Opportunities for Concrete, Buildings, and Pavements to Contribute to Greenhouse Gas Reduction Targets

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Iowa Better Concrete Conference
Ames, IA
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Cement and concrete are often viewed as problems

de zeen design magazine

Architects should give up concrete say experts at Architecture of Emergency climate summit

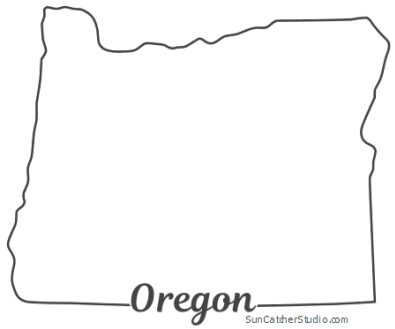
MIT CSHub

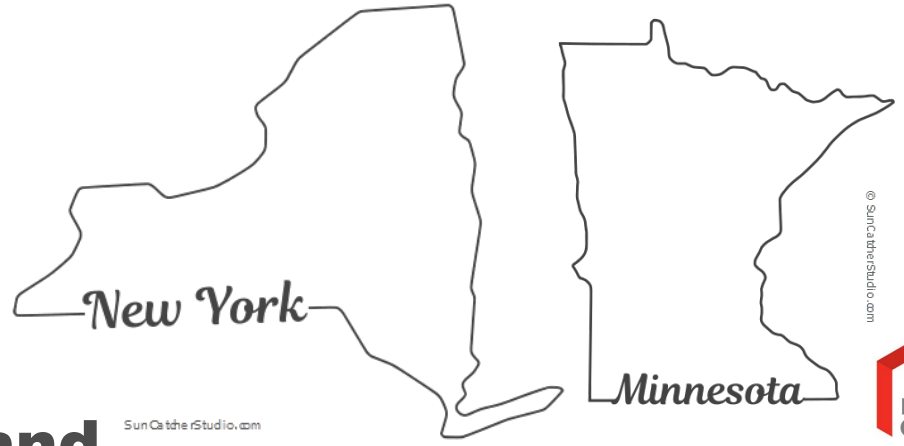
Embodied carbon in cement and concrete is on the radar of politicians and NGOs

HOUSE COMMITTEE ON
ENERGY & COMMERCE
CHAIRMAN FRANK PALLONE, JR.

HOUSE SELECT COMMITTEE ON THE
CLIMATE CRISIS

BUY CLEAN



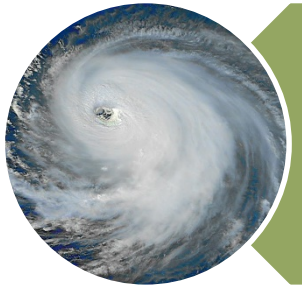


City of Portland
Marin County

Cement and concrete are critical to meeting societal goals

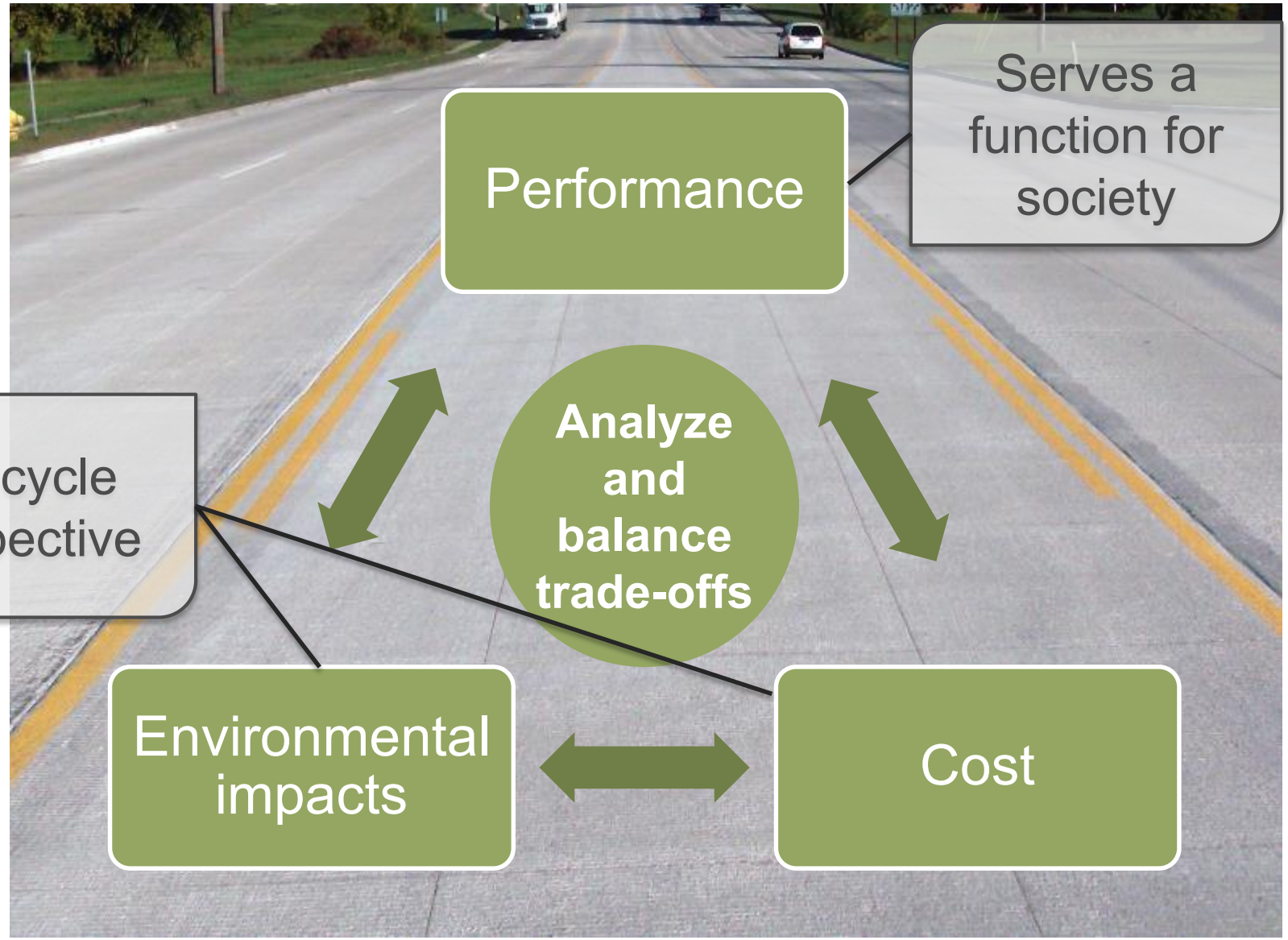
Meeting UN sustainable development goals

Addressing affordable housing shortage



Decreasing costs from natural disasters

Quantitative sustainability assessments require a life cycle perspective and trade-off analysis



A life cycle perspective should be used to evaluate potential to contribute to sustainability targets

Materials Production

- Use recycled materials
- Improve energy efficiency
- Improve material performance

Design & Construction

- Use less (i.e., stronger) material
- Create longer-lasting designs

Use

- Reduce vehicle fuel consumption
- Reduce building energy consumption
- Reduce heat island effects

