U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Overview of life cycle impacts of buildings

Where do buildings come from and where do they go when they die?

Life-Cycle Energy & Related Impacts of Buildings Webinar Series

October 16, 2020

Agenda

I. Opening Remarks
David Nemtzow - Director, U.S. DOE Building Technologies Office

II. Introduction to Life Cycle Carbon
Lyla Fadali - AAAS Policy Fellow, U.S. DOE Building Technologies Office

III. Embodied Carbon Overview
Ed Mazria - CEO, Architecture 2030

IV. Life Cycle Assessment
Kate Simonen - Professor and Chair of Architecture, University of Washington

V. Building Life Cycle Impacts: Challenges and Opportunities
Michael Deru - Engineering Manager, National Renewable Energy Laboratory

VI. Q&A Session
Cedar Blazek - Management & Program Analyst, U.S. DOE Building Technologies Office

Building Life Cycle Impacts DOE Webinar Series

Topic	Date	Time
Overview of life cycle impacts of buildings	Oct. 16	12:00pm – 1:00pm ET
Challenges of assessing life cycle impacts of buildings	Oct. 29	12:00pm – 1:00pm ET
Innovative building materials	Nov. 12	12:00pm – 1:00pm ET
"Real Life" buildings striving to minimize life cycle impacts	Dec. 3	12:00pm – 1:00pm ET
Intersection of life cycle impacts & circular economy potential for the building sector	Dec. 17	12:00pm – 1:00pm ET

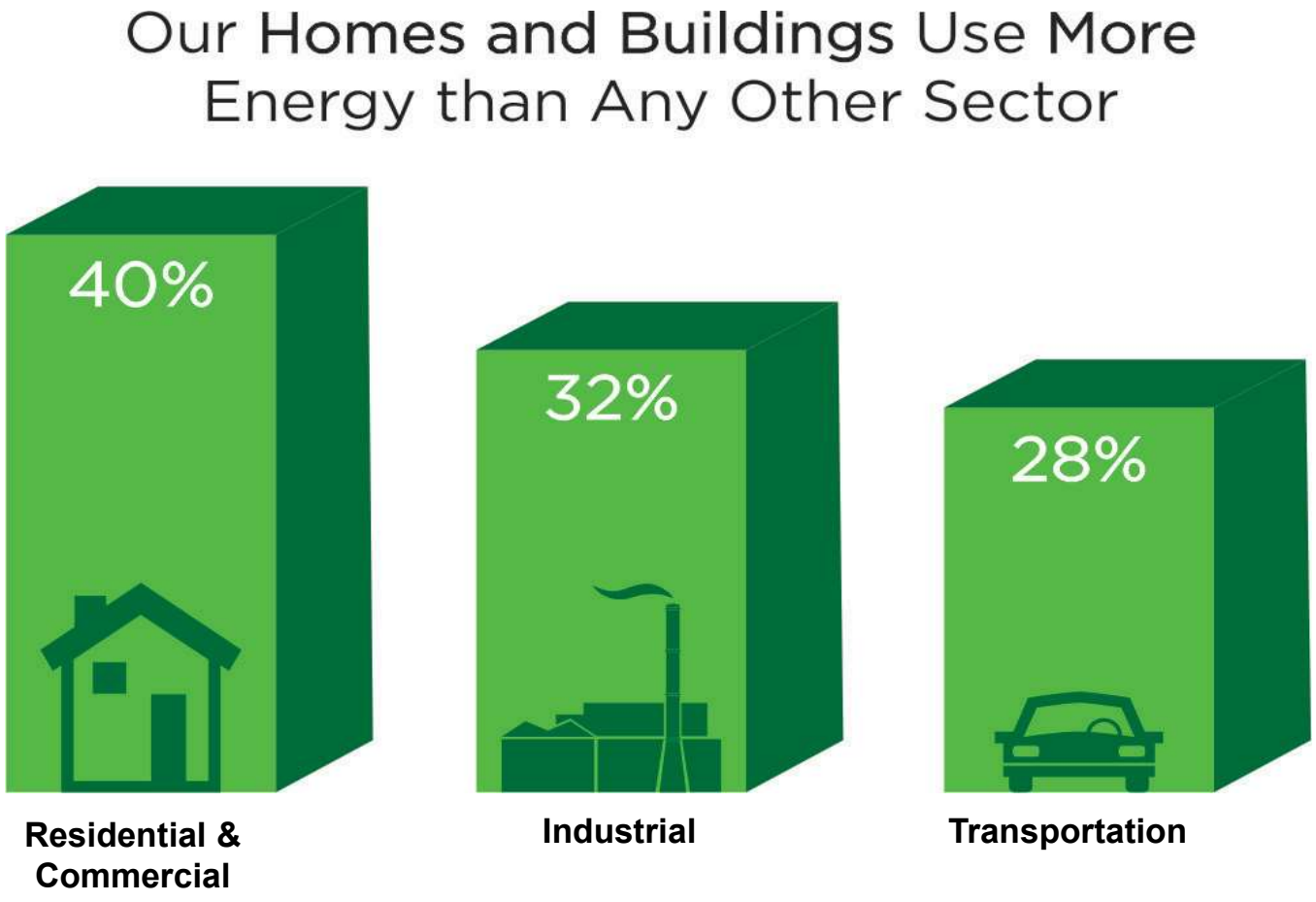
Poll Questions

- What industry are you from?
- How familiar are you with life cycle analysis?

David Nemtzow

Building Technologies Office Director

Efficiency is key to meeting U.S. energy goals



Source: EIA Monthly Energy Review

Building Technologies Office

BTO invests in energy efficiency & related technologies that make homes and buildings more affordable and comfortable, and make the US more sustainable, secure and prosperous.

Budget ~US$285M/year; activities include:

R&D
Pre-competitive, early-stage investment in next-generation technologies

Integration
Technology validation, field & lab testing, metrics, market integration

Codes & Standards
Whole building & equipment standards technical analysis, test procedures, regulations

DOE research has saved energy and saved consumers money

FOR EXAMPLE:

Past

Units **half** the price, almost 20% bigger, and **75% less energy** to operate – AND have more features!

Present

- $550 purchase
- $50/year to operate
- 22 cubic feet

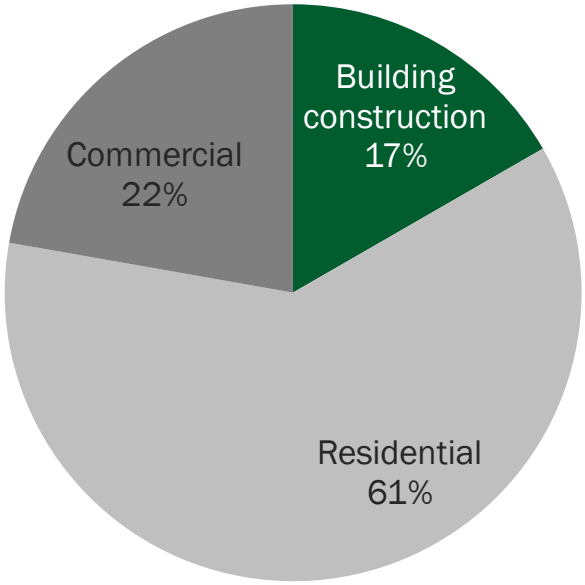
Our impact on a national scale

Energy efficiency standards completed through 2016 are expected to save **142 quadrillion Btu through 2030** — more energy than the entire nation consumes in one year.

