BUILDINGENERGY BOSTON

Design with a Carbon Conscience: Estimating Embodied Carbon at the Planning Level

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SASAKI

Designing with a Carbon Conscience:

Estimating Embodied Carbon at the Planning Level

NESEA BuildingEnergy Boston 2/28/2022

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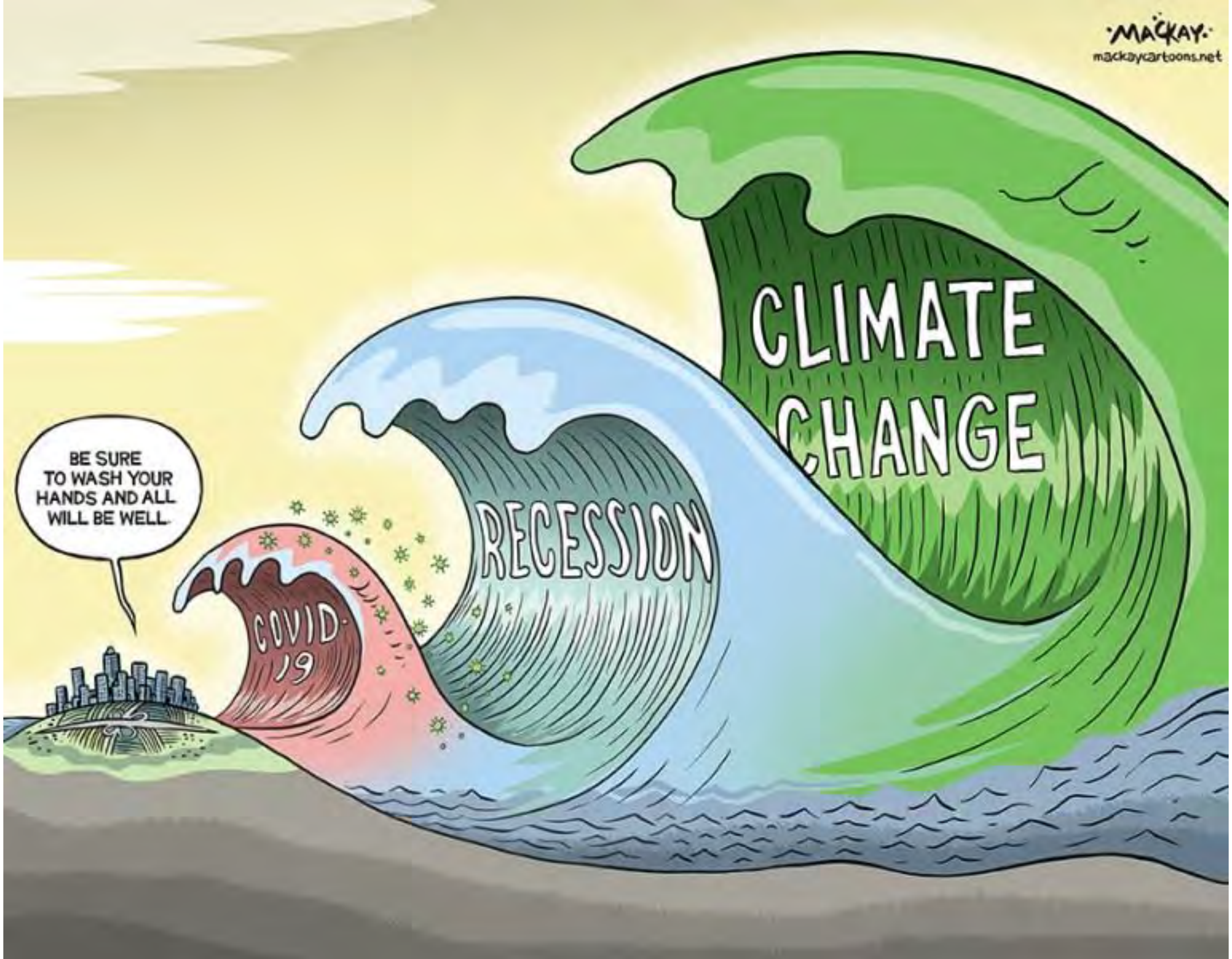
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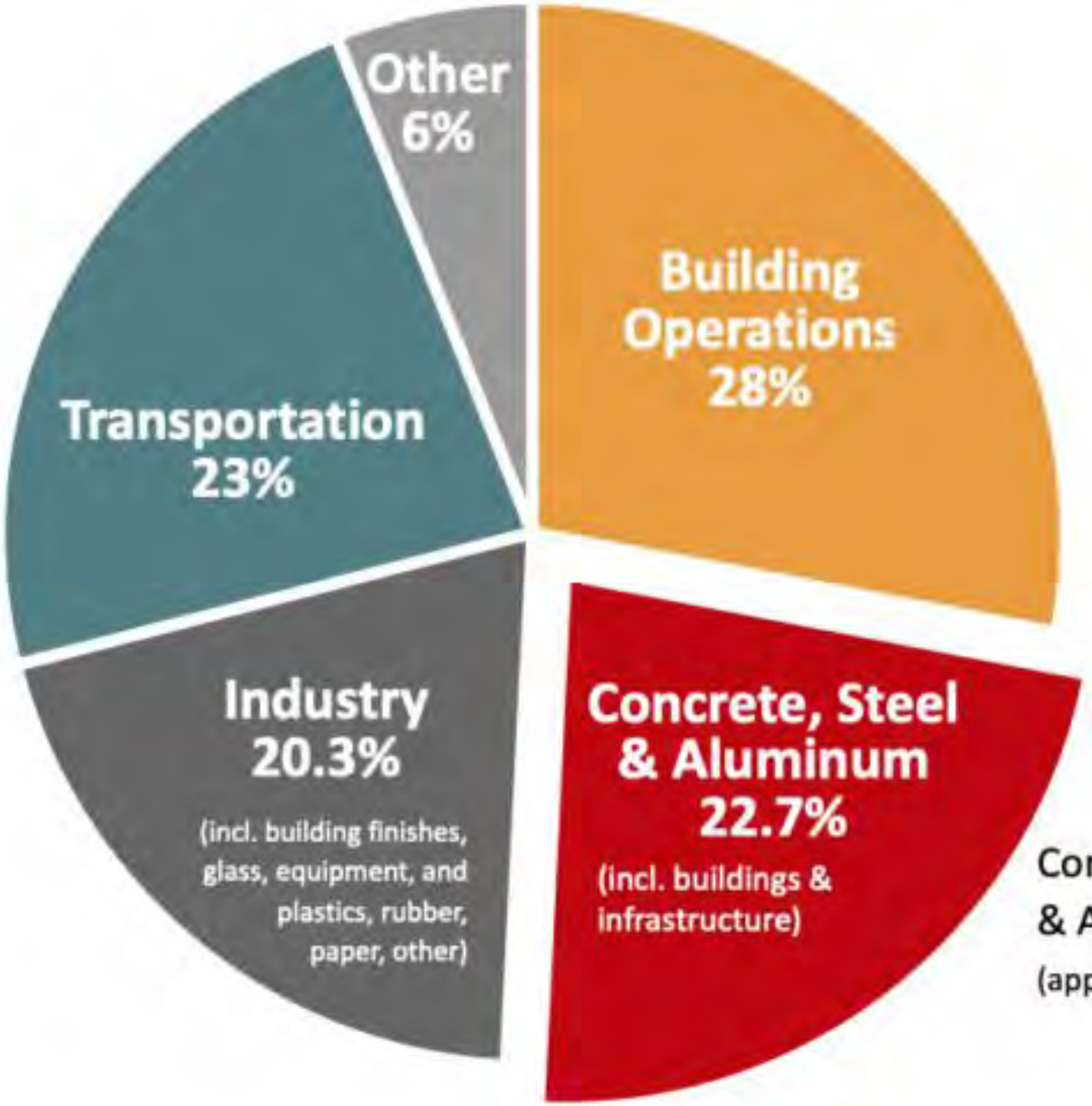
BE SURE TO WASH YOUR HANDS AND ALL WILL BE WELL.
COVID-19
RECESSION
CLIMATE CHANGE

We know how to design **Energy Positive** projects.
BUT... how can we design **Carbon Positive** projects?

Global Carbon Emissions by Sector



Concrete 11.1%, Steel 10.1% & Aluminum 1.5%
(approximate, 2017)

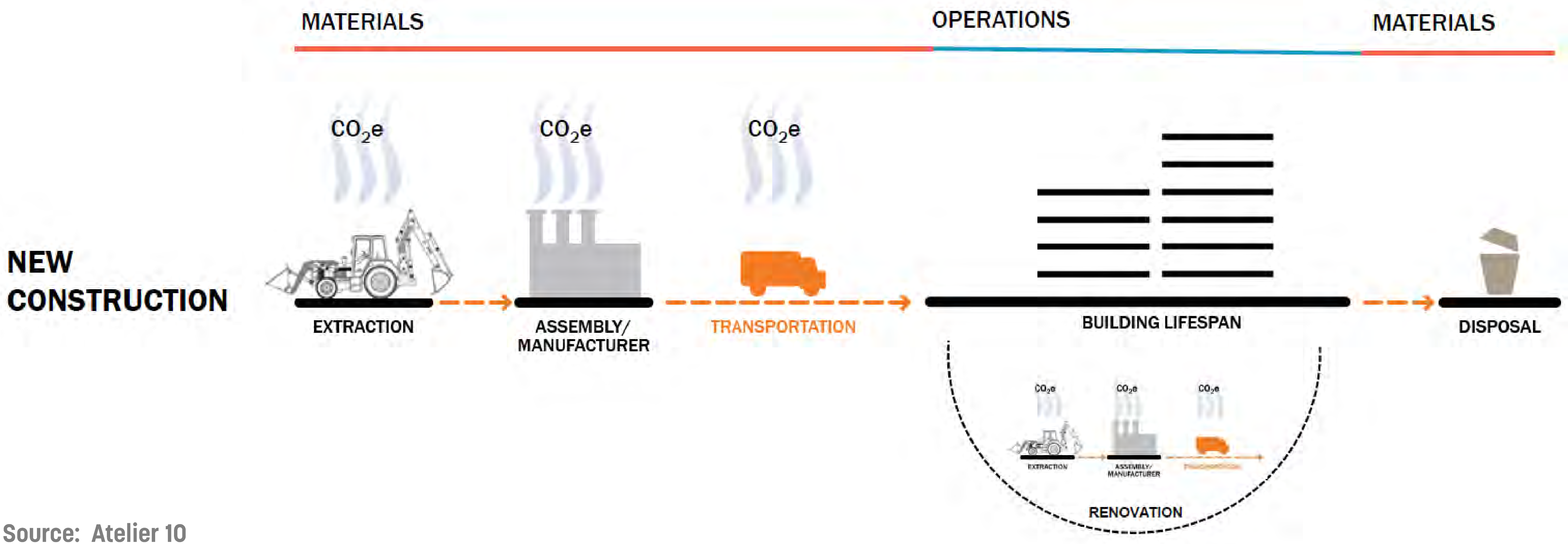
Source:
2018 Global ABC Report; IEA

Carbon Positive projects would also track **embodied carbon** emissions from building and sitework materials

Embodied Carbon Life Cycle Analysis

Embodied Carbon Emissions

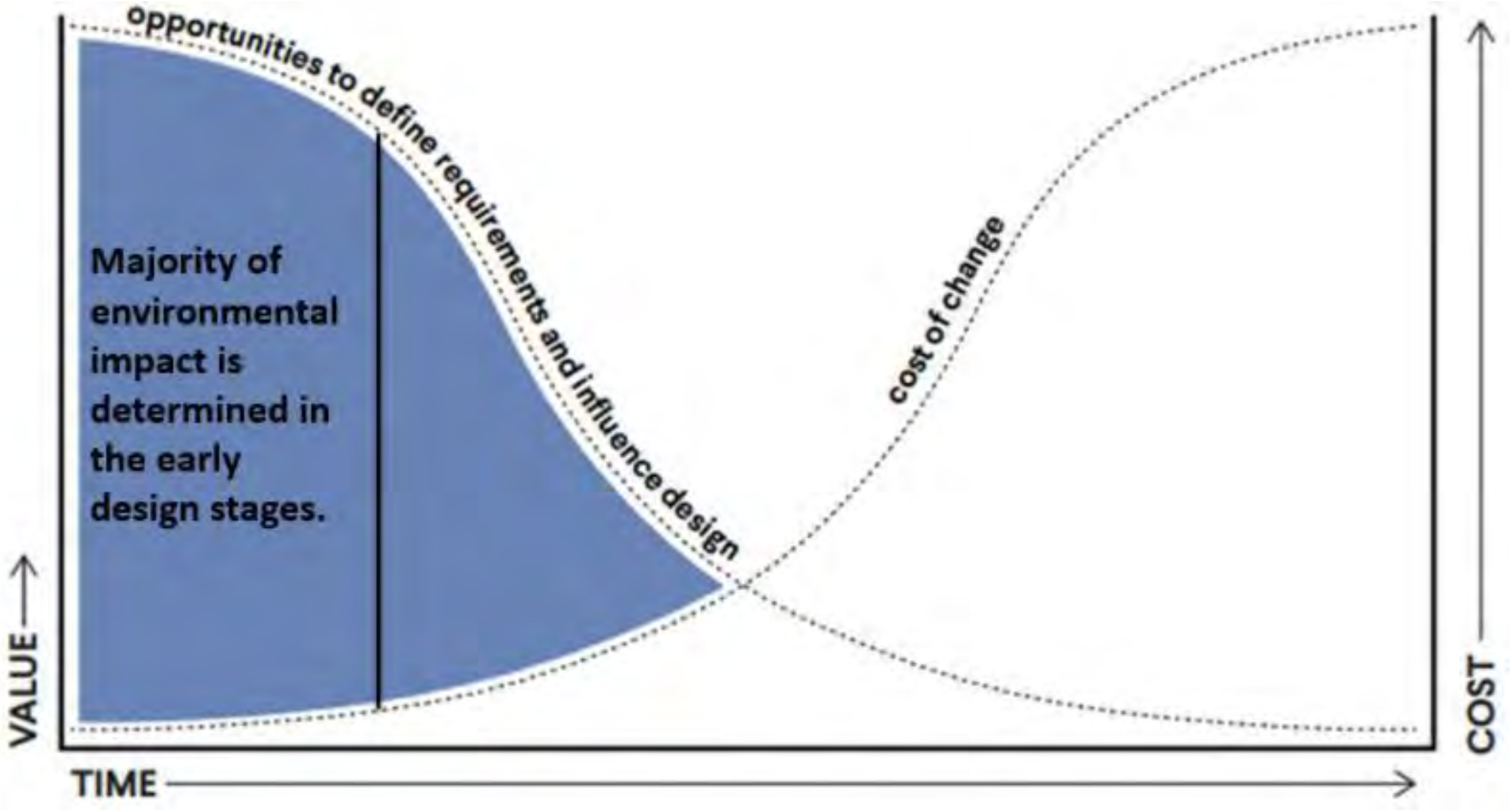
Operational Energy Emissions



Source: Atelier 10

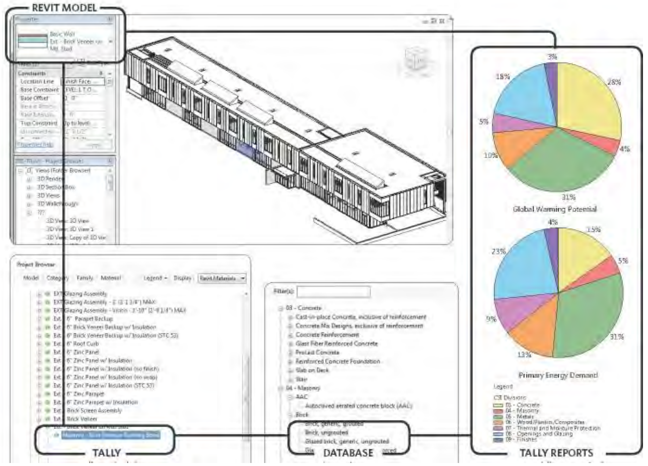
A planning tool can consider
embodied carbon
in materials for both
architecture and landscape

