NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Life-Cycle Assessment for Pavements and Transportation Infrastructure

August 17, 2023

1:00 – 2:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

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Purpose Statement

This webinar will provide multiple perspectives from public and private sectors and academia for stakeholders to learn about LCA process, current tools and data, the newest trends, and future needs.

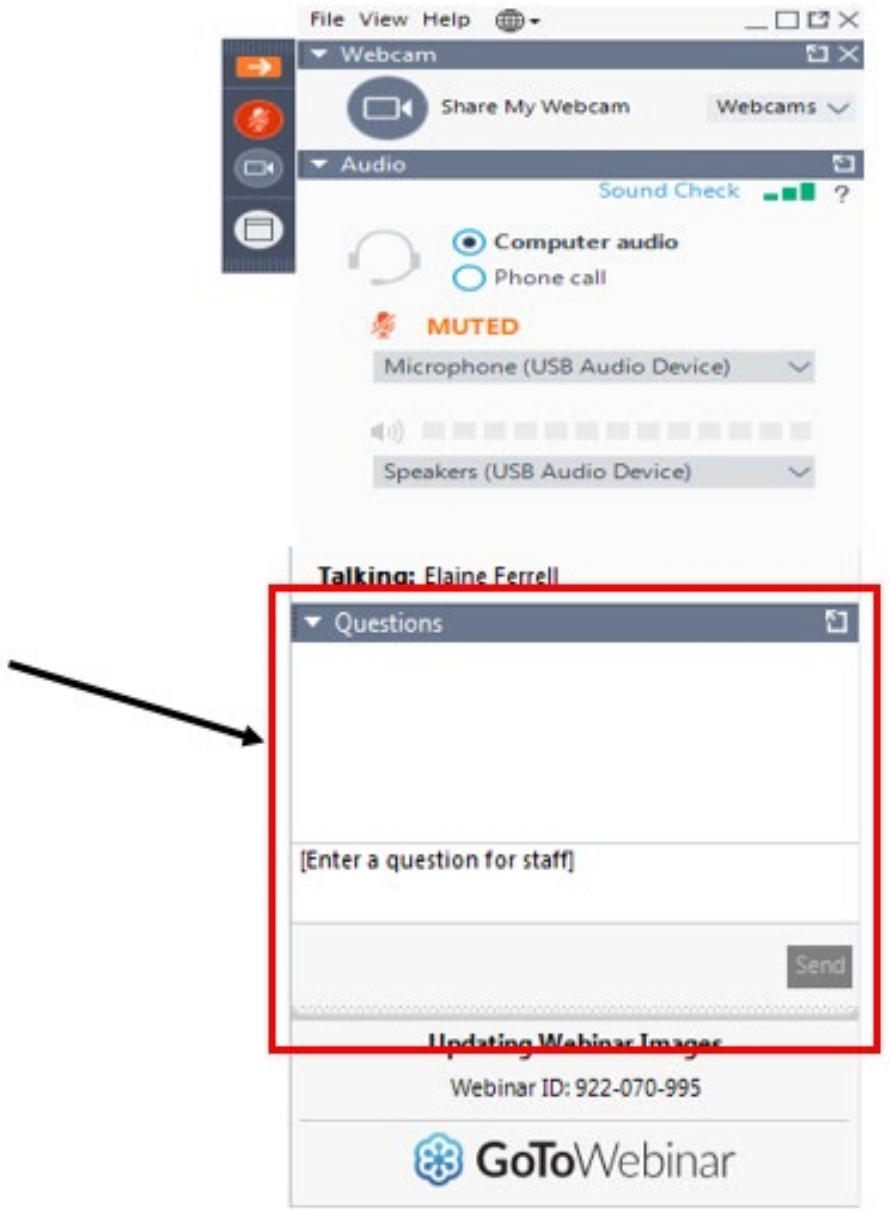
Learning Objectives

At the end of this webinar, you will be able to:

- Utilize key pavement LCA tools and databases
- Identify the primary stakeholders for pavement LCA and their role in LCA
- Discuss state-of-practice, limitations, and future needs in pavement LCA

