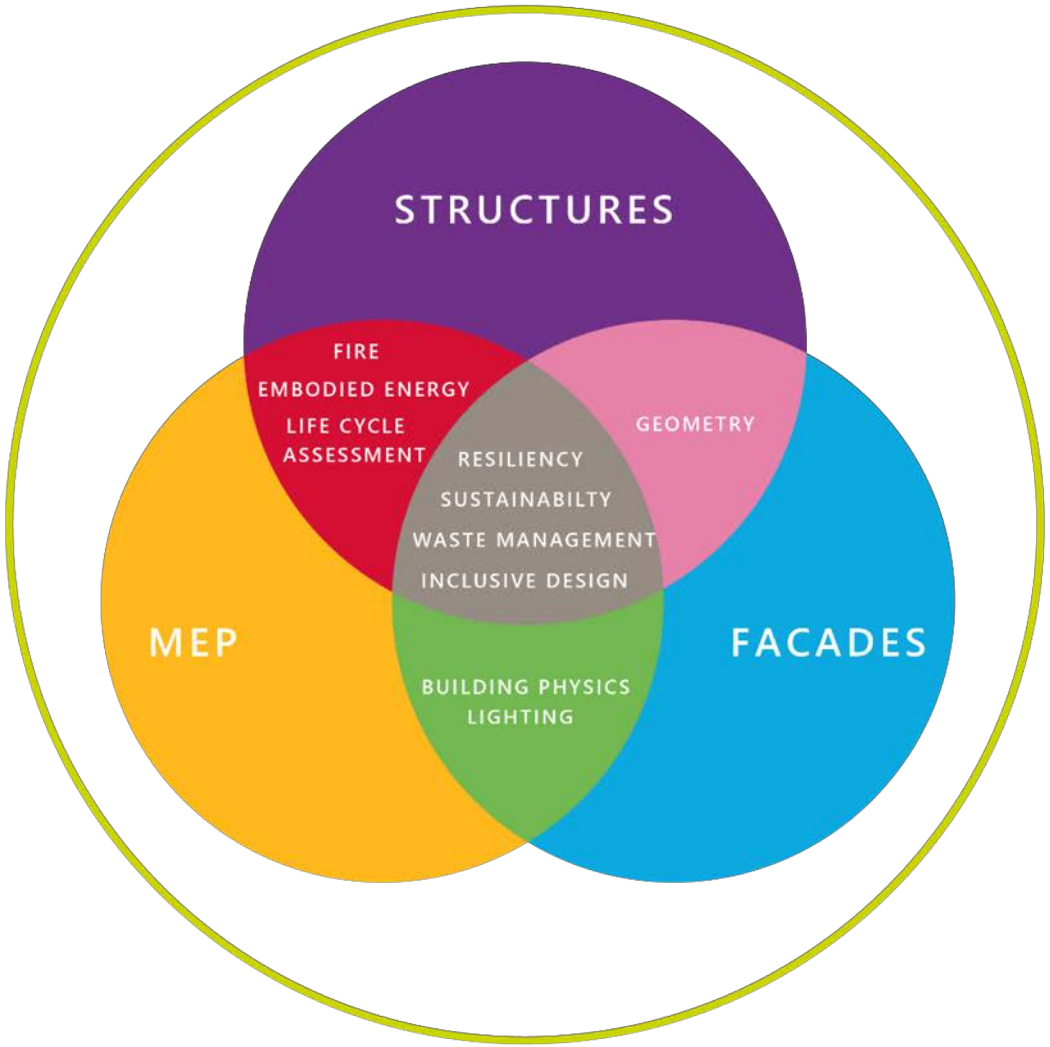
LIFE CYCLE ASSESSMENT

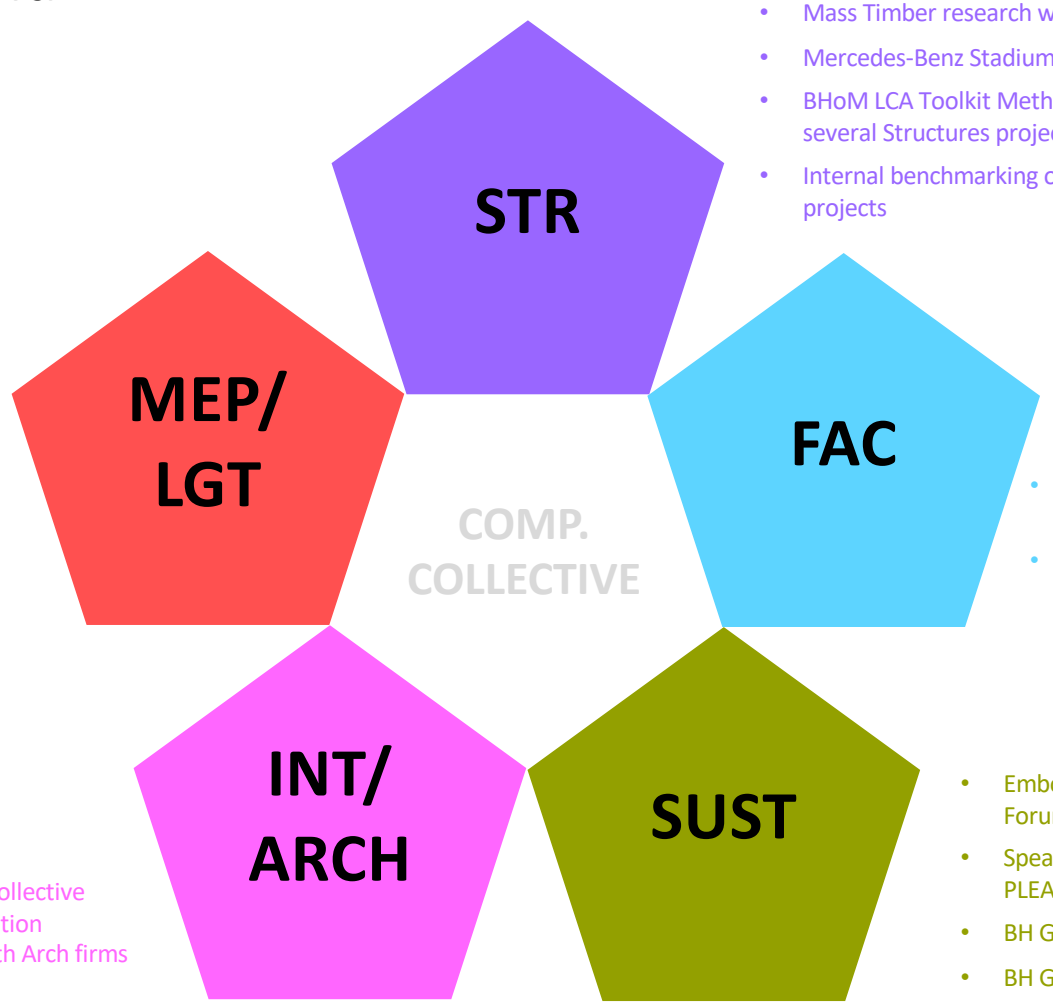
Centering **embodied carbon** as a key design driver will illuminate **diverse structural pathways** to low-carbon designs.

