EMBODIED CARBON IN BUILDINGS

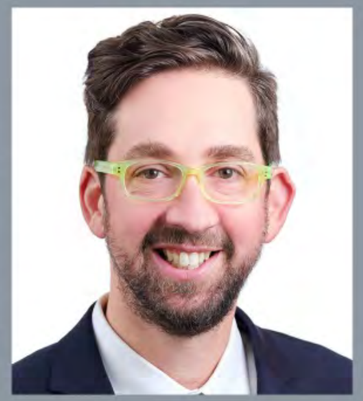
BSA

EMBODIED CARBON IN BUILDINGS

The BSA Embodied Carbon in Buildings advisory group

Jean Carroon FAIA
BSA President; Goody Clancy

Lori Ferriss AIA
Goody Clancy



Jason Forney AIA
Bruner/Cott

Jeremy Gregory
MIT Concrete Sustainability Hub

Andrea Love AIA
Payette

EMBODIED CARBON IN BUILDINGS

BSA

EMBODIED CARBON IN BUILDINGS

Session 1: Embodied Carbon 101

Marc Rosenbaum PE
South Mountain Company

Greg Norris
International Living Future Institute

Kate Simonen AIA
Carbon Leadership Forum

Maggie Wildnauer
thinkstep

Embodied Carbon: Upfront, Ignored, Important…ACT NOW!

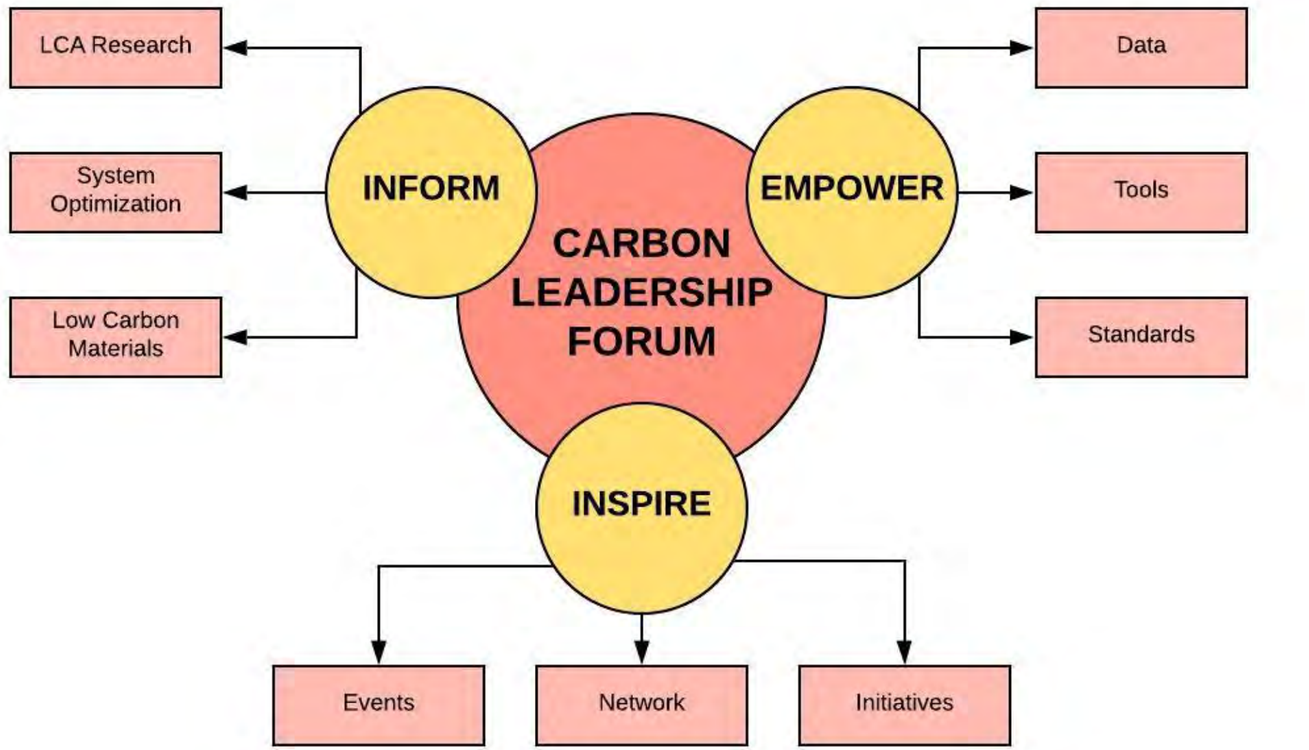
CARBON LEADERSHIP FORUM

Inform, Inspire and Enable Low Carbon Construction

Industry sponsored
Ten year track record
Academic research collaborative
Focused on embodied carbon

Values:
Transparency,
Open source data
Collaboration
Impact

www.carbonleadershipforum.org



CARBON LEADERSHIP FORUM

Inspire, Inform and Enable Low Carbon Construction

DIAMOND

MITHŪN

StopWaste — at home • at work • at school

Carbon Innovations

The Russell Family Foundation

PLATINUM

The American Institute of Architects

ARUP

SKANSKA

Interface

Thornton Tomasetti

CENTRAL — Stronger, Cleaner, Greener Concrete. — A U.S. Concrete Company

Orca — Optimal Ready-Mixed Concrete Aggregates — Distributed by Eagle Rock Aggregates Inc.

GOLD

climate earth

Magnusson Klemencic Associates — Structural + Civil Engineers

Kieran Timberlake

Owens Corning

Simpson Gumpertz & Heger — Engineering of Structures and Building Enclosures

thinkstep

Urban Fabrick — Connecting Policy and Practice with Design

walter p moore

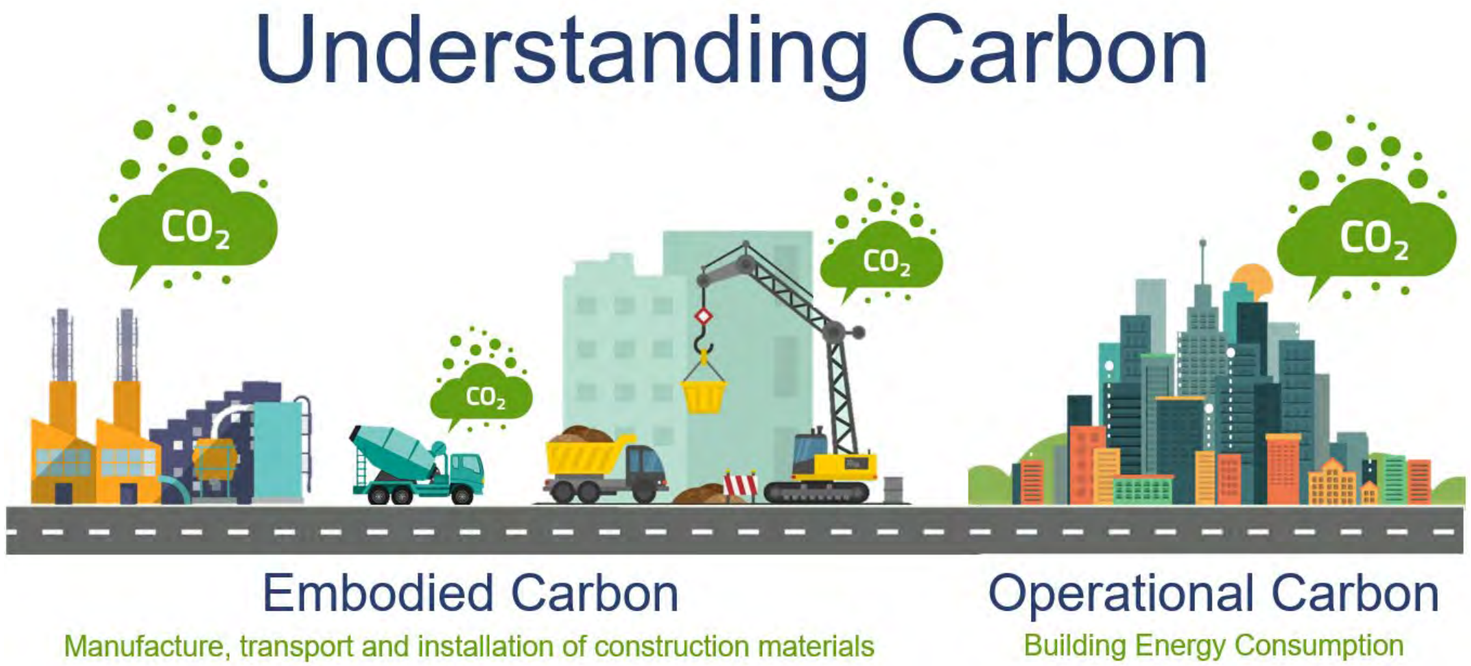
SILVER

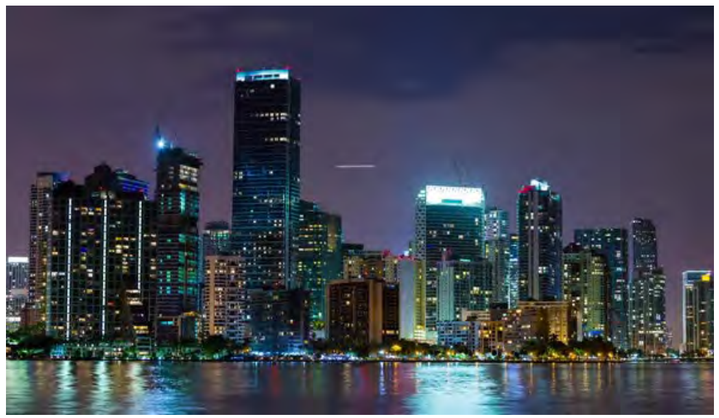
ADRIAN SMITH + GORDON GILL | ARKIN TILT | CARBONCURE | COUGHLIN PORTER LUNDEEN | KATERRA | LMN ARCHITECTS | LUND OPSAHL | NATIONAL READY MIXED CONCRETE CO. | NRMCA | SELLEN | SHKS | SIEGEL & STRAIN ARCHITECTS | WRNS STUDIO

SUPPORTERS

ARCHITECTURE 2030 | ATHENA SMI | CASBA | C-CHANGE LABS | COALITION TO PRESERVE LA | CORRIM | ECOLOGICAL BUILDING NETWORK | ENDEAVOUR CENTRE | NET ZERO ENERGY COALITION

Operating vs Embodied Carbon



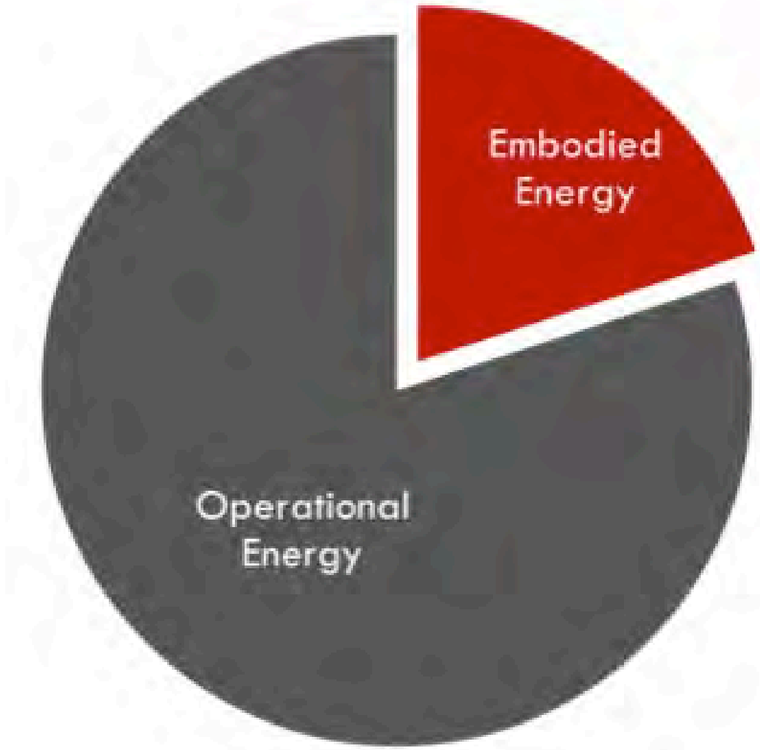


architecture 2030

Operating vs Embodied Carbon

Net Zero = Zero Carbon??

