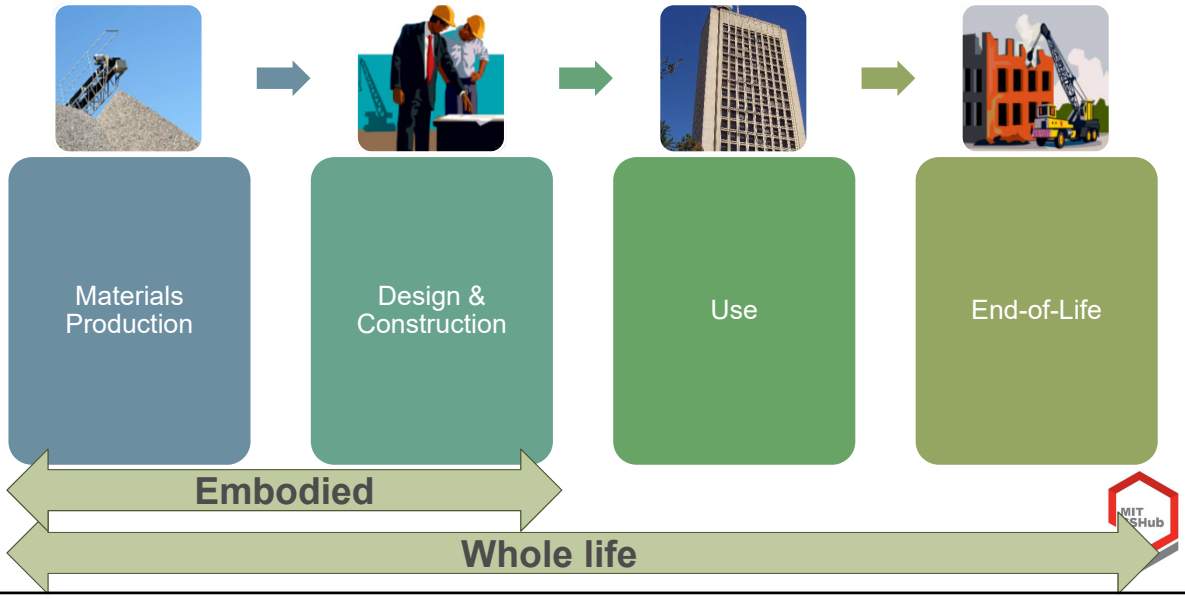
A life cycle perspective should be used to evaluate concrete's (or any technology's or activity's) environmental impact



A life cycle perspective should be used to evaluate concrete's (or any technology's or activity's) environmental impact

Materials Production
- Impacts of extraction
- Emissions due to energy consumption
- Emissions due to process chemistry

Design & Construction
- Fuel use by vehicles and processing equipment
- Efficiency and waste of materials

Use
- Material properties impact energy use
- Materials may be chemically active
- Materials may directly impact the environment

What are these for pavements?

End-of-Life
- Implications of material recovery
- Carbon uptake

Embodied

Whole life

During pavement use excess fuel consumption (EFC) of vehicles caused by pavement design and maintenance

Pavement-vehicle interaction (PVI)

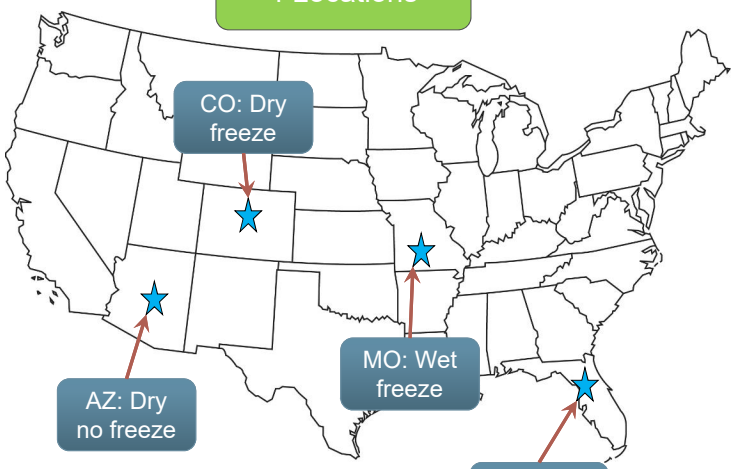
Pavement Deflection

Pavement Roughness

Deflection & Roughness → **Excess Fuel Consumption** → **Economic & Environmental Impacts**