Buro Happold Disciplines



BURO HAPPOLD

LCA @ Buro Happold



- Mass Timber research with MIT
- Mercedes-Benz Stadium LEEDv4 LCA
- BHoM LCA Toolkit Methods developed + used on several Structures projects
- Internal benchmarking of embodied carbon of past projects

- Refrigerant research
- MEP embodied carbon calcs via BHoM
- Collaboration with KieranTimberlake & Eskew+Dumez+Ripple on establishing North America MEP LCA protocol and database
- MEP Embodied Carbon R&D Effort

- Passive House study using The House at Cornell Tech
- Insulation options with healthy material overlay

- Computational Collective leading collaboration opportunities with Arch firms

- Embodied Carbon Network and Carbon Leadership Forum membership
- Speaking (e.g. UPenn guest lecture, AIA ECN, BSA 101, PLEA 2020)
- BH Global scope and Corporate Sustainability
- BH Global collaboration

BURO HAPPOLD

Buro Happold Team

Julie Janiski
Project Advisor

Principal, Integrated Design
Buro Happold Engineering

Paul Richardson
Structural Advisor

Principal, Structures
Buro Happold Engineering

Aurora Jensen
Lead LCA Analyst

Sustainability and Analytics
Buro Happold Engineering

BURO HAPPOLD

Integrated Team

BURO HAPPOLD

Structural Engineering

Life Cycle Assessment

Sustainability Consulting

Thermal Performance

MEP Engineering

GENERATE

Architectural Design

Olifant

INVEST IN WHAT'S BIGGER

Market Development

Carbon Policy

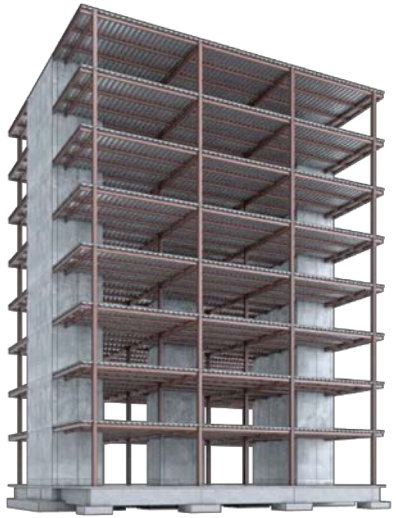
BURO HAPPOLD

Mass Timber Solutions I

A Comparative Study of GHG emissions for an Eight Story Mixed-Use Building

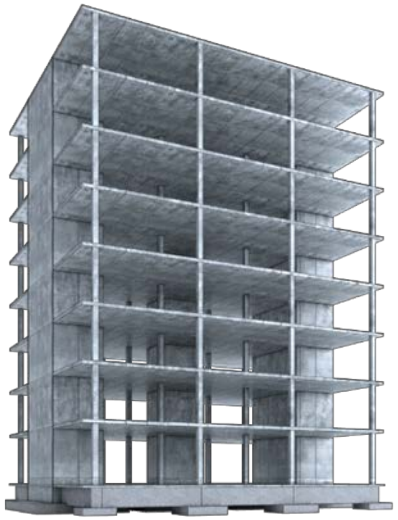
August 20, 2020

Design Options



Reference 1

Concrete Slab on Steel Frame
>=20’ grid
Full encapsulation



Reference 2

Concrete Flat Slab
>=20’ grid
No encapsulation

concrete cores

BURO HAPPOLD

Design Options

Timber 1

Timber Post & Plate
<=12’ grid
Full encapsulation

Timber 2

Timber Post, Beam & Plate
12’ to 20’ grid
Full encapsulation

Timber 3

Timber Post, Beam & Plate
12’ to 20’ grid
Partial encapsulation

Timber 4

Timber Post, Beam & Plate
12’ to 20’ grid
Partial encapsulation

Timber 5

Timber Post, Beam & Plate
12’ to 20’ grid
Exposed char layer

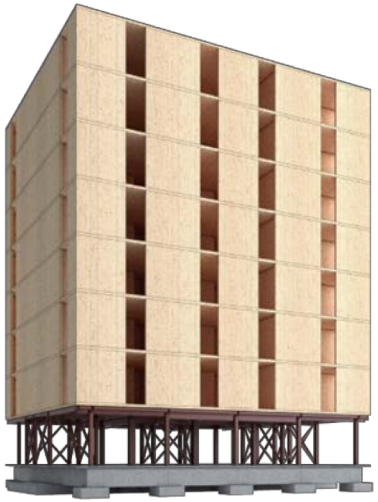
concrete cores

BURO HAPPOLD

Design Options

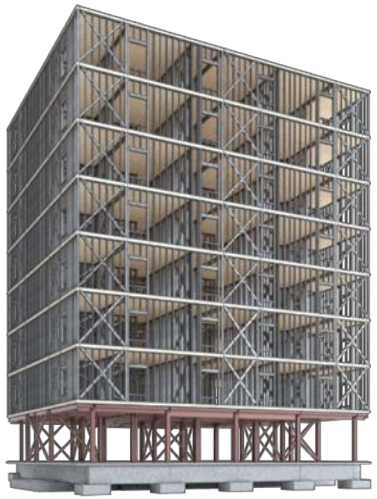
Timber 6

Timber Post, Beam & Plate
>=20’ grid
Partial encapsulation



Timber 7

Timber Floors & Shear Walls
<=12’ grid
Partial encapsulation



Timber 8

Timber Floors & LGM Framing
<=12’ grid
Partial encapsulation

Timber 9

Timber Floors & Steel Frame
12 to 20’ grid
Partial encapsulation

concrete cores

cellular framing on steel frame podium

steel-timber hybrid

BURO HAPPOLD

Study Parameters

Functional Equivalence

Program	Level 1 retail, Levels 2-8 residential program
Structure	Approximately Level of Development (LOD) 200 without optimizations
Fire Rating	Encapsulation to meet IBC requirements
Thermal	Opaque assemblies R-26.5; Glazing U-0.54; WWR of 23% on N/S curtainwall, 7% on E/W
Acoustic	Vertical STC rating of 55

System Boundary

CRADLE-TO-GATE
- A1. Raw Material Supply
- A2. Transport
- A3. Manufacturing
- X. Biogenic Carbon (-)

CONSTRUCTION
- A4. Transport
- A5. Construction and Installation

USE
- B1. Use
- B2. Maintenance
- B3. Repair
- B4. Replacement
- B5. Refurbishment
- B6. Operational Energy
- B7. Operational Water

END-OF-LIFE
- C1. Demolition
- C2. Transport
- C3. Waste Processing
- C4. Disposal
- X2. Biogenic Carbon (+)
- D. Benefits and Loads
  - 1. Reuse
  - 2. Recycling
  - 3. Energy Recovery

Building Elements

Foundations
- Mat slabs
- Footings

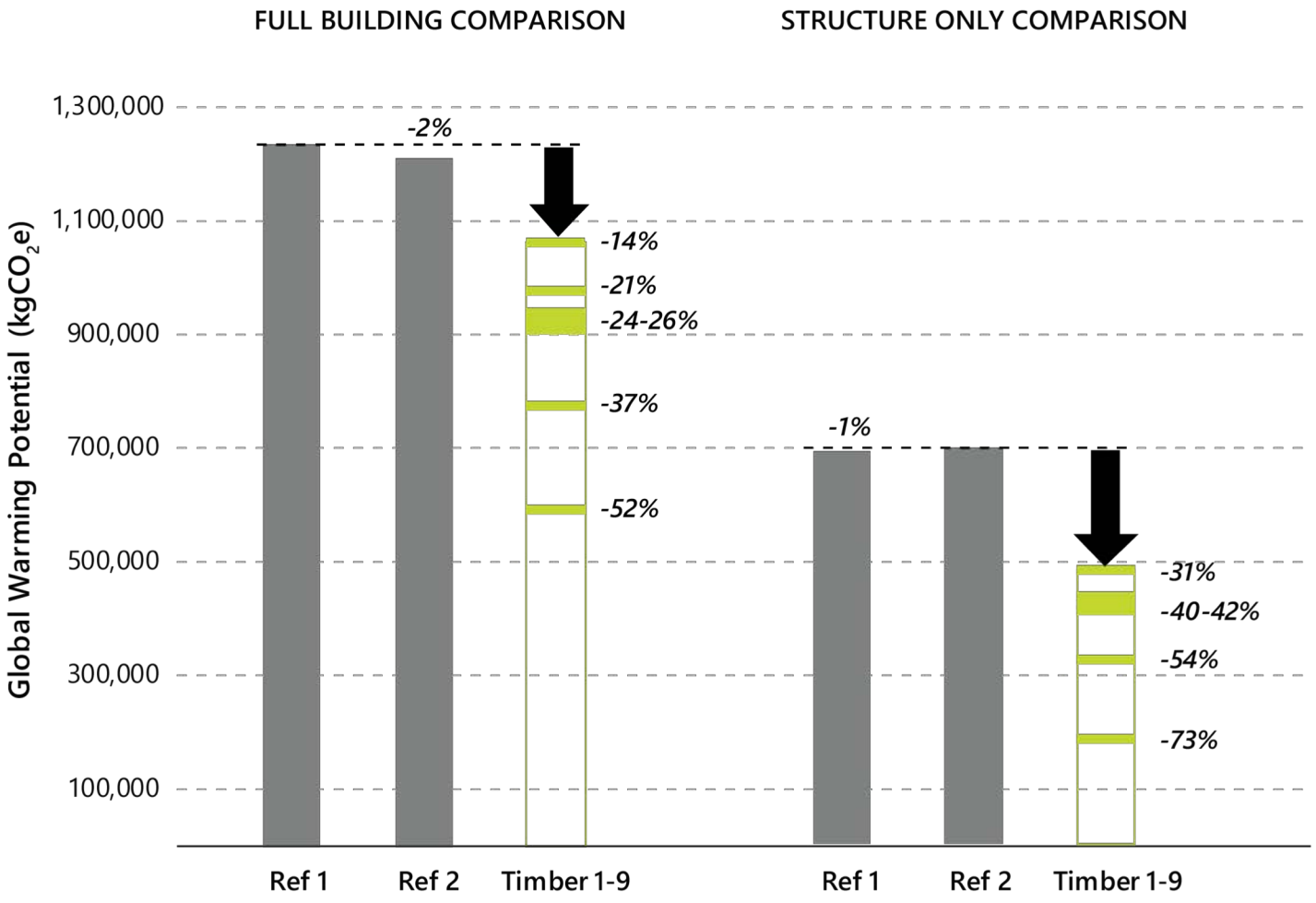
Structure
- Slab on Grade
- Elevated slabs
- Structural framing
- Columns
- Structural Walls