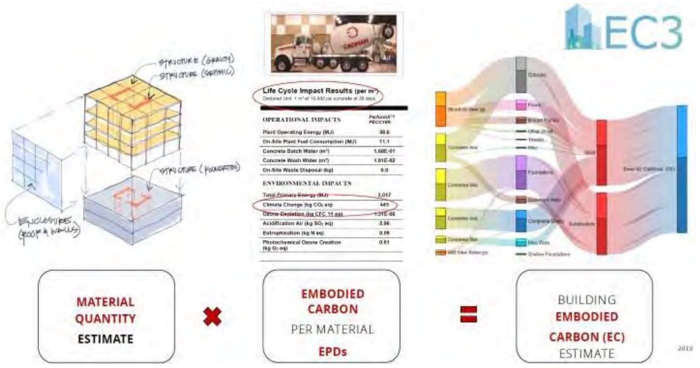
From the Earliest Concept Design Phase



Embodied Carbon Estimates

Sources: Calculators, Programs





Architecture & Building Systems
(Tally, Athena, EC3)

Planning (EcoGIS, Presto, iTree)
Landscape (Climate Positive / Pathfinder)

Other Resources and cited sources of information.

Additional Embodied Carbon Calculators

- One-Click LCA: The engineer's software of choice for LCAs as well as embodied carbon calculations. https://www.oneclicklca.com/
- Beacon (for structural systems), from the Embodied Carbon Lab at Thornton Tomasetti : https://core-studio.gitbook.io/beacon/
- Kaleidoscope (for facades, flooring) from Payette: https://www.payette.com/kaleidoscope/
- Concrete LCA tool (for concrete mixes) from ZGF: https://www.zgf.com/news_post/lca-calculator-reduces-concretes-embodied-carbon/
- EA Tool (for structural systems) from SOM: https://www.som.com/news/new_tool_measures_emissions_from_buildings

Additional LCA resources

- Epic (LCA) Database, University of Melbourne. https://msd.unimelb.edu.au/research/projects/current/environmental-performance-in-construction/epic-database
- U.S. Life Cycle Inventory Database. https://www.nrel.gov/lci/ EPD
- International. https://www.environdec.com/

Energy Modeling Programs

- Cove.tool (energy modeling for individual builds and neighborhoods): https://www.cove.tools/
- IES VE (whole building energy simulation): https://www.iesve.com/software/building-energy-modeling
- DesignBuilder (performance analysis tools): https://designbuilder.co.uk/

Additional Resources:

- Carbon Smart Materials Pallette: https://materialspalette.org/
- EPD Quicksheet: https://architecture2030.org/epd-quicksheet/
- Architecture 2030: https://architecture2030.org/
- USGBC - How LEED V4.1 addresses embodied carbon: https://www.usgbc.org/articles/how-leed-v41-addresses-embodied-carbon
- Climate Positive Design - Resource Recommendations: https://climatepositivedesign.com/resources/
- Society for Ecological Restoration Resource Center: https://www.ser-rrc.org/
- iTree (for detailed arboriculture tools): https://www.itreetools.org/
- Eco GIS (monitor energy consumption and CO2 emissions): http://www.ecogis.info/

Literature Review & Data Sources

~160 sources

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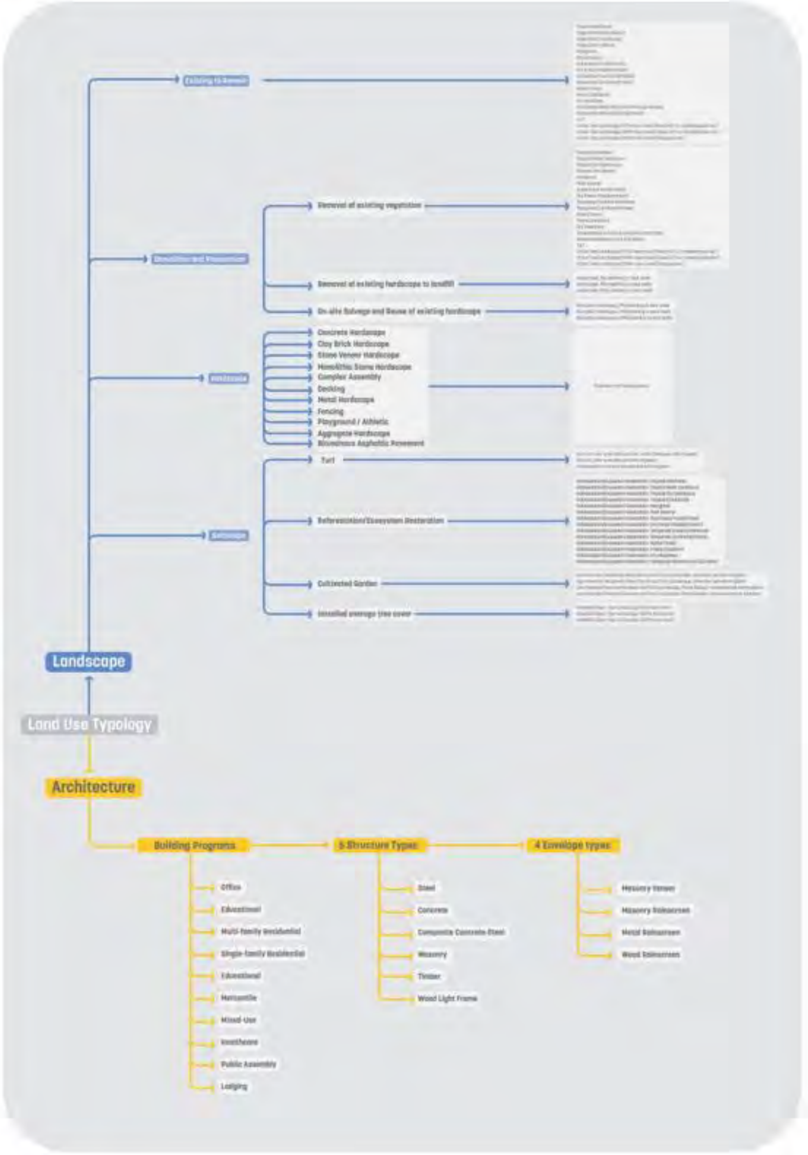
Project Planning: Architecture, Landscape, Infrastructure

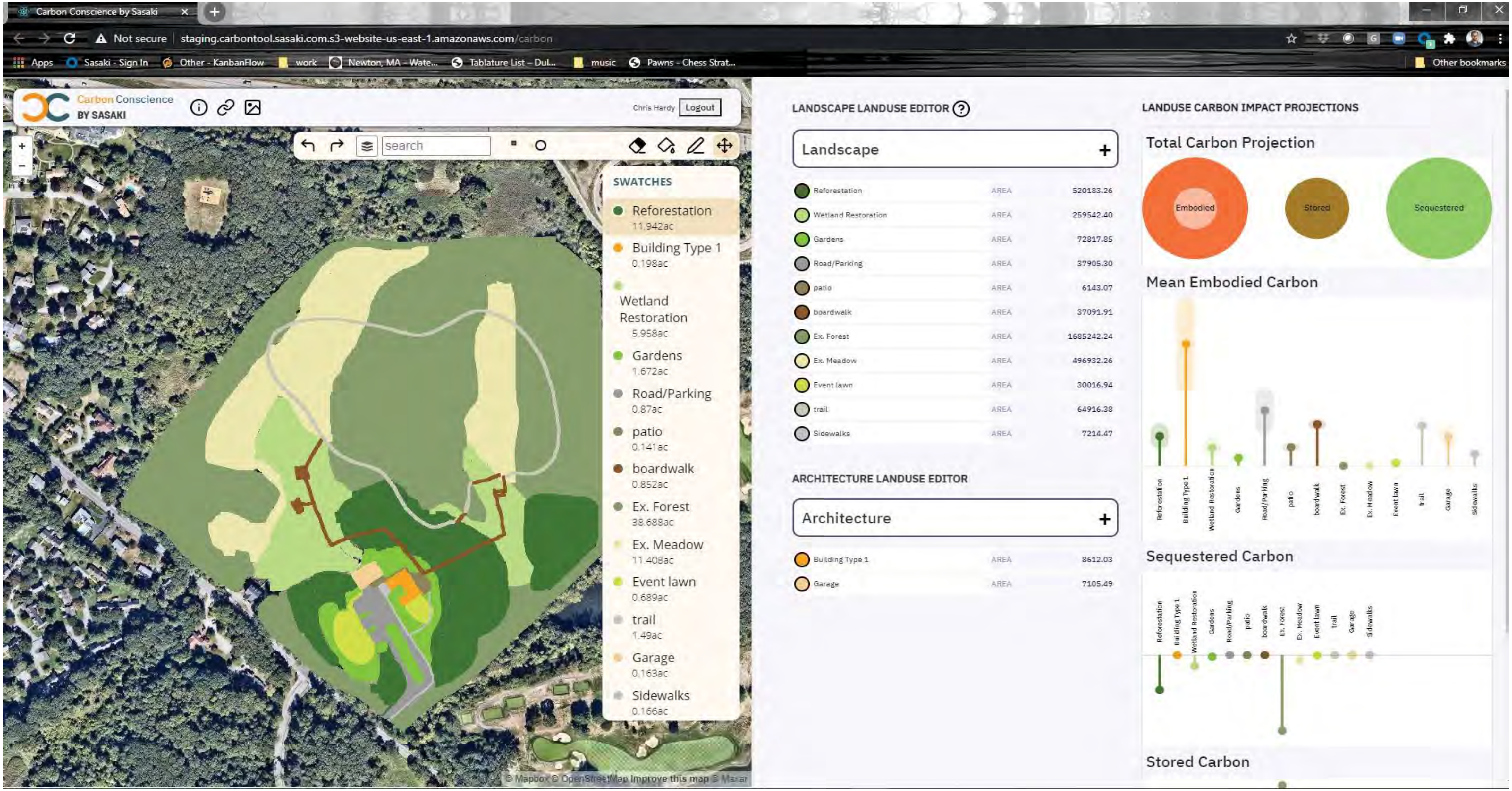
Embodied Carbon Estimates

Architecture:
- Program
- Structural System
- Facades

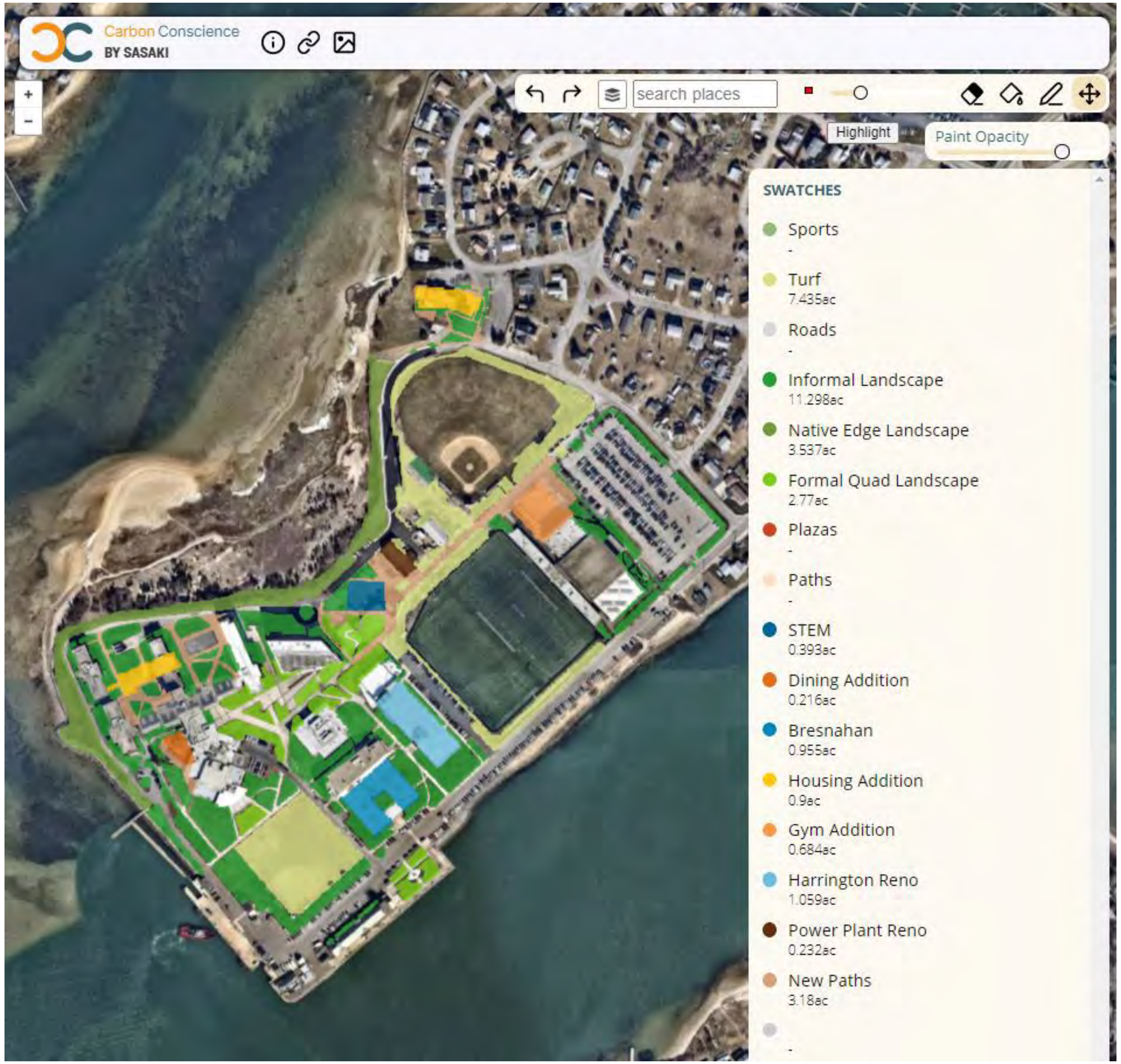
Landscape:
- Undisturbed soils
- Demolition and prep
- Hardscape
- Softscape