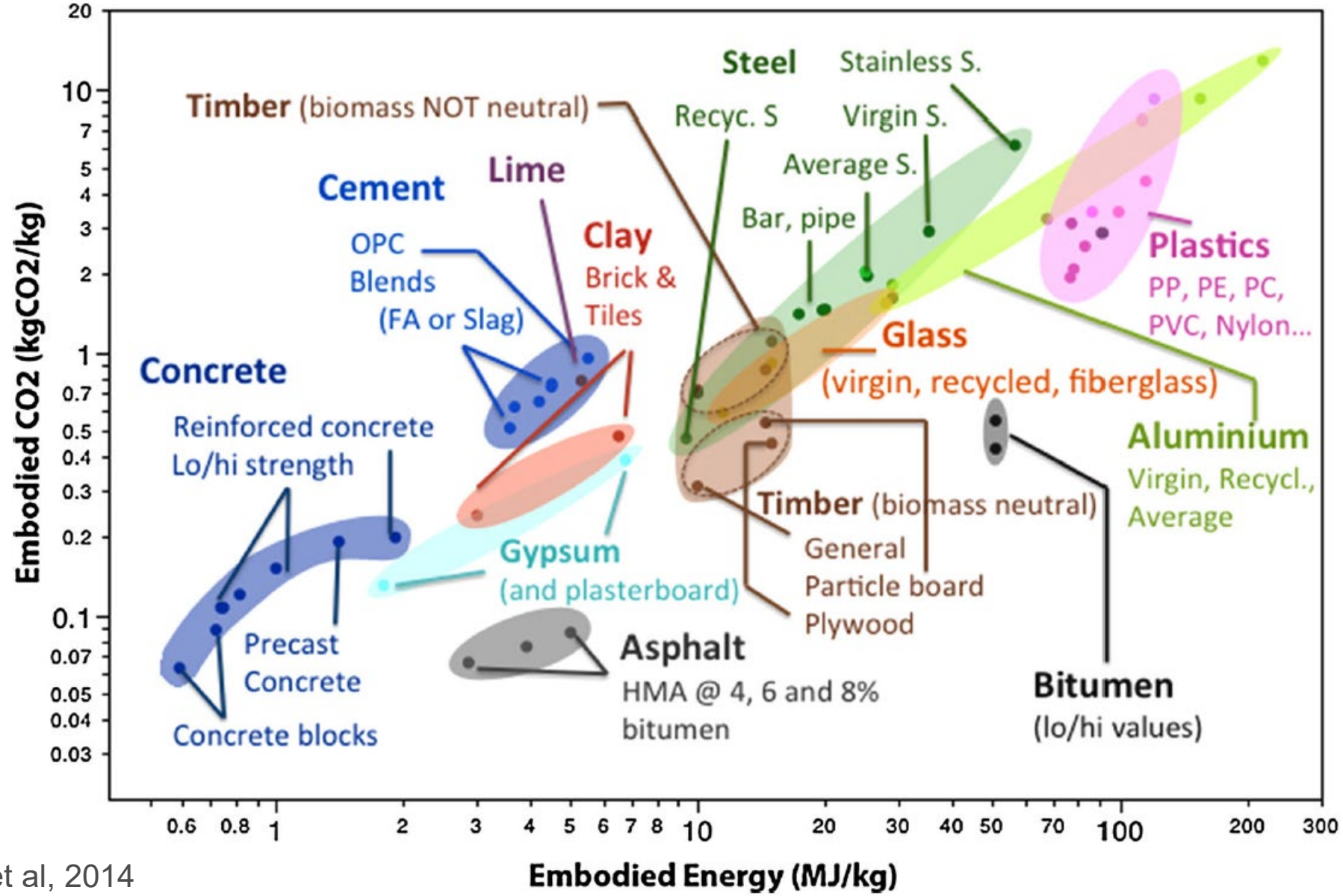
End-of-Life

- Enable material recovery
- Increase carbonation

Embodied

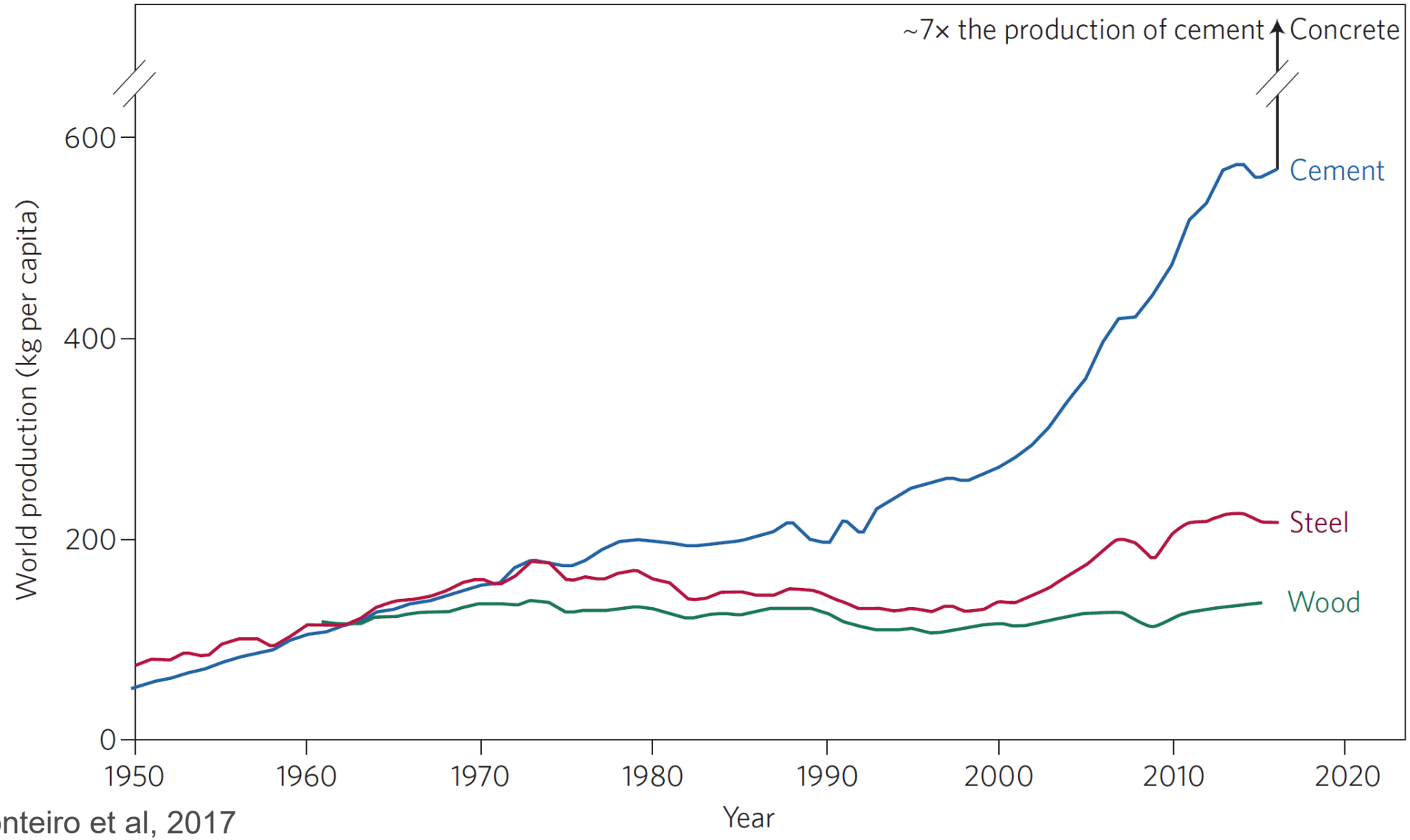
Whole life

Concrete is a low-impact material



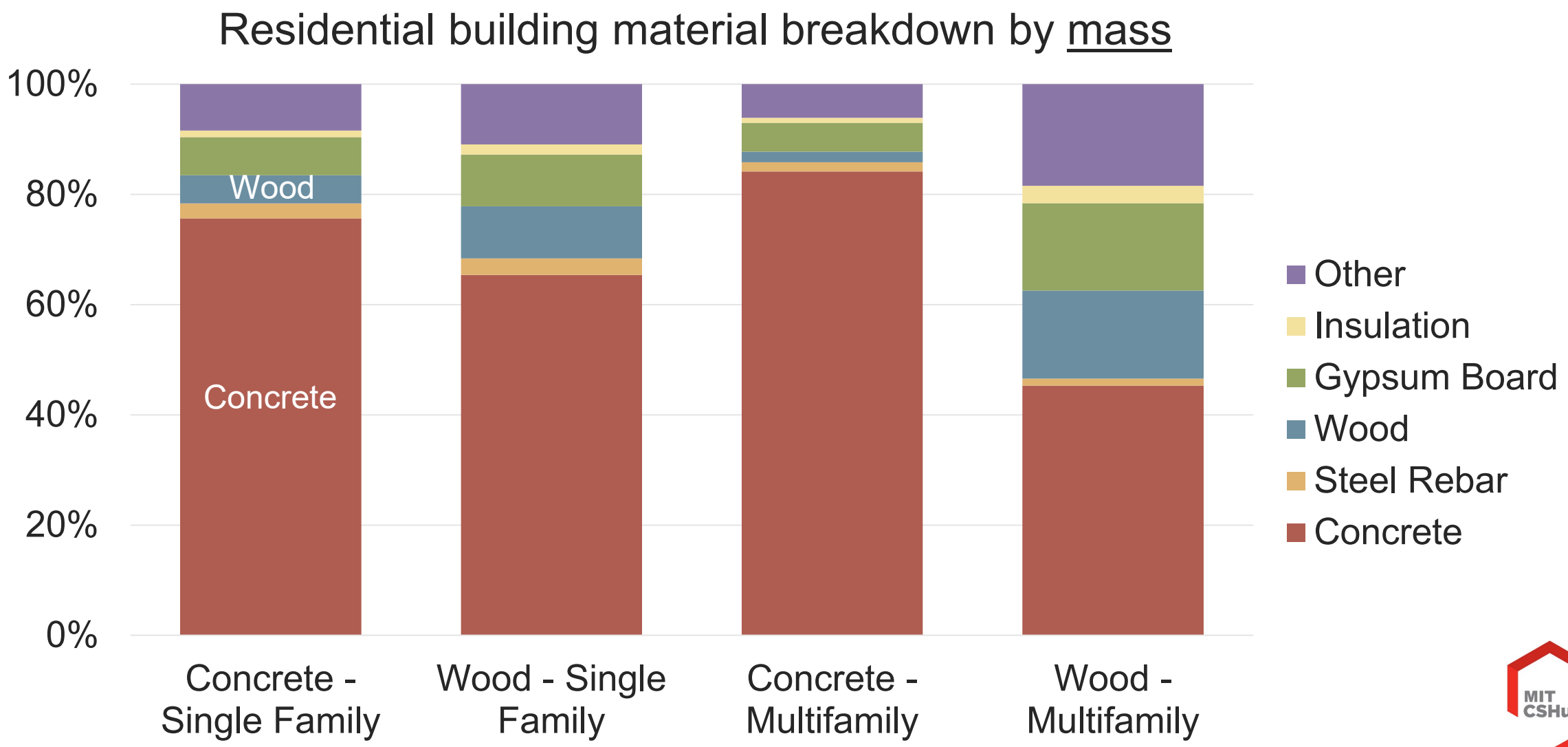
Source: Barcelo et al, 2014

Concrete is the most used building material in the world



Source: Monteiro et al, 2017

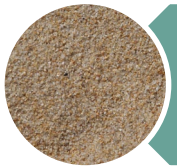
Concrete is a significant portion of nearly all buildings



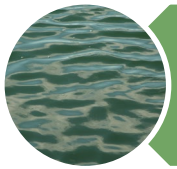
Concrete is a mixture that can be designed to meet performance requirements

