RC 2018 XVII Reunión del CONCRETO

El evento del Cemento, el Concreto y los Prefabricados

RC 2018 XVII Reunión del CONCRETO

El evento del Cemento, el Concreto y los Prefabricados

Reducing vehicle fuel consumption through sustainble pavement design & maintenance

Jeremy Gregory
Executive Director, MIT Concrete Sustainability Hub
United States

TODO EL Concreto ESTÁ EN Asocreto
CEMENTO CONCRETO PREFABRICADOS

What is a green pavement?

pave GREEN

BUILDING BETTER COMMUNITIES
THROUGH SUSTAINABLE PRACTICES.

A life cycle perspective should be used to quantify environmental impacts

Materials Production

- Use recycled
- Reduce energy
- Improve material performance

Design & Construction

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

Use

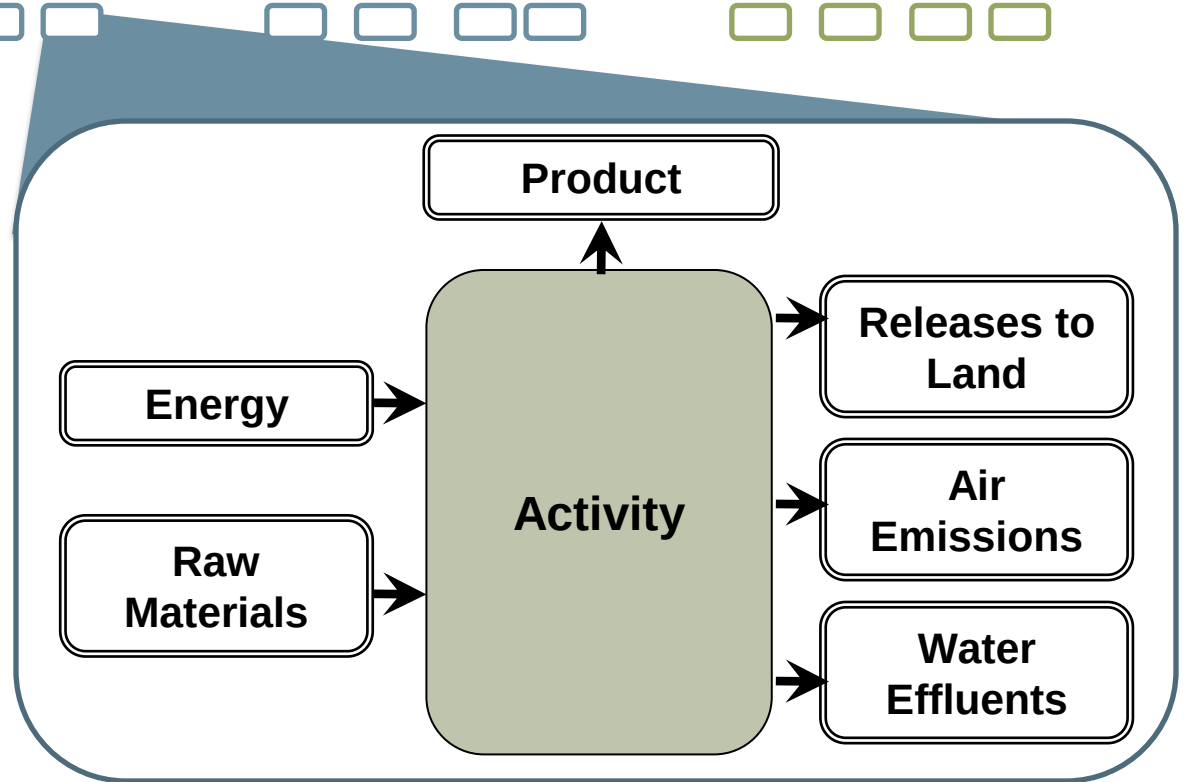
- Reduce vehicle fuel consumption
- Reduce heat island effects

End-of-Life

- Enable material recovery

LCA – Life-cycle assessment:
Method for quantifying environmental impact

Materials Production | Design & Construction | Use | End-of-Life



Environmental product declarations are available for paving materials

NRMCA NATIONAL READY MIXED CONCRETE ASSOCIATION

SUSTAINABILITY

NRMCA EPD Program

NAPA

NATIONAL ASPHALT PAVEMENT ASSOCIATION

NAPA EPD Program

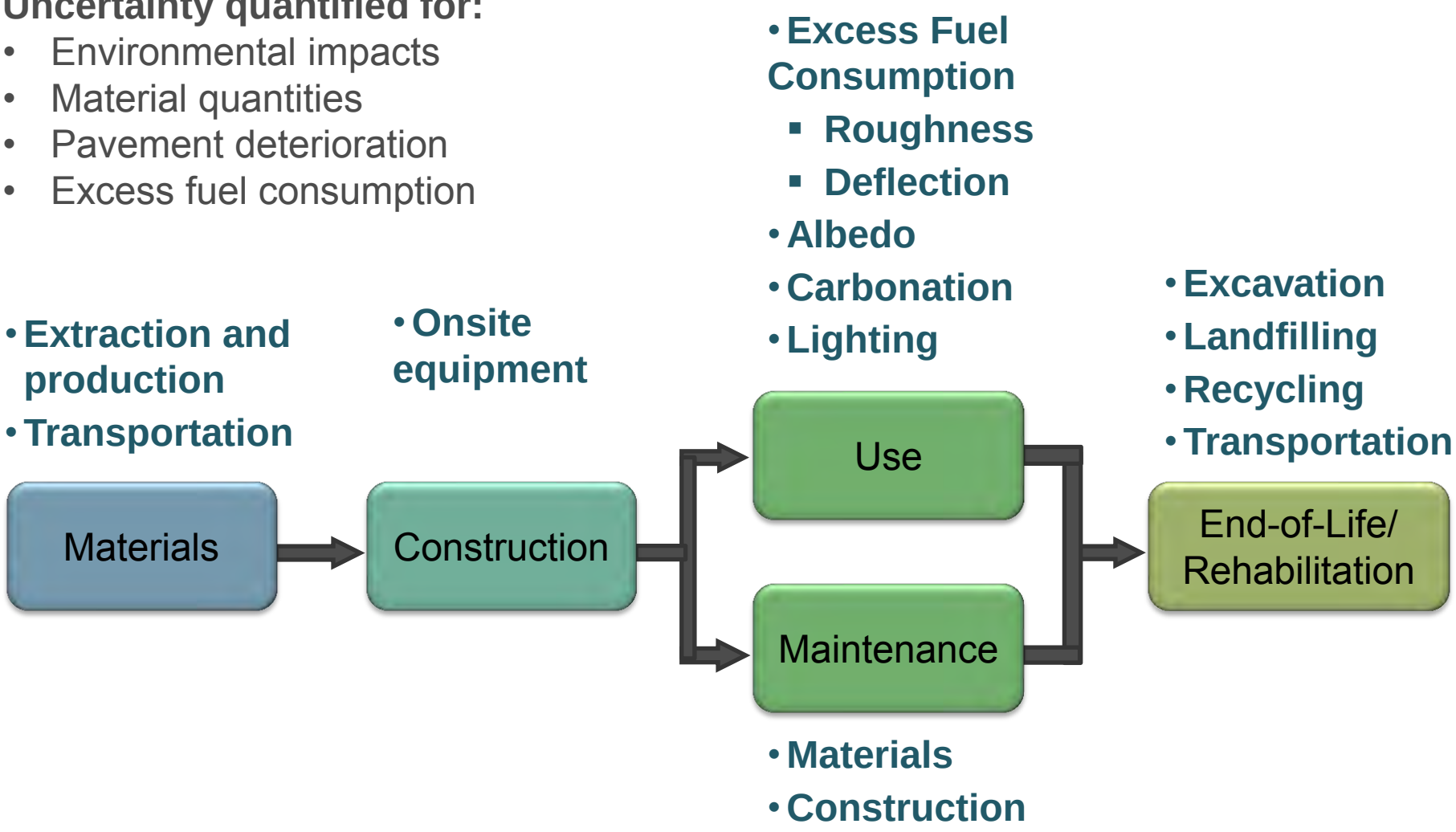
Emerald ECO LABEL

EPDs are LCIs of paving materials – they are *not* a pavement LCA

Scope of CSHub probabilistic LCA model

Uncertainty quantified for:

- Environmental impacts
- Material quantities
- Pavement deterioration
- Excess fuel consumption



Use phase elements

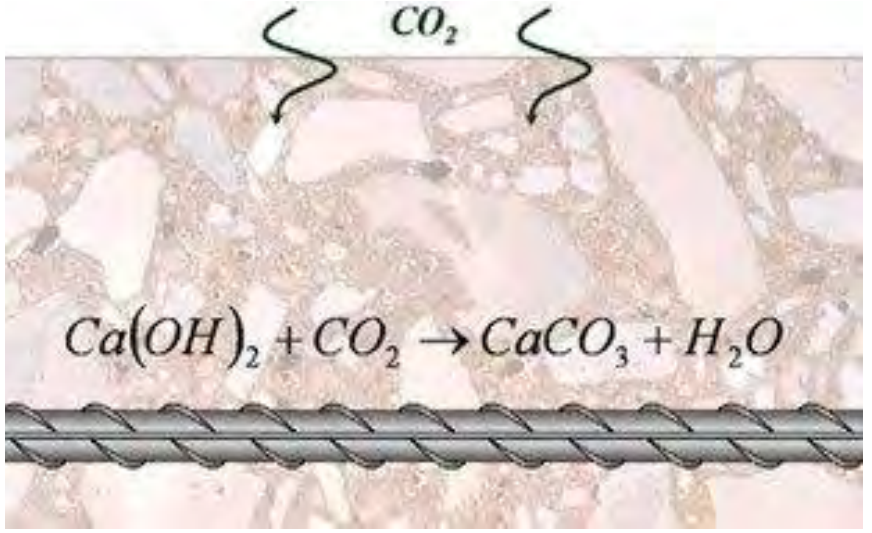
Albedo

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

Lighting

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

Carbonation



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

Excess fuel consumption of vehicles calculated due to pavement design and maintenance

Pavement-vehicle interaction (PVI)