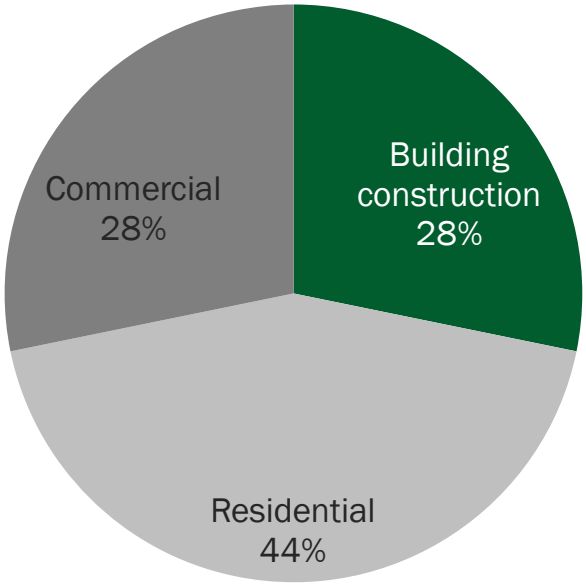
BTO's work is making a difference, but we're missing part of the picture.

Historically, BTO has focused on operating buildings.

Global energy use in buildings



Global emissions from buildings



2018 Global Status Report. United Nations Environment Programme.
International Energy Agency for the Global Alliance for Building and Construction (GlobalABC)

Let's look at the whole picture:

Lifecycle carbon refers to carbon emissions associated with all stages of a building's life

Resource extraction

Manufacturing

Transportation

Construction/ Installation

Equipment Replacement/ Maintenance

Demolition/ End of life

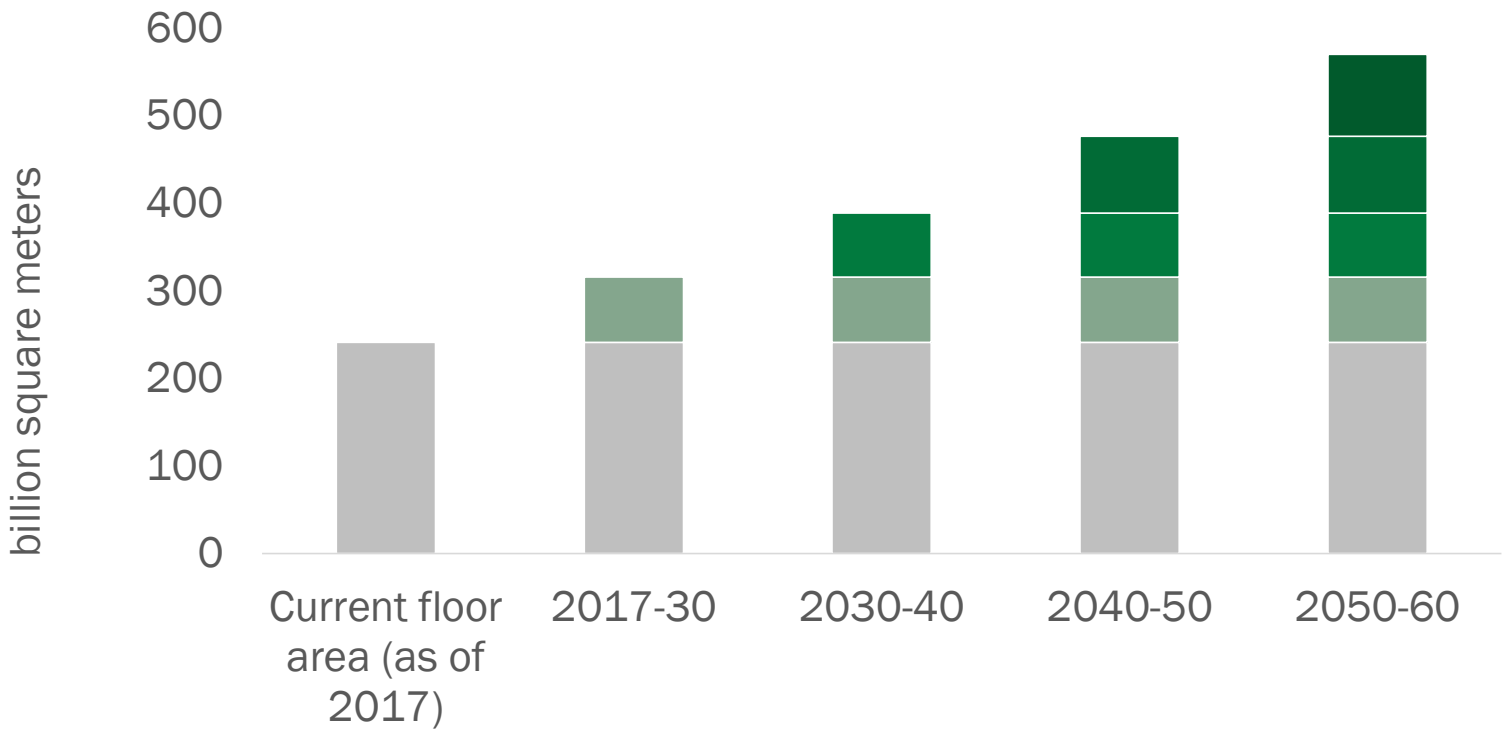
Operations

Embodied carbon is the carbon associated with all stages of a building's life cycle not including operating the building

Operational carbon is the carbon associated with operating the building

Global building stock expected to more than double, making embodied carbon increasingly important.

Global building stock through 2060



Source data from GlobalABC Status Report in 2017

Where are the biggest opportunities? Where is BTO needed?

What types of buildings?

- Residential or commercial?
- New construction or retrofits?

What types of materials in the building?

- Envelope? Lighting? HVAC?

What parts of the life cycle?

- Transportation?
- Material extraction?
- End of life?

Poll Question

- What aspect of lifecycle carbon should BTO focus on? Include alternate answers in the question box!