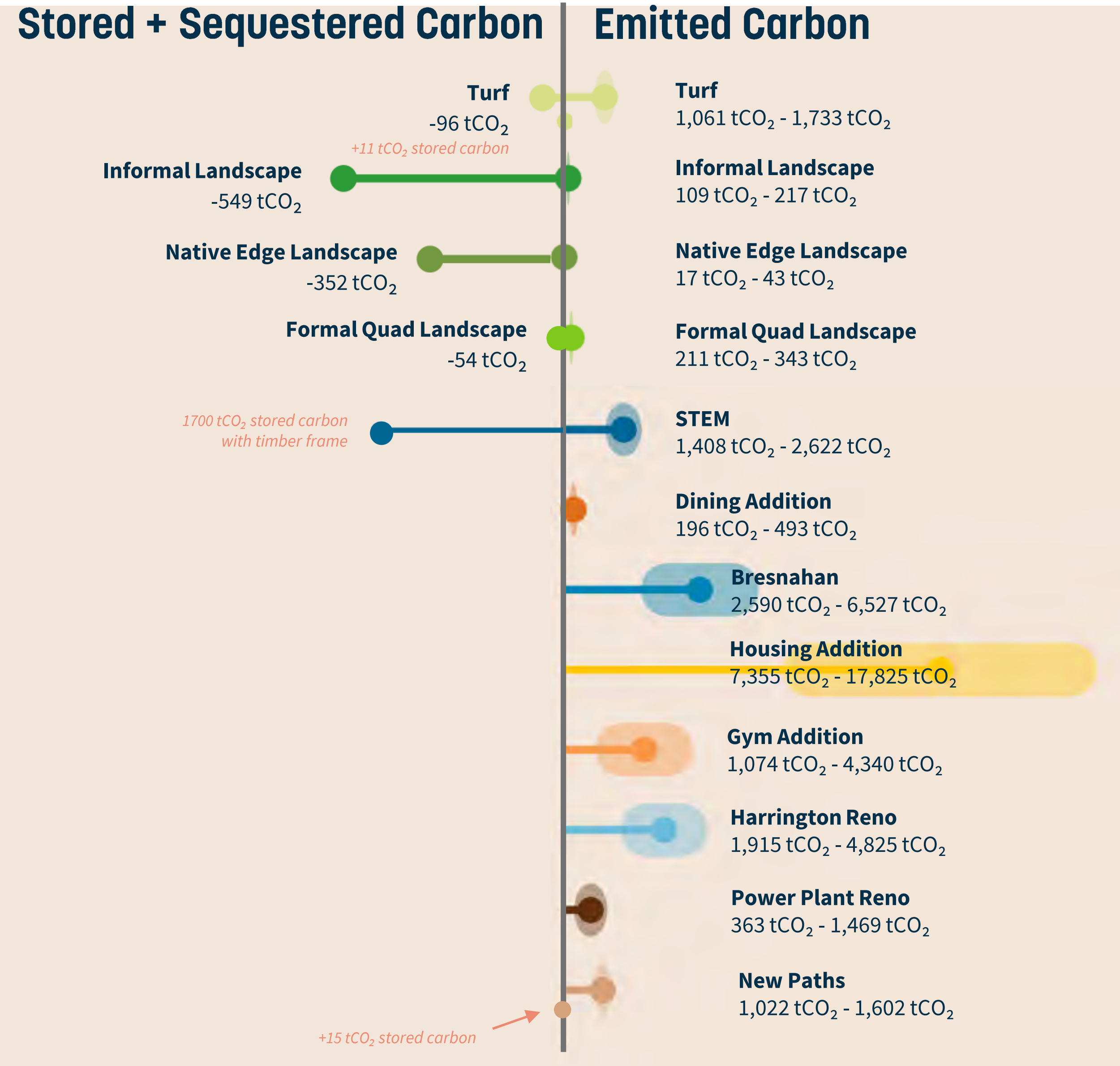


Carbon Conscience: Alpha



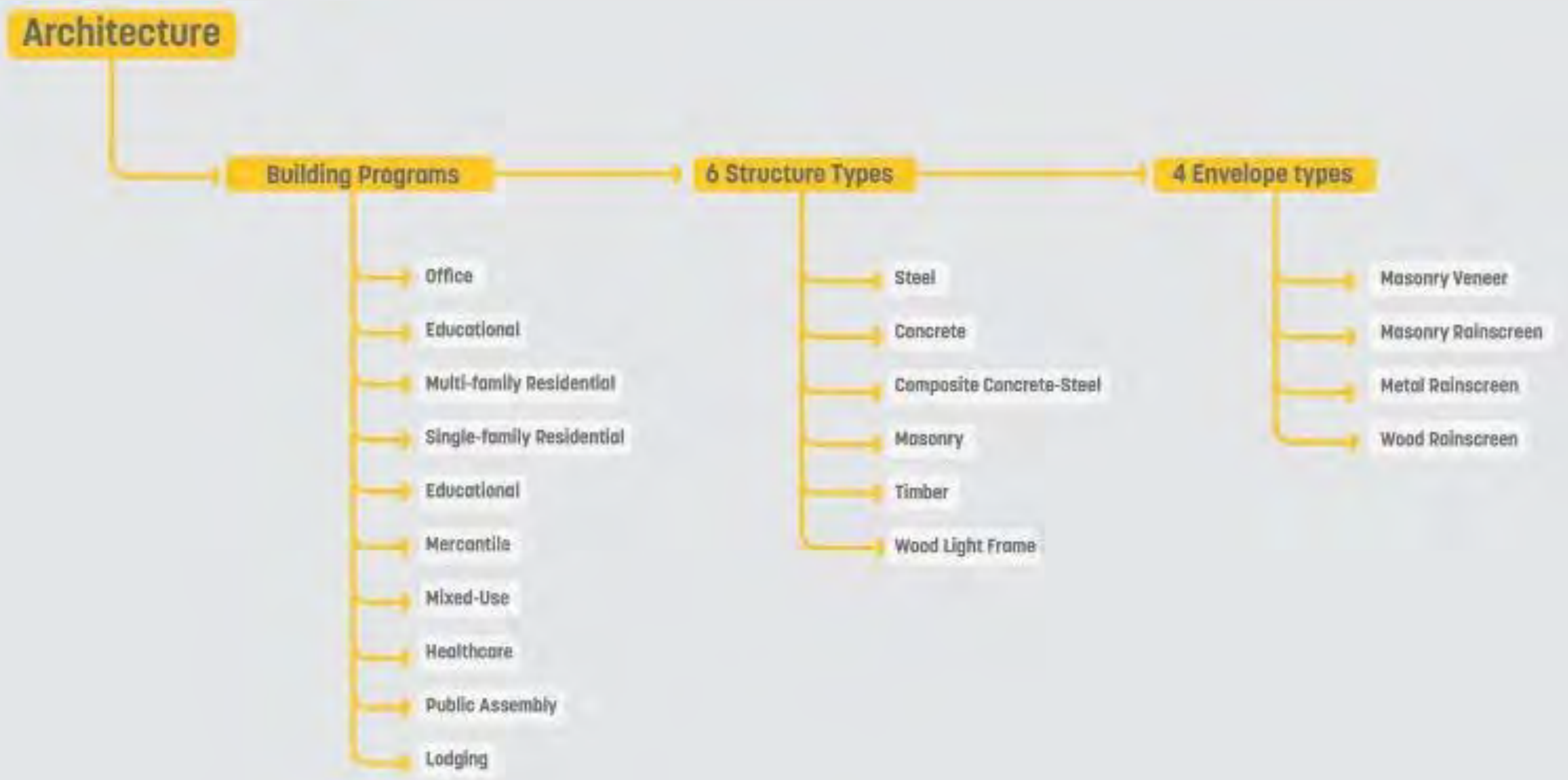
Carbon Conscience: Beta



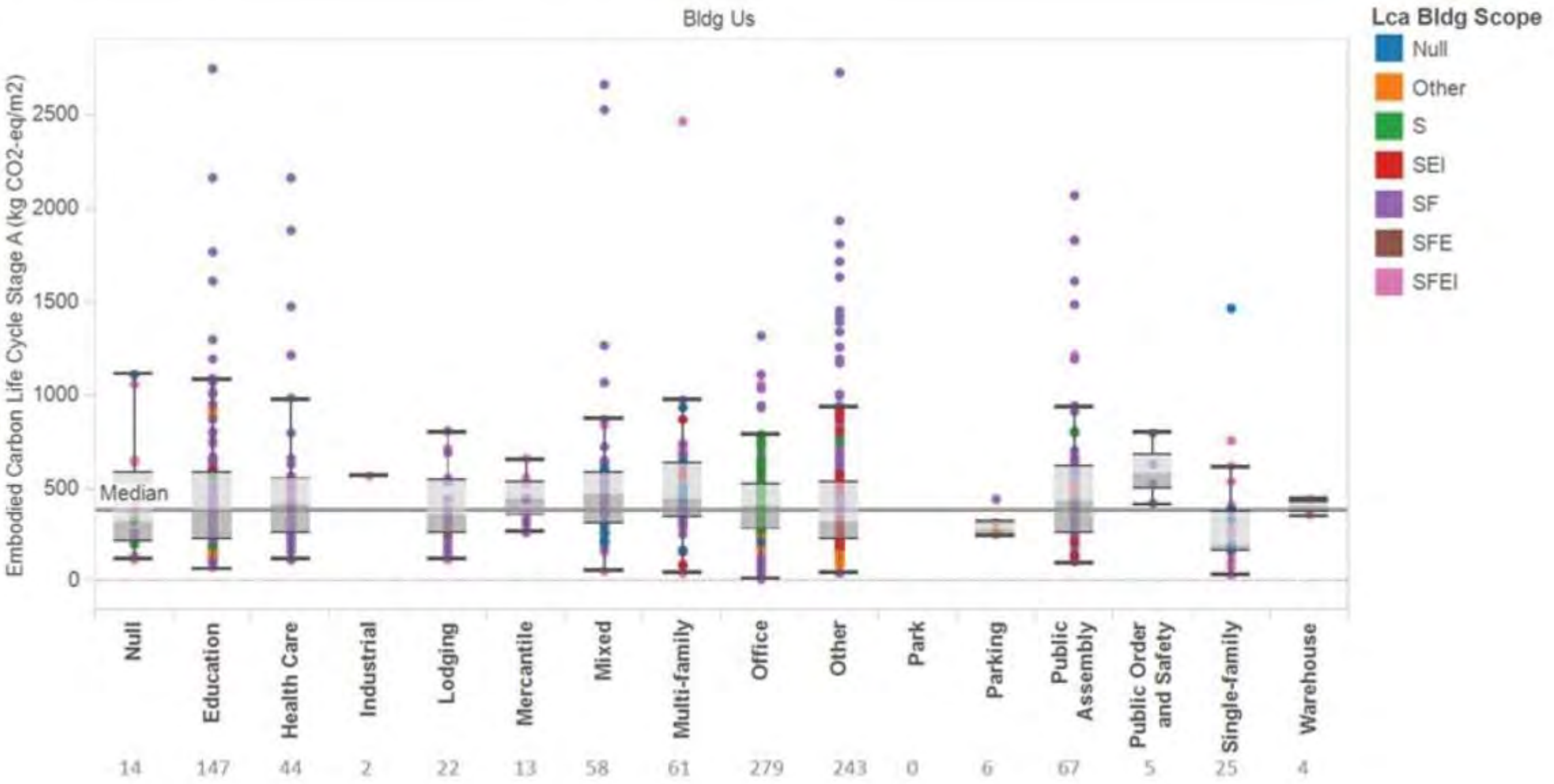


Architecture Land Uses

Developing the Architecture Data Set



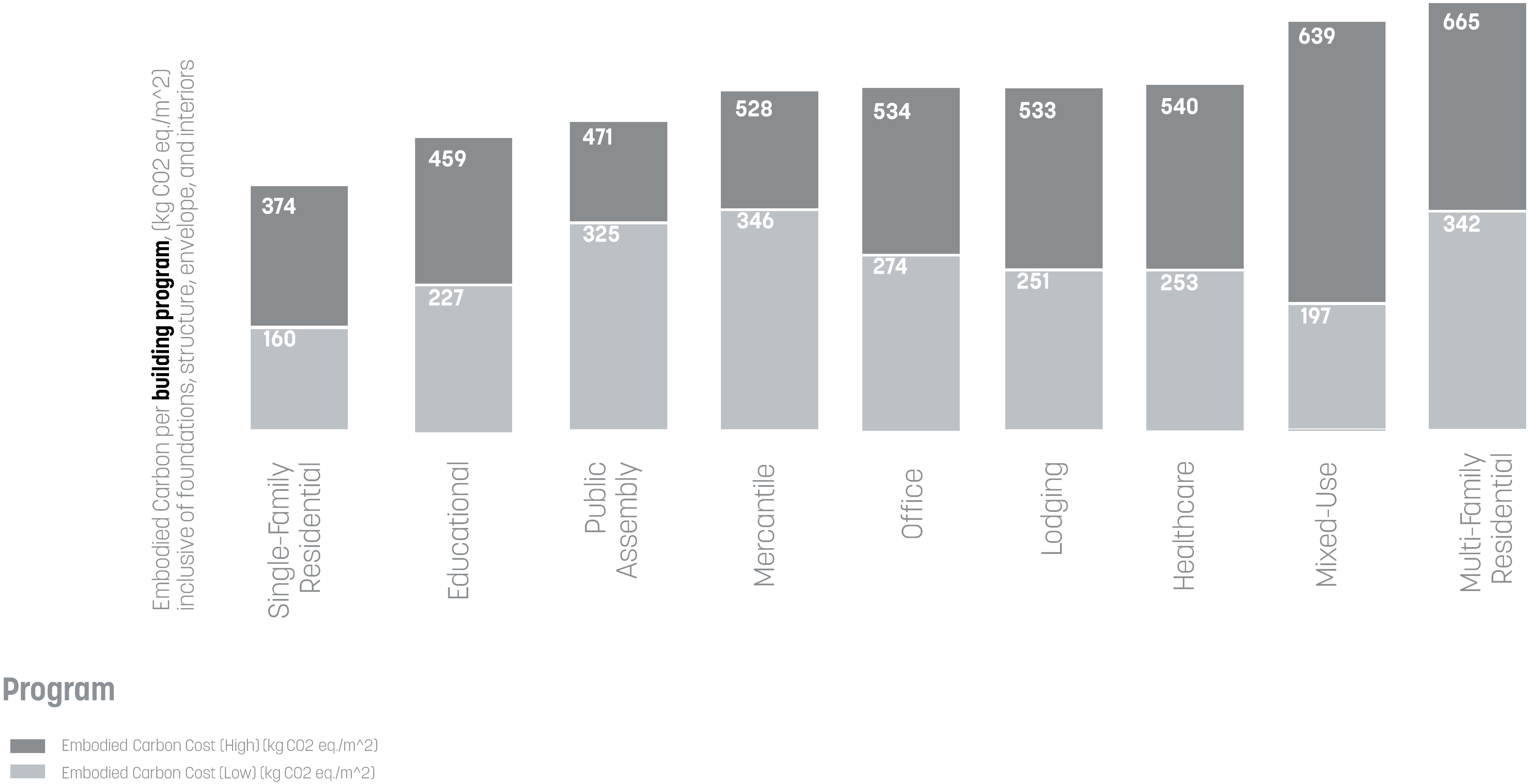
Carbon Leadership Forum: Benchmark Study, 2017



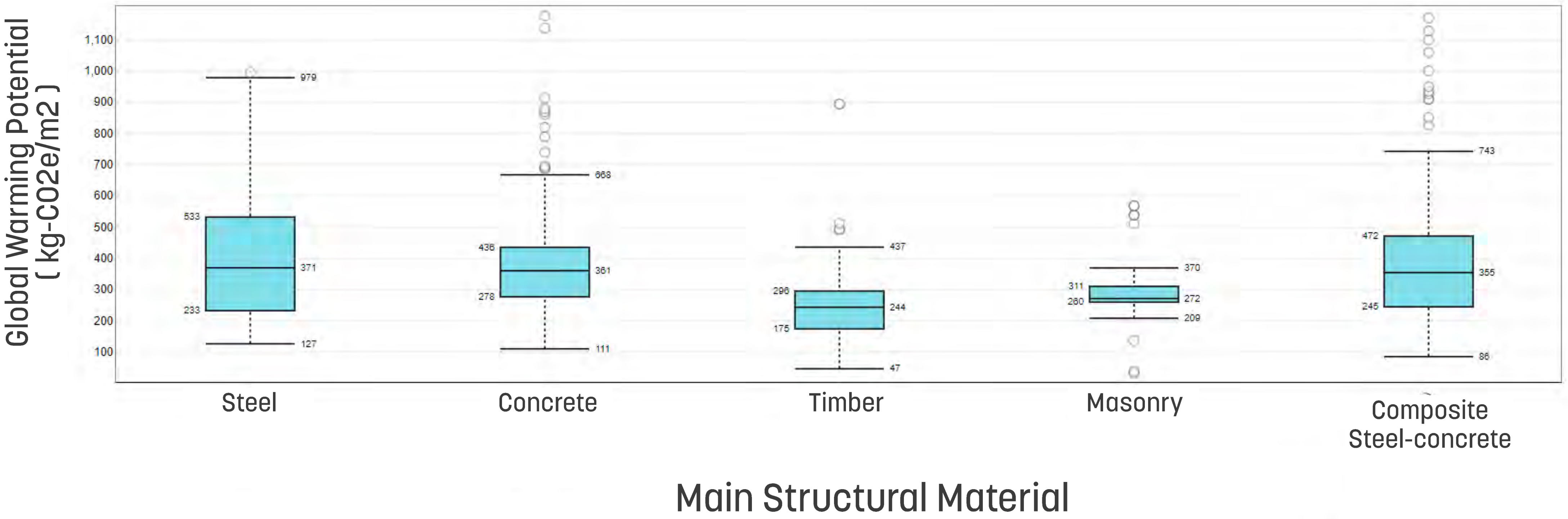
Embodied Carbon per SM, Whole Building averages, 1007 Building Survey

CLF Carbon Leadership Forum

Selection of Program Types



Primary Data Set Refinement: Structure



Embodied Carbon per SM, structural system averages, 639 Building Survey

deQo

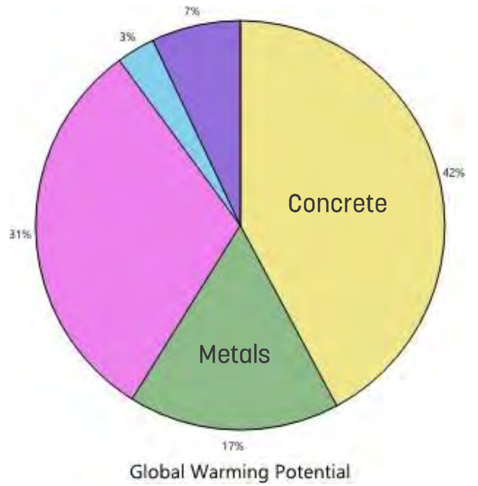
carbondeqo.com

Whole Building LCA Test: 4 Buildings, Bonnet Springs Park

Nature Center

Heavy timber &
light wood framing structure

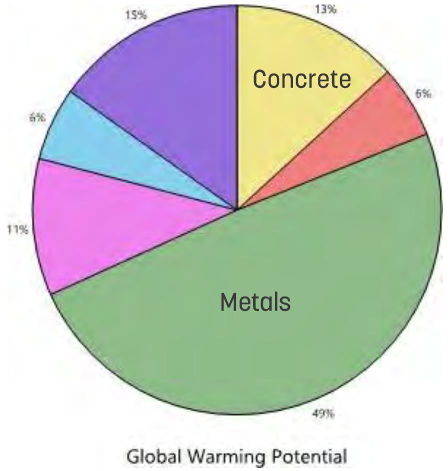
kgCO2/m^2 = 161.6



Event Center

Hybrid structure: steel columns, mass timber glulam beams and CLT roof

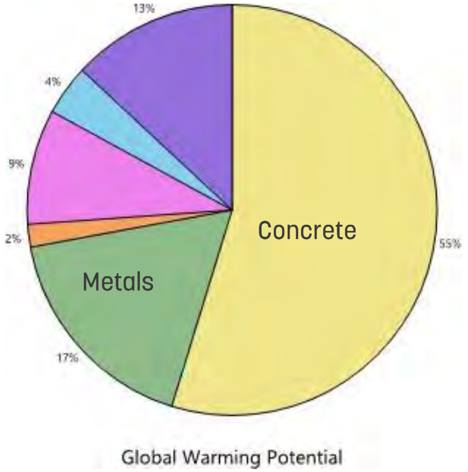
kgCO2/m^2 = 176.3



Children's Museum

Steel & concrete composite structure

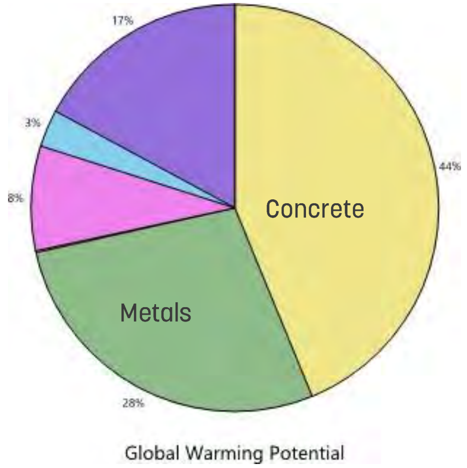
KgCO2/m^2 = 330.3



Welcome Center

Steel & concrete composite structure

kgCO2/m^2 = 433.1



Secondary Data Set Refinement : Envelope

- Begin with Sasaki library of exterior assemblies
- LCAs for each assembly using Tally
- Create groups by cladding type, and assign factor

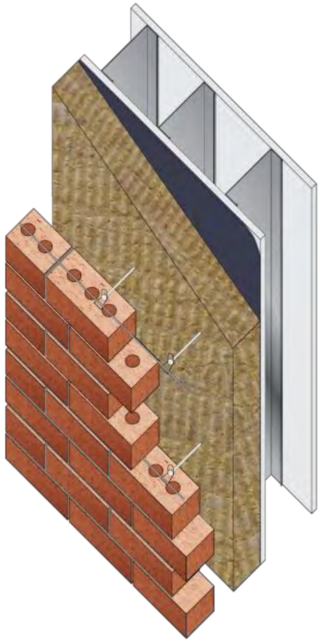
WALL ASSEMBLY

	CLAD TYPE 01	CLAD TYPE 02	CLAD TYPE 03	CLAD TYPE 04