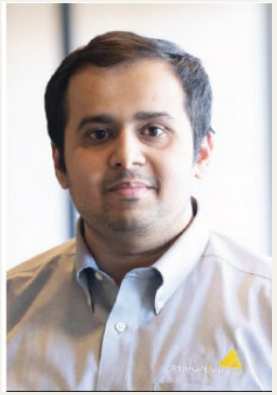
Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Migdalia Carrion
migdalia.carrion@dot.gov
FHWA



Chaitanya Bhat
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LCA Efforts in Asphalt Industry – Importance of Data

Chait Bhat, Ph.D., LCACP
Sustainability Engineer
Asphalt Institute
Lexington, KY

TRB Webinar
Life Cycle Assessment of Pavements and Transportation Infrastructure
August 17th, 2023

Overview of the Seminar

- LCA Fundamentals: Relevance of Data
- Environmental Product Declaration (EPD) Methodology
- Asphalt Industry Efforts
- Considerations for Path Forward
- Q&A, Discussions

LCA Fundamentals

ISO 14040 Definitions

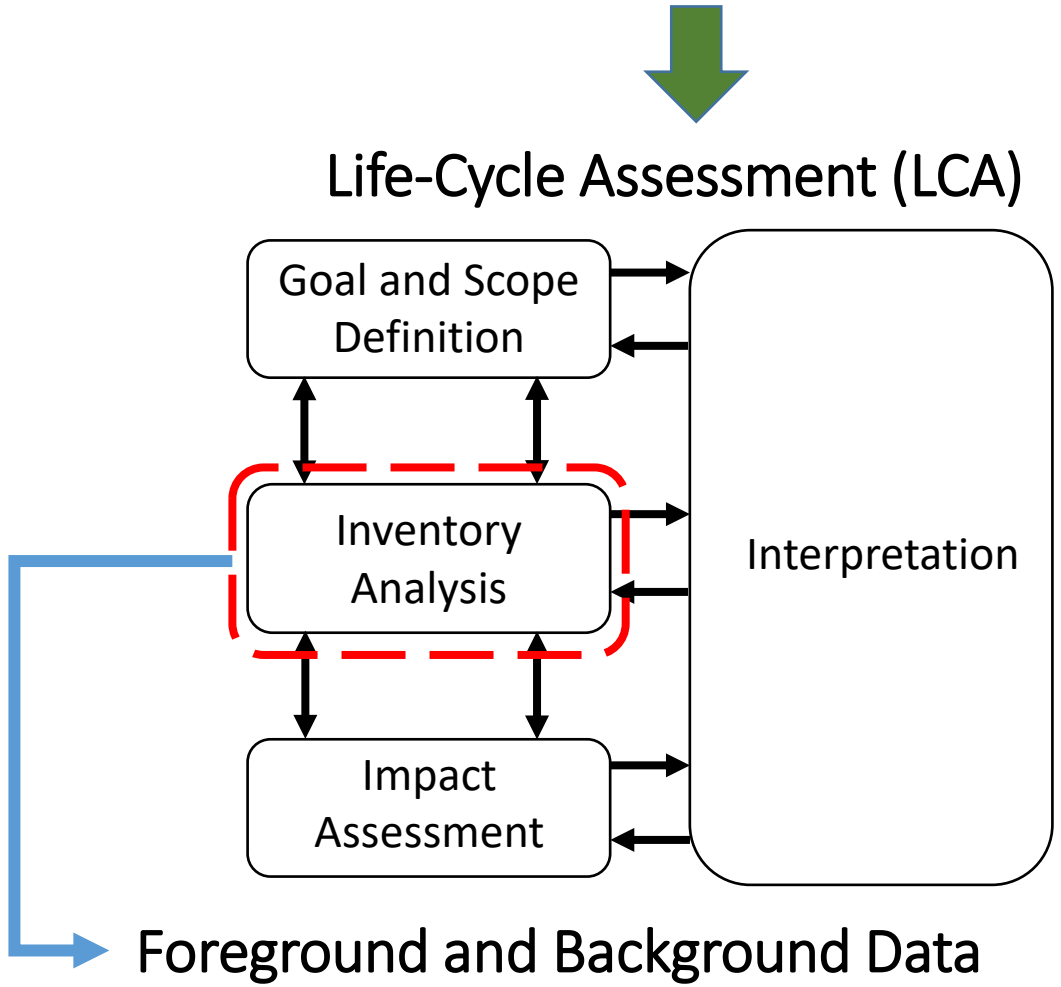
- Life Cycle Assessment
  - ***Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle***