Concrete Constituents


Coarse aggregates


Fine aggregates


Binder


Water

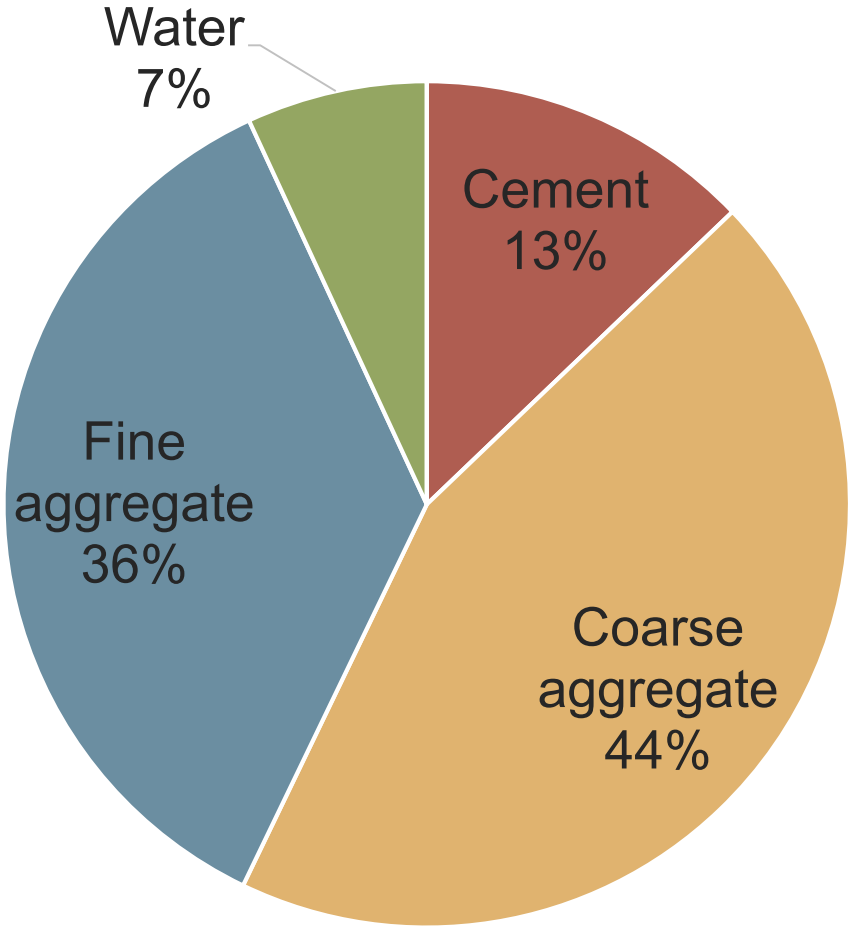

Admixtures

Performance Requirements

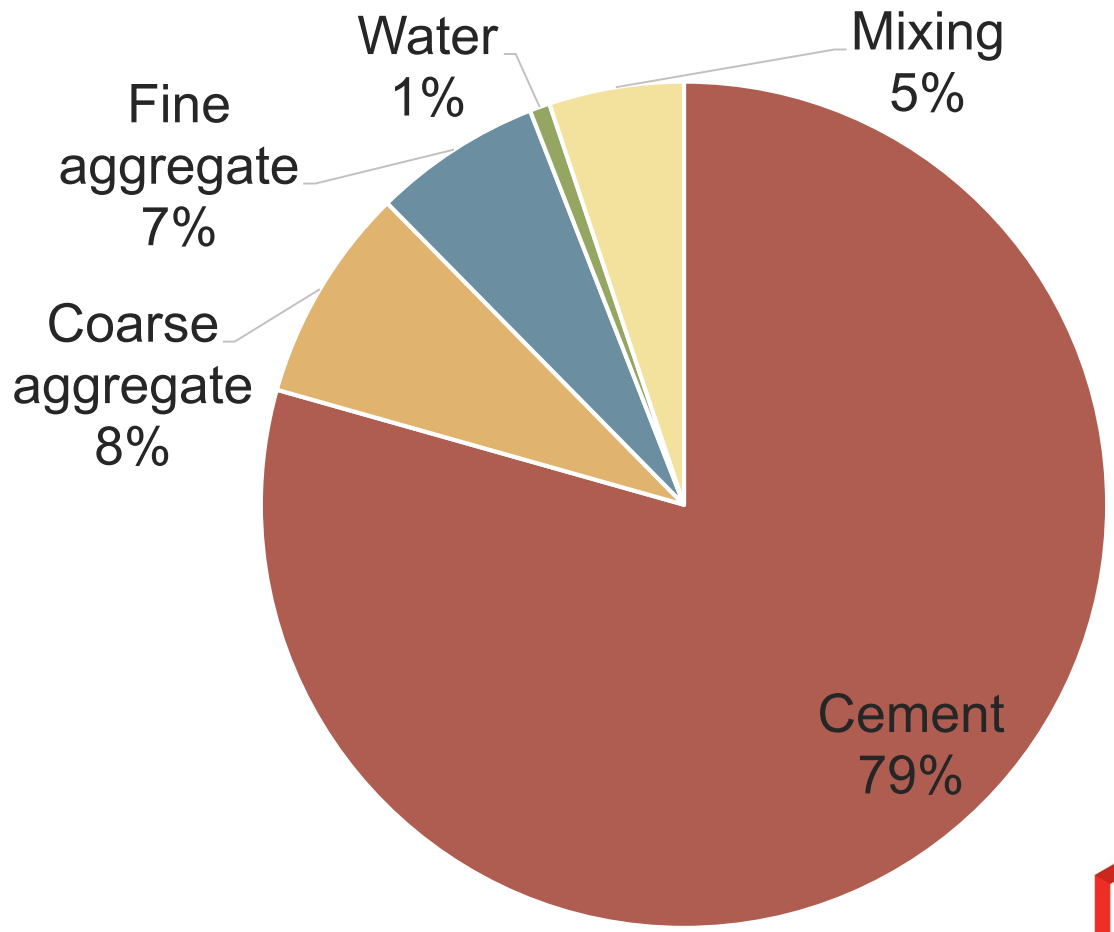
- 28-Day strength
- 3-Day strength
- Modulus of elasticity
- Density
- Slump
- Thermal control
- Chloride permeability
- Alkali-silica reaction
- Freeze-thaw
- Other durability

Cement drives concrete's environmental impact

Constituent contribution by **mass**



Constituent contribution by **GHG emissions**



3000 psi mixture with no SCMs

There are numerous solutions available today for lowering concrete's environmental impact

Bold = widespread use today

Cement

- **Alternative fuels**
- **Energy efficiency**
- **Clinker replacement**
- Cement formulation
- Carbon sequestration at cement plant
- Carbon sequestration in cement production

Concrete

- **Cement replacement**
- **Performance-based specifications**
- Carbon sequestration in concrete production
- Carbon sequestration in aggregate production

Recommendations for reducing embodied impacts

1. Promote adoption of energy efficiency technologies for new and retrofit cement plants
2. Encourage and facilitate increased use of alternative fuels in cement plants
3. Encourage and facilitate use of blended cements
4. Support development and deployment of carbon capture, use, and storage technologies for cement and concrete production
5. Support deployment of performance-based specifications for concrete and EPD reporting to spur innovation in low-carbon concrete mixtures

Adapted from WBCSD-IEA Technology Roadmap for Cement Industry

A life cycle perspective should be used to evaluate potential to contribute to sustainability targets

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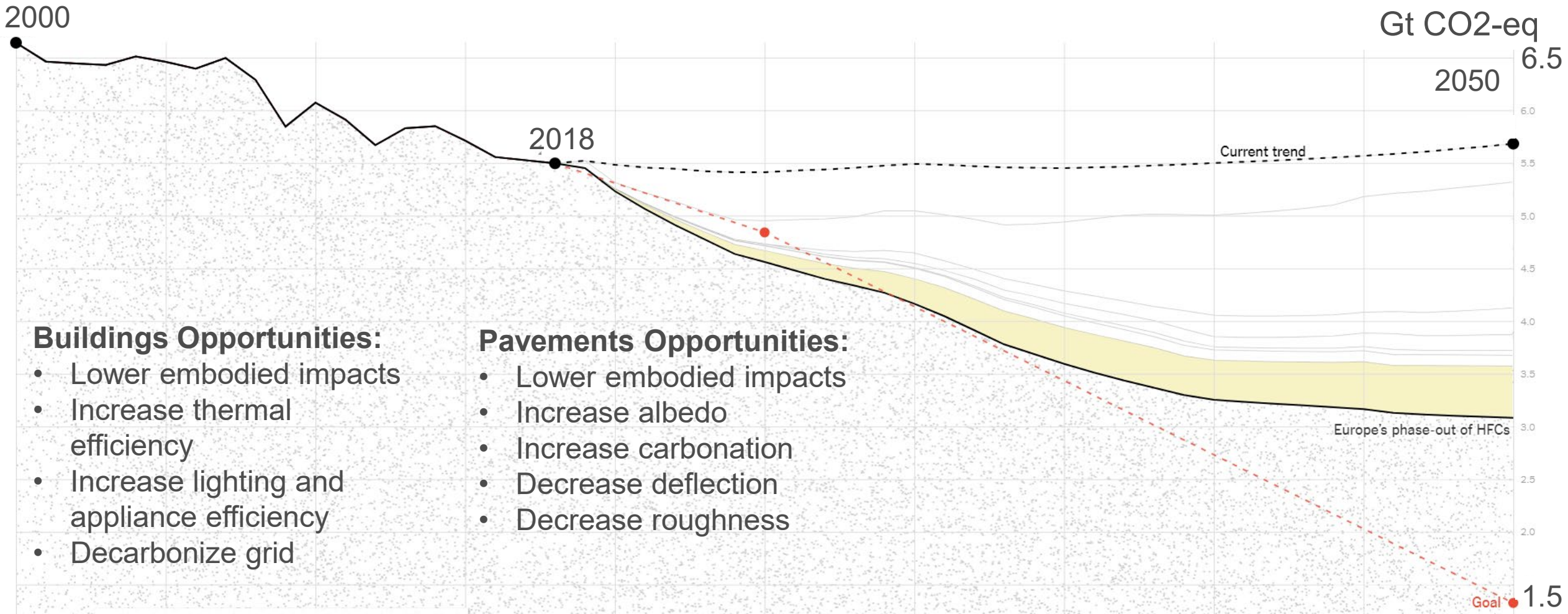
Embodied

Whole life

GHG reduction opportunities for concrete, buildings, and pavements

How to Cut U.S. Emissions Faster? Do What These Countries Are Doing. (NYTimes, Feb 2019)



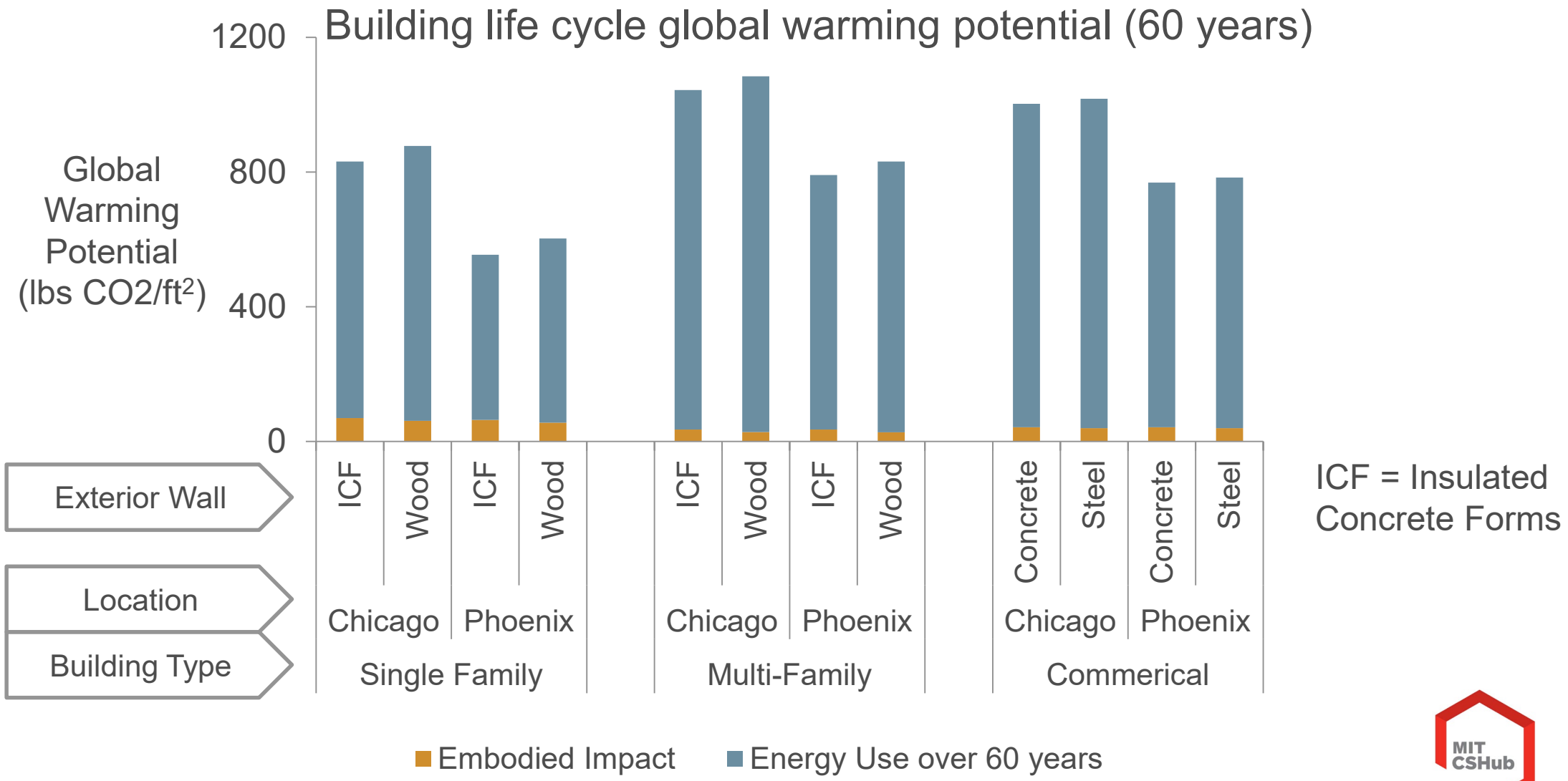
Buildings Opportunities:

- Lower embodied impacts
- Increase thermal efficiency
- Increase lighting and appliance efficiency
- Decarbonize grid

Pavements Opportunities:

- Lower embodied impacts
- Increase albedo
- Increase carbonation
- Decrease deflection
- Decrease roughness