SERIES 0 MONOLITHIC/FOUNDATION WALLS	C8 (CIP) C12 (CMU) C16 (CFMF) *CIP CONCRETE INFILL*	M4 (CIP) M8 (CMU) M12 (CFMF) *CMU INFILL*	EWA-01C (CIP) EWA-02C (CMU) *FOUNDATION WALL*	
SERIES 10 UNIT MASONRY CAVITY WALLS	EWA-10C (CIP) EWA-10M (CMU) EWA-10S (CFMF) *CMU CAVITY WALL*	EWA-11C (CIP) EWA-11M (CMU) EWA-11S (CFMF) *SPLIT-FACE CAVITY WALL*		
SERIES 20 PRECAST/STONE WALL PANEL	EWA-20C (CIP) EWA-20M (CMU) EWA-20S (CFMF) *STONE CLADDING*	EWA-21C (CIP) EWA-21M (CMU) EWA-21S (CFMF) *SPLIT-FACE STONE CLADDING*	EWA-22C (CIP) EWA-22M (CMU) EWA-22S (CFMF) *ARCHTECTURAL PRECAST CONCRETE RAINSCREEN*	EWA-23C (CIP) EWA-23M (CMU) EWA-23S (CFMF) *ARCHITECTURAL PRECAST CONCRETE BARRIER WALL*
SERIES 30 THIN PANEL RAINSCREEN CLADDING	EWA-30C (CIP) EWA-30M (CMU) EWA-30S (CFMF) *FIBER CEMENT COMPOSITE PANEL*	EWA-31C (CIP) EWA-31M (CMU) EWA-31S (CFMF) *TERRA-COTTA RAINSCREEN CLADDING*	EWA-32C (CIP) EWA-32M (CMU) EWA-32S (CFMF) *HIGH PRESSURE COMPACT LAMINATE*	
SERIES 40 PANELIZED METAL RAINSCREEN	EWA-40C (CIP) EWA-40M (CMU) EWA-40S (CFMF) *LAP-SEAM METAL PANEL*	EWA-41C (CIP) EWA-41M (CMU) EWA-41S (CFMF) *BATTEN-SEAM METAL PANEL*	EWA-42C (CIP) EWA-42M (CMU) EWA-42S (CFMF) *BATTEN-SEAM METAL PANEL*	EWA-43C (CIP) EWA-43M (CMU) EWA-43S (CFMF) COMPOSITE *METAL PANEL BARRIER WALL*
SERIES 50 WOOD	EWA-50C (CIP) EWA-50M (CMU) EWA-50S (CFMF) *WOOD SIDING RAINSCREEN*	EWA-51C (CIP) EWA-51M (CMU) EWA-51S (CFMF) *WOOD RAINSCREEN PANEL*	EWA-51C (CIP) EWA-51M (CMU) EWA-51S (CFMF) *WOOD VENEER LAMINATE PANEL*	
SERIES 60 DIRECT-APPLIED FINISH SYSTEM	EWA-60C(CIP) EWA-60M (CMU) EWA-60S (CFMF) *EXTERIOR INSULATION AND FINISH SYSTEM (EIFS)*			