- Life Cycle
  - ***Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal***

Life Cycle Assessment: Fundamentals

ISO Standards

14040 and **14044**



Background Data

Foreground Data

GATE/ PLACEMENT

At Source

At Grid

At plant

Crude Oil

Rock

Coal Deposits

Electricity from Wind

Electricity from Coal

Electricity from Gasoline

Asphalt Binder

Aggregate

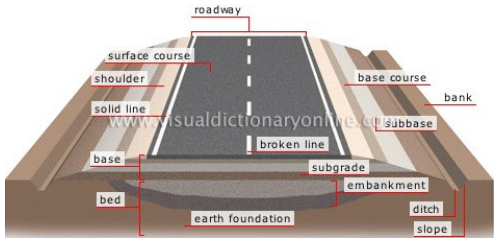
Diesel

Natural Gas

Electricity

Stakeholder: Plant Manager

Asphalt Mixture



Source: (Visualdictionaryonline.com, 2019)

Data Quality is Crucial

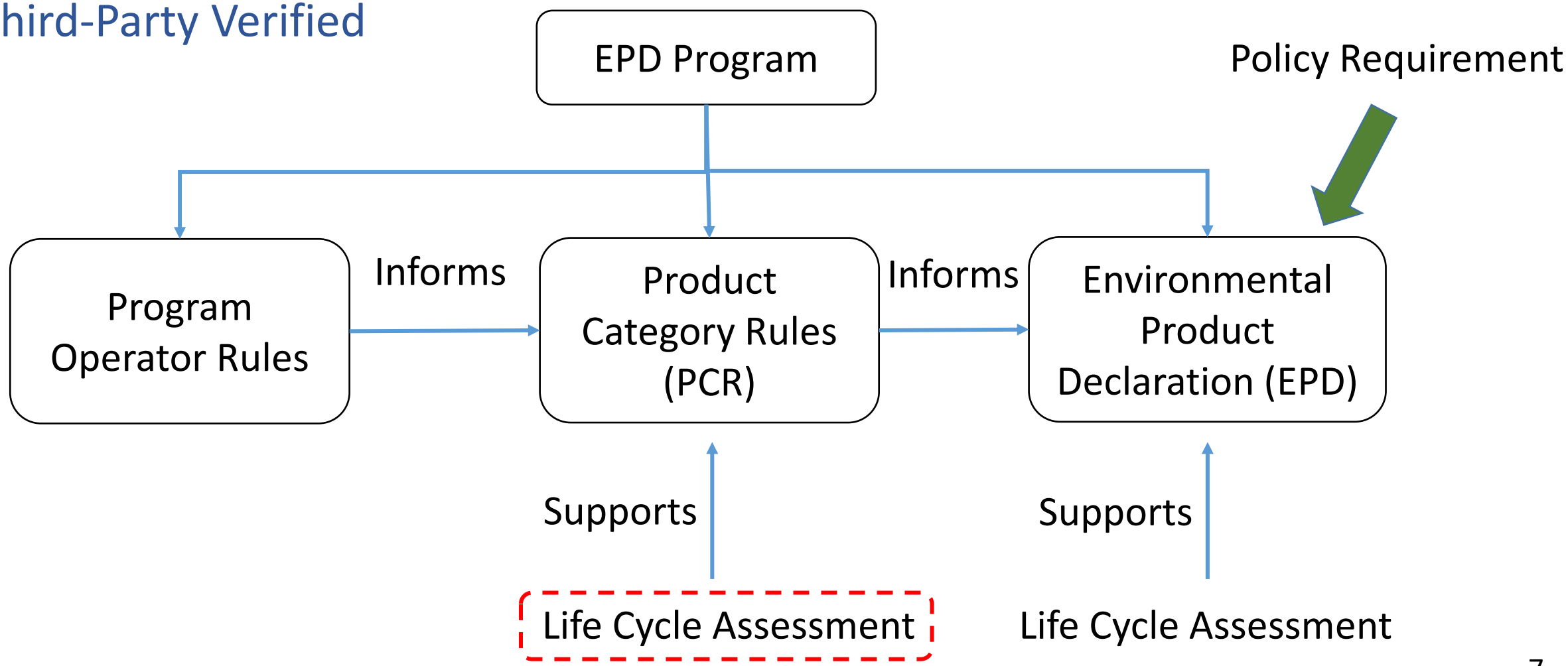
- Representative
- Reviewed
- Updated

Complete Supply-Chain for Asphalt Mixture

6

EPD Program: Development Process

- Multiple Stakeholders: Program Operator, PCR Committee, Review Panel
- Consensus-Based
- Third-Party Verified



EPD: Introduction

- Environmental Product Declarations (EPDs) are the current state of the art for representing third-party verified environmental impacts of products