Ed Mazria

Architecture 2030

Carbon Leadership Forum

Life Cycle Assessment

Kate Simonen, AIA SE

Director Carbon Leadership Forum

University of Washington

www.carbonleadershipforum.org

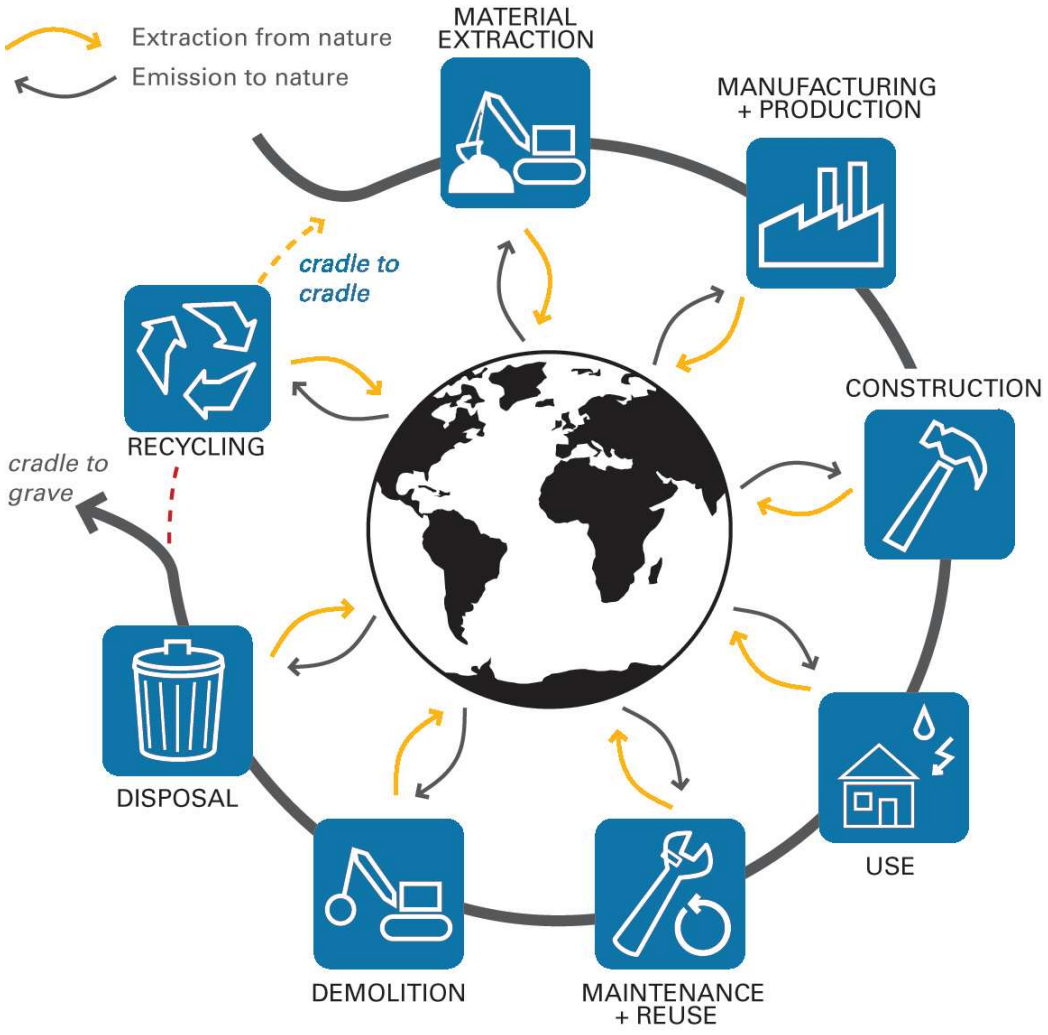
Life Cycle Thinking

Life Cycle Costing (LCC)

FINANCIAL Impacts

Life Cycle Assessment (LCA)

ENVIRONMENTAL I Impacts



Building Sector Decarbonization

Image: S. Smedley Skanska

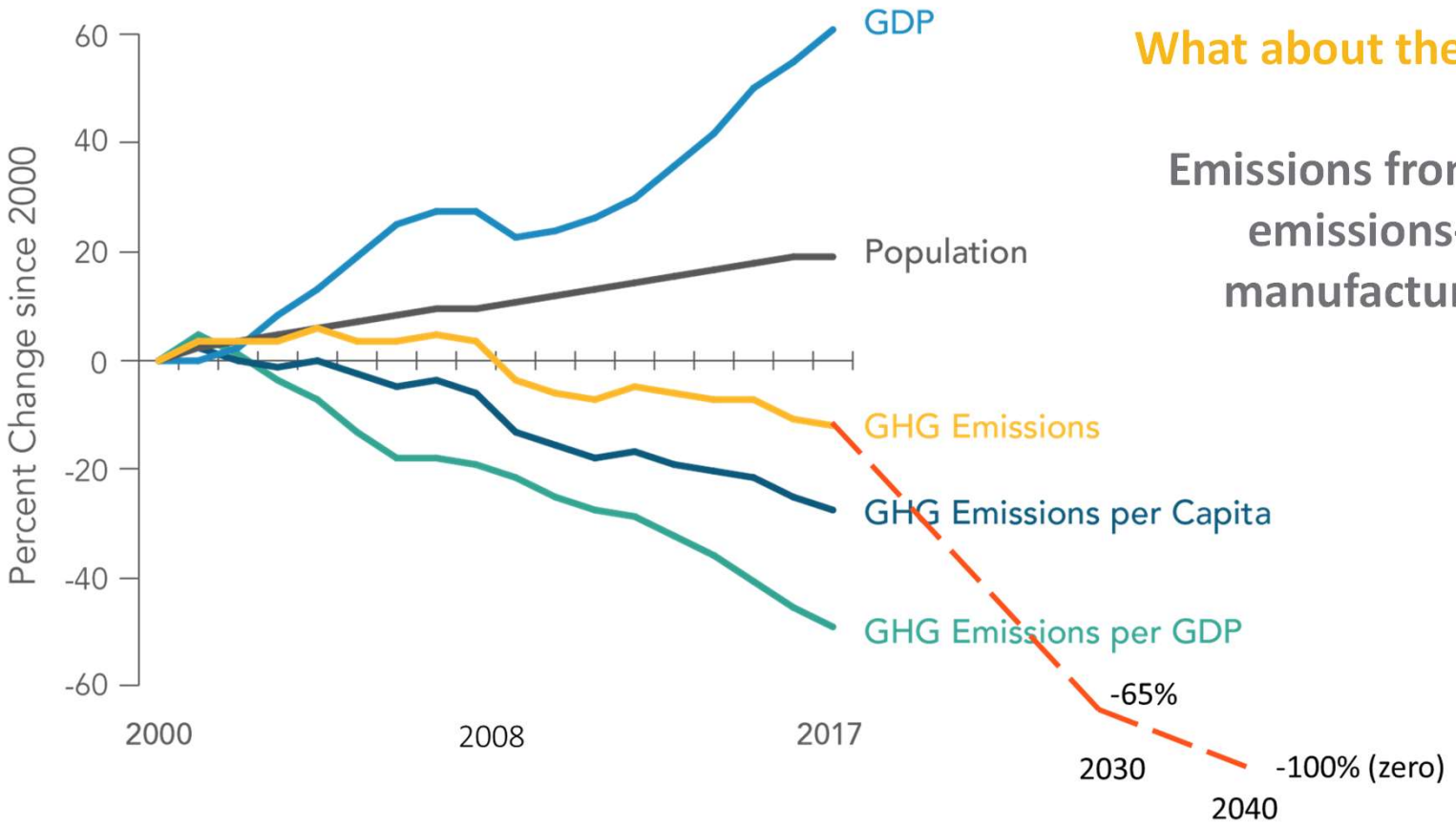
Total Carbon = Embodied Carbon + Operational Carbon

$$TC = EC + OC$$

Carbon Smart Building

- **New Buildings – Operations and Embodied Emissions.** All new buildings and developments are net zero carbon by 2030, with increase in carbon-storing material use.
- **Existing Buildings – Operations and Embodied Emissions.** Extend building lifespan to 100 + years and retrofit existing buildings to net zero carbon operations by 2050.
- All new building (material production, construction, and use) is **healthy, equitable and just.**

California GHG Emissions since 2000



What about the 'Carbon Loophole'?

Emissions from purchased goods emissions-when they are manufactured out of state?