Buildings: Total Lifetime Energy Use



Typical Building
Typical Carbon Grid
Longer Lifespan

High Performance
Low Carbon Grid
Shorter Lifespan

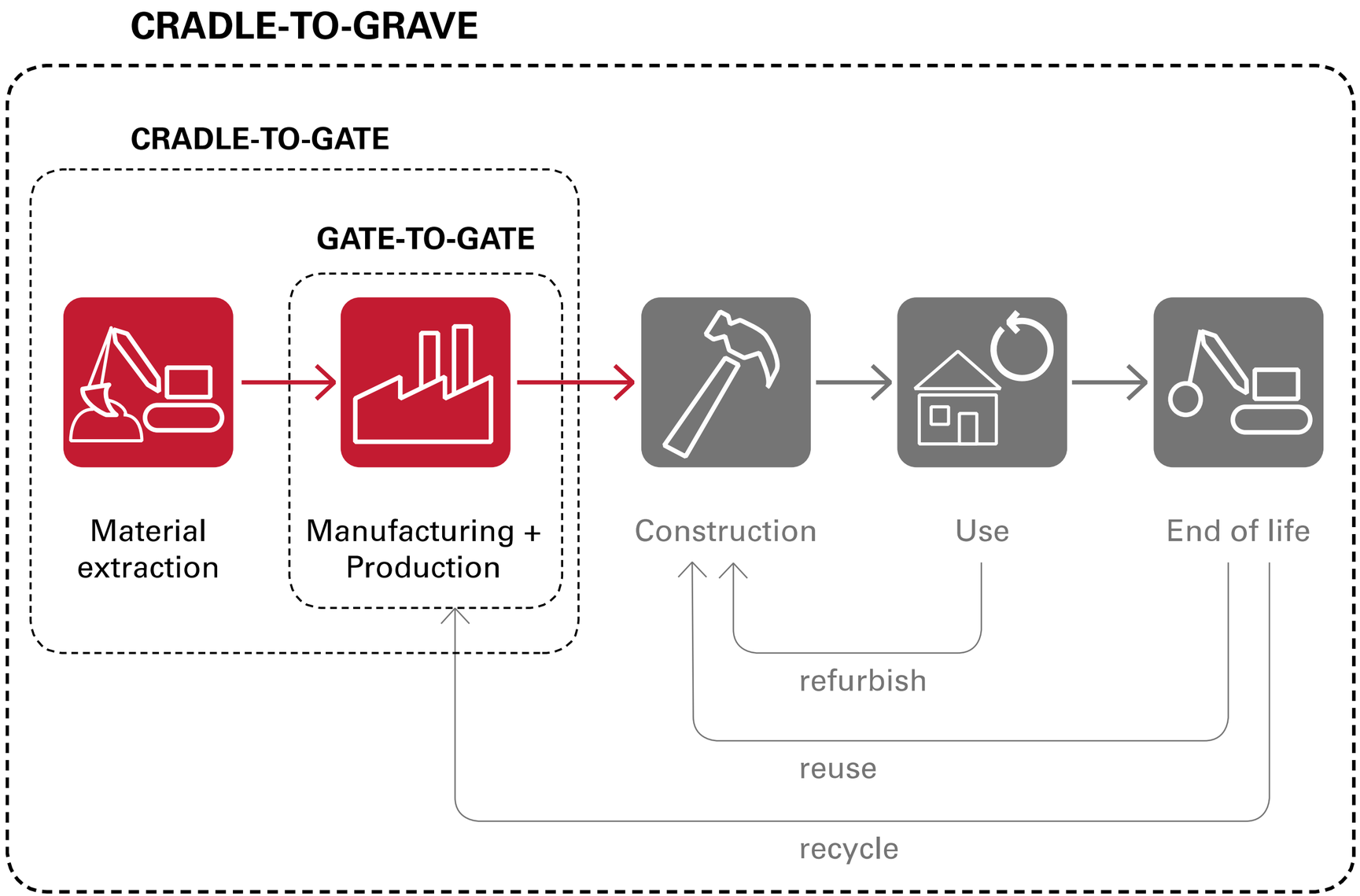
How the building sector meets global climate targets

1. New Buildings to Zero Net Operating Carbon by 2030
2. Existing Buildings to Zero Net Operating Carbon by 2050
3. Integrate Buildings into an Optimized Energy Grid
4. Eliminating Embodied Carbon in Buildings
5. Measure & Improve Health & Equity

http://carbonsmartbuilding.org/declaration

CARBON SMART BUILDING DECLARATION

Life Cycle Assessment: Life Cycle Scopes

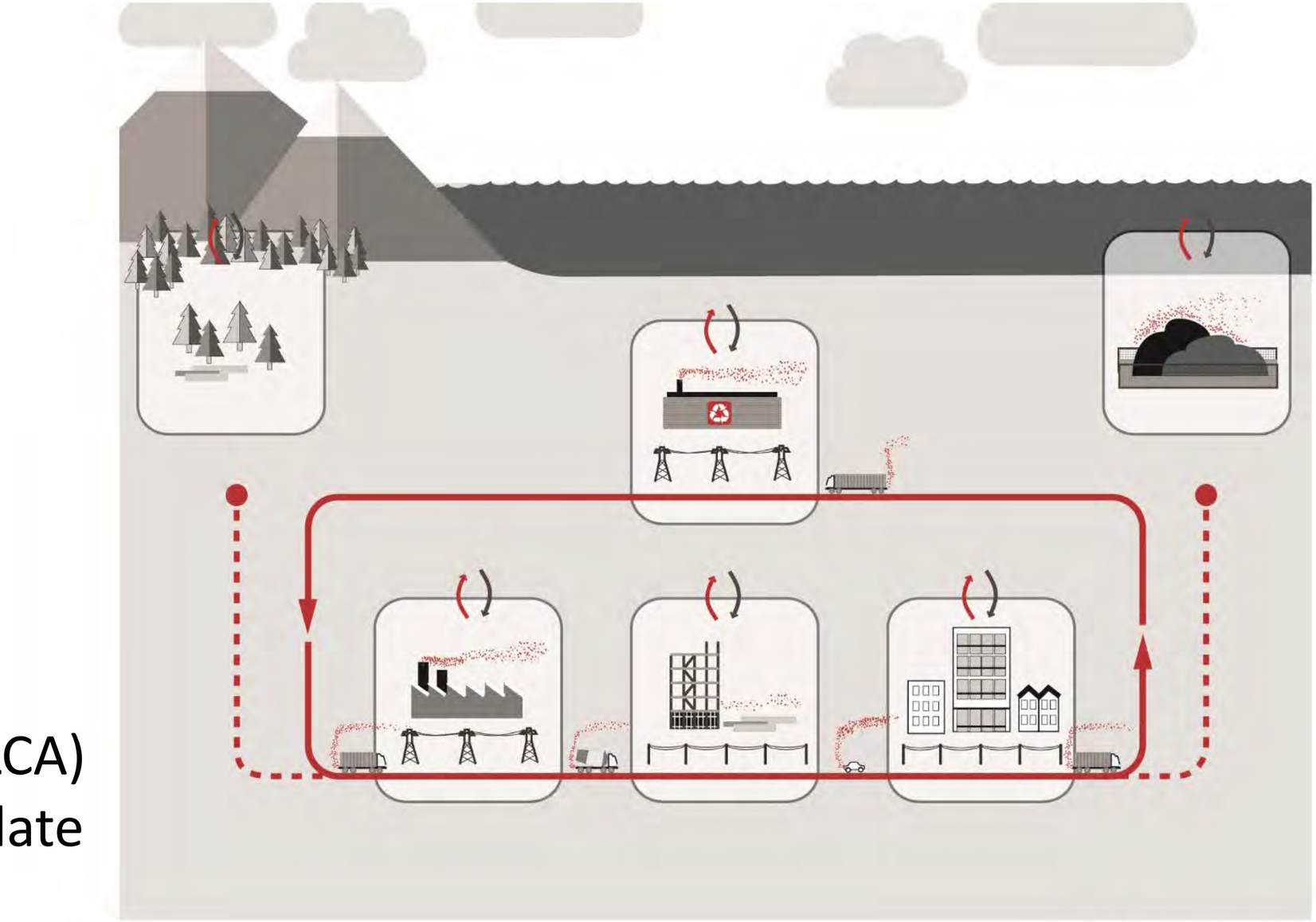


Life Cycle Assessment: Embodied Carbon

Emissions due to:

- Material extraction
- Transportation
- Manufacturing

Life Cycle Assessment (LCA) is method used to calculate embodied carbon.



Credit: Meghan Lewis

Embodied Carbon Market Drivers

Rating Systems/Challenges

- LEED v4
- 2030 Challenge for Products
- ILFI: Materials petal/zero carbon certification

Industry

- SE 2050
- AIA Materials Pledge

Policy

- Buy Clean
- Low Carbon Concrete Codes
- Vancouver Embodied Carbon Targets

COMMON THEMES:
DISCLOSURE & OPTIMIZATION

EPDs Enable Embodied Carbon Transparency

Environmental Product Declarations

Nutrition Facts

Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount Per Serving	
Calories 230	Calories from Fat 40
	% Daily Value*
Total Fat 8g	**12%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**12%**
Dietary Fiber 4g	**16%**
Sugars 1g	
Protein 3g	

Life Cycle Impact Results (per m^3)
Declared Unit: 1 m^3 of 10,000 psi concrete at 28 days

OPERATIONAL IMPACTS	*PerformX™ PECC10K*
Plant Operating Energy (MJ)	38.6
On-Site Plant Fuel Consumption (MJ)	11.1
Concrete Batch Water (m^3)	1.68E-01
Concrete Wash Water (m^3)	1.91E-02
On-Site Waste Disposal (kg)	0.0
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,017
Climate Change (kg CO_2 eq)	445
Ozone Depletion (kg CFC 11 eq)	1.31E-08
Acidification Air (kg SO_2 eq)	2.96
Eutrophication (kg N eq)	0.09
Photochemical Ozone Creation (kg O_3 eq)	0.61

EPDs Enable Embodied Carbon Transparency

Environmental Product Declarations

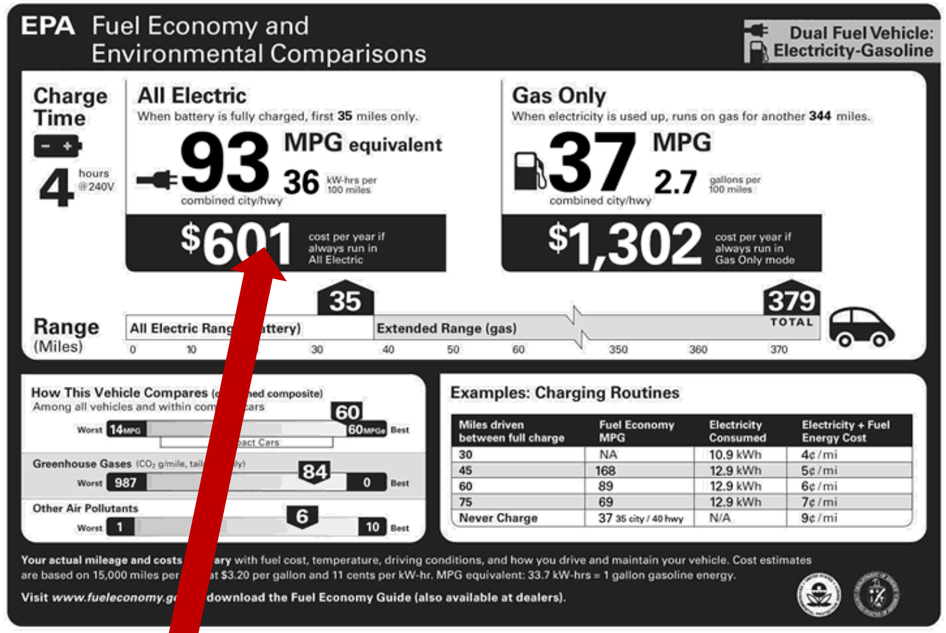
Nutrition Facts

Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount Per Serving	
Calories 230	Calories from Fat 40
	% Daily Value*
Total Fat 8g	**12%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**12%**
Dietary Fiber 4g	**16%**
Sugars 1g	
Protein 3g	