Enclosure
- Curtainwall
- Glazing
- Façade
- Roofing

Interiors
- Interior walls
- Encapsulation
- Flooring

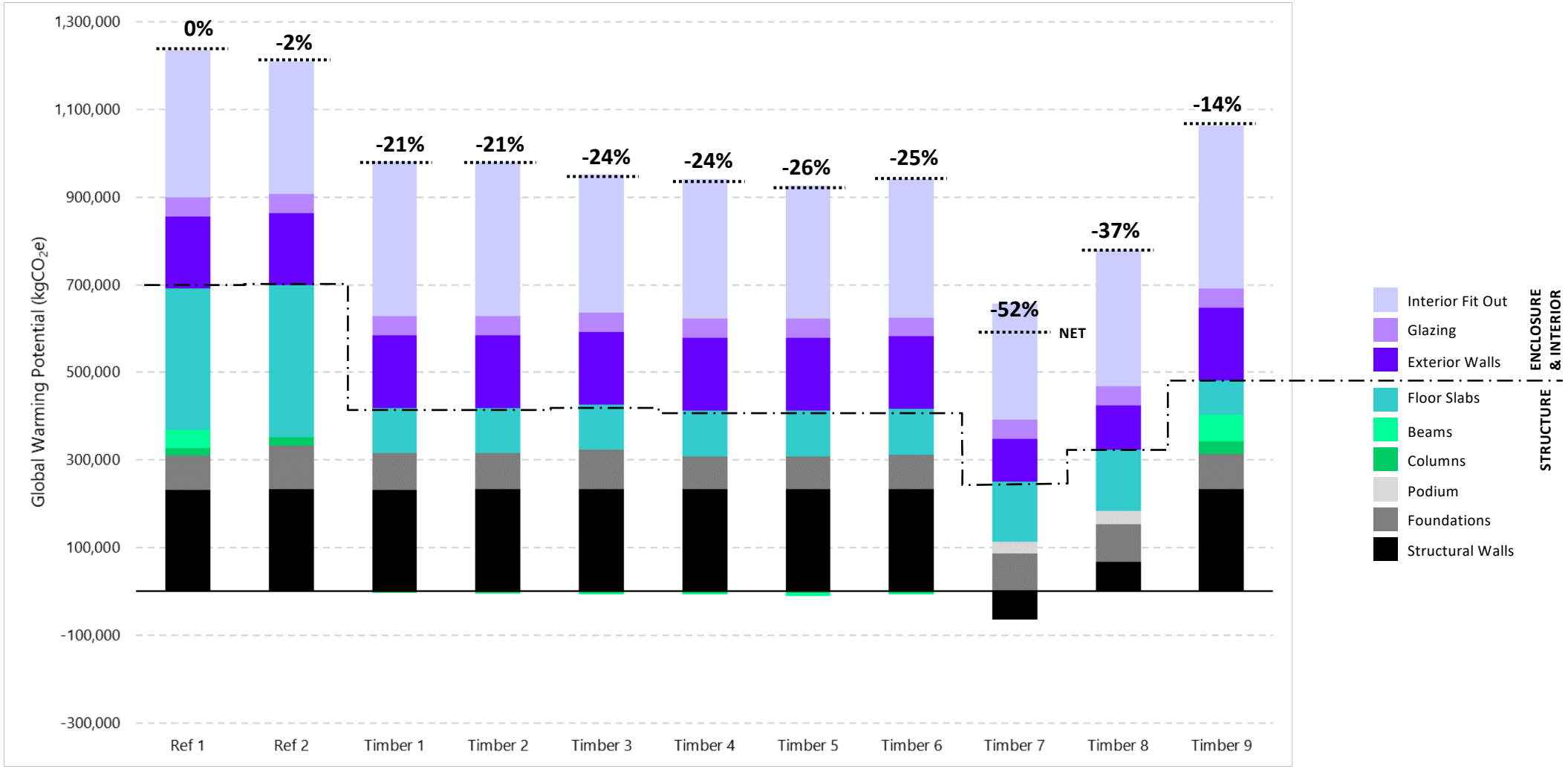
BURO HAPPOLD

Full Building and Structural Comparison



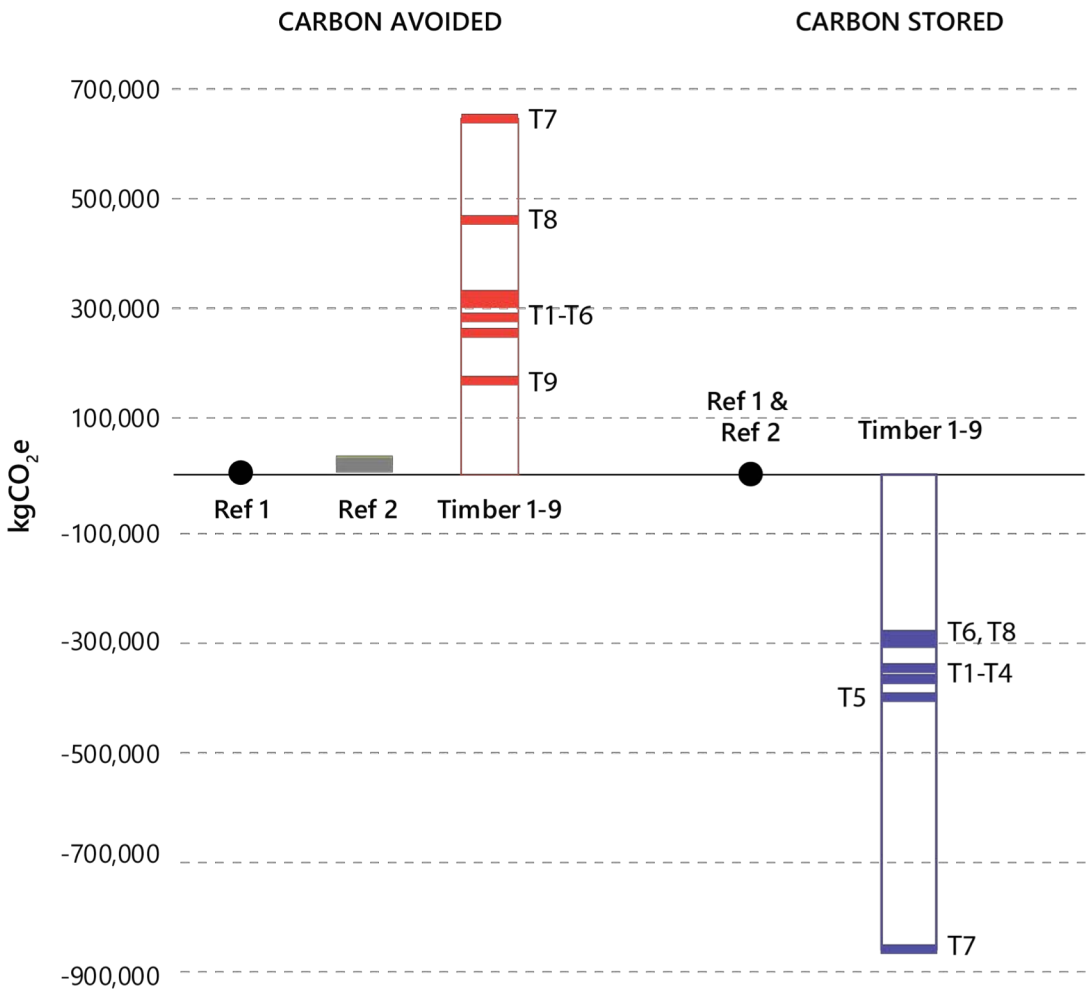
BURO HAPPOLD

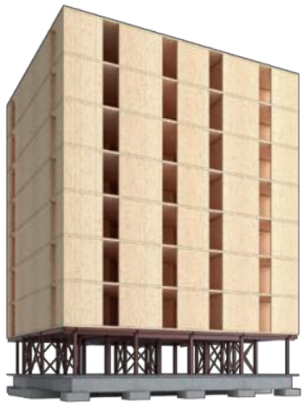
Full Building by Element



BURO HAPPOLD

Carbon Avoided and Stored



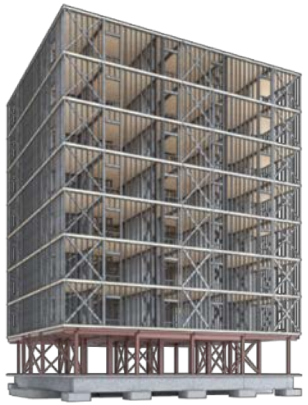


Timber 7

Timber Floors & Shear Walls

<=12’ grid

Partial encapsulation



Timber 8

Timber Floors & LGM Framing

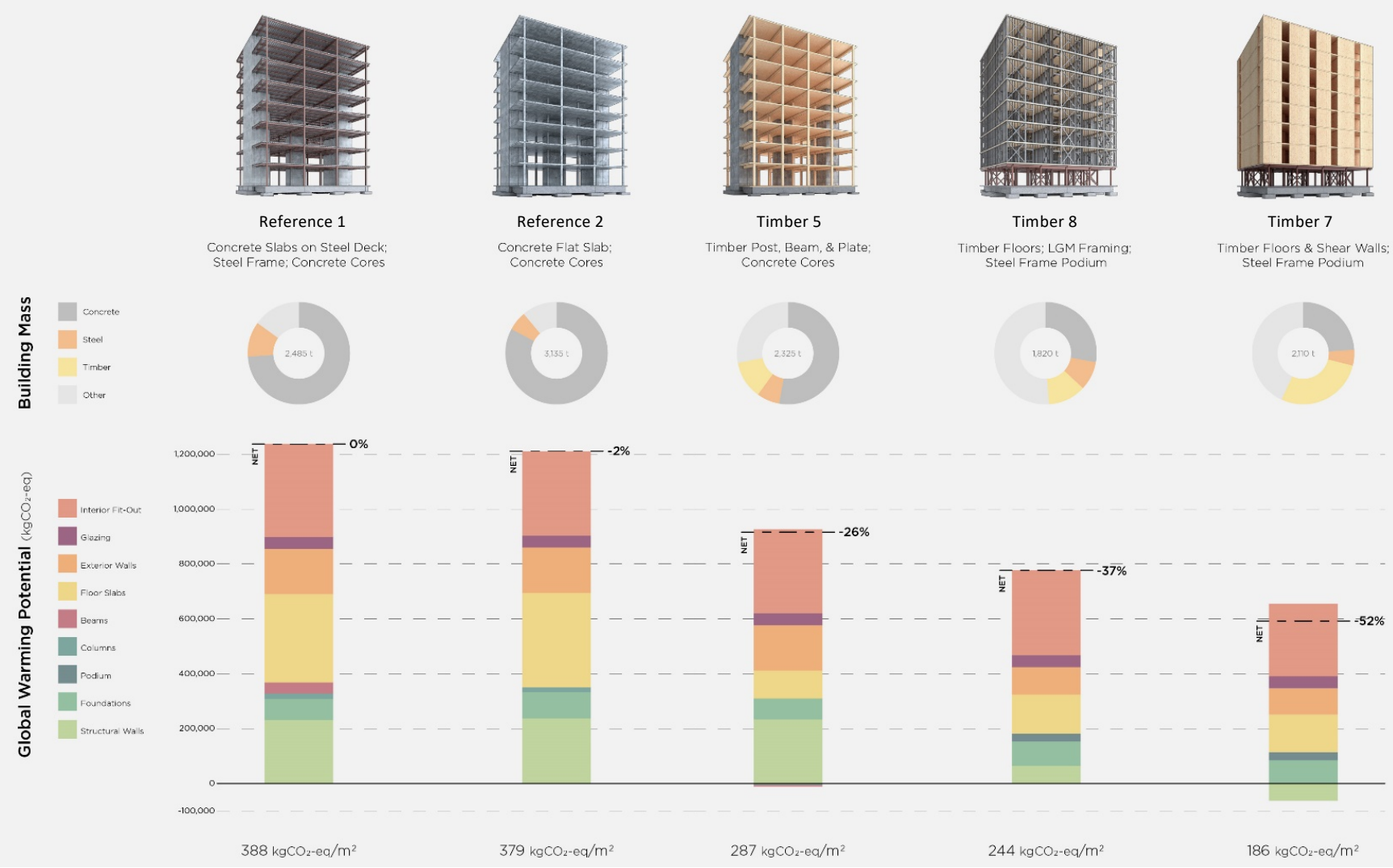
<=12’ grid

Partial encapsulation

BURO HAPPOLD

Study Conclusions

- **Designing with mass timber** can yield lower whole building embodied carbon
- **Engineering out the concrete core walls** led to the most consequential GWP reductions 37-52%.
- **Using larger grid spacing and exposing timber members** led to the largest GWP reduction (among T1-T6)
- **Fireproofing and acoustic equivalence** did not significantly impact the GWP reductions of the timber designs.



BURO HAPPOLD

BURO HAPPOLD

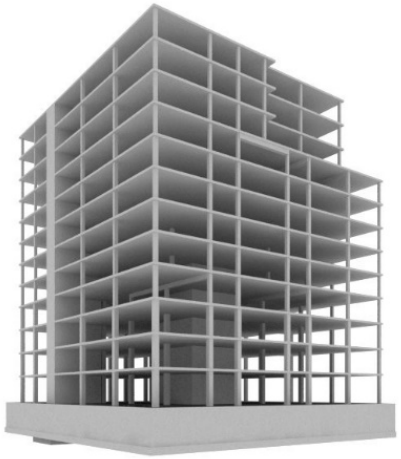
Mass Timber Solutions II

A Comparative Study of GHG emissions for a Twelve Story Mixed-Use Building