Energy use dominates building life cycle impacts

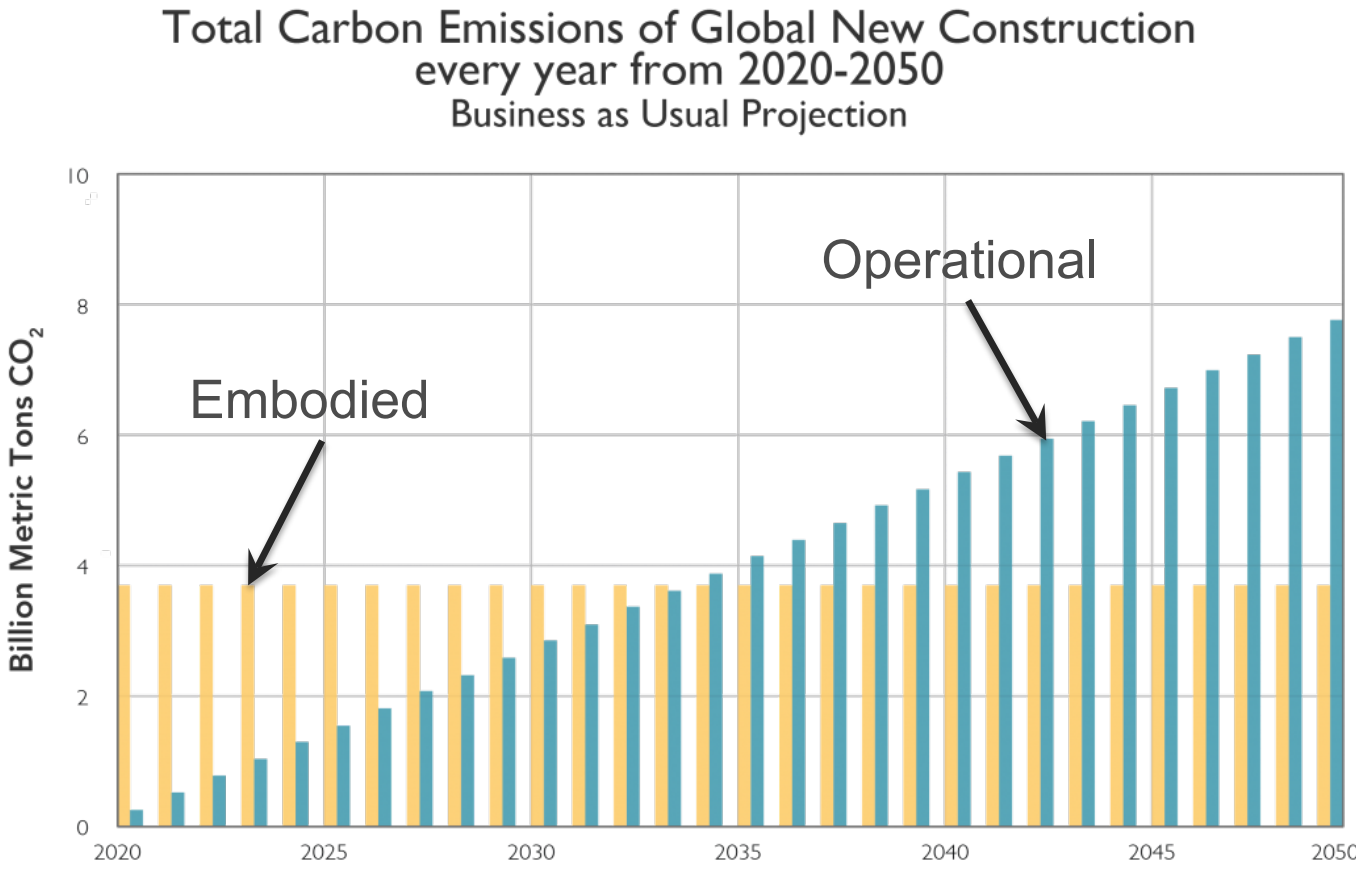


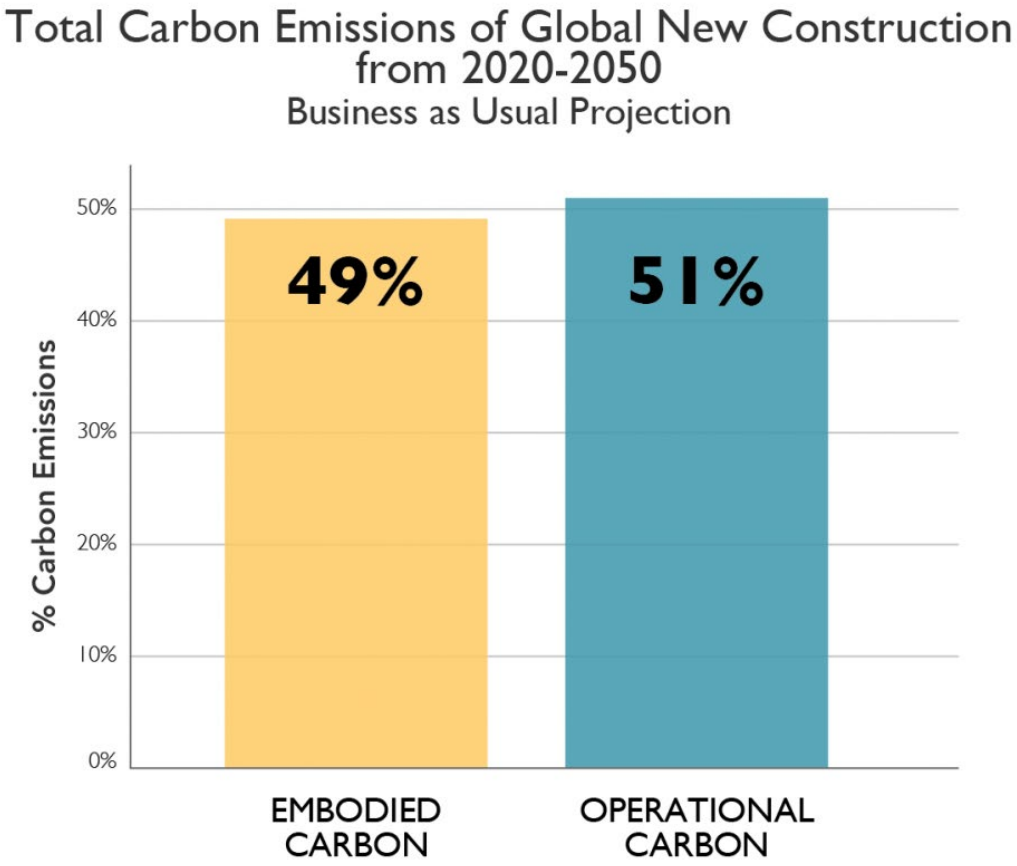
Ref: MIT CSHub, [Methods, Impacts, and Opportunities in the Concrete Building Life Cycle]

Results applicable for this case study only

Architecture 2030 claims that embodied carbon is significant

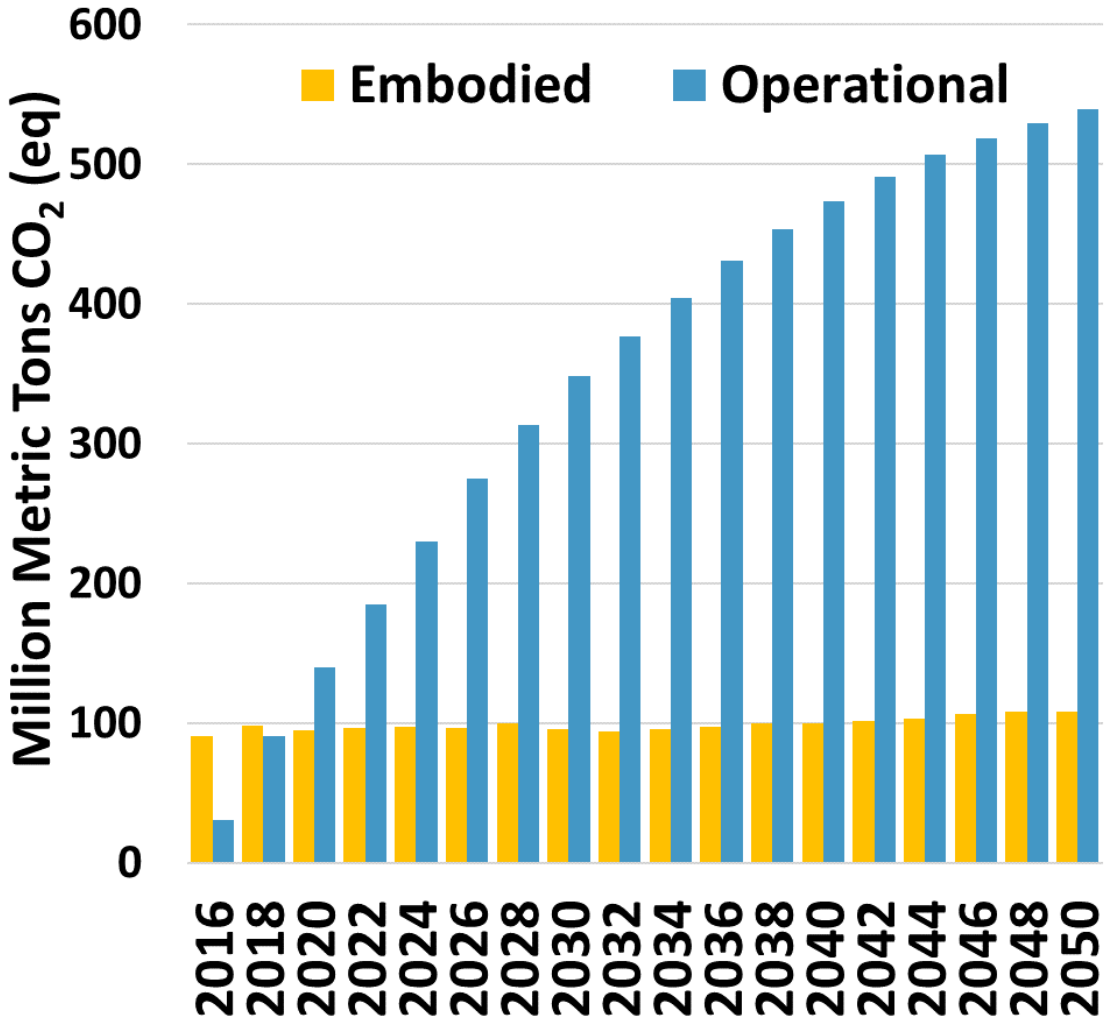
Approach: top-down estimate based on global economic and energy sector data

