WOODWORKS
WOOD PRODUCTS COUNCIL

Measure, Report and Reduce: Using Comparative LCA to Highlight the Embodied Carbon Benefits of Wood Construction

Ashley Cagle, PE, SE

April 13, 2023

Carbon Benefits of Wood

- **Lower embodied carbon** as compared to other common building materials
- **Less fossil fuel** consumed during manufacture
- Extended **carbon storage** in products
- **Carbon sequestration** in forests and promote **forest health**

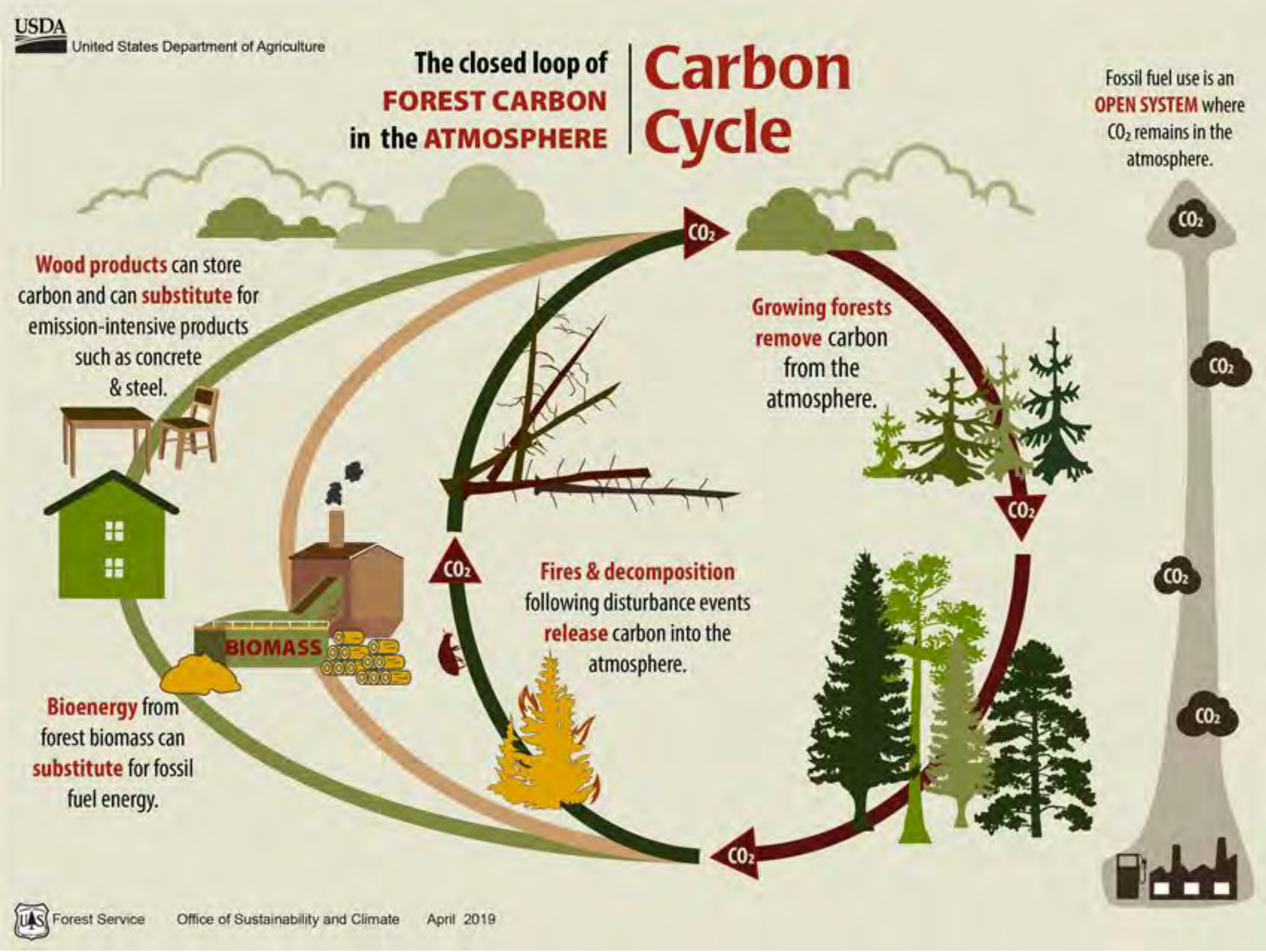


Image: USDA US Forest Service

Life Cycle Assessment (LCA)

"Evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle"

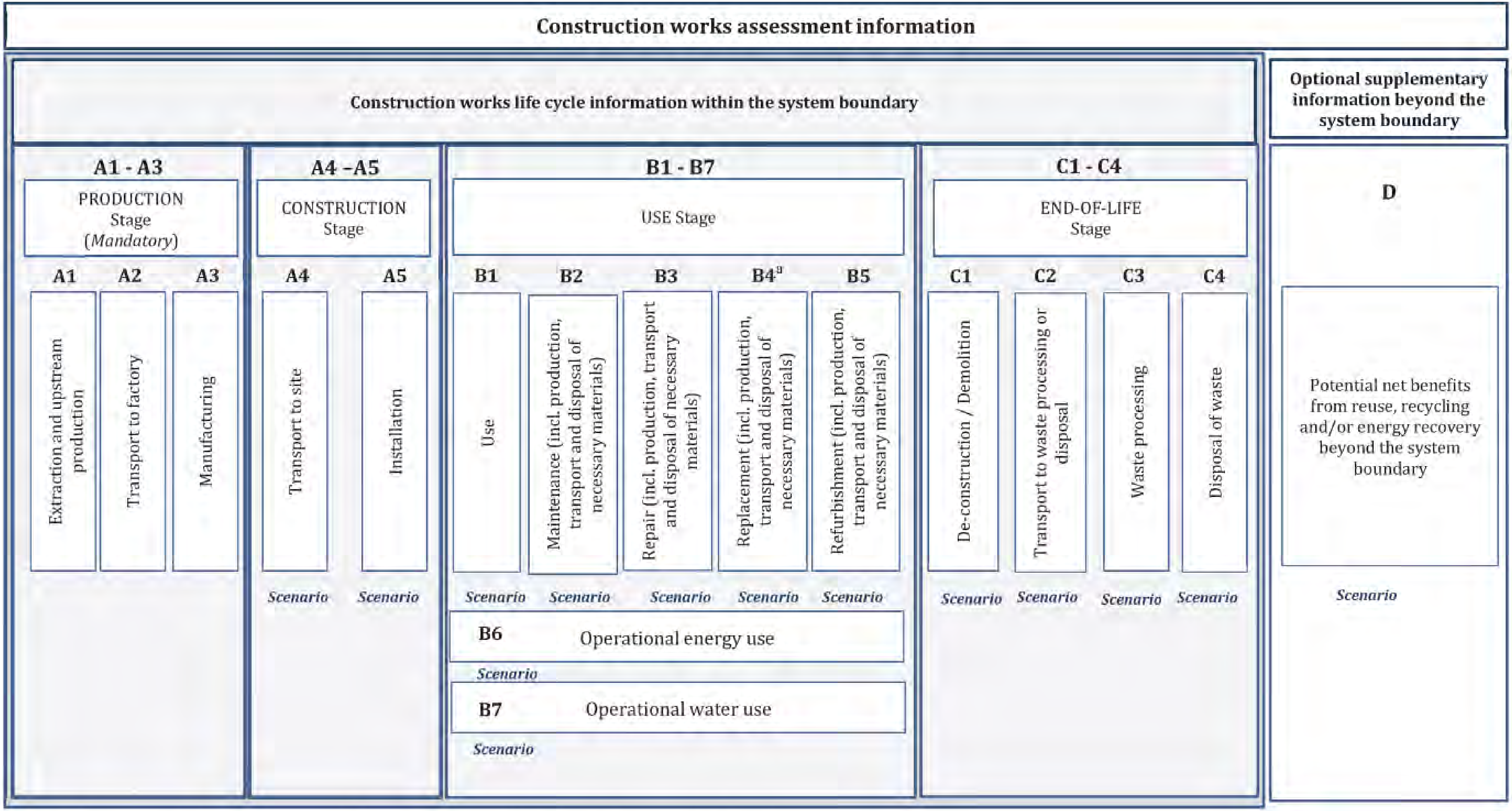
- Systematic, scientific **quantification**

Used for:

- Single products or processes: e.g., a wood product
- Complex, integrated systems: e.g., an entire building (**WBLCA**)

https://www.woodworks.org/resources/introduction-to-whole-building-life-cycle-assessment-the-basics/

Source: ISO 21930:2017(E), 3.3.2



[a] Replacement information module (B4) not applicable at the product level.

Source: ISO 21930:2017(E), Figure 2

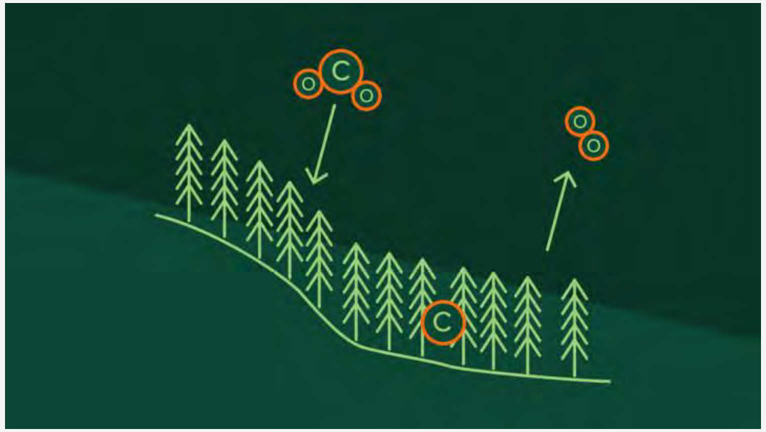
What makes wood different?

Biogenic Carbon

"**<u>Carbon derived from… material of biological origin</u>** excluding material embedded in geological formations or transformed to fossilized material and excluding peat."

Photosynthesis:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6\ \text{(stored)} + 6\ O_2\ \text{(released)}$$



Source: ISO 21930:2017(E), 3.7

Carbon Storage

Wood ≈ **50% Carbon** (dry weight)

Biogenic Carbon Accounting

-1 in

Removal of carbon from the atmosphere

+1 out

Emission or export of carbon from product system

https://www.woodworks.org/resources/when-to-include-biogenic-carbon-in-an-lca/

Source: ISO 21930:2017(E), 7.2.7

Biogenic Carbon

"For wood, biogenic carbon may be characterized with a -1… when entering the product system **only when the wood originates from sustainably managed forests.**"

So…

What is a sustainably managed forest?

Source: ISO 21930:2017(E), 7.2.7

Sustainably Managed Forests

"… zero emissions associated with land use change"

Option 1:

Includes wood products *responsibly sourced and certified* to:

- **Standards** globally endorsed by PEFC and FSC
- FSC, SFI, CSA, ATFS, etc.

Option 2: (Note 2)

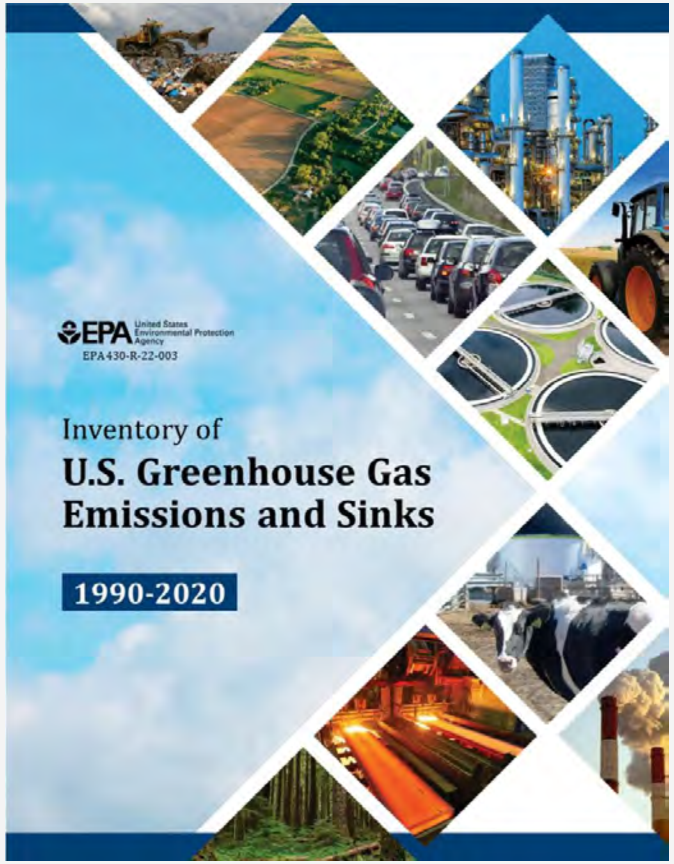
- "The concept of sustainably managed forests is linked but not limited to respective certification schemes"
- Evidence such as national reporting under UNFCCC to identify forests with stable or increasing forest carbon stocks

https://www.woodworks.org/resources/when-to-include-biogenic-carbon-in-an-lca/

Source: ISO 21930:2017(E), 7.2.11

UNFCCC National Reporting

"… stable or increasing forest carbon stocks"

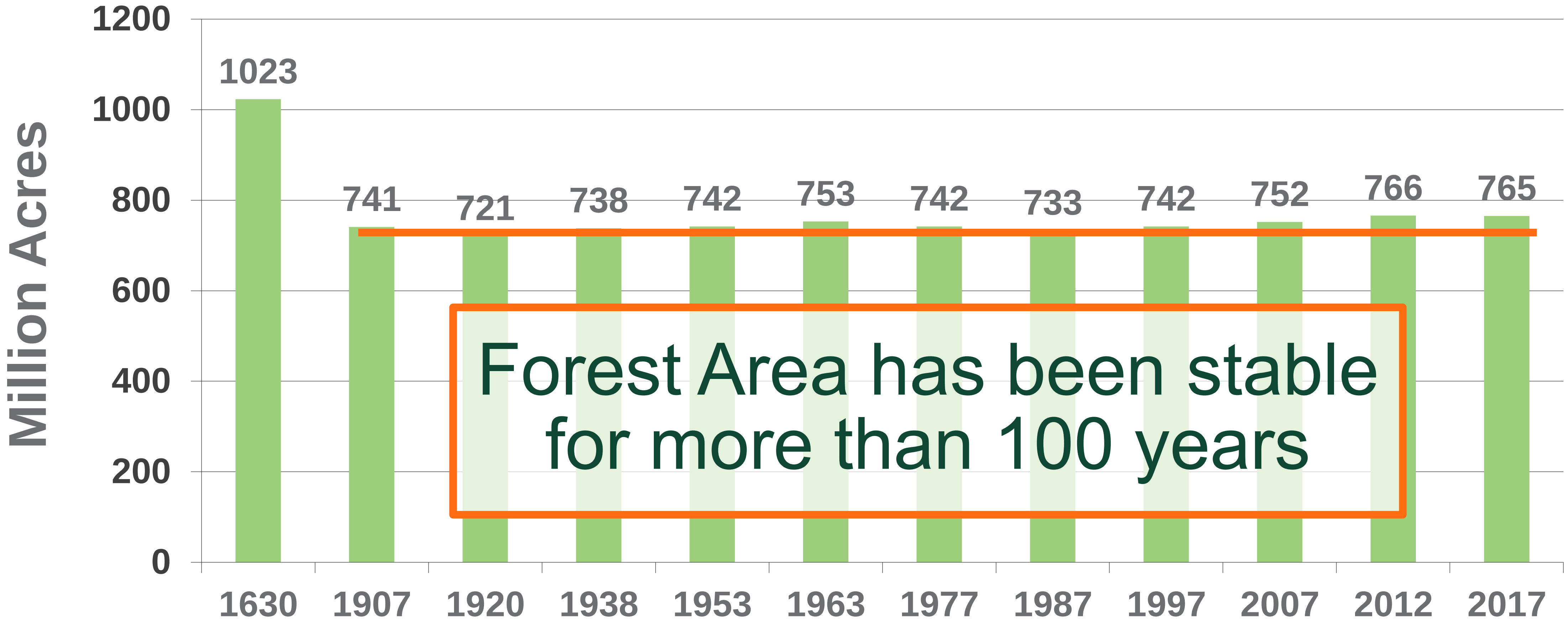


See Table 6-10

See Table 6-1

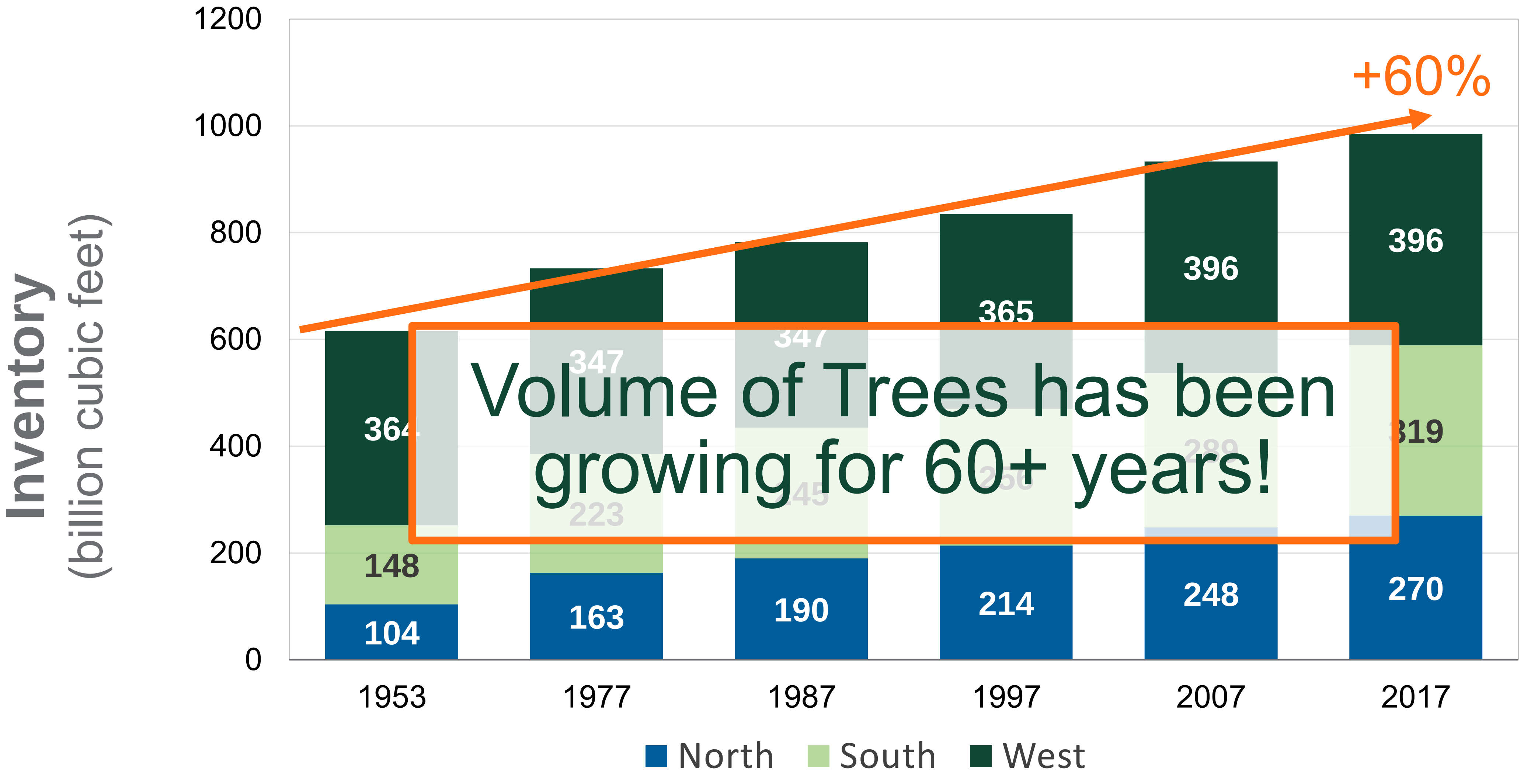
U.S. Forest Land:

Forest Area in the United States 1630 – 2017



Source: USDA-Forest Service, Forest Resources of the United States, 2017 (2018)

State of our Forests: US Timber Volume on Timberland

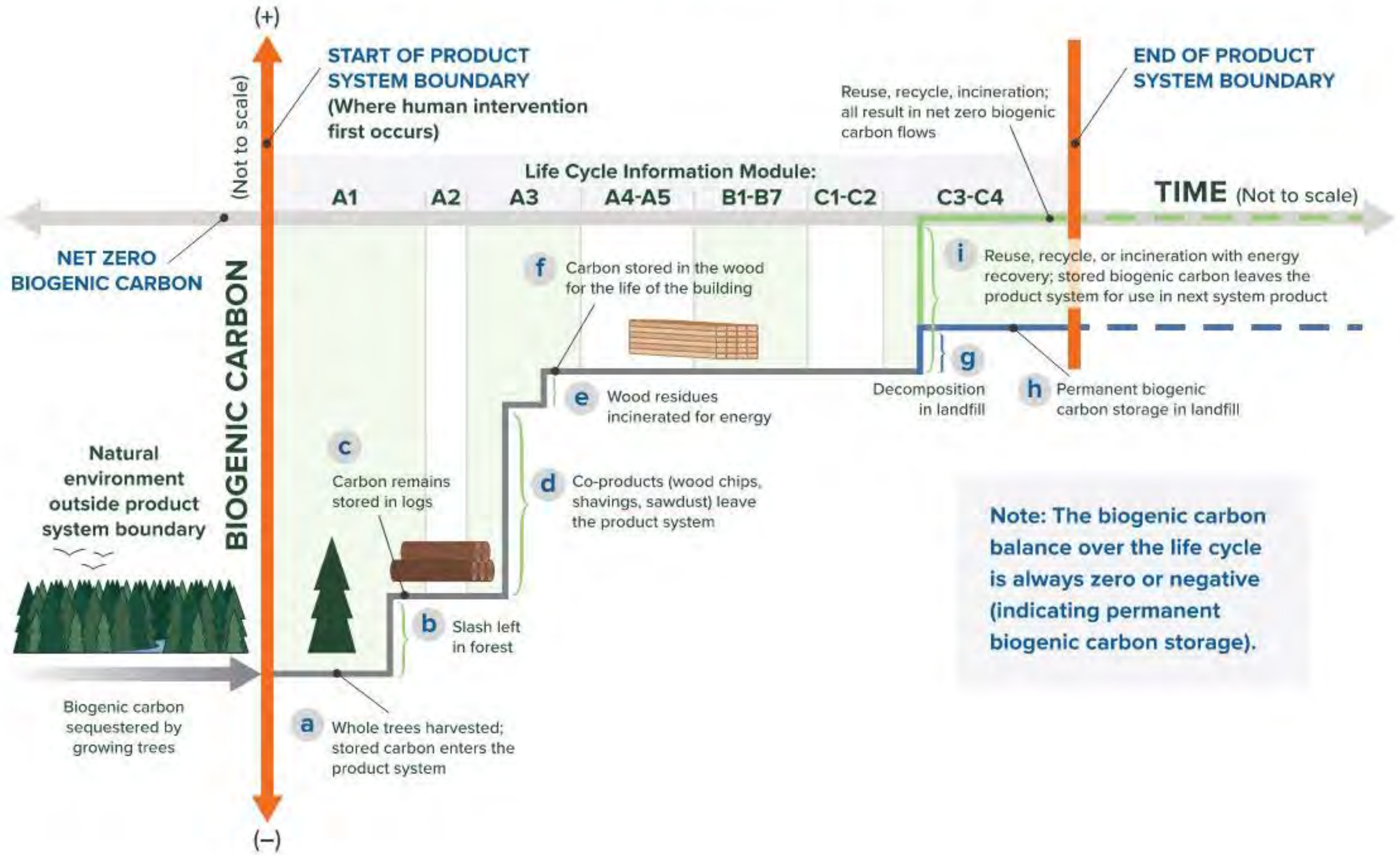


Source: USDA-Forest Service, Forest Resources of the United States, 2017 (2018)

Should I include biogenic carbon?

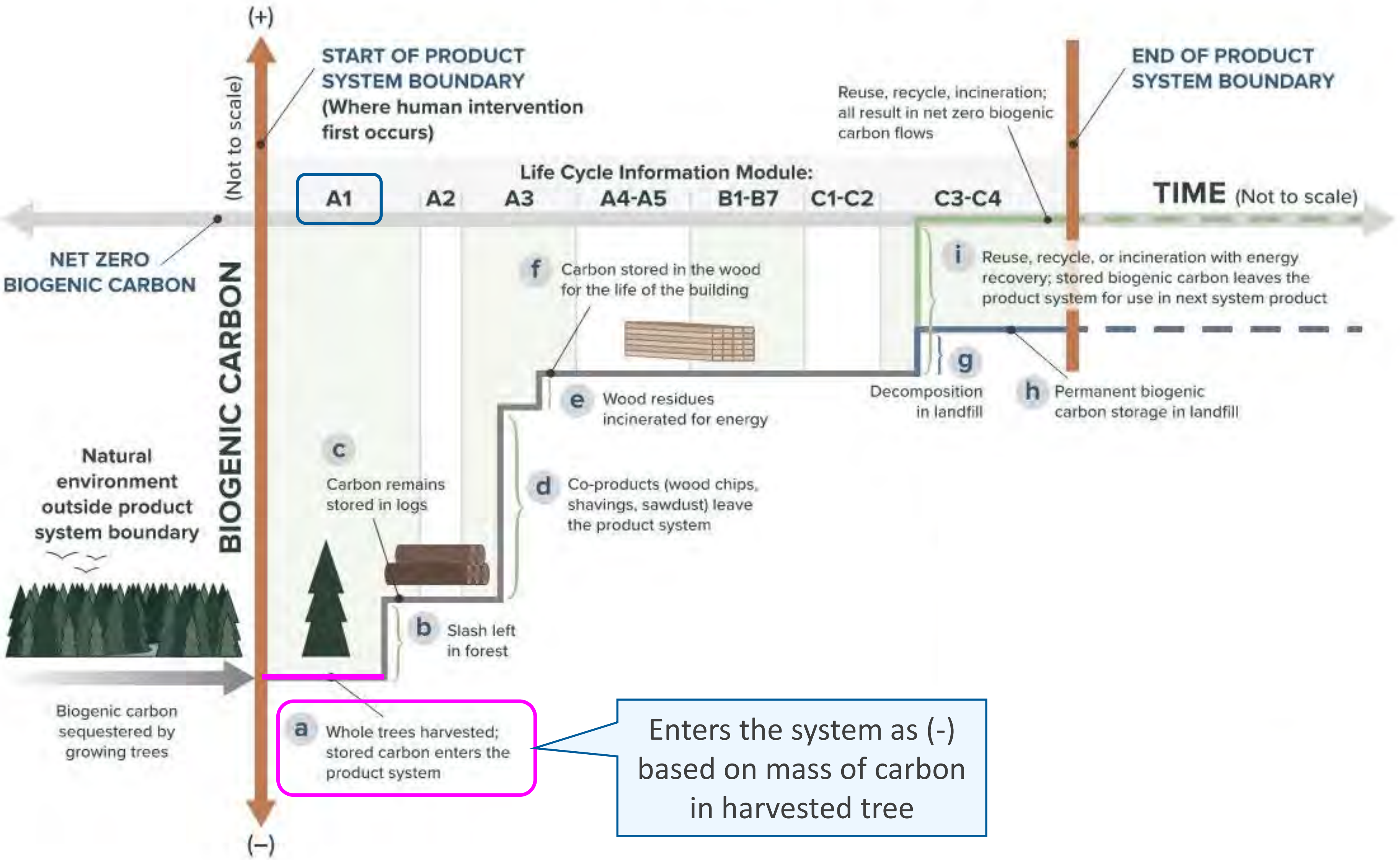
Yes! But how?

