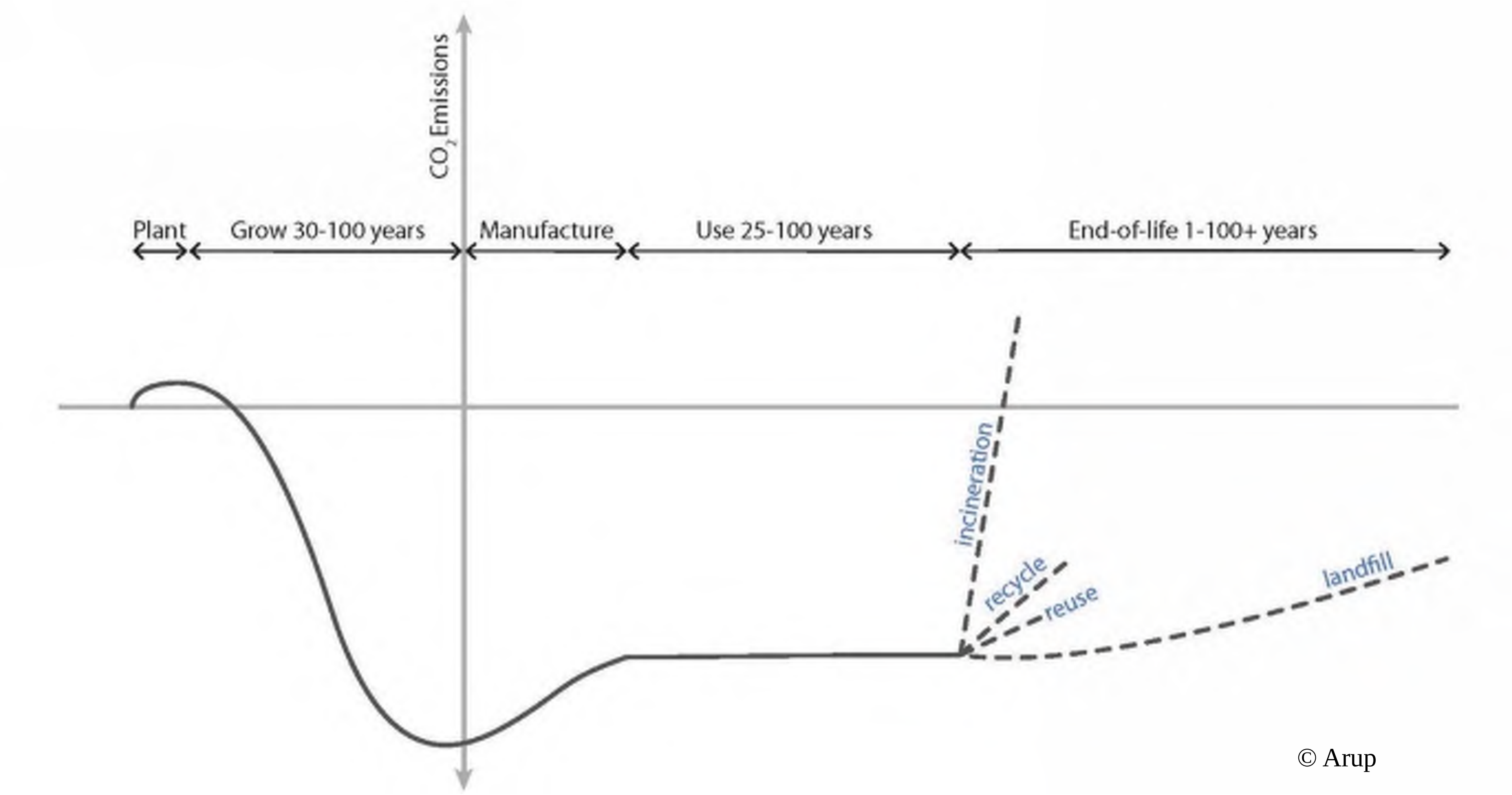
Industry Claims



MATERIAL	Kg	Lbs	
BRICK	88	193	
GLASS	154	339	
CONCRETE	265	583	
STEEL	649	1,428	
PLASTIC	2,502	5,504	(2.5 tons for a ton)
ALUMINUM	4,532	9,979	(4.5 tons for a ton)
WOOD FRAMING	33	72	
MDF	60	132	
WOOD FRAMING	-457	-1,008	as a result of carbon sequestration
MDF	-382	-842	as a result of carbon sequestration

Source: http://woodforall.wiki.awinet.org/CarbonNegative

CARBON OVER LIFE OF A WOOD PRODUCT



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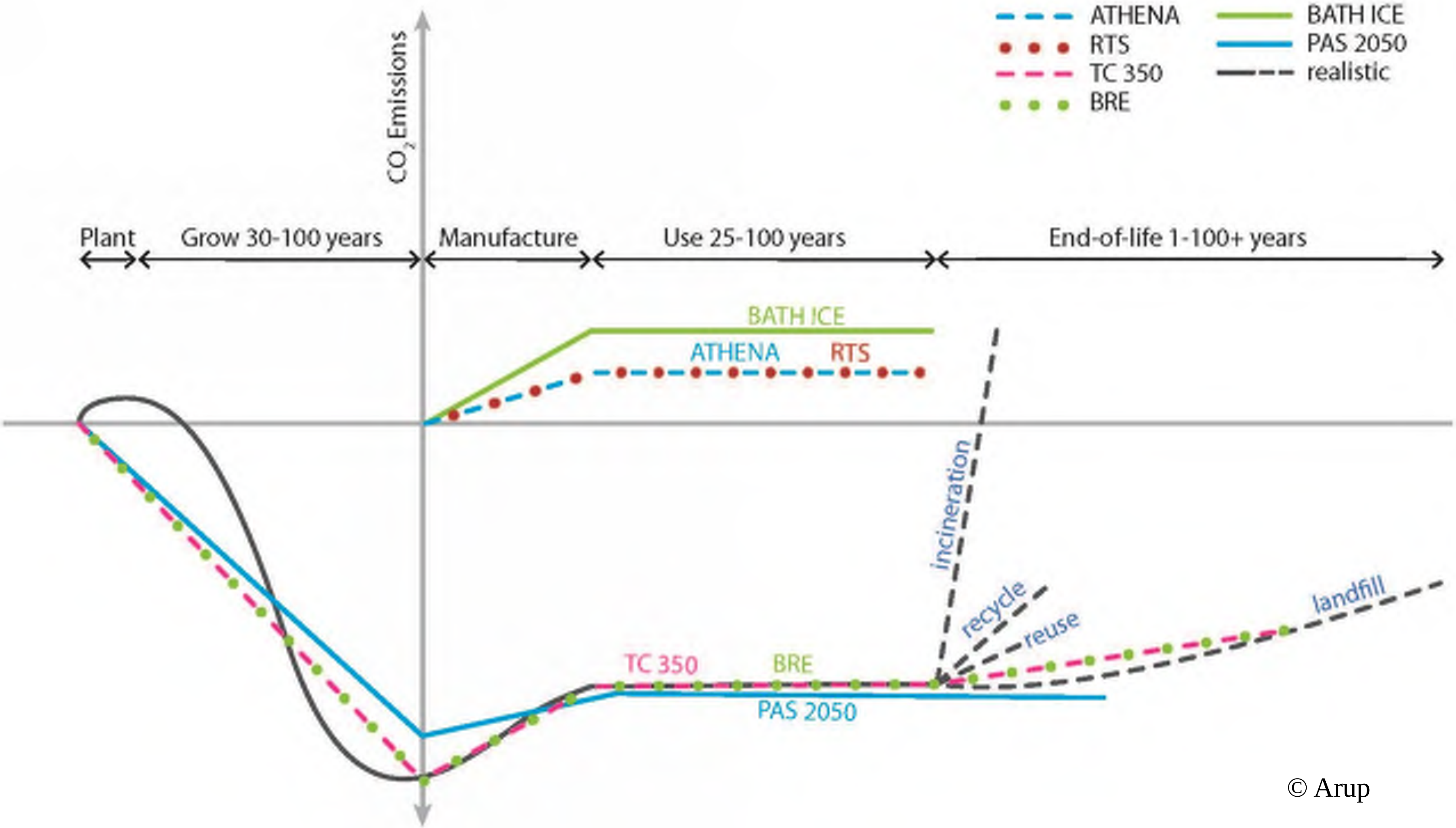
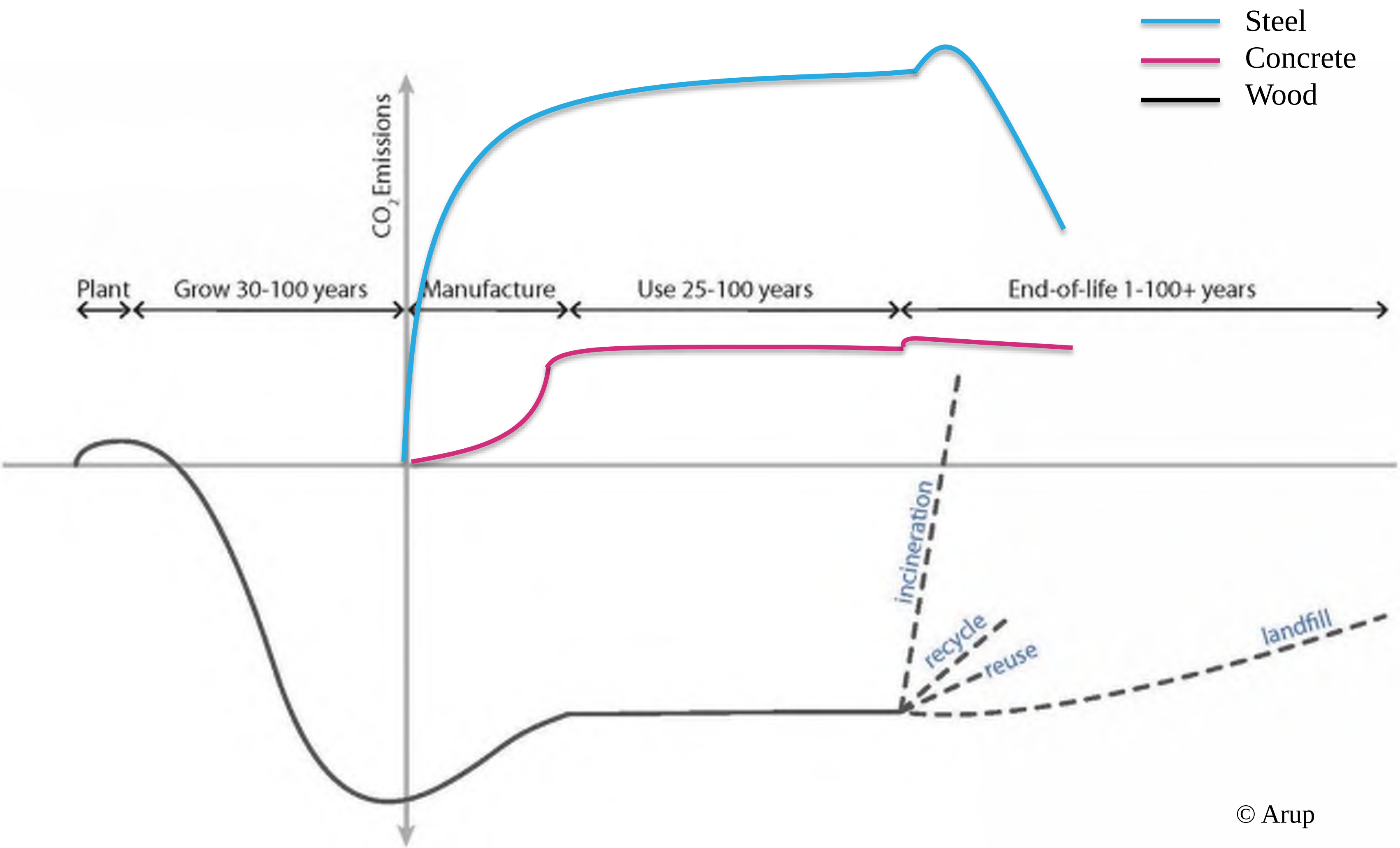
LCA TOOLS AND STANDARDS



CARBON OVER LIFE OF STRUCTURAL PRODUCTS



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CONCRETE VS. TIMBER CARBON STUDY

Framework, Portland

VS.