Life Cycle Impact Results
Declared Unit: 1 m^3 of 10,000 psi concrete at 28 days

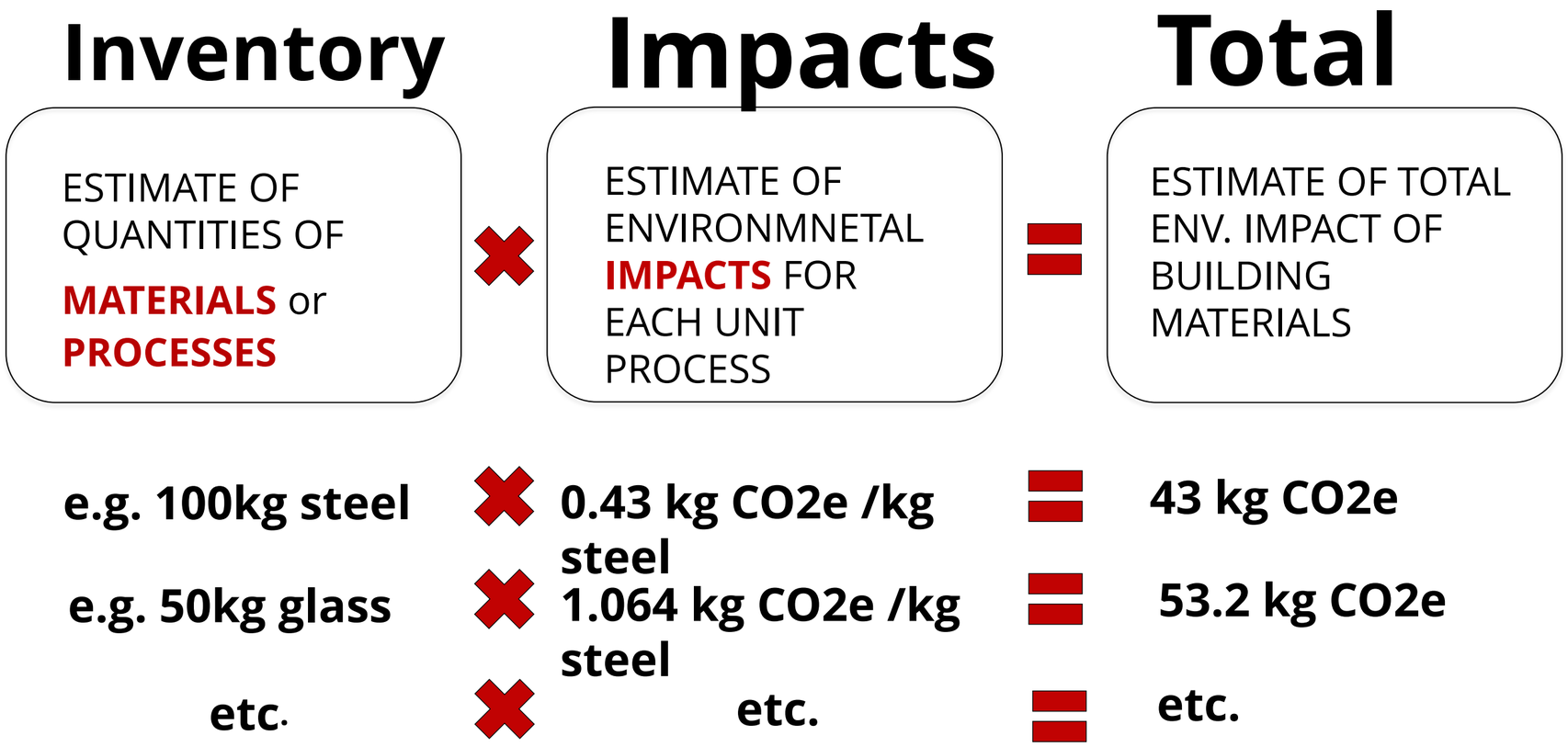
OPERATIONAL IMPACTS	*PerformX™ PECC10K*
Plant Operating Energy (MJ)	38.6
On-Site Plant Fuel Consumption (MJ)	11.1
Concrete Batch Water (m^3)	1.68E-0
Concrete Wash Water (m^3)	1.91E-
On-Site Waste Disposal (kg)	0.0
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,
Climate Change (kg CO_2 eq)	445
Ozone Depletion (kg CFC 11 eq)	1.31E-08
Acidification Air (kg SO_2 eq)	2.96
Eutrophication (kg N eq)	0.09
Photochemical Ozone Creation (kg O_3 eq)	0.61



EPD Results are like MPG

- Estimates based on standard assumptions (PCR)
- Known variability
- Directionally accurate

LCA: Materials/Processes to Impacts



Carbon Leadership Forum: Research to Outreach

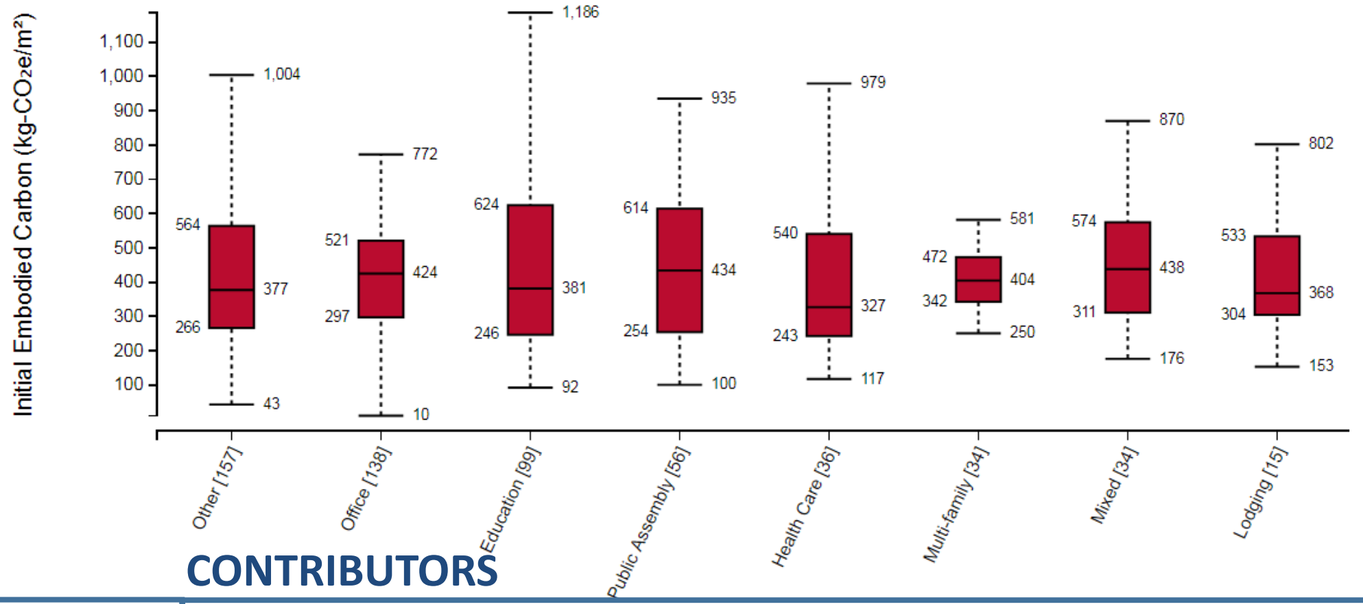
Carbon Smart Building	Embodied Carbon Network	SE 2050 Challenge	Buy Clean Study
Model LCA Specs	LCA Practice Guide	Embodied Carbon Education	Embodied Carbon Benchmark
Concrete PCR	EC3	Seismic Damage and LCA	USDA CLT Optimization
LCA of MEP Systems	LCA of Tennant Improvement	Embodied Carbon as LCA Proxy	NSF Resilient Sustainable Buildings

CLF Embodied Carbon Benchmarking Study

CARBON LEADERSHIP FORUM
UNIVERSITY of WASHINGTON

Embodied Carbon Benchmarking Study

- Over 1,000 building entries
- 12 Building Categories
- Open Source Database
- Phase 1 of Larger LCA Practice Guide Funded Project



SPONSORS

SKANSKA

State of Oregon Department of Environmental Quality

CHARLES PANKOW FOUNDATION
Building Innovation through Research

CONTRIBUTORS

Thornton Tomasetti
ARUP
Athena Sustainable Materials Institute
climate earth
SOM
MAGNUSSON KLEMENCIC ASSOCIATES
SIEGEL & STRAIN Architects
WALTER P MOORE
A S G G
tally
thinkstep
Massachusetts Institute of Technology
eTool
University of Colorado Boulder
URBAN FABRICK
architecture 2030
EBNet
Ecological Building Network
the art and science of building well
BuildingGreen
UBC
wrap
INTERNATIONAL LIVING FUTURE INSTITUTE
U.S. GREEN BUILDING COUNCIL

EC3: Embodied Carbon Calculator for Construction

PROJECT SPONSORS

CHARLES PANKOW FOUNDATION

MAGNUSSON KLEMENCIC ASSOCIATES FOUNDATION

SKANSKA

Interface

AISC AIA

aci Foundation

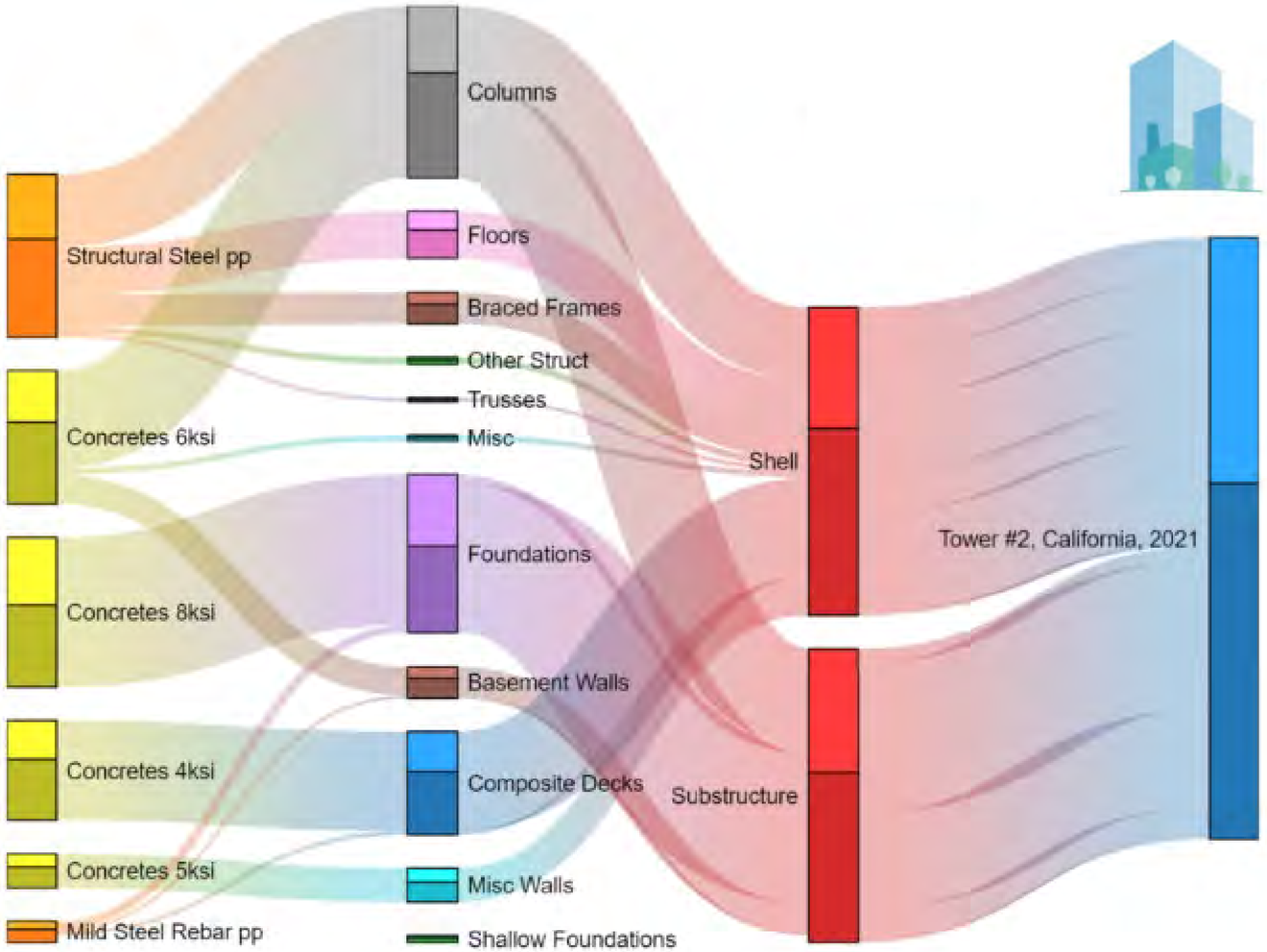
Microsoft

ALEXANDRIA

AUTODESK

WEBCOR

PERKINS+WILL



EC3

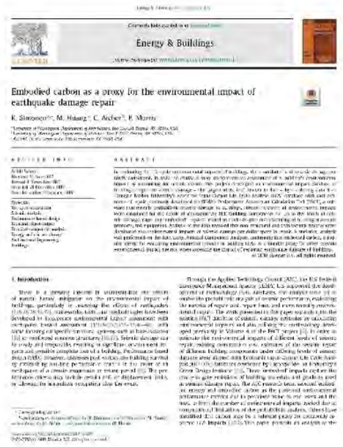
PROJECT LEADERSHIP

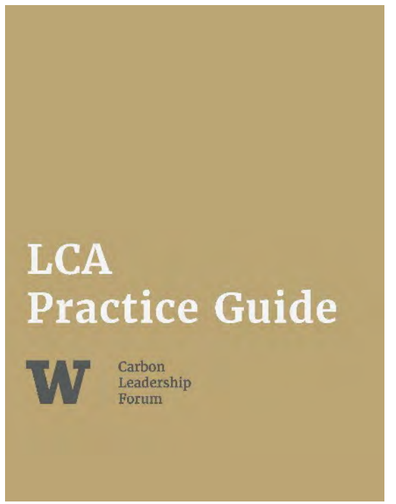
CLF Carbon Leadership Forum
UNIVERSITY of WASHINGTON