BIOGENIC CARBON FLOWS

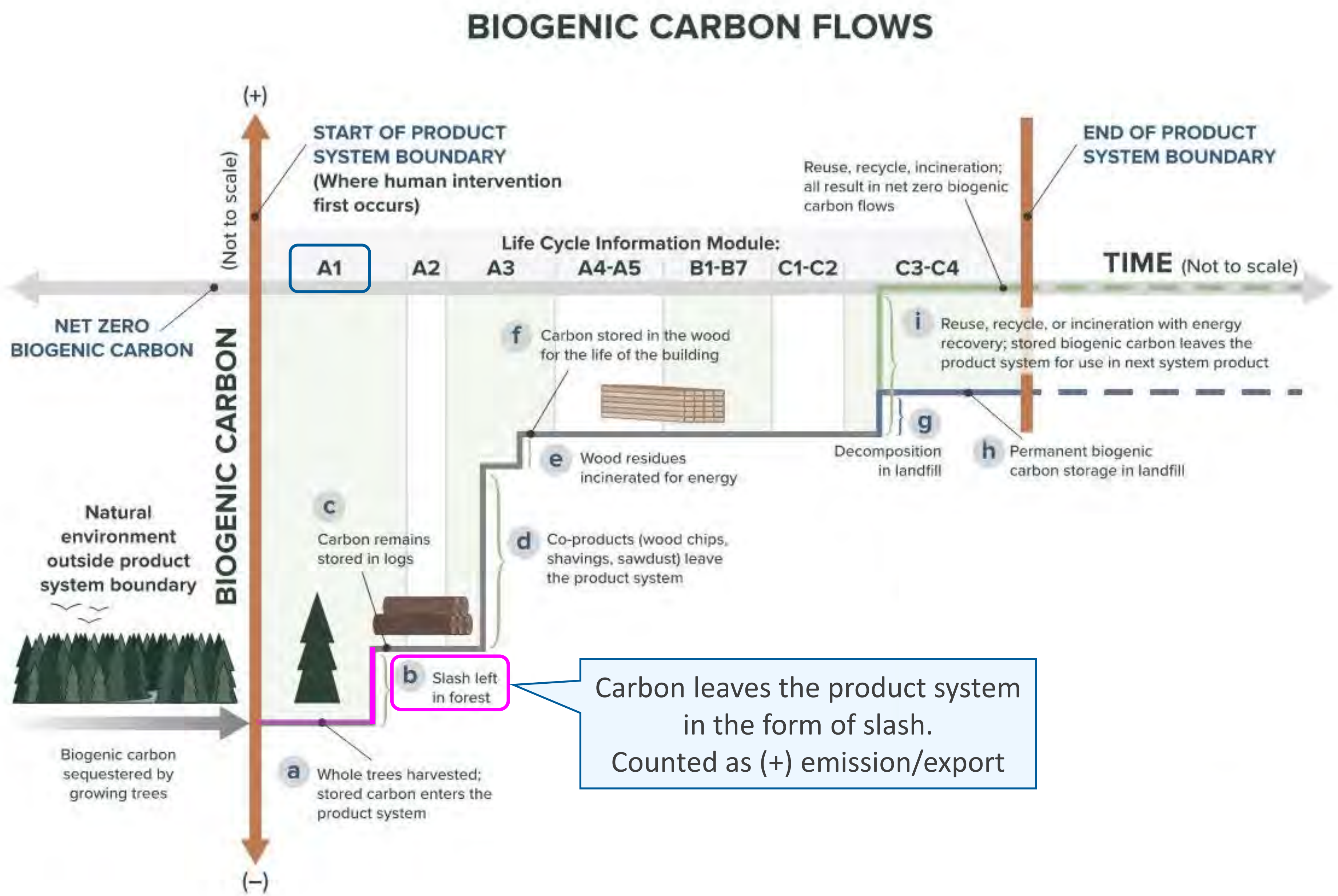


https://www.woodworks.org/resources/how-to-include-biogenic-carbon-in-an-lca/

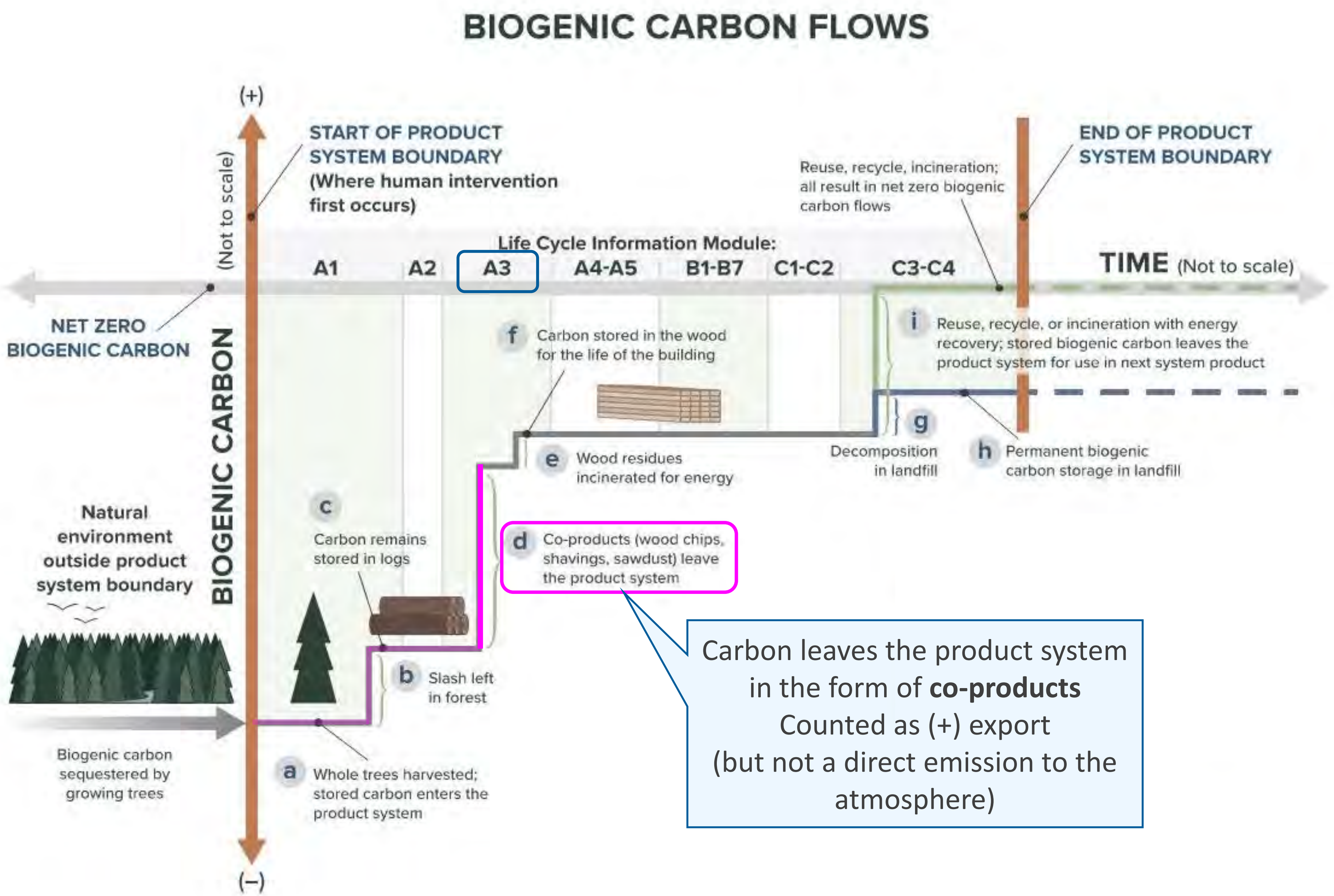
BIOGENIC CARBON FLOWS



Enters the system as (-) based on mass of carbon in harvested tree

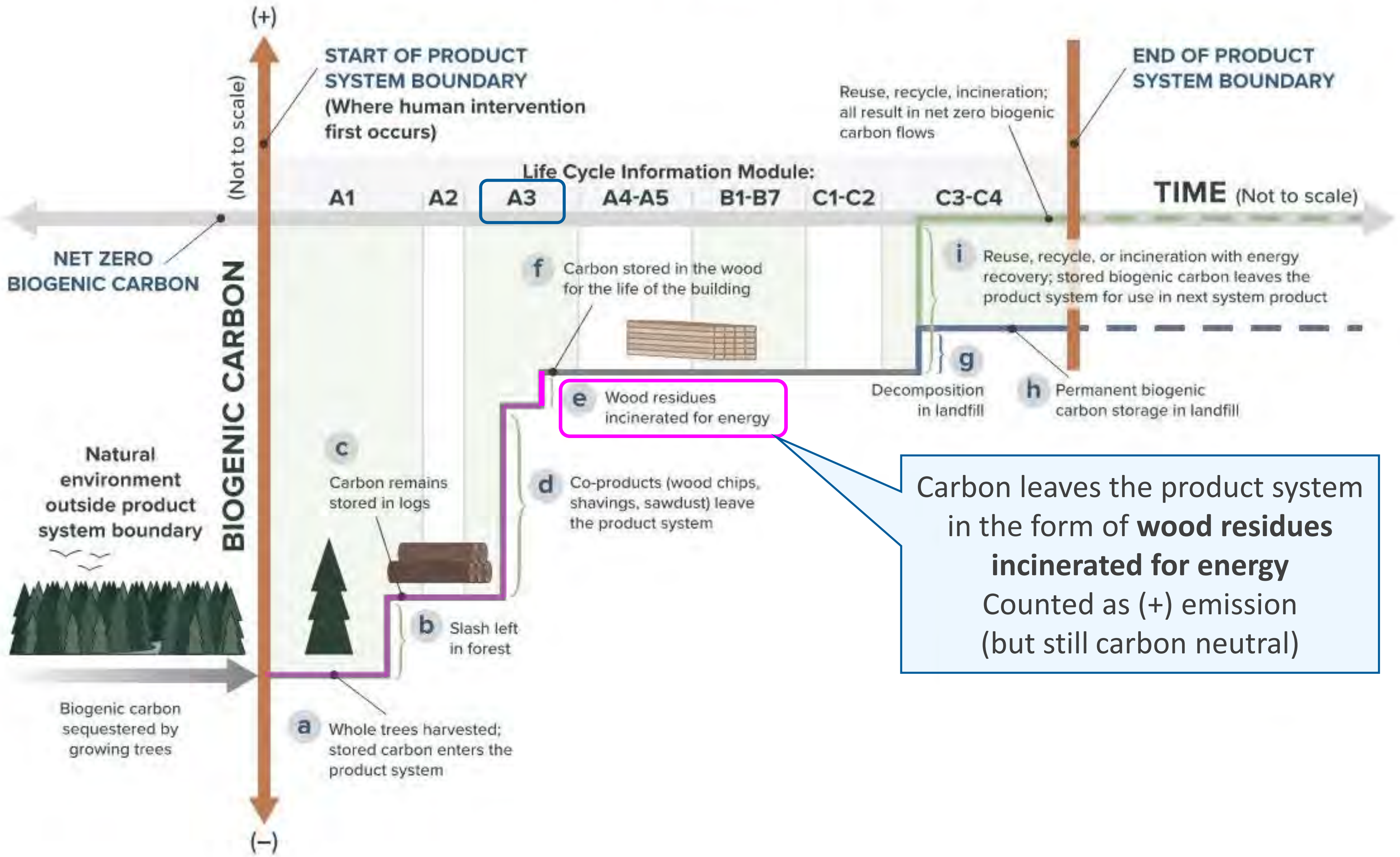


Carbon leaves the product system in the form of slash.
Counted as (+) emission/export



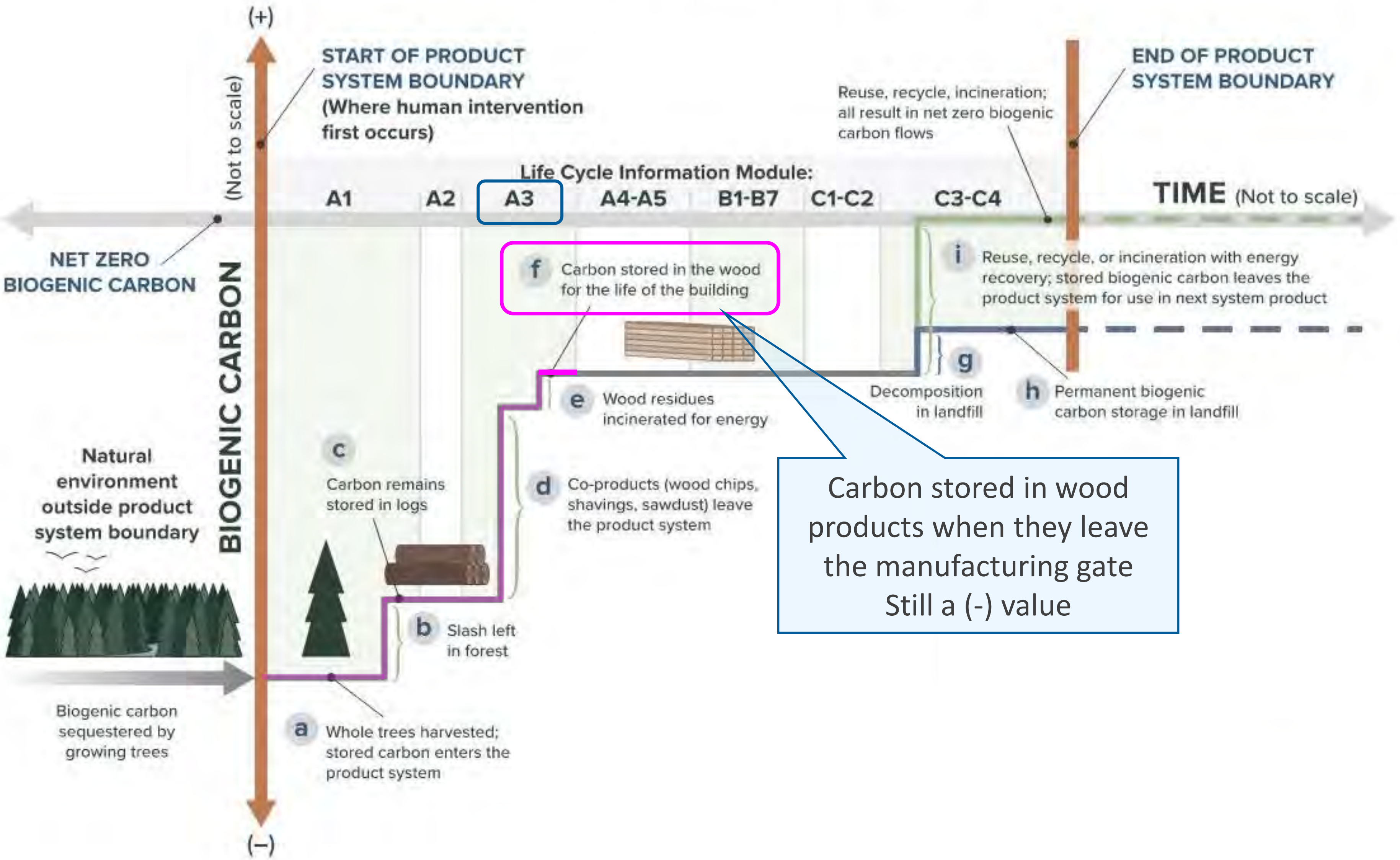
Carbon leaves the product system in the form of **co-products**
Counted as (+) export
(but not a direct emission to the atmosphere)

BIOGENIC CARBON FLOWS

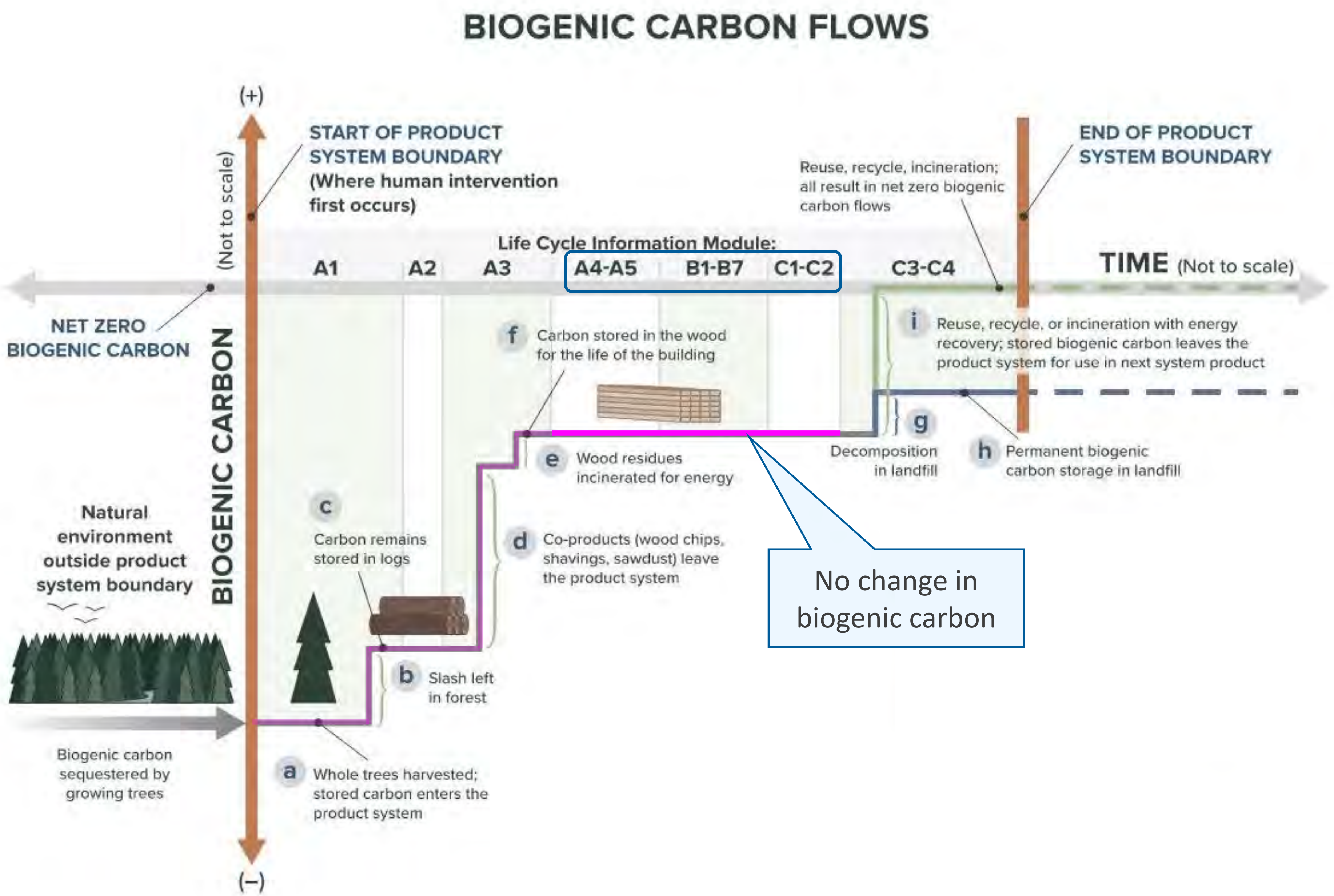


Carbon leaves the product system in the form of **wood residues incinerated for energy**
Counted as (+) emission
(but still carbon neutral)

BIOGENIC CARBON FLOWS



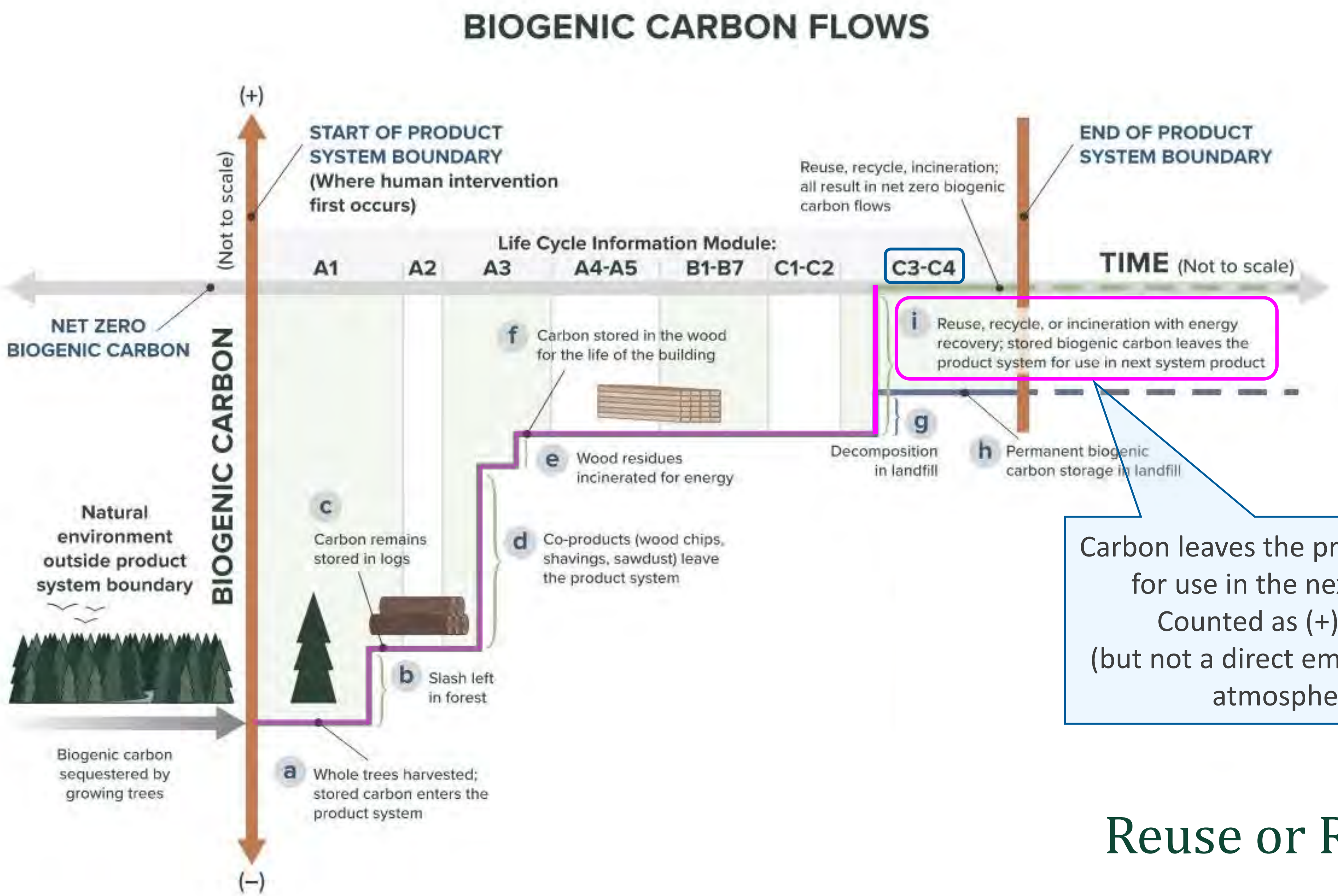
Carbon stored in wood products when they leave the manufacturing gate
Still a (-) value



BIOGENIC CARBON FLOWS
(+)
(–)
BIOGENIC CARBON
(Not to scale)
START OF PRODUCT SYSTEM BOUNDARY (Where human intervention first occurs)
END OF PRODUCT SYSTEM BOUNDARY
Reuse, recycle, incineration; all result in net zero biogenic carbon flows
Life Cycle Information Module:
A1
A2
A3
A4-A5
B1-B7
C1-C2
C3-C4
TIME (Not to scale)
NET ZERO BIOGENIC CARBON
f Carbon stored in the wood for the life of the building
i Reuse, recycle, or incineration with energy recovery; stored biogenic carbon leaves the product system for use in next system product
g
e Wood residues incinerated for energy
Decomposition in landfill
h Permanent biogenic carbon storage in landfill
c Carbon remains stored in logs
d Co-products (wood chips, shavings, sawdust) leave the product system
Natural environment outside product system boundary
b Slash left in forest
Biogenic carbon sequestered by growing trees
a Whole trees harvested; stored carbon enters the product system
No change in biogenic carbon