475 W 18th St, New York

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CONCRETE VS. TIMBER CARBON STUDY

475 W 18th St, New York

	Concrete Design Option	Timber Design Option
Gravity System	Concrete flat slab Concrete columns	CLT floor and roof panels Glulam framing
Lateral System	Concrete shear walls	CLT shear walls
Foundations	Concrete mini piles	Concrete mini piles
Column Grid	19’ x 22’	12’ x 12’

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MATERIAL QUANTITIES

	Concrete Design Option	Timber Design Option
Cross-laminated Timber (ft^3)	0	48,622
Glulam Sections (ft^3)	0	8,170
Solvent Based Varnish (gallons)	0	108
Bolts, Fasteners, Clips (tons)	0	8
Concrete 4000 psi (yd^3)	1,805	920
Concrete 6000 psi (yd^3)	292	0
Rebar (tons)	211	60
Gypsum Board (ft^2)	0	1,350

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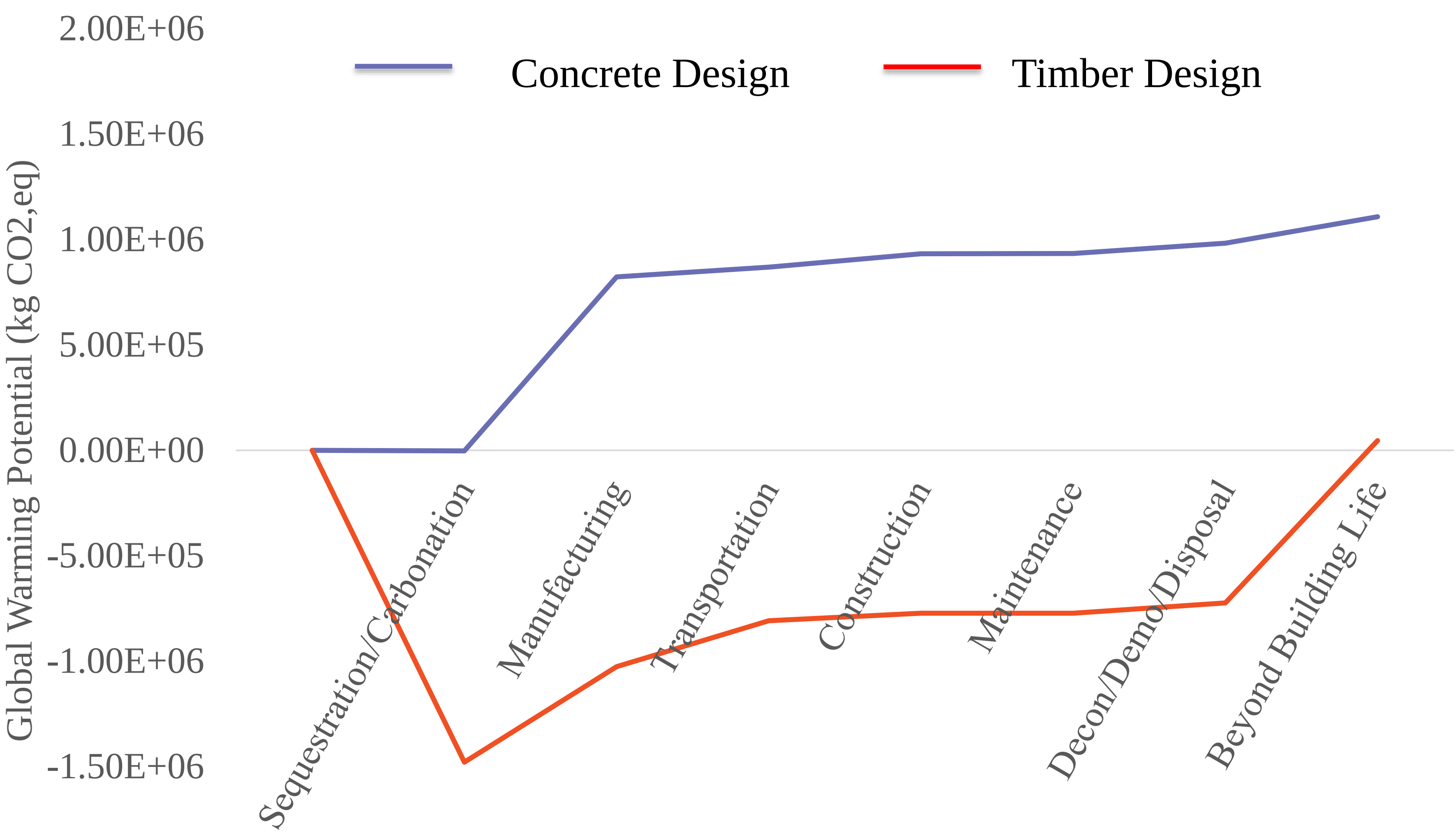
CARBON FROM WOOD ON PROJECT



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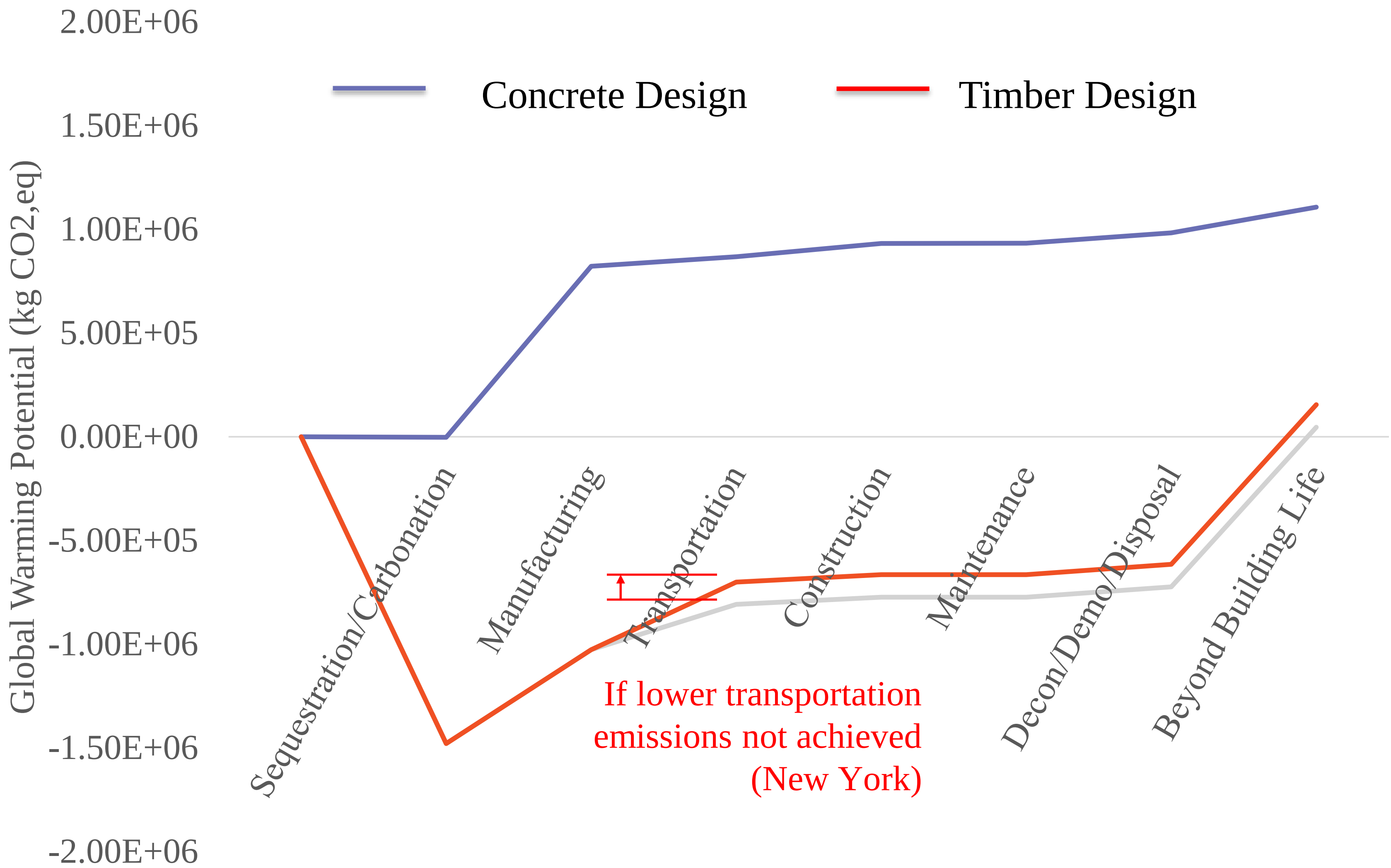
CARBON FROM WOOD ON PROJECT



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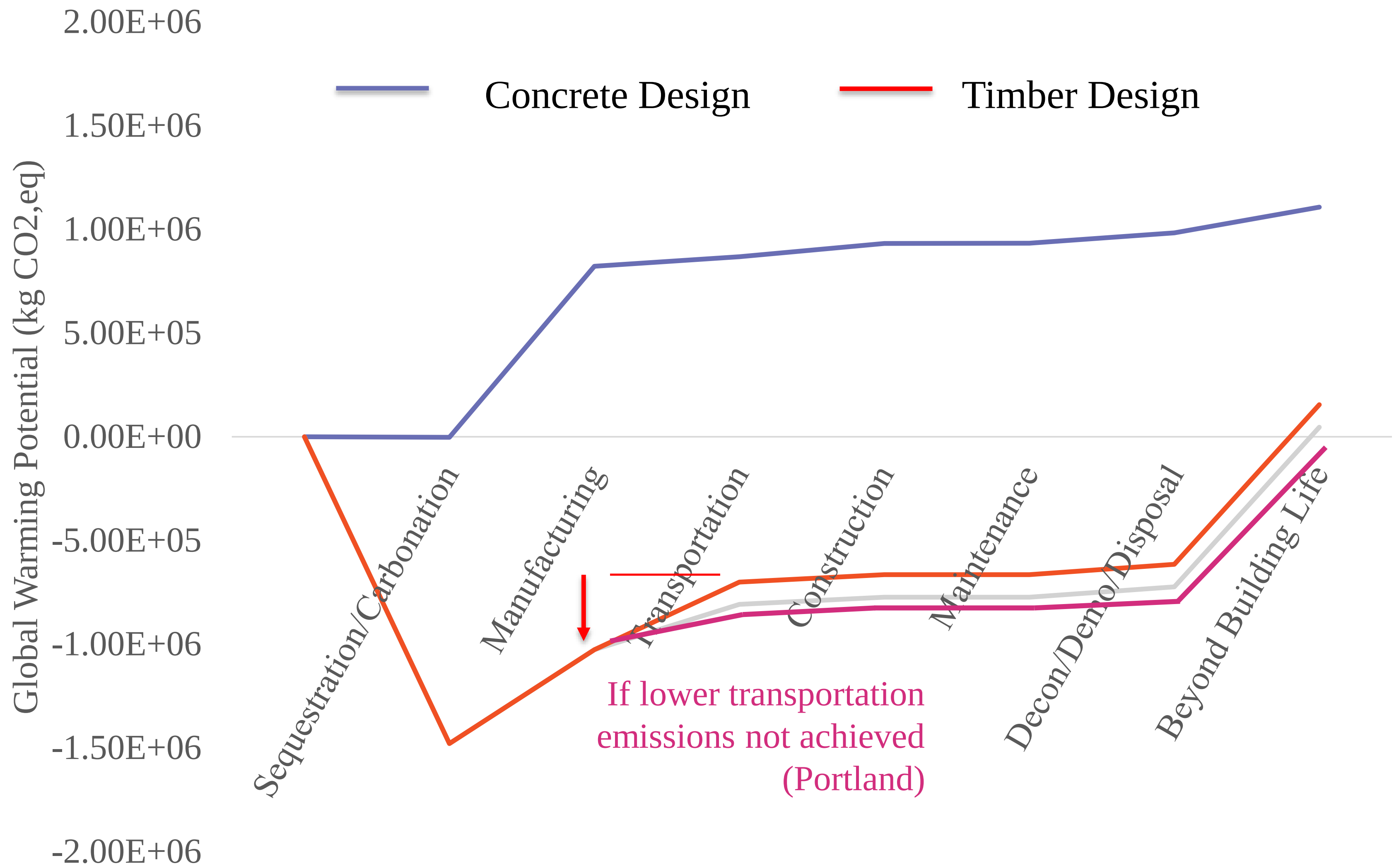