cchange labs

2019

EMBODIED CARBON NETWORK





www.carbonleadershipforum.org/resources/

www.embodiedcarbonnetwork.org

RECOMMENDED ACTIONS (Practitioners)

- Act **NOW** on Embodied Carbon
- Demand embodied carbon transparency via EPDs.
- Start making purchasing based on Embodied Carbon
- Learn more: **Become and embodied carbon leader!**

IN ORDER TO:

- Incentivize low carbon material/products
- Help drive market innovation and investment
- Drive better quality data and tools

EMBODIED CARBON IN BUILDINGS

BSA

Embodied Carbon 101: Data in LCA

Embodied Carbon in Buildings

Maggie Wildnauer
Consulting Team Lead, Americas
thinkstep, Inc.

May 31, 2019

Data Sources in LCA

An LCA is only as good as the data that comprises it:

- Primary data:
  - BOM
  - Material details: source, technology, recycled content, etc.
- Secondary data:
  - LCI databases
  - EPDs

Data Quality

ISO 14044

ISO 14040/44 includes the following topics in the required data quality assessment:

- time-related coverage
- geographical coverage
- technology coverage
- precision (e.g. variance)
- **completeness**
- **representativeness**
- consistency (of methodology)
- reproducibility (of LCA)
- sources of the data
- uncertainty of the information

Data Quality

Representativeness & Completeness

- Selecting a dataset requires consideration of representativeness
  - Geographic
  - Temporal
  - Technological
- And completeness, which can be confirmed by using
  - A reputable source (for background data as well as LCA)
  - Available documentation

Data Quality

Precision of dataset

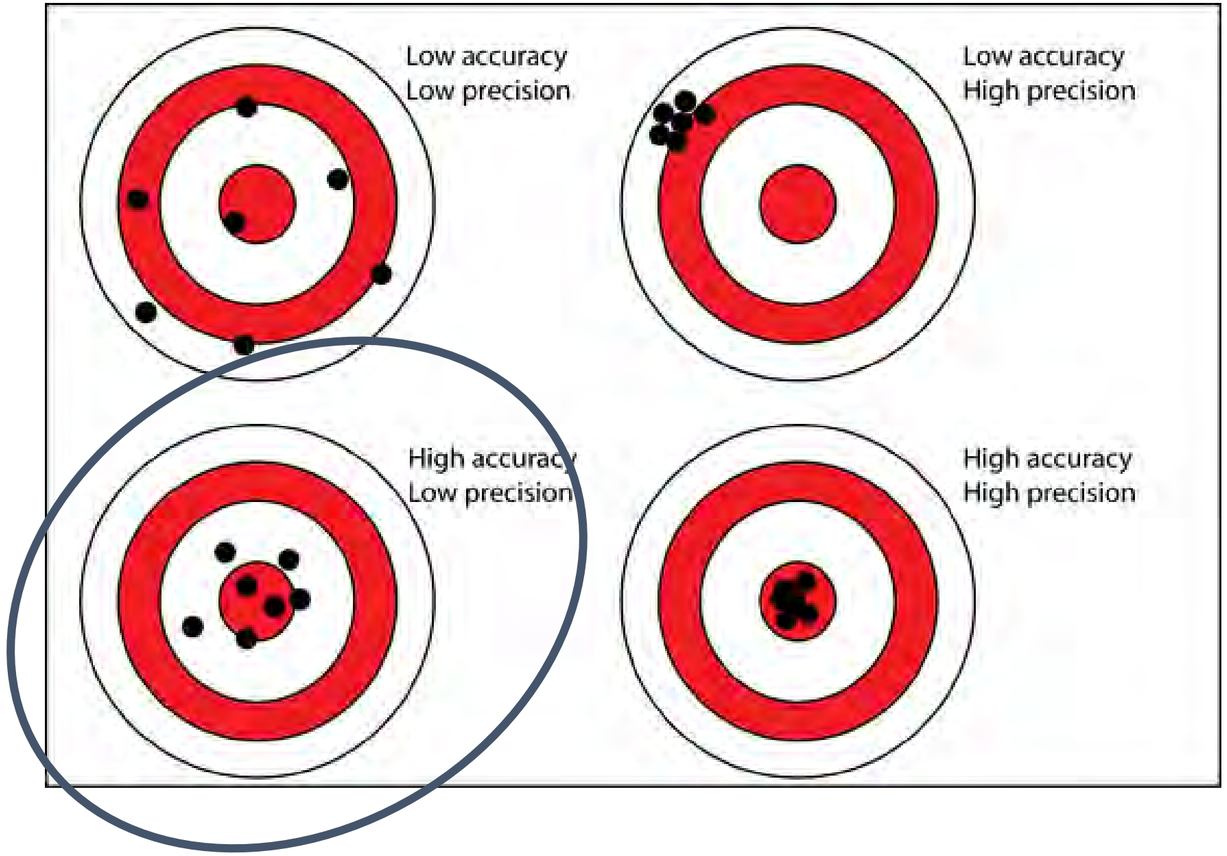
100%

Precision

0%

Data source:

- Facility-level information for specified product
- Company-level information for specified product
- Industry-average data (typ. regional)
- Global or different regional data



Data Sources

Building LCA Tools

tally

Athena Impact Estimator for Buildings

Databases

GaBi Databases

European Commission - Joint Research Centre
LCA Tools, Services and Data

ecoinvent Centre
Swiss Centre for Life Cycle Inventories

QUARTZ

U.S. Life Cycle Inventory Database

Industrial data

EUROFER
The European Steel Association

european aluminium association

FEFCO
European Federation of Corrugated Board Manufacturers

worldsteel ASSOCIATION

zinc ...essential for life

International Aluminium Institute

& more

Tally

Geographical Relevance: United States

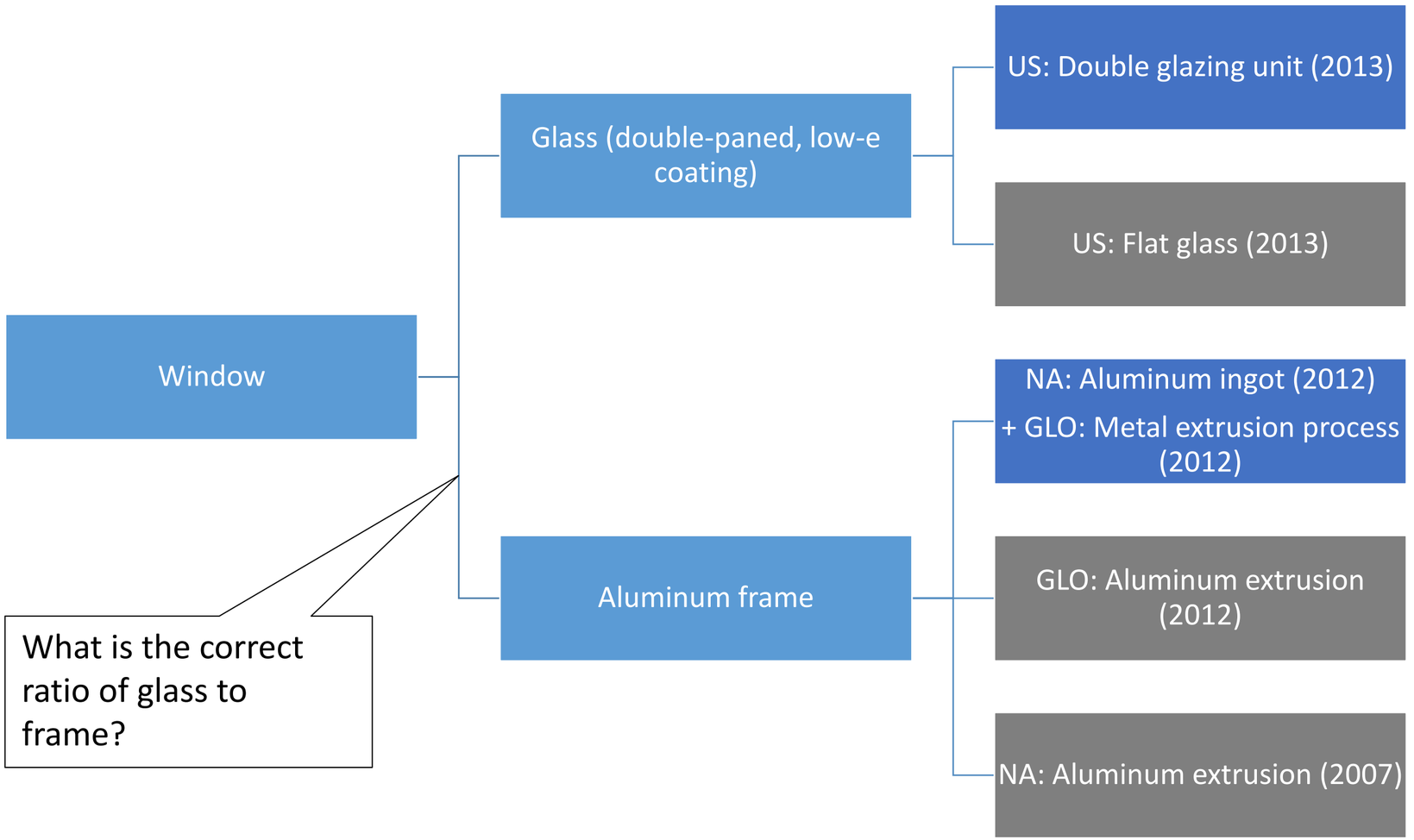
Temporal Relevance: 2018

System Boundary: Manufacturing (A1-A3), Inbound transport to site (A4), transport to EoL treatment (C2), EoL treatment (C3-C4), credits or burdens beyond the system boundary, e.g., recycling potential (D)