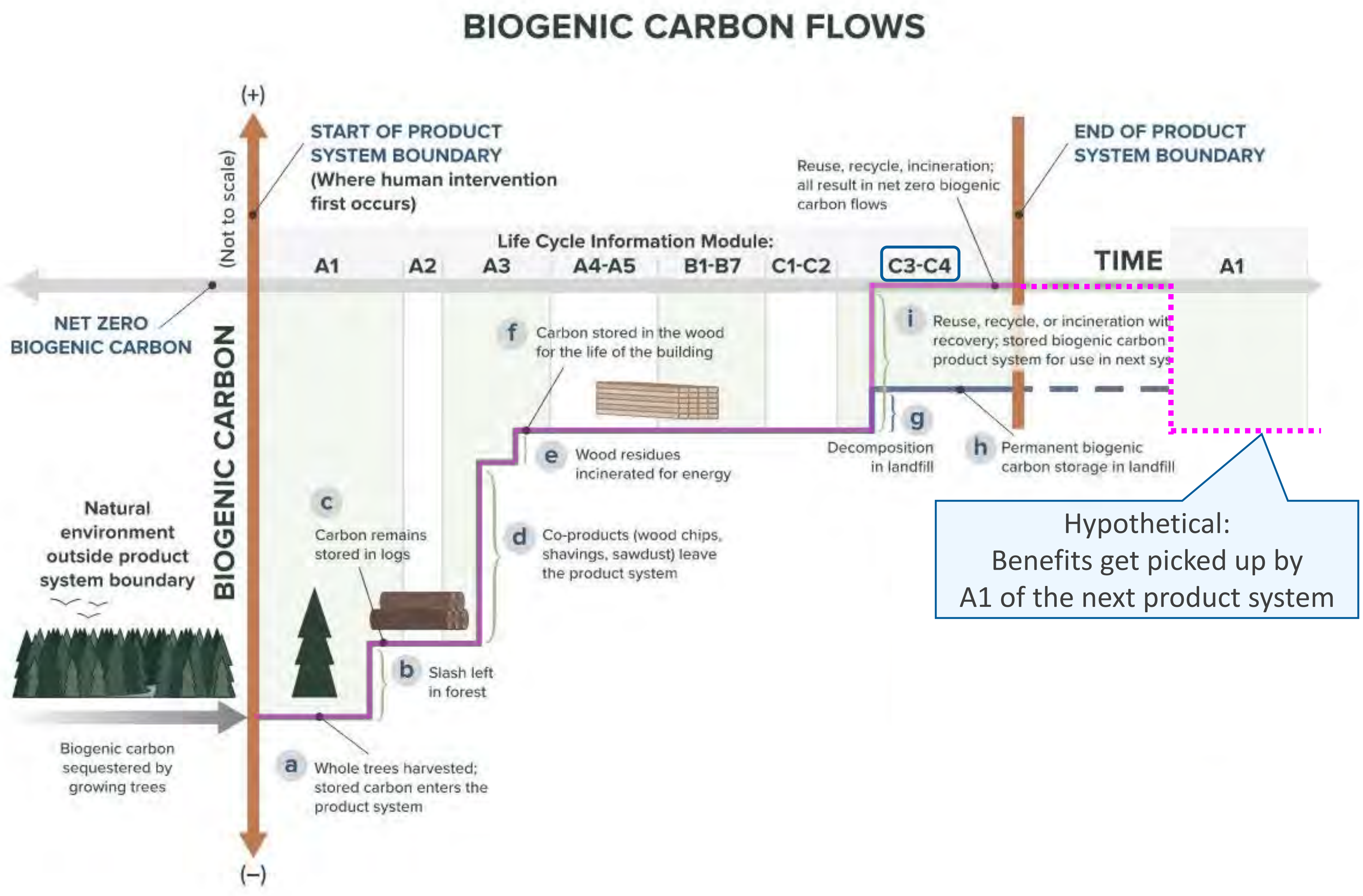
End-of-Life Fates for Wood Products

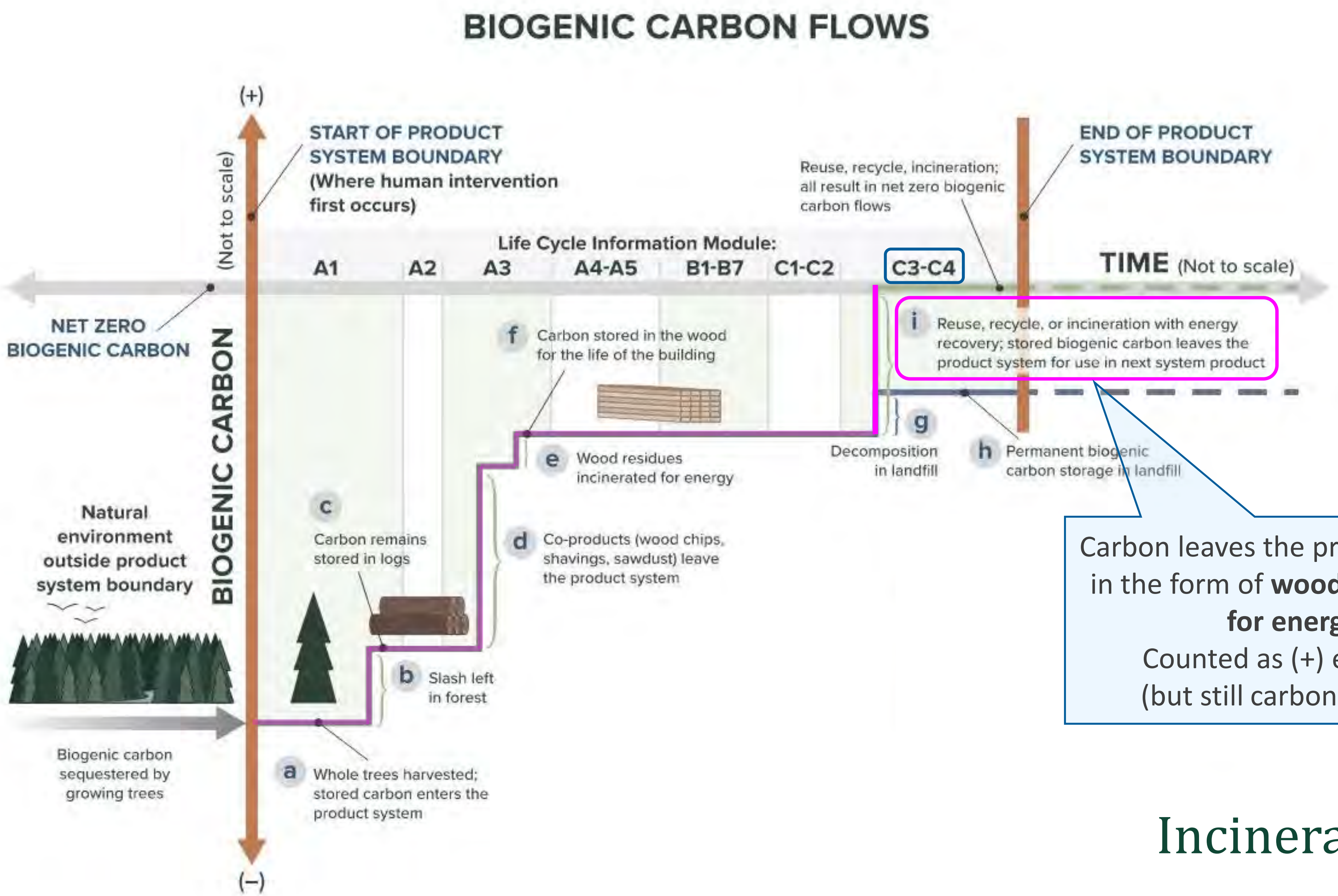
1. **Landfill**
2. **Incineration (for energy recovery)**
3. **Recycle**
4. **Direct Reuse**



Carbon leaves the product system for use in the next system
Counted as (+) export
(but not a direct emission to the atmosphere)

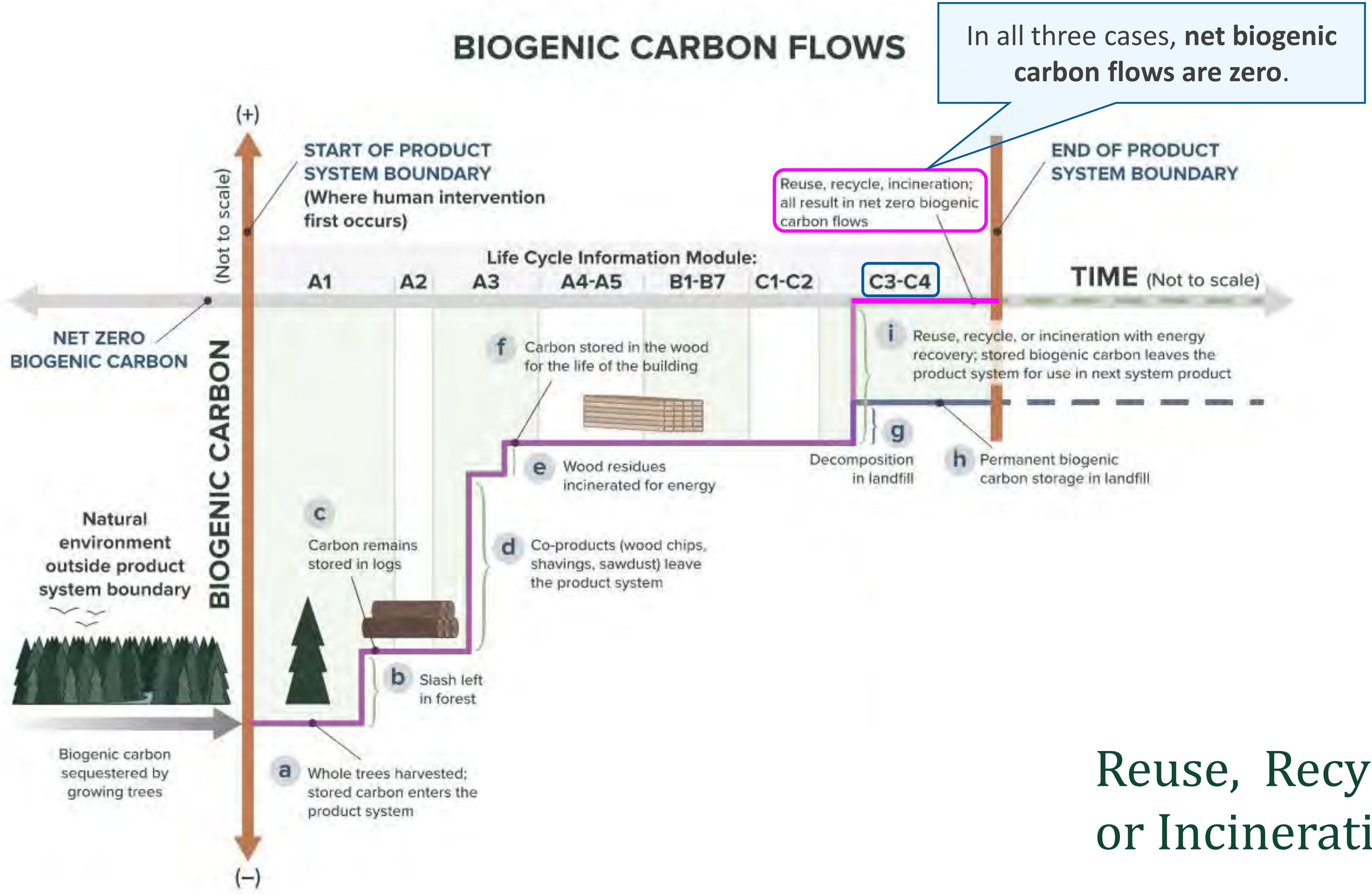
Reuse or Recycle


BIOGENIC CARBON FLOWS
(+)
(–)
BIOGENIC CARBON
(Not to scale)
START OF PRODUCT SYSTEM BOUNDARY (Where human intervention first occurs)
END OF PRODUCT SYSTEM BOUNDARY
Reuse, recycle, incineration; all result in net zero biogenic carbon flows
Life Cycle Information Module:
A1
A2
A3
A4-A5
B1-B7
C1-C2
C3-C4
TIME
A1
NET ZERO BIOGENIC CARBON
Natural environment outside product system boundary
Biogenic carbon sequestered by growing trees
a Whole trees harvested; stored carbon enters the product system
b Slash left in forest
c Carbon remains stored in logs
d Co-products (wood chips, shavings, sawdust) leave the product system
e Wood residues incinerated for energy
f Carbon stored in the wood for the life of the building
g Decomposition in landfill
h Permanent biogenic carbon storage in landfill
i Reuse, recycle, or incineration wit recovery; stored biogenic carbon product system for use in next sys
Hypothetical:
Benefits get picked up by
A1 of the next product system



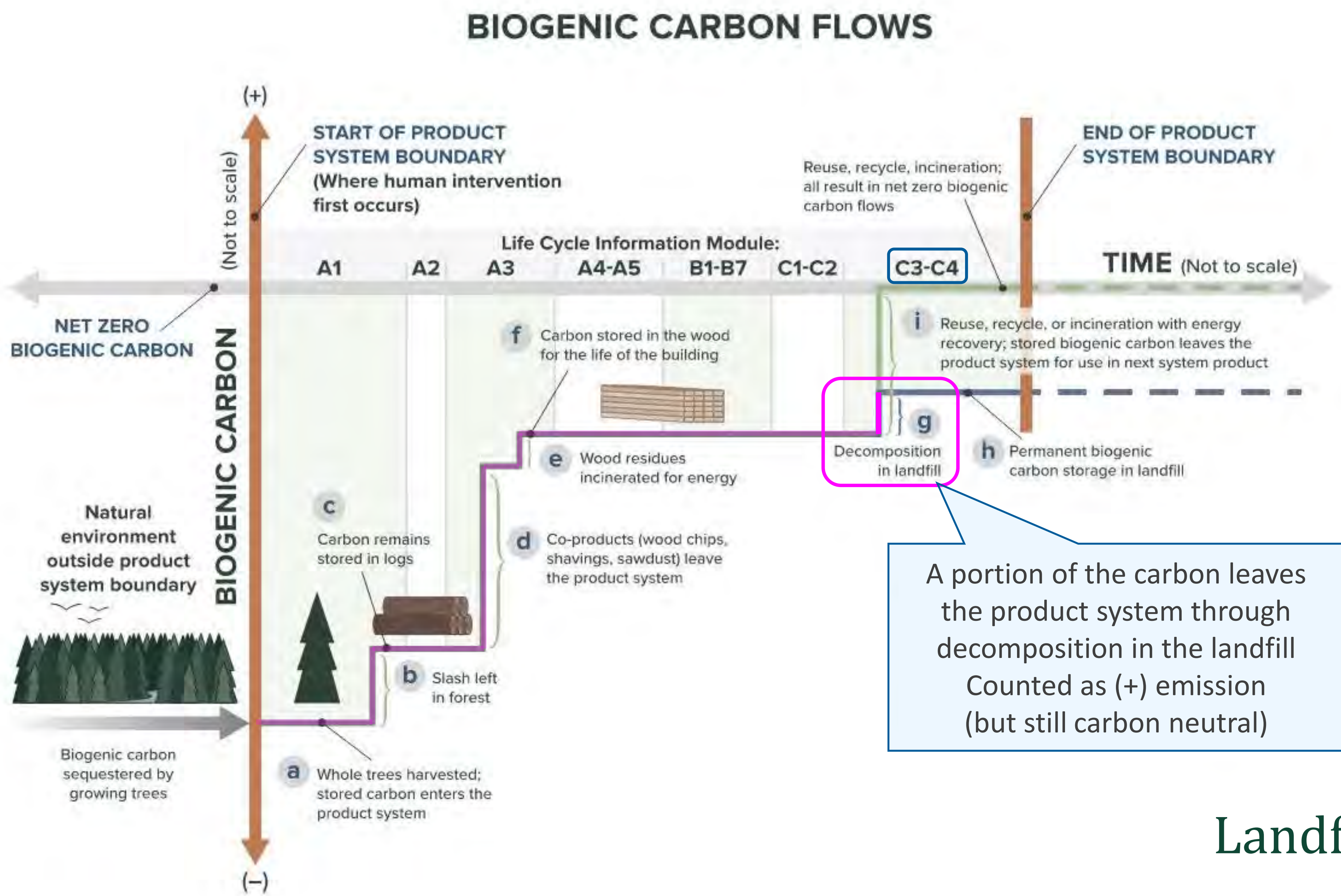
Carbon leaves the product system in the form of **wood incinerated for energy**
Counted as (+) emission
(but still carbon neutral)

Incineration

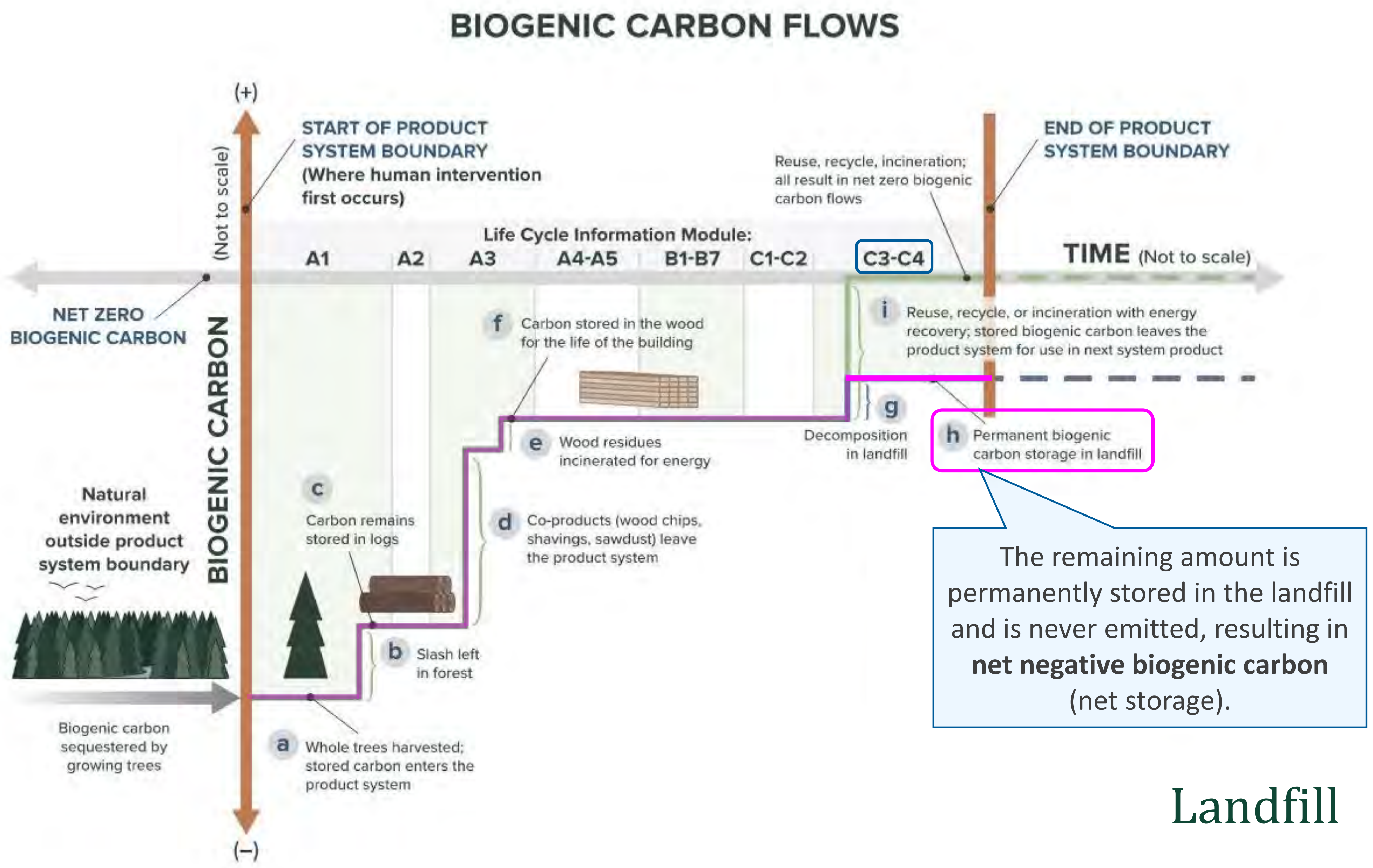


Reuse, Recycle or Incineration

Landfill

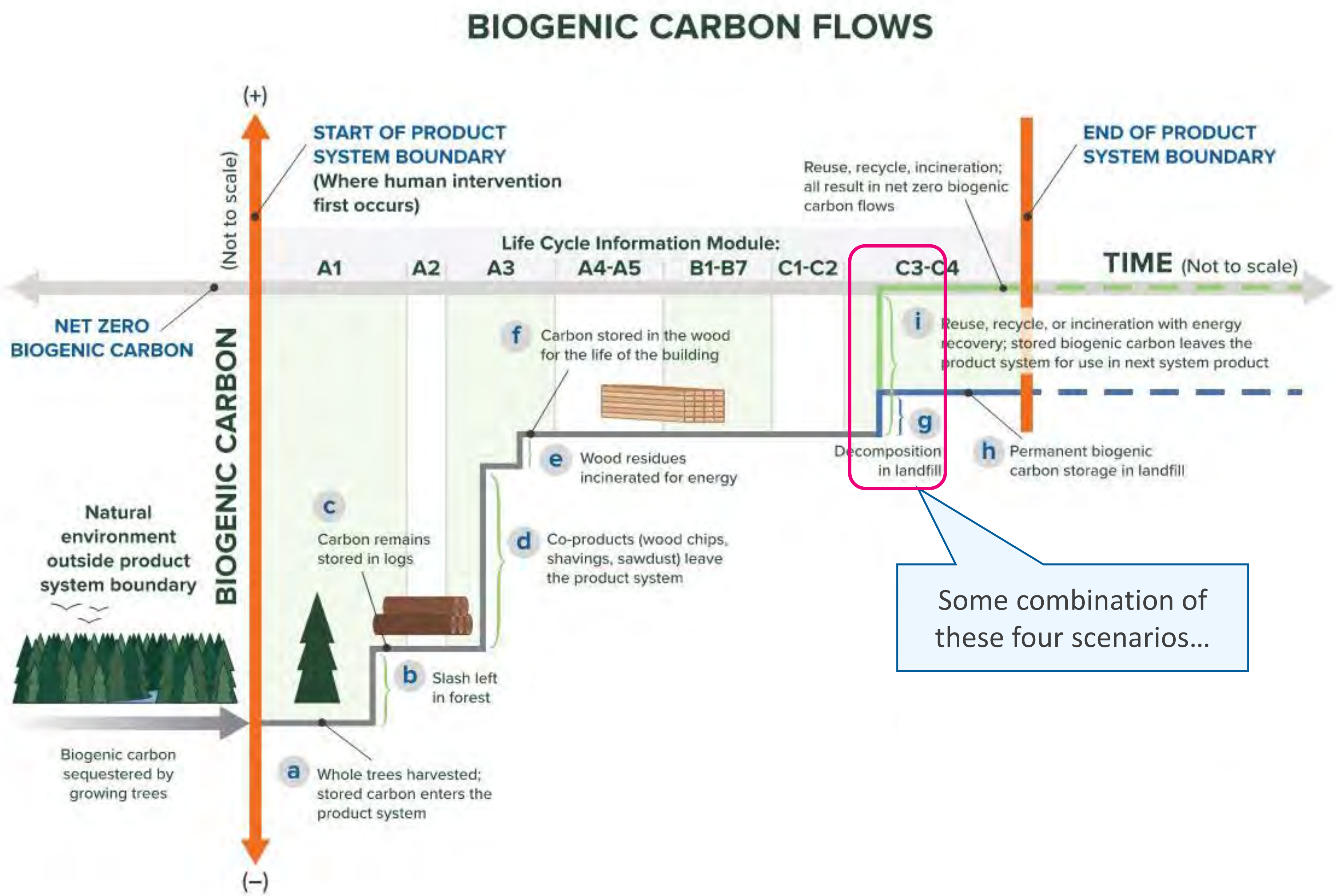


A portion of the carbon leaves the product system through decomposition in the landfill
Counted as (+) emission
(but still carbon neutral)

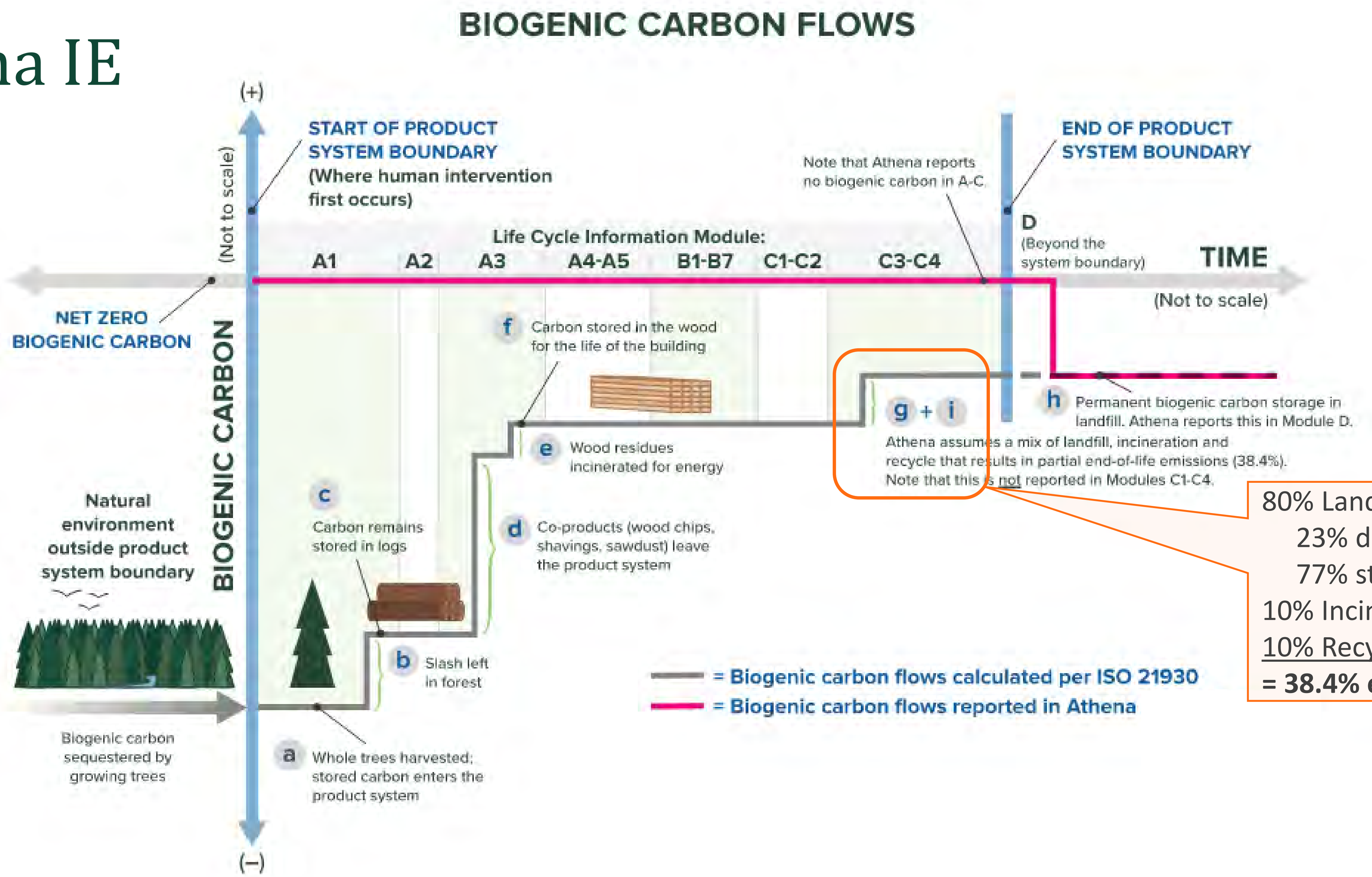

BIOGENIC CARBON FLOWS
(+)
(–)
(Not to scale)
BIOGENIC CARBON
START OF PRODUCT SYSTEM BOUNDARY (Where human intervention first occurs)
END OF PRODUCT SYSTEM BOUNDARY
Reuse, recycle, incineration; all result in net zero biogenic carbon flows
Life Cycle Information Module:
A1
A2
A3
A4-A5
B1-B7
C1-C2
C3-C4
TIME (Not to scale)
NET ZERO BIOGENIC CARBON
i Reuse, recycle, or incineration with energy recovery; stored biogenic carbon leaves the product system for use in next system product
f Carbon stored in the wood for the life of the building
g Decomposition in landfill
h Permanent biogenic carbon storage in landfill
e Wood residues incinerated for energy
c Carbon remains stored in logs
d Co-products (wood chips, shavings, sawdust) leave the product system
Natural environment outside product system boundary
b Slash left in forest
Biogenic carbon sequestered by growing trees
a Whole trees harvested; stored carbon enters the product system
The remaining amount is permanently stored in the landfill and is never emitted, resulting in **net negative biogenic carbon** (net storage).

Landfill

What end-of-life option should I use?