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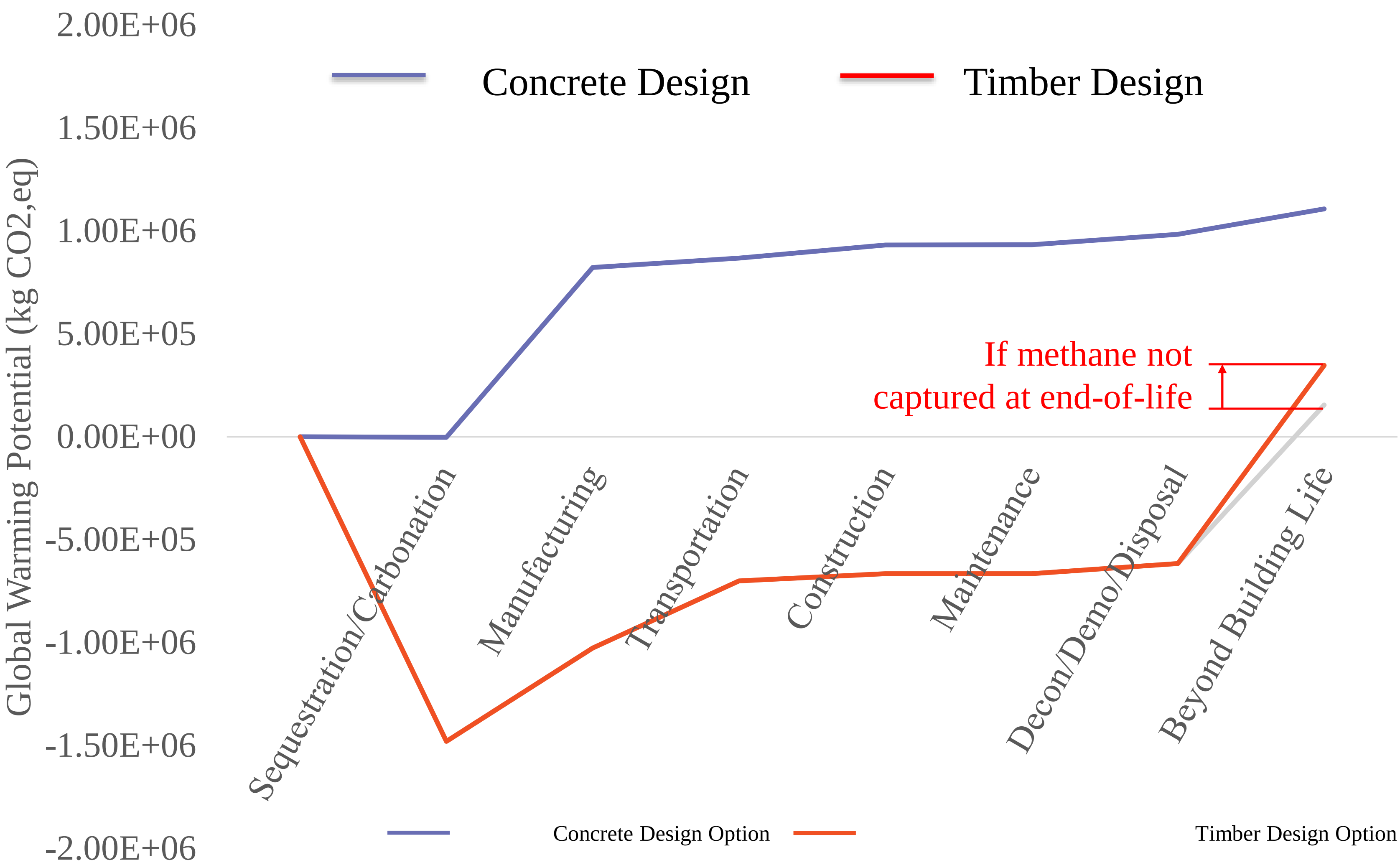

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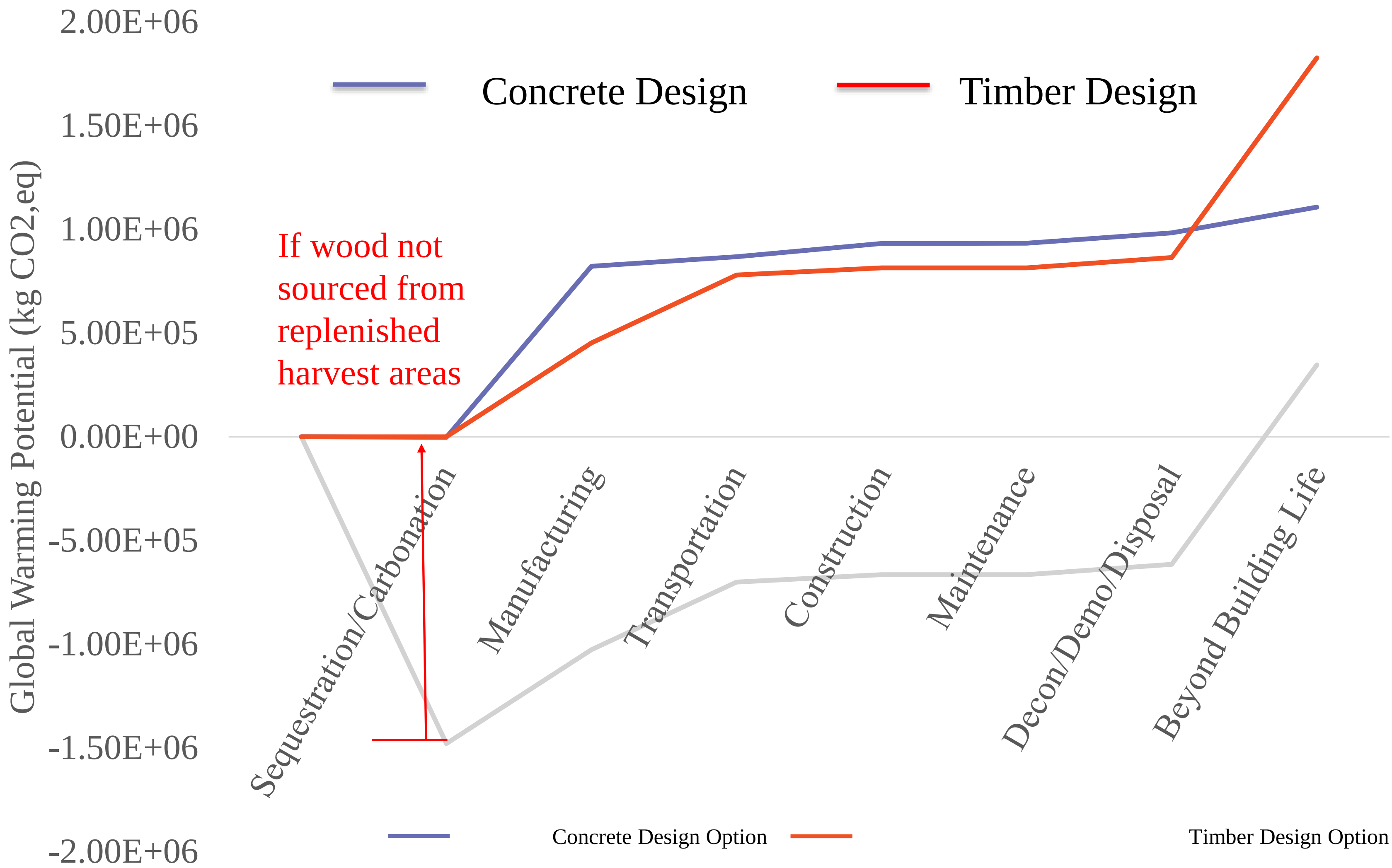

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LESSONS FROM PROJECT CARBON STUDIES

Lower Transportation Emissions

Source timber from the vicinity and/or change transport efficiency

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LESSONS FROM PROJECT CARBON STUDIES