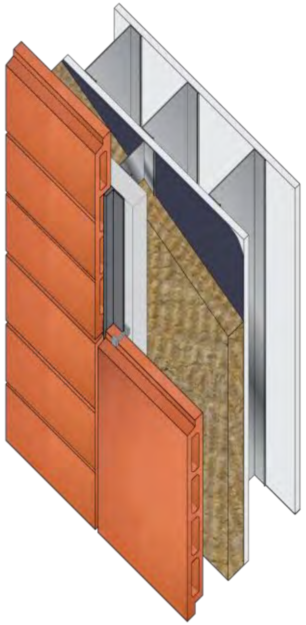
Secondary Data Set Refinement: Envelope

Metal Rainscreen

Masonry Veneer

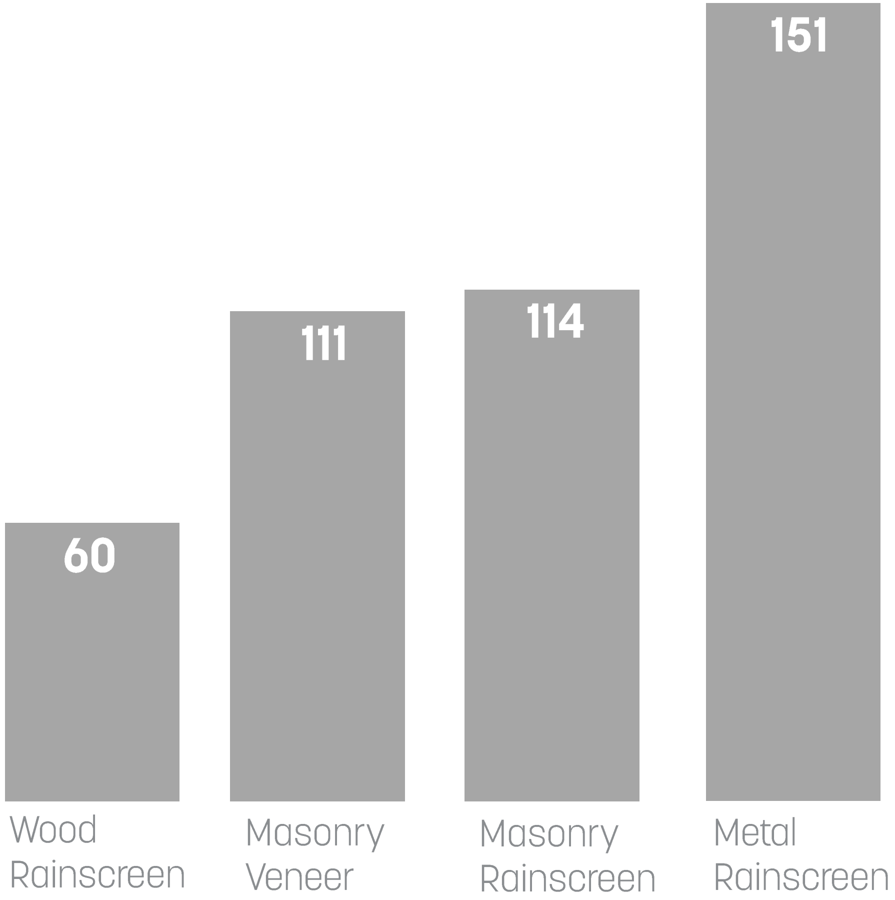


Masonry Rainscreen



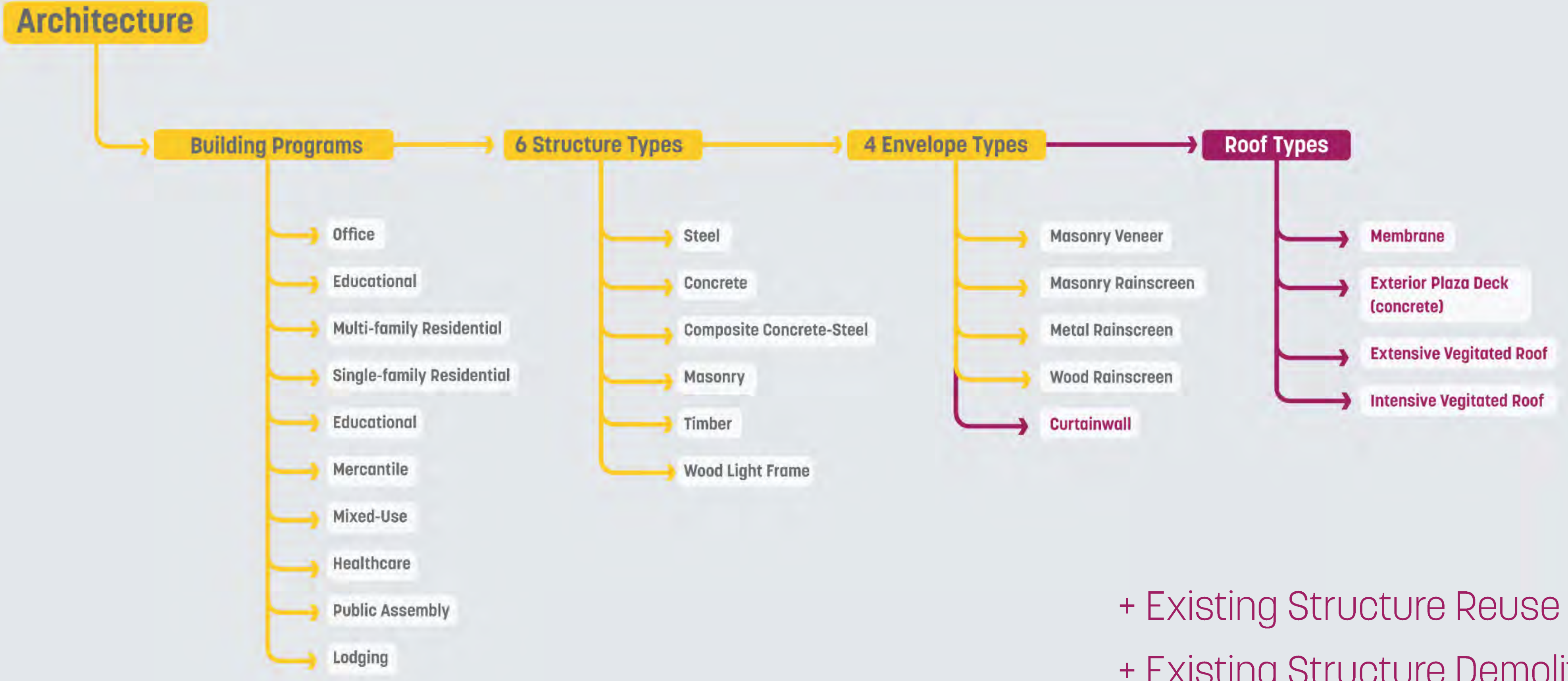
Wood Rainscreen

Exterior Wall Assembly Groups



Embodied Carbon (GWP) per envelope type
(kg CO2 eq./m^2) average and mean carbon cost.

Next Steps:



+ Existing Structure Reuse
+ Existing Structure Demolition
+ New & Archive Projects WBLCA

Future Data Integration

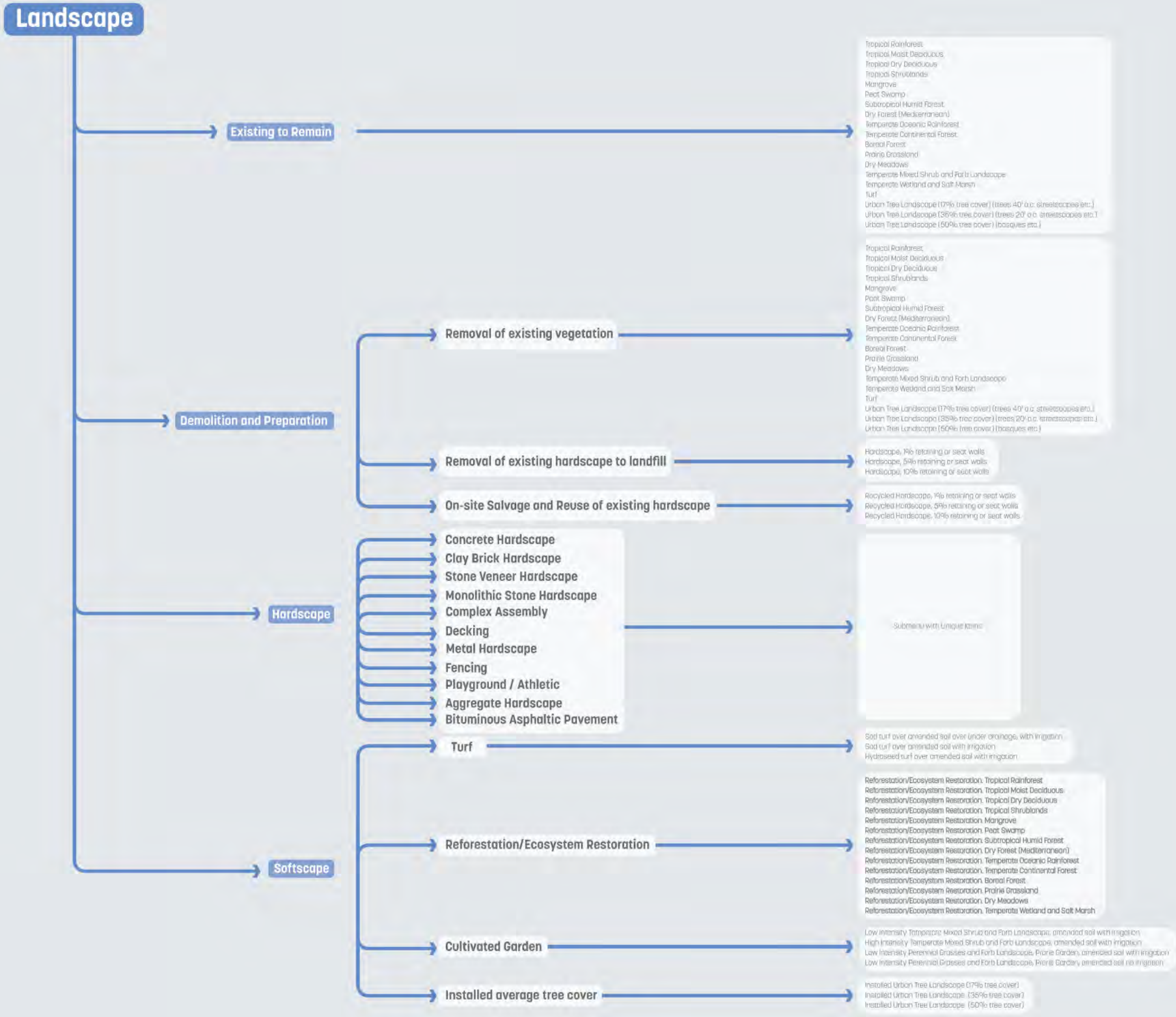
	WBLCA		Product EPDs
EC3	Public shared Buildings data set	EC3	Annually updated material baselines (CLF)
AIA 2030 COMMITMENT	Sasaki Buildings data set		EPD dataset from Sasaki built work
Athena Impact Estimator for Buildings	Proprietary data set for WBLCA baselines	mindful MATERIALS	Alignment of databases between MM and AIA Material Pledge
GSA	Future public data set for WBLCA baselines	GSA	Future public data set for Products and Materials