BIOGENIC CARBON FLOWS
(+)
START OF PRODUCT SYSTEM BOUNDARY (Where human intervention first occurs)
(Not to scale)
Reuse, recycle, incineration; all result in net zero biogenic carbon flows
END OF PRODUCT SYSTEM BOUNDARY
Life Cycle Information Module:
A1
A2
A3
A4-A5
B1-B7
C1-C2
C3-C4
TIME (Not to scale)
NET ZERO BIOGENIC CARBON
BIOGENIC CARBON
f Carbon stored in the wood for the life of the building
i Reuse, recycle, or incineration with energy recovery; stored biogenic carbon leaves the product system for use in next system product
g Decomposition in landfill
h Permanent biogenic carbon storage in landfill
e Wood residues incinerated for energy
c Carbon remains stored in logs
d Co-products (wood chips, shavings, sawdust) leave the product system
Natural environment outside product system boundary
b Slash left in forest
Biogenic carbon sequestered by growing trees
a Whole trees harvested; stored carbon enters the product system
(–)
Some combination of these four scenarios…

Athena IE



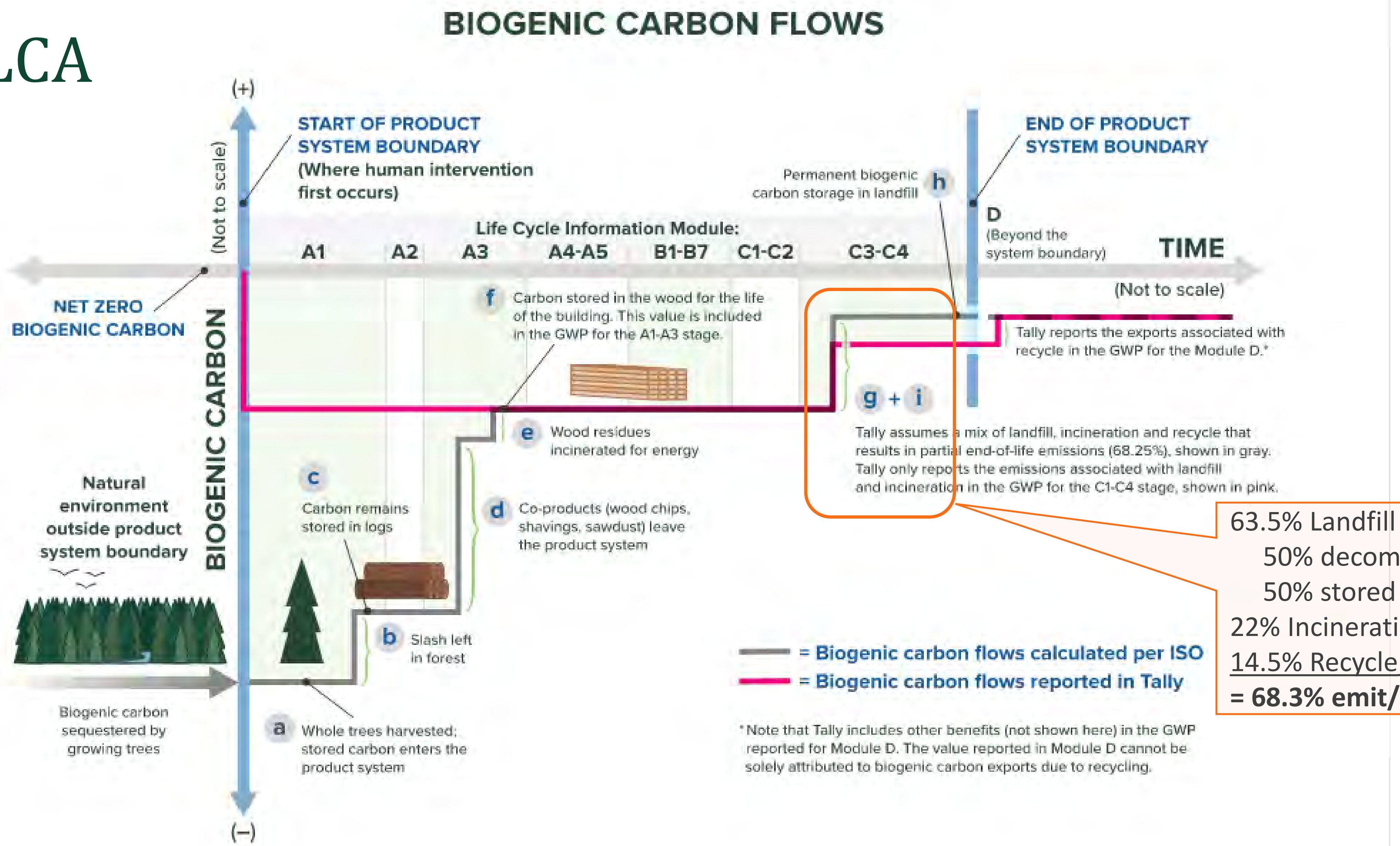
80% Landfill
- 23% decompose
- 77% stored

10% Incineration

10% Recycle

= 38.4% emit/export

TallyLCA

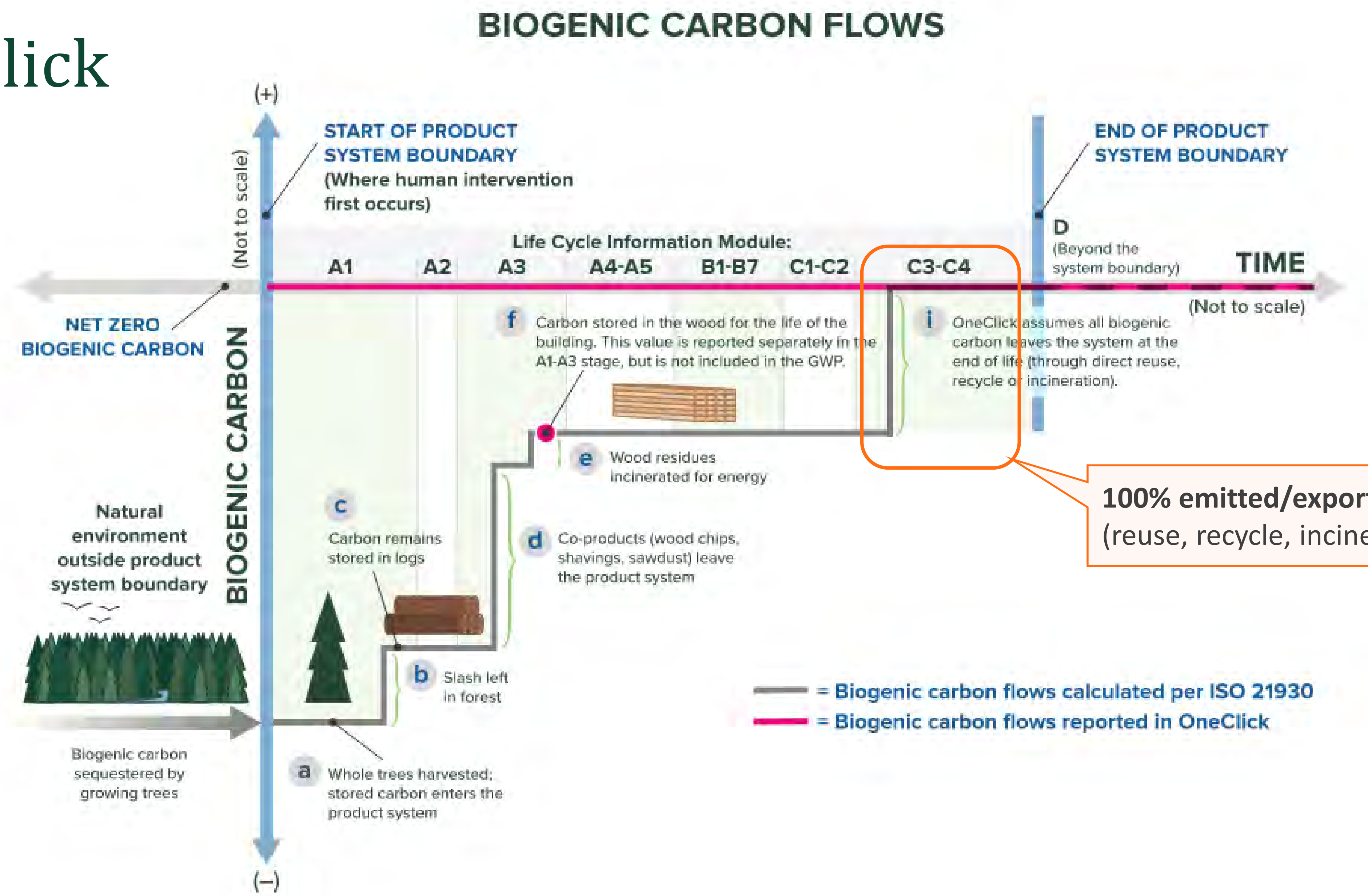


63.5% Landfill
- 50% decompose
- 50% stored

22% Incineration
14.5% Recycle
= 68.3% emit/export

https://www.woodworks.org/resources/biogenic-carbon-accounting-in-wblca-tools/

OneClick



100% emitted/exported
(reuse, recycle, incineration)

https://www.woodworks.org/resources/biogenic-carbon-accounting-in-wblca-tools/

A Note About Tools:

In addition to differences in end-of-life scenarios:

» Where end-of-life effects are reported (C3-C4 vs Module D)

» Methodology (ISO compliance)

» LCI Databases (background data)

» User interface, workflow

https://www.woodworks.org/resources/biogenic-carbon-accounting-in-wblca-tools/
https://www.woodworks.org/resources/calculating-the-embodied-carbon-of-different-structural-systems/

Resources from WoodWorks

Whole Building Life Cycle Assessment (WBLCA)

» Introduction to Whole Building Life Cycle Assessment: The Basics

Biogenic Carbon and Carbon Storage

» When to Include Biogenic Carbon in an LCA
» How to Include Biogenic Carbon in an LCA
» Biogenic Carbon Accounting in WBLCA Tools
» Long-Term Biogenic Carbon Storage
» Calculating the Carbon Stored in Wood Products

Environmental Product Declarations (EPDs)

» Current EPDs for Wood Products
» How to Use Environmental Product Declarations

Scan to view

Photo: DPR Office, SmithGroup, photo Chad Davies

Copyright Materials

Funding provided in part by the Softwood Lumber Board

KL&A
Engineers & Builders

MEASURE, REPORT, AND REDUCE:

USING COMPARATIVE LCA TO HIGHLIGHT THE EMBODIED CARBON BENEFITS OF WOOD CONSTRUCTION

Alexis Feitel, PE
Team Carbon Unit Director & Structural Engineer afeitel@klaa.com

Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.

Photo Credit: JC Buck

- PLATTE FIFTEEN LCA CASE STUDY
- RETURN TO FORM LCA CASE STUDY
- CASE STUDY TRENDS

OUTLINE

Photo by Aleksandar Radovanovic on Unsplash

CRADLE TO GATE

CRADLE TO GRAVE

Life Cycle Stages & Study Scope

Product			Constr-uction		Use							End-of-Life				Module D		
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D1	D2	D3
Raw material supply	Transport	Manufacturing	Transport	*Construction\Installation*	Use	Maintenance	Repair	Replacement	Refurbishment	*Operational Energy Use*	Operational Water Use	Deconstruction	Transport	Waste Processing	Disposal	Reuse	Recycling	Energy Recovery
✓	✓	✓	✓			✓	✓	✓	✓				✓	✓	✓	✓	✓	✓

Figure 3. Life Cycle Stages[3] as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

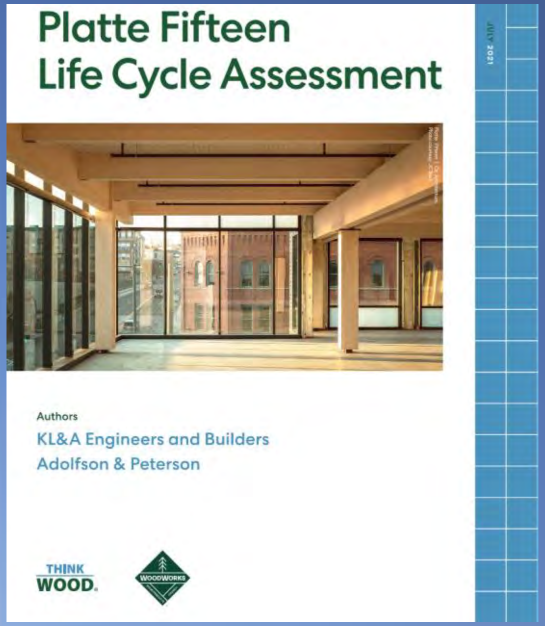
Office / Retail

Type III-B over IA Construction, IBC 2015

- P2: Concrete Mat Slab Foundation
- P1, L1: Concrete Slabs
- L2: Concrete Podium Slab
- L3- Roof: Mass Timber

Concrete Cores

30’ x 30’ Grid



PLATTE FIFTEEN

Denver, Colorado

Office / Retail

Type III-B over IA Construction, IBC 2015

- P2: Concrete Mat Slab Foundation
- P1, L1: Concrete Slabs
- L2: Concrete Podium Slab
- L3- Roof: Mass Timber

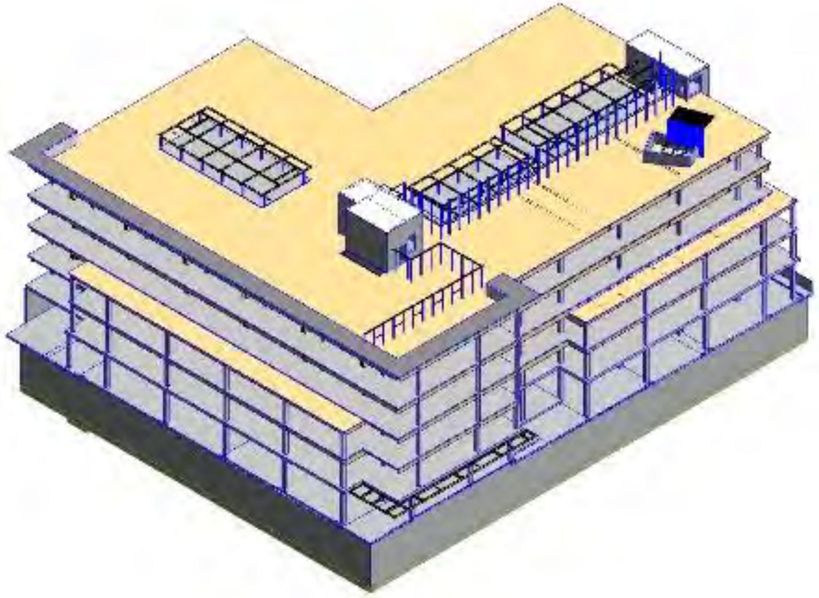
Concrete Cores

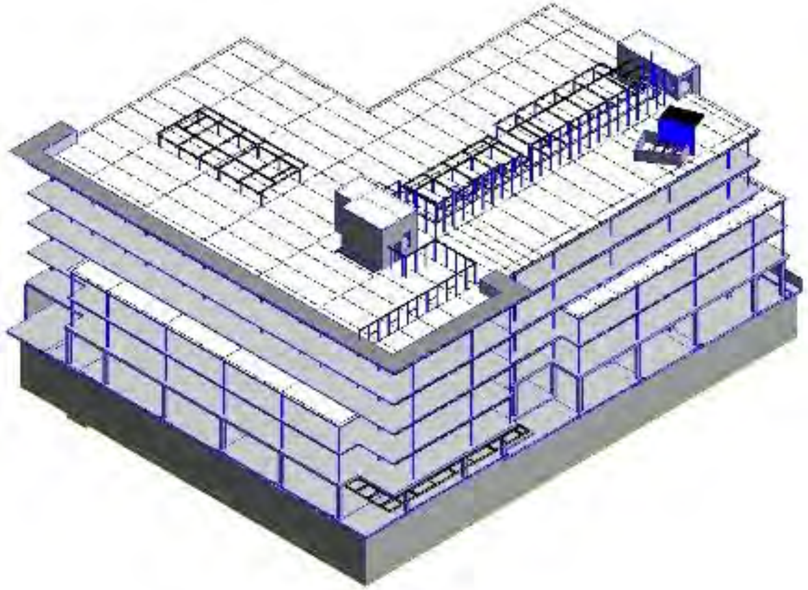
30’ x 30’ Grid

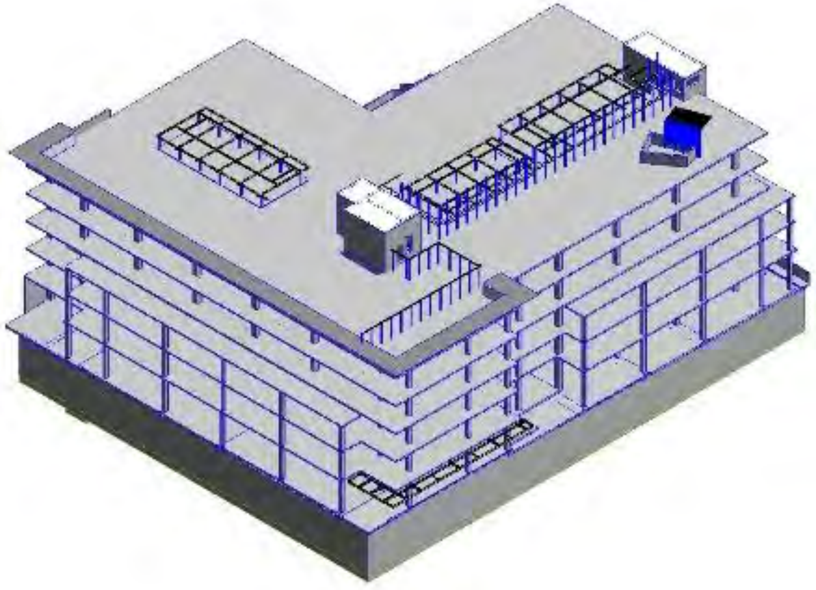
PLATTE FIFTEEN

Denver, Colorado

Photo Credit: JC Buck



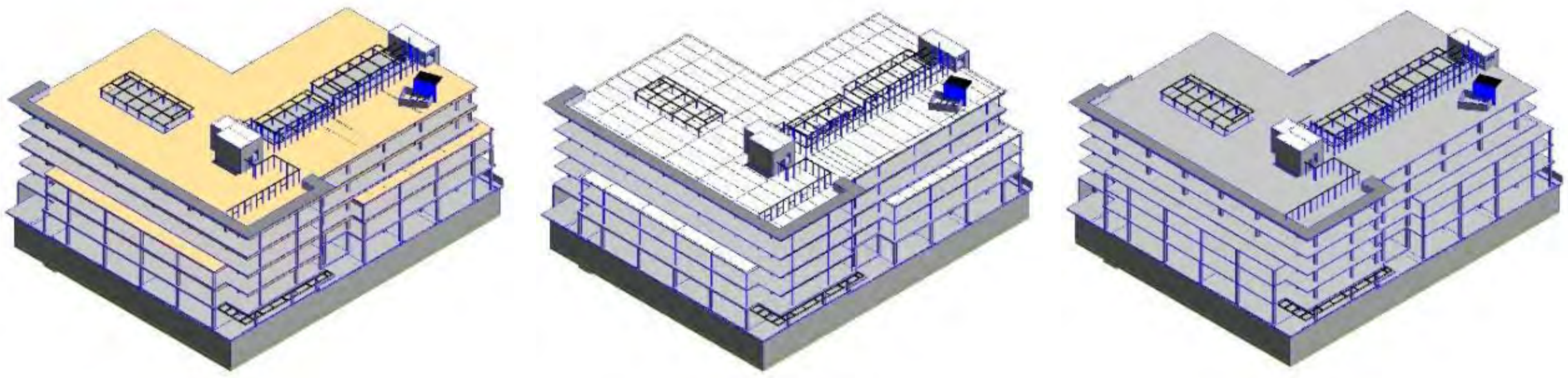


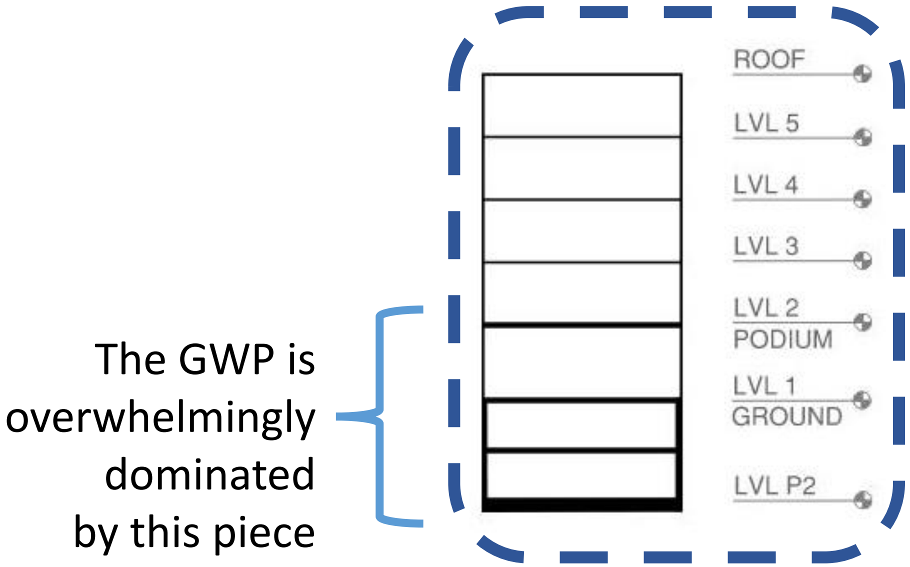


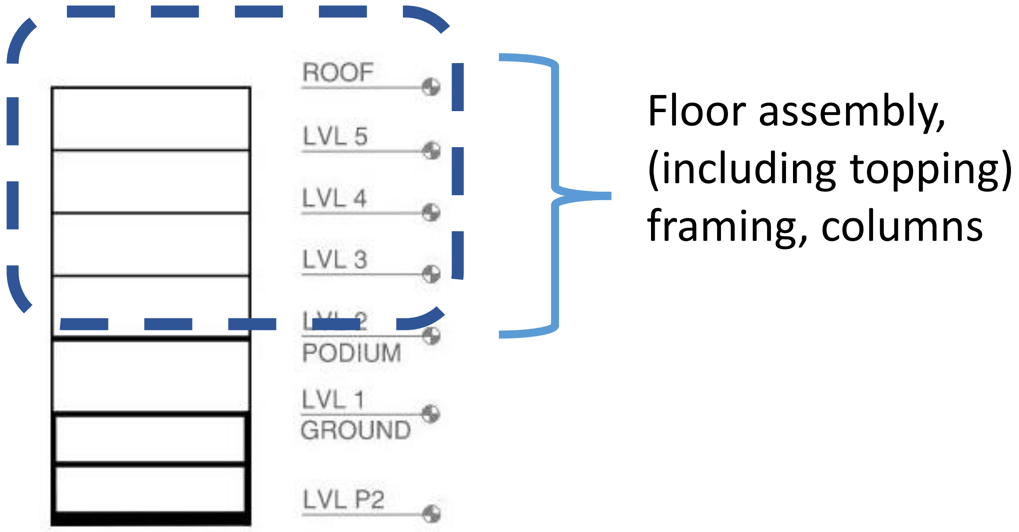
MASS TIMBER
(AS CONSTRUCTED)

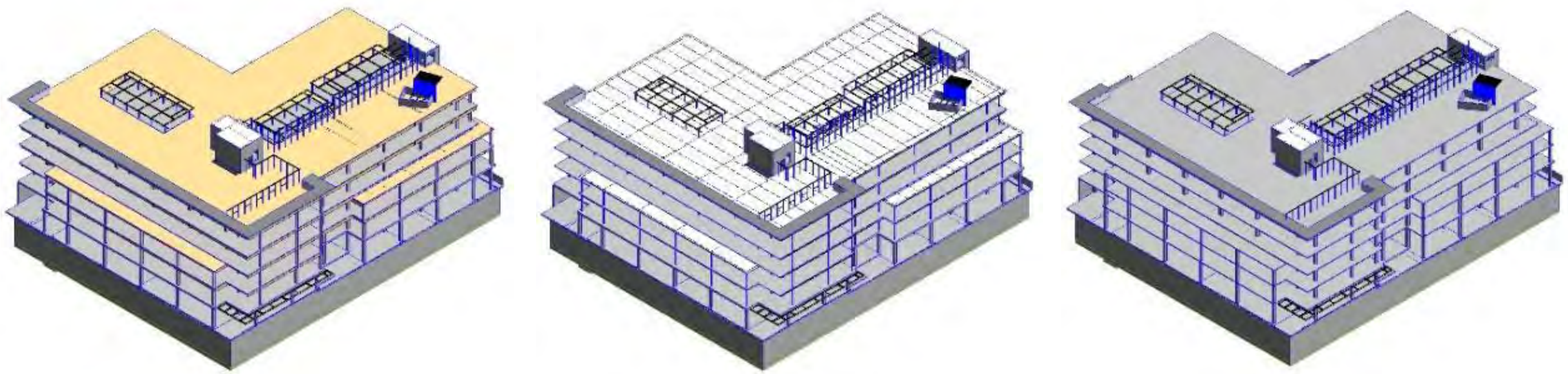
STEEL

PT CONCRETE

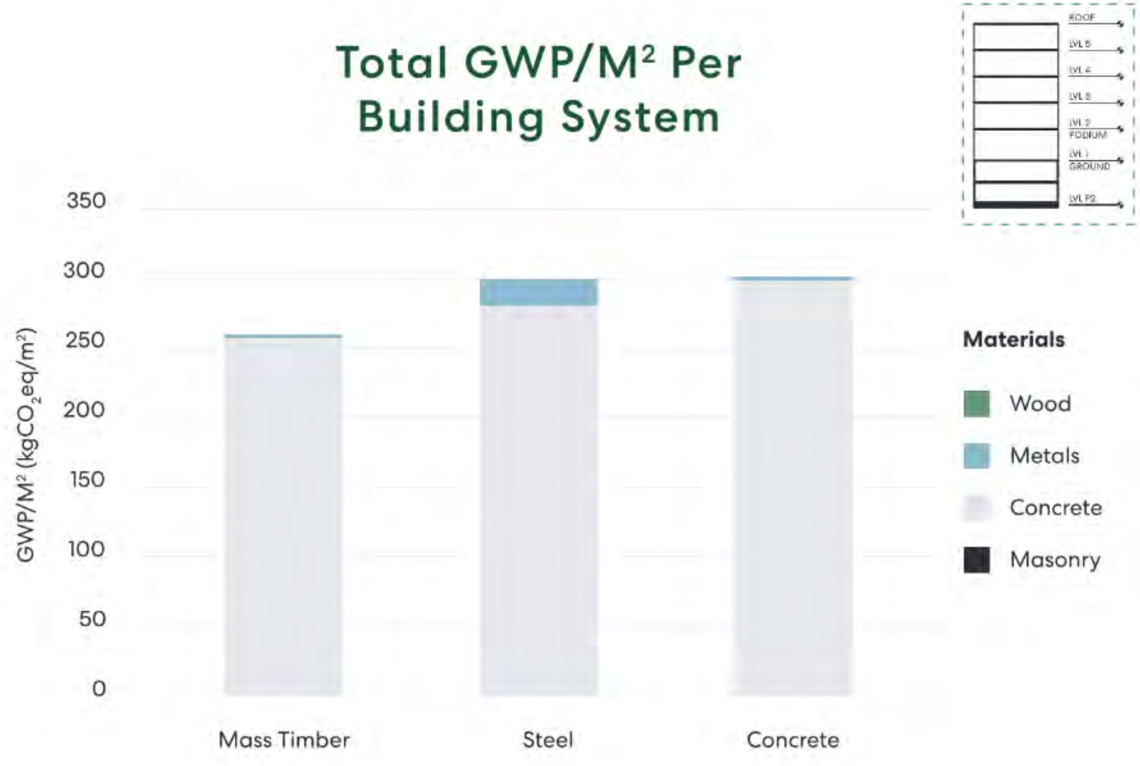



The GWP is overwhelmingly dominated by this piece
ROOF
LVL 5
LVL 4
LVL 3
LVL 2
PODIUM
LVL 1
GROUND
LVL P2