Lower Transportation Emissions

Source timber from the vicinity and/or change transport efficiency

Improve Beyond Building Life

Capture methane emissions from landfill OR better

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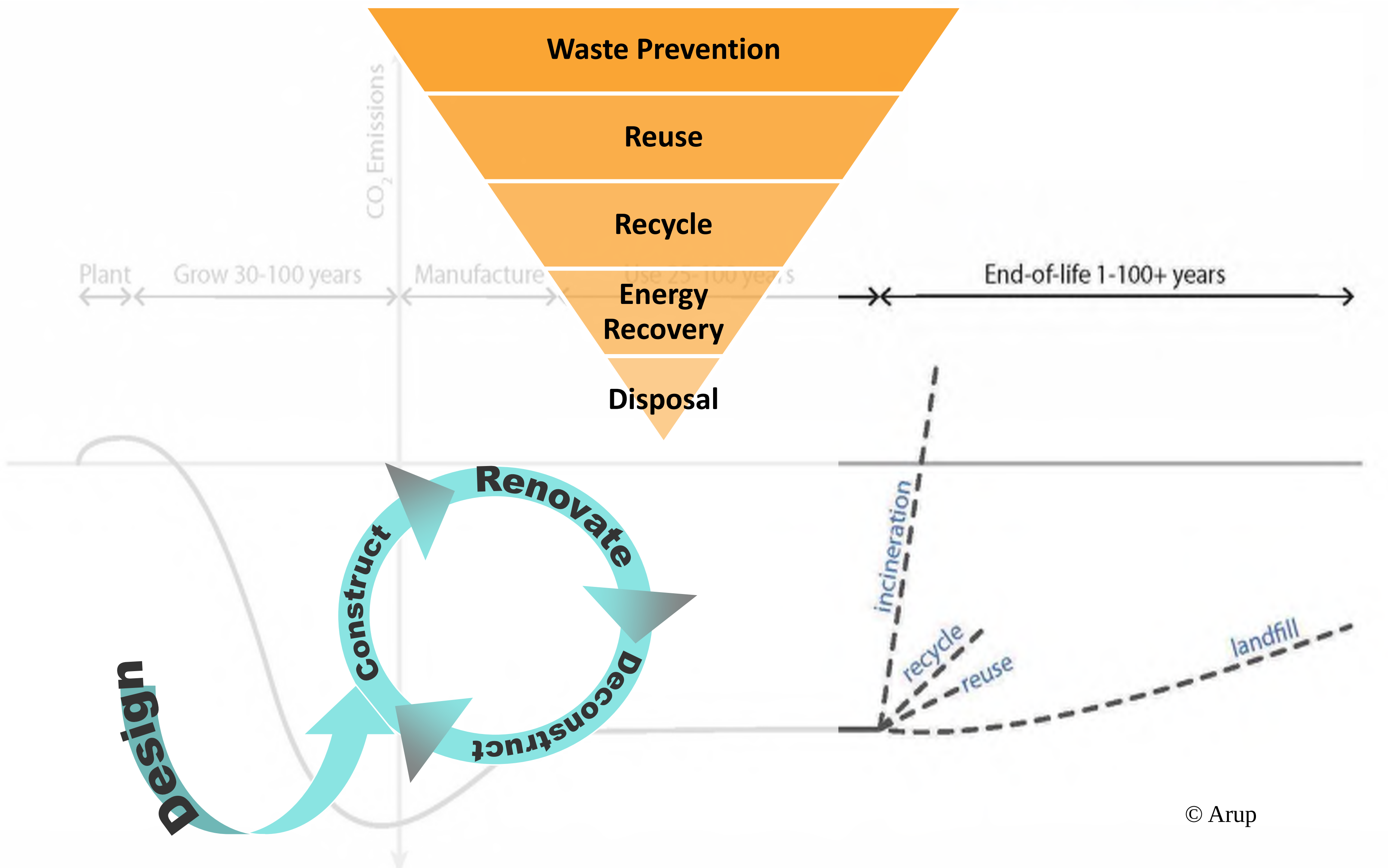
WASTE HIERARCHY



LESSONS FROM PROJECT CARBON STUDIES

Lower Transportation Emissions

Source timber from the vicinity and/or change transport efficiency

Improve Beyond Building Life

Capture methane emissions from landfill OR better

Source from Replenished Harvest Areas

Select wood from harvest areas that are unquestionably replenished

Source timber with FSC, SFI, or PEFC certification

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Summary:

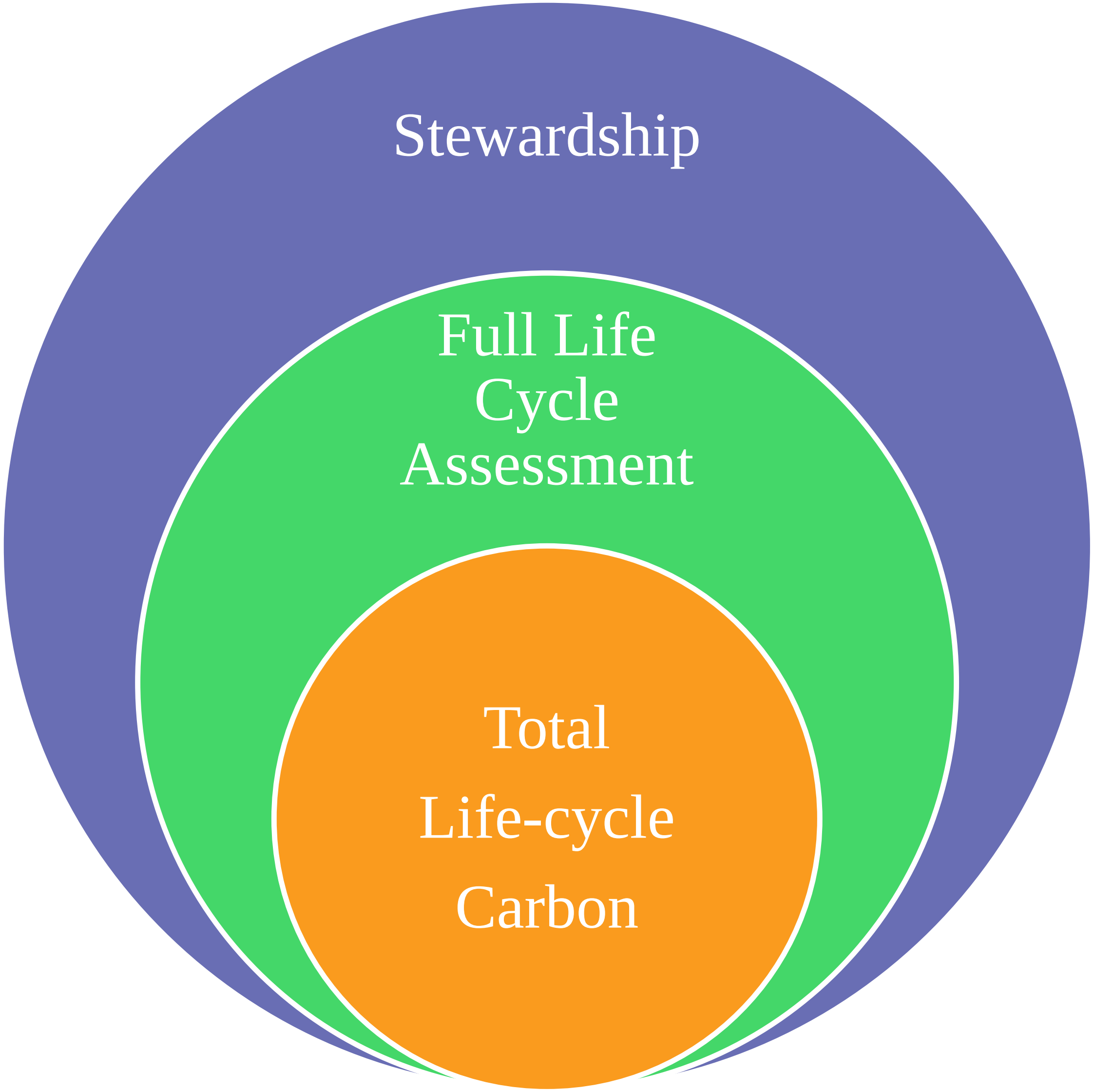
Timber design options must ensure appropriate strategies are implemented for proper comparison

Further Study:

Explore concrete strategies (i.e., high and low cement mix options) compared to timber strategies

Include operational carbon to improve context of structural results

Bigger Picture



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Comparative LCA of Glulam vs. Steel

Raleigh-Durham Airport T2 Roof Truss

Athena Impact Estimator's Bill of Materials + Transport

Multiple Impact Categories

Using Glulam instead of Steel

Key Performance Indicator	Reduction
Energy Consumption	85%
Global Warming Potential	86%
Acidification Potential	48%
HH Respiratory Effects Potential	61%
Eutrophication Potential	99%
Ozone Depletion Potential	(23%)

Due to formaldehyde-based adhesives in GLB. *(Now CLT using PUR-based adhesives.)*