Slide 4

To understand significance of the use phase CSHub conducted LCAs for a wide range of contexts



Pavement design and maintenance schedules developed by Applied Research Associates (ARA), Inc

3 Traffic Levels

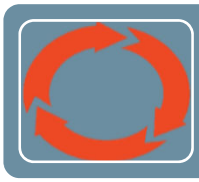
- Rural local street/highway
- Rural state highway
- Urban interstate

Several framing conditions

- Pavement designs
- Maintenance schedules
- Design life
- Analysis period

Slide 5

Key findings from initial phases of CSHub research on the pavement lifecycle



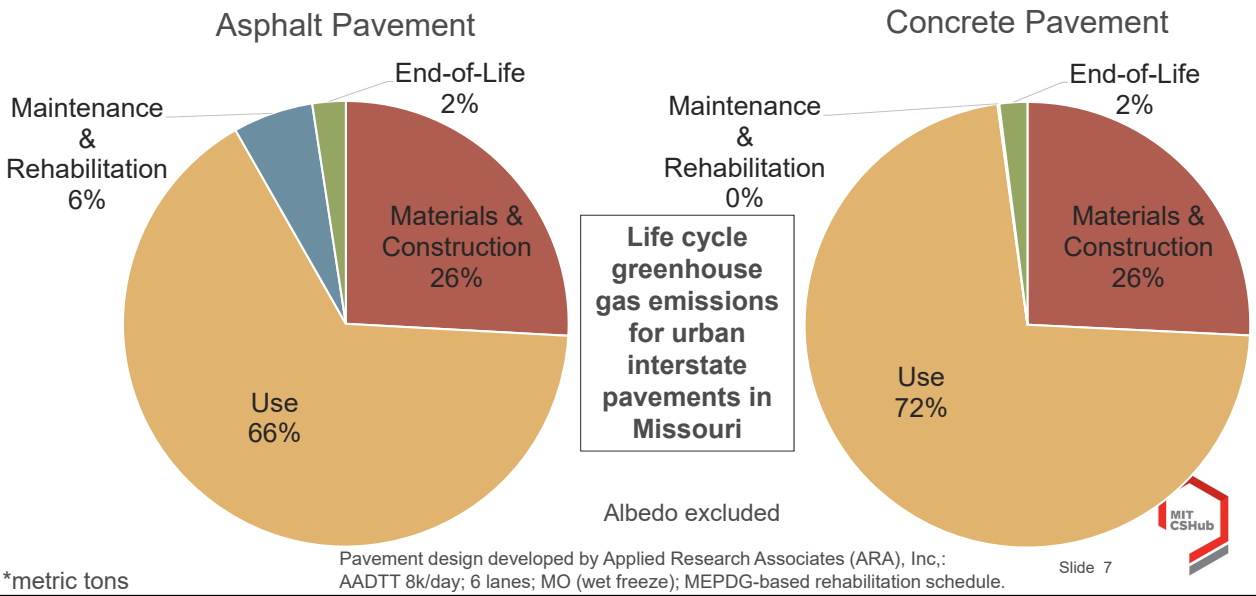
Life cycle perspective matters

Pavement-vehicle interaction matters

Context matters

Slide 6

Life cycle perspective matters: Use phase impacts can drive overall emissions



*metric tons

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

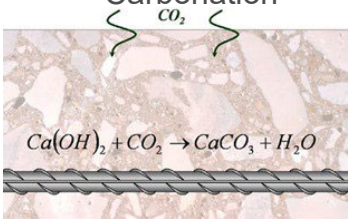
Slide 7

Other pavement use effects: Radiative forcing, Building energy use, Carbon Uptake