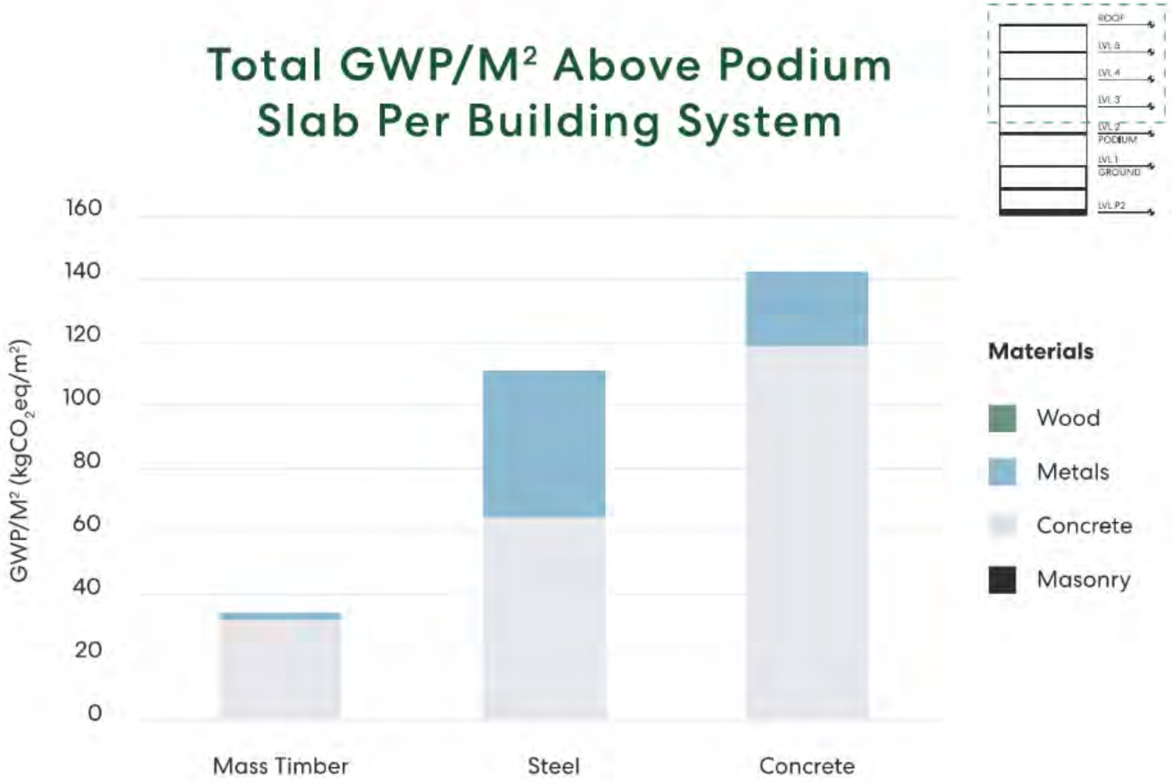

ROOF
LVL 5
LVL 4
LVL 3
PODIUM
LVL 1
GROUND
LVL P2
Floor assembly, (including topping) framing, columns

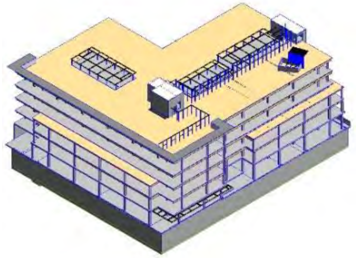


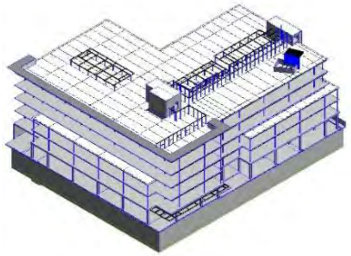
Total GWP/M² Per Building System

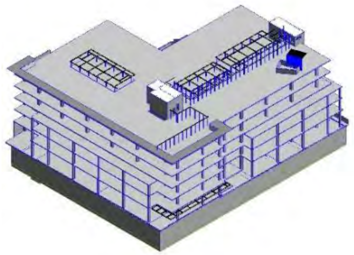


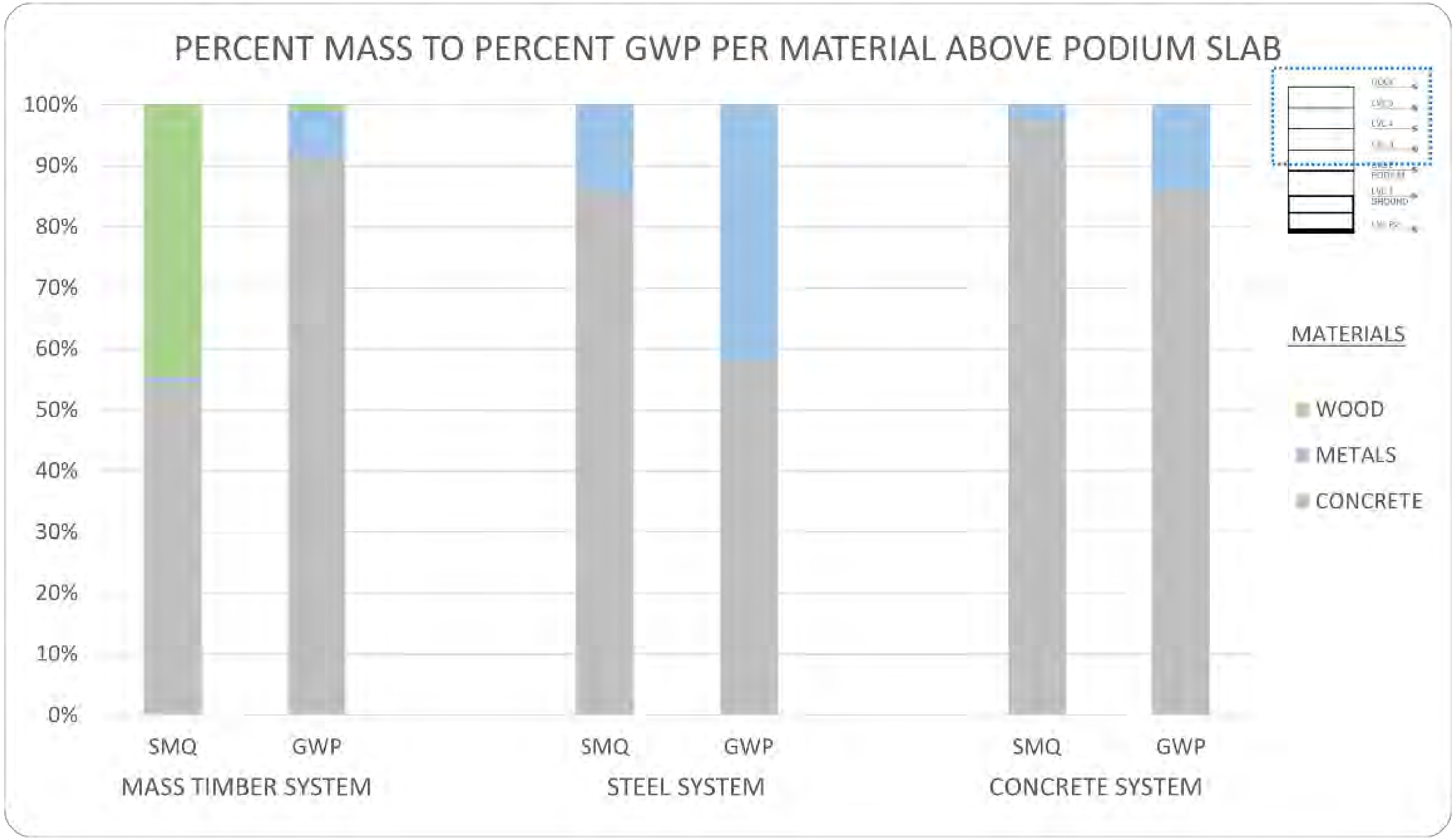
Total GWP/M² Above Podium Slab Per Building System



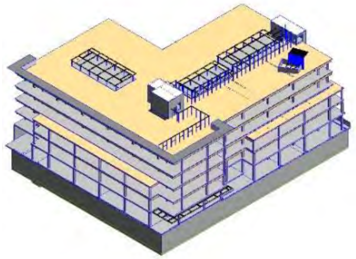


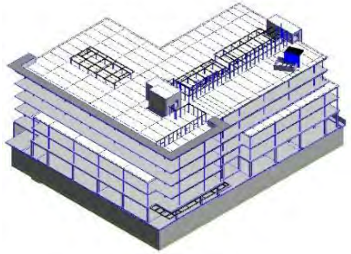


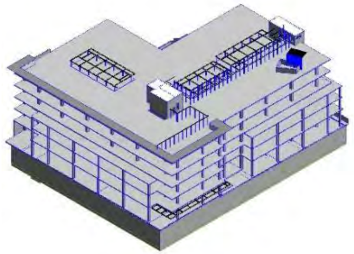




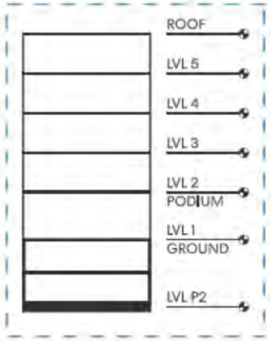
PERCENT MASS TO PERCENT GWP PER MATERIAL ABOVE PODIUM SLAB
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SMQ
GWP
MASS TIMBER SYSTEM
SMQ
GWP
STEEL SYSTEM
SMQ
GWP
CONCRETE SYSTEM
MATERIALS
WOOD
METALS
CONCRETE

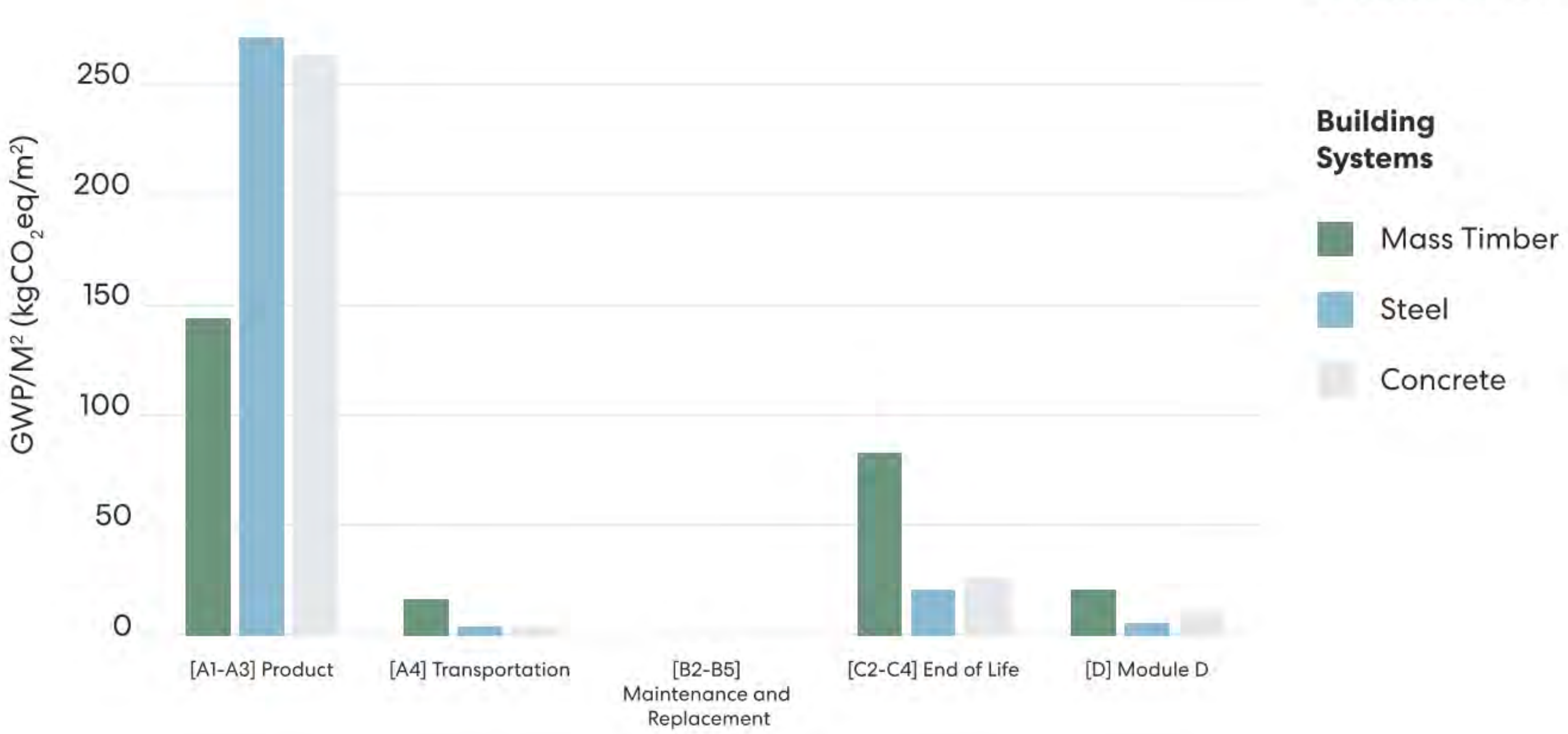




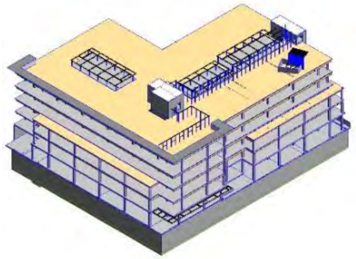


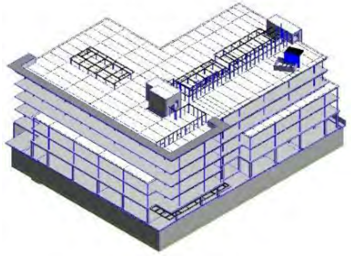
Total GWP/M² Per Life Cycle Stage

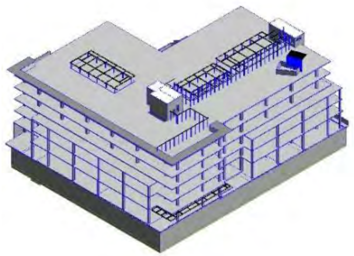


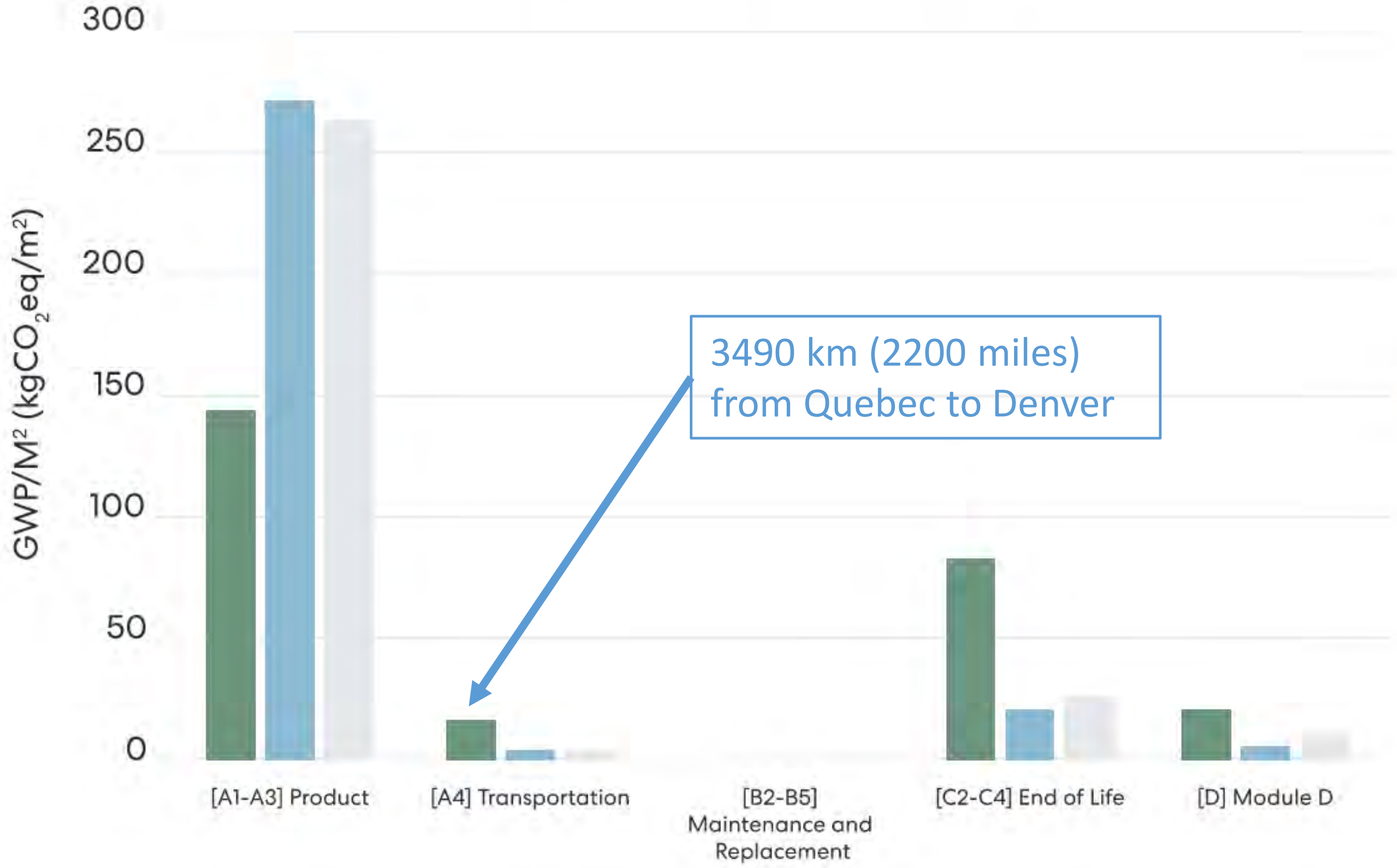


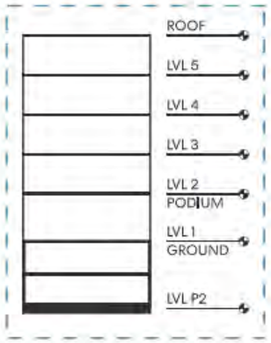
Total GWP/M² Per Life Cycle Stage









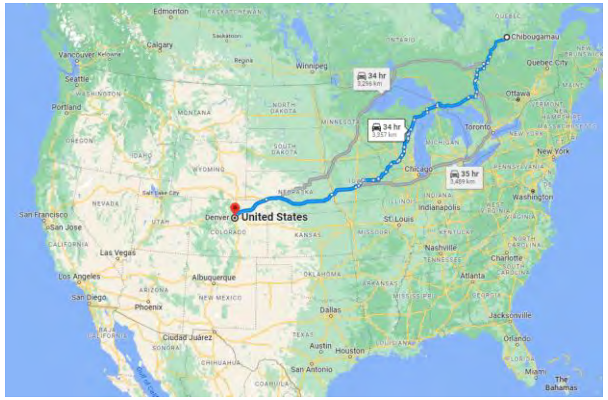


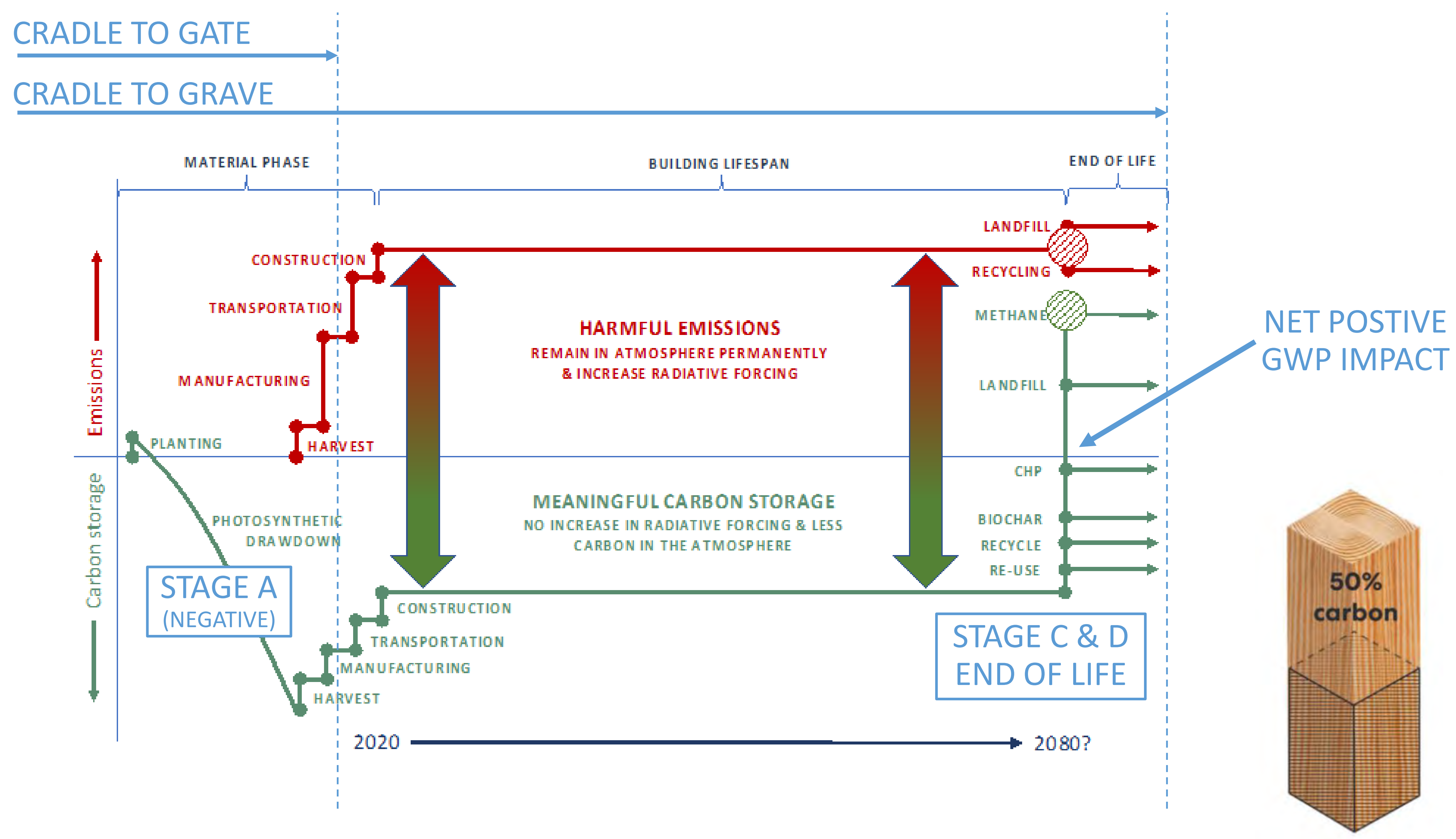
Building Systems

Mass Timber

Steel

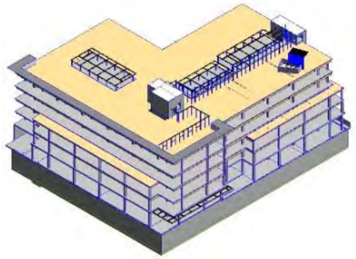
Concrete

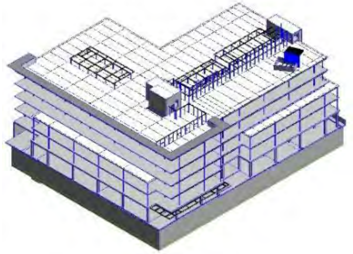


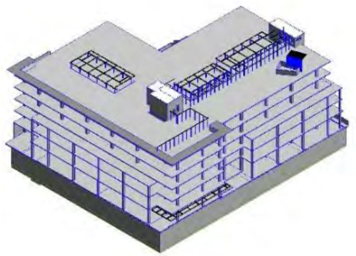


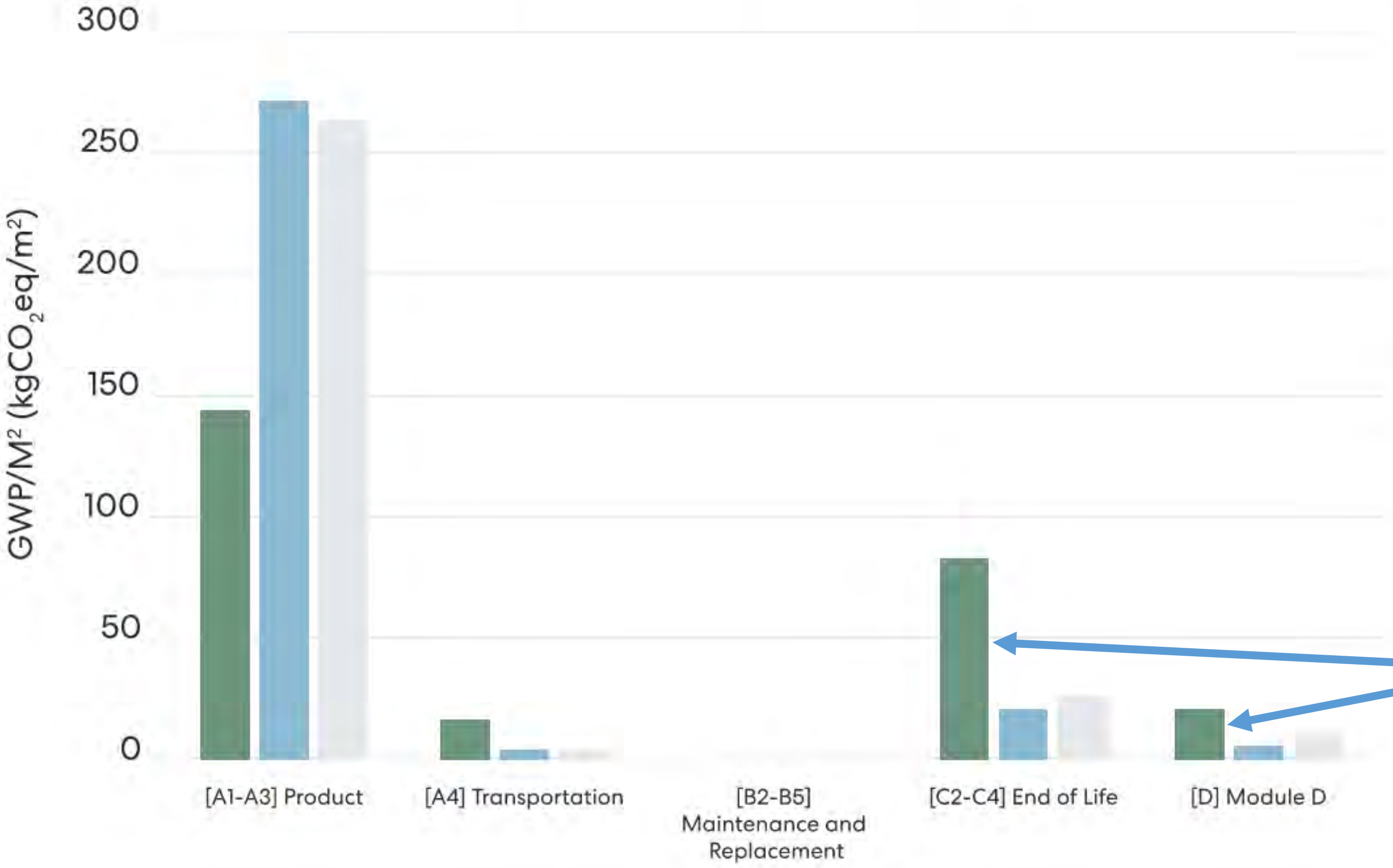
CRADLE TO GATE
CRADLE TO GRAVE
MATERIAL PHASE
BUILDING LIFESPAN
END OF LIFE
Emissions
Carbon storage
CONSTRUCTION
TRANSPORTATION
MANUFACTURING
PLANTING
HARVEST
PHOTOSYNTHETIC DRAWDOWN
STAGE A (NEGATIVE)
HARMFUL EMISSIONS
REMAIN IN ATMOSPHERE PERMANENTLY & INCREASE RADIATIVE FORCING
MEANINGFUL CARBON STORAGE
NO INCREASE IN RADIATIVE FORCING & LESS CARBON IN THE ATMOSPHERE
CONSTRUCTION
TRANSPORTATION
MANUFACTURING
HARVEST
LANDFILL
RECYCLING
METHANE
LANDFILL
CHP
BIOCHAR
RECYCLE
RE-USE
NET POSTIVE GWP IMPACT
STAGE C & D END OF LIFE
2020
2080?
50% carbon