Life-Cycle Carbon of Façade Options

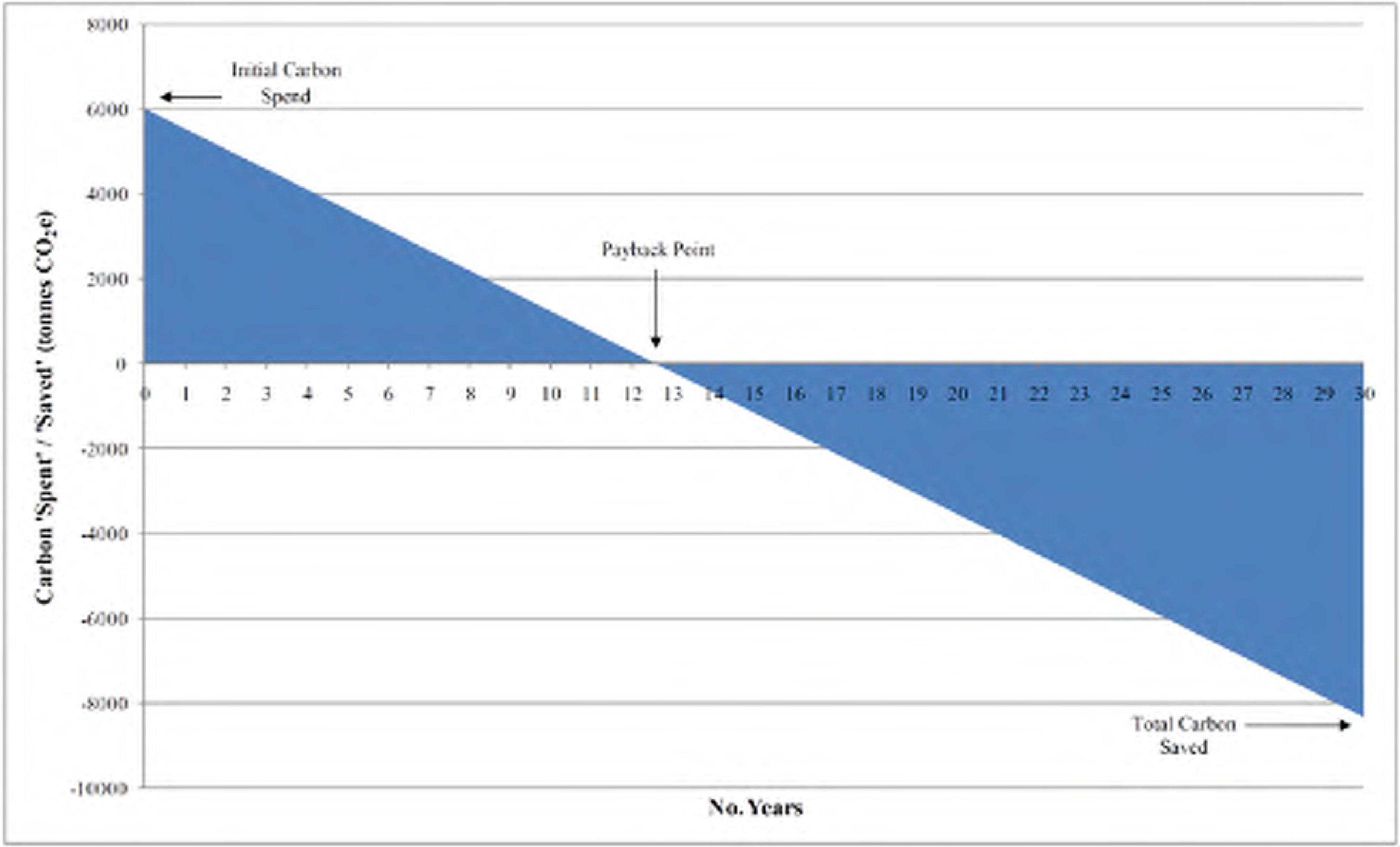
PV Laminate

Image courtesy of **wd** Partners

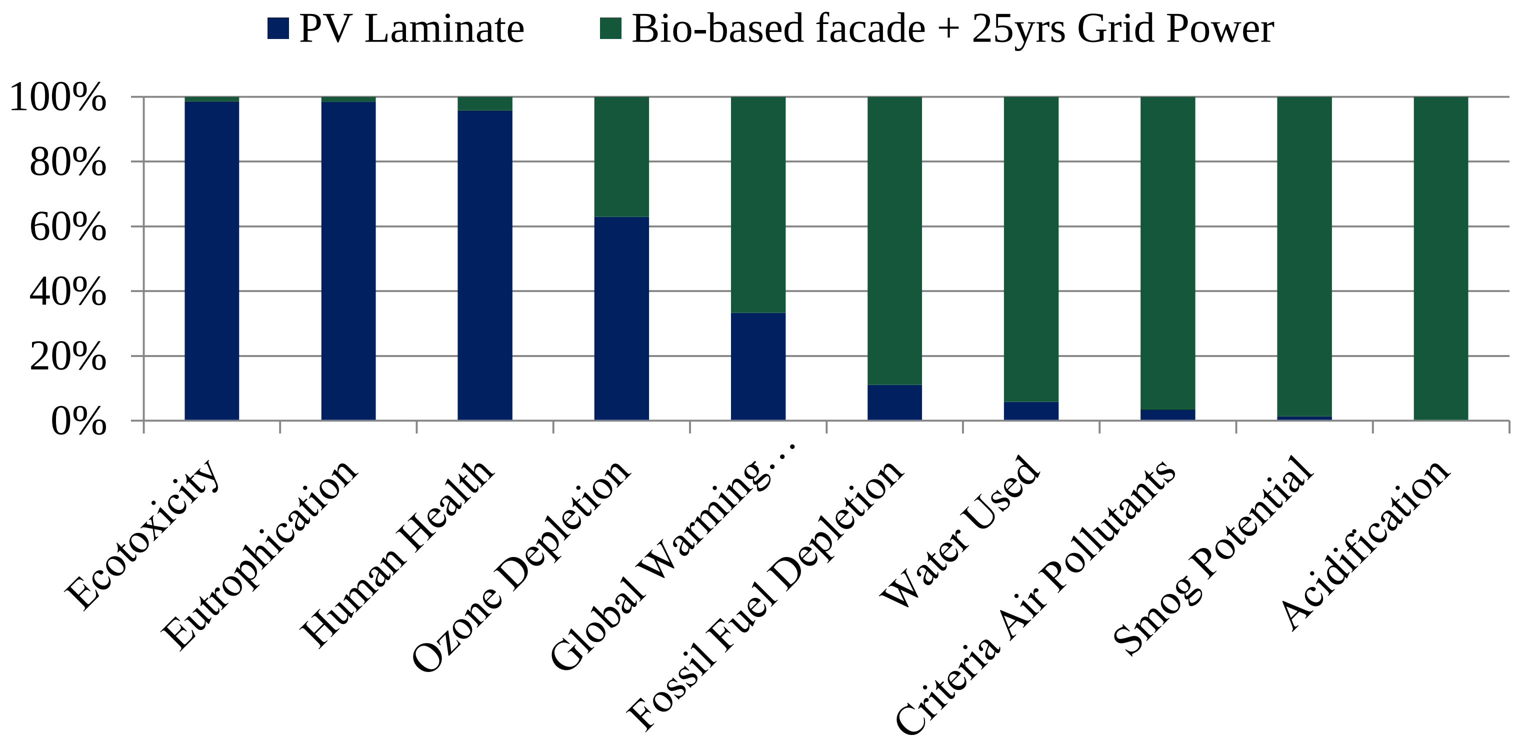
Bio-based Facade

+ 25yrs Grid Electricity

Payback on Initial Environmental Burden



Life-cycle Impacts of Façade Options



RESPONSIBLE FOREST MANAGEMENT

FSC vs. SFI

+ Land use
+ Habitat
+ Biodiversity
+ Fair Labor
+ Indigenous Peoples' Rights
+ Local Economies

ECOSYSTEM SERVICES

Source: freshwaterwatch.thewaterhub.org

LOW CARBON + STEWARDSHIP

Framework, Portland

Project: Framework - Tall Wood Project ARUP
Sheet Title: Gravity CLT Carbon Questionaire **Issue Da** 6/7/2016

Instructions to Bidders: Fill out the input cells (yellow boxed cells) pertaining only to the product defined in the declared unit (bolded) below. See Instructions tab

inputs

Declared unit *This portion of input is to enable comparison of material quantities required for the specified design. Lower material demand does not necessarily reduce the total embodied carbon. Carbon emissions also depend on the carbon intensity of the activities in the life-cycle of the*

Sequestratio *As seen on the graph in the Instructions tab, the growth phase of the wood product life-cycle has the most significance in whether the product results in high, low, or negative carbon*

Transport to *This portion of input is meant to allow comparison between sourcing from harvest areas of different distances from the manufacturing facilities, and uses different carbon emissions factors for various modes of transport. The total volume should represent the amount of wood arriving to the milling/manufacturing plant in order to produce the quantity declared in cell C8.*
If the manufacturing facilities are in different locations, use the most conservative distance/mode combination. If the same volume of product is transported using multiple modes, the volume should be entered again in each input cell for each mode. Distances should

Volume and distance for wood transported from harvest to manufacture by **truck**:		ft3		mi
Volume and distance for wood transported from harvest to manufacture by **train**:		ft3		mi
Volume and distance for wood transported from harvest to manufacture by **barge**:		ft3		mi

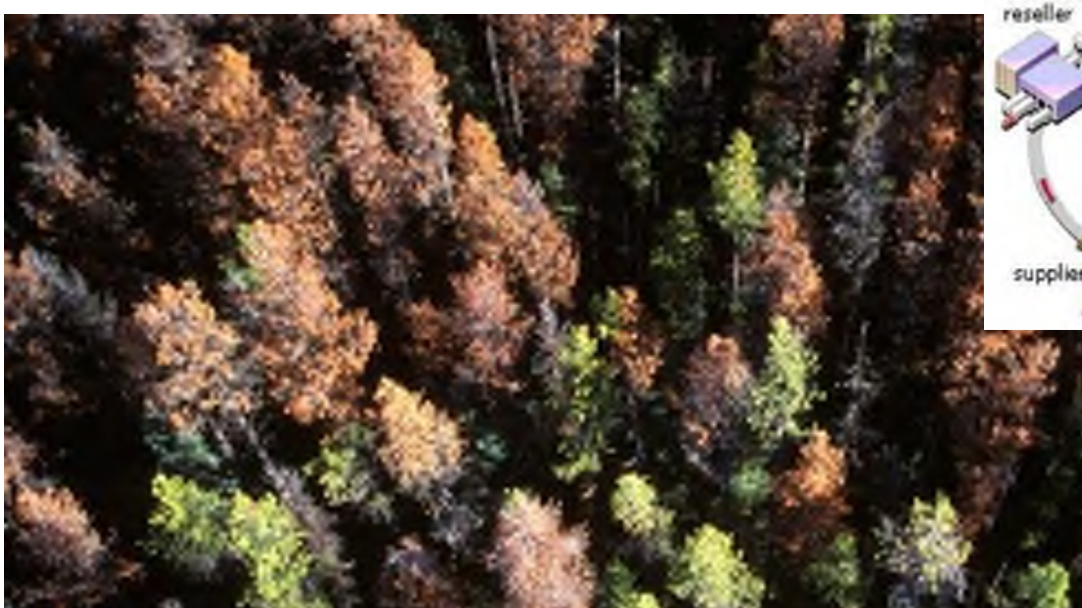
Manufacturing Energy *All major steps within the manufacturing phase should be included. At a minimum the values reported here should include the milling, drying, laminating, and CNC processing, based on the last year of operations. If the same facilities are used for production of other wood product types that demand much higher energy use, it is allowable to allocate energy use based on proportioning by mass of product produced, before dividing by the volume of CLT produced in*

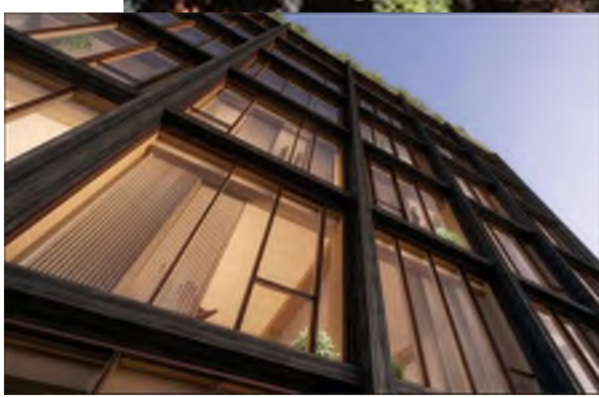
Manufacturing Wood Waste *The responses here are collected for information only and are not used in the carbon calculation. In an LCA used to generate an EPD, co-allocation and system boundary rules would be used to attribute a portion of life-cycle impacts to waste that is used for other*

How much material is taken in for processing versus the amount shipped, i.e. what is the output divided by input of wood in percent by mass? percentage

What becomes of wood waste from the fabrication process? (Values entered below must sum to 100%)

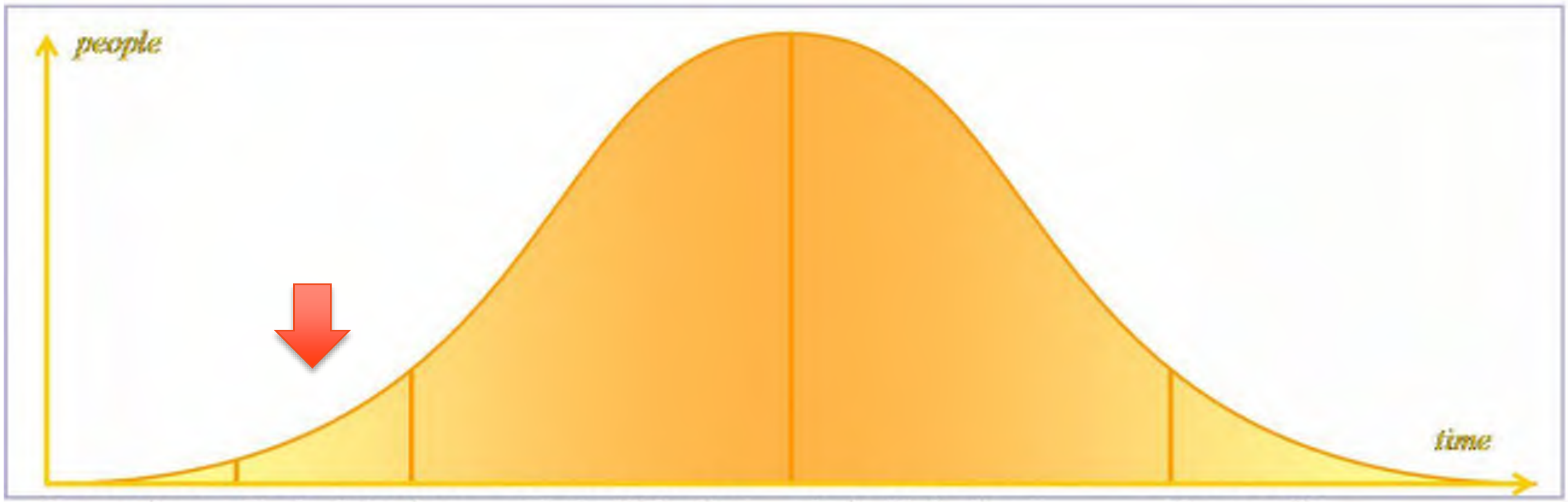
LOW CARBON + STEWARDSHIP





475 W 18th St, New York

INNOVATION ADOPTION CURVE



Innovators
(2.5%) are risk takers who have the resources and desire to try new things, even if they fail

Early Adopters
(13.5%) are selective about which technologies they start using. They are considered the "one to check in with" for new information and reduce others' uncertainty about a new technology by adopting it.

Early Majority
(34%) take their time before adopting a new idea. They are willing to embrace a new technology as long as they understand how it fits with their lives.