Embodied Carbon Reduction Strategies

Optimize Project

Strategies
- New vs Retrofit
- Smaller footprint
- Design for Disassembly

Rules of Thumb/LCAs

Optimize System

Strategies
- Alternate materials
- Building shape
- Life cycle thinking

Life Cycle Assessment

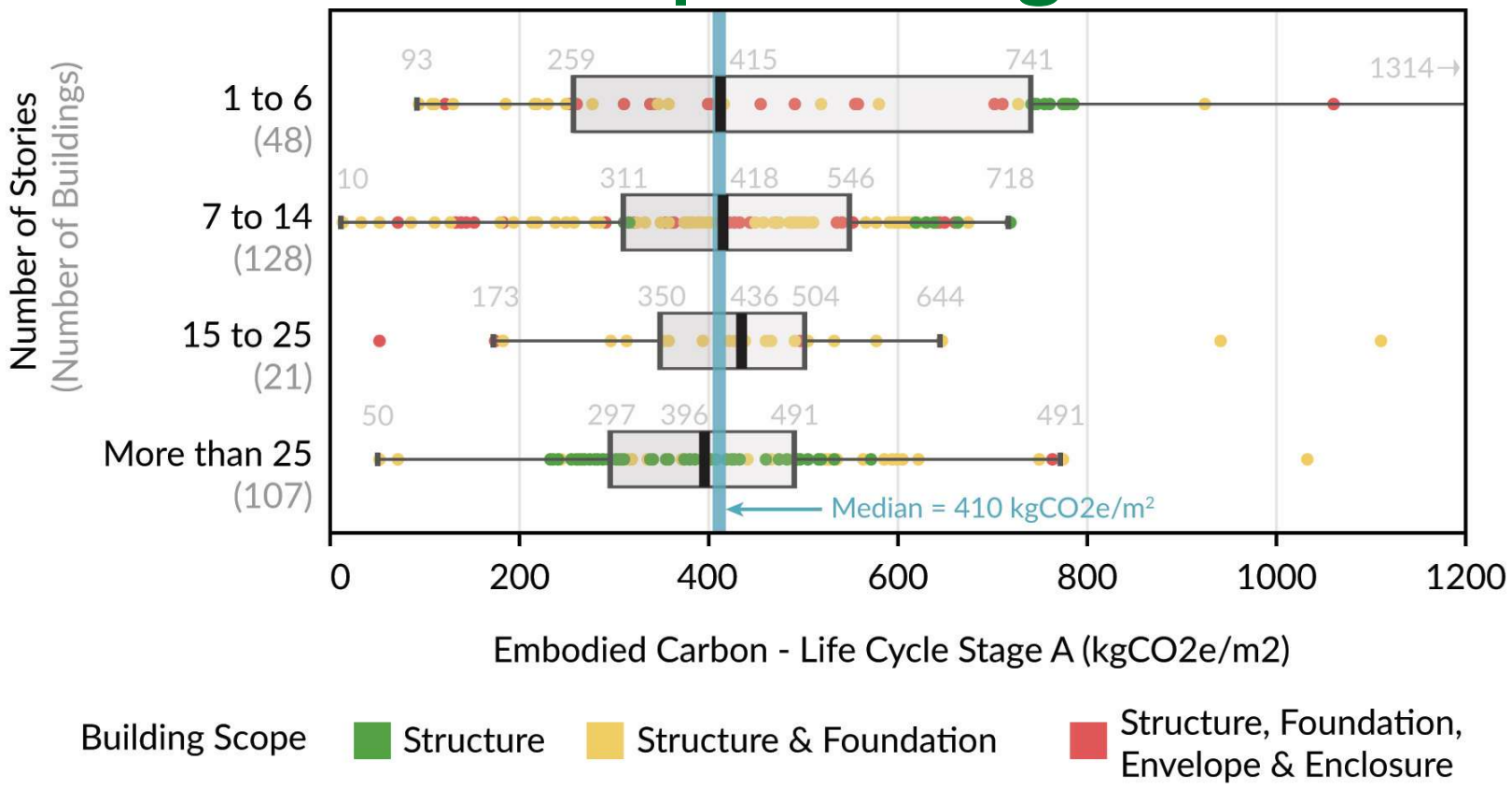
Optimize Procurement

Strategies
- Transparency
- EC limits/incentives
- Low carbon specs

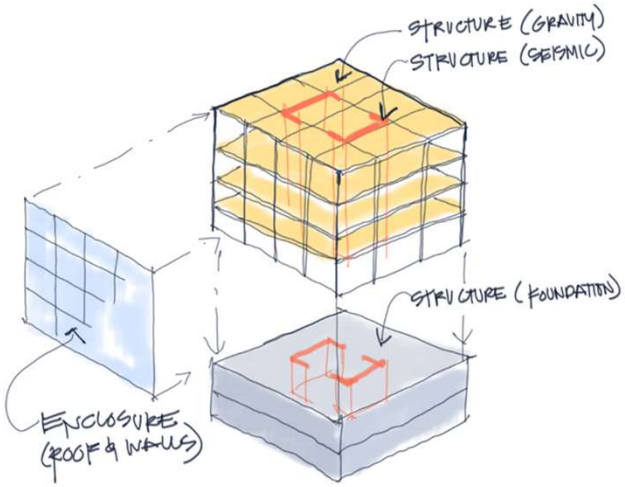
EPDs, EC3 Buy Clean

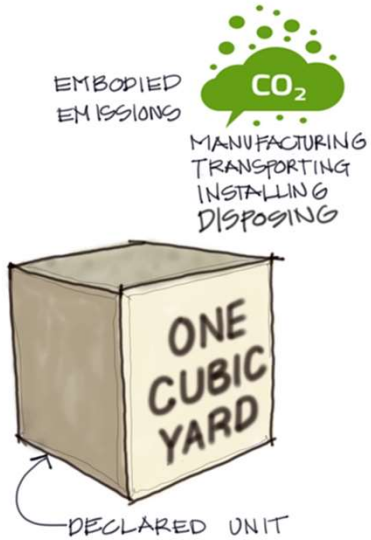
22

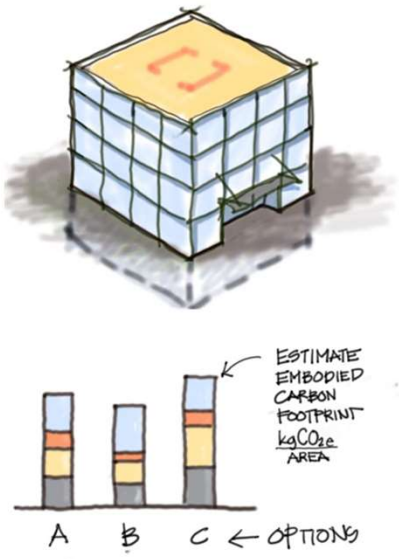
CLF Embodied Carbon Benchmark Study
www.carbonleadershipforum.org