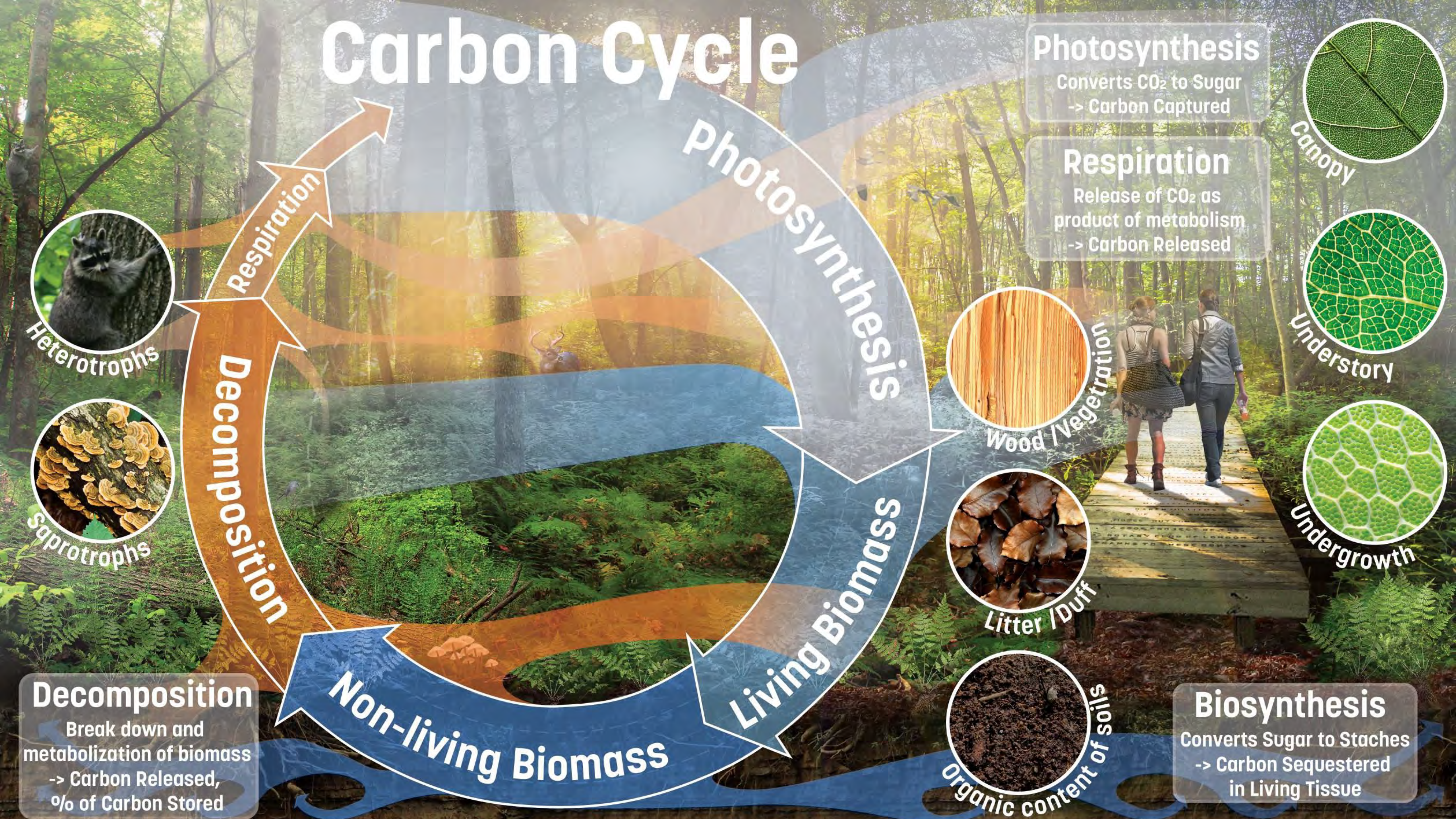
Program

Structure

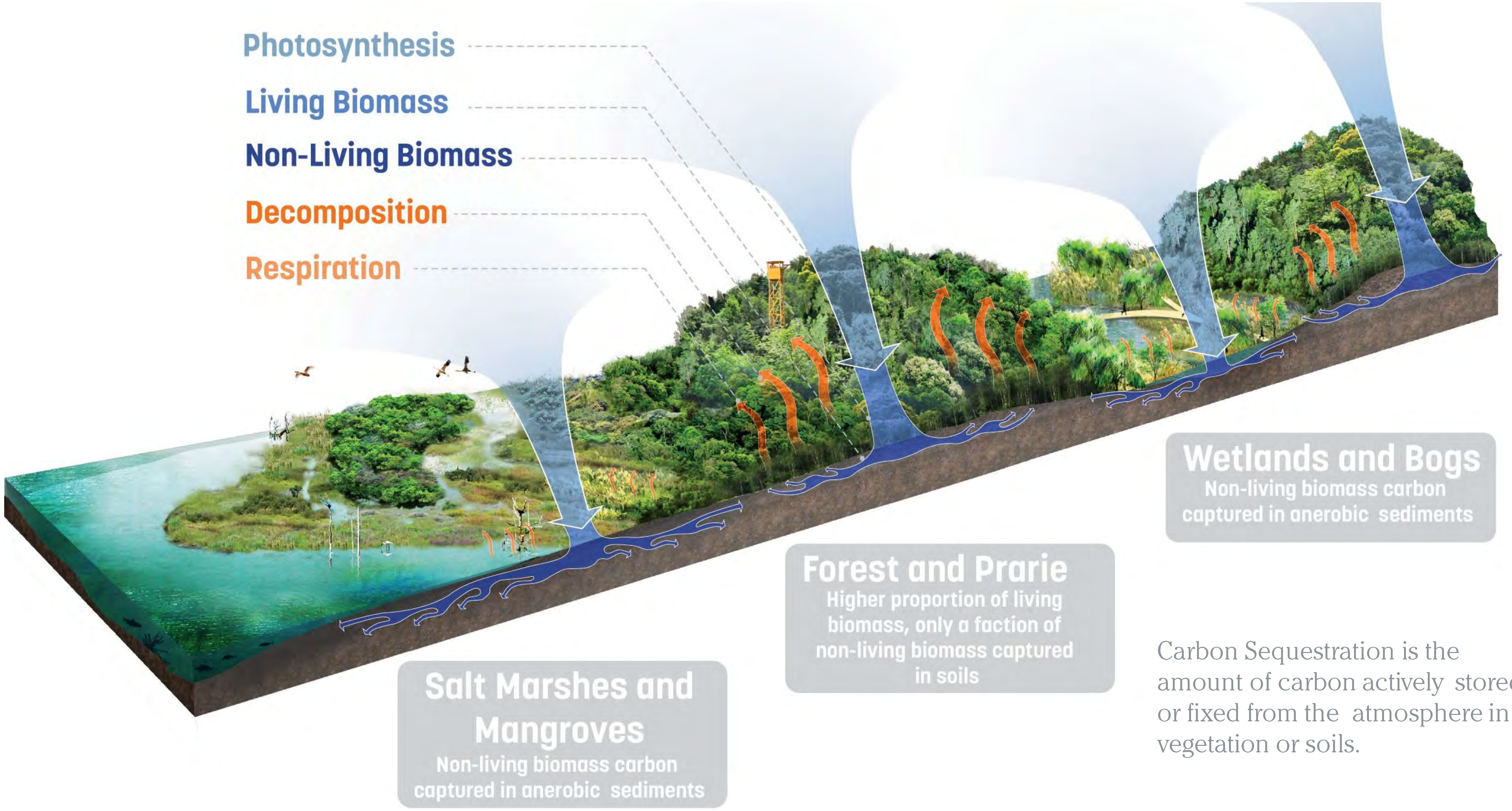
Envelope

Landscape Land Uses


Landscape
Existing to Remain
Tropical Rainforest
Tropical Moist Deciduous
Tropical Dry Deciduous
Tropical Shrublands
Mangrove
Peat Swamp
Subtropical Humid Forest
Dry Forest (Mediterranean)
Temperate Oceanic Rainforest
Temperate Continental Forest
Boreal Forest
Prairie Grassland
Dry Meadows
Temperate Mixed Shrub and Forb Landscape
Temperate Wetland and Salt Marsh
Turf
Urban Tree Landscape (17% tree cover) (trees 40' o.c. streetscapes etc.)
Urban Tree Landscape (35% tree cover) (trees 20' o.c. streetscapes etc.)
Urban Tree Landscape (50% tree cover) (bosques etc.)
Demolition and Preparation
Removal of existing vegetation
Tropical Rainforest
Tropical Moist Deciduous
Tropical Dry Deciduous
Tropical Shrublands
Mangrove
Peat Swamp
Subtropical Humid Forest
Dry Forest (Mediterranean)
Temperate Oceanic Rainforest
Temperate Continental Forest
Boreal Forest
Prairie Grassland
Dry Meadows
Temperate Mixed Shrub and Forb Landscape
Temperate Wetland and Salt Marsh
Turf
Urban Tree Landscape (17% tree cover) (trees 40' o.c. streetscapes etc.)
Urban Tree Landscape (35% tree cover) (trees 20' o.c. streetscapes etc.)
Urban Tree Landscape (50% tree cover) (bosques etc.)
Removal of existing hardscape to landfill
Hardscape, 1% retaining or seat walls
Hardscape, 5% retaining or seat walls
Hardscape, 10% retaining or seat walls
On-site Salvage and Reuse of existing hardscape
Recycled Hardscape, 1% retaining or seat walls
Recycled Hardscape, 5% retaining or seat walls
Recycled Hardscape, 10% retaining or seat walls
Hardscape
Concrete Hardscape
Clay Brick Hardscape
Stone Veneer Hardscape
Monolithic Stone Hardscape
Complex Assembly
Decking
Metal Hardscape
Fencing
Playground / Athletic
Aggregate Hardscape
Bituminous Asphaltic Pavement
Submenu with Unique Items
Softscape
Turf
Sod turf over amended soil over under drainage, with irrigation
Sod turf over amended soil with irrigation
Hydroseed turf over amended soil with irrigation
Reforestation/Ecosystem Restoration
Reforestation/Ecosystem Restoration. Tropical Rainforest
Reforestation/Ecosystem Restoration. Tropical Moist Deciduous
Reforestation/Ecosystem Restoration. Tropical Dry Deciduous
Reforestation/Ecosystem Restoration. Tropical Shrublands
Reforestation/Ecosystem Restoration. Mangrove
Reforestation/Ecosystem Restoration. Peat Swamp
Reforestation/Ecosystem Restoration. Subtropical Humid Forest
Reforestation/Ecosystem Restoration. Dry Forest (Mediterranean)
Reforestation/Ecosystem Restoration. Temperate Oceanic Rainforest
Reforestation/Ecosystem Restoration. Temperate Continental Forest
Reforestation/Ecosystem Restoration. Boreal Forest
Reforestation/Ecosystem Restoration. Prairie Grassland
Reforestation/Ecosystem Restoration. Dry Meadows
Reforestation/Ecosystem Restoration. Temperate Wetland and Salt Marsh
Cultivated Garden
Low Intensity Temperate Mixed Shrub and Forb Landscape, amended soil with irrigation
High Intensity Temperate Mixed Shrub and Forb Landscape, amended soil with irrigation
Low Intensity Perennial Grasses and Forb Landscape, Prarie Garden, amended soil with irrigation
Low Intensity Perennial Grasses and Forb Landscape, Prarie Garden, amended soil no irrigation
Installed average tree cover
Installed Urban Tree Landscape (17% tree cover)
Installed Urban Tree Landscape (35% tree cover)
Installed Urban Tree Landscape (50% tree cover)

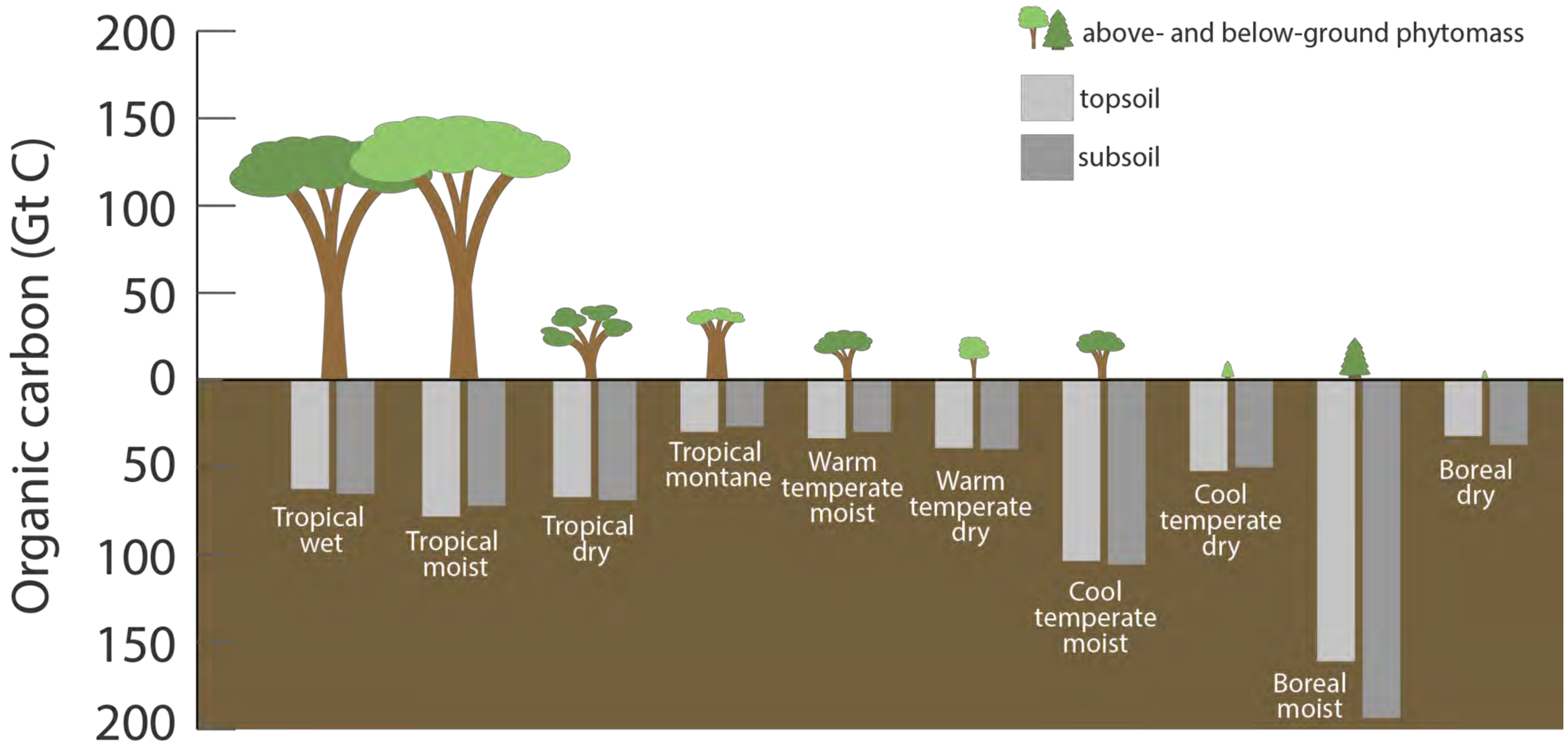

Carbon Cycle
Photosynthesis
Converts CO_2 to Sugar
-> Carbon Captured
Respiration
Release of CO_2 as
product of metabolism
-> Carbon Released
Canopy
Understory
Undergrowth
Photosynthesis
Respiration
Decomposition
Living Biomass
Non-living Biomass
Heterotrophs
Saprotrophs
Wood /Vegetation
Litter /Duff
Organic content of soils
Decomposition
Break down and
metabolization of biomass
-> Carbon Released,
% of Carbon Stored
Biosynthesis
Converts Sugar to Staches
-> Carbon Sequestered
in Living Tissue

Carbon Sequestration



Carbon Sequestration is the amount of carbon actively stored or fixed from the atmosphere in vegetation or soils.

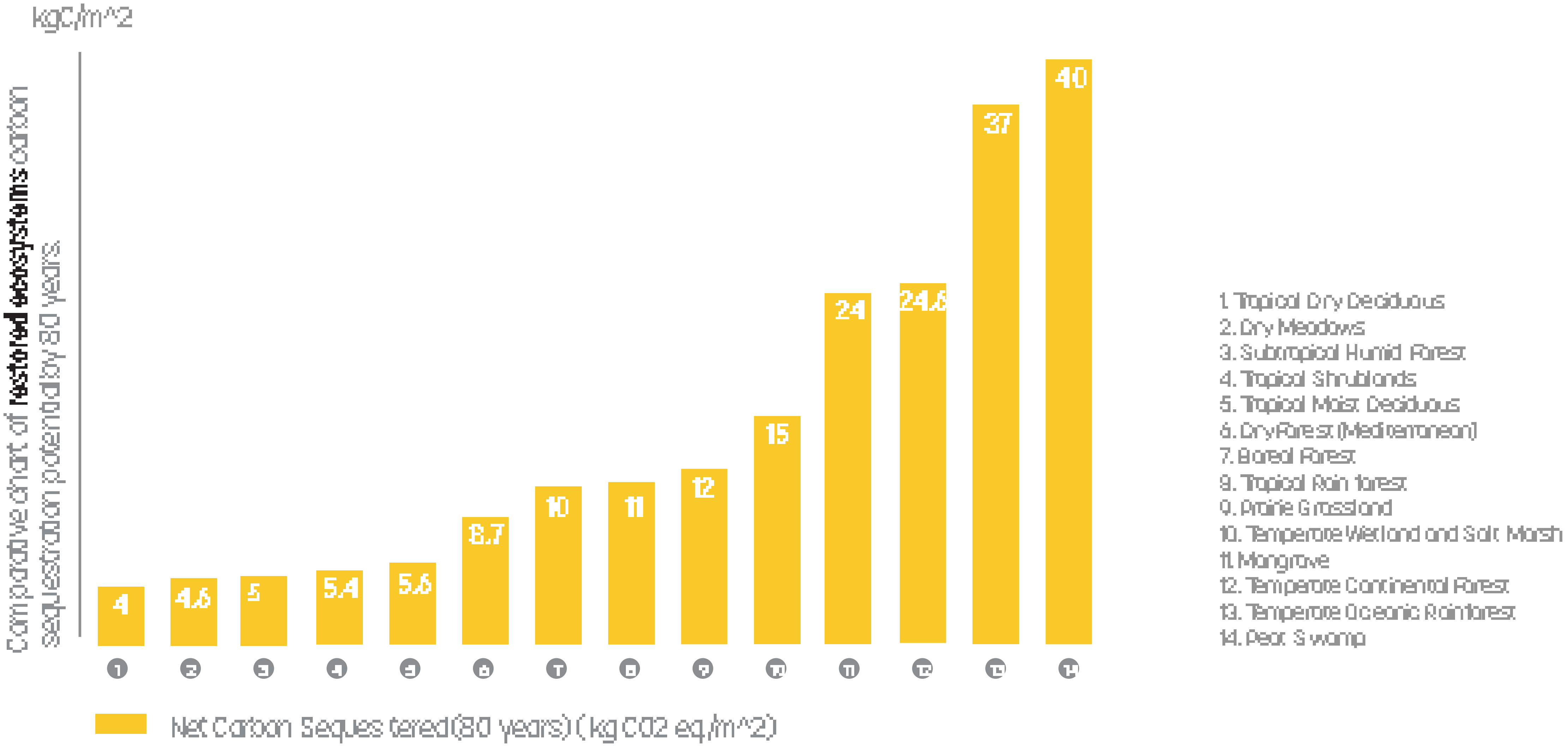
Carbon Sequestration by Ecosystem



- Globally, soil carbon represents more than half of the stock of carbon in forests.
- Forest landscapes have larger proportion of carbon above ground than below ground, while meadow landscapes have a larger proportion of carbon below than above ground.
- Dead biomass is a larger proportion of carbon storage in forests than in meadows.
- Plant litter is a more important pathway for carbon into the soil in forests, than in grasslands.