Design Options

Reference 1

Concrete Slab on Steel Frame
14-30’ grid
Full encapsulation
Code compliant



Reference 2

Concrete Flat Slab
14-30’ grid
Encapsulation as finish
Code compliant

concrete cores

BURO HAPPOLD

Design Options

Timber A

Hybrid Timber/Steel
14-30’ grid
Partial encapsulation
Code compliant

Timber B

Hybrid Timber/Steel
14-30’ grid
Partial encapsulation
Code variant

Timber C

Timber Post, Beam & Plate
14-30’ grid
Char layer for fire
Code variant

Timber D

Timber Post, Beam & Plate
14-30’ grid
Partial encapsulation
Code compliant

Timber E

Timber Post, Beam & Plate
14-30’ grid
Partial encapsulation
Code variant

concrete cores

steel-timber hybrid

BURO HAPPOLD

Study Parameters

Functional Equivalence

Program	B basement; L1 Commercial, Retail ,BOH; L2-L4 – Office; L5-12 residential
Structure	Approximately Level of Development (LOD) 200 without optimizations, same structural spans
Fire Rating	Encapsulation to meet IBC requirements, showing code compliant and code variant options
Thermal	Opaque assemblies R-17.5; Punched glazing U-0.42; Curtainwall Glazing U-0.38; WWR 33%
Acoustic	Vertical STC/IIC rating of 55