Embodied Carbon Estimates: Use Life Cycle Assessment

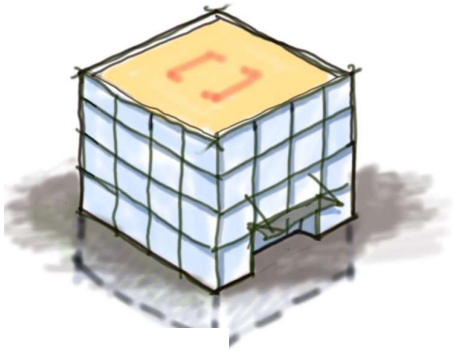




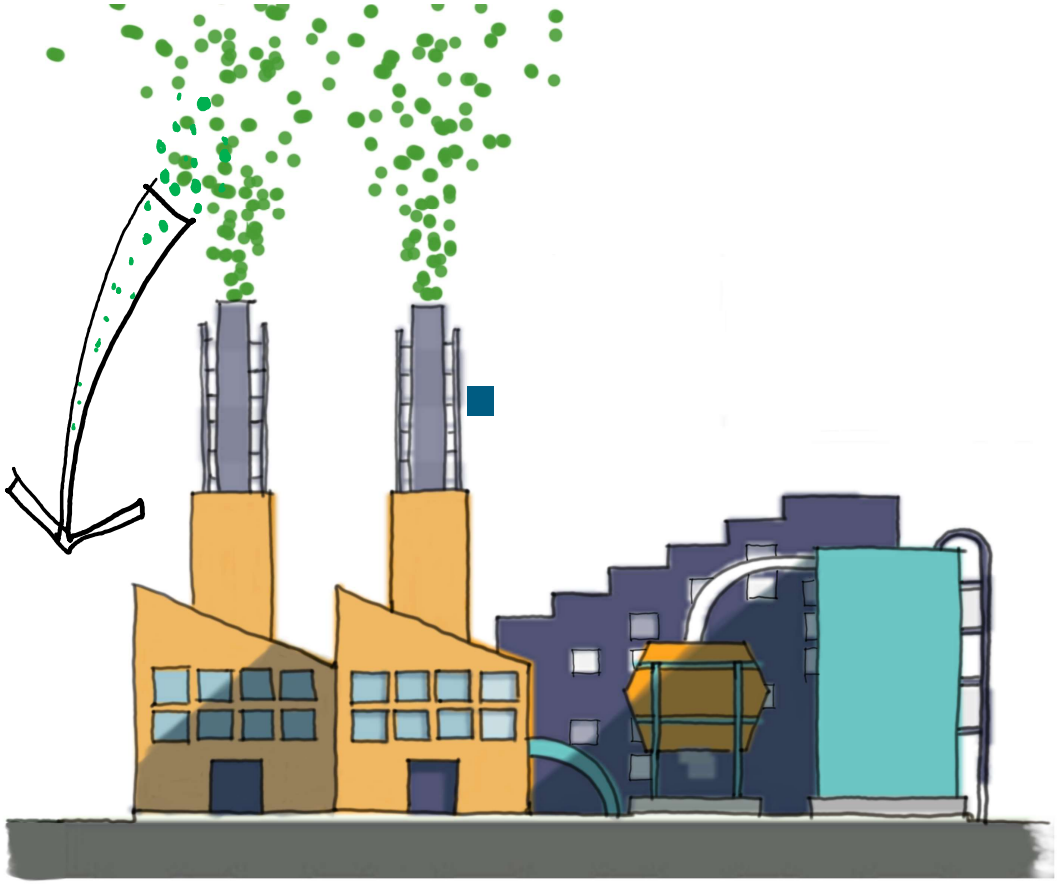


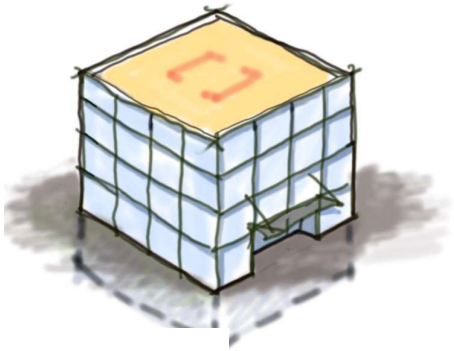
MATERIAL QUANTITY ESTIMATE × **EMBODIED CARBON PER UNIT MATERIAL** = **BUILDING EMBODIED CARBON (EC) ESTIMATE**

Embodied Carbon Solution Strategies

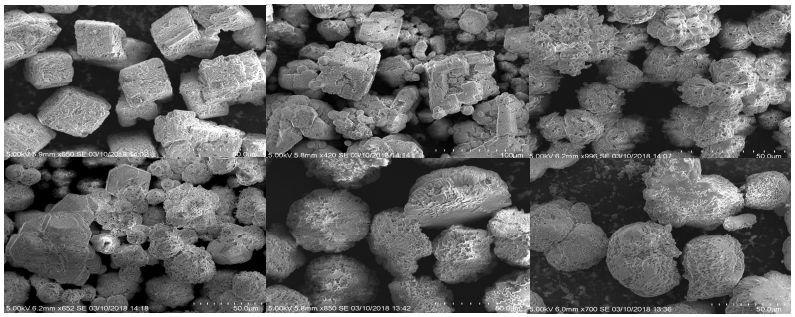


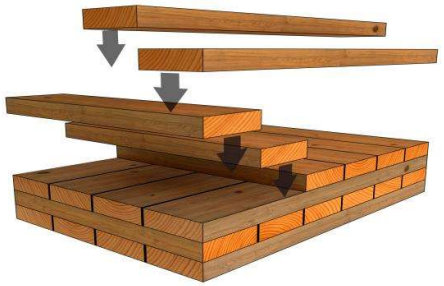
Embodied Carbon Solution Strategies





Innovative Carbon Storing Materials





Environmental Impacts

Concrete Innovations

- Grow concrete with algae
- Store carbon in rocks
- Cure concrete with CO2

Bio Based Materials

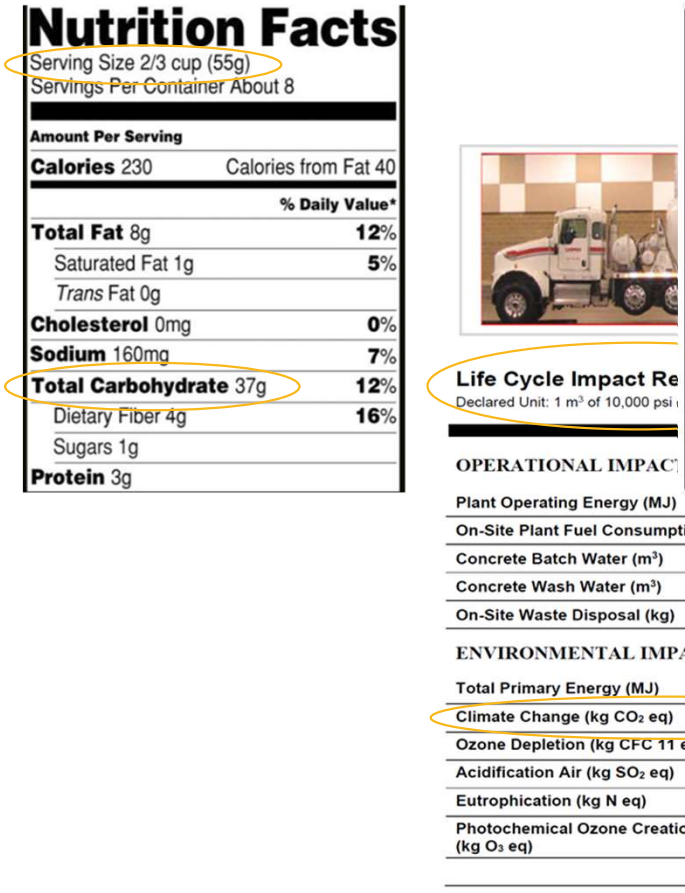
- Long life wood products from sustainably managed forests
- Agricultural waste to building products
- Bio based insulations