Zac Kayler, Maria Janowiak, Chris Swanston - https://www.fs.usda.gov/ccrc/topics/global-carbon

Maximize High-Carbon Sequestration Land Uses



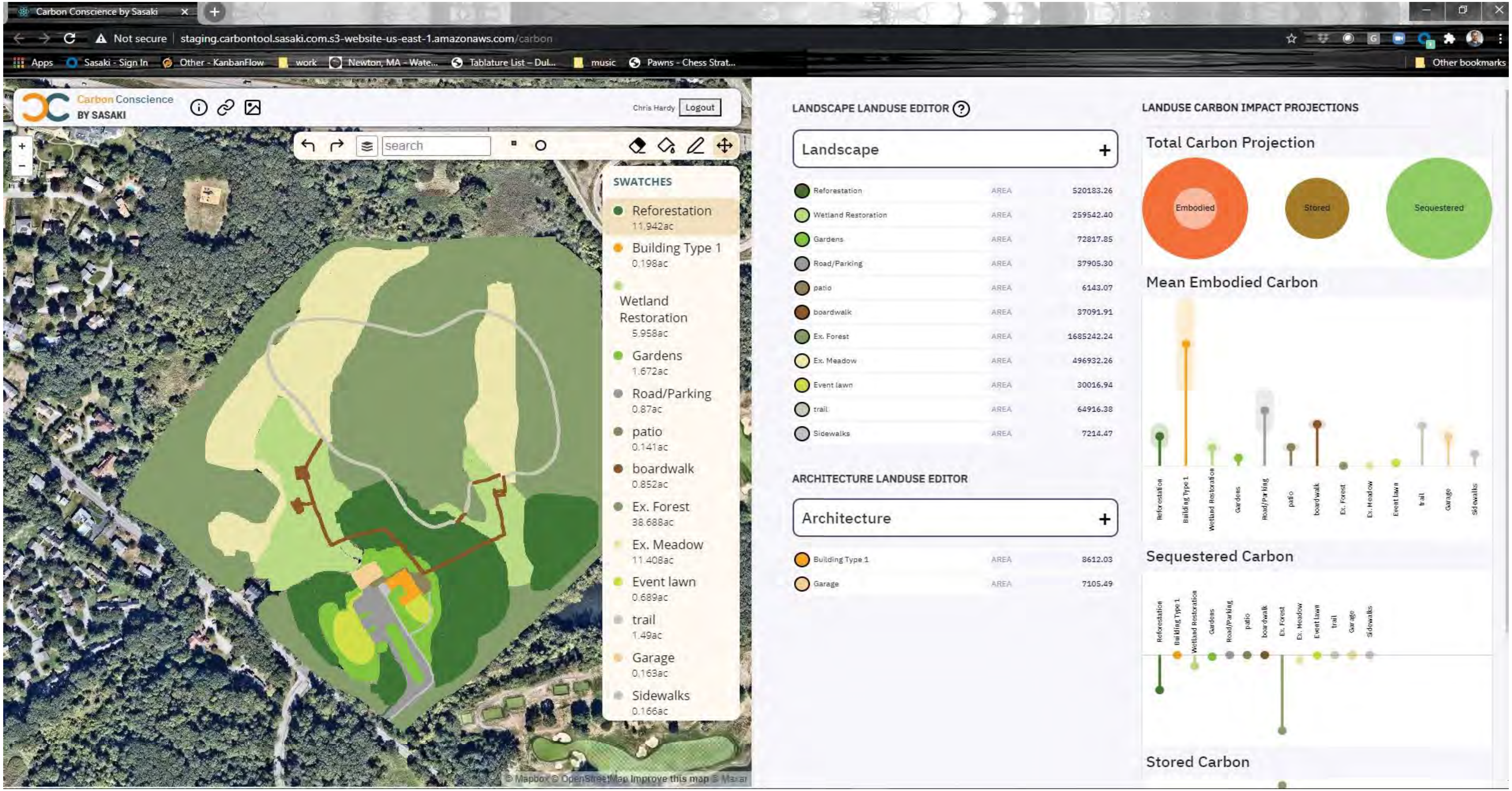
Data Set for Hardscape and Softscape

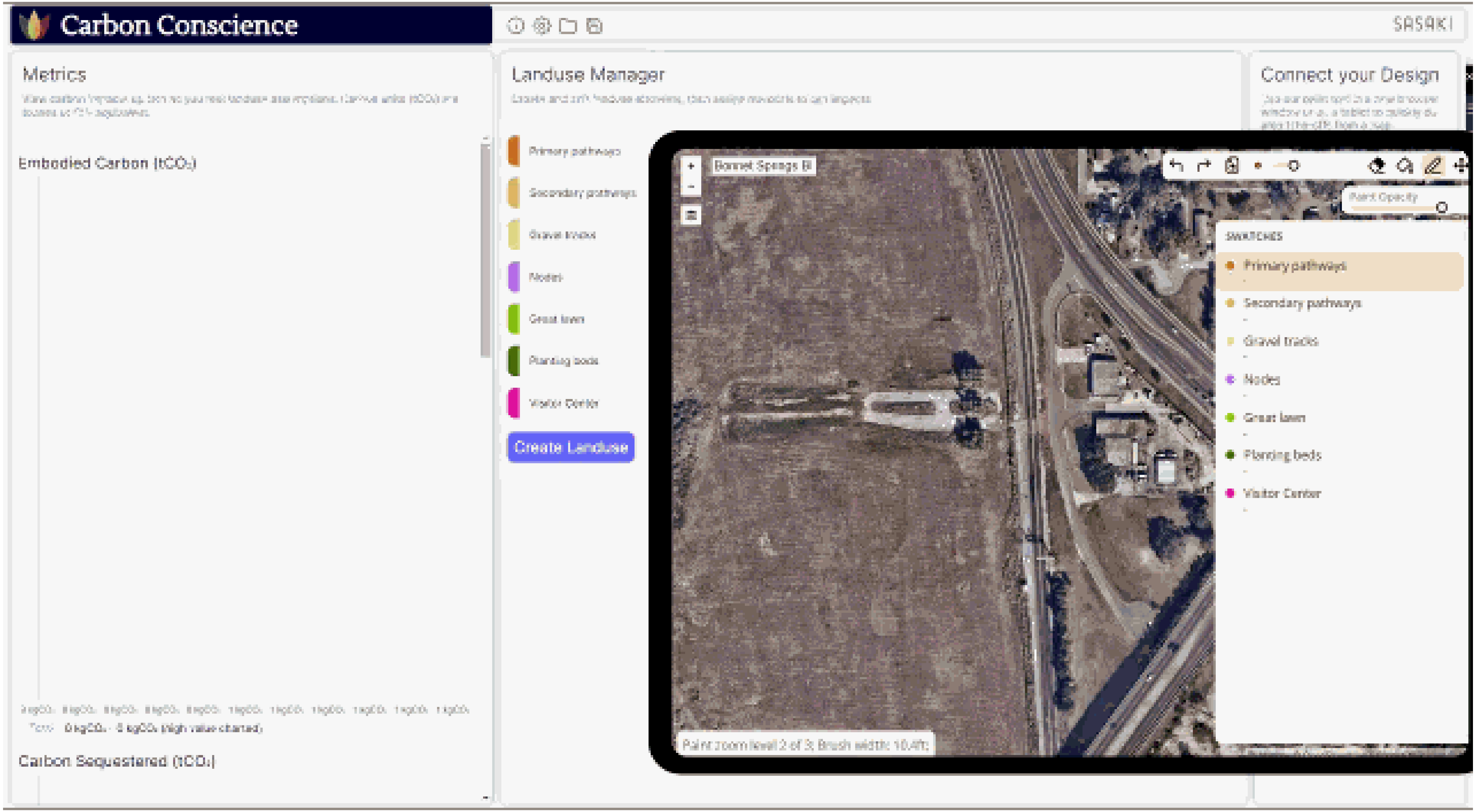
Parameter Quotation	QNT.	Unit
Primary Materials Carbon Factors		
Clay Brick (Air/Sun Dried)	0.060	kgC/kg
Clay Brick (Baked)	0.230	kgC/kg
Stone (Quarried and Dressed)	0.073	kgC/kg
Cement	0.226	kgC/kg
Mortar (1:3 cement to sand)	0.058	kgC/kg
Concrete (1:2:4, type 1 or 2)	0.050	kgC/kg
Precast Concrete	0.059	kgC/kg
Sand / Soil (Mined, screened)	0.002	kgC/kg
Aggregate Base (Crushed)	0.040	kgC/kg
Gravel (mined, screened, not crushed)	0.002	kgC/kg
Cinder Blocks (Aerated Concrete Block)	0.076	kgC/kg
Asphaltic Concrete (HMA)	0.059	kgC/kg
Bitumen Tar	0.410	kgC/kg
Polyurethane Resin	4.260	kgC/kg
Polyurethane Resin Bonded Aggregate	0.111	kgC/kg
Steel	0.482	kgC/kg
Galv. Steel	0.763	kgC/kg
Stainless Steel	0.983	kgC/kg
Bronze	3.730	kgC/kg
Brass	2.460	kgC/kg
Aluminum	8.240	kgC/kg
Copper	2.600	kgC/kg
Timber (Rough Cut)	0.125	kgC/kg
Glue laminated timber	0.234	kgC/kg
Milled hardwood	0.343	kgC/kg
Milled softwood	0.274	kgC/kg
HDPF (High Density Foam Polyolefin)	6.400	kgC/kg
Polycarbonate Plastic	6.030	kgC/kg
ABS Plastic (Acrylonitrile butadiene styrene)	16.000	kgC/kg
EPS Geofoam (expanded polystyrene geofoam)	2.550	kgC/kg
Geotextile (polypropylene fabric)	7.400	kgC/kg
LDPE (Polyethylene)	2.130	kgC/kg
Fiberglass	1.350	kgC/kg
Ceramic Tile	0.450	kgC/kg
EPDM Rubber (Playground Surfacing)	3.700	kgC/kg
Engineered Mulch (Fibar Playground Surfacing)	0.400	kgC/kg
Nylon/polypropylene carpeting (proxy for synthetic turf)	19.400	kgC/kg
Mulch	0.015	kgC/kg
Lime	0.760	kgC/kg
Damp proofing/membrane	4.200	kgC/kg
Paint	2.420	kgC/kg

Simplified average coverages into about <u>200 unique landscape</u> landuses that could be combined in relative ratios to create many options

C	D	E	F	G	H	I	J	K
Land Use SubMenu Tier 1: Category	Land Use SubMenu Tier 2: Unique Item	Assembly (Item Ref. #)	*Assumptions:* Assembly Composition	Assembly Percentage	Embodied Carbon Cost (Low) (kgC/m^2)	Embodied Carbon Cost (High) (kgC/m^2)	Net Carbon Sequestered (@ 80 years) -(kgC/m^2)	Carbon Stored (kg CO2 eq./m^2)
Concrete Hardscape	Pedestrian Concrete Hardscape. Mostly flatwork, minimal walls (1% or less), minimal drain structures and furnishings.		*Assume 98% 100 mm reinforced CIP concrete over 150mm aggregate, assume 1% of area = 1M high CIP reinforced retaining wall with 1M deep spread footer. Assume 1% of area stainless steel drain structure with HDPE drain body. Assume 0.025% of area concrete catch basin. Assume 1% area painted steel 25 mm thick, and wood 50mm thick, to provide average for landscape furnishing. Assume 1 SM of geotextile.*		70.26	118.48	0.00	1.01
Concrete Hardscape	CIP Pedestrian Concrete Hardscape. Mostly flatwork, some walls (5%), limited drain structures and lightly furnished.		Assume 93% 100 mm reinforced CIP concrete over 150mm aggregate, assume 5% of area = 1M high CIP reinforced retaining wall with 1M deep spread footer.) Assume 2% of area stainless steel drain structure with HDPE drain body. Assume 0.025% of area concrete catch basin. Assume 3% area painted steel 25 mm thick, and wood 50mm thick, to provide average for landscape furnishing. Assume 1 SM of geotextile.		106.99	179.55	0.00	3.02
		033001.01	100 mm deep CIP Concrete	0.93	31.78	56.63	0	0
		321100.01	150mm deep crushed aggregate base	0.93	12.11	20.66	0	0
		033001.21	Reinforcing for concrete pavement (no. 4 rebar 300mm o.c.e.w.)	0.93	8.37	12.84	0	0
		033001.04	1M high CIP retaining wall with 1M deep spread footer	0.05	34.17	60.89	0	0
		033001.22	1M high CIP retaining wall / footing Steel rebar (no. 4 rebar 300mm o.c.e.w.)	0.05	1.35	2.07	0	0
		334000.01	stainless steel drain structure	0.02	3.51	5.68	0	0
		334000.02	HDPE drain body	0.02	5.05	5.05	0	0
		334000.03	concrete catch basin	0.00025	0.01	0.01	0	0
		323300.01	steel 25 mm thick	0.03	8.83	13.54	0	0
		323300.02	hardwood 50mm thick (Domestic Source)	0.03	1.45	1.72	0	3.0195
		321100.06	1 SM of geotextile	1	0.26	0.33	0	0
		099001.01	Paint or Stain (3 coats) 1 SM (for painted steel or stains on wood)	0.01	0.11	0.13	0	0
Concrete Hardscape	CIP Pedestrian Concrete Hardscape. Complex hardscape, significant walls (10%), extensive drain structures and heavily furnished.		Assume 87% 100 mm reinforced CIP concrete over 150mm aggregate, assume 10% of area = 1M high CIP reinforced retaining wall with 1M deep spread footer. Assume 3% of area stainless steel drain structure with HDPE drain body. Assume 0.025% of area concrete catch basin. Assume 5% area painted steel 25 mm thick, and wood 50mm thick, to provide average for landscape furnishing. Assume 1 SM of geotextile.		150.27	252.23	0.00	5.03
Concrete Hardscape	CIP Concrete wall and drainrock		50% of area = 1M high CIP reinforced retaining wall with 1M deep spread footer. 50% 0.5M deep drain rock. Assume 1M length 100mm dia. perf. pipe, 1 SM of geotextile.		378.27	668.01		