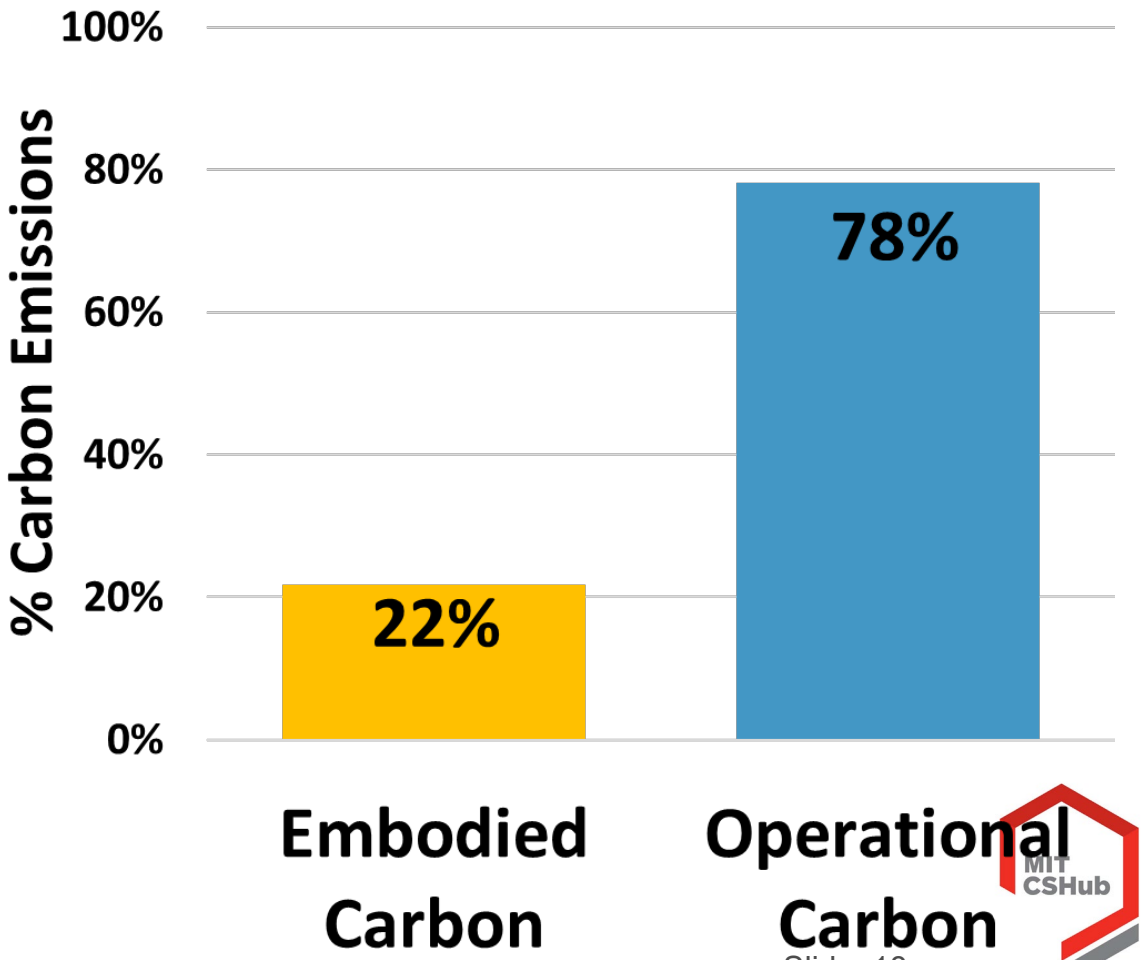




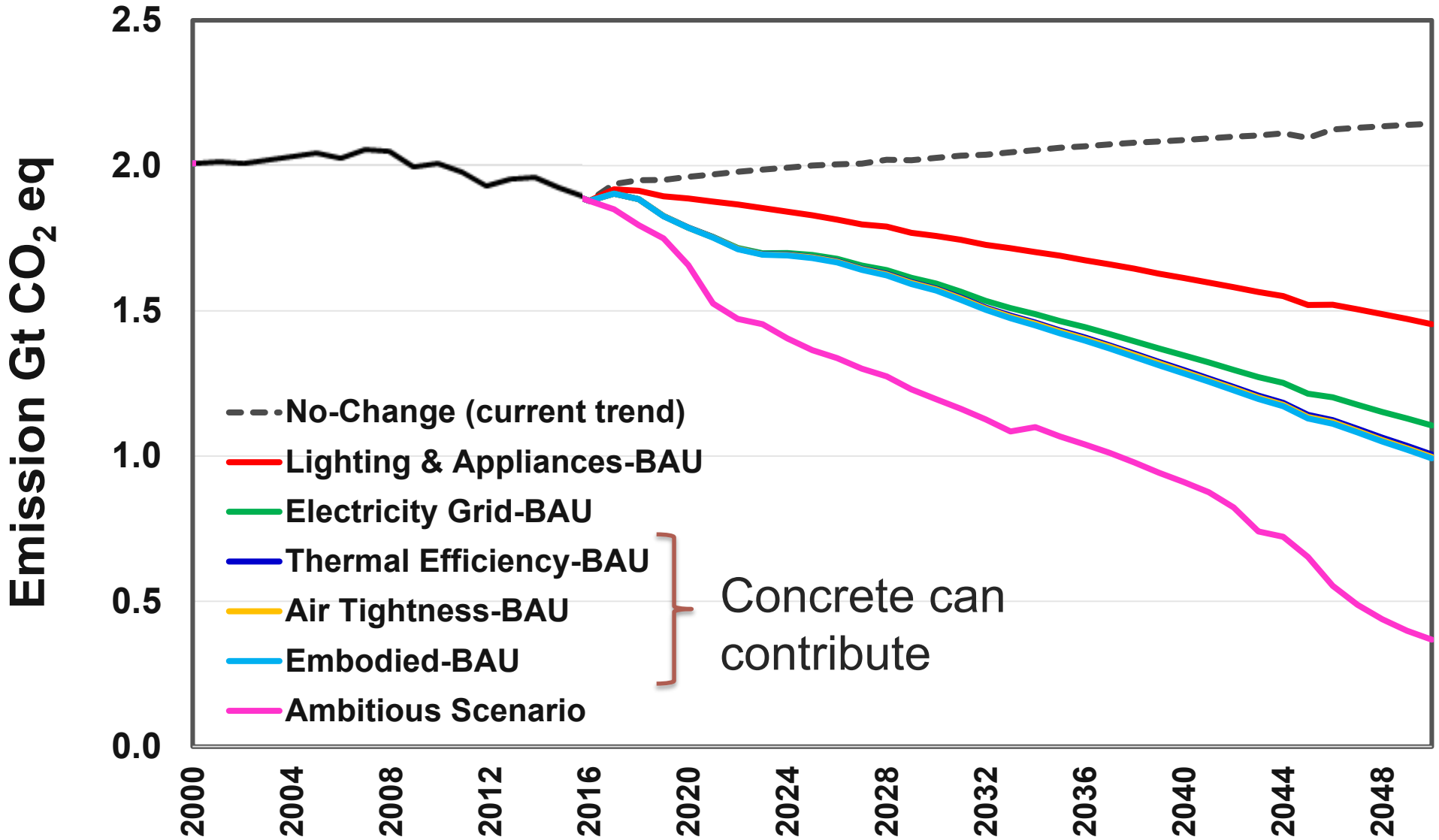
Our analysis of the US shows a very different picture

Approach: bottom-up estimate based on modeling of US buildings

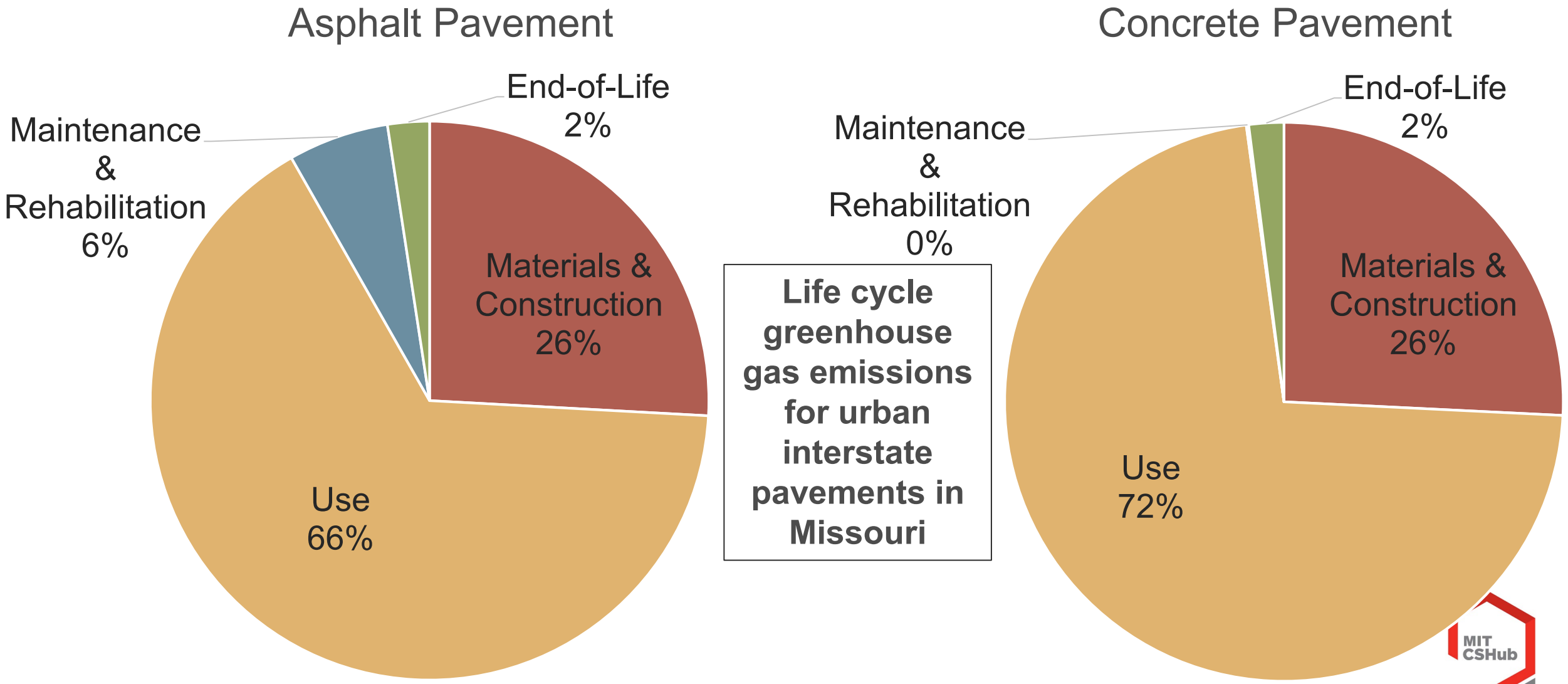




There are opportunities to reduce embodied carbon, but opportunities for operational carbon are much larger



Excess fuel consumption dominates pavement life cycle impacts

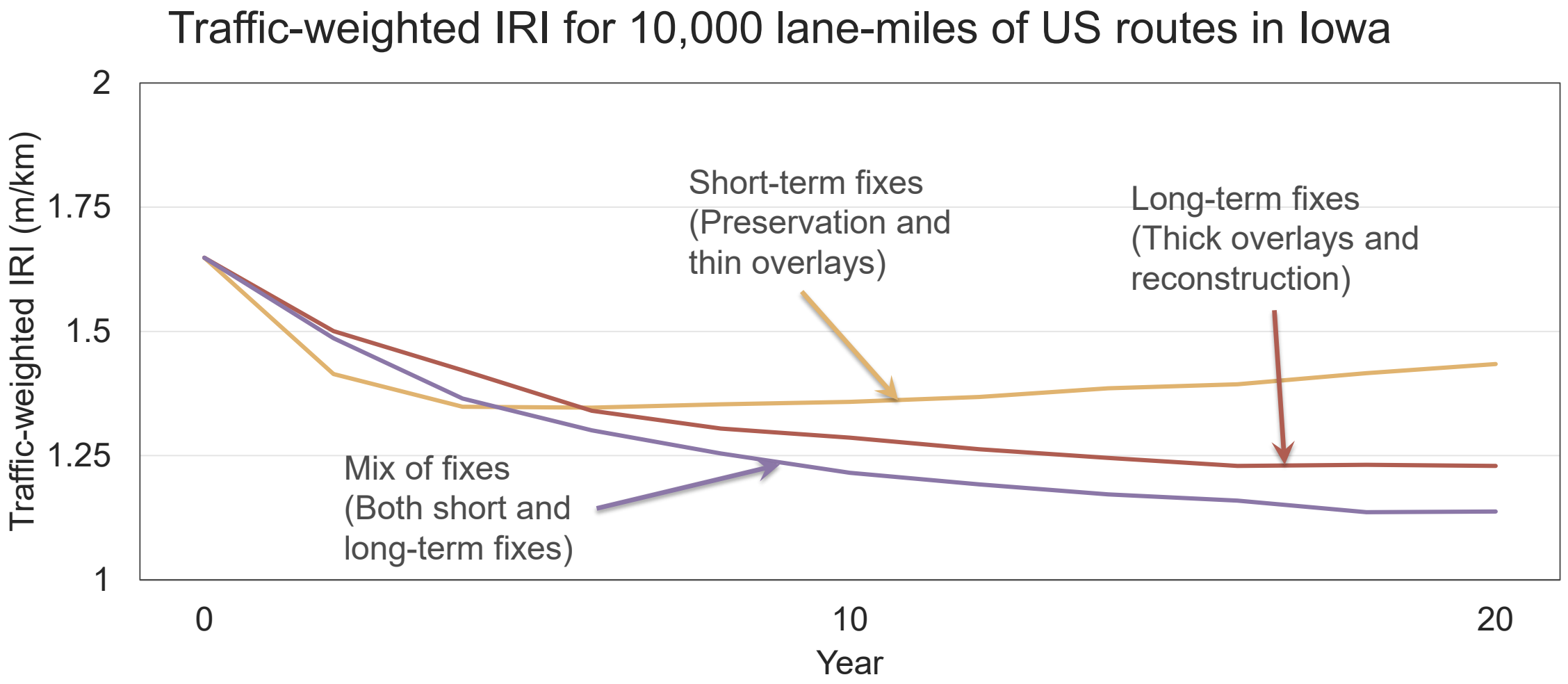


Life cycle greenhouse gas emissions for urban interstate pavements in Missouri

*metric tons

Pavement design developed by Applied Research Associates (ARA), Inc,:
AADTT 8k/day; 6 lanes; MO (wet freeze); MEPDG-based rehabilitation schedule.