Steel Innovations

- Hydrogen Steel Production

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	

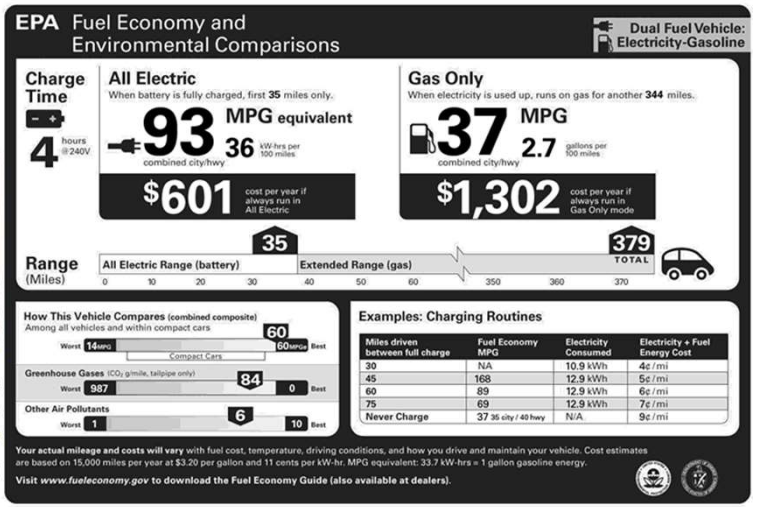
Life Cycle Impact Re
Declared Unit: 1 m^3 of 10,000 psi

OPERATIONAL IMPAC

Plant Operating Energy (MJ)	
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



EPA Fuel Economy and Environmental Comparisons

Dual Fuel Vehicle: Electricity-Gasoline

Charge Time: 4 hours @ 240V

All Electric — When battery is fully charged, first 35 miles only.
93 MPG equivalent
36 kW-hrs per 100 miles
combined city/hwy
$601 cost per year if always run in All Electric

Gas Only — When electricity is used up, runs on gas for another 344 miles.
37 MPG
2.7 gallons per 100 miles
combined city/hwy
$1,302 cost per year if always run in Gas Only mode

Range (Miles): All Electric Range (battery) 35; Extended Range (gas); 379 TOTAL
0 10 20 30 40 50 60 350 360 370

How This Vehicle Compares (combined composite)
Among all vehicles and within compact cars
Worst 14 MPG — 60 — 60 MPG Best
Compact Cars
Greenhouse Gases (CO_2 g/mile, tailpipe only)
Worst 987 — 84 — 0 Best
Other Air Pollutants
Worst 1 — 6 — 10 Best

Examples: Charging Routines

Miles driven between full charge	Fuel Economy MPG	Electricity Consumed	Electricity + Fuel Energy Cost
30	NA	10.9 kWh	4¢/mi
45	168	12.9 kWh	5¢/mi
60	89	12.9 kWh	6¢/mi
75	69	12.9 kWh	7¢/mi
Never Charge	37 35 city / 40 hwy	N/A	9¢/mi

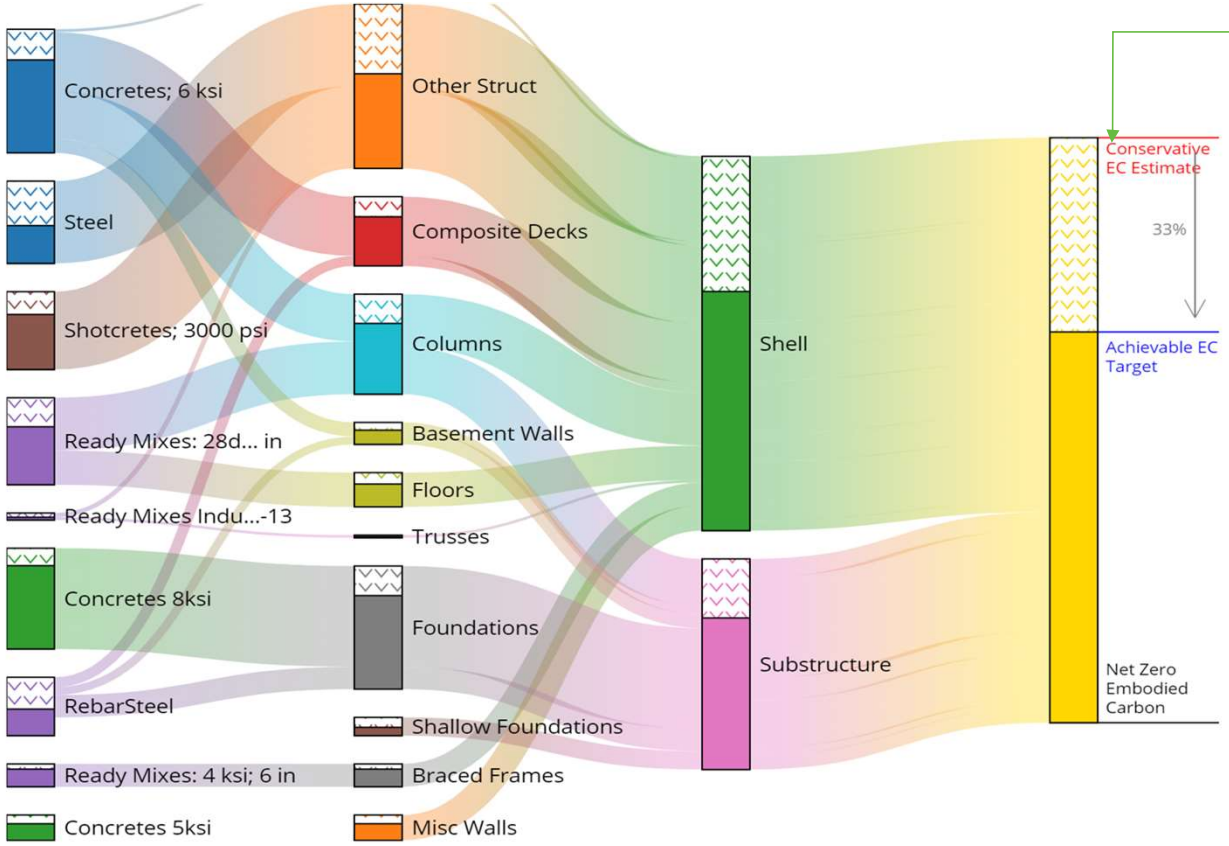
Your actual mileage and costs will vary with fuel cost, temperature, driving conditions, and how you drive and maintain your vehicle. Cost estimates are based on 15,000 miles per year at $3.20 per gallon and 11 cents per kW-hr. MPG equivalent: 33.7 kW-hrs = 1 gallon gasoline energy.
Visit *www.fueleconomy.gov* to download the Fuel Economy Guide (also available at dealers).