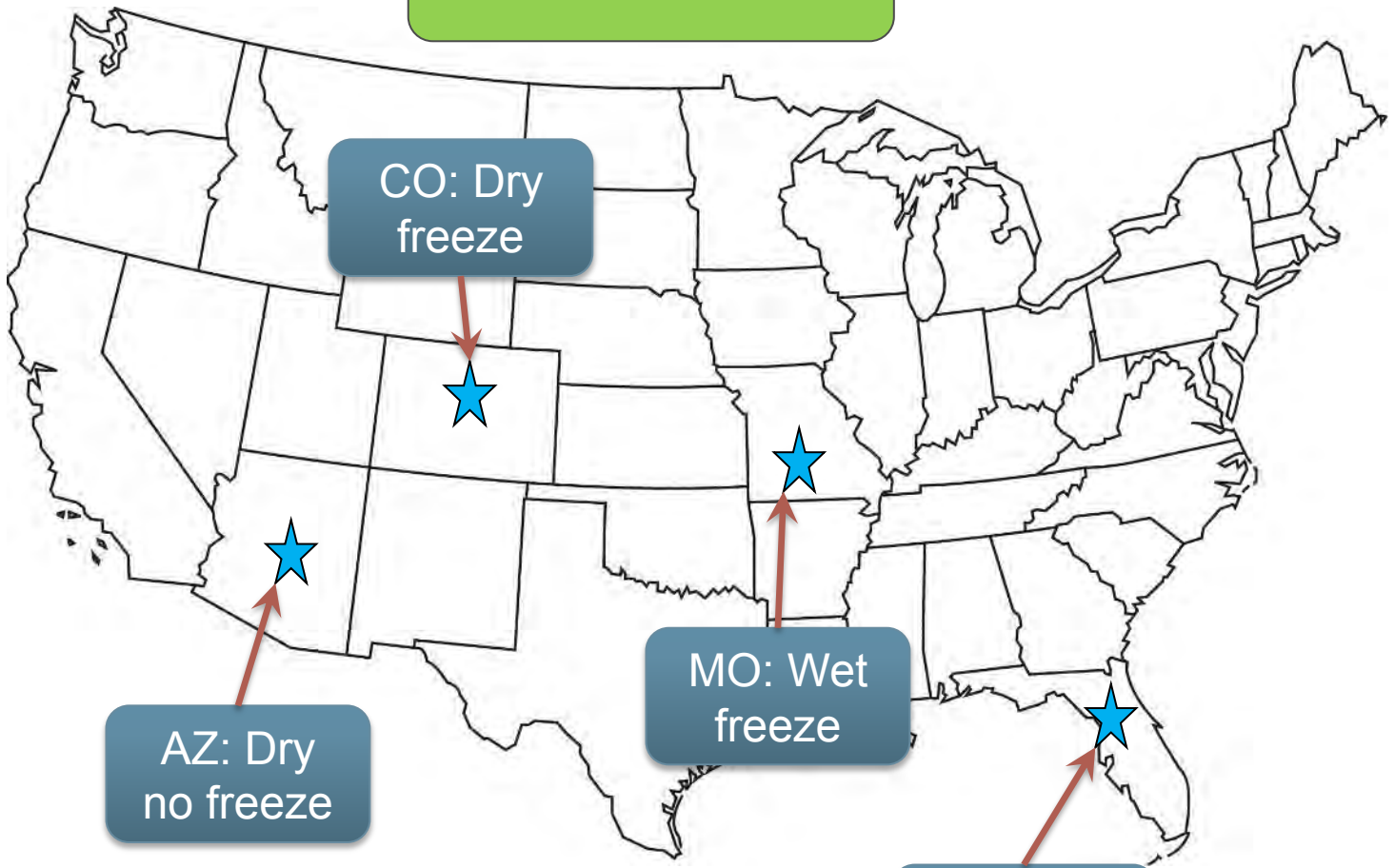
Pavement Deflection

Pavement Roughness

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

CSHub conducted LCAs for a wide range of scenarios

4 Locations



3 Traffic Levels

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

Several framing conditions

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

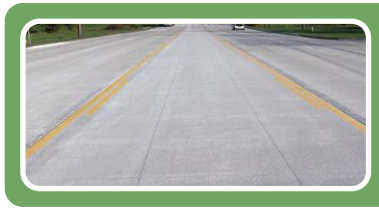
Pavement design and maintenance schedules developed by Applied Research Associates (ARA), Inc

Key findings from CSHub LCA research

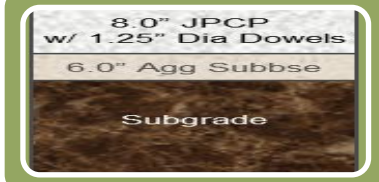
Life cycle perspective matters

Pavement-vehicle interaction matters

Context matters



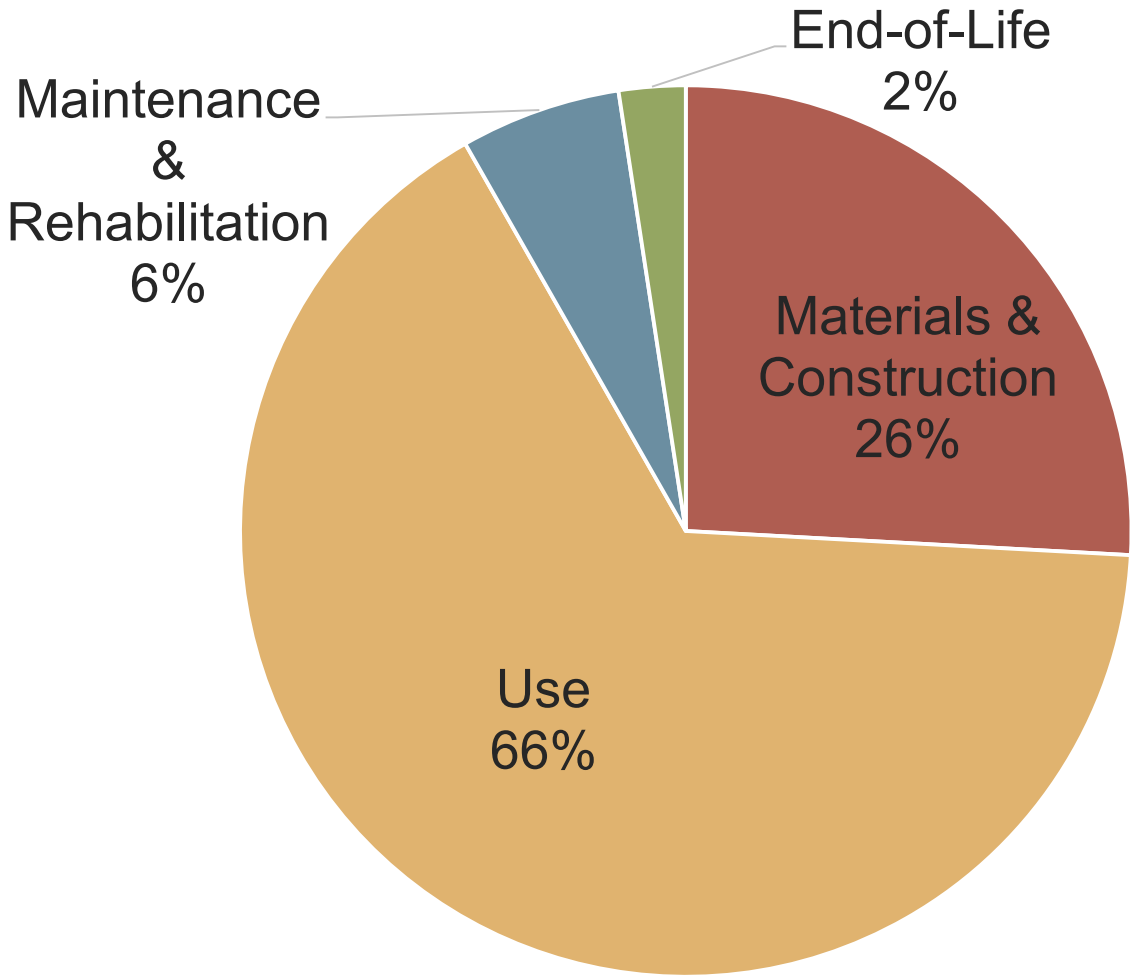
M&R strategies affect PVI



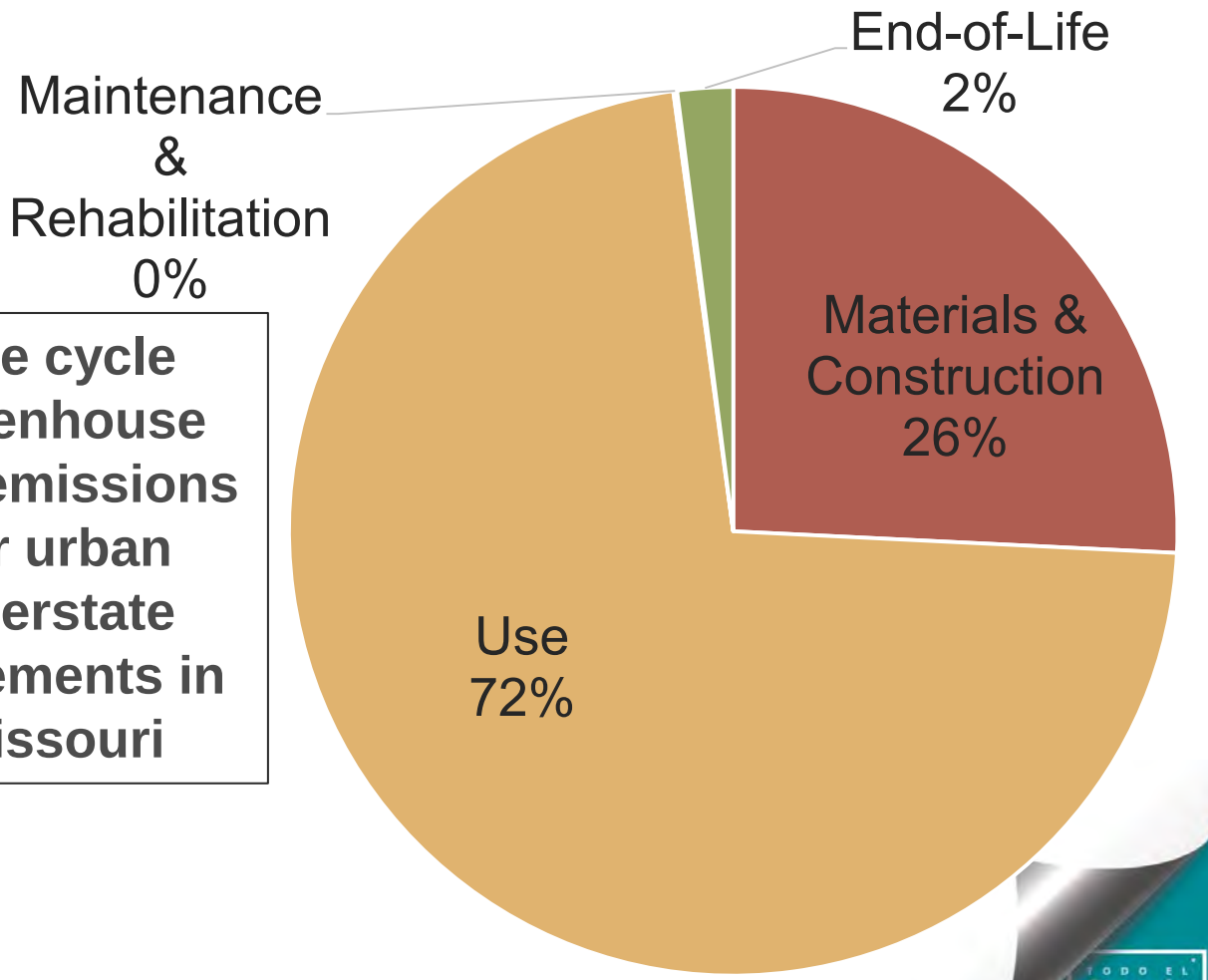
Large opportunities to improve exist

Life cycle perspective matters: M&C and use drive impacts

Asphalt Pavement: 17.5 kton* CO2e/mi



Concrete Pavement: 18.8 kton CO2e/mi



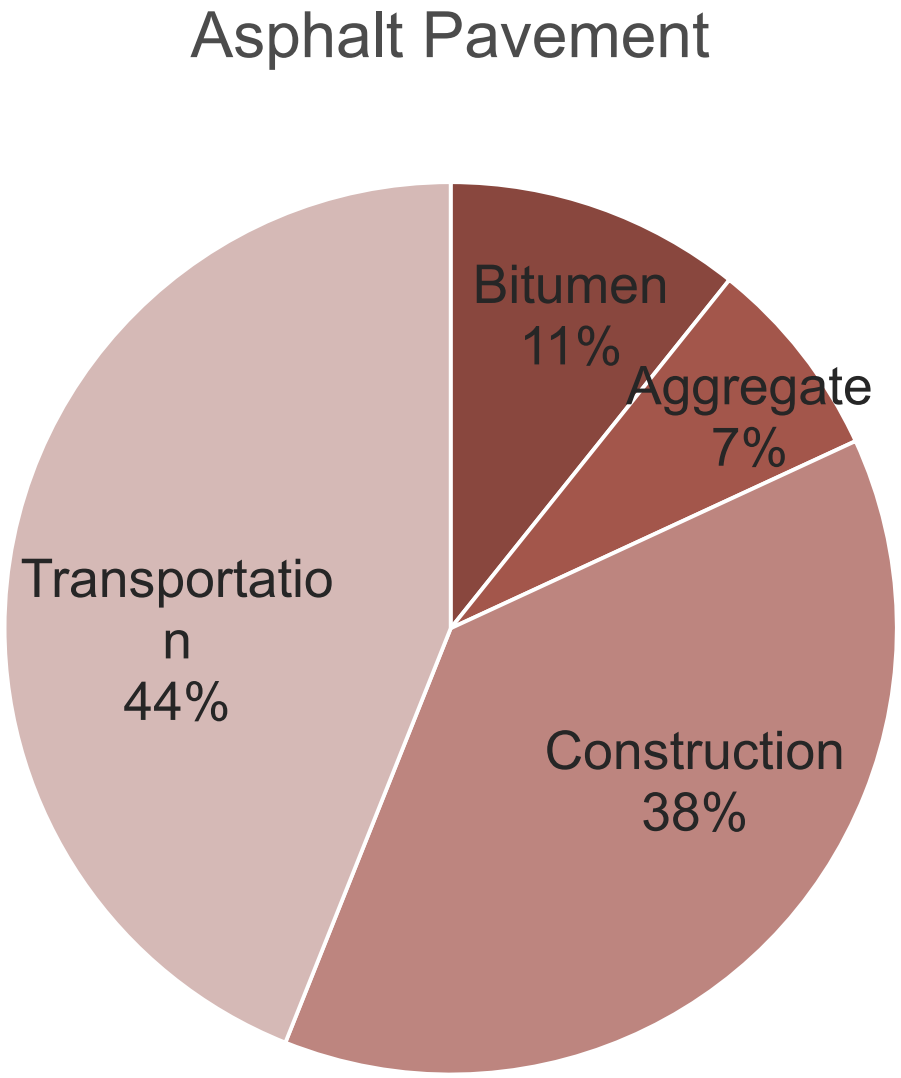
Life cycle greenhouse gas emissions for urban interstate pavements in Missouri