System Boundary

CRADLE-TO-GATE
- A1. Raw Material Supply
- A2. Transport
- A3. Manufacturing
- X. Biogenic Carbon (-)

CONSTRUCTION
- A4. Transport
- A5. Construction and Installation

USE
- B1. Use
- B2. Maintenance
- B3. Repair
- B4. Replacement
- B5. Refurbishment
- B6. Operational Energy
- B7. Operational Water

END-OF-LIFE
- C1. Demolition
- C2. Transport
- C3. Waste Processing
- C4. Disposal
- X2. Biogenic Carbon (+)
- D. Benefits and Loads
  - 1. Reuse
  - 2. Recycling
  - 3. Energy Recovery

Building Elements

Foundations
- Mat slabs
- Footings
- Piles, Pile Caps

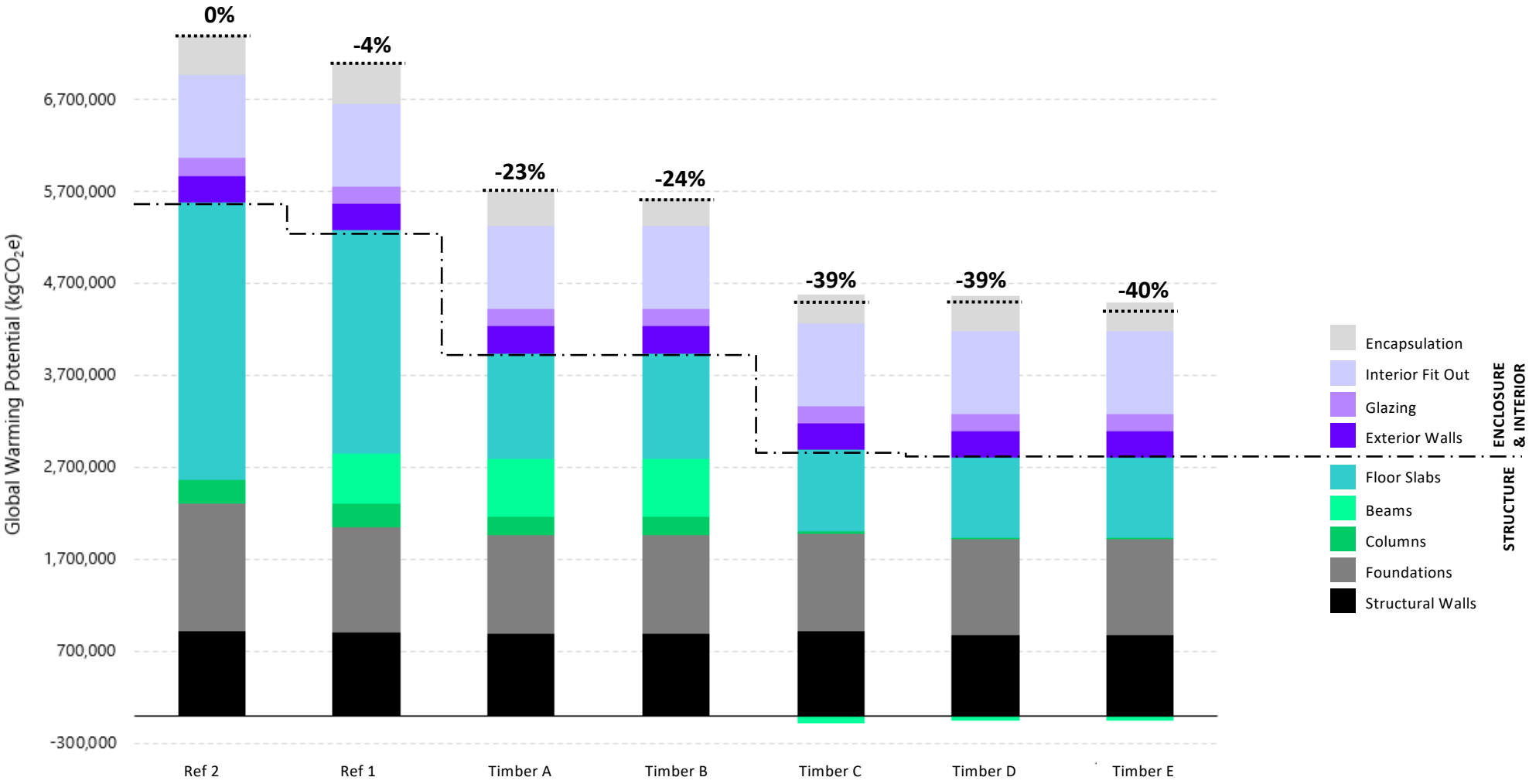
Structure
- Slab on Grade
- Elevated slabs
- Structural framing
- Columns
- Structural Walls