Albedo

https://heatisland.lbl.gov/coolscience/cool-pavements

Carbonation



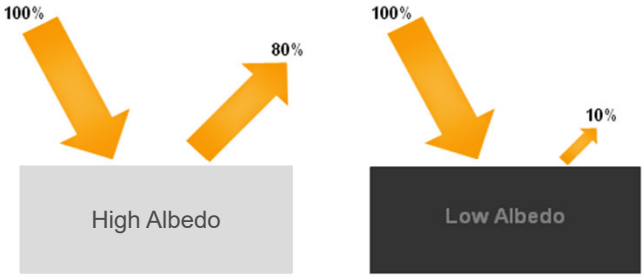
https://theconstructor.org/concrete/carbonation-of-concrete-structures/7791/

Pavement-Vehicle Interaction

Slide 8

Higher albedo pavements tend to stay cooler in the sun than conventional

- Albedo:
  - Fraction of solar radiatio reflected from a surface
- Pavements that …
  - Reflect more energy
  - Stores less heat
  - Has lower surface temperature

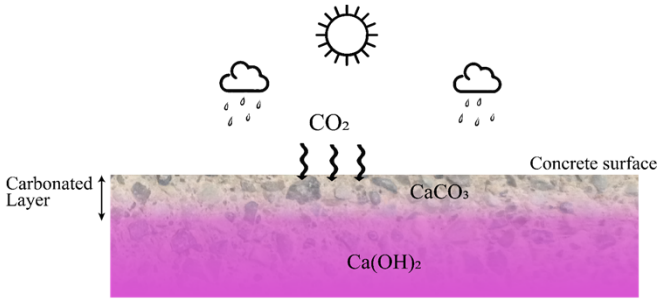


Cool Pavements | HEATISLAND (lbl.gov)

Slide 9

Concrete carbon uptake (aka carbonation) can be a natural carbon sink

- Reaction of CO_2 with the hydrated cement.
- Concrete carbon uptake is a natural process that can happen during the use and end-of-life phases of concrete life cycle.



$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

Slide 10

More detailed modeling of pavement use in context of cool pavements

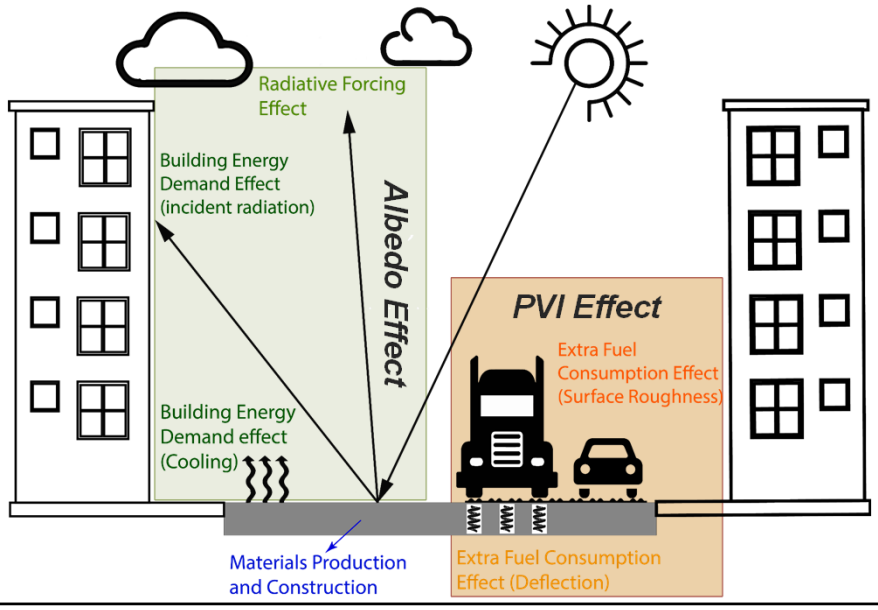
All cool pavement strategies increase embodied emissions …

Research question:

Do cool pavements create net global climate benefits or burdens?