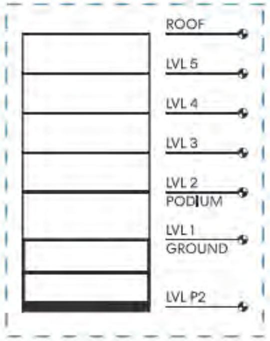
Total GWP/M² Per Life Cycle Stage











Building Systems

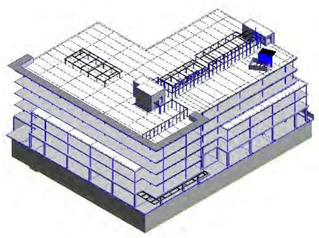
- Mass Timber
- Steel
- Concrete

Mix Assumptions for Wood:
- 63.5% Landfill
- 22.0% Incineration
- 14.5% Recycle

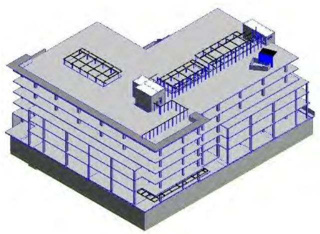
DOLLAR COST
vs
TIME COST
vs
CARBON COST

Photo by Michele dot com on Unsplash

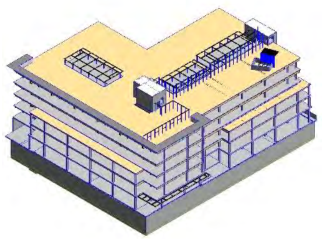
DOLLAR COST



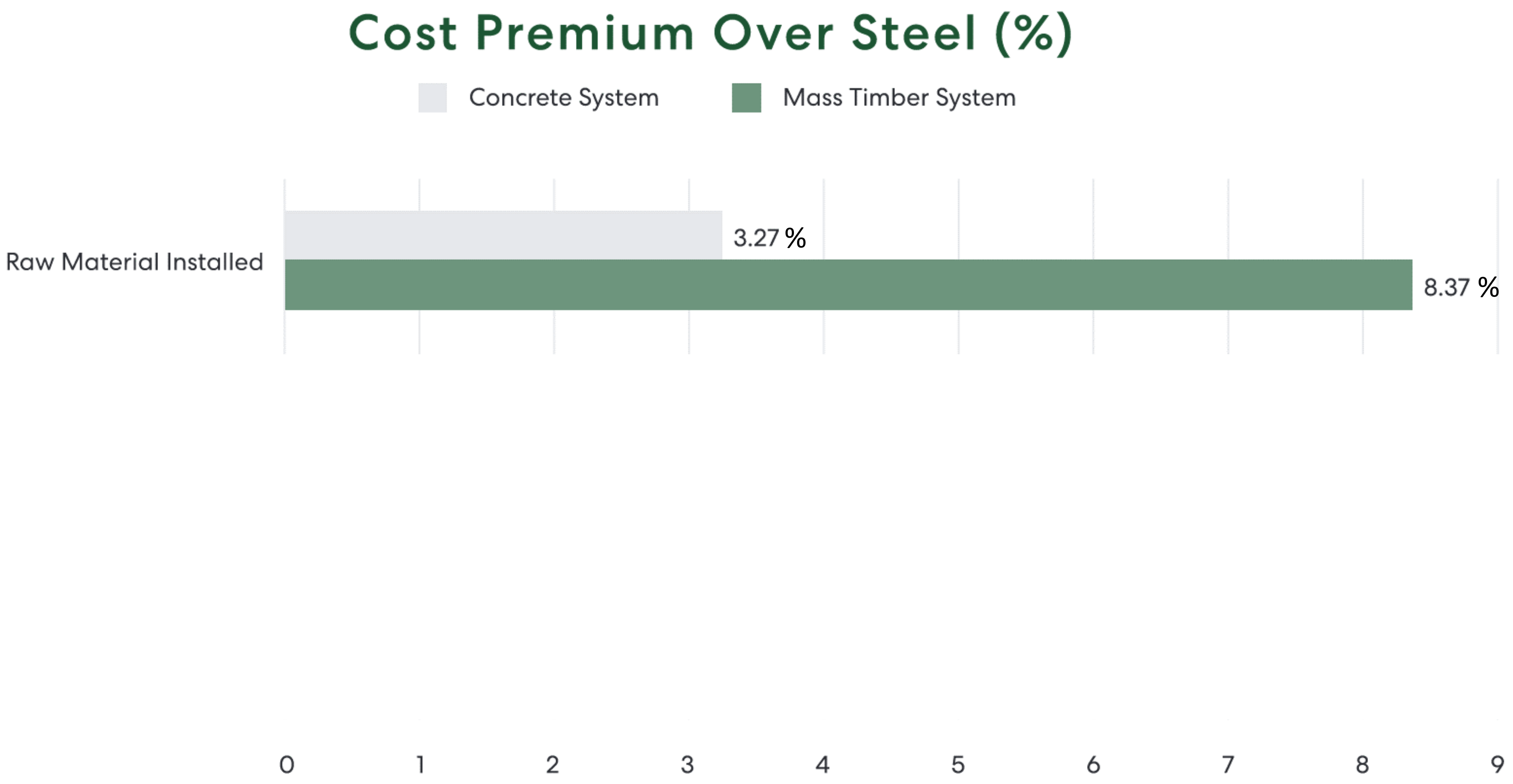
Steel: Lowest = Baseline



Concrete: Middle



Mass Timber: Highest



PLATTE FIFTEEN

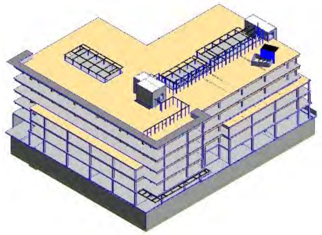
TIMELAPSE

MT CONSTRUCTION SPEED:

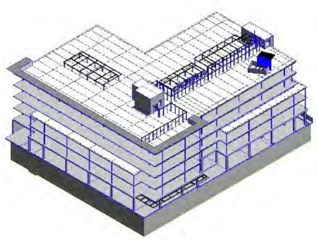
2,000 SF / DAY

6-8 WORKERS

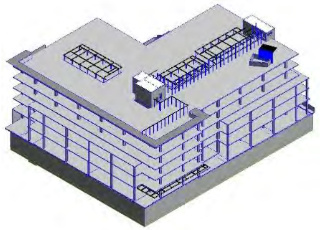
DOLLAR COST & TIME COST



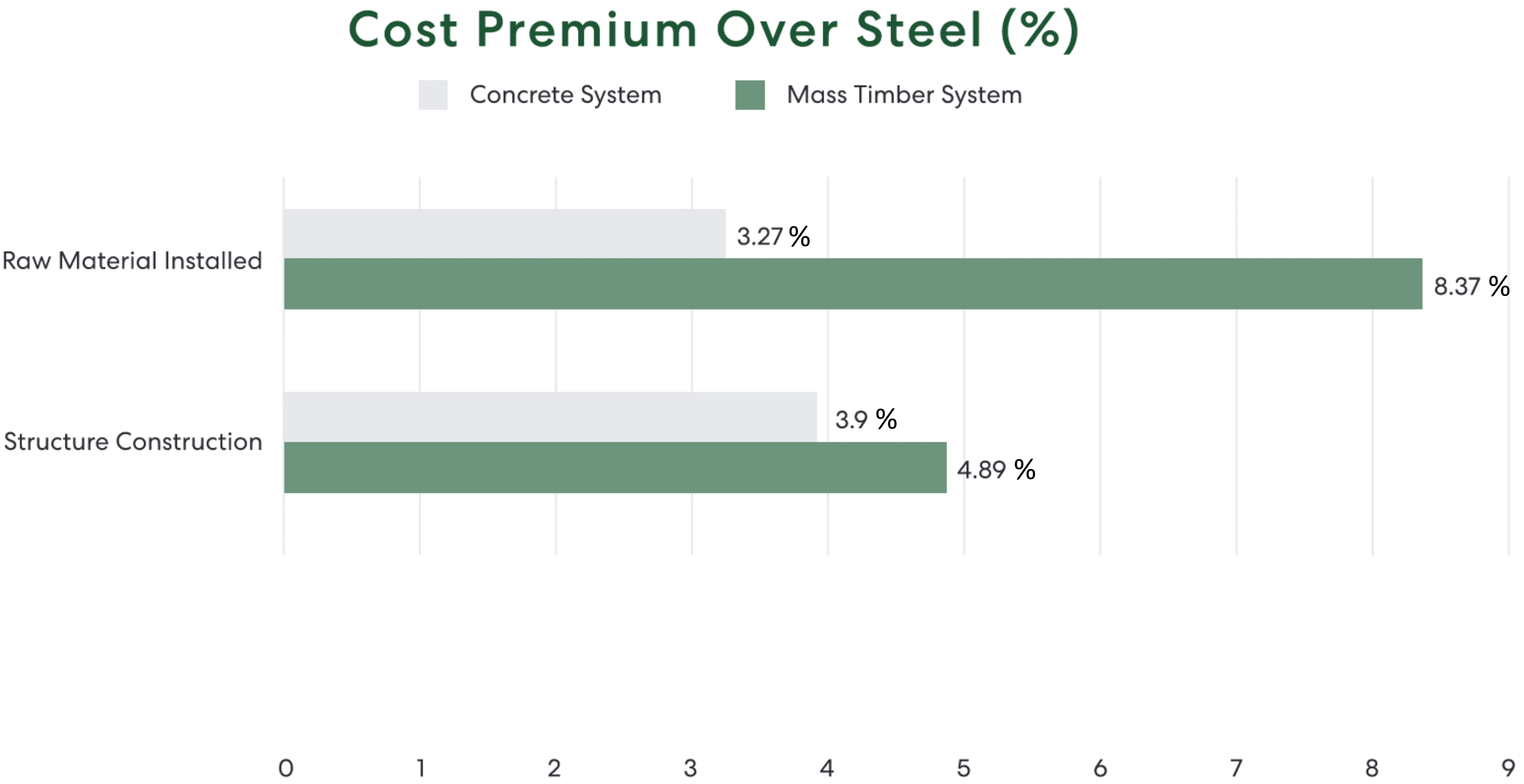
Mass Timber:
Baseline time



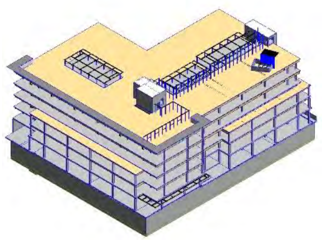
Steel:
+ 2 months



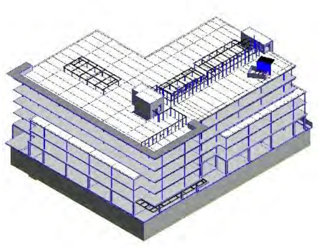
Concrete:
+ 3.5 months



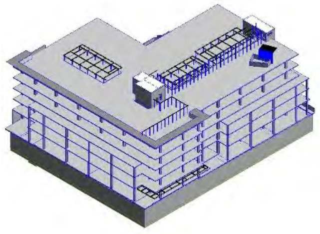
DOLLAR COST & TIME COST



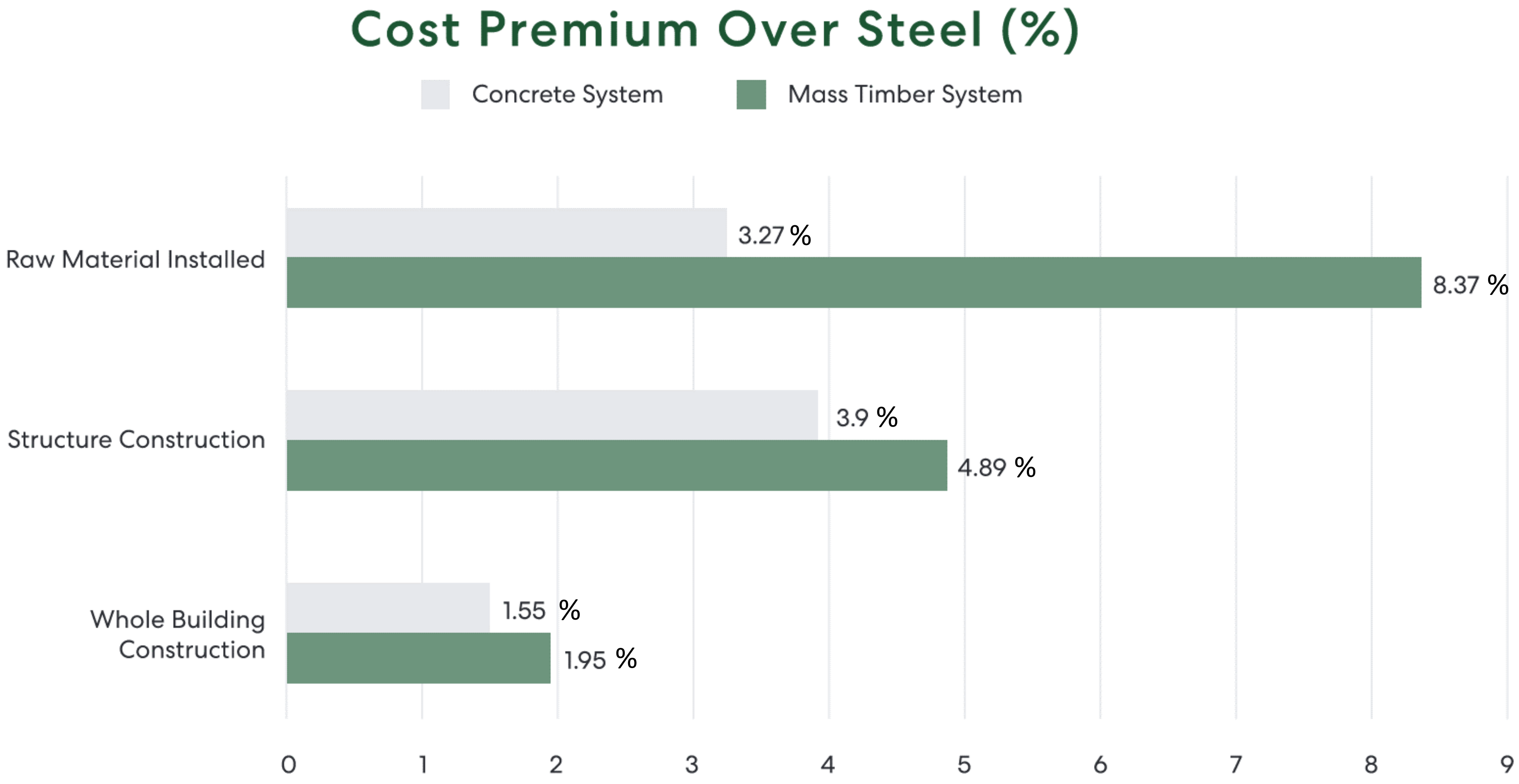
Mass Timber:
Baseline time



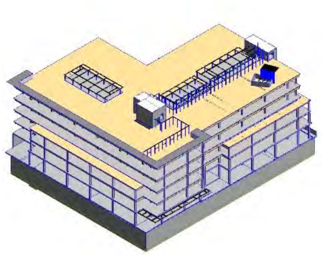
Steel:
+ 2 months



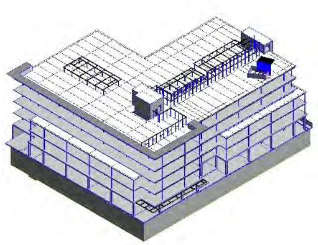
Concrete:
+ 3.5 months



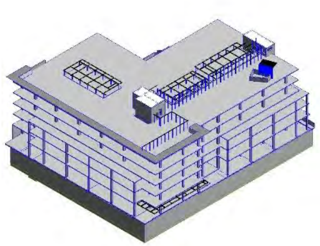
DOLLAR COST vs CARBON COST



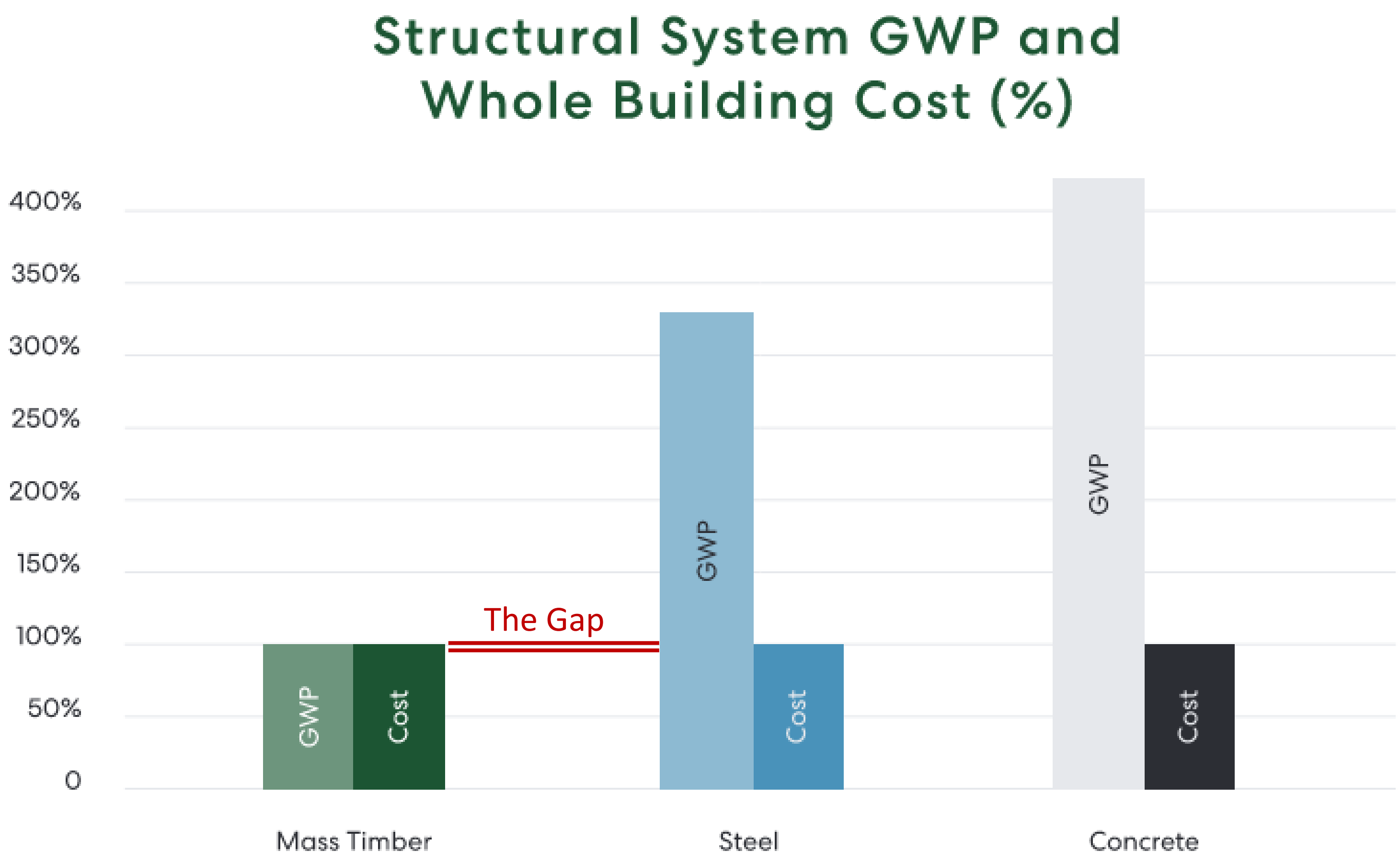
Mass Timber: Baseline

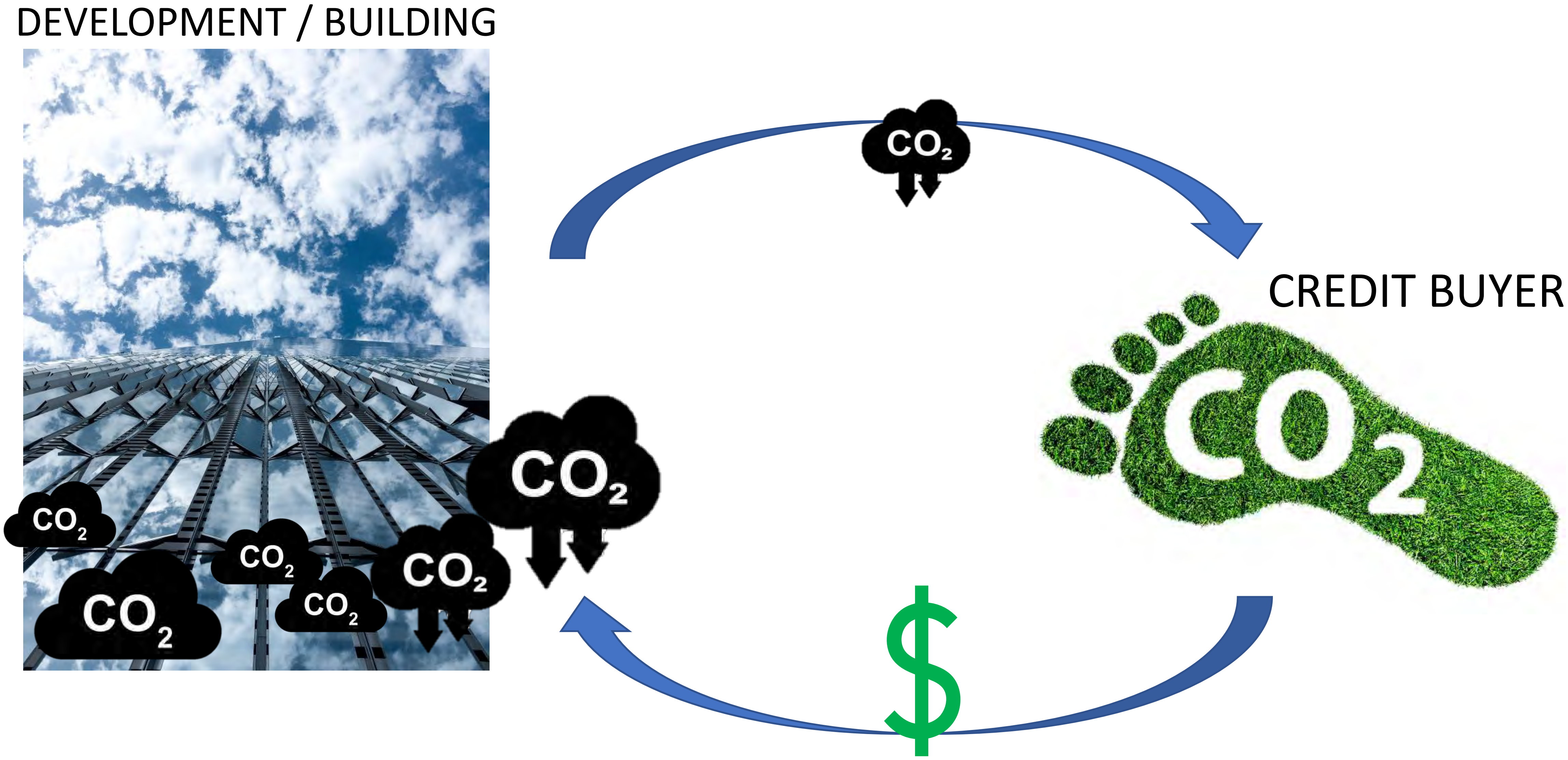


Steel

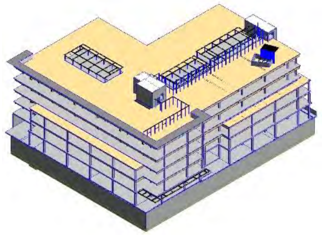


Concrete

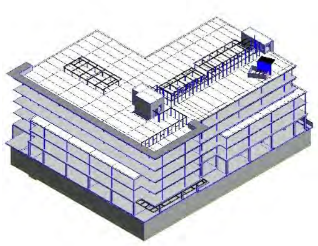



DEVELOPMENT / BUILDING
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CREDIT BUYER
CO_2
$