Late Majority
(34%) adopt in reaction to peer pressure, emerging norms, or economic necessity. Most of the uncertainty around an idea must be resolved before they adopt.

Laggards
(16%) are traditional and make decisions based on past experience. They are often economically unable to take risks on new ideas.

Bryce Ryan & Neal Gross (1943)

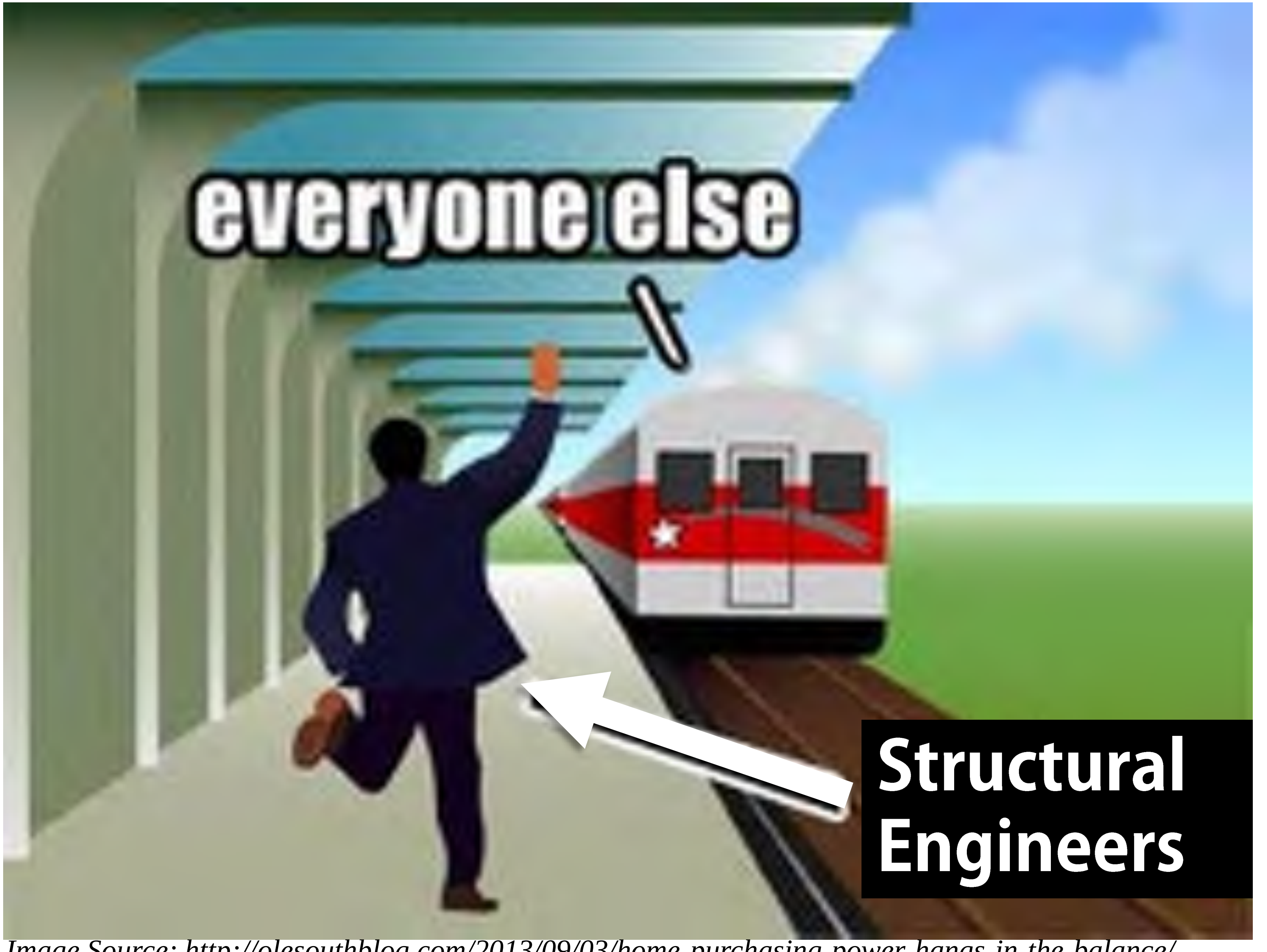
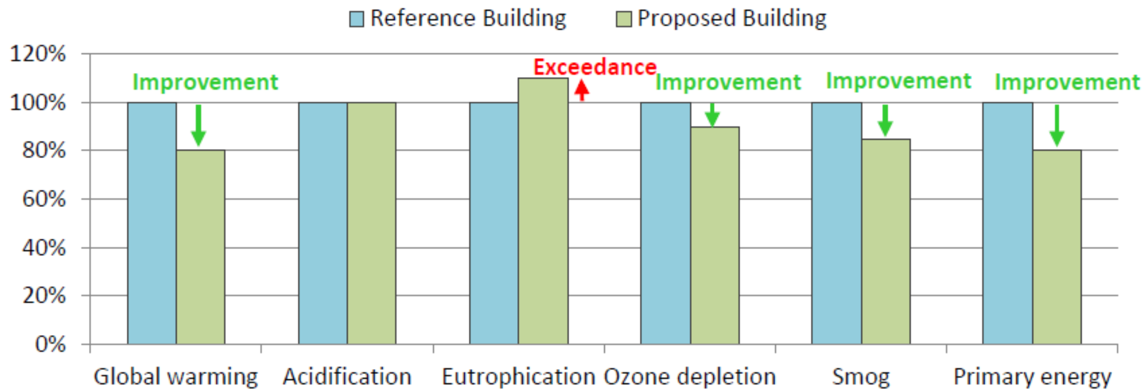
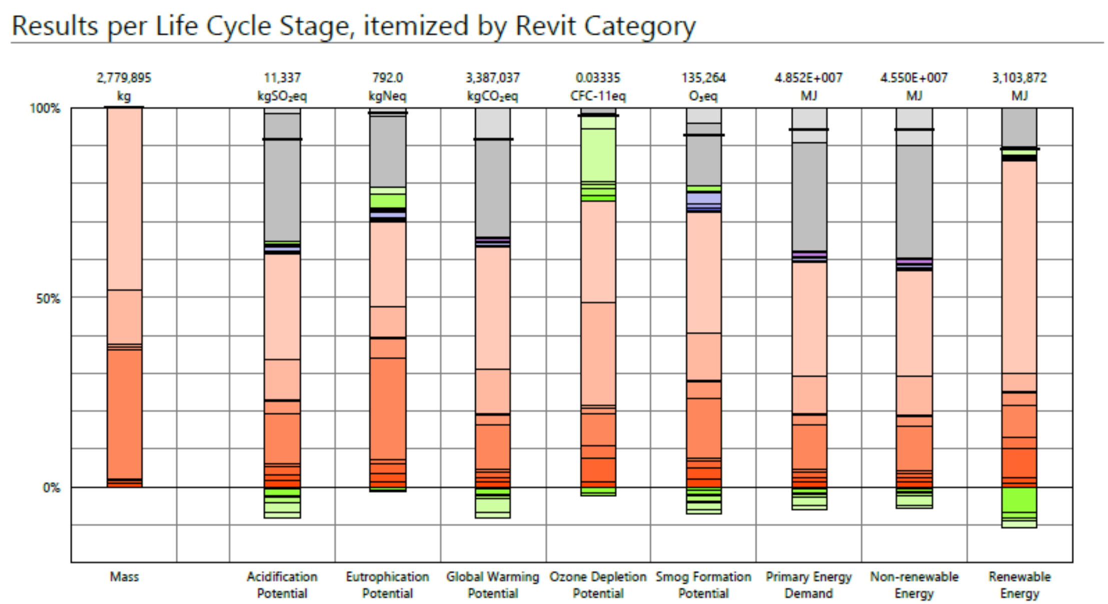


Image Source: http://olesouthblog.com/2013/09/03/home-purchasing-power-hangs-in-the-balance/