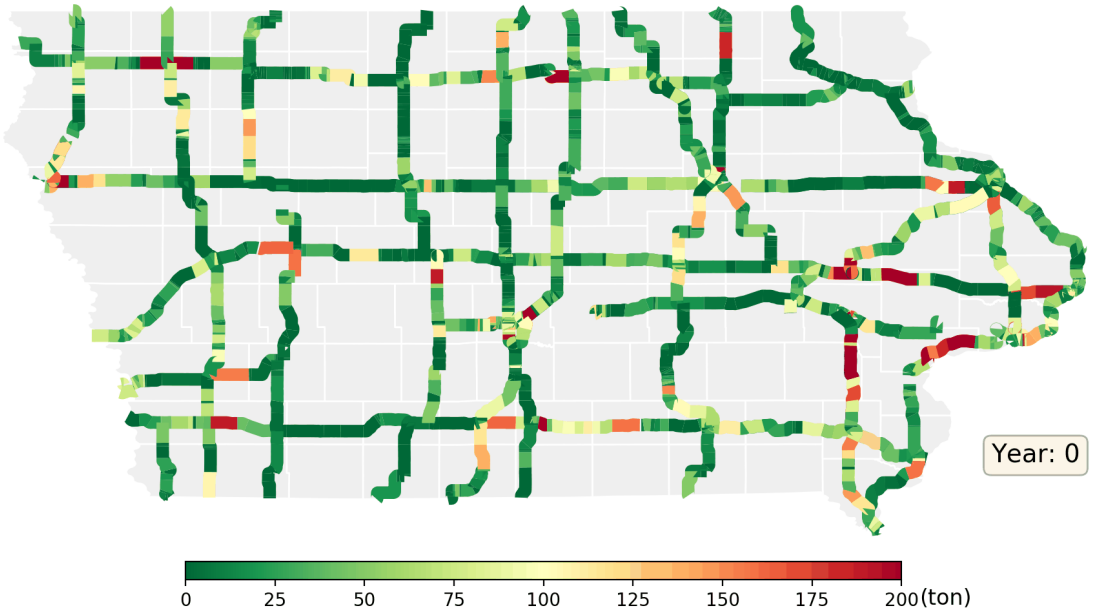
Pavement asset management strategies affect network performance



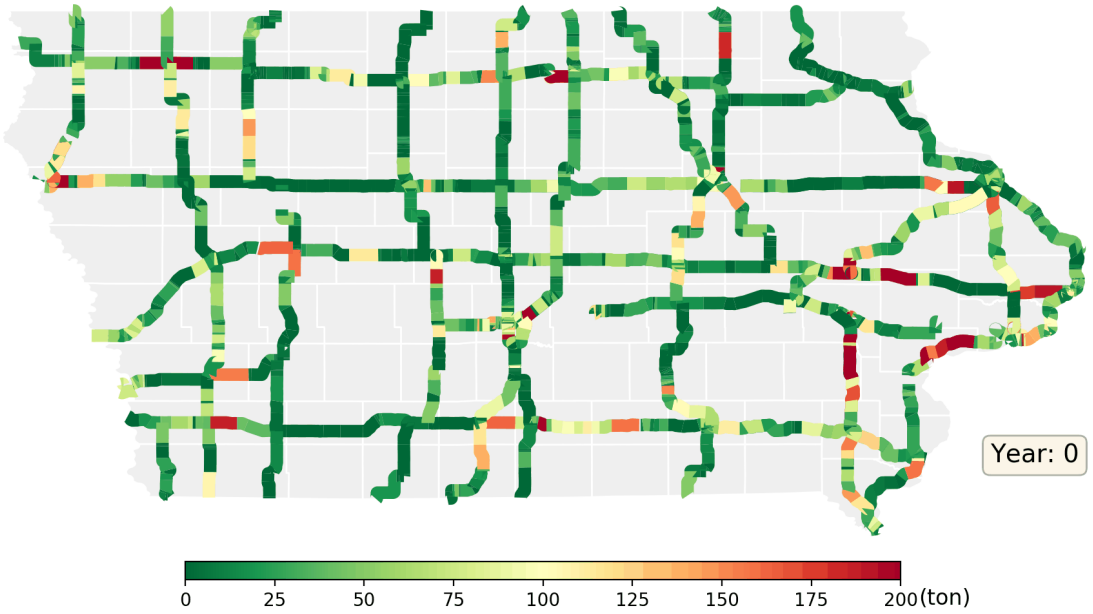
A mix of fixes lowers network GHG emissions

GHG emissions due to roughness-induced excess fuel consumption on US routes in Iowa

Short-term treatments

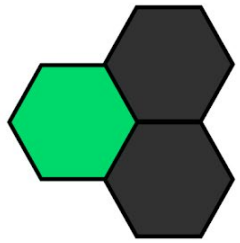


Mix of fixes



Cumulative reduction of 6000 tons of CO2 over 20 years

Measure pavement roughness using Carbin app



Carbin

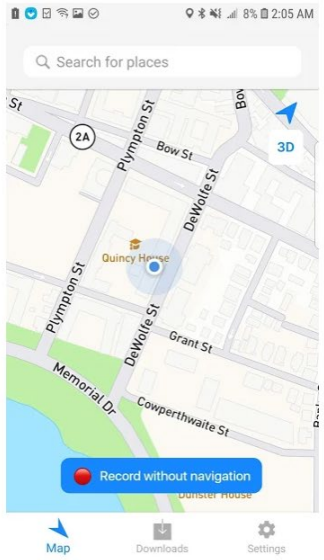
Bader Anini Education

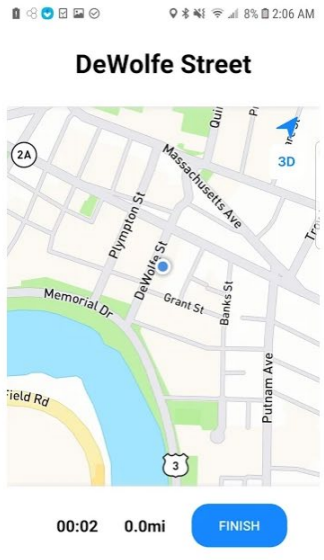
★★★★★ 5

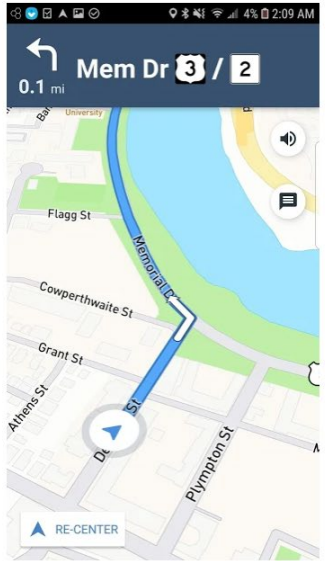
Everyone

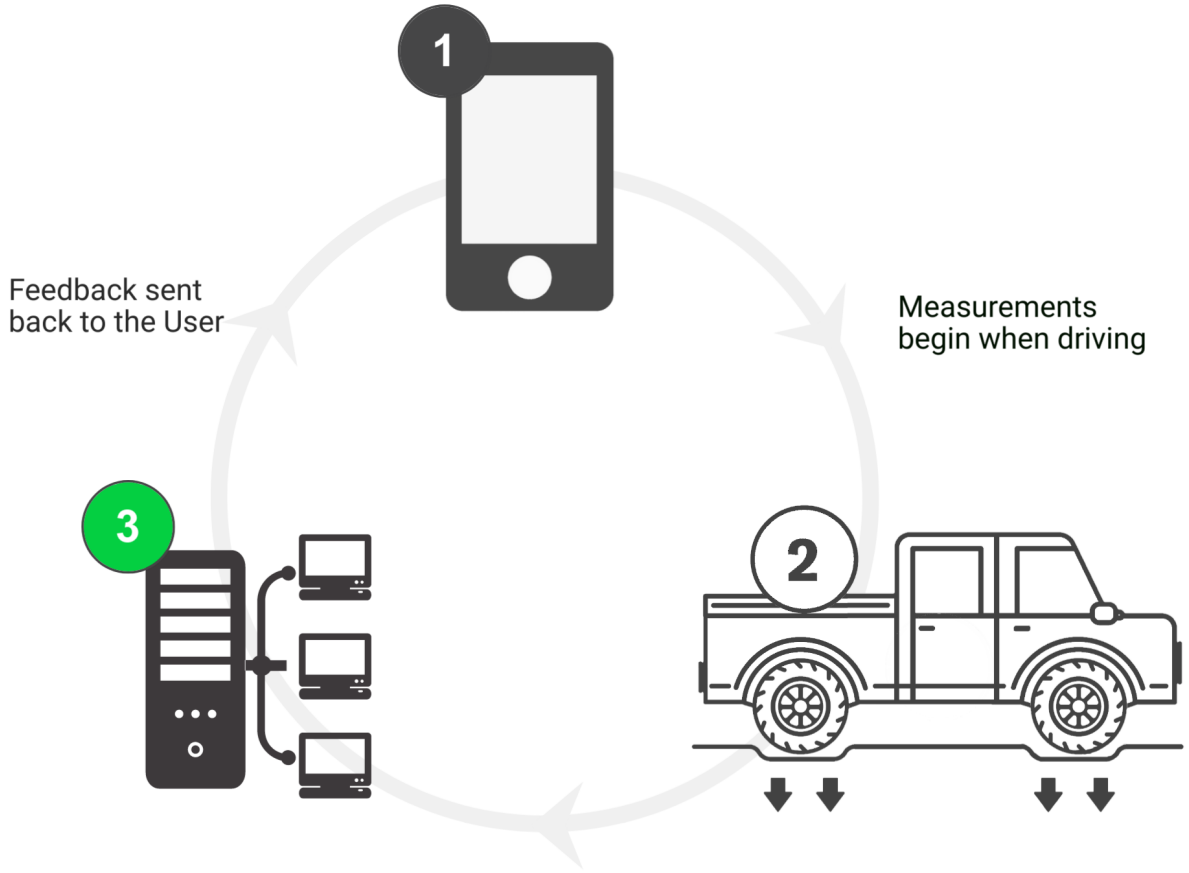
You don't have any devices.