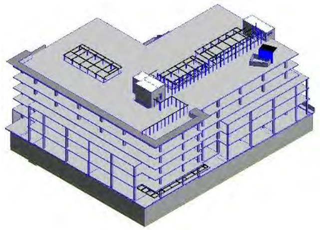
DOLLAR COST & CARBON COST



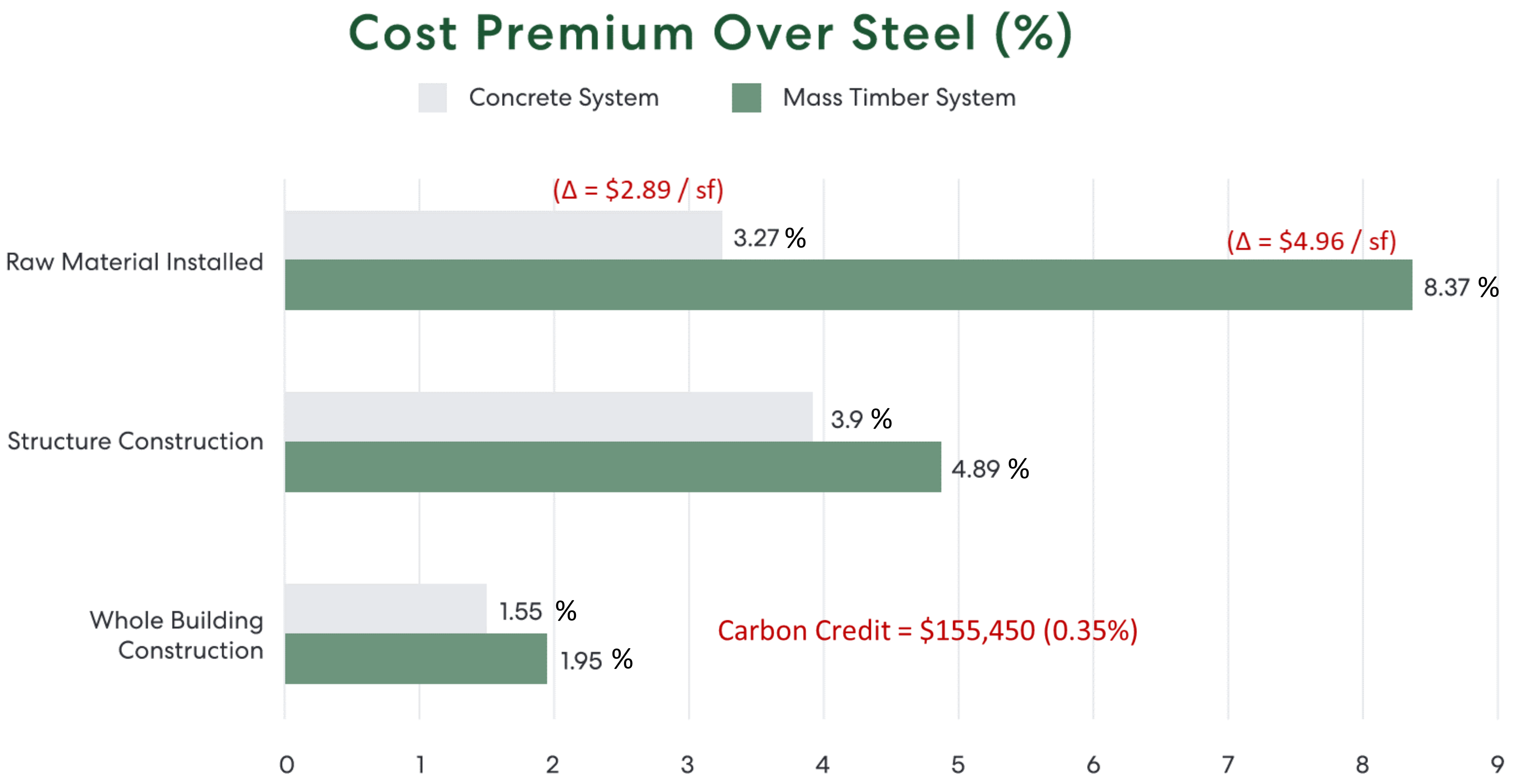
Mass Timber:
Baseline time



Steel:
+ 2 months



Concrete:
+ 3.5 months




CASE STUDY SERIES
USDA, SLB, WW, THINKWOOD, KL&A


Multifamily / Retail
Type IV-B Construction, IBC 2018 with Denver Amendments
12 Story
No below grade
L1: Drilled Piers + Concrete Slab on Grade
L2-L4: Concrete Slabs
L5 - Roof: Mass Timber
Concrete Cores
20’ x 20’ Grid
RETURN TO FORM
Denver, Colorado

Multifamily / Retail

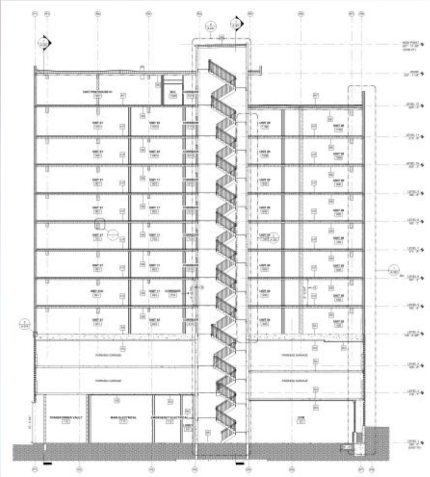
Type IV-B Construction, IBC 2018 with Denver Amendments

12 Story

- No below grade
- L1: Drilled Piers + Concrete Slab on Grade
- L2-L4: Concrete Slabs
- L5 - Roof: Mass Timber

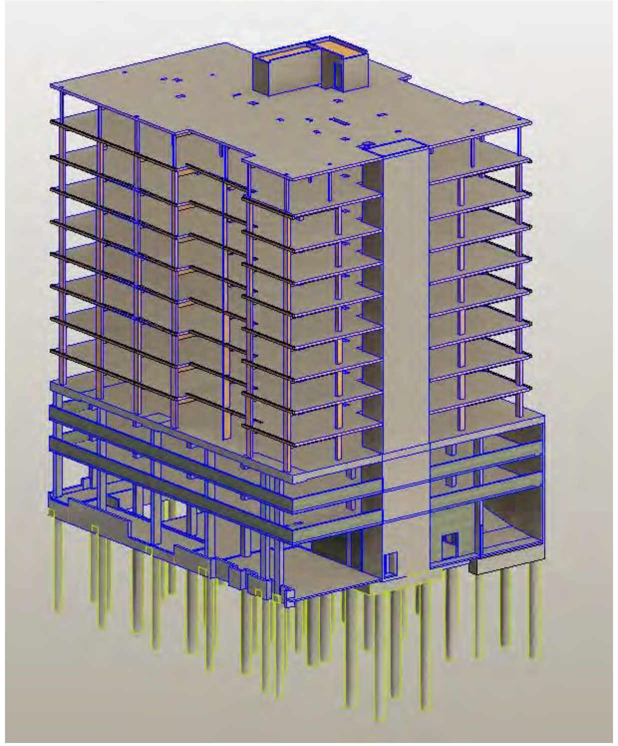
Concrete Cores

20’ x 20’ Grid

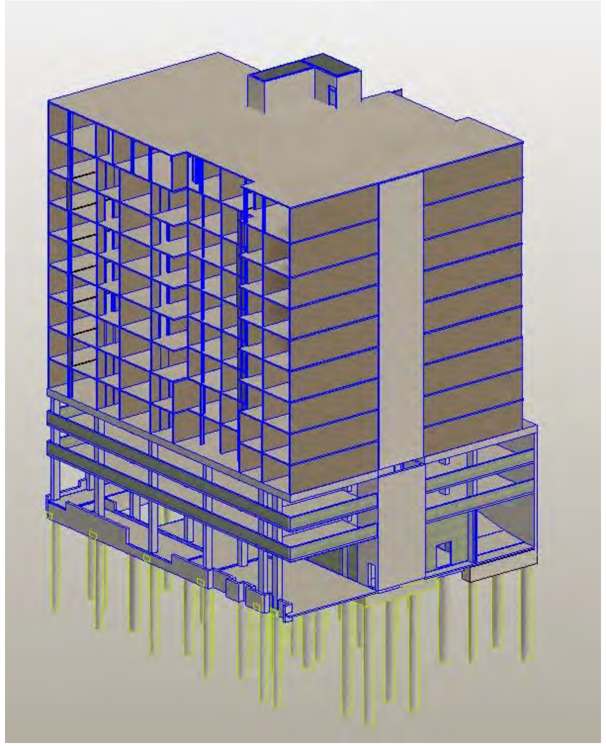


RETURN TO FORM

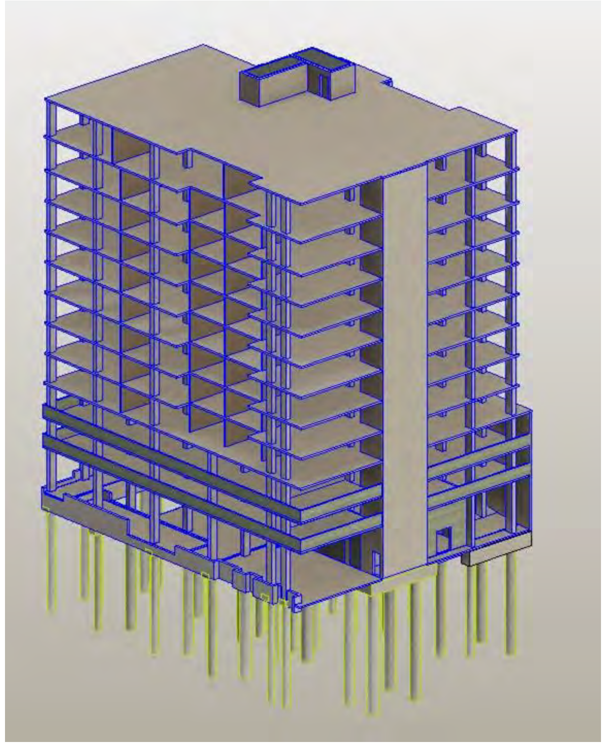
Denver, Colorado



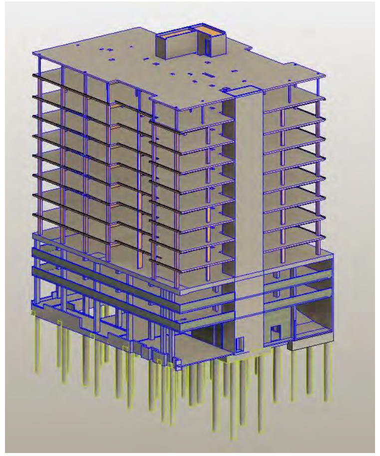
MASS TIMBER
(AS DESIGNED)

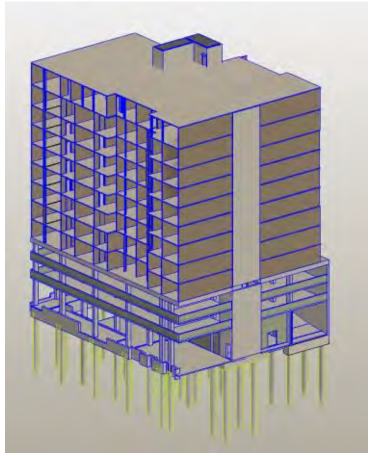


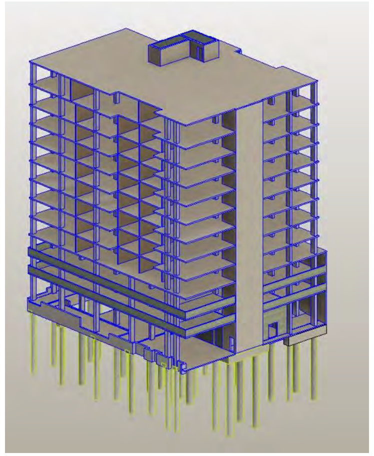
STEEL
(CFS & DECK)

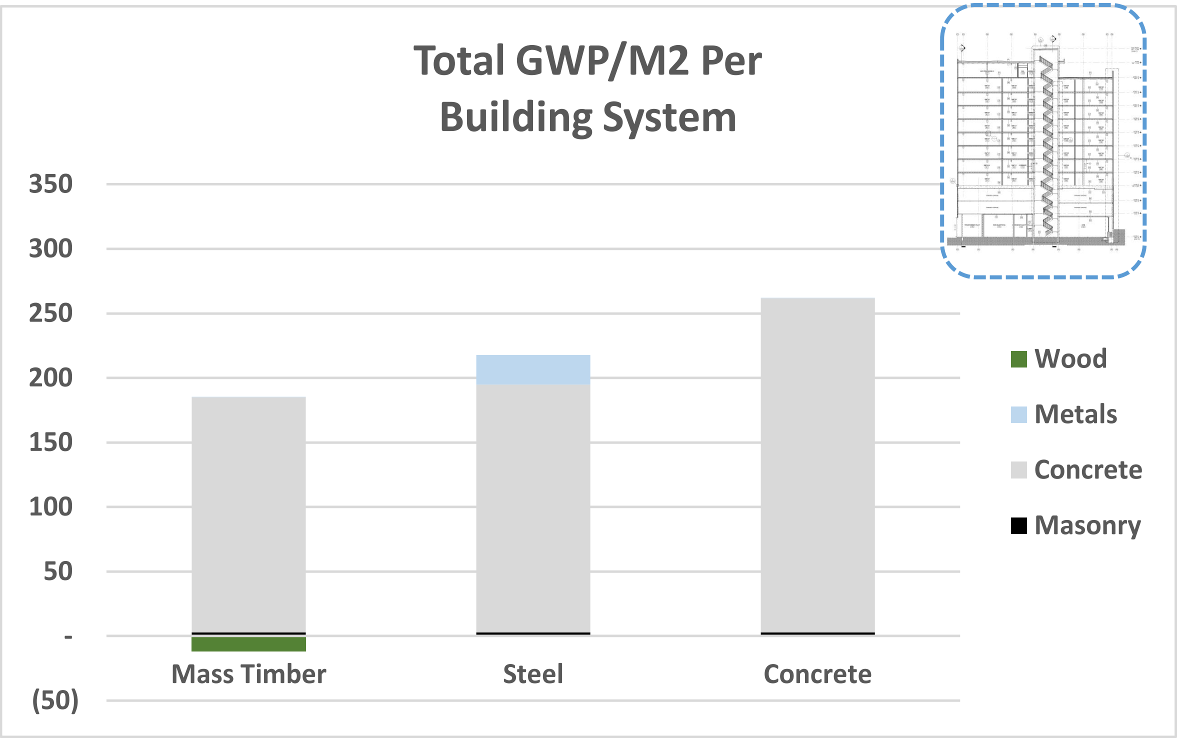


PT CONCRETE

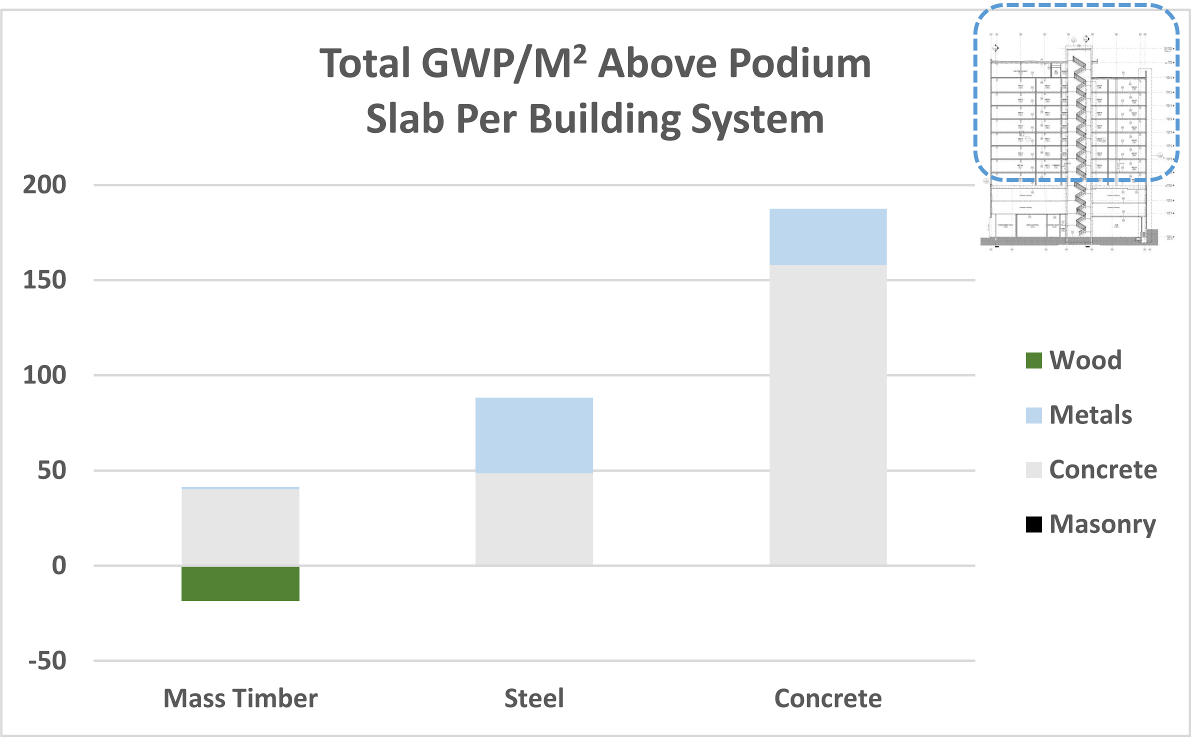




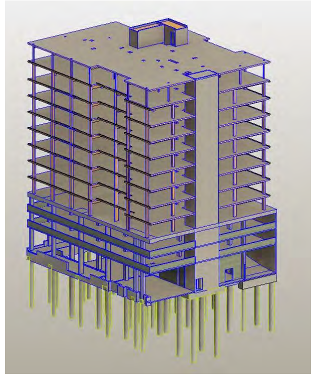
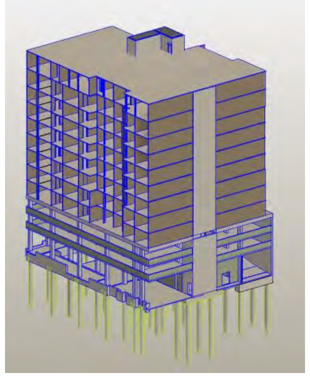
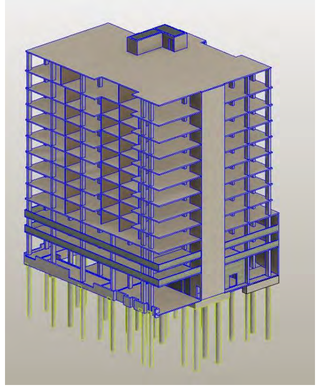
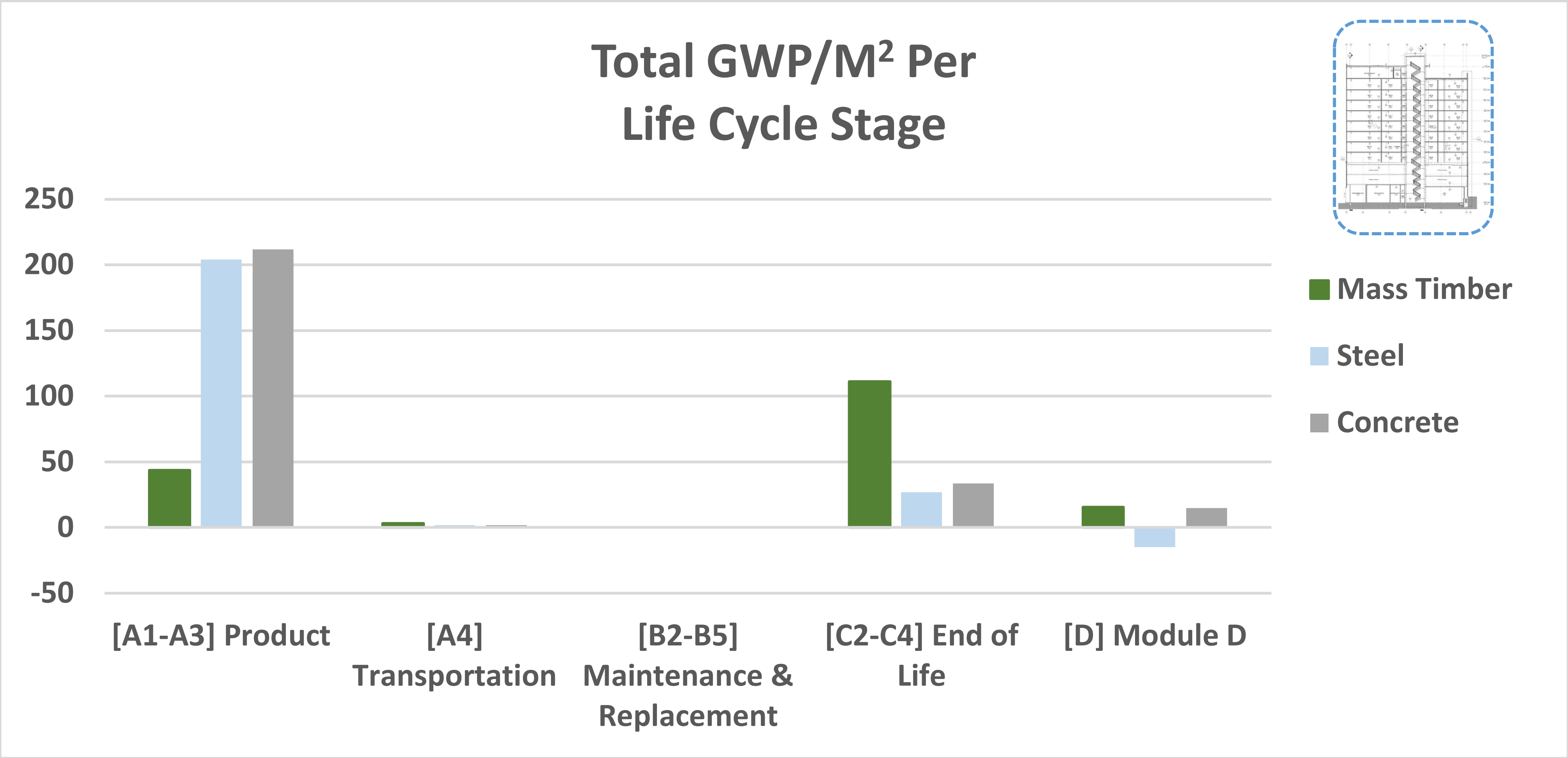


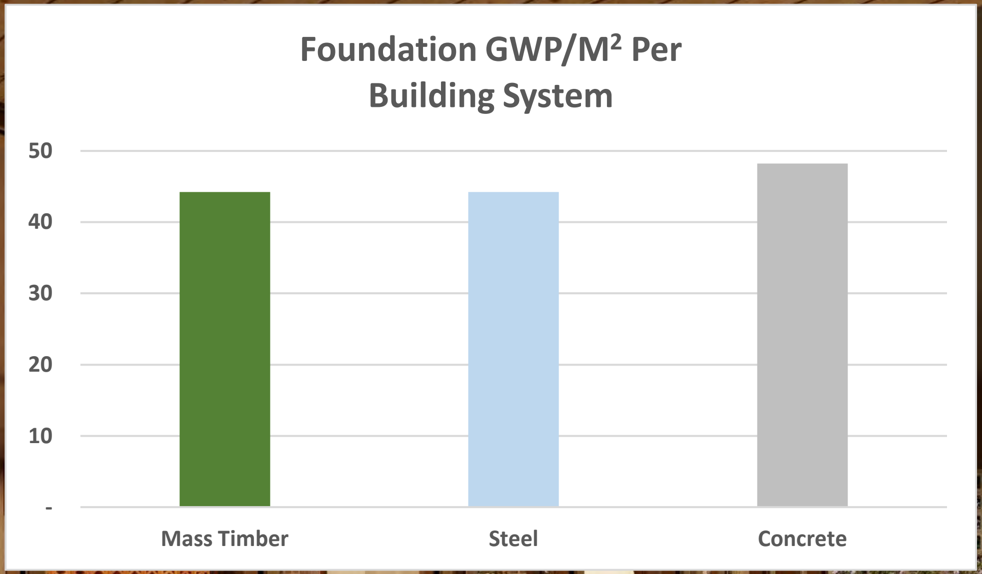


Total GWP/M2 Per Building System
350
300
250
200
150
100
50
-
(50)
Mass Timber
Steel
Concrete
Wood
Metals
Concrete
Masonry

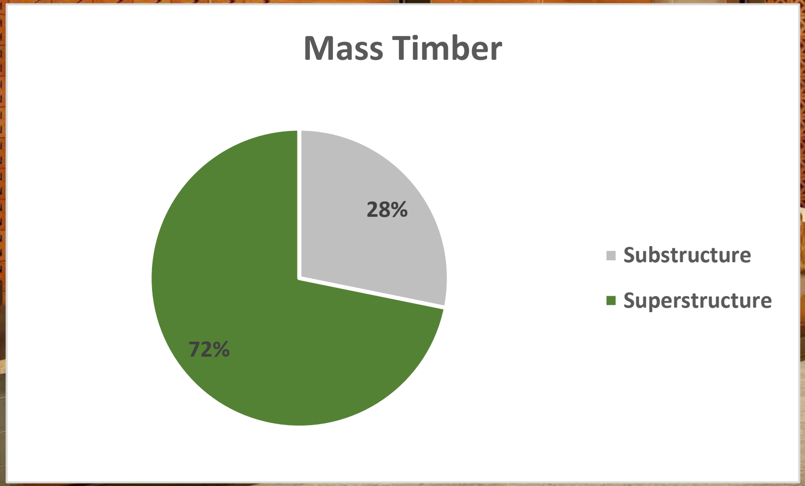


Total GWP/M² Above Podium Slab Per Building System
200
150
100
50
0
-50
Mass Timber
Steel
Concrete
Wood
Metals
Concrete
Masonry

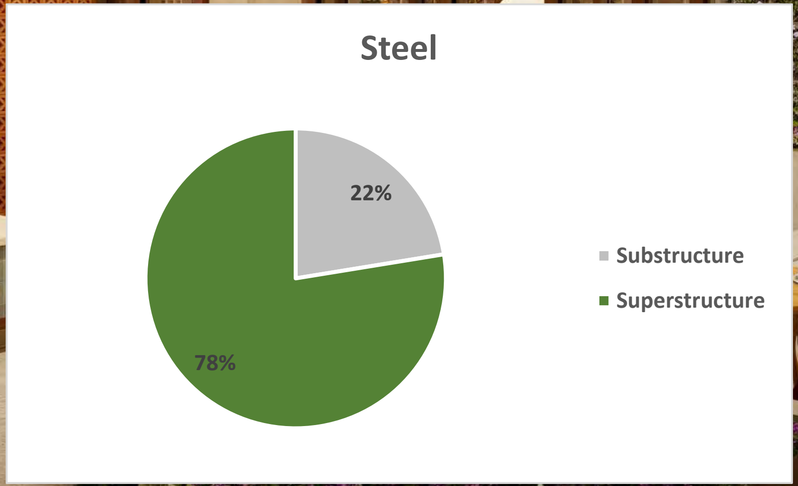




Total GWP/M² Per
Life Cycle Stage
250
200
150
100
50
0
-50
[A1-A3] Product
[A4] Transportation
[B2-B5] Maintenance & Replacement
[C2-C4] End of Life
[D] Module D
Mass Timber
Steel
Concrete