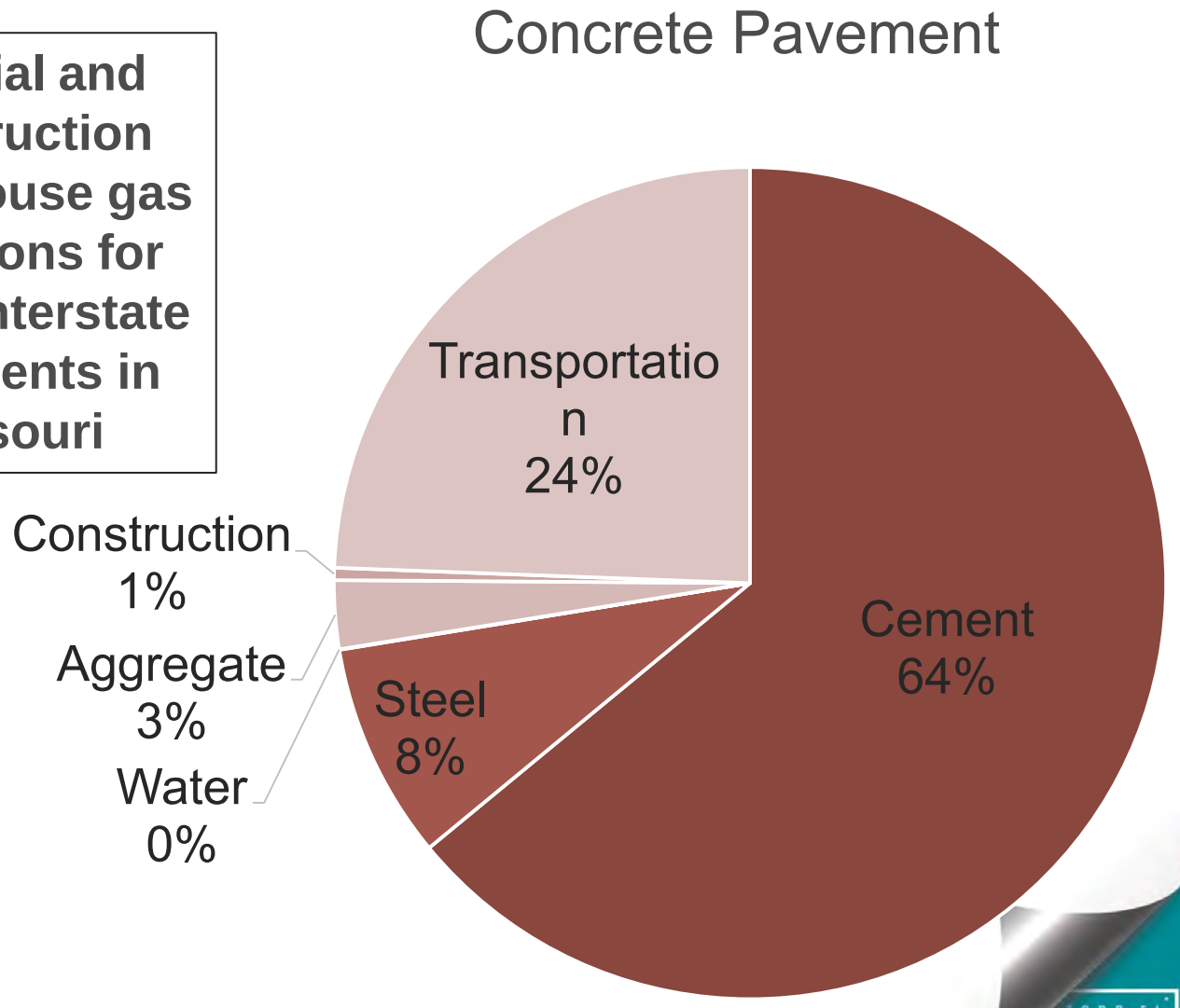
*metric tons

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

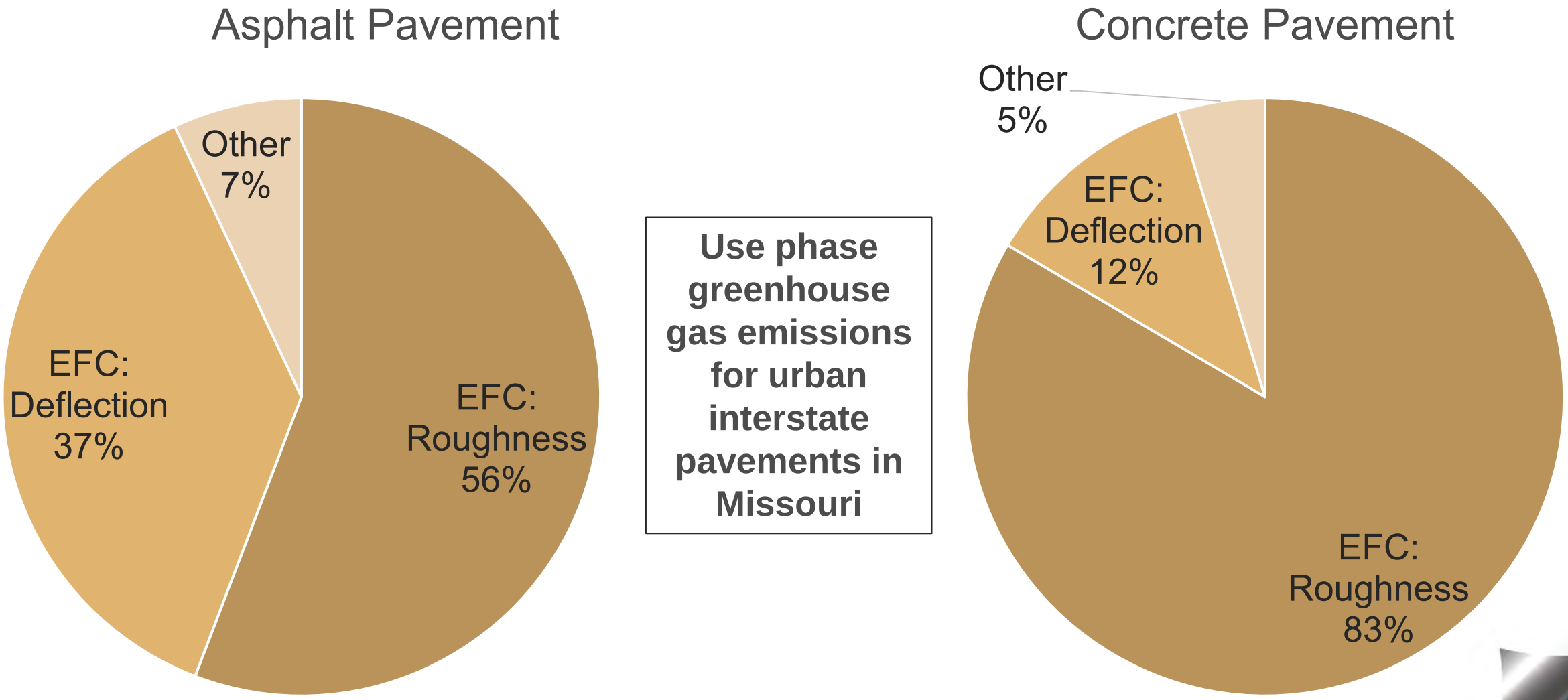
Drivers of M&C impacts depend on pavement design

Material and construction greenhouse gas emissions for urban interstate pavements in Missouri