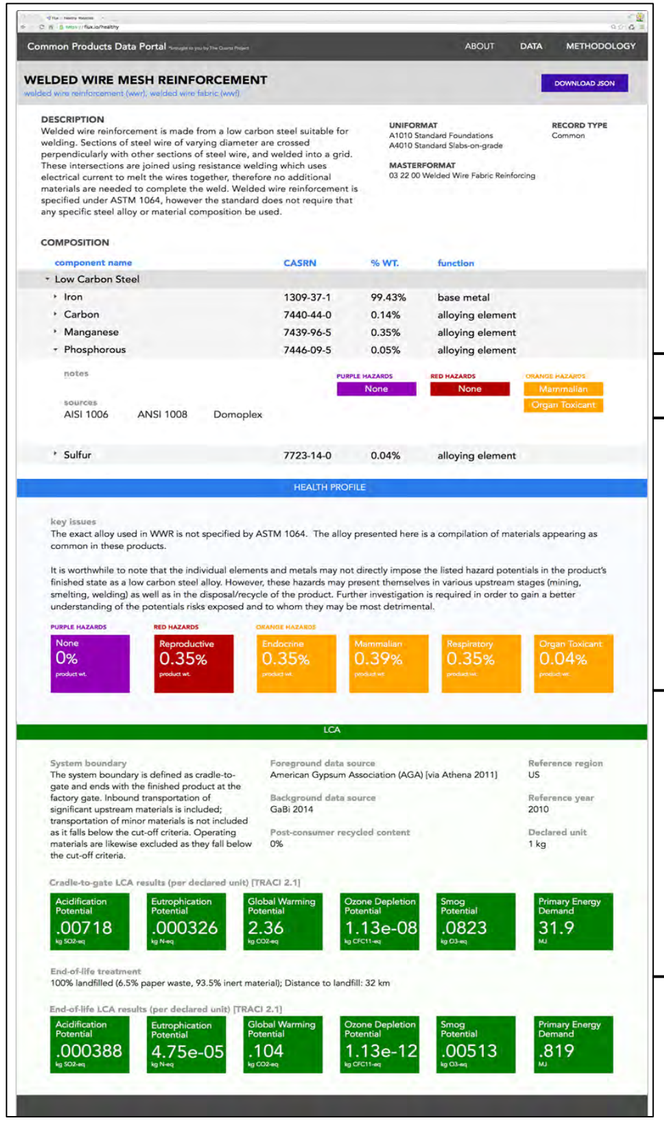
Impact Categories

Global Warming Potential, incl. biogenic carbon	TRACI 2.1
Global Warming Potential, excl. biogenic carbon	TRACI 2.1
Acidification Potential	TRACI 2.1
Eutrophication Potential	TRACI 2.1
Ozone Depletion Potential	TRACI 2.1
Smog Formation Potential	TRACI 2.1
Primary Energy Demand	Inventory indicator

Making a Tally Entry



Quartz



free, transparent, download-able

composition

components +
residuals and contaminants
0.01 % disclosure (100 ppm)

health hazard screening

pharos screening (60+ lists)
human health hazards (13)

life cycle assessment

Cradle-to-gate + EoL
TRACI 2.1 impact indicators (4) + IPCC AR5
GWP + PED

Quartz

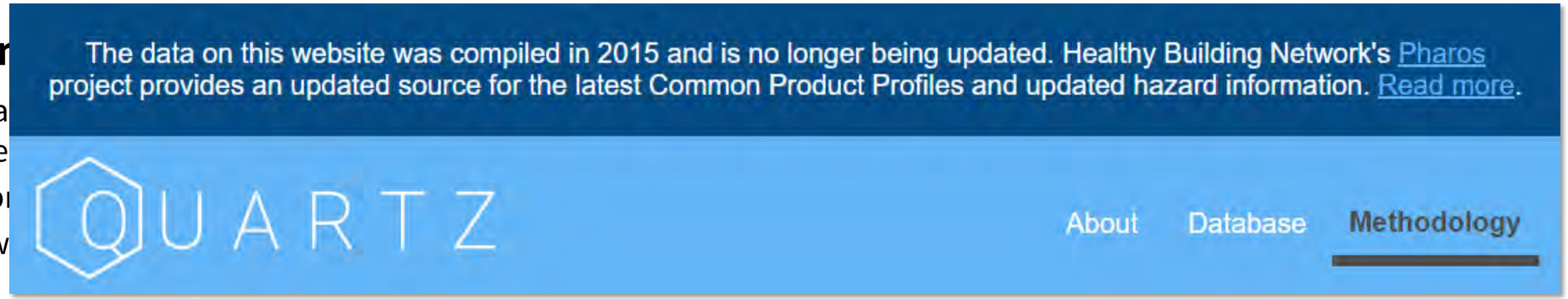
LCA Data Development

Geographical Relevance: United States

Temporal Relevance: 2015

Syster

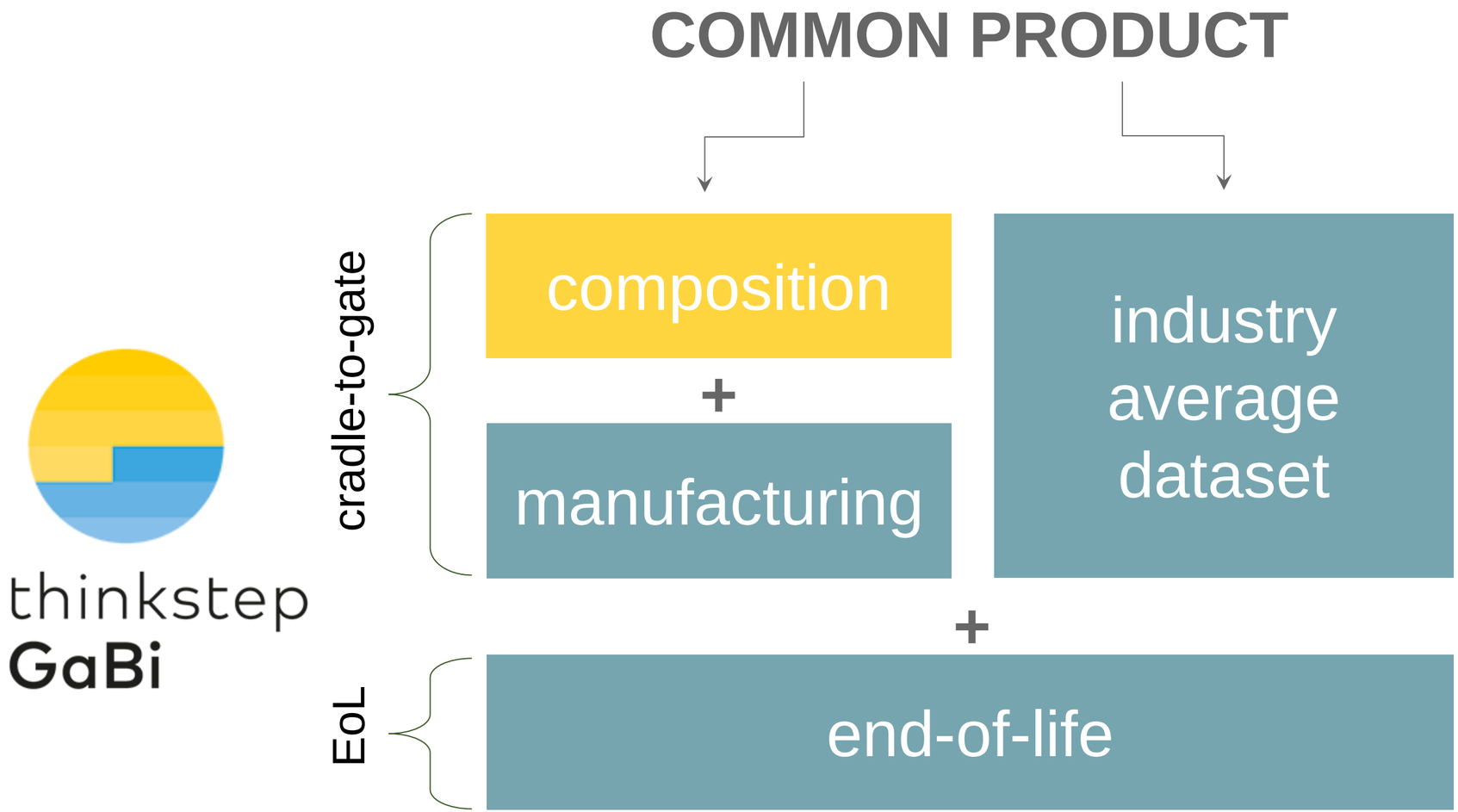
- Insta
  wate
  - pr
  - w



Impact Categories

Global Warming Potential, incl. biogenic carbon	IPCC AR5
Acidification Potential	TRACI 2.1
Eutrophication Potential	TRACI 2.1
Ozone Depletion Potential	TRACI 2.1
Smog Formation Potential	TRACI 2.1
Primary Energy Demand	Inventory indicator

Making a Quartz Entry



Summary

- Data needs to be representative of what you're trying to model
- Accuracy is the goal in LCA, not necessarily precision
- Compromises will likely need to be made when selecting data (geographical, technical, and temporal accuracy)

EMBODIED CARBON IN BUILDINGS

BSA

RATING SYSTEMS AND HANDPRINTING

Gregory Norris
Director, SHINE@MIT
Chief Scientist, ILFI

INTERNATIONAL
LIVING FUTURE
INSTITUTE℠

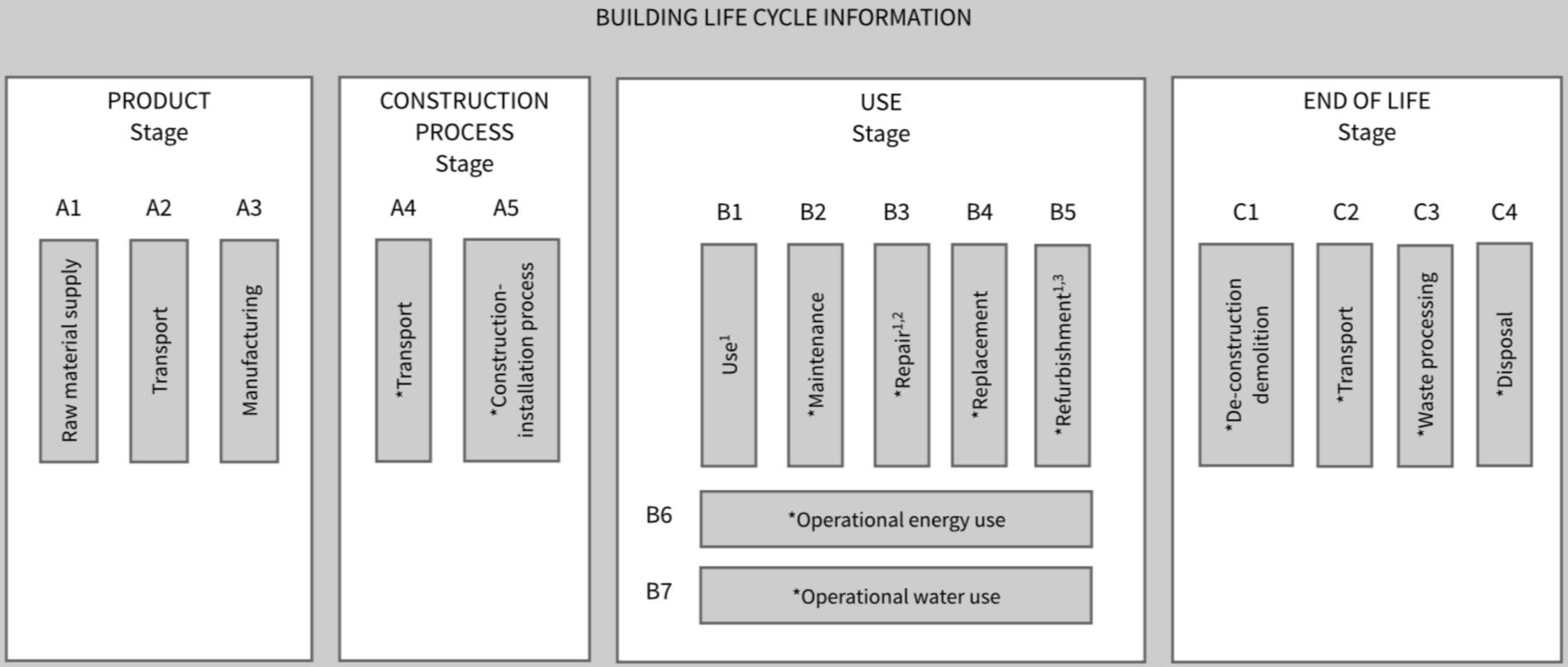
shine
Sustainability and Health
Initiative for NetPositive Enterprise