Test & Iterate

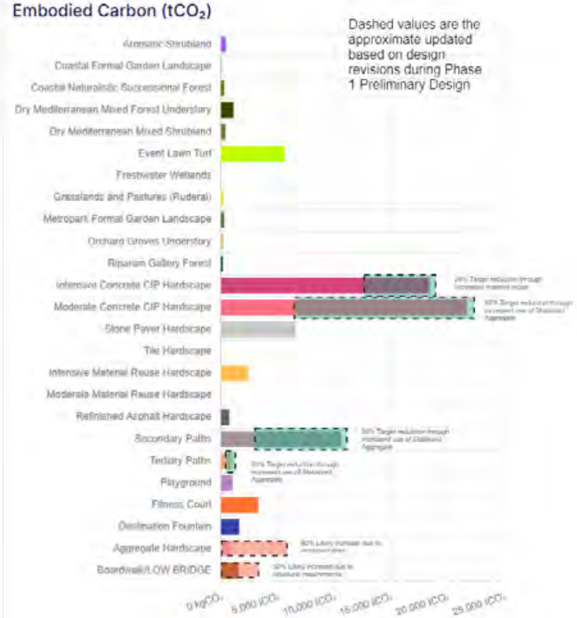




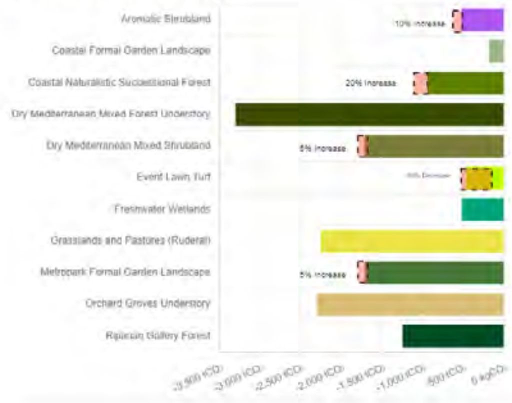
Carbon Conscience
SASAKI
Metrics
Embodied Carbon (tCO₂)
Carbon Sequestered (tCO₂)
Landuse Manager
Primary pathways
Secondary pathways
Nodes
Great lawn
Planting beds
Visitor Center
Create Landuse
Connect your Design
SWATCHES
Primary pathways
Secondary pathways
Gravel tracks
Nodes
Great lawn
Planting beds
Visitor Center

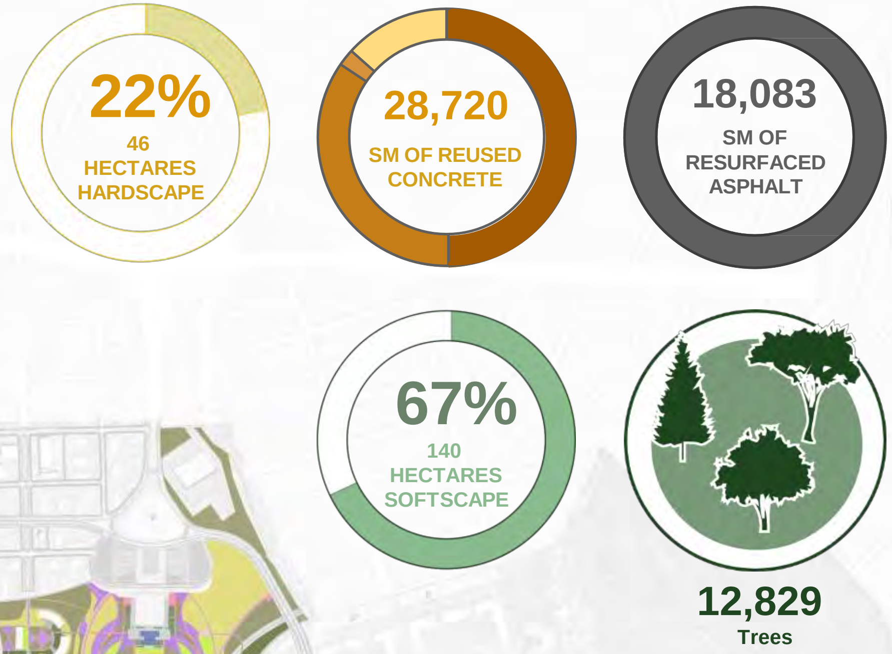
Apply

Embodied Carbon (tCO_2)

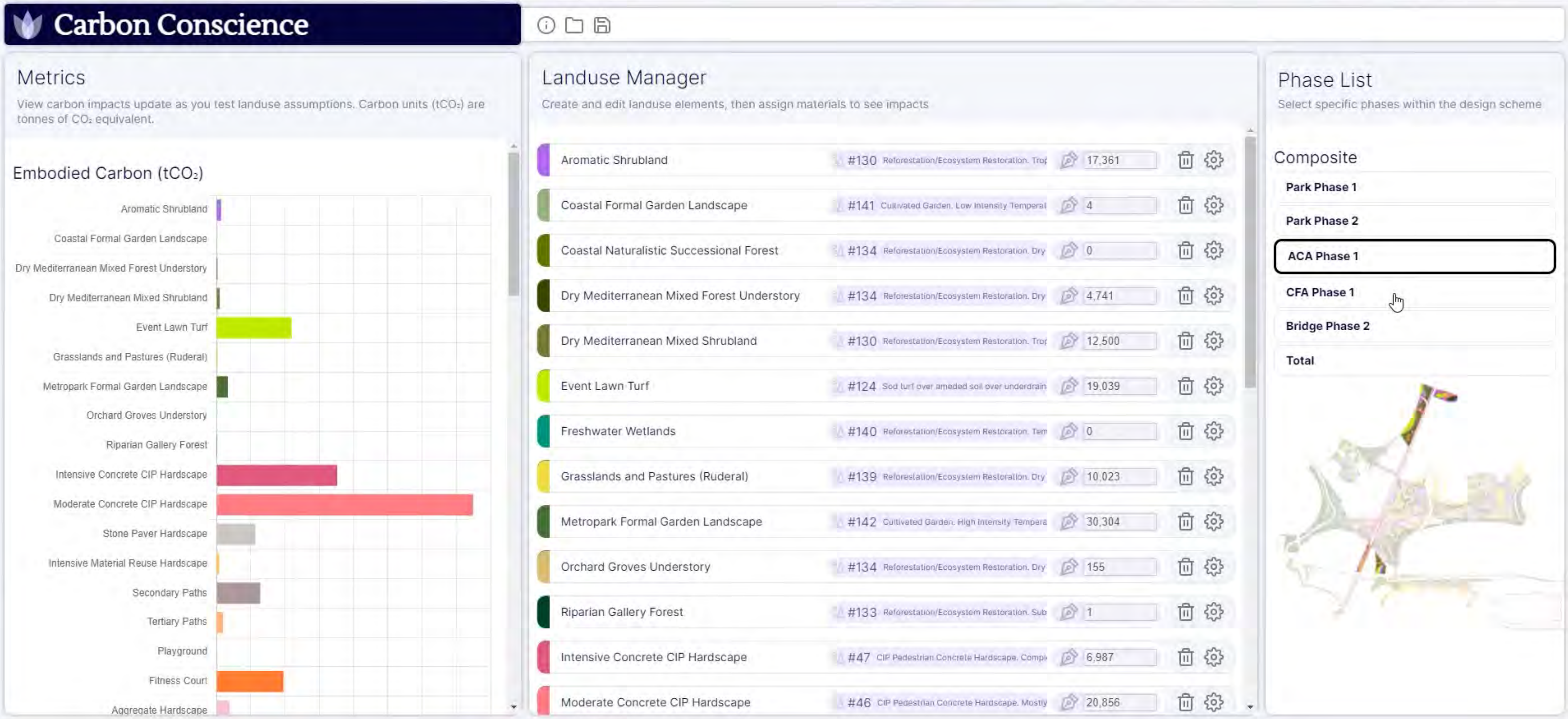


Carbon Sequestered (tCO_2)





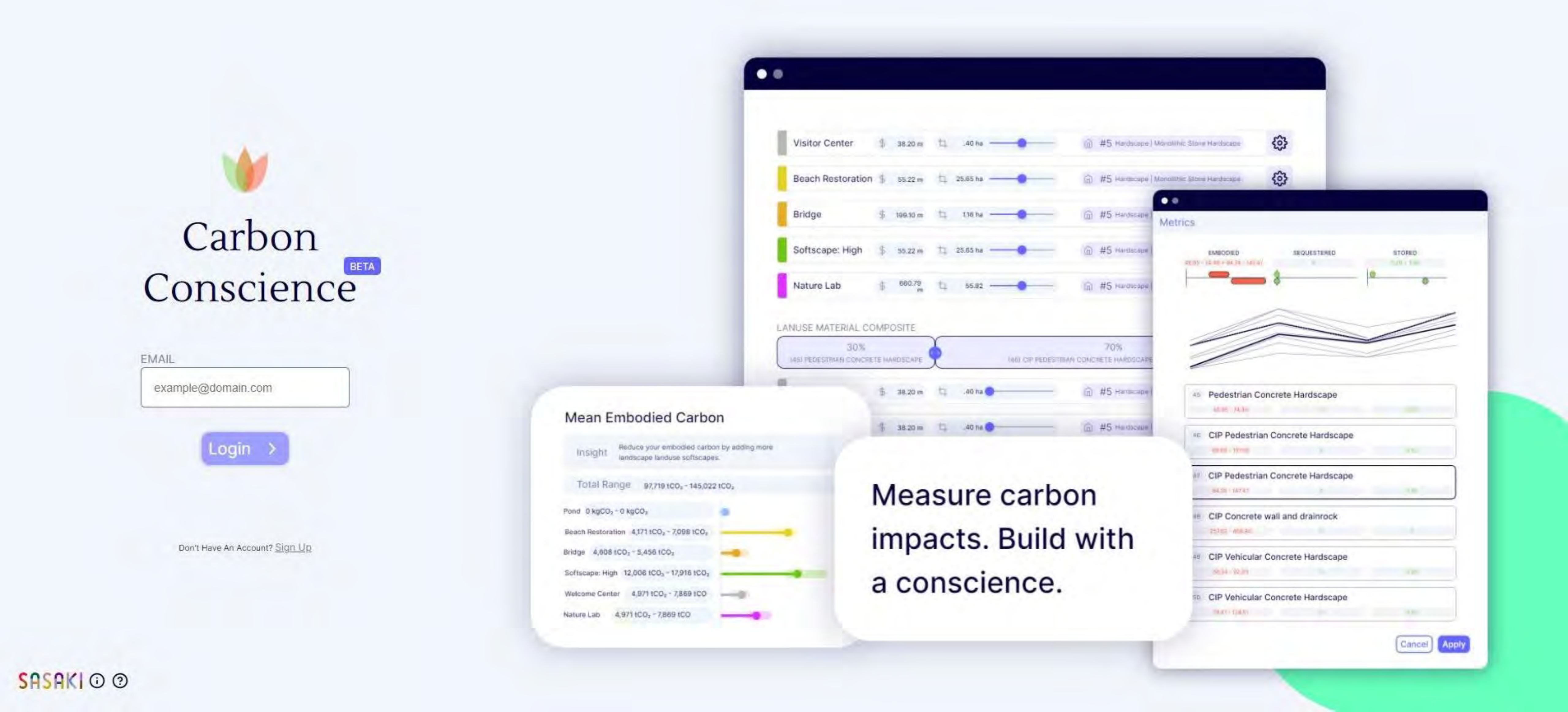
Integration



Demonstration

https://carbon-conscience.web.app/

https://visualizations.sasaki.com/staging/carbon-conscience-public/



Lessons Learned

*Note: following slides built from 2021 ASLA Conference: *Design with Carbon: Reconsidering Landscapes from Planning to Soils* by Christopher R. Ng-Hardy, Pamela Conrad, Deanna Lynn

+ Maximize the carbon stored in **plants and soil**

+ Preserve and protect existing habitats, with a priority for mature forests and wetlands.
- Minimize Turf grasses
+ Fast-growing
+ Long-lived
+ Long growing season
+ Low maintenance

- Minimize **hardscape**

- Concrete & metals
+ Low impact to soils
- Less piping, more natural drainage
+ Cement substitutes: SCMs
+ Recycled materials & content
+ Permeable paving

- Minimize & reuse
carbon embodied in materials

+ + Reuse & recycle architecture and landscape elements
+ + Select low-carbon materials, EPDs
+ + Prioritize local material
+ Structures: Use wood & mass timber
+ Facades: Use wood & thin masonry claddings, minimize glazing

- Minimize Day 1 & Day-to-Day Emissions + **keep carbon stored** longer

+ Electric/hand-powered equipment
+ Organic v. chemical amendments
+ Build & protect soil carbon
+ Tree/plant litter management & recycling
+ Protect existing trees + ecosystems
- Low water

Top 5 things we can do

Every design move has a carbon impact.
Consider carbon from the onset of the design process.
Set – and track - an embodied carbon budget.
Reuse existing buildings and landscapes.

Less is more.

Questions?