Enclosure
- Curtainwall
- Glazing
- Façade
- Roofing

Interiors
- Interior walls
- Encapsulation
- Flooring
- Ceilings
- Doors

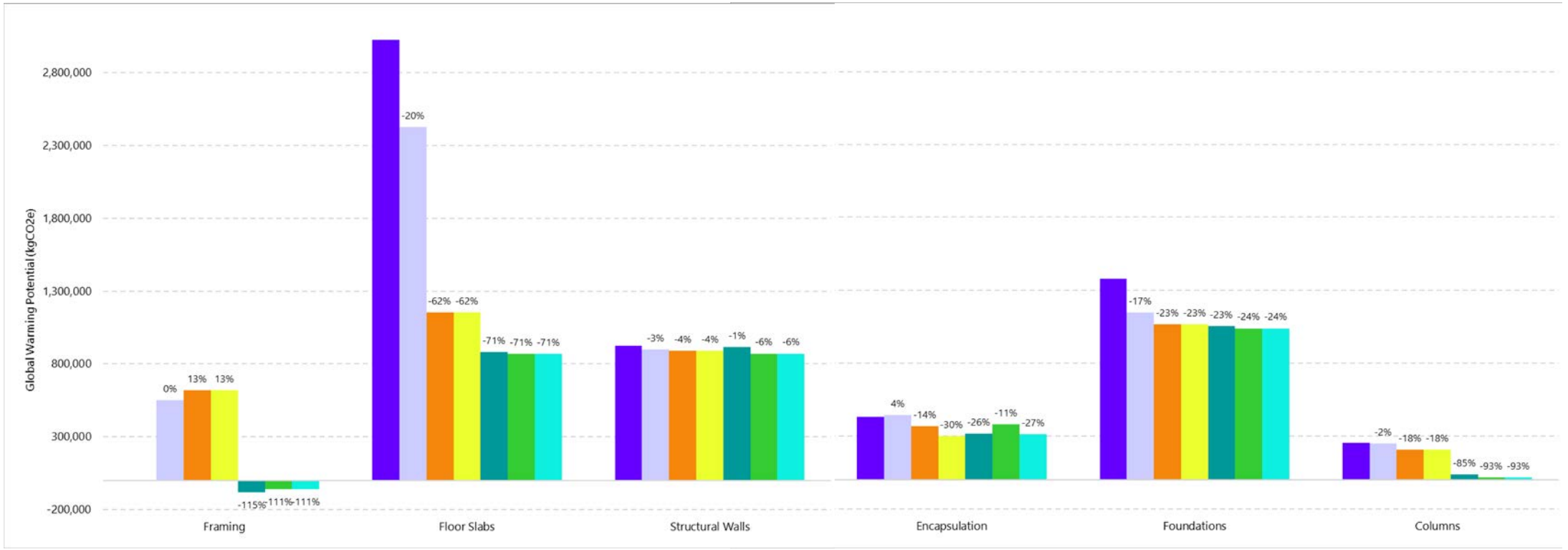
BURO HAPPOLD

Full Building by Element



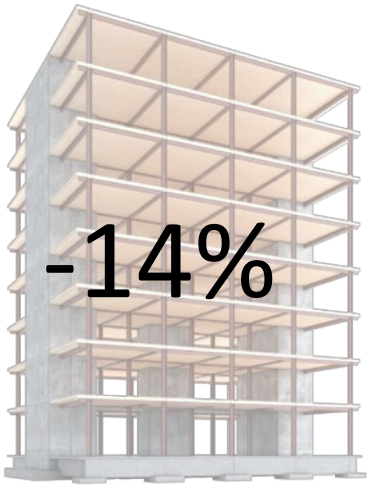
BURO HAPPOLD

Element Comparison



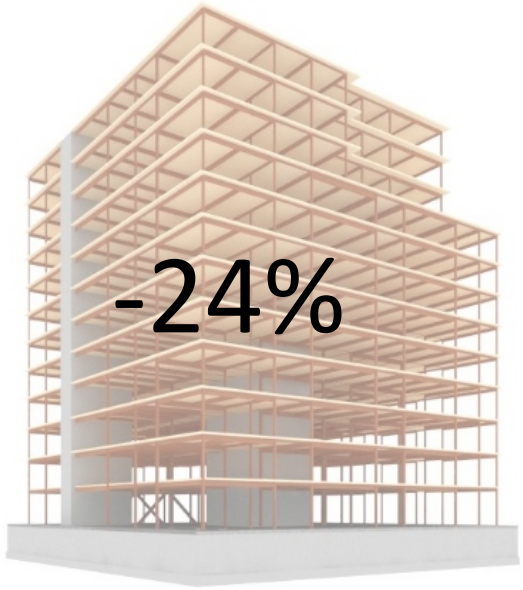
BURO HAPPOLD

Full Building by Element



Eight Story - Timber 9

Timber Floors & Steel Frame
12 to 20’ grid
Partial encapsulation



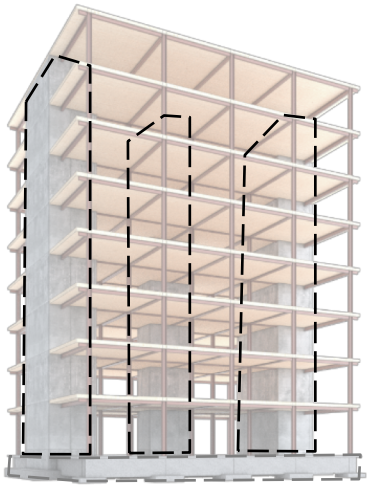
Twelve Story - Timber A

Hybrid Timber/Steel
14-30’ grid
Partial encapsulation

BURO HAPPOLD

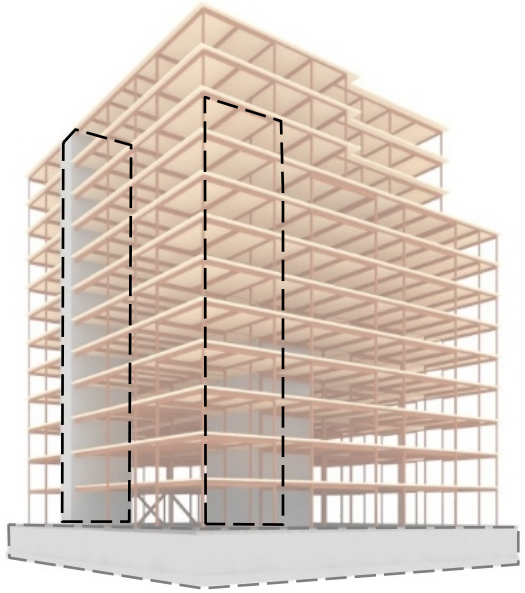
Full Building by Element

structural walls



Eight Story - Timber 9

Timber Floors & Steel Frame
12 to 20’ grid
Partial encapsulation



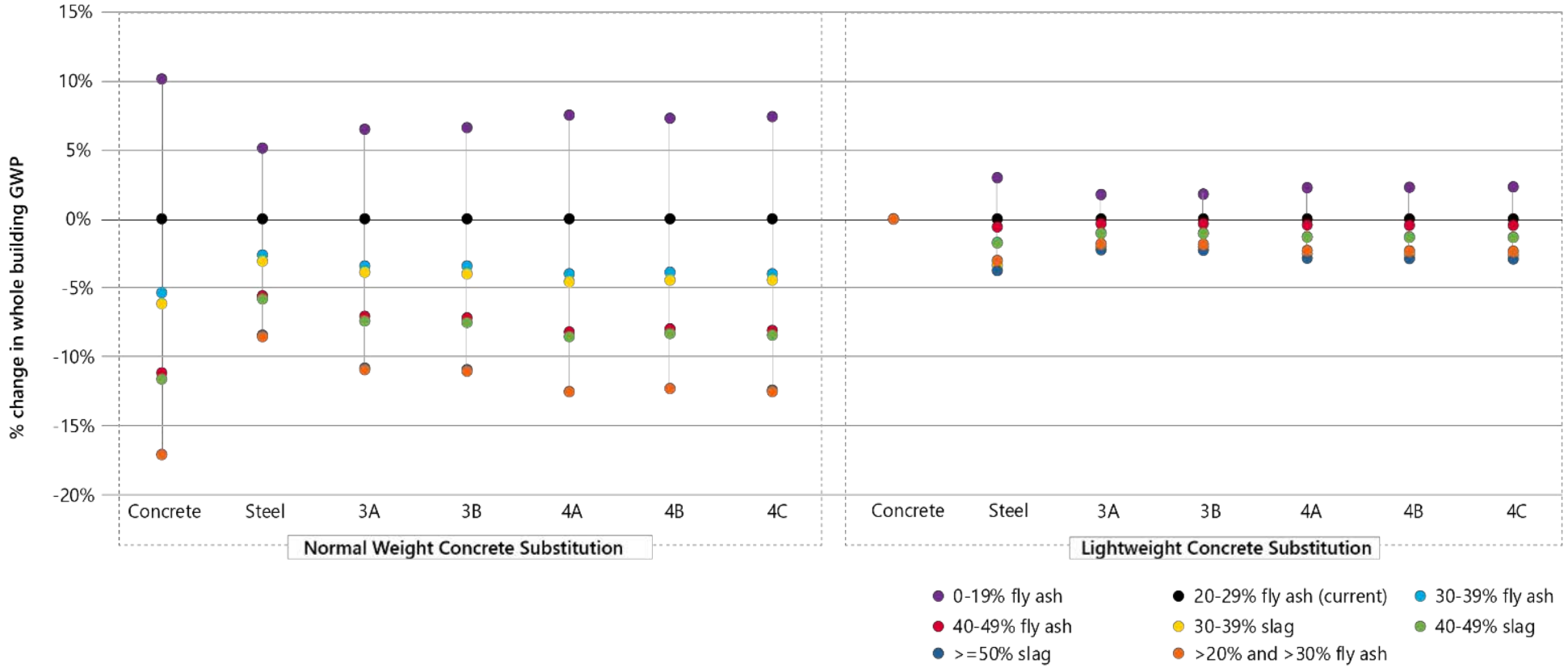
foundations

Twelve Story- Timber A

Hybrid Timber/Steel
14-30’ grid
Partial encapsulation

BURO HAPPOLD

Concrete Sensitivity Study



BURO HAPPOLD

Future Work

- Study **sensitivity** of results to:
    - forestry management practices
    - In-forest sequestration during life of building
    - transportation distances
    - specific timber data as available
    - variability of reference cases
    - Building program and typologies

- Extend **scope of study** to be more holistic:
    - MEP
    - full tenant improvement
    - furnishings
    - operational energy comparisons
    - Healthy materials/toxicity overlay