MIT

- Towards Zero, over what scope?
- Beyond Zero

TWO NORTH AMERICAN RATING SYSTEMS: ILFI'S LBC AND USGBC'S LEED

BUILDING LIFE CYCLE SCOPE



Source: CLF LCA Practice Guide 2018

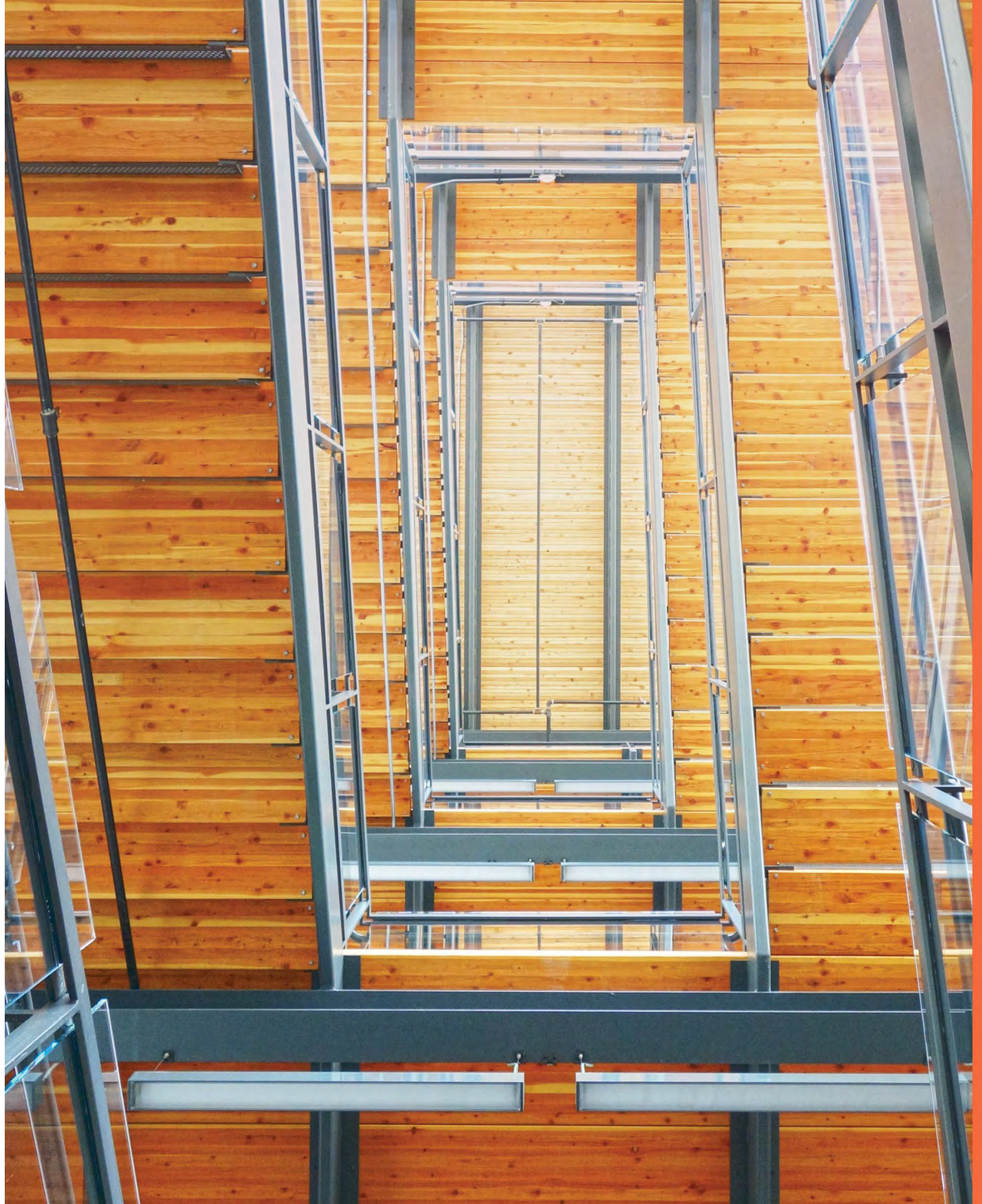
- LEED
  - Building Life Cycle Impact Reduction
  - Building Product Disclosure and Optimization: EPDs
  - BPD&O: Sourcing of Raw Materials
  - BPD&O: Material Ingredients
- LEED ZERO
  - Carbon
  - Energy
  - Water
  - Waste

LEED BUILDING LIFE CYCLE IMPACT REDUCTION

- Option 1: Historic building reuse
- Option 2: Renovate abandoned or blighted building
- Option 3: Building and material reuse
- Option 4: Whole-building life cycle assessment
  - LCA of structure and enclosure
  - Demonstrate at least 10% reduction vs. baseline, in at least 3 of 6 impact categories, one of which must be GHGs
  - No impact category can increase by more than 5%

LEED ZERO CARBON

- Operational Phase Only (Currently)
- Carbon Caused – Carbon Avoided
- Caused
  - Energy consumption
  - Transportation to site
  - *Water* *in development*
  - *Waste* *in development*
  - *Embodied Carbon in development*
- Avoided
  - Onsite electricity to grid
  - Offsite renewable added to grid, including carbon offsets