Slide 11

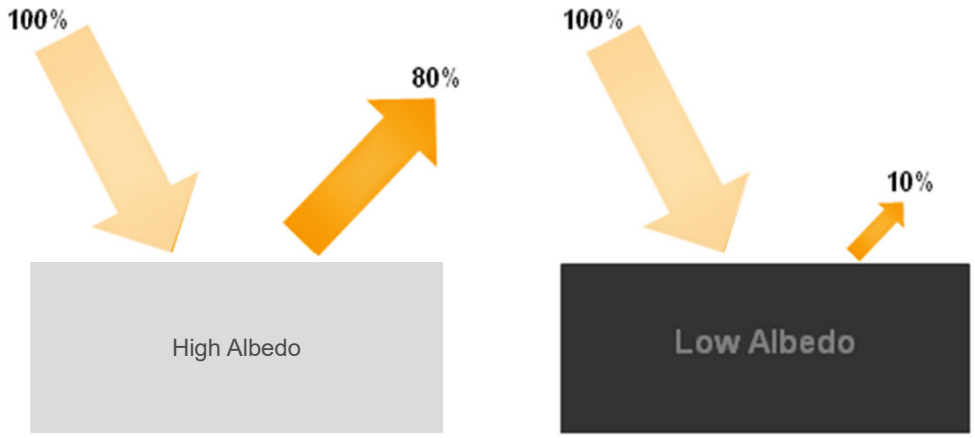
CSHub modeling now captures all use phase impacts: PVI, albedo-related, and carbon uptake



Slide 12

Radiative forcing simply means a change in the net radiation in to the earths atmosphere

Changing surface albedo changes outbound energy and, therefore, the net

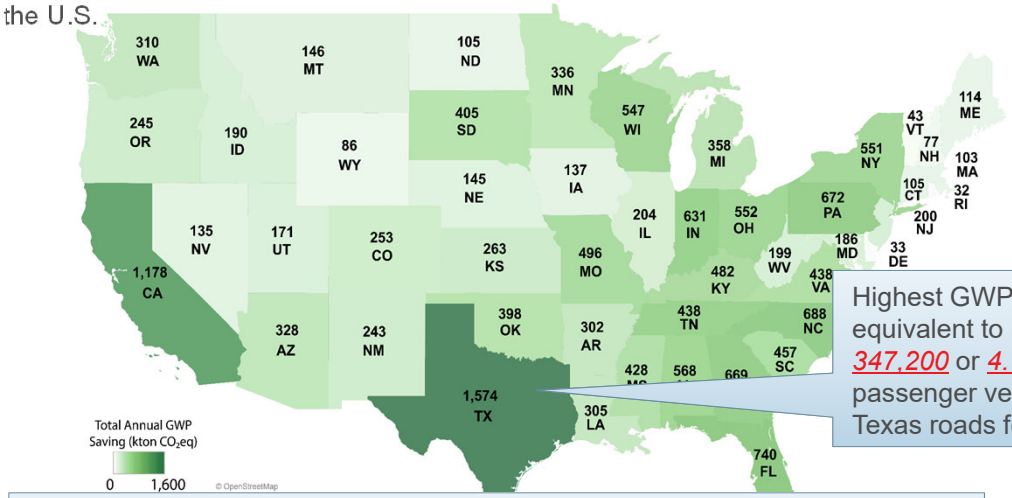


http://www.nc-climate.ncsu.edu/edu/Albedo

Slide 13

Nationwide analysis of pavement albedo impact on RF

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



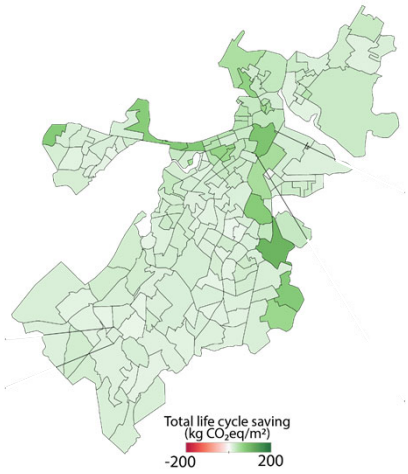
Highest GWP savings: equivalent to removing *347,200* or *4.1%*, of passenger vehicles from Texas roads for one year.