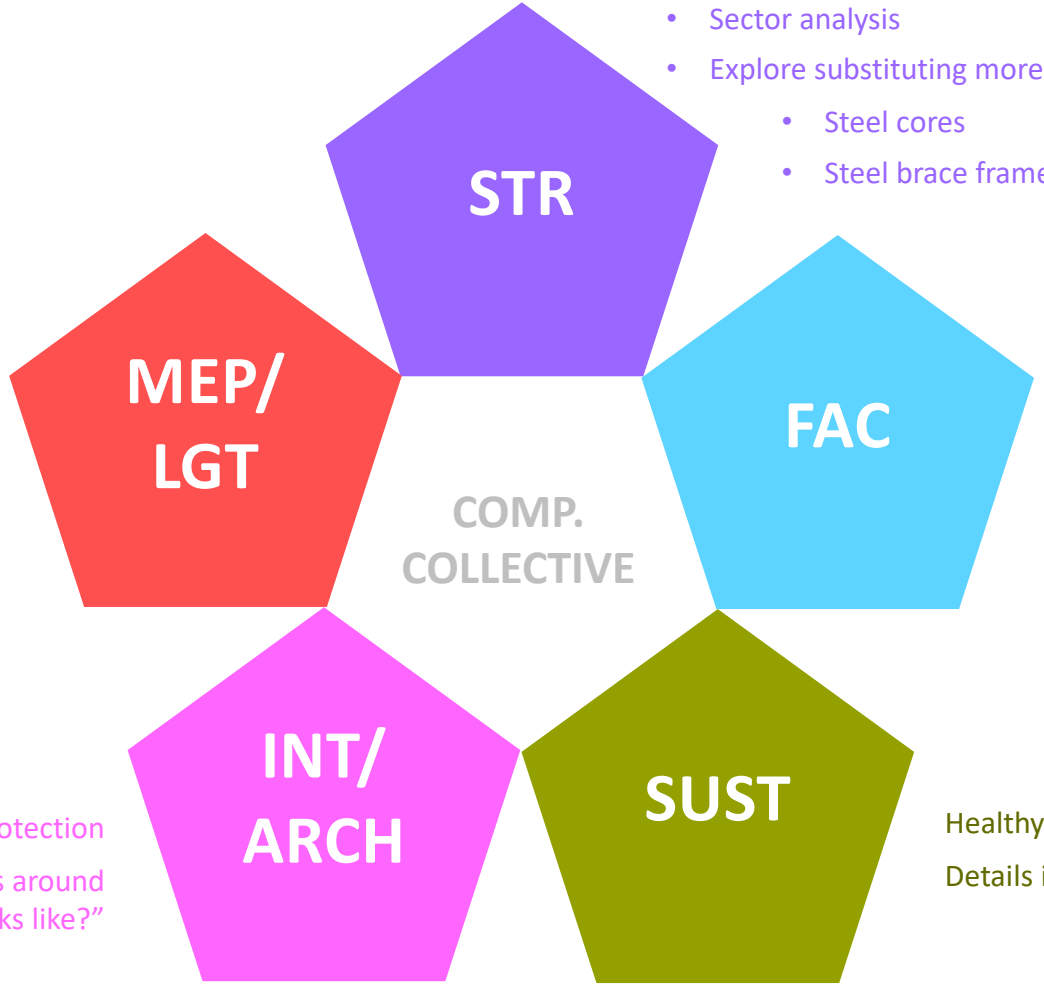
Nelson City Council, NZ

BURO HAPPOLD

LCA @ Buro Happold

Hybrid engineering possibilities

- Optimizing structural grid spacing
- Sector analysis
- Explore substituting more concrete for steel
  - Steel cores
  - Steel brace frames



Structural – MEP relationships

Fire protection

Collaboration with architects around "What good looks like?"

Healthy building overlay

Details in EPDs

BURO HAPPOLD

Thank you!

Buro Happold Engineering

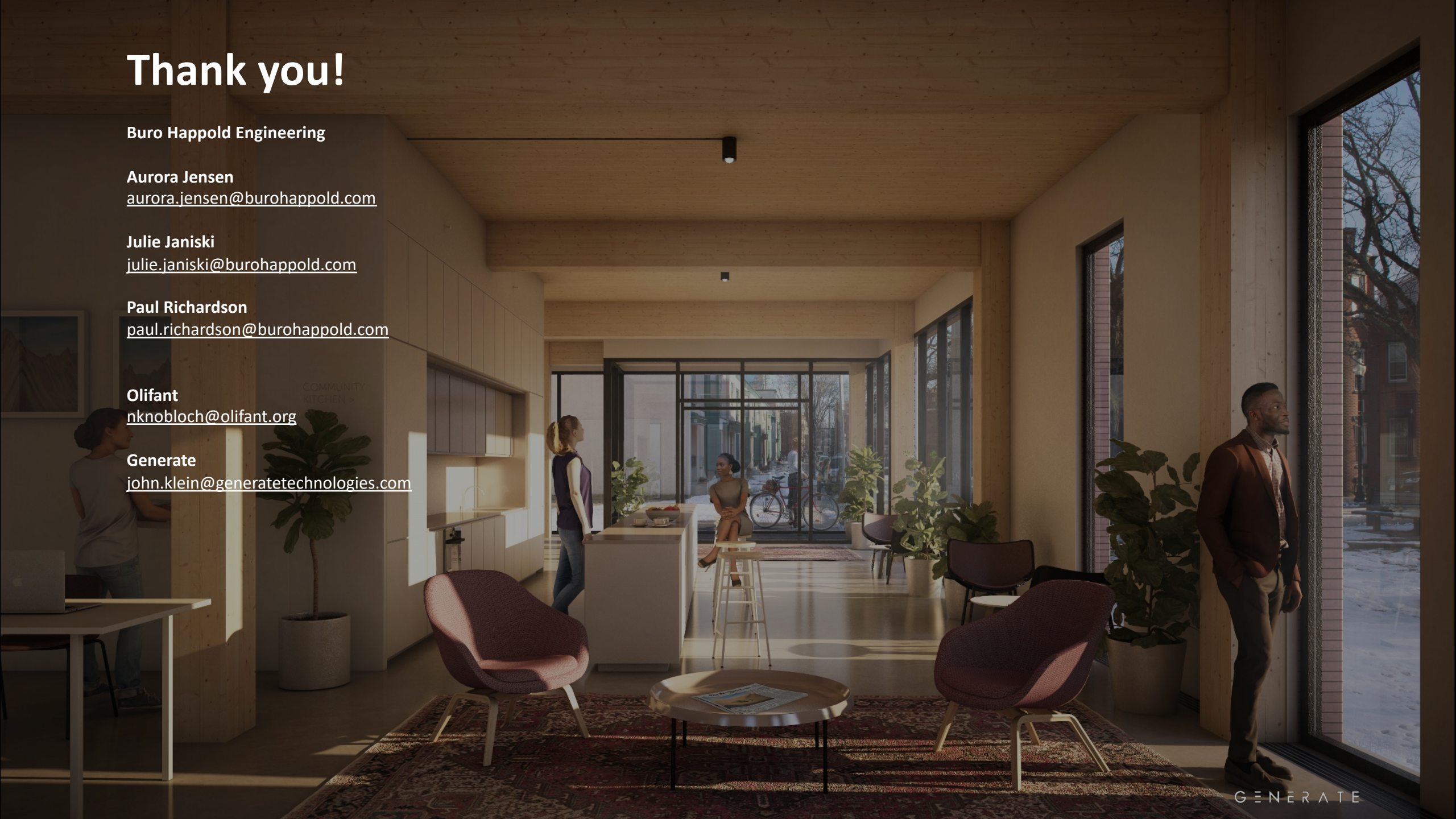
Aurora Jensen
aurora.jensen@burohappold.com