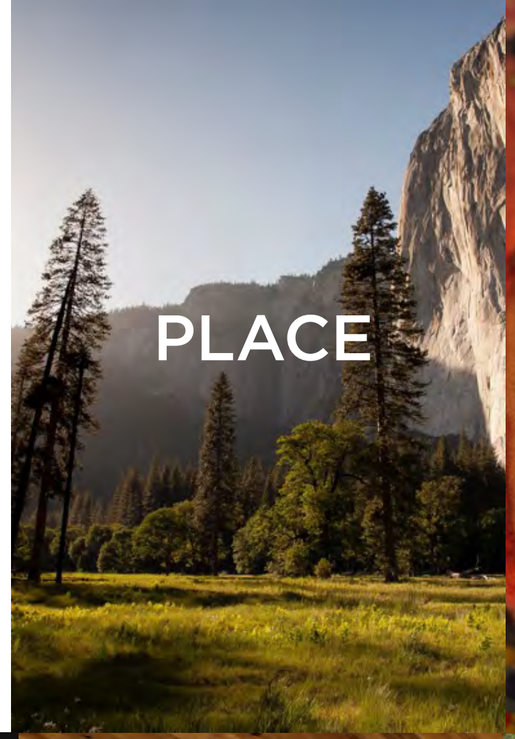


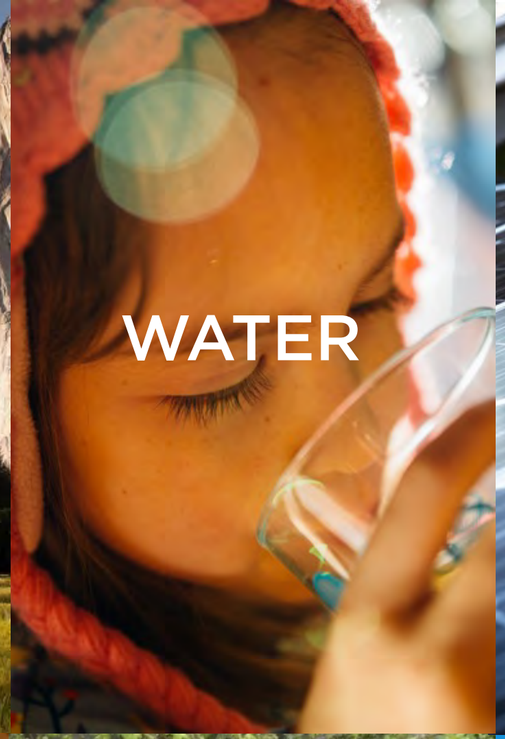
LIVING BUILDING CHALLENGE℠ 4.0

A Visionary Path to a Regenerative Future

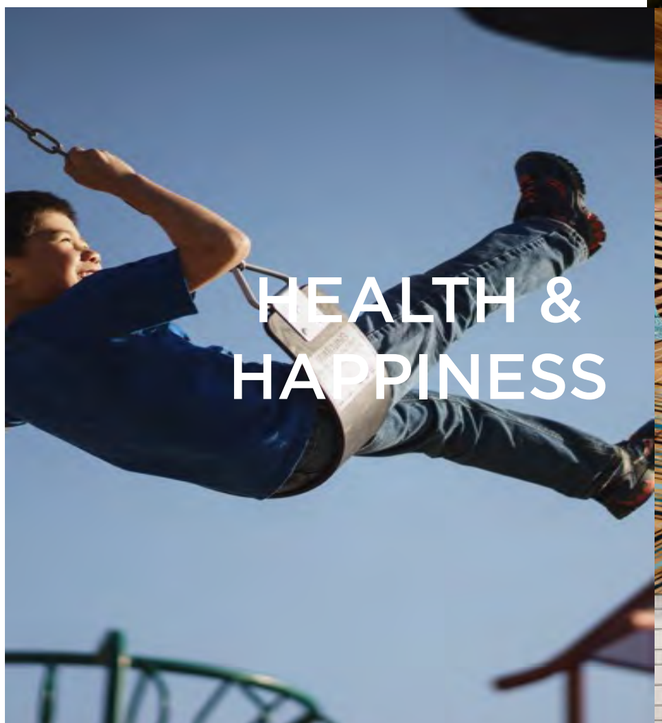
INTERNATIONAL LIVING FUTURE INSTITUTE℠

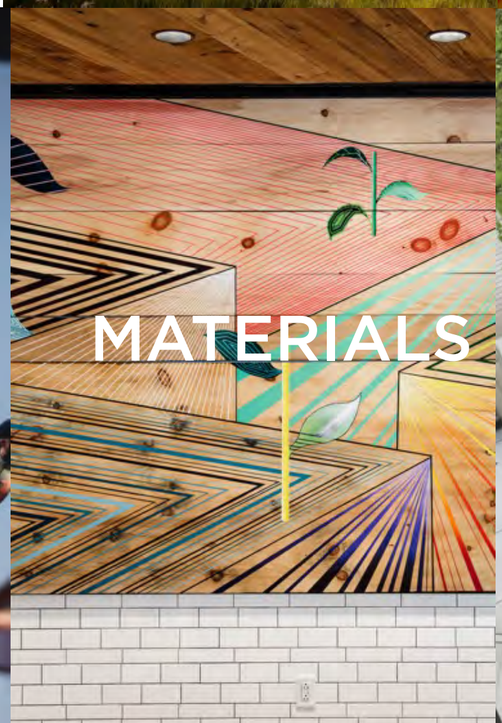
PETALS


PLACE


WATER


ENERGY

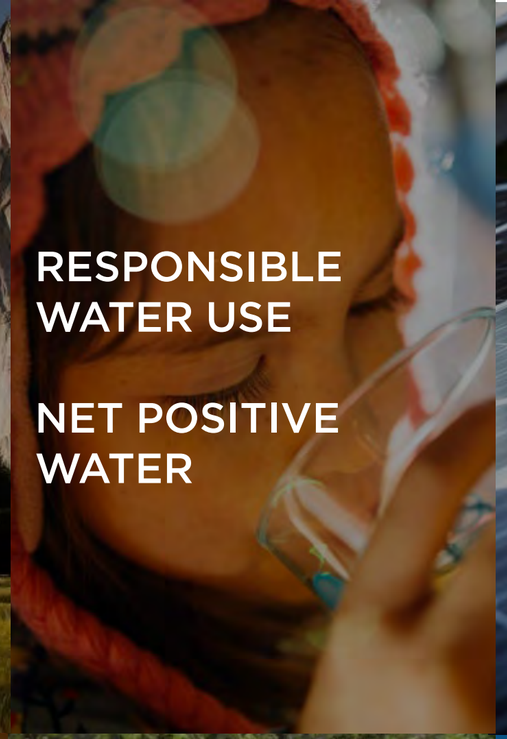

HEALTH &
HAPPINESS

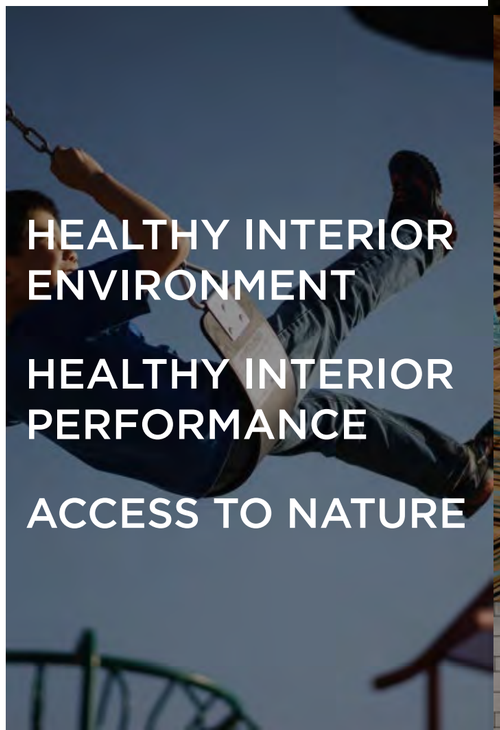

MATERIALS

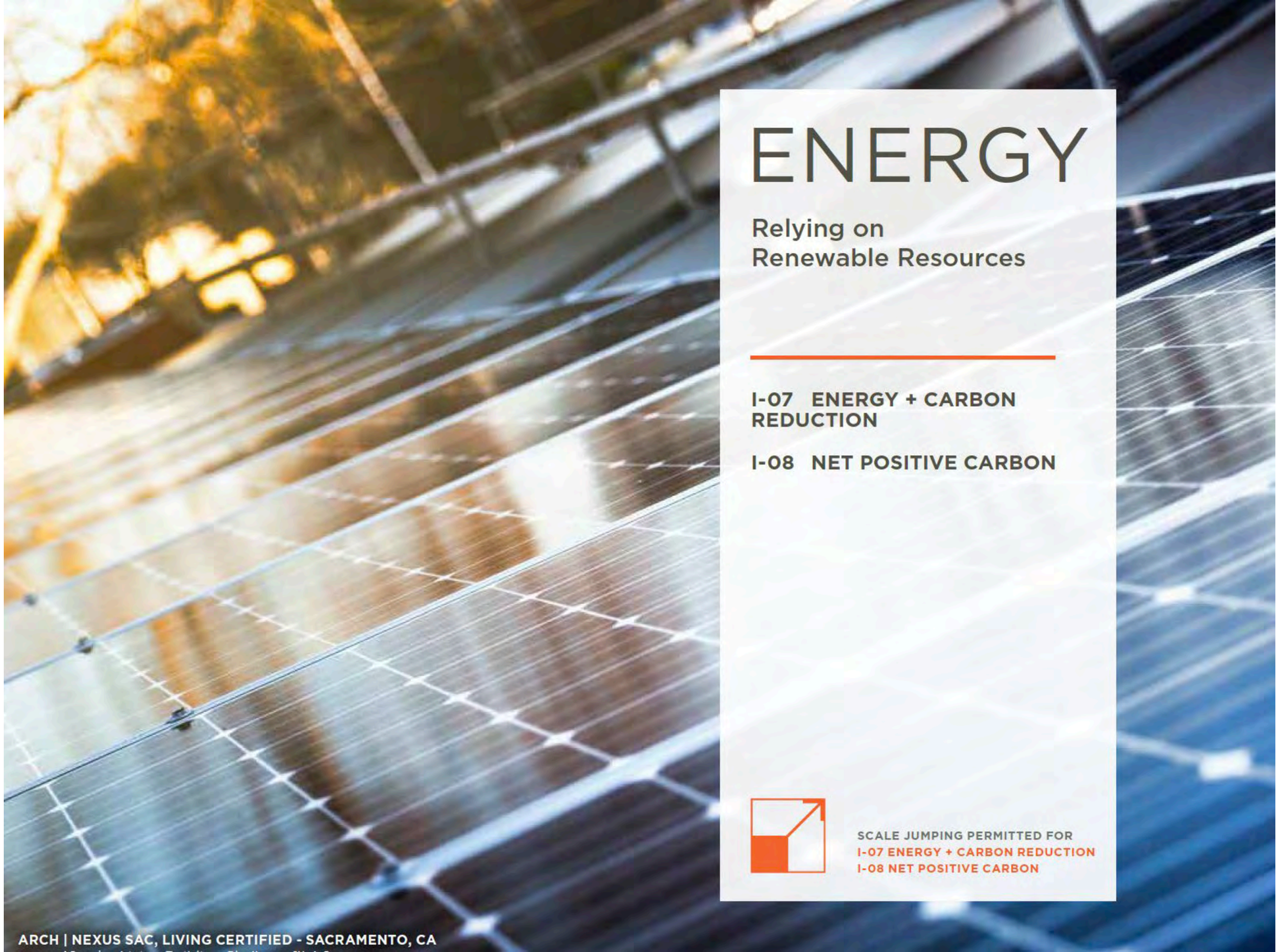

EQUITY


BEAUTY

IMPERATIVES







ENERGY

Relying on Renewable Resources

I-07 ENERGY + CARBON REDUCTION

I-08 NET POSITIVE CARBON

SCALE JUMPING PERMITTED FOR
I-07 ENERGY + CARBON REDUCTION
I-08 NET POSITIVE CARBON

ARCH | NEXUS SAC, LIVING CERTIFIED - SACRAMENTO, CA

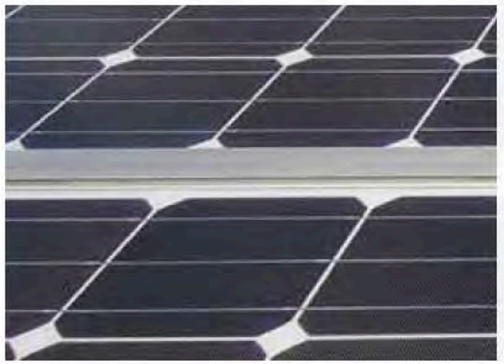
ENERGY

CORE
IMPERATIVE

07

ENERGY + CARBON REDUCTION

SCALE JUMPING PERMITTED



The intent of this Imperative is to treat energy as a precious resource and minimize energy-related carbon emissions that contribute to climate change.

All projects must achieve a reduction in total net annual energy consumption (after accounting for on-site renewable power), as compared to a typical existing building with comparable climate, size, use and occupancy, and combustion must be limited as follows:[19]

	NEW BUILDING	EXISTING BUILDING	INTERIOR
ENERGY PERFORMANCE REQUIREMENT	70% reduction from an equivalent building baseline	50% reduction from an equivalent building baseline	35% reduction from an equivalent building baseline
COMBUSTION LIMITS[20]	Not Allowed (except through existing exceptions)	Allowed for HVAC systems that are not in project scope. Phase out plan and advocacy are required.	
RENEWABLES	Must be on-site to count towards the efficiencies above.		

All projects must meter energy used by the project.

New or Existing Building projects must demonstrate a twenty percent reduction in the embodied carbon of primary materials compared to an equivalent baseline.[21] Existing Buildings may count in-situ materials against the required twenty percent.

All projects (except Landscape + Infrastructure) must select interior materials with lower than industry average carbon footprint for product categories for which embodied carbon data is readily available.[22]

All projects must be designed to be "zero ready" through strategies such as designating area(s) and/or pre-installing wiring and connections for both electric vehicle charging and future installation of renewable energy systems.

19 Projects must establish their baseline through using tools such as Zero Tool, World Bank EDGE or other approved tools.
20 The allowance for Existing Buildings & Interiors is only for Imperative 07, Energy + Carbon Reduction. Combustion is not allowed, except through an exception, for Imperative 08, Net Positive Carbon.
21 Refer to the v4.0 Energy Petal Handbook for recommended tools to establish a baseline
22 Refer to the v4.0 Energy Petal Handbook for relevant interior product categories and industries averages.

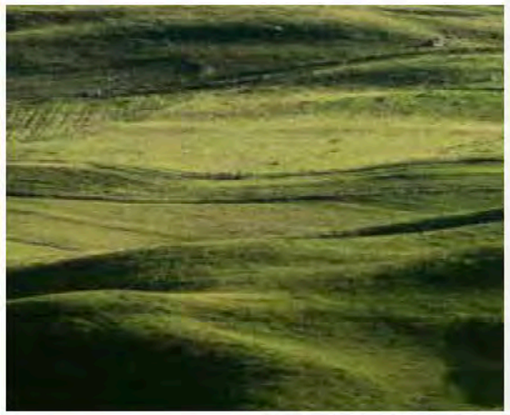
PHIPPS CENTER FOR SUSTAINABLE LANDSCAPES, LIVING CERTIFIED - PITTSBURGH, PA

ENERGY

IMPERATIVE 08

NET POSITIVE CARBON

SCALE JUMPING PERMITTED



The intent of this Imperative is to foster the development and use of carbon-free renewable energy resources while avoiding the negative impacts of fossil fuel use, primarily the emissions that contribute to global climate change.

All projects must supply one hundred and five percent of their project's energy needs through on-site renewable energy on a net annual basis, without the use of combustion.[23]

All projects (except single-family residential) must sub-meter major energy end uses.

All single-family residential projects must develop a method to understand and trouble-shoot energy use.

All projects must account for the total embodied carbon emissions (tCO2e) from its construction (including the energy consumed during construction) through the utilization of carbon-sequestering materials and/or through a one-time carbon offset purchase through an ILFI-approved carbon offset provider.[24]

All projects must develop and incorporate a resilience strategy to allow the building to be habitable for one week, or otherwise participate in support for the local community in a disaster, through the use of batteries, storage etc.

23 Refer to the v4.0 Energy Petal Handbook for a list of renewable energy systems, clarifications, and exceptions, including sub-metering requirements. Energy consumed during construction must be accounted for with either a carbon offset or renewable energy on site.

24 Refer to the v4.0 Energy Petal Handbook for approved carbon offset programs, clarifications, and exceptions.

ASSESSING IMPACTS OF LIVING BUILDINGS

96 Projects included

LBC versions 1.3 through 3.1

Five impact categories for each of up to 5 project attributes, plus ecosystem benefits of FSC

		Impact Types Assessed				
		Climate	Water	Energy	Health	Ecosystem
Project Attributes Assessed	Embodied					
	Energy Supply					
	Water Supply					
	Sanitation					
	Special: LES					
	Special: FSC					

METHOD OF ASSESSMENT

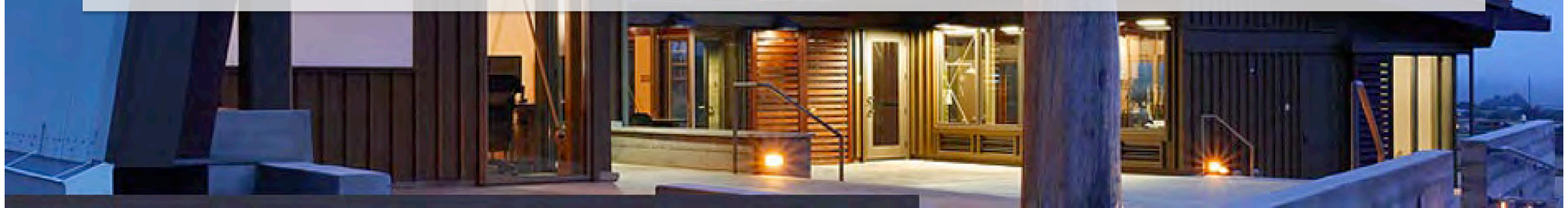
		Impact Types Assessed				
		Climate	Water	Energy	Health	Ecosystem
Project Attributes Assessed	Embodied	Embodied Impact Calculator (Input/Output LCA)				
	Energy Supply	Energy System Impact Calculator (Process LCA)				
	Water Supply	Water Supply Impact Calculator (Process LCA)				
	Sanitation	Sanitation System Impact Calculator (Process LCA)				
	Special: LES	Inbound Transport Impact Calculator (Input/Output LCA)				
	Special: FSC					(I/O LCA)

- Life cycle assessment (LCA) of conventional vs. LBC
- Developed system-specific calculators, for use by future project teams, ILFI staff, and others to assess benefits of Living Building

PROJECT COVERAGE BY ATTRIBUTE

		Impact Types Assessed				
		Climate	Water	Energy	Health	Ecosystem
Project Attributes Assessed	Embodied	2 Projects				
	Energy Supply	70 Projects				
	Water Supply	23 Projects				
	Sanitation	23 Projects				
	Special: LES	38 Projects				
	Special: FSC					2 Projects