Nationwide, savings would be equivalent to removing nearly *3.75 million*, or roughly *3.2%,* of passenger vehicles

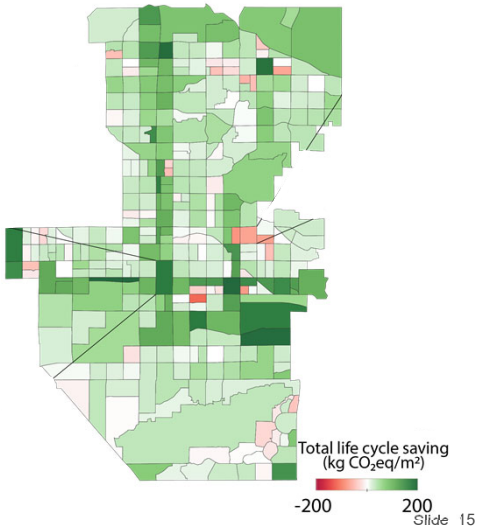
Slide 14

Most pavements in Boston and Phoenix would provide global climate benefit if switched to cool pavement

Boston



Phoenix



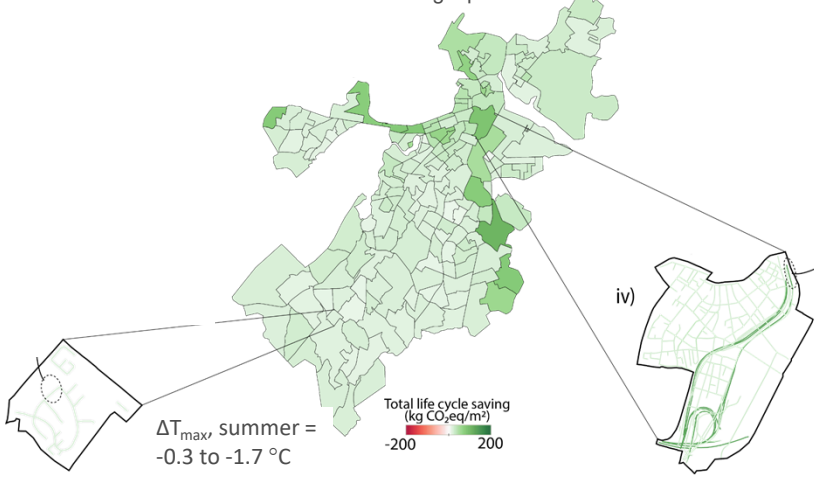
Slide 15

Albedo can be as significant as PVI

Materials & Construction ■ EFC-ROUGH ■ EFC-DEF
Albedo-RF ■ Albedo-BED ■ EoL ● Total

Boston

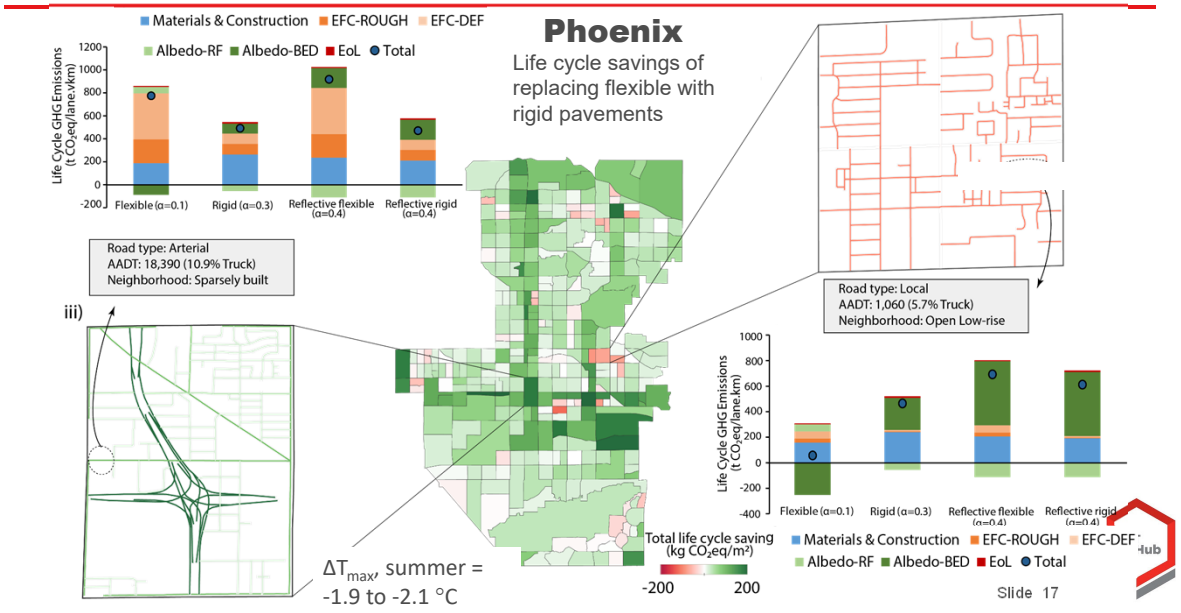
Life cycle savings of replacing flexible with rigid pavements