Add to Wishlist Install

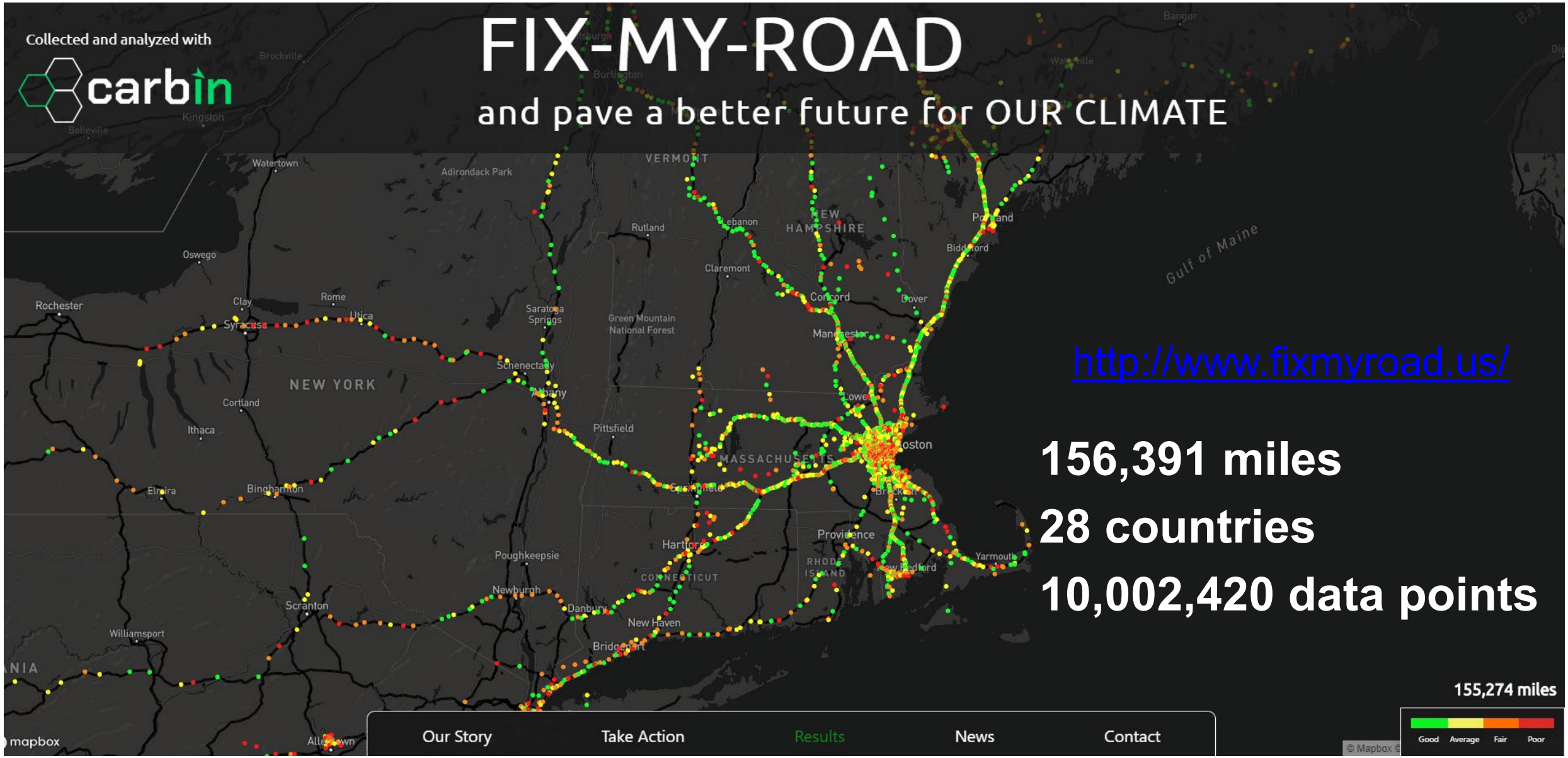






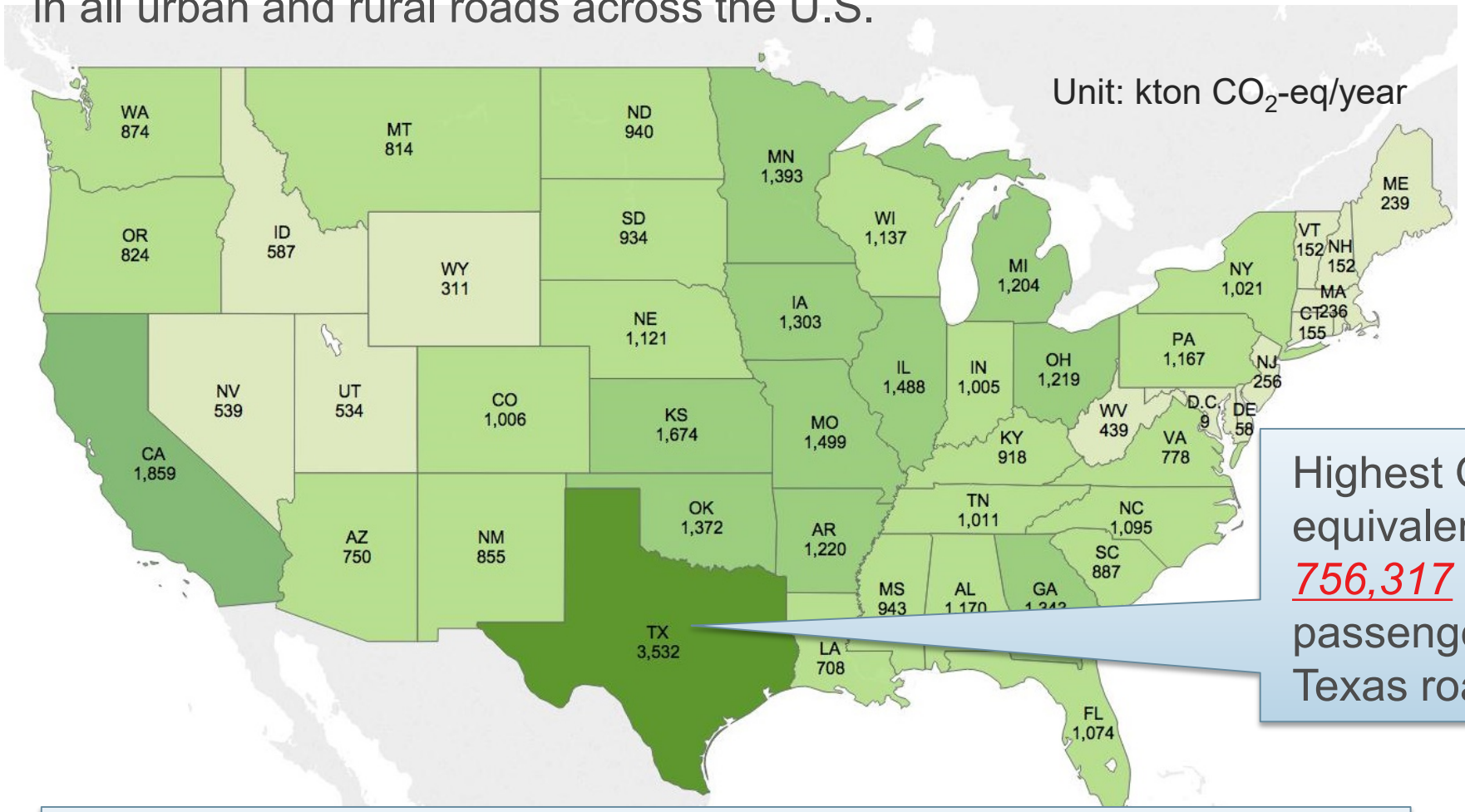


Crowdsourced data can support asset management



Increasing pavement albedo nationwide has significant potential for global warming potential savings

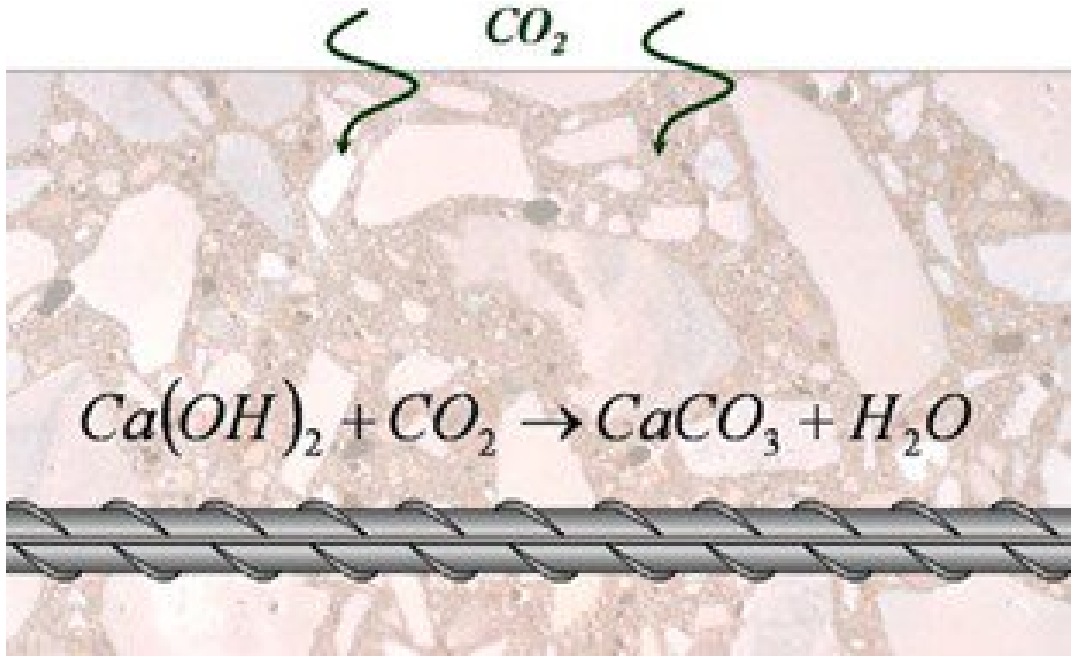
Annual GWP savings from radiative forcing due to 0.2 albedo increase in all urban and rural roads across the U.S.



Highest GWP savings: equivalent to removing *756,317* or *9%*, of passenger vehicles from Texas roads for one year.