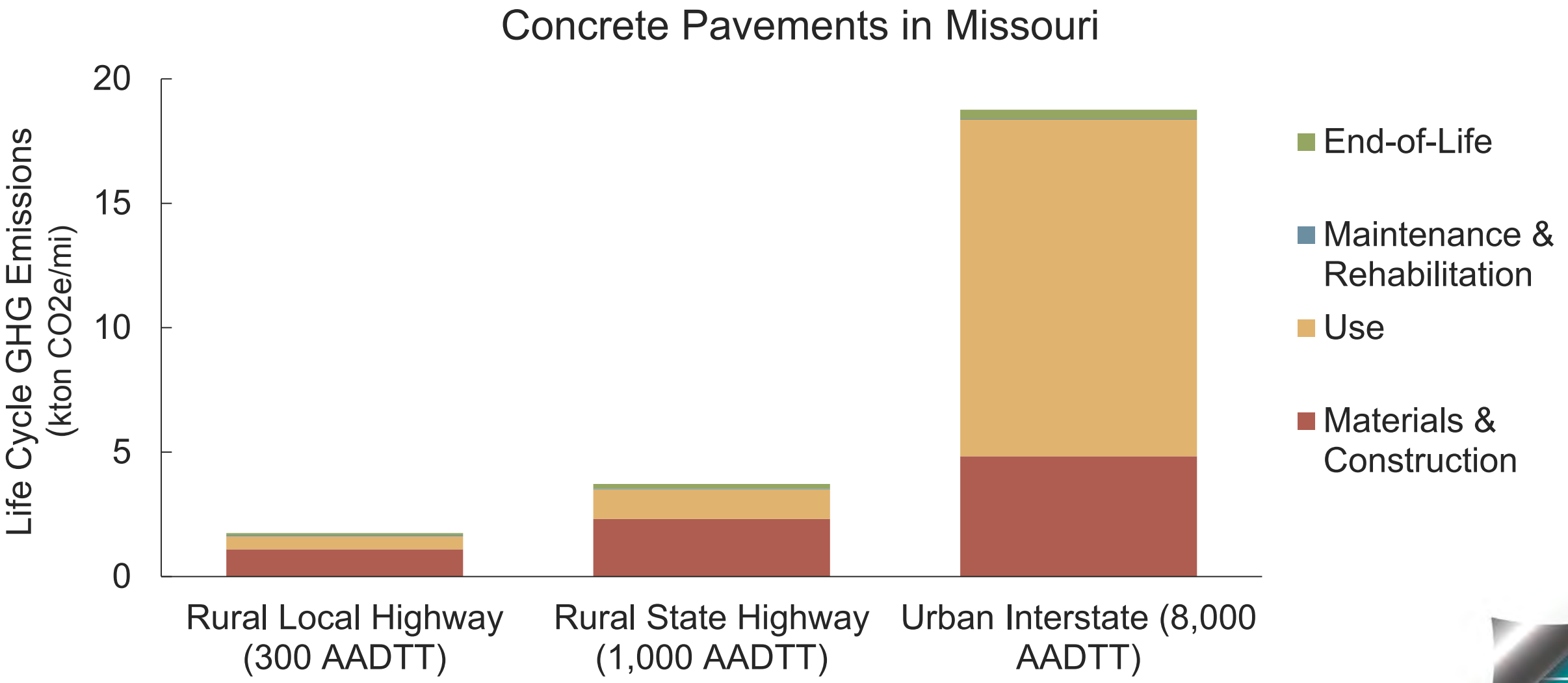


PVI matters: Excess fuel consumption drives use phase impacts

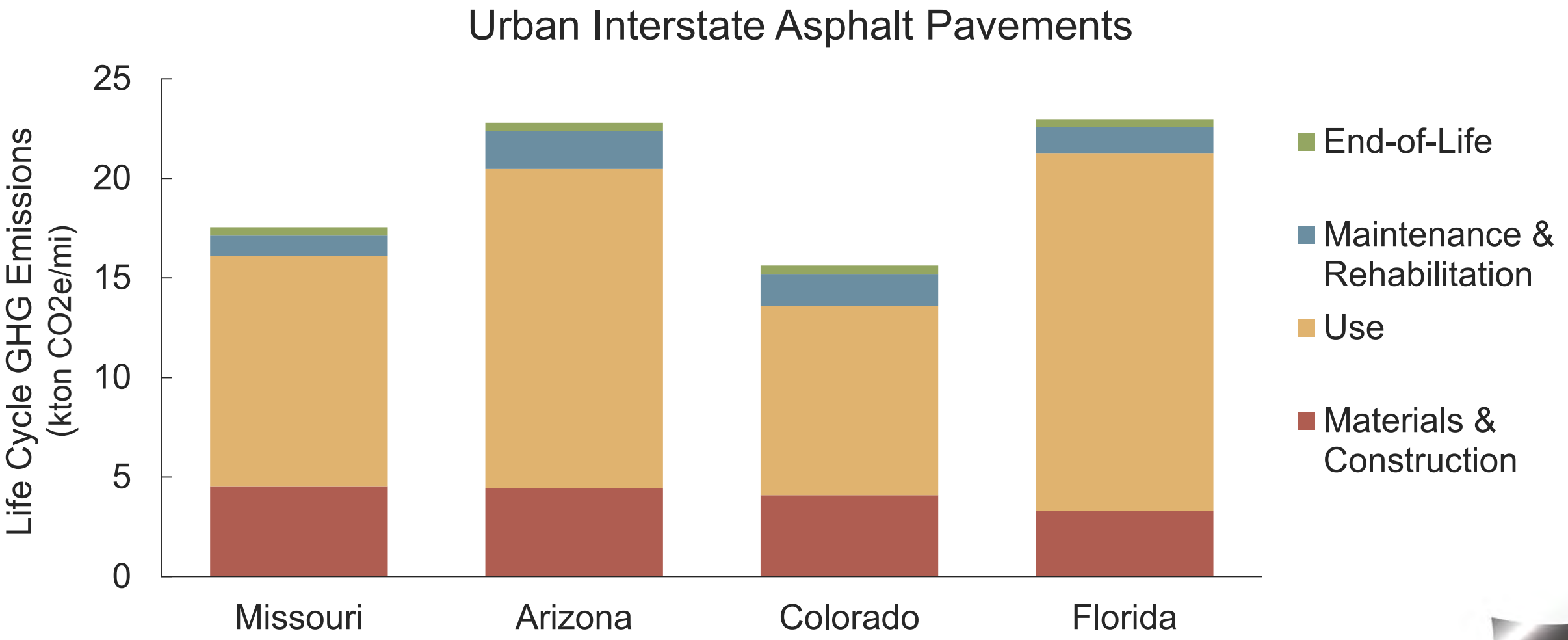


*Other: carbonation & lighting

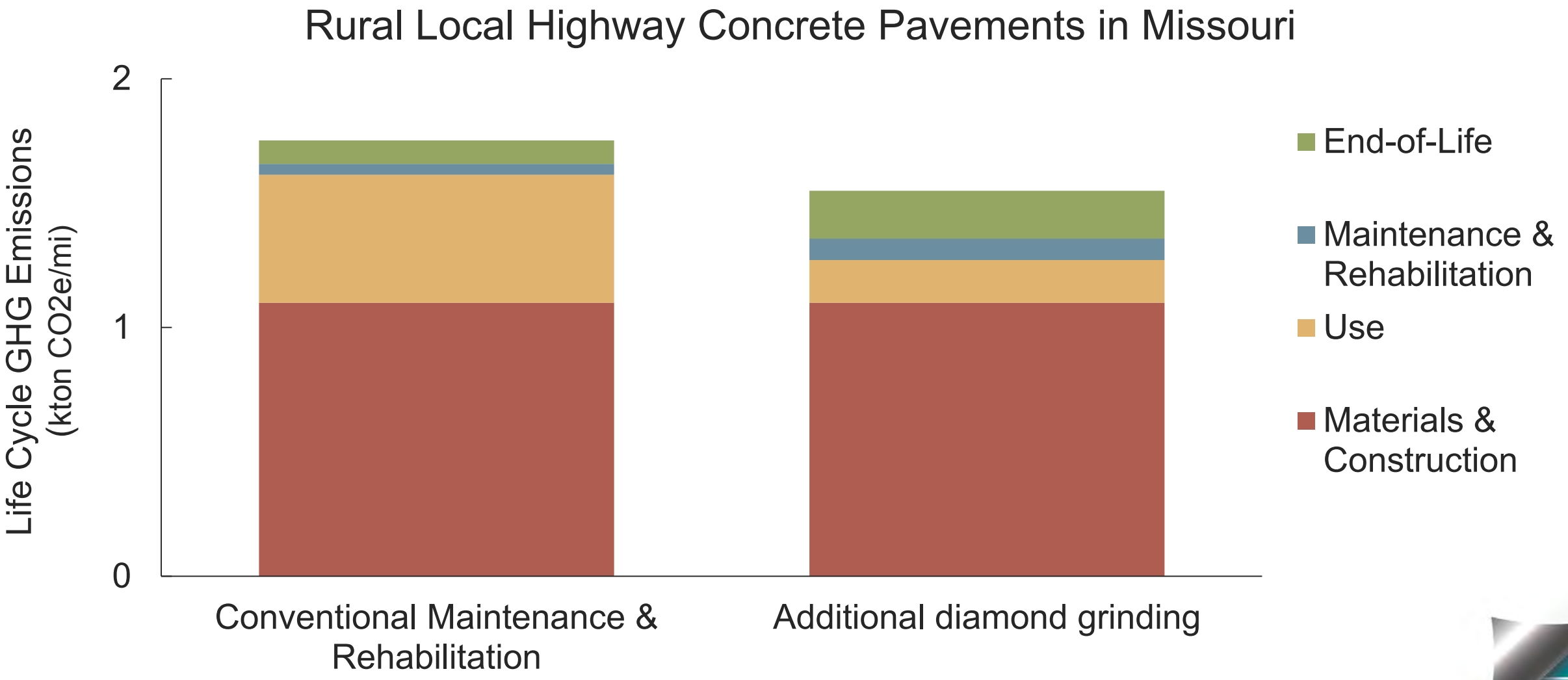
Context matters: impacts vary with traffic level



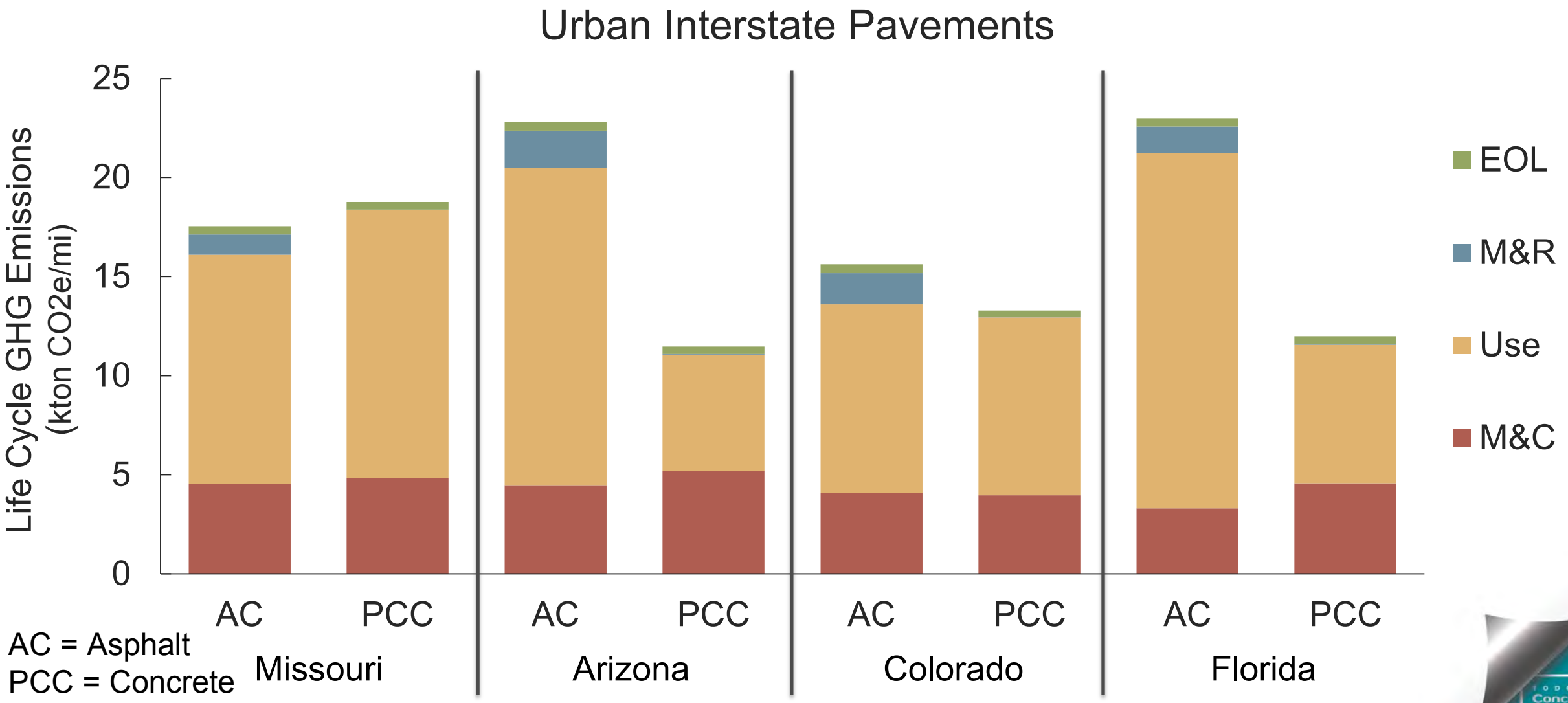
Context matters: impacts vary with location



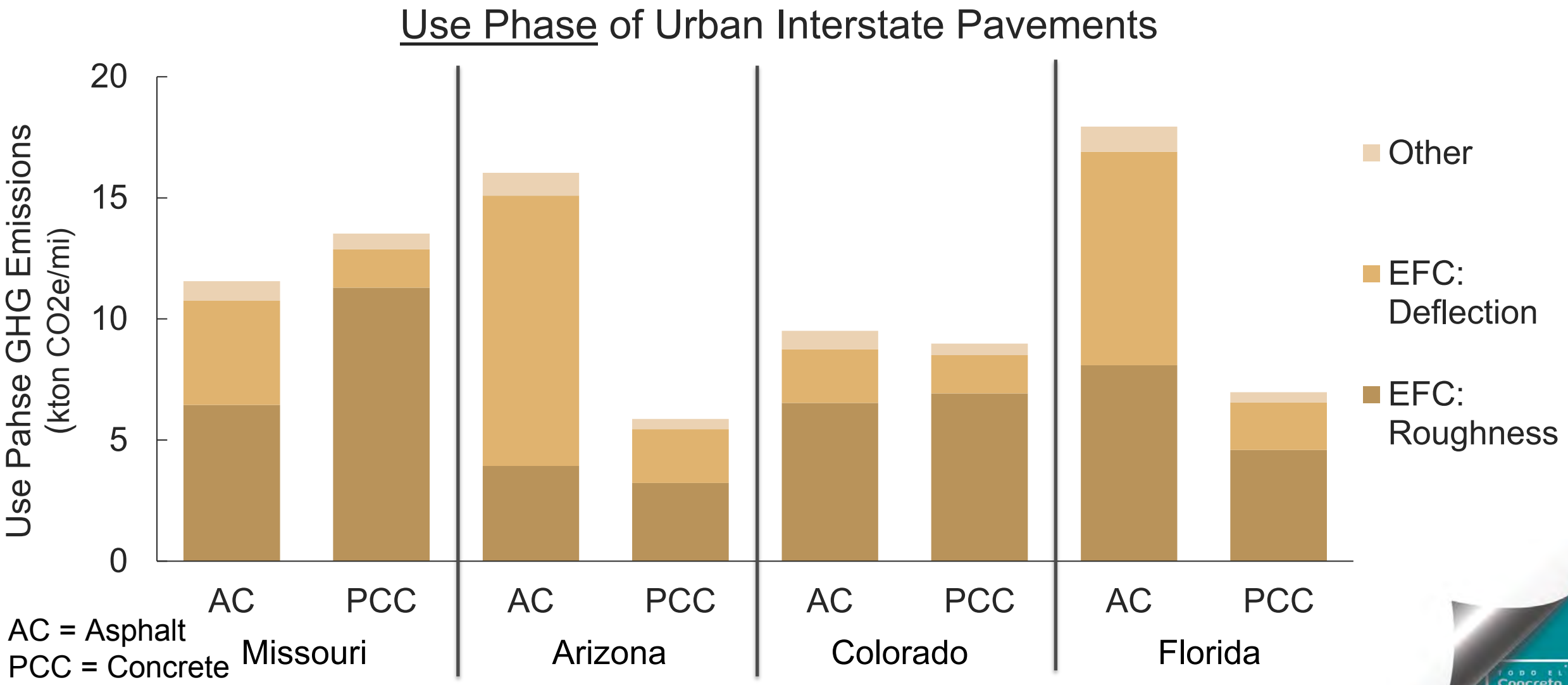
Context matters: impacts vary with M&R activities