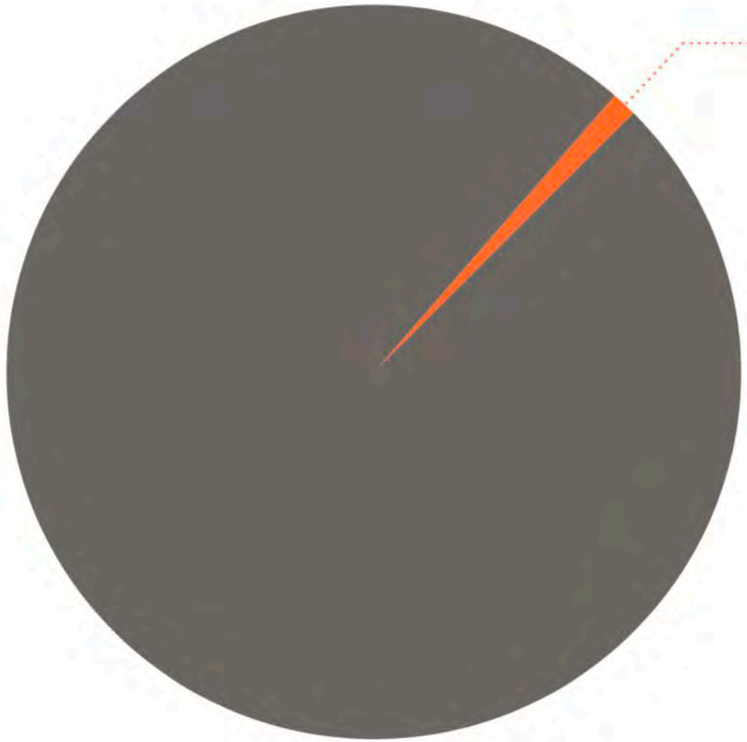
- We studied energy, water, and sanitation attribute impacts for all relevant projects
- We performed two case studies of embodied impacts
  - This data is also used to assess benefits of FSC



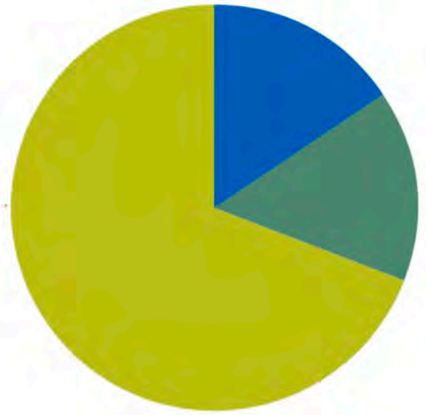
ANNUAL BENEFITS OF LBC: ENERGY SYSTEMS

	Climate	Water	Energy	Health	Ecosystem
	kg CO2e	m3	kg oil eq	DALYs	species-yrs
Net vs. conventional	8,688,804	26,283,978	2,478,486	23.3	0.08
Benefit of excess elect	716,119	2,922,592	191,417	2.13	0.001
Total benefit	9,404,923	29,206,570	2,669,903	25.43	0.08

IMAGINE if **1% of new US construction** across 3 building sectors were Living Buildings. In just one year...

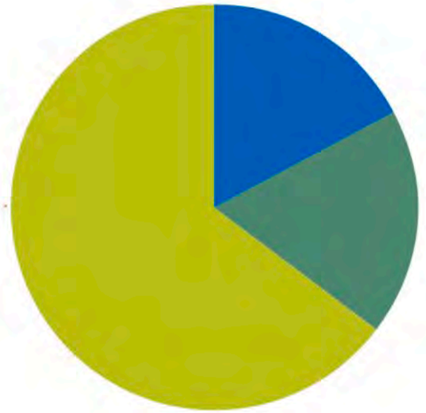


We would prevent the emissions of **5.7 million tons of CO_2** and save **14,000 years** of human life



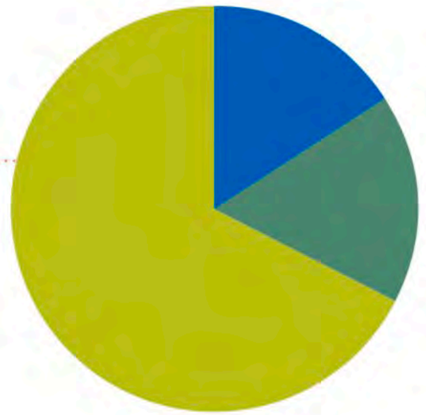
5.7 MILLION
TONS OF CO_2 AVOIDED

Educational	886,845
Commercial	865,662
Single Family	3.9 Million



13.8 BILLION
CUBIC METERS OF WATER SAVED

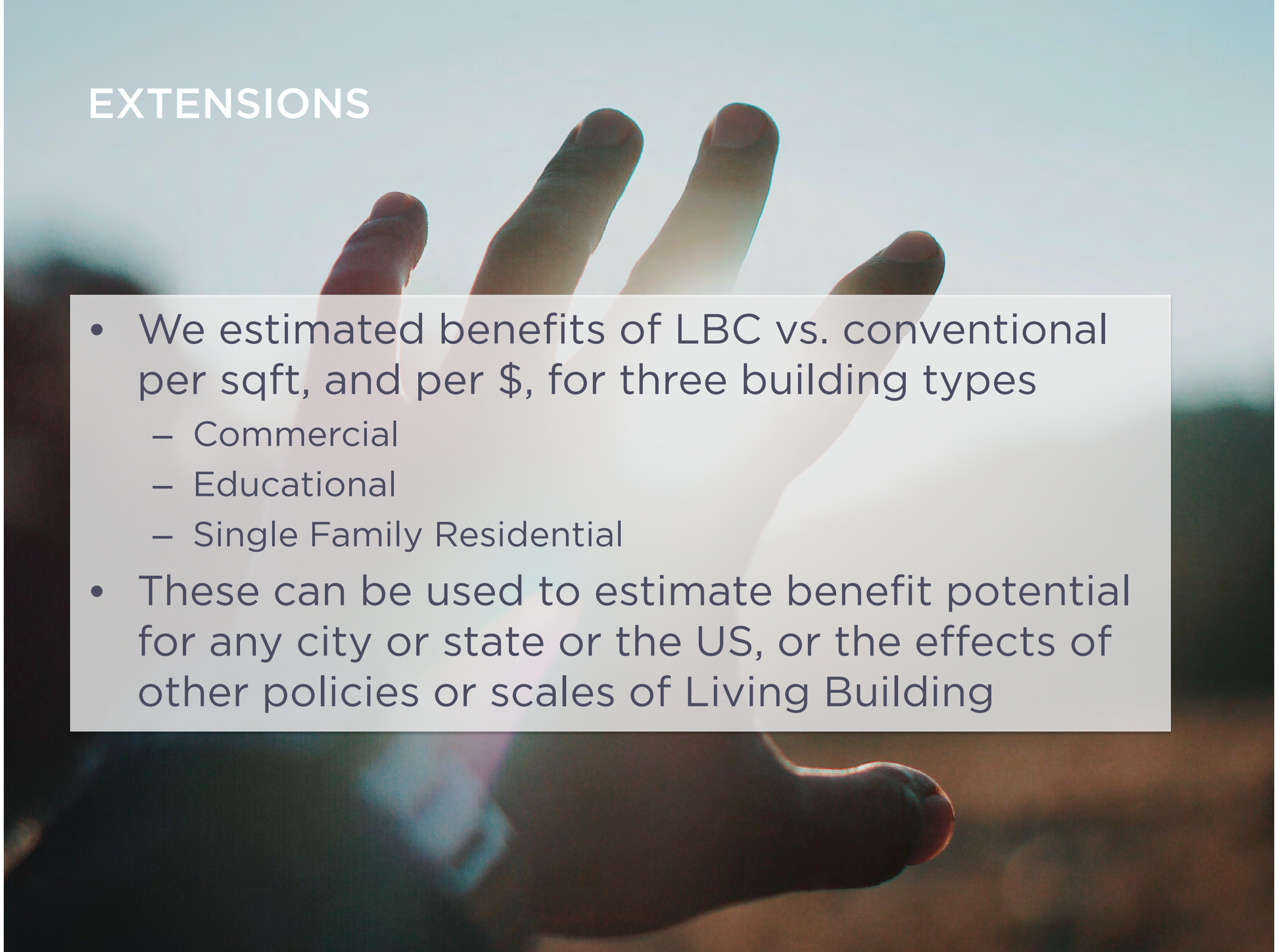
Educational	2.4 Billion
Commercial	2.5 Billion
Single Family	8.9 Billion



14,007
LIFE YEARS SAVED

Educational	2,236
Commercial	2,341
Single Family	9,431

EXTENSIONS



- We estimated benefits of LBC vs. conventional per sqft, and per $, for three building types
  - Commercial
  - Educational
  - Single Family Residential
- These can be used to estimate benefit potential for any city or state or the US, or the effects of other policies or scales of Living Building

SURPRISES AND KEY FINDINGS

- Impacts of construction itself have been ignored
- They are 20-25% of total embodied impacts!
- Even if embodied impacts of LBC were not offset, climate/water/health payback: 4-11 years
- FSC is key for reducing ecosystem impacts

Figure 6: Contractors' Influence on Activities Resulting in GHG Emissions

Most Influence		
Fuel selection	Equipment idling	Electricity use
Equipment maintenance	Equipment selection	Materials recycling
Some Influence Possible		
Materials selection	Employee commuting	
Materials shipment	Vegetation removal	
Little Influence		
Site selection	Structure design and performance	

- Towards Zero, over what scope?
- Beyond Zero

B. Monginoux / Landscape-Photo.net (cc by-nc-

Flickr:


Footprints are True.
But Footprints are not the whole story.
Photo credit: Flikr user Hartwig HKD


Can we give more than we take?

What we “Take”: Our Footprints:

- The Negative Impacts of Production and Consumption
- My Footprints: My shares of the total mess, for each mess
- The Burdens or Costs of our Presence/Existence

Handprints: Definition:

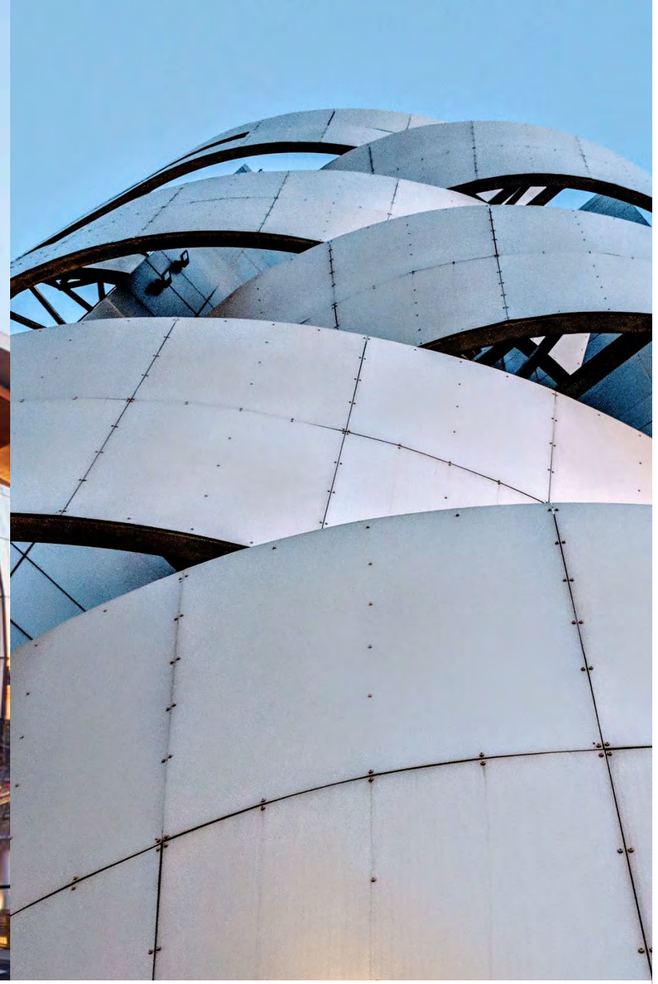
- Positive impacts that we cause (change), relative to business as usual. Including:
- Reductions we create in the human footprint
  - Our own footprint
  - The footprints of others
- Beneficial impacts we cause which are measurable in footprint units.

Handprints

- For every impact category on which we have footprints, we can also have handprints.

- Carbon Footprint
- Water Footprint
- Health Footprint
- Biodiversity Footprint
- Slavery Footprint
- Poverty Footprint

- Carbon Handprint
- Water Handprint
- Health Handprint
- Biodiversity Handprint
- Slavery Handprint
- Poverty Handprint



LIVING PRODUCT EXPO 19

JUNE 19 - 20, 2019
NET POSITIVE SYMPOSIUM
FOR HIGHER EDUCATION
R.W. Kern Center
Amherst, MA

OCTOBER 8 – 10, 2019
Music City Center
Nashville, TN

NOVEMBER 7 - 8, 2019
BUILDING RESILIENCE
Cleveland, OH

HAMPSHIRE COLLEGE 1965 Non Satis Scire

aashe
The Association for the Advancement of Sustainability in Higher Education

RESILIENT DESIGN INSTITUTE

BuildingGreen