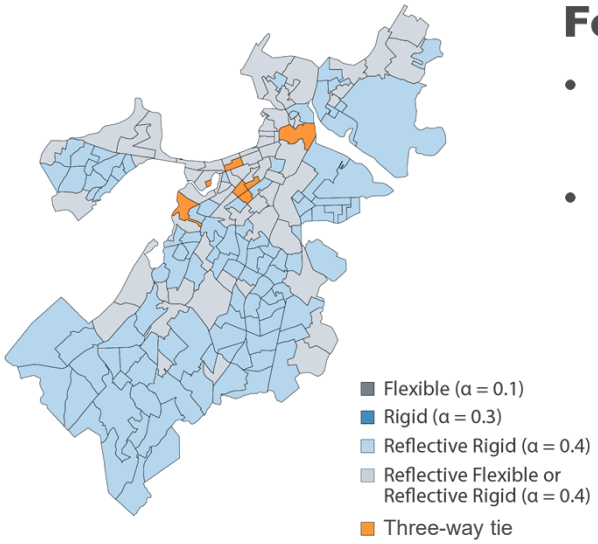
GIS data enables hyper-local contextual analyses

Slide 16

In hot Phoenix, PVI effects tend to dominate



Cool pavement design is almost always preferred, lowest GWP alternative varies by location



For Boston

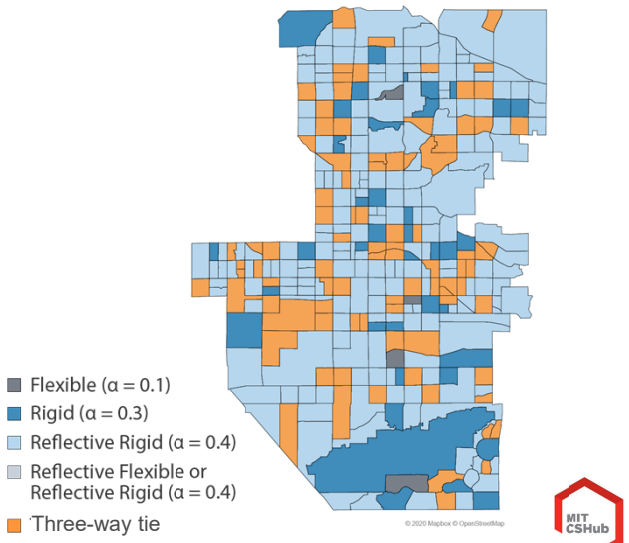
- Higher albedo pavement is preferred in ALL cases
- Lowest GWP solution
  - Reflective (high albedo) rigid
    - ~55% of lane-kms
  - Reflective rigid or flexible
    - ~45% of lane-kms

Slide 18

Cool pavement design is almost always preferred, lowest GWP alternative varies by location