EPD Results are like MPG

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

EC3: Embodied Carbon in Construction Calculator

www.buildingtransparency.org



CLF Conservative Baseline:

If you don't know the supplier, don't assume 'average'

Target:

At least 20% of products in EC3 are below this

Embodied Carbon Reduction Strategies

Optimize Project

Strategies
- New vs Retrofit
- Smaller footprint
- Program efficiency

Rules of Thumb

Optimize System

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- Alternate materials
- Building shape
- Life cycle thinking

Life Cycle Assessment

Optimize Procurement

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EPDs, EC3 Buy Clean

www.carbonleadershipforum.org

CLF Carbon Leadership Forum

Research

- Data assessment
- Data methodology
- Policy
- Strategies

Resources

- Newsletters
- Toolkits
- Curricula
- References

Network

- Local hubs
- Focus groups
- Online community
- NGO roundtable
- Members

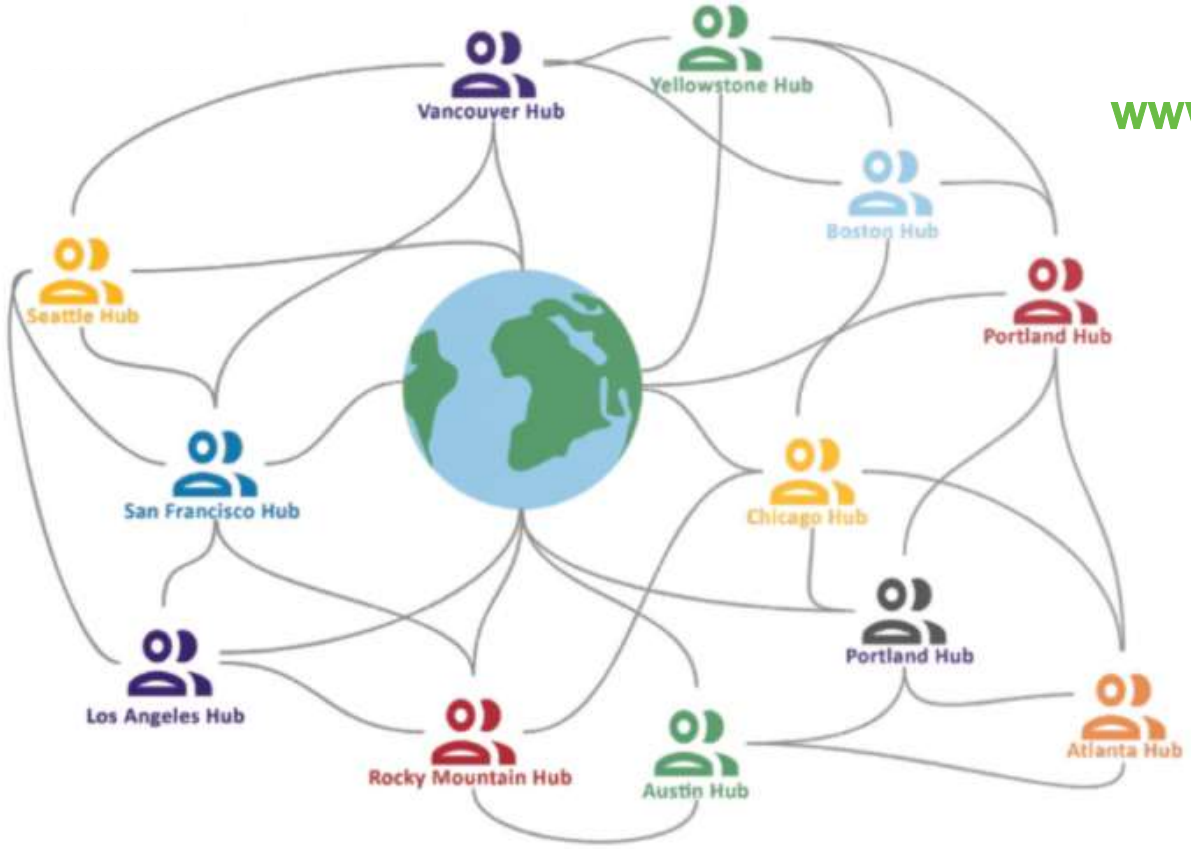
Initiatives

- SE 2050 Challenge
- EC3 Tool
- Events
- Etc.

Sponsors

- Organizations
- Foundations
- Individuals

Carbon Leadership Forum Network
12 Regional Hubs, 12 more under development!



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Building Life Cycle Impacts: Challenges and Opportunities

Michael Deru

October 16, 2020

Challenge and Opportunity #1

Challenge: Massive new construction and retrofits of existing buildings are needed to meet the demands of growing and shifting populations and energy and climate goals

Opportunity: Transform the construction of our buildings to be more sustainable, economical, and equitable

Challenge and Opportunity #2

Challenge: Growing environmental and economic impact of energy consumption, resource constraints, and aging infrastructure

Opportunity: Transform our energy generation, distribution, and consumption systems to be low carbon, efficient, resilient, and reliable

Solutions

Advanced Building Construction Initiative

https://www.energy.gov/eere/buildings/advanced-building-construction-initiative

Transform the construction industry:

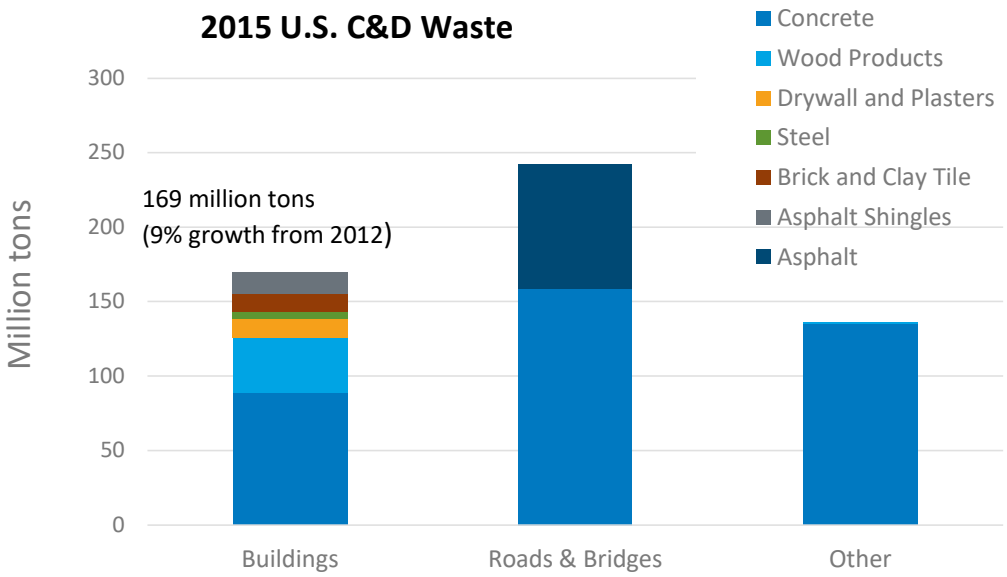
- Improve energy performance
- Increase labor productivity
- Improve circularity
- Address social and economic inequities

Circular Economy for Buildings and Building Materials

Minimize embodied carbon
Minimize waste
Reduce material consumption
Reduce toxic materials
Improved end-of-life actions