Context matters: impacts vary with pavement design



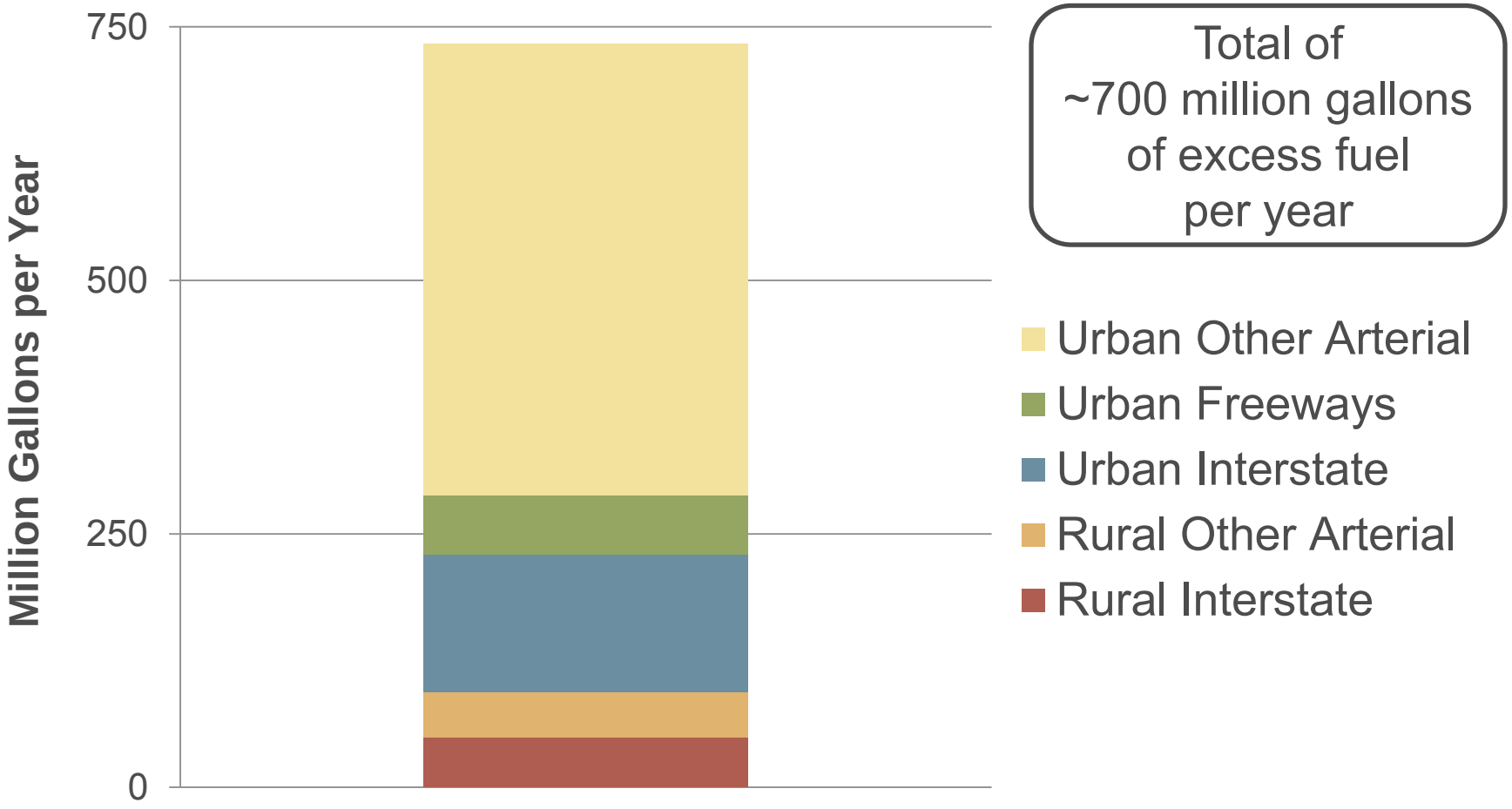
Context matters: EFC varies with pavement design and location



PVI matters: network scale

Excess fuel consumption from PVI is significant

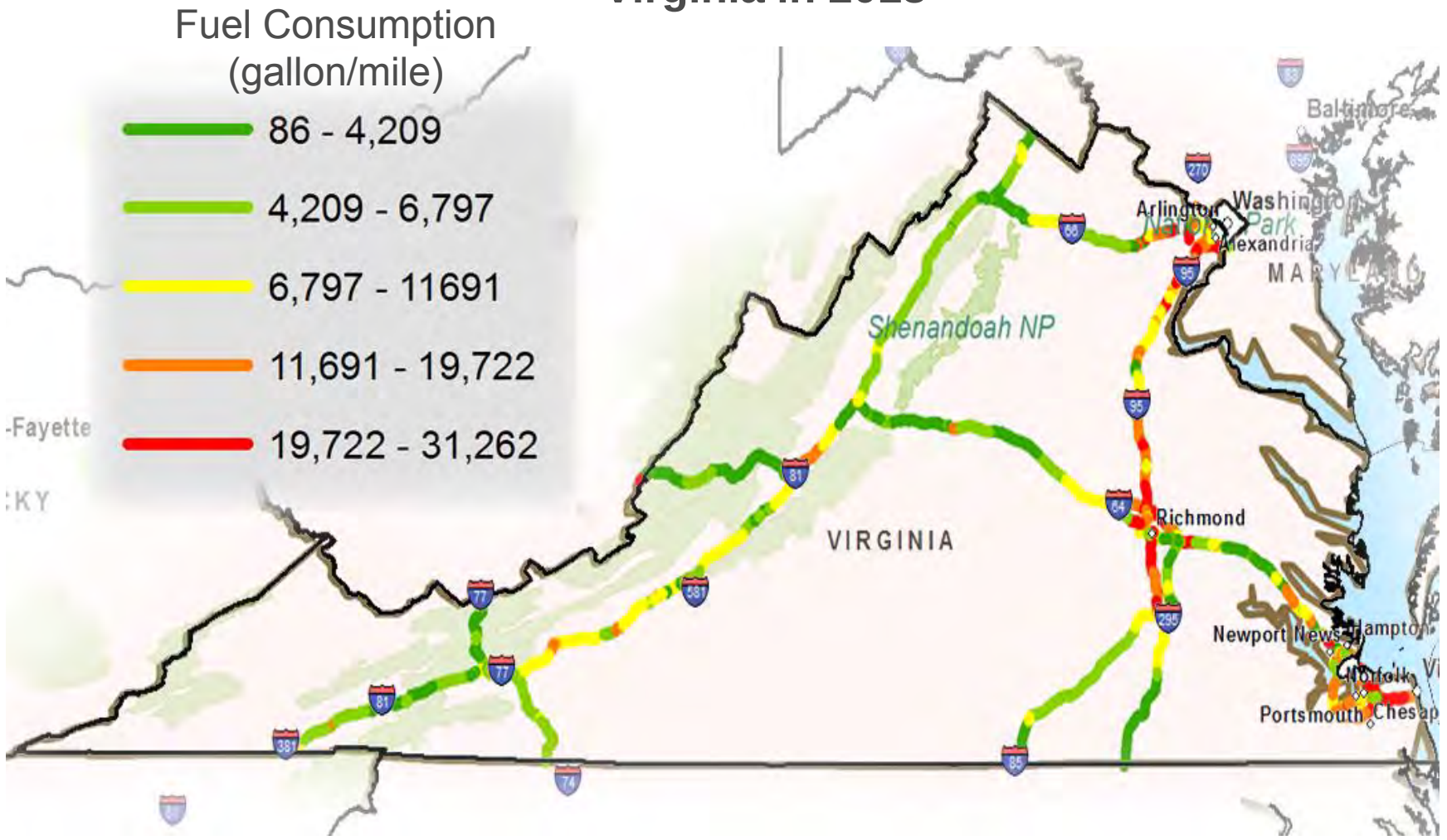
Estimate of extra fuel consumption from PVI in US pavement test sections



PVI matters: network scale

PVI data can be used in network pavement management

Excess fuel consumption due to PVI for cars & trucks on interstates in Virginia in 2013



Assumed speed= 100 km/h=62.6 mph; assumed temperature= 16 C/61 F

EFC analyses connect pavements and air quality

Impact Category	Annual Caltrans Footprint (CARB)	Annual PVI Contribution
Excess Fuel (liter)	21 Million	2.5%
CO_2 (ton)	197 Million	1.9%
NO_x (ton)	323 Thousand	0.5%
$PM_{2.5}$ (ton)	6 Thousand	4.4%
PM_{10} (ton)	7 Thousand	1.4%