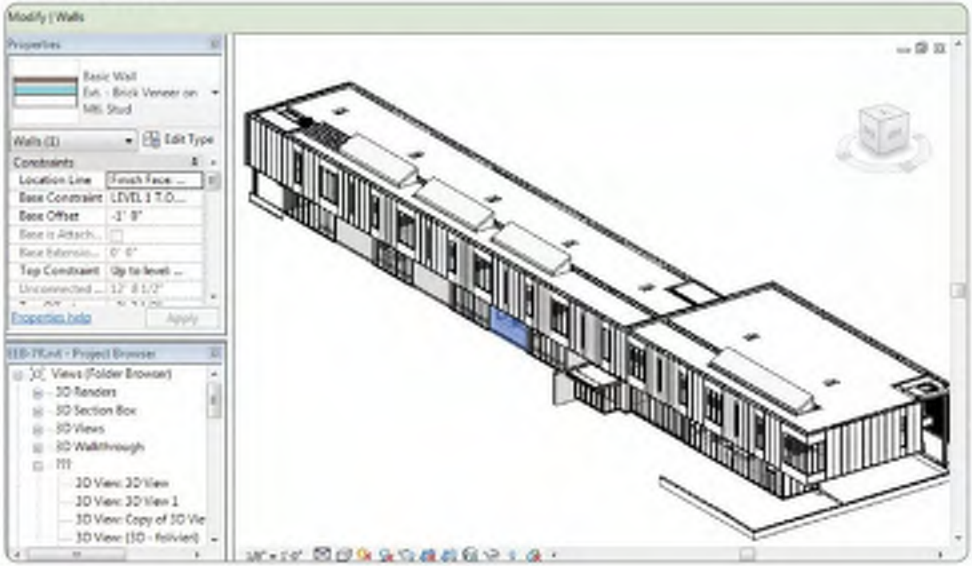


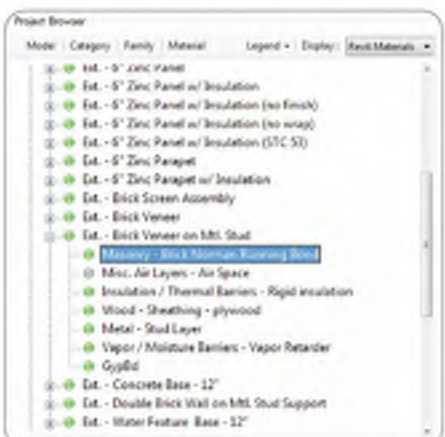
ATHENA® Impact Estimator for buildings

Figure 2: The Comparative Concept in the Green Building Programs



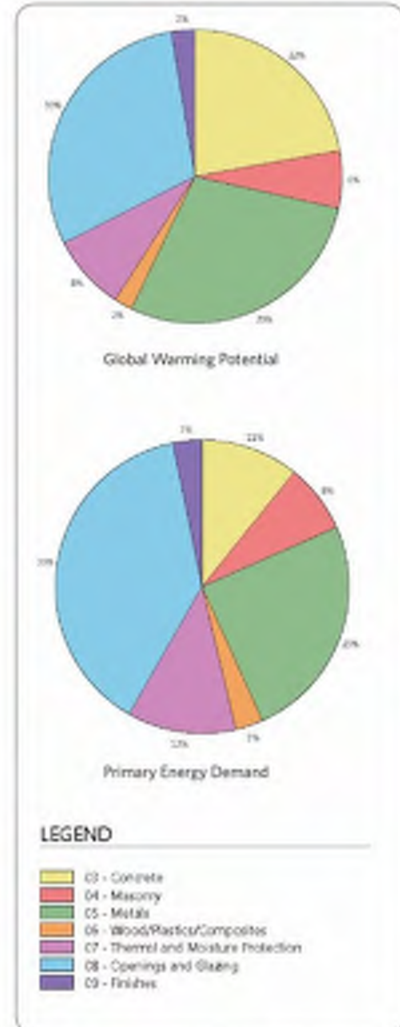
REVIT MODEL





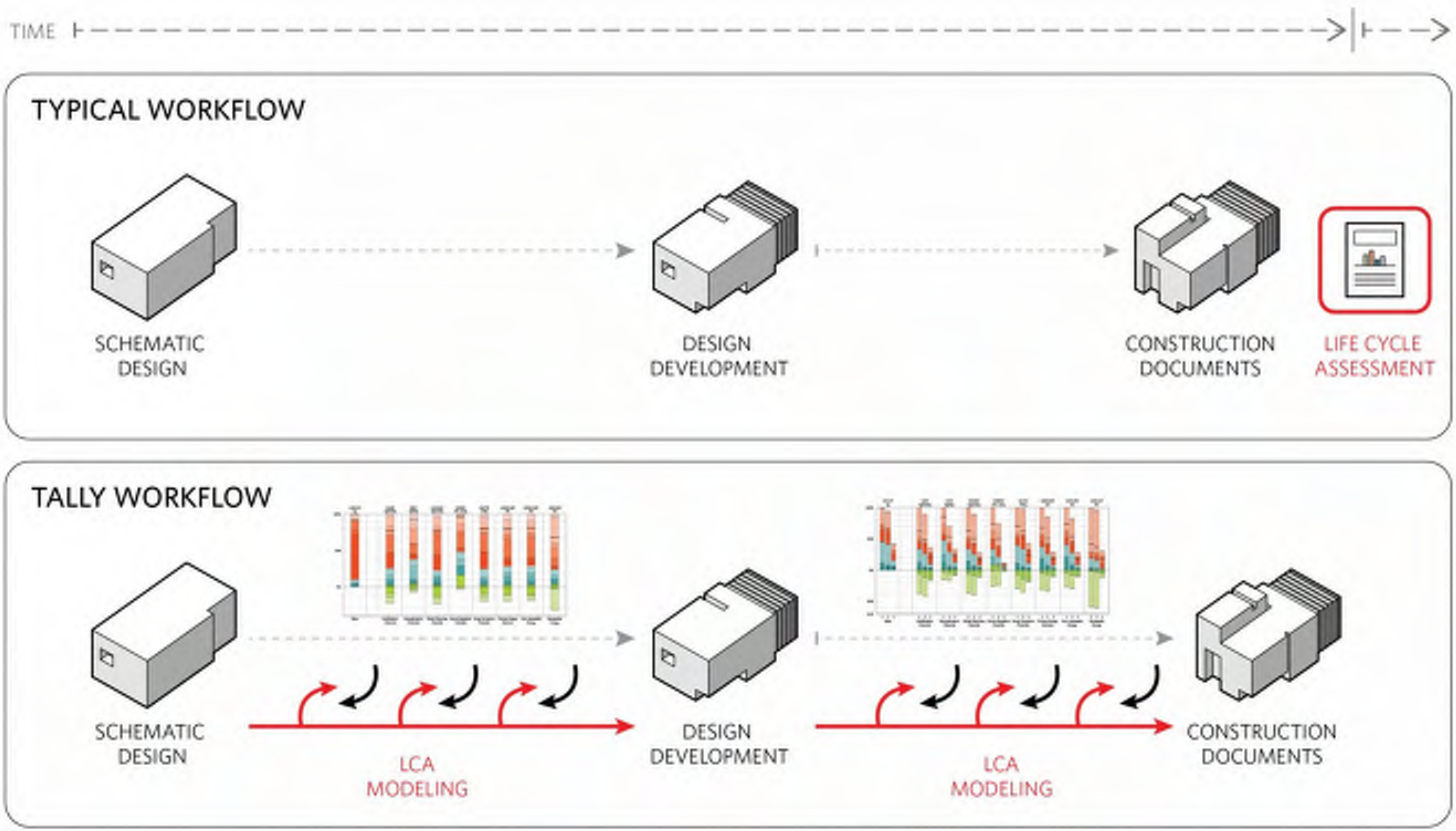
TALLY™ Material quantities are pulled from the Revit model

DATABASE Impacts are captured in an LCA database



TALLY™ REPORT Design and material selection questions are rapidly answered

INFORM DESIGN



LEED GREEN BUILDING STANDARD

MATERIAL & RESOURCES		POSSIBLE: 13
MRp1	Storage and collection of recyclables	REQUIRED
MRp2	Construction and demolition waste Mgmt planning	REQUIRED
MRc1	Building life-cycle impact reduction	5
MRc2	Building product disclosure and optimization - environmental product declarations	2
MRc3	Building product disclosure and optimization - sourcing of raw materials	2
MRc4	Building product disclosure and optimization - material ingredients	2
MRc5	Construction and demolition waste Mgmt	2

LIVING BUILDING CHALLENGE

2.0™

LIVING
BUILDING
CHALLENGE™
2.0

A Visionary Path to a Restorative Future

MATERIALS

ENDORSING PRODUCTS AND PROCESSES THAT ARE SAFE FOR ALL SPECIES THROUGH TIME

- Red List
- Embodied Carbon Footprint
- Responsible Industry
- Appropriate Sourcing
- Conservation + Reuse

OTHER RATING SYSTEMS AND STANDARDS…

IgCC
SAFE & SUSTAINABLE BY THE BOOK

architecture 2030

DGNB
Deutsche Gesellschaft für Nachhaltiges Bauen e.V.
German Sustainable Building Council

U.S. GREEN BUILDING COUNCIL
LEED
USGBC

BREEAM®

Living Building Challenge

green star

Greenroads

INSTITUTE FOR SUSTAINABLE INFRASTRUCTURE
I S I

Welcome to the Arup Project Embodied Carbon ar Energy Database (PECD) demo!

This database is a collection of embodied carbon and energy calculations from Arup projects, ot variety of trade-sponsored studies (AISC, World Steel, PCA, Canadian Precast, etc.), academic c of Canterbury), whole building LCA tools (Envest2, Arup PECC) and author-researchers (Adalbert Treloar, etc.), to name a few.

The PECD has been created to allow designers to spot and investigate trends, and also benchma the following tabs you will be able to select whether you wish to see embodied carbon or energ against which you wish this plotted. You can also select or hover over any particular data point not in the reports are captured in the PECD, such as: detailed descriptions, foundation info, LCI climate zones, occupancy, building design life, and element groups included in the calculations.

It is hoped that this database will become a web-based interactive tool that:

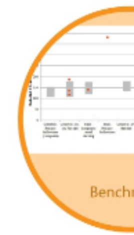
(1) allows immediate benchmarking of results from embodied carbon or energy calculations,

(2) provides a place for those calculations to reside and be shared,

(3) offers a common platform from which results can be more easily compared, and

(4) overcomes some of the problems due to inconsistent methodology, by sheer statistics, while it

(5) motivates standardization of LCA to narrow the bands of deviation due to methodology.

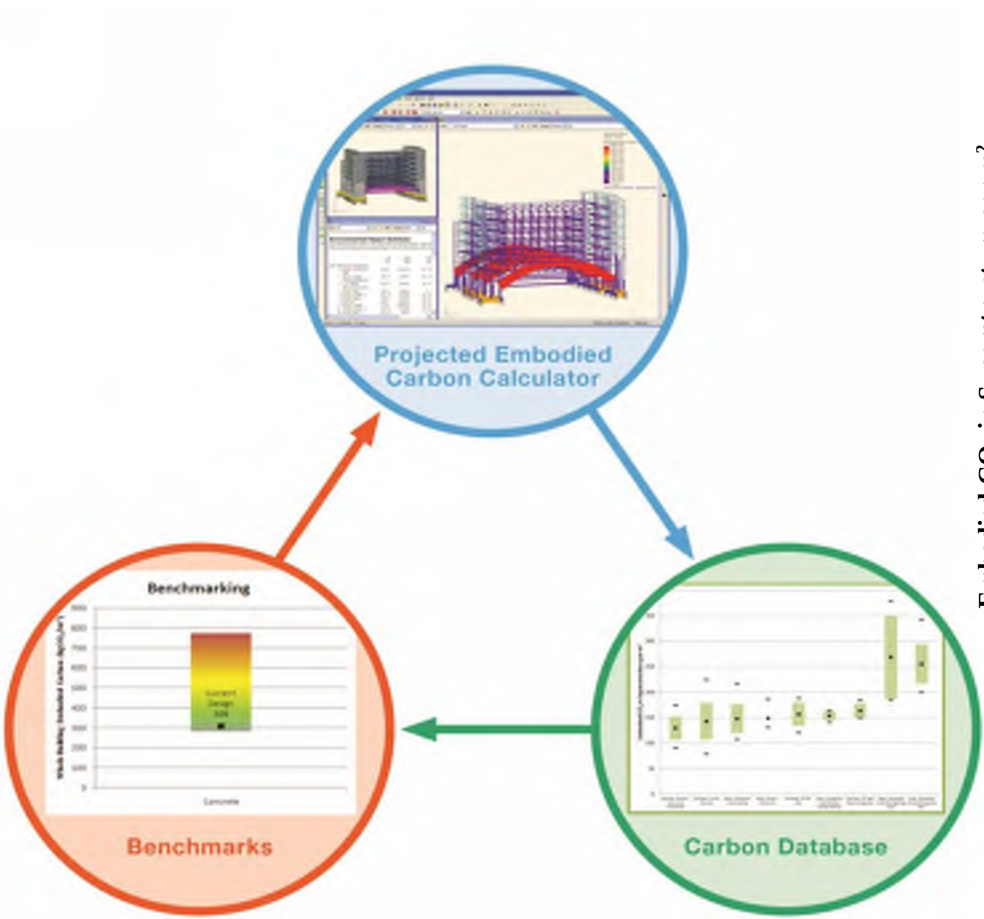


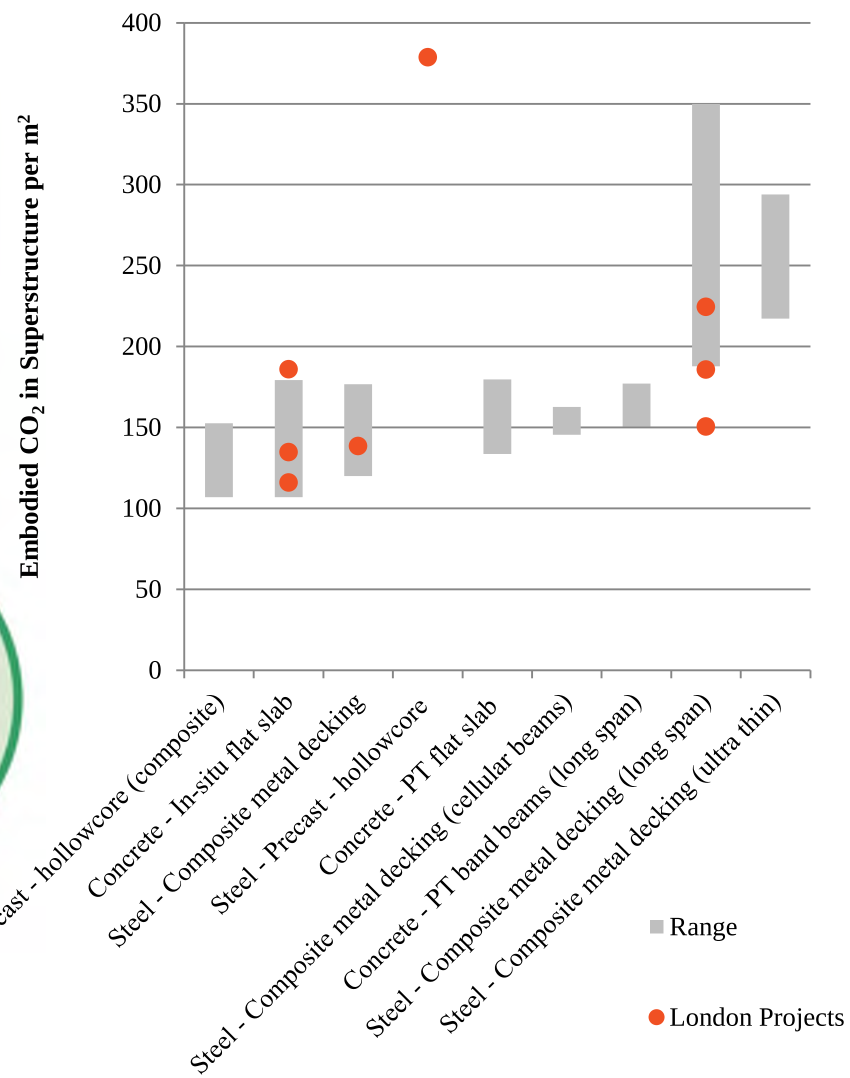
In the UK, work is underway by the non-profit, Waste Reduction Action Programme (WRAP), to produce such a future tool. If you are interested in sponsoring such a tool in North America, please contact frances.yang@arup.com