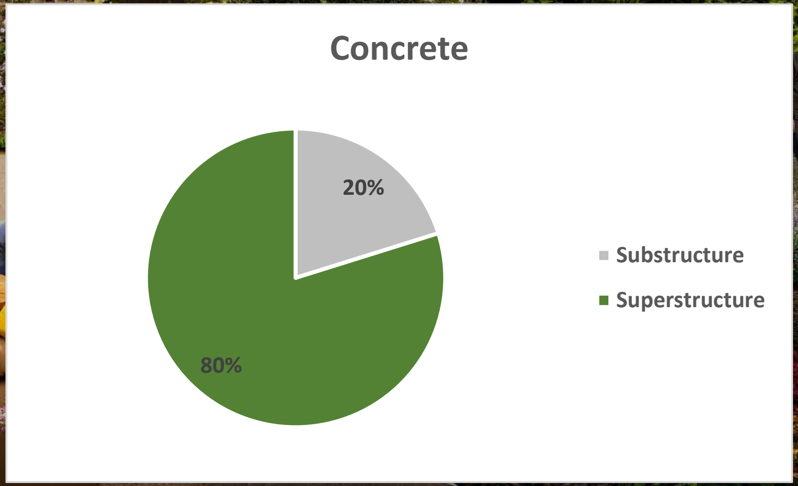
Foundation GWP/M² Per Building System
50
40
30
20
10
-
Mass Timber
Steel
Concrete



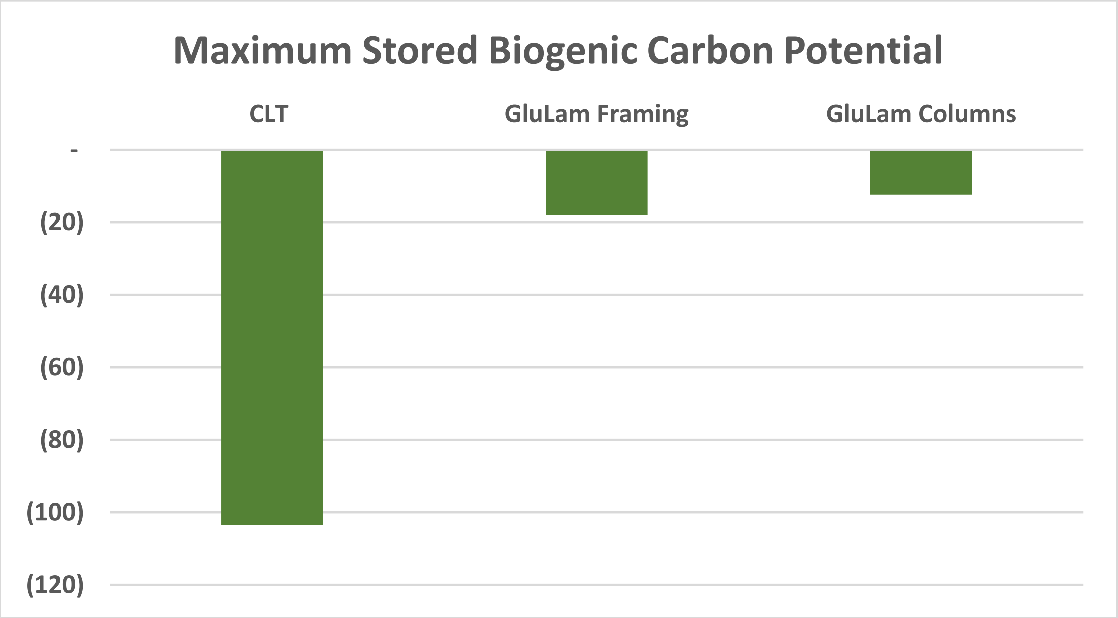
Mass Timber
28%
72%
Substructure
Superstructure



Steel
22%
78%
Substructure
Superstructure



Concrete
20%
80%
Substructure
Superstructure



1738 Metric Ton of CO_2eq

= 4.3 Million Miles Driven by Standard Vehicle
= 240 First Class Roundtrip Flights from Denver to London
= 335 Homes' Electricity Use for 1 Year

= 5 Minutes for US and Canadian Forests to Grow

Office / Retail

Type III-B over IA Construction, IBC 2015

7 Story

- P2: Concrete Mat Slab Foundation
- P1, L1: Concrete Slabs
- L2: Concrete Podium Slab
- L3- Roof: Mass Timber

Concrete Cores

30' x 30' Grid

Multifamily / Retail

Type IV-B Construction

12 Story

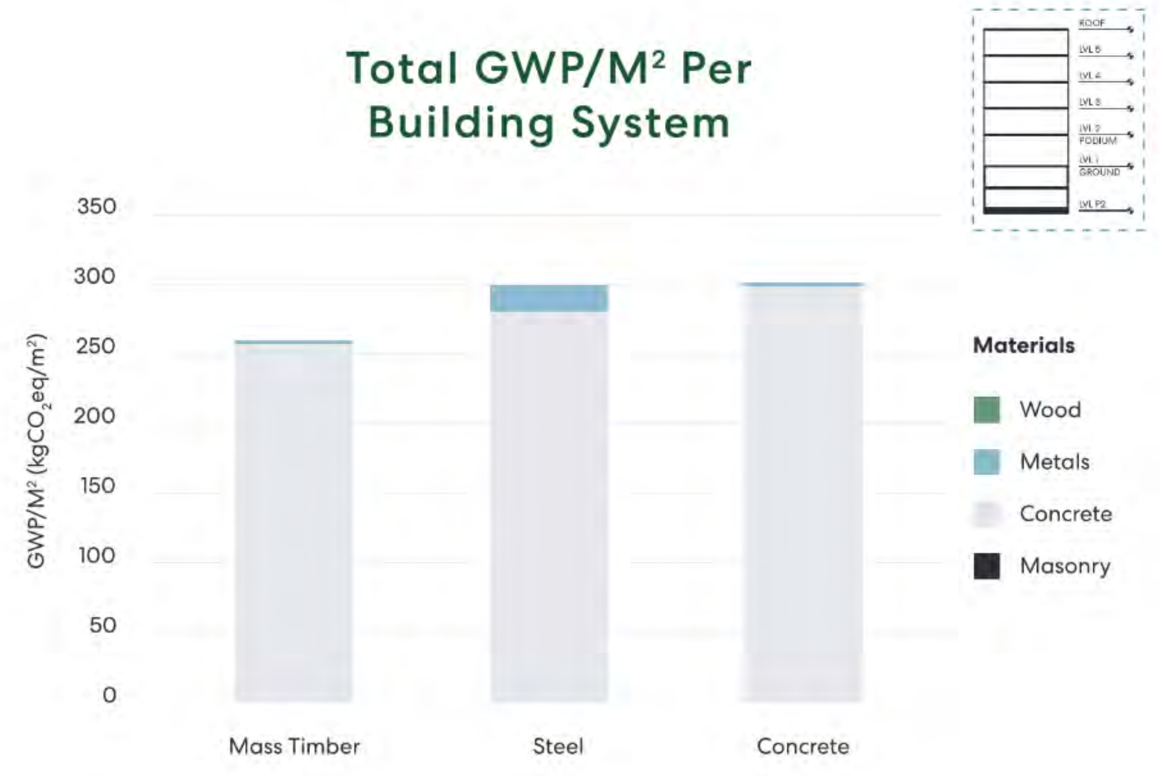
- No below grade
- L1: Drilled Piers + Concrete Slab on Grade
- L2-L4: Concrete Slabs
- L5 - Roof: Mass Timber

Concrete Cores

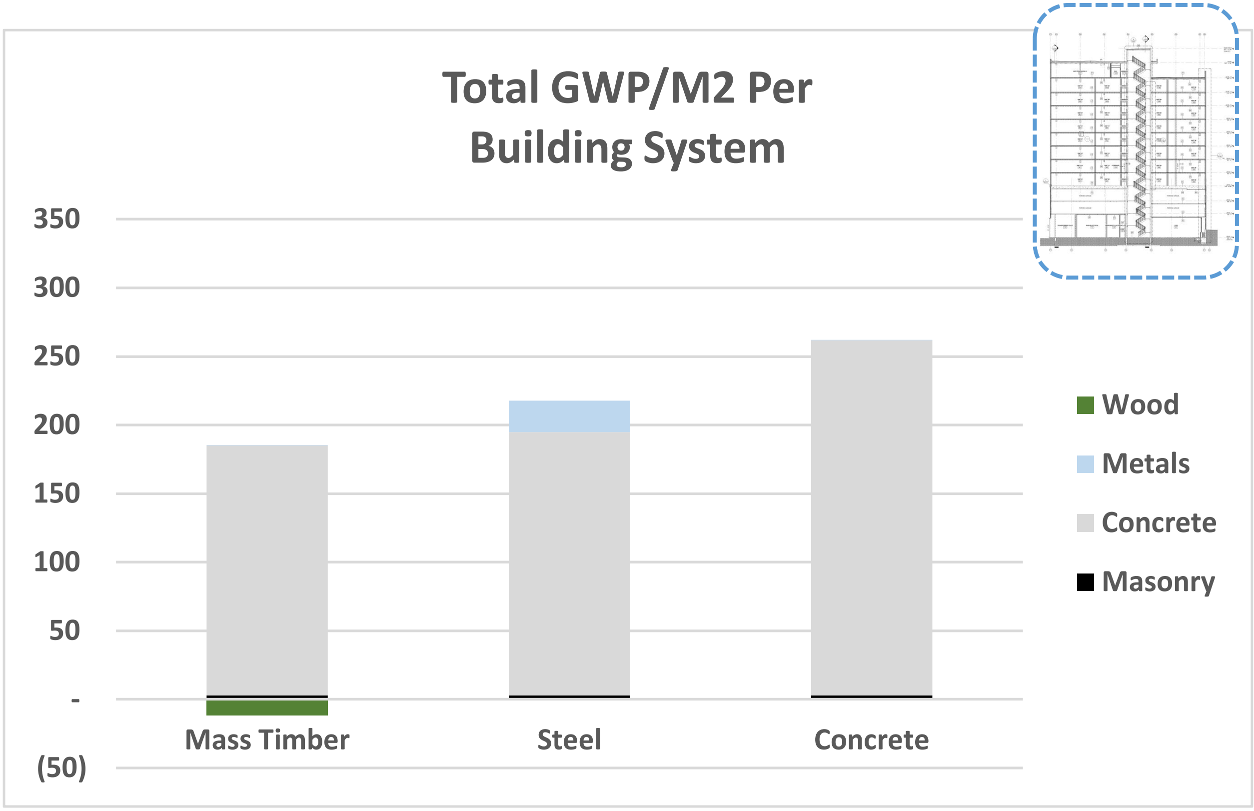
20' x 20' Grid

PLATTE FIFTEEN
&
RETURN TO FORM

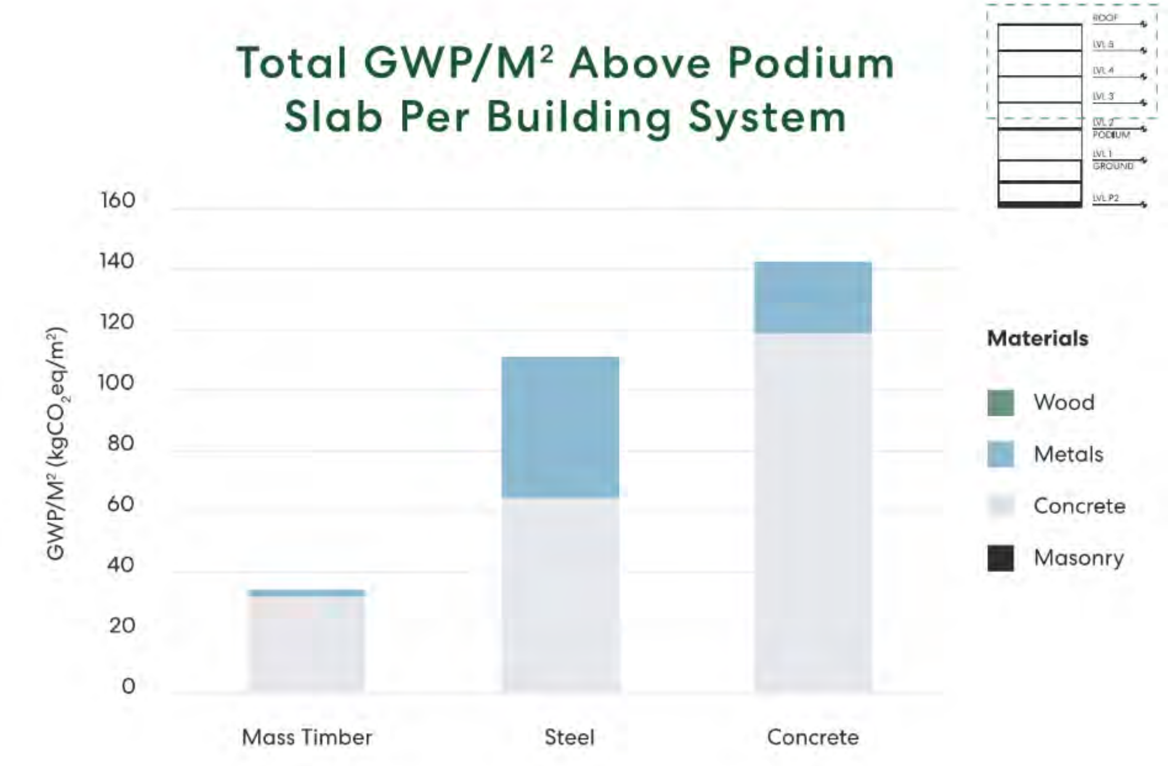
PLATTE FIFTEEN



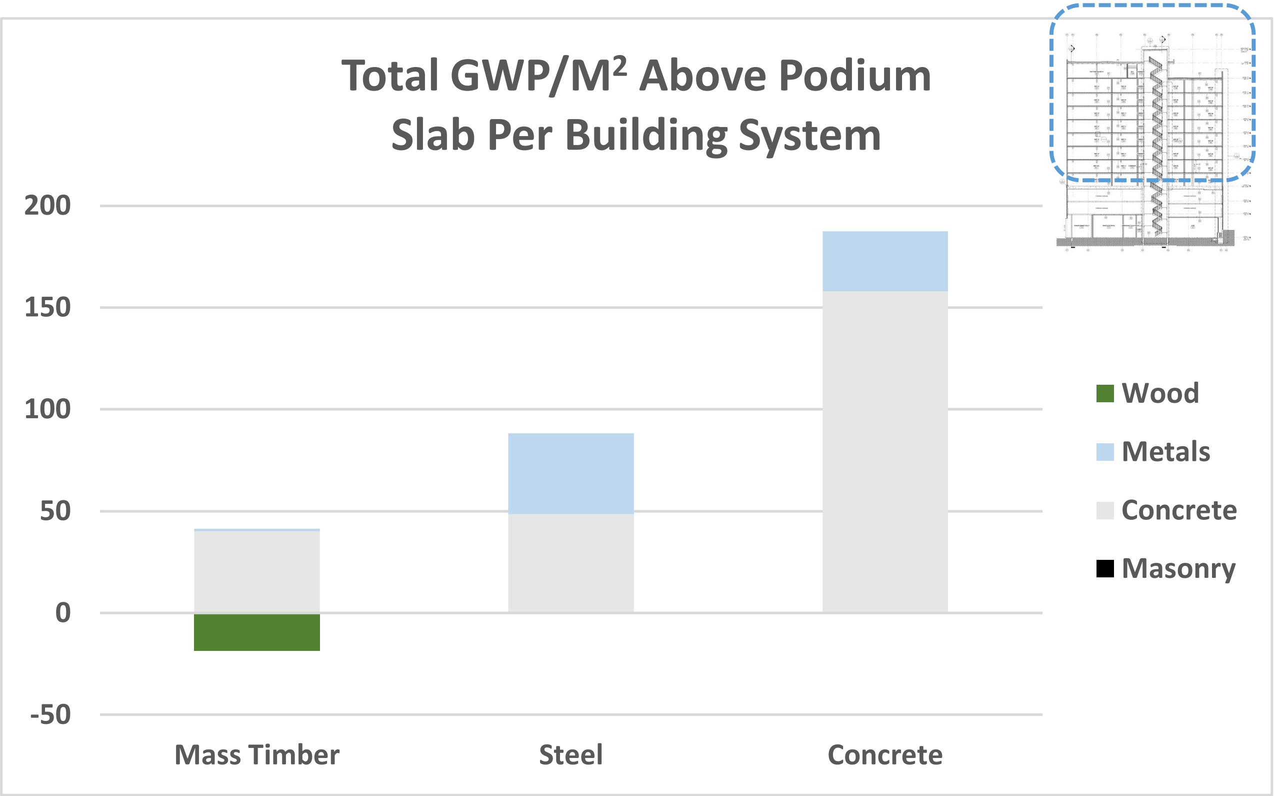
RETURN TO FORM



PLATTE FIFTEEN



RETURN TO FORM



HOW TO LEVERAGE MASS TIMBER IN DESIGN

- COST
  - GRID EFFICIENCY
  - PANEL OPTIMIZATION
  - BEARING & SCREWED CONNECTIONS
  - FINISHES
- PREFABRICATION
  - PANELIZED SYSTEM
  - COORDINATE & PRECUT
- SPEED OF CONSTRUCTION
  - CORE WALLS CRITICAL PATH
  - PREFABRICATED/ PANELIZED FAÇADE
  - PANEL SEQUENCING
  - TEMPORARY PROTECTION

- DESIGN FOR DISASSEMBLY / EASE OF DECONSTRUCTION & RECOVERY

Photo Credit: JC Buck

MASS TIMBER IS SUSTAINABLE…

- LOW EMBODIED CARBON
- STORES CARBON
- RENEWABLE
- REUSABLE
  - EASE OF DECONSTRUCTION & RECOVERY

Photo by Aleksandar Radovanovic on Unsplash

UNDER CONSTRUCTION, MASS TIMBER…

- IS FAST
- IS QUIET
- IS LIGHTER
- REQUIRES LIMITED LABOR
- HAS LITTLE WASTE
- REDUCES CONSTRUCTION TRAFFIC

IN THE FINISHED BUILDING, MASS TIMBER…

- IS HEALTHY - CREATES BIOPHILIC ENVIRONMENT
- NATURAL AESTHETIC
- HIGH LEASE RATES
- HIGH LEASING VELOCITY
- ADVANCES DEVELOPER BRANDING, ESG COMMITMENTS
- EARNS CARBON CREDITS, GREEN FINANCING

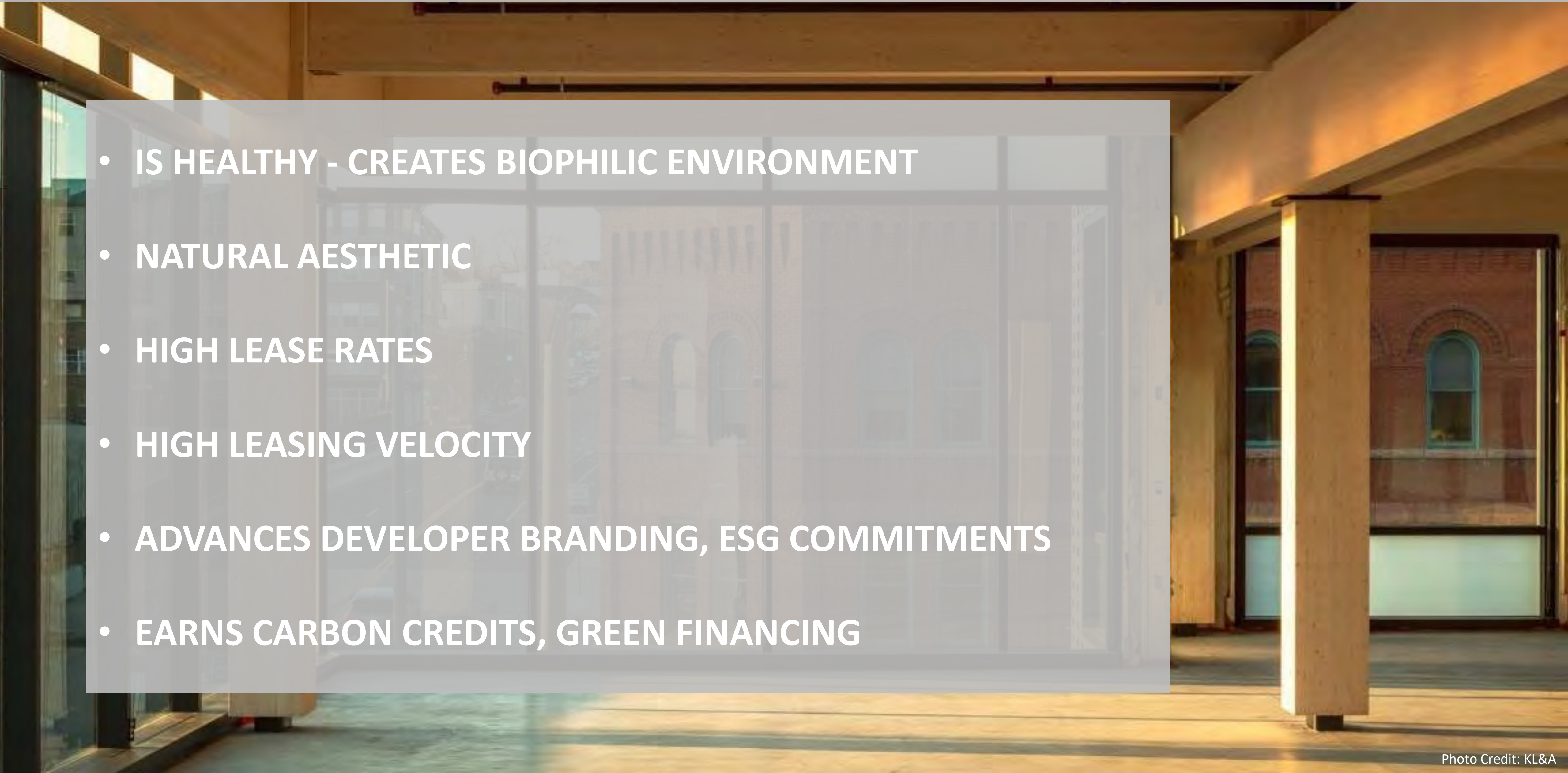


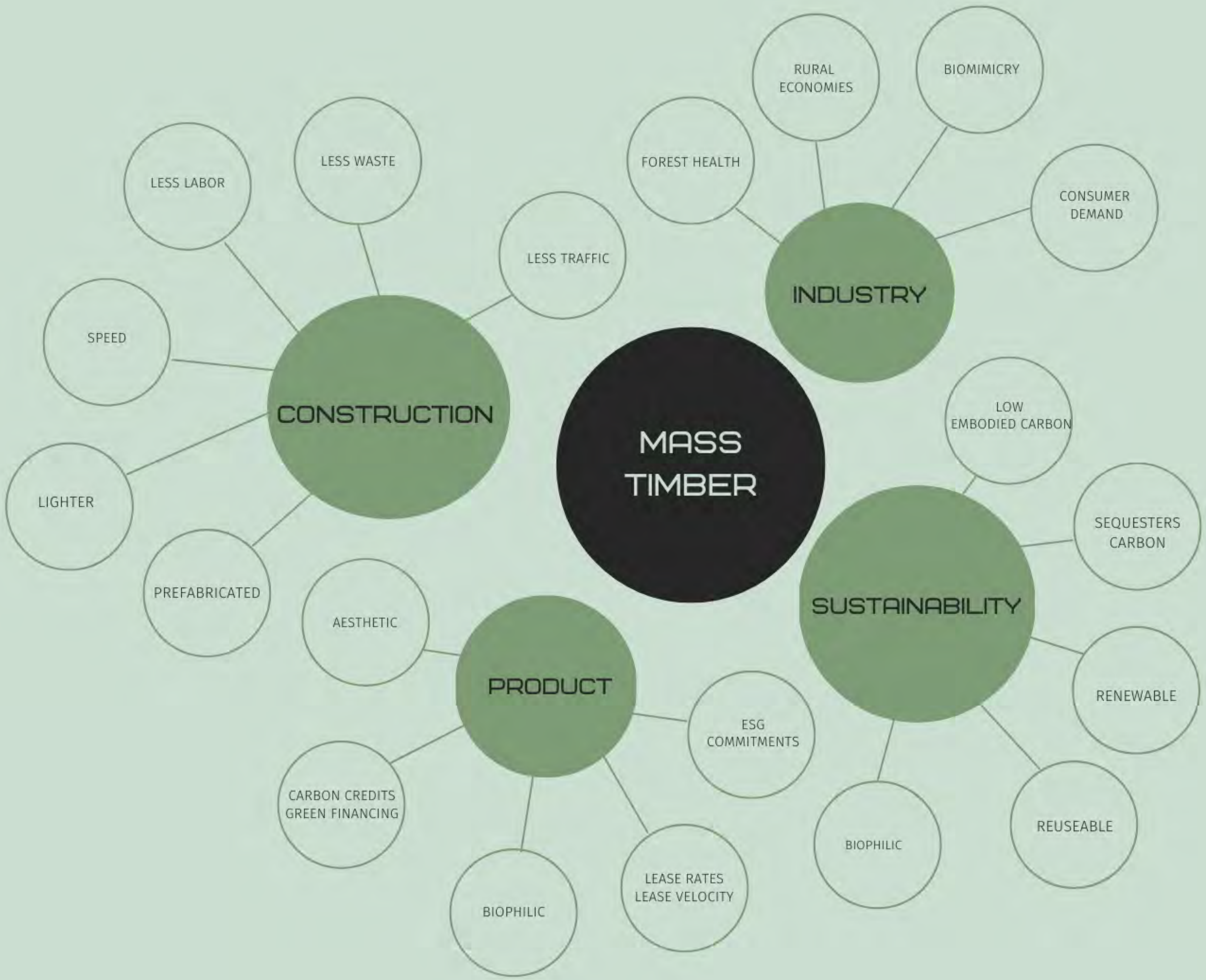
Photo Credit: KL&A

MASS TIMBER INDUSTRY…

- ENCOURAGES FOREST HEALTH & MAINTENANCE
- SUPPORTS RURAL ECONOMIES
- LEVERAGES BIOMIMICRY
- RESPONDS TO SOCIETAL DEMAND FOR SUSTAINABLE CONSUMER PRODUCTS

Photo by Joel Vodell on Unsplash


Photo Credit: JC Buck


MASS TIMBER
CONSTRUCTION
LESS LABOR
LESS WASTE
LESS TRAFFIC
SPEED
LIGHTER
PREFABRICATED
INDUSTRY
FOREST HEALTH
RURAL ECONOMIES
BIOMIMICRY
CONSUMER DEMAND
SUSTAINABILITY
LOW EMBODIED CARBON
SEQUESTERS CARBON
RENEWABLE
REUSEABLE
BIOPHILIC
PRODUCT
AESTHETIC
ESG COMMITMENTS
LEASE RATES LEASE VELOCITY
BIOPHILIC
CARBON CREDITS GREEN FINANCING

THANK YOU

Alexis Feitel, PE, Team Carbon Unit Director & Structural Engineer afeitel@klaa.com

Photo Credit: JC Buck