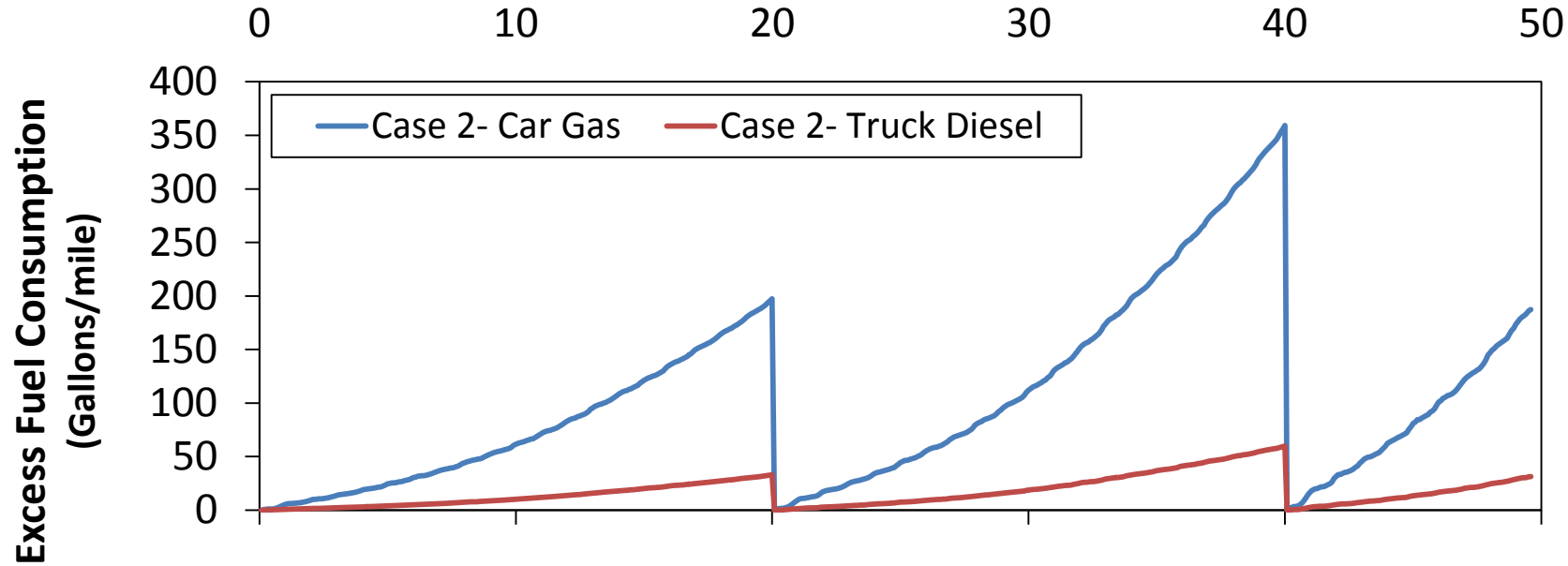
2013 Data

EFC impacts include GHG and other air quality emissions

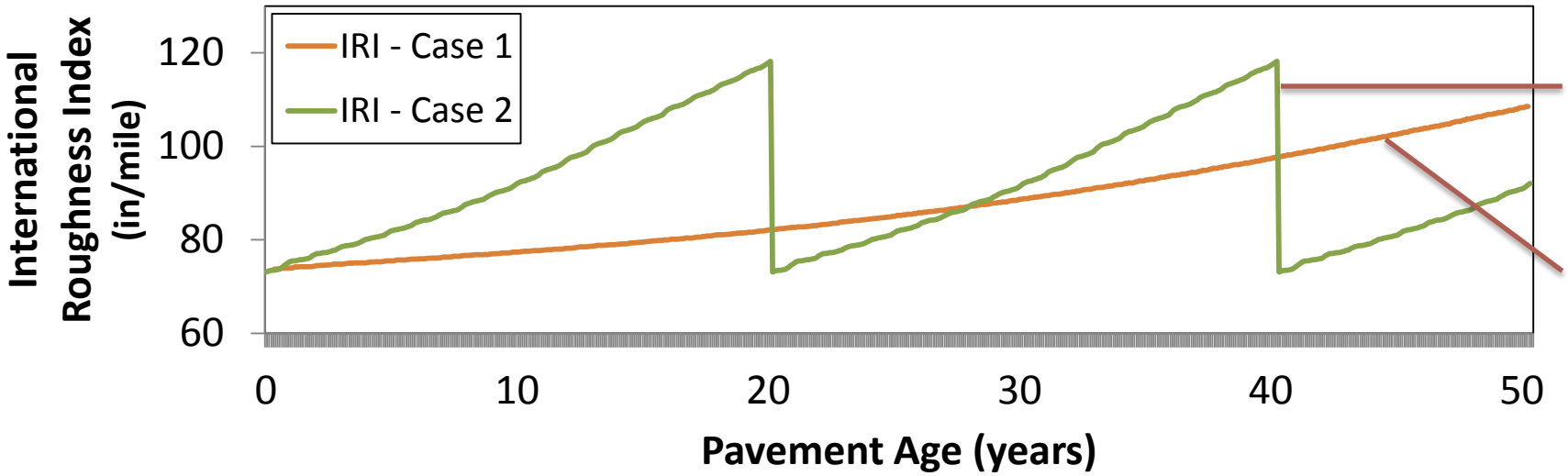
Impact Category					
Fuel Consumption (liter/km)	104- 3,074	3,074- 12,055	12,055- 36,472	36,472- 104,351	104,351- 694,955

Maintenance and rehabilitation strategies drive EFC & impacts

Moderate deterioration and regular rehabilitation

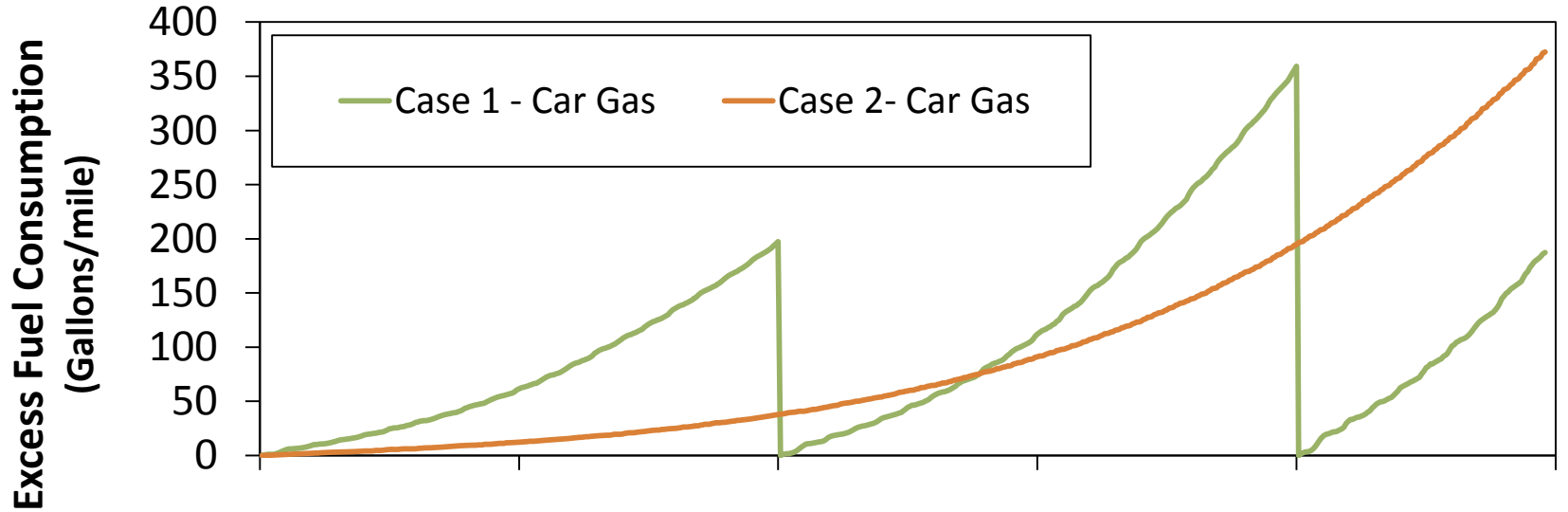


Decreasing deterioration rate minimizes M&R

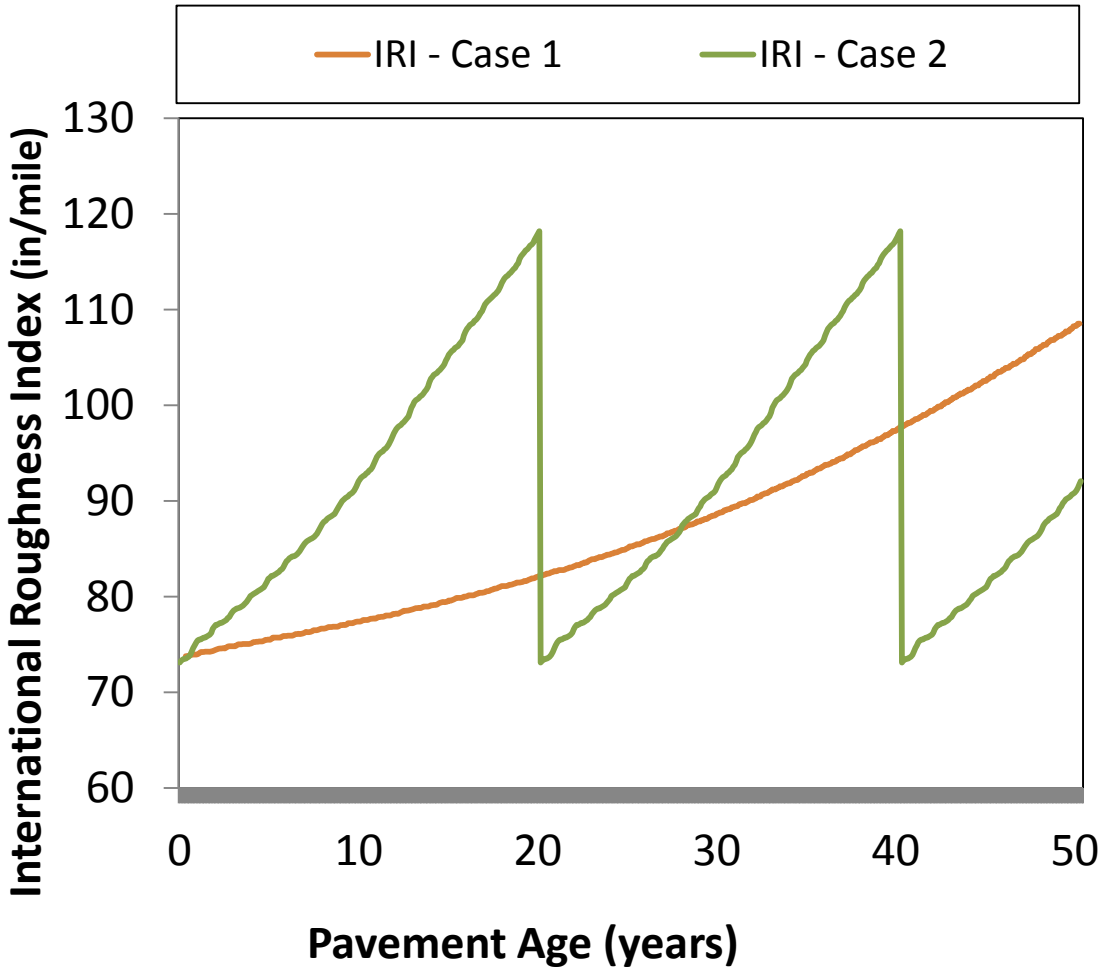


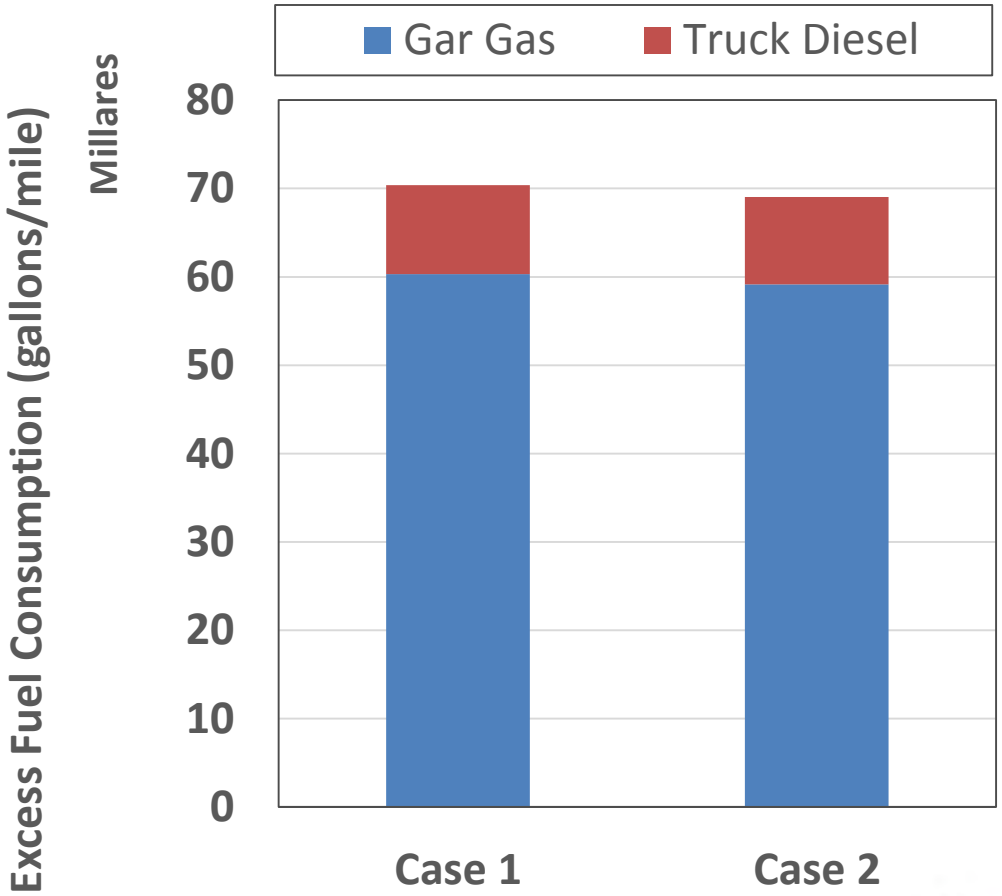
Moderate deterioration and regular rehabilitation