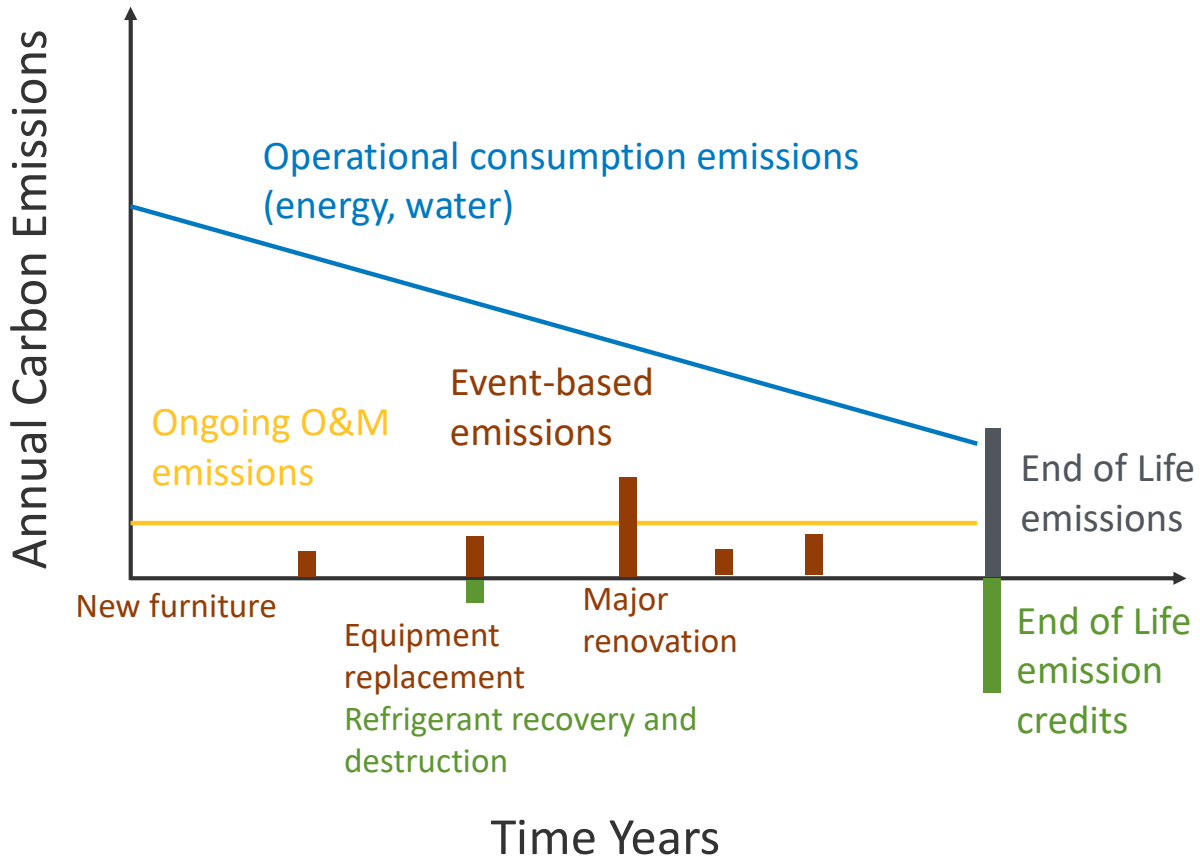
Why CE thinking is important

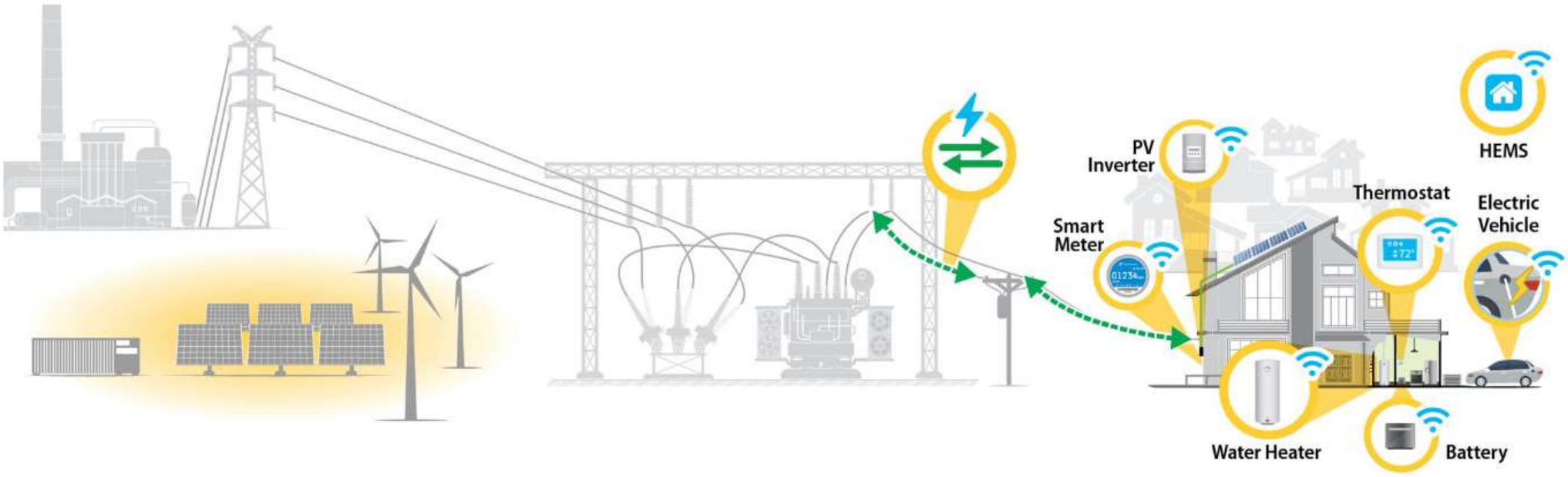
Global construction expected to double building stock by 2060 = NYC every month for 40 years



Operational Carbon Decision Making

Framework and data to help facility operators make smart low-carbon decisions





Clean Energy Generation

Transmission and Distribution

Smart and Efficient Loads
Distributed Energy Resources

Transformation of our energy systems

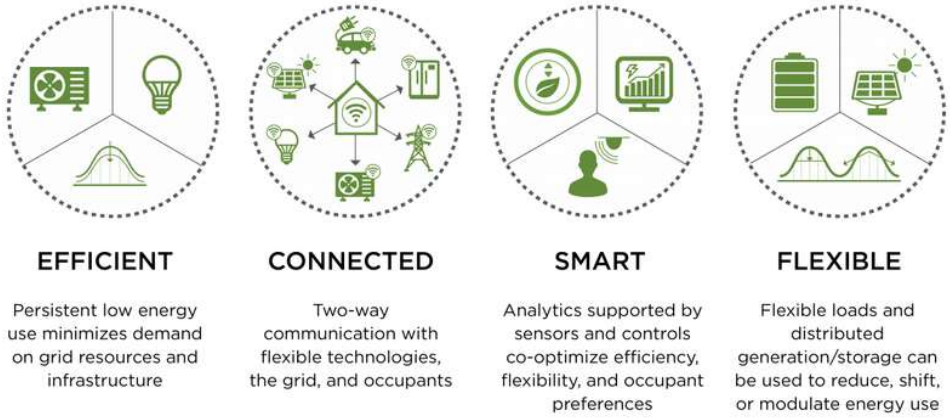
- Decarbonization
- Efficient
- Resilient
- Secure

Grid-Interactive Efficient Buildings – GEB

(https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings)

Grid and buildings operating as one large system

Distributed energy resources
- Generation
- Storage
- Flexible loads



Los Angeles 100% Renewable Energy Study

LADWP

$6 billion annual budget

9,400 employees

4 million residents

Advisory Group

Diverse energy backgrounds

Quarterly meetings

Policy oriented

Integrated Electricity Modeling

Full range power system modeling

Integrated transmission and distribution analysis

Environmental Analysis

Air quality

Environmental Impact

Economic Analysis

Job creation

Job migration

Economic development

Thank You

www.nrel.gov

michael.deru@nrel.gov

Q&A Session

- **Use the Q&A feature to ask a question**
- **Panelists**
  - Ed Mazria - CEO, Architecture 2030
  - Kate Simonen - Professor and Chair of Architecture, University of Washington
  - Michael Deru - Engineering Manager, National Renewable Energy Laboratory

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