Julie Janiski
julie.janiski@burohappold.com

Paul Richardson
paul.richardson@burohappold.com

Olifant
nknobloch@olifant.org

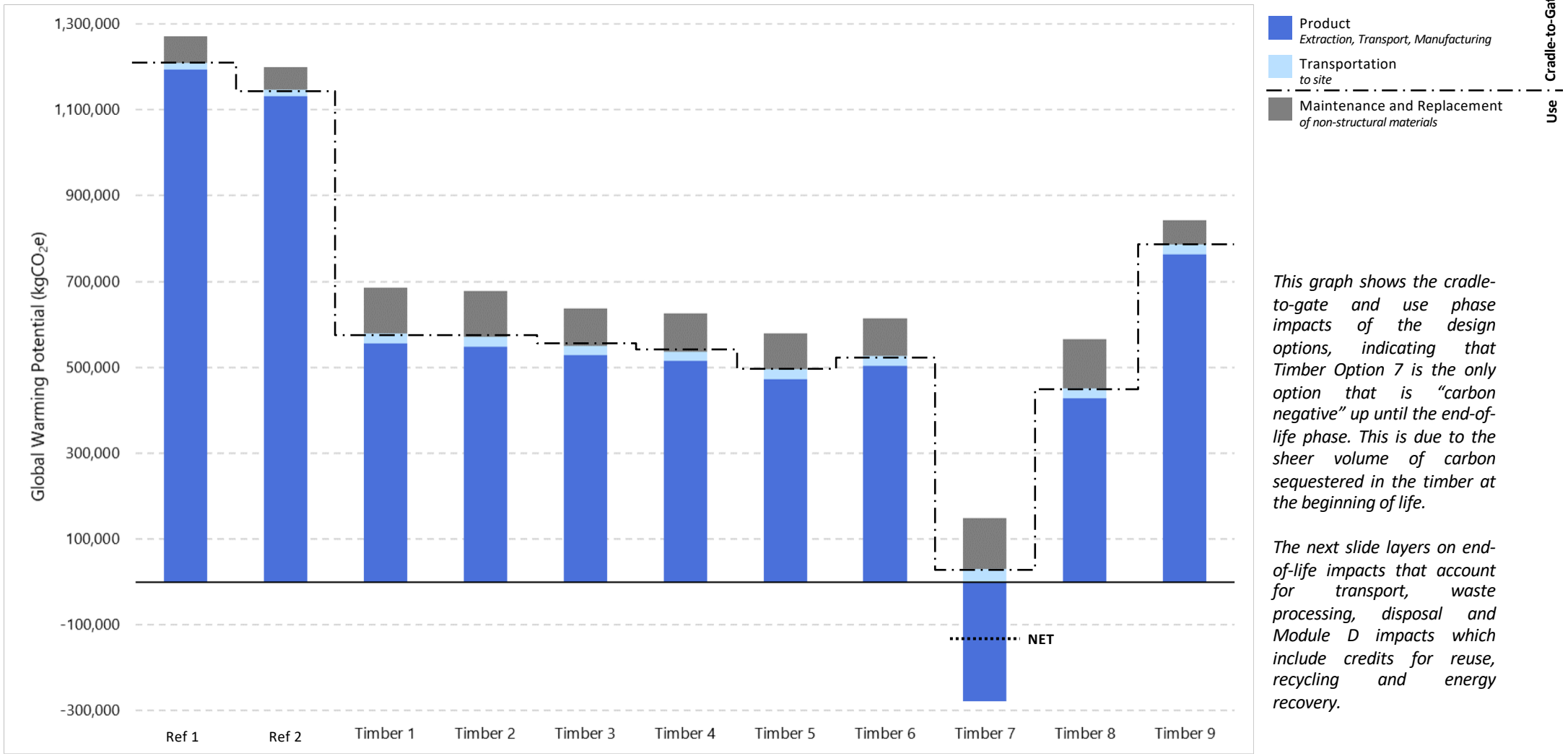
Generate
john.klein@generatetechnologies.com



APPENDIX

Full Building Comparison

Cradle-to-Gate and Use phases, without End-of-Life phases



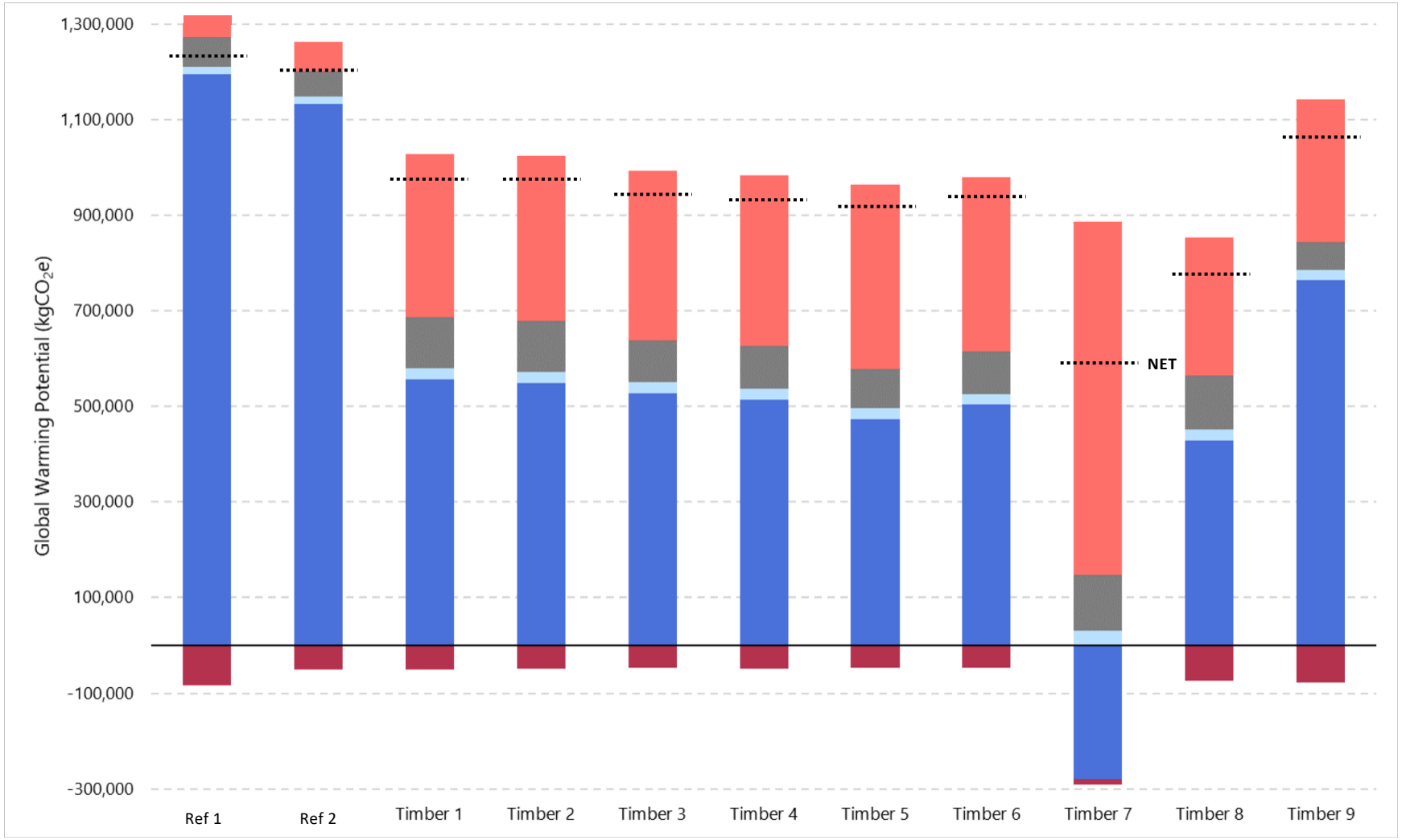
This graph shows the cradle-to-gate and use phase impacts of the design options, indicating that Timber Option 7 is the only option that is "carbon negative" up until the end-of-life phase. This is due to the sheer volume of carbon sequestered in the timber at the beginning of life.

The next slide layers on end-of-life impacts that account for transport, waste processing, disposal and Module D impacts which include credits for reuse, recycling and energy recovery.

BURO HAPPOLD

Full Building Comparison

All Life Cycle Phases



Product
Extraction, Transport, Manufacturing

Transportation
to site

Maintenance and Replacement
of non-structural materials

End of Life
Transportation, Waste Processing, Disposal

Module D
Reuse, Recycling, Energy Recovery

Cradle-to-Gate

Use

End-of-Life

This graph layers in the end-of-life and Module D impacts on the previous graph. The end-of-life processes for timber - where some amount is incinerated, recycled and landfilled - results in CO_2 emissions. The negative values credited in Module D are primarily due to a credit from the recycling of metals.

Note that LCA doesn't assign any credit for the duration of carbon sequestration, which enables additional forest productivity. Therefore LCA doesn't capture the full benefit of using mass timber.

BURO HAPPOLD