Slow deterioration and no rehabilitation

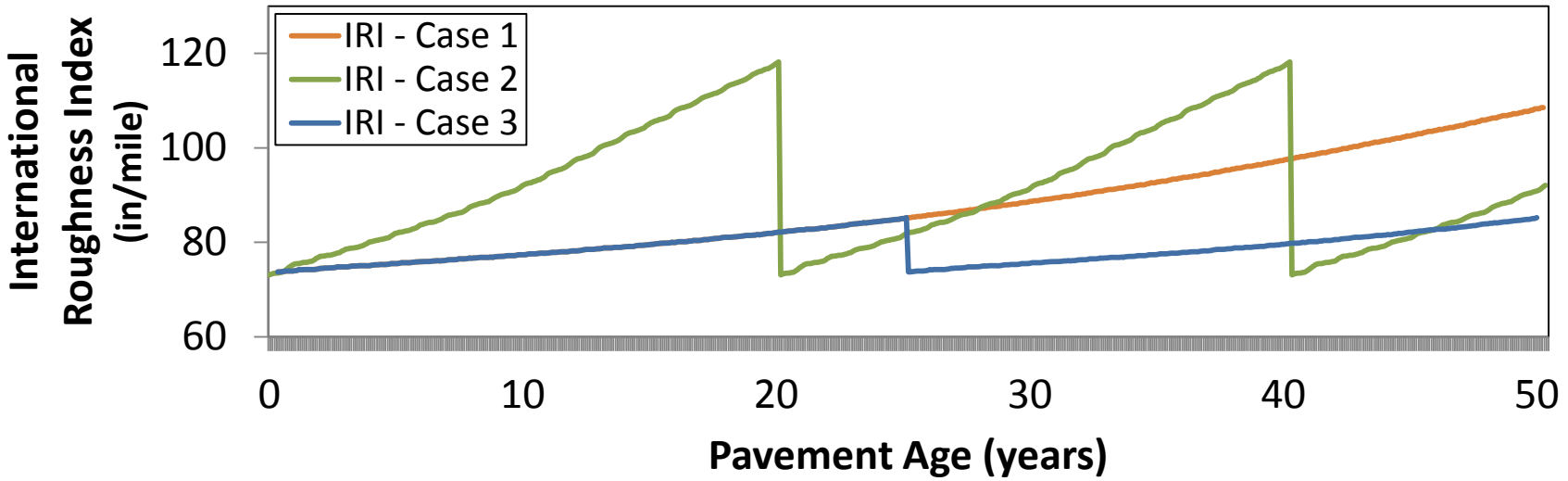


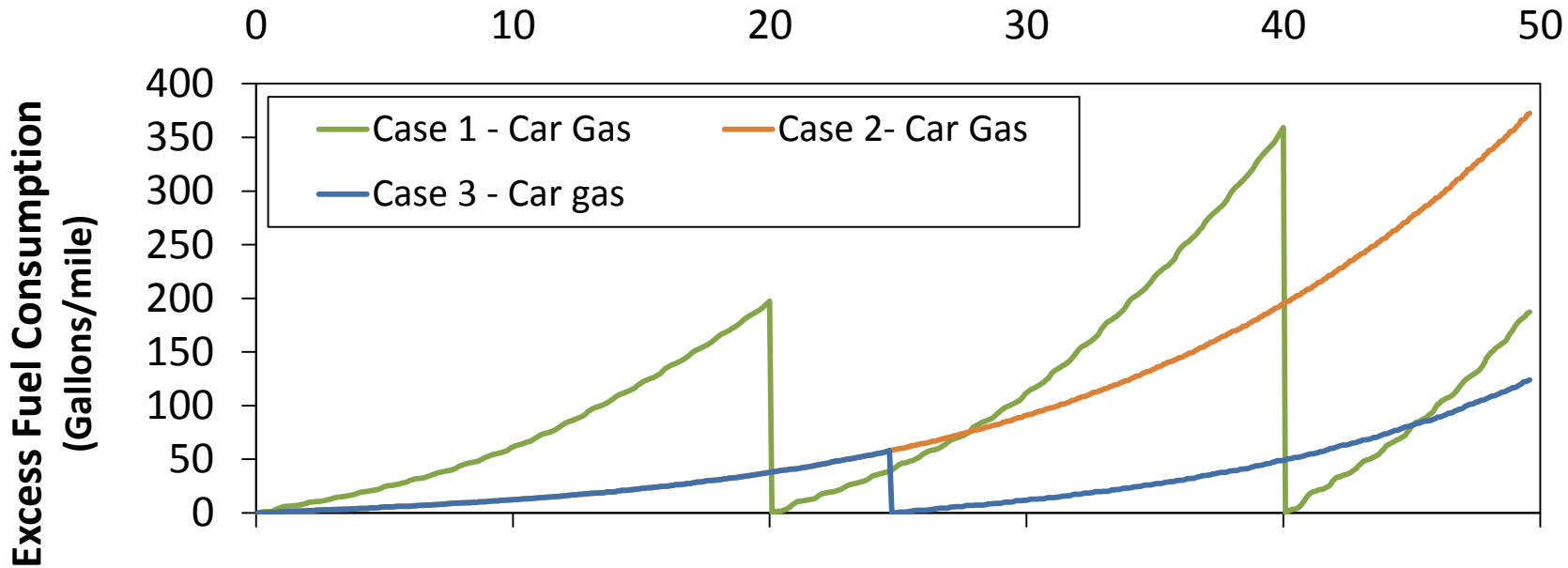
Case 1: equivalent EFC for no M&R





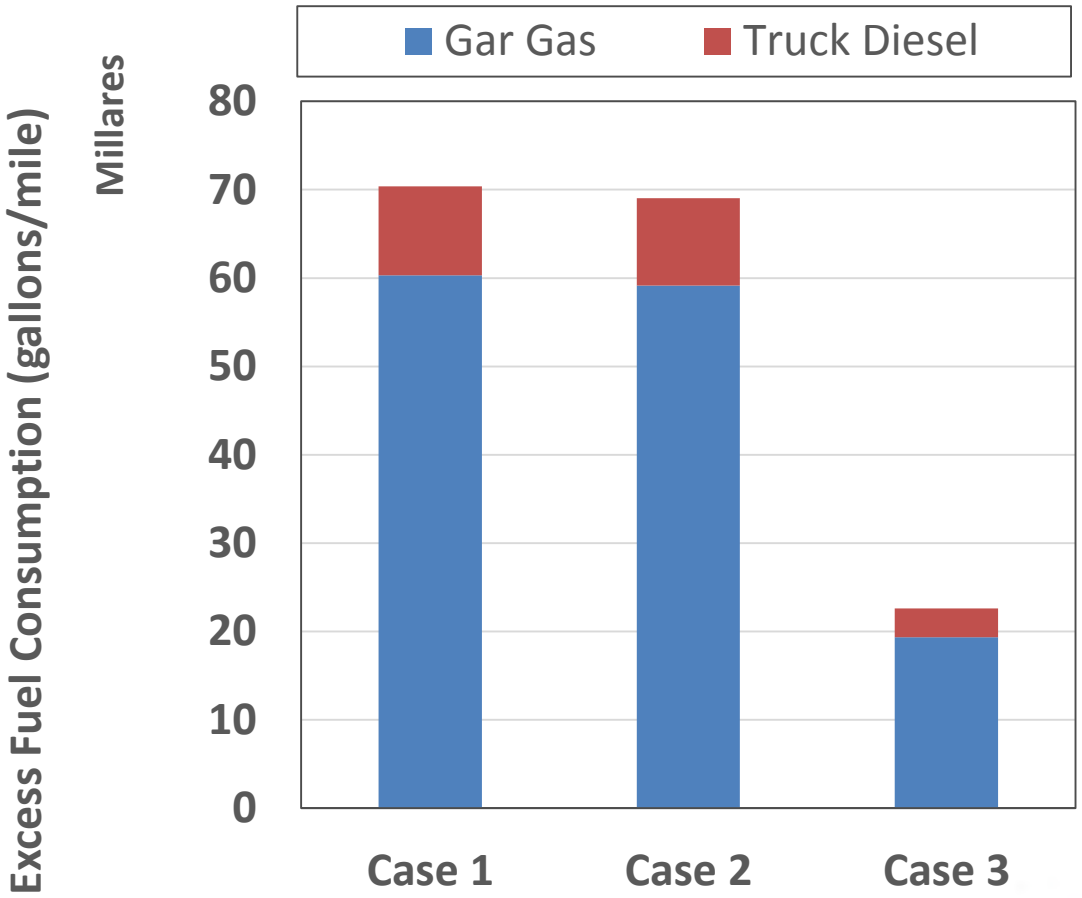
Case 3: slow deterioration and M&R



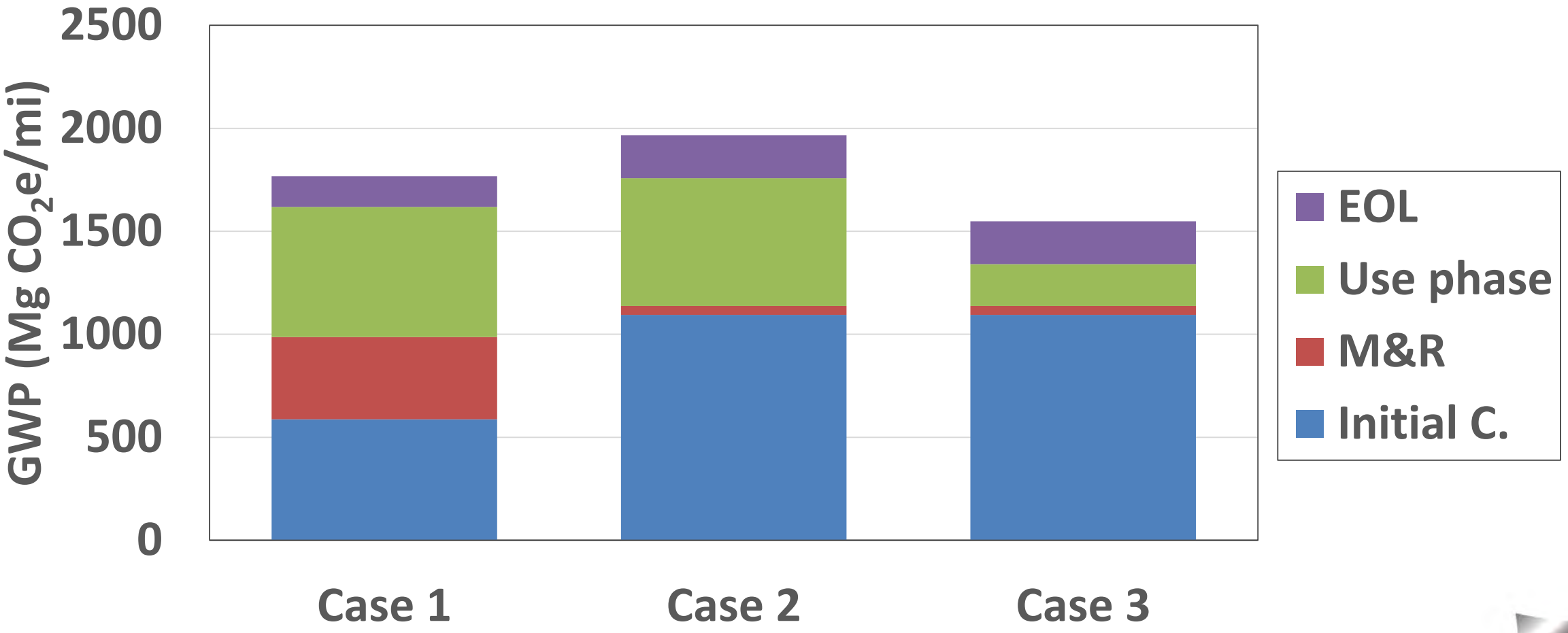


Diamond grinding can be used on concrete pavements for M&R

Significant EFC benefits for slow deterioration & M&R



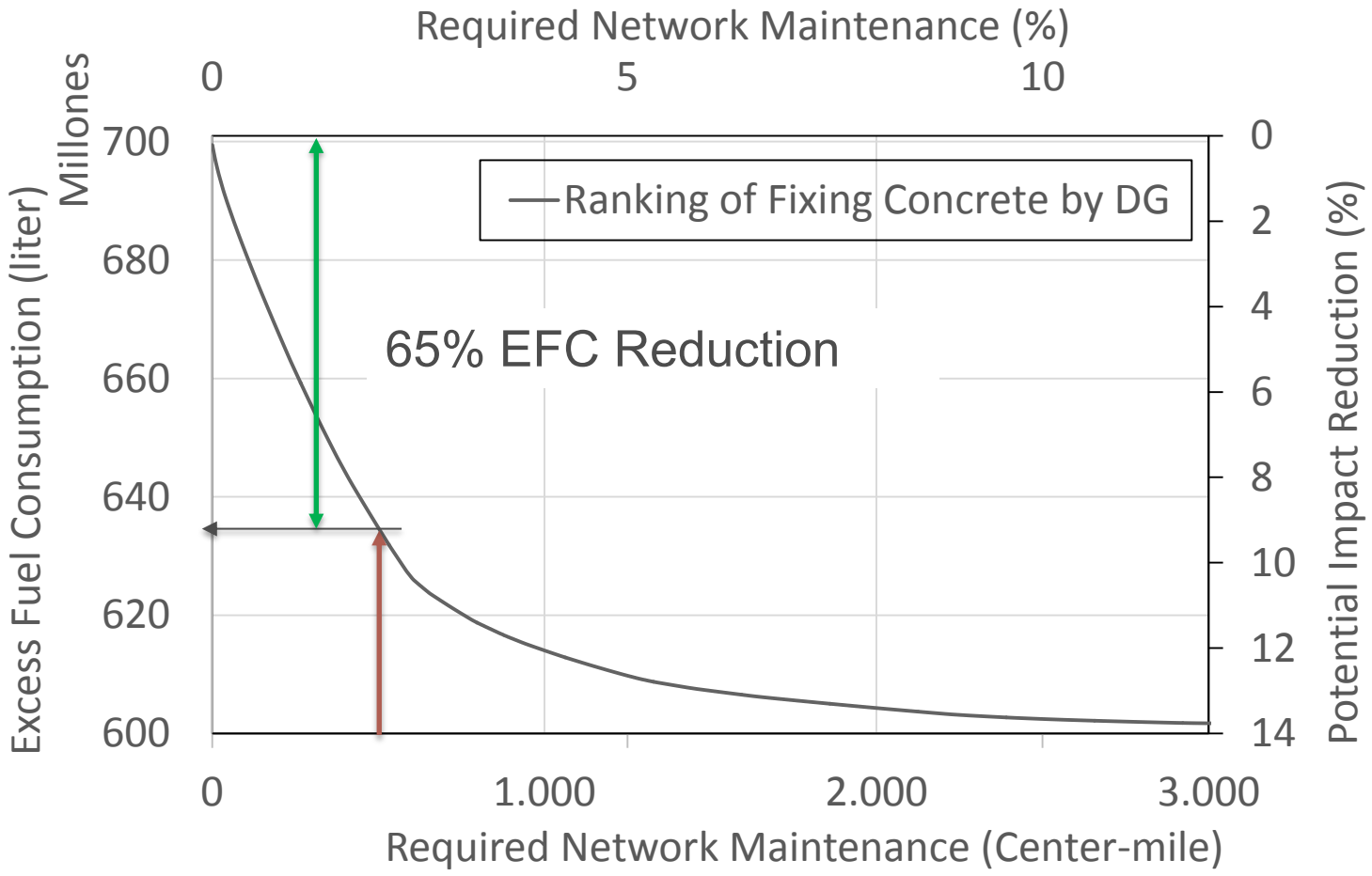
Life cycle GHG benefits of case 3 are significant



Local highway in MO. Case 1: AC, Case 2,3: PCC

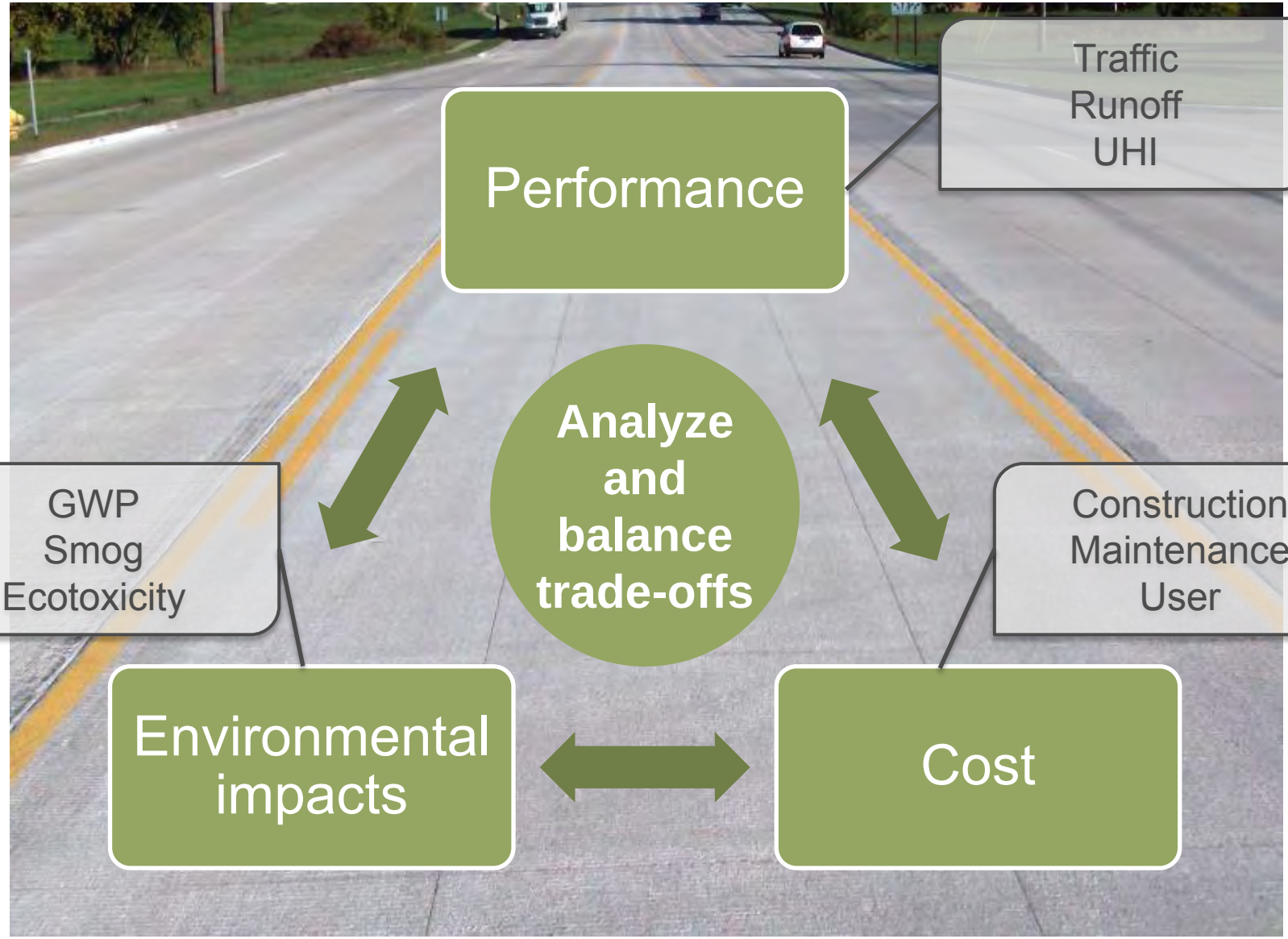
Significant EFC benefits are possible from diamond grinding

Analysis of concrete pavements in Caltrans network



Only 500 miles of M&R reduces PCC impact by 65%

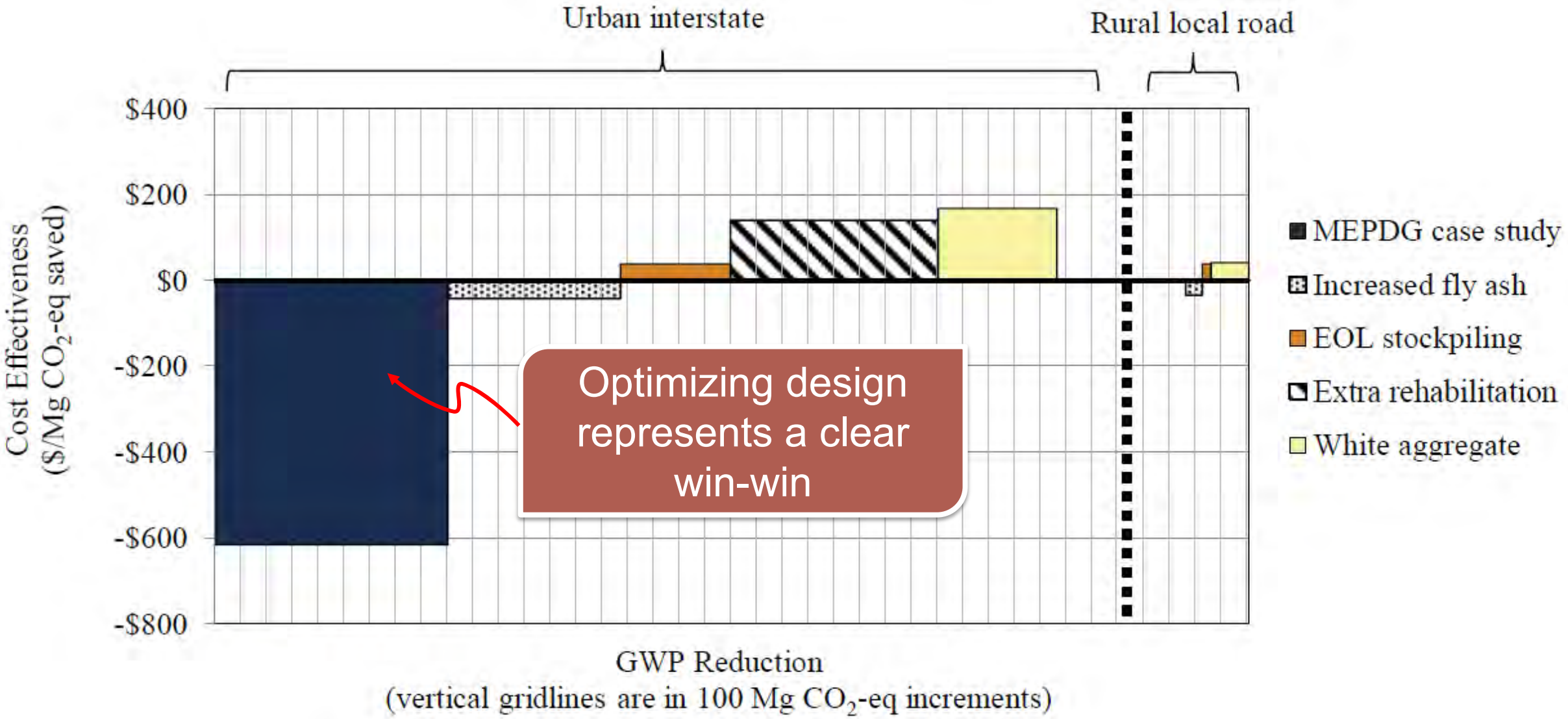
Quantitative sustainability assessments require a life cycle perspective and trade-off analysis



Large opportunities to improve exist:

Concrete pavement design optimization saves GHGs & $

Average annual life-cycle GHG emissions from all new concrete pavements in the U.S.: 3.1 Mtons

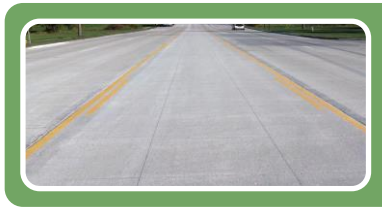


Key findings from CSHub LCA research

Life cycle perspective matters

Pavement-vehicle interaction matters

Context matters



M&R strategies affect PVI

Large opportunities to improve exist

Key target areas for reducing environmental impacts

Materials & Construction

- Concrete: increase use of supplementary cementitious materials and portland-limestone cements
- Asphalt: reduce construction impacts
- Reduce transportation distances

Use

- Minimize EFC-deflection impacts: Increase pavement stiffness
- Minimize EFC-roughness impacts: Decrease pavement roughness

Significant opportunities for LCA to support pavement decisions

Design & Construction

- Low impact materials
- Use of recycled content
- Increased durability
- Long-life design
- Innovative construction
- High albedo

Maintenance & Rehab.

- Pavement preservation
- Innovative M&R activities
- Traffic delay

Asset Management

- Network allocation strategy
- Decision trees

Combine with LCCA to illuminate eco-efficient solutions

Thank you

http://cshub.mit.edu/

cshub@mit.edu