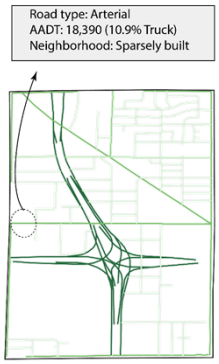
For Phoenix

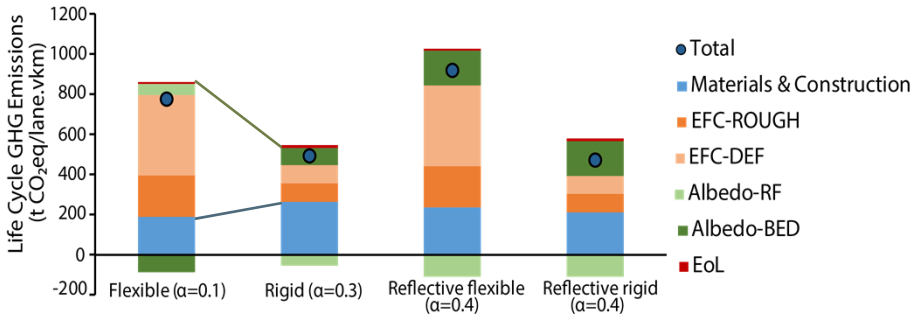
- Rigid Pavement is the dominant low GWP solution
  - Reflective: 73% of lane-kms
  - Conventional:9% of lane-kms
- More information needed to choose: 17% of lane-kms
- 1% of lane-kms should remain as flexible



Slide 19

Do the global climate change benefits of a cool pavement outweigh the embodied impacts? **YES** (most of the time)





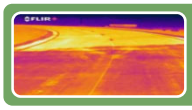
Slide 20

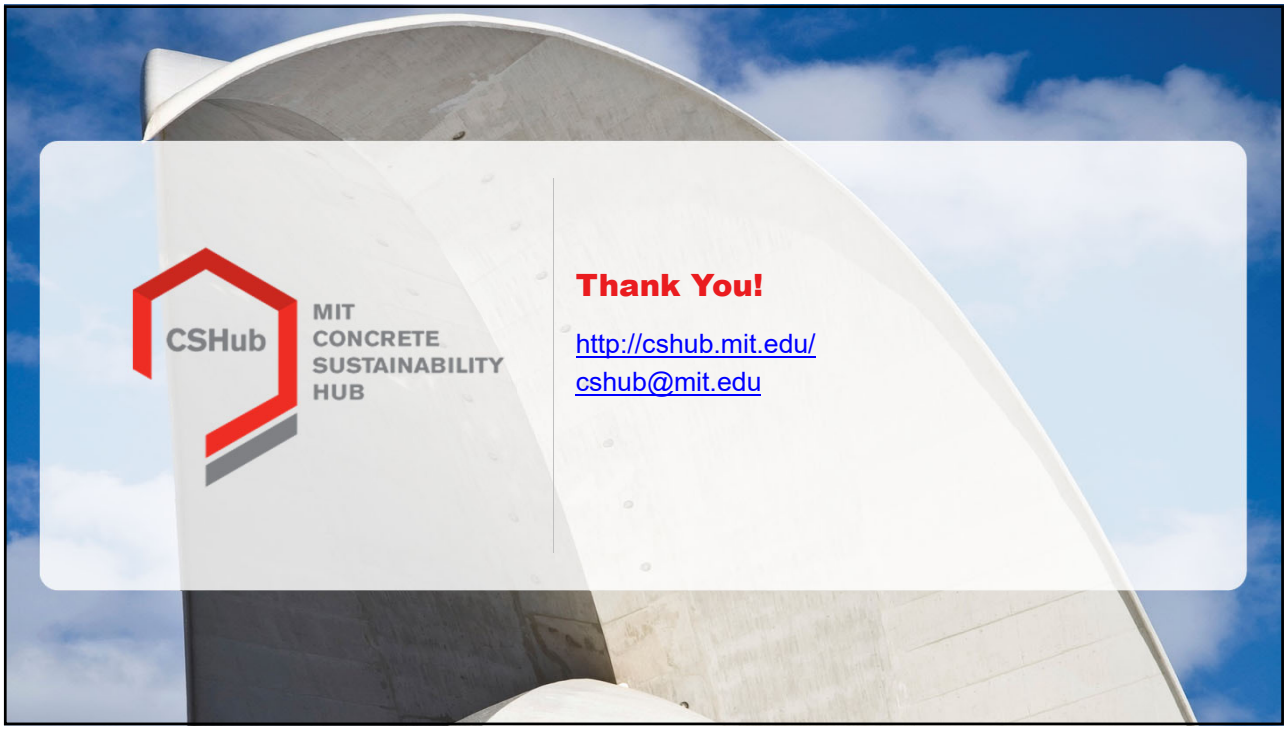
Key findings from CSHub research on the pavement lifecycle

Life cycle perspective matters

Pavement-vehicle interaction matters

Context matters


Albedo matters

Significant opportunities to improve

Slide 21