Example of a feed Database and a pr

Much thanks is due to the people who built, guided, and supported the development of this database:
Adam Friedberg Andrea Charlson Luka Vukotic Ed Hoare Lauren Wingo Mallory Taub Sarah Kaethner Greg Hardie
And our database developer and host ClimateEarth

Embodied Carbon and Energy Database





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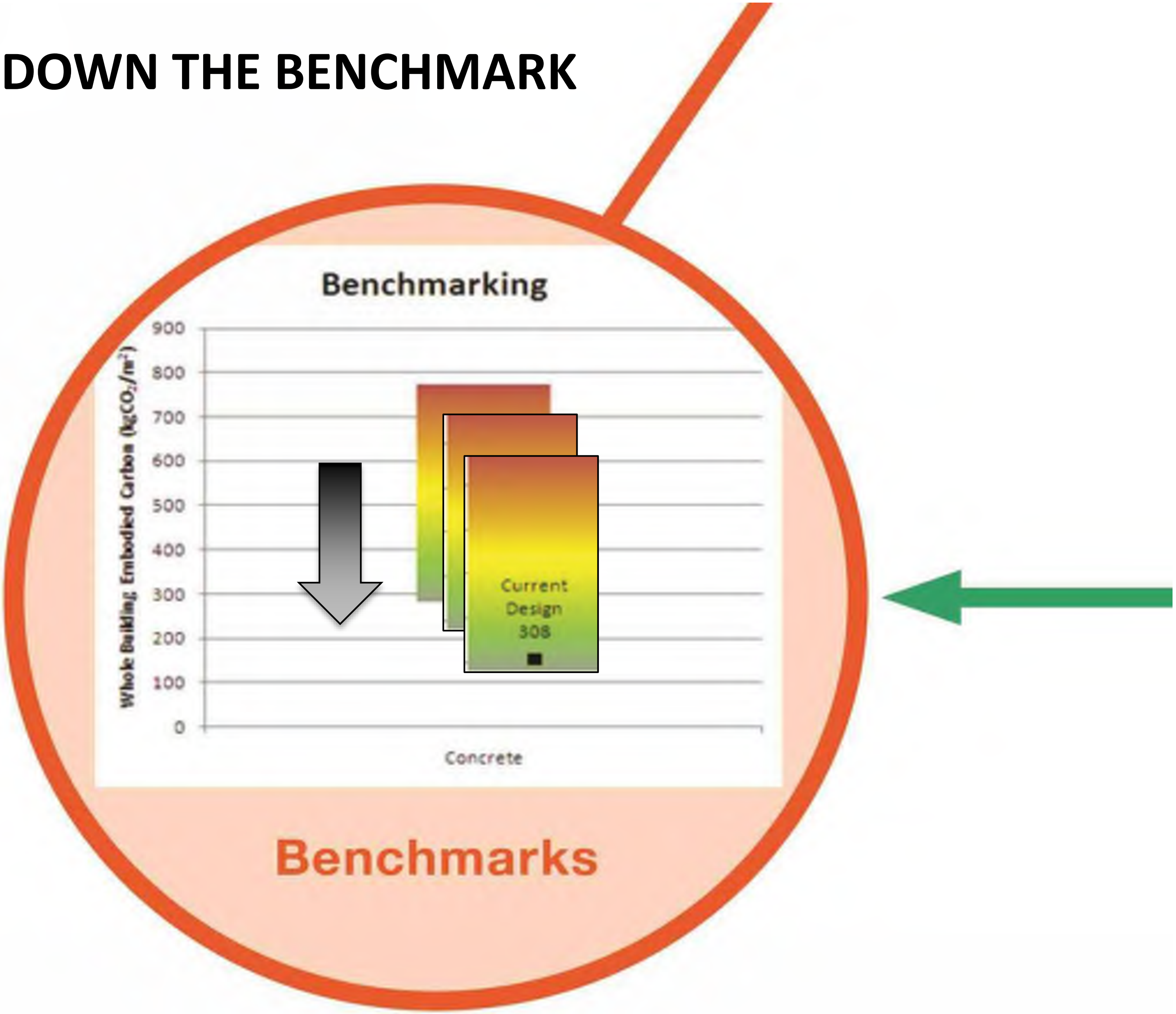
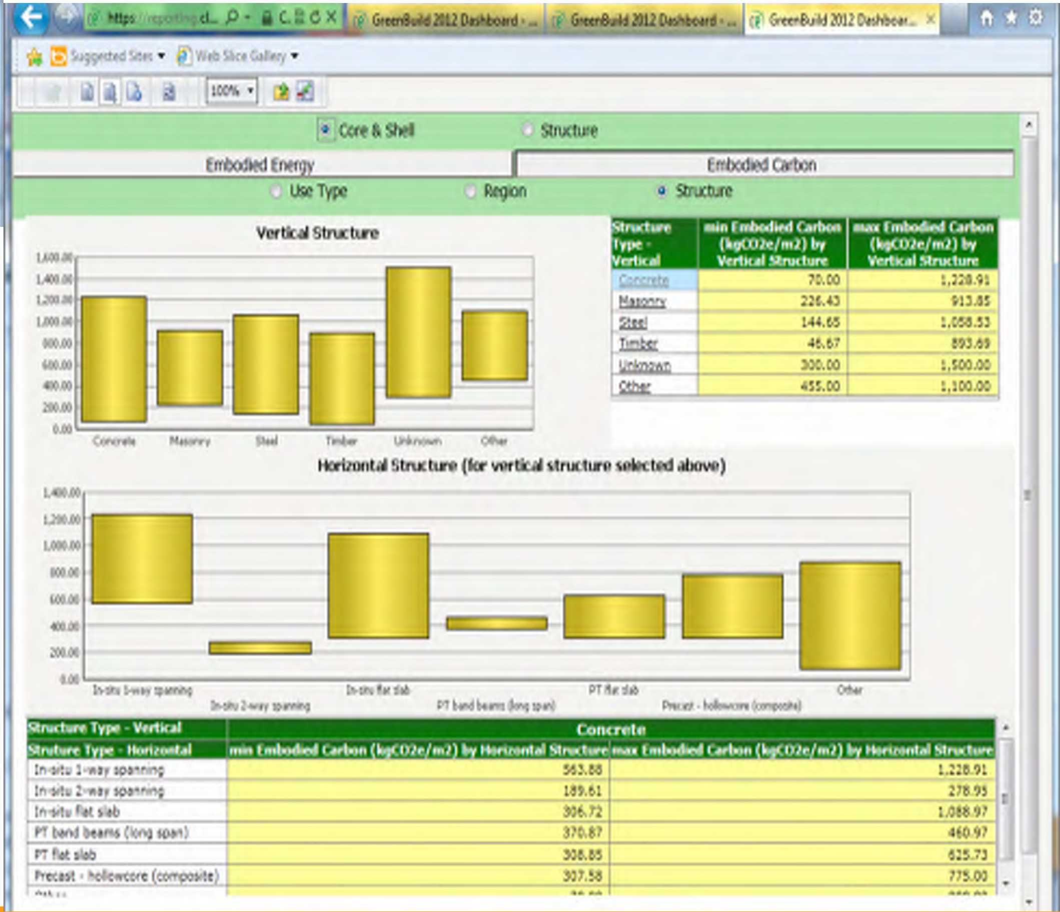
DRIVE DOWN THE BENCHMARK



Embodied Carbon & Embodied Energy



Sort by:

- Area
- Storeys
- Avg Floor Height
- Use Type
- Region
- Structure Type
- Etc…

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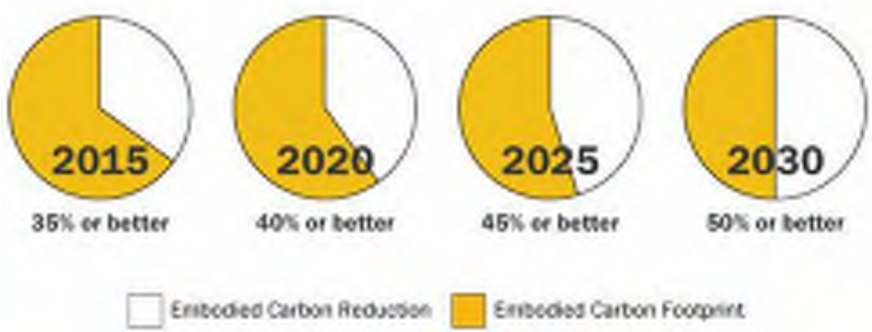
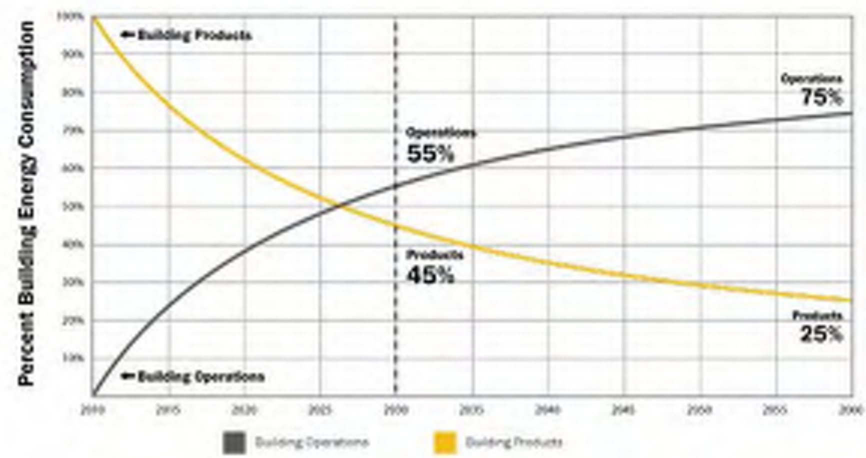
ARCHITECTURE 2030 CHALLENGE

Watch this space!

Products ➡ Projects



The 2030 Challenge for Products



Operating/Embodied Energy (Typical Residence Built in 2010)

Data Source: EIA (2011). Richard Stein.

WOOD IS ~~THE~~ A SOLUTION

Framework, Portland © LEVER

low carbon

\+

health

\+

stewardship

QUESTIONS?

frances.yang@arup.com