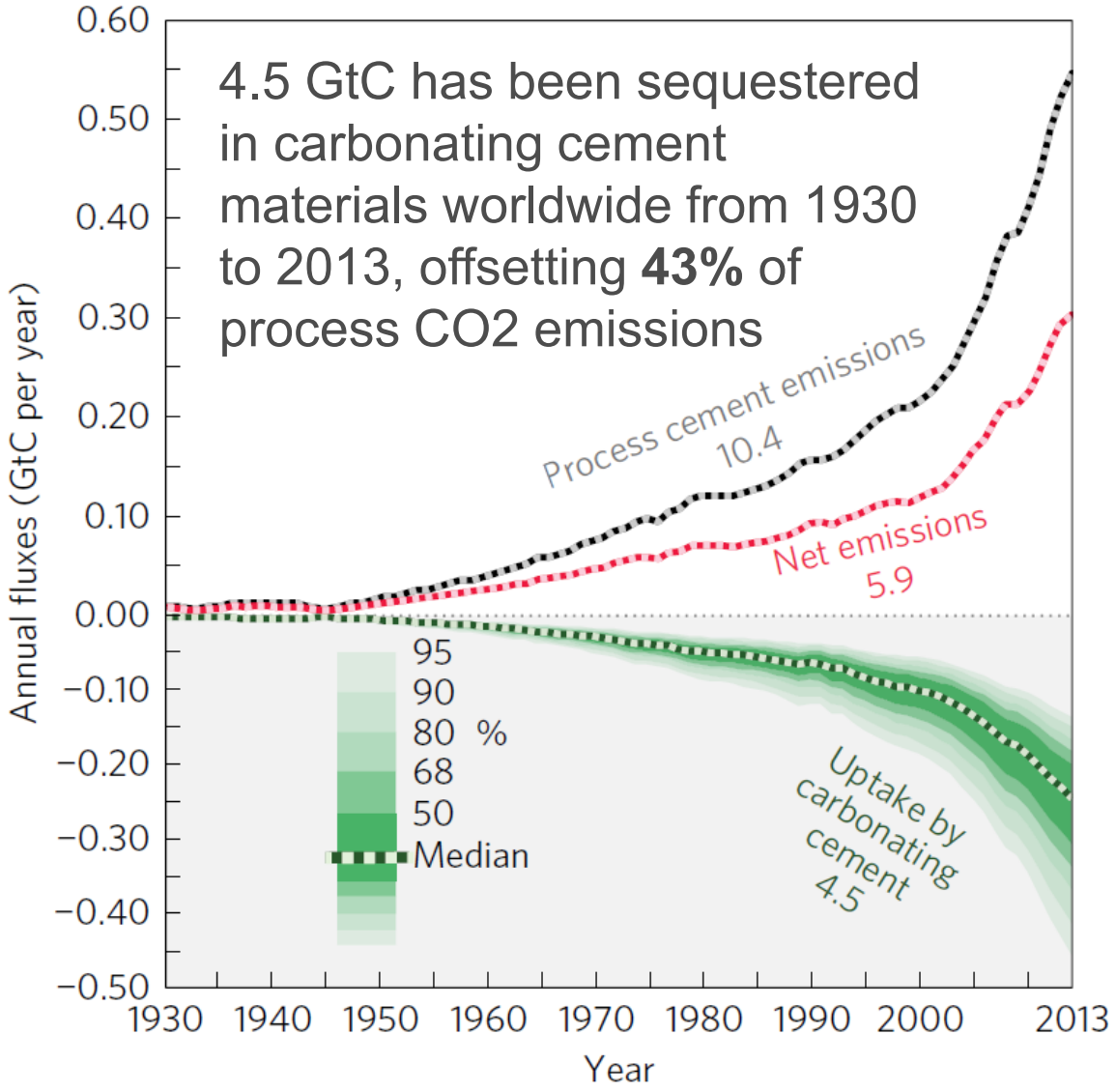
Nationwide, savings would be equivalent to removing nearly *9.4 million*, or roughly *8%,* of passenger vehicles

Carbon uptake in concrete over time



Factors that affect carbon uptake rate:

- Exposed surface area
- Concrete mixture
- Climate

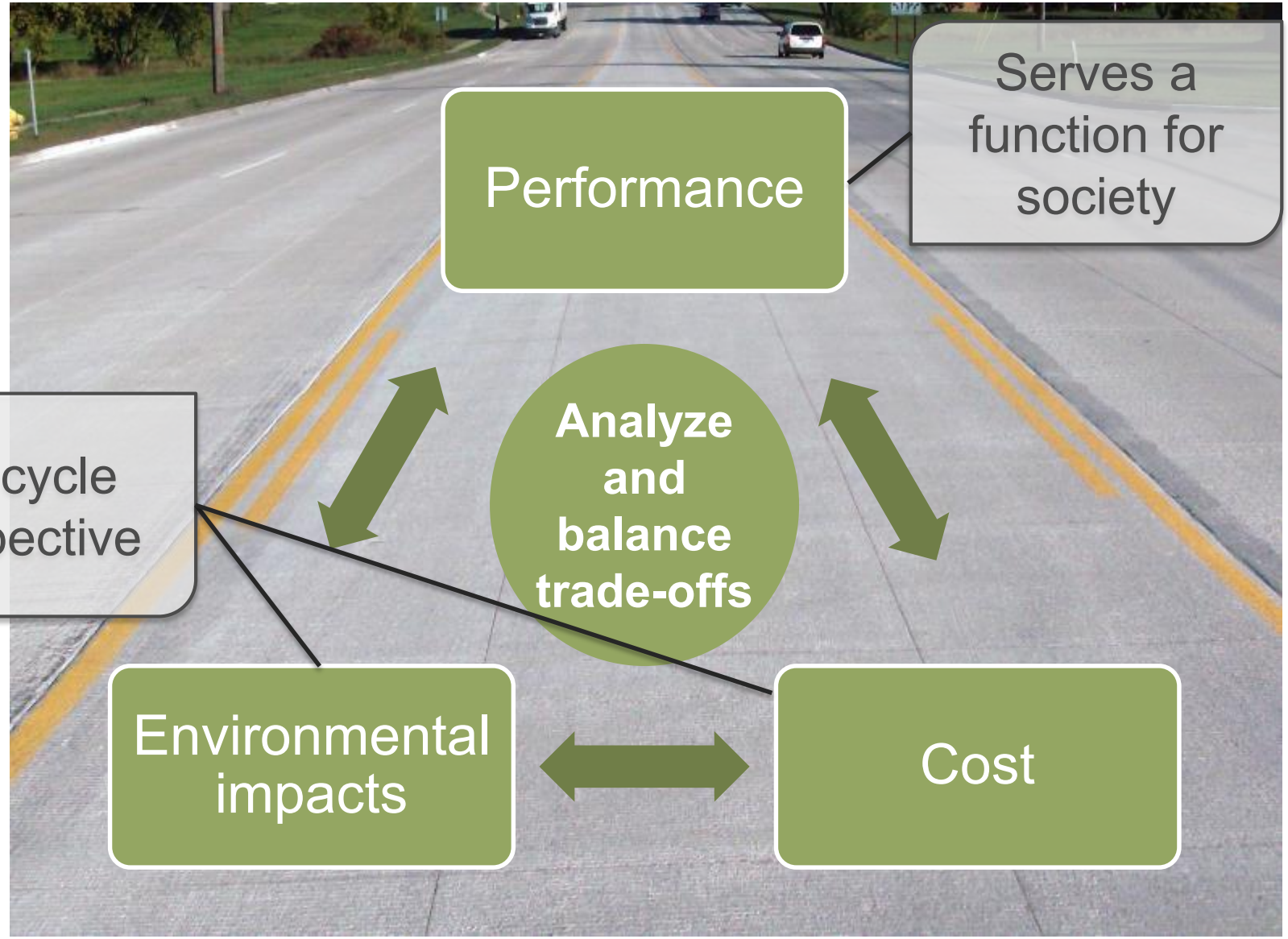


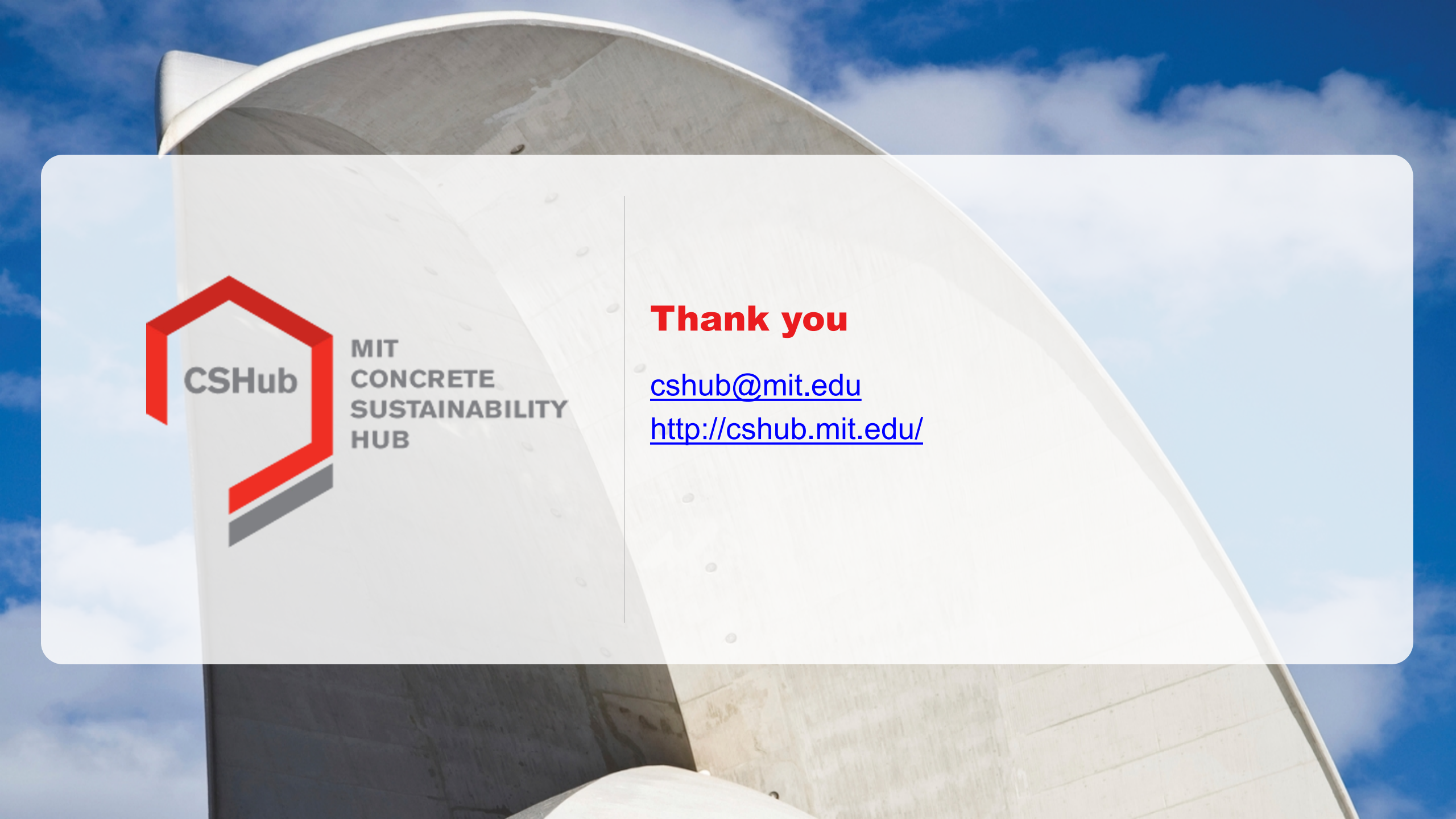
Source: Xi et al, Nature Geoscience, 2016

Recommendations for reducing life cycle impacts

1. Buildings: enable reduction of energy consumption through energy-efficient design
2. Pavements:
    1. Enable reduction of vehicle excess fuel consumption through smoother and stiffer pavements at project level
    2. Employ mix of fixes to lower roughness in asset management
    3. Create cool pavements through higher albedo
3. Carbon uptake: request estimates of uptake in concrete structures

Quantitative sustainability assessments require a life cycle perspective and trade-off analysis





Thank you

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