- Based on ISO Standards 14025 (2006), 21930 (2017)/ EN 15804

- LEED v.4 led adoption of EPDs
  - Up to two points available in its green building rating system
  - Most impact in vertical infrastructure products

EPD: Analogy with Nutrition Label

Nutrition Label

Nutrition Facts

Serving size 1 potato (148g/5.2oz)

Amount per serving

Calories **110**

	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 0mg	**0%**
Total Carbohydrate 26g	**9%**
Dietary Fiber 2g	**7%**
Total Sugars 1g	
Includes 0g Added Sugars	**0%**
Protein 3g	
Vitamin D 0mcg	0%
Calcium 20mg	2%
Iron 1.1mg	6%
Potassium 620mg	15%
Vitamin C 27mg	30%
Vitamin B_6 0.2mg	10%

* The % Daily Value (DV) tells you how much a nutrient in a sering of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Environmental Product Declaration

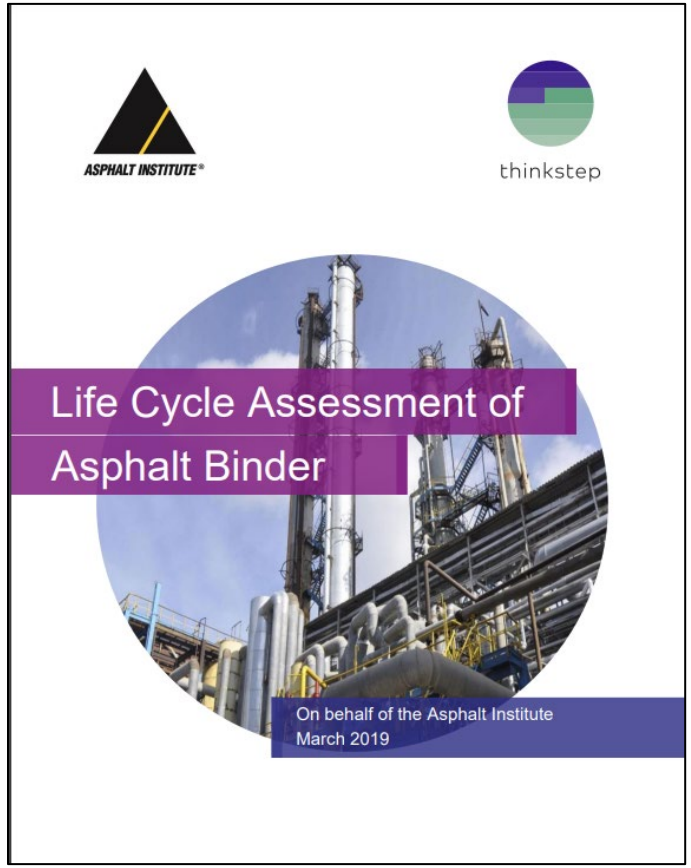
Declared Unit: 1 short ton of asphalt mixture

PARAMETER	UNIT	A1
Global Warming Air, incl. Biogenic Carbon	[kg CO2-Equiv.]	17.7
Ozone Depletion Air	[kg CFC 11-Equiv.]	3.72e-09
Acidification	[kg SO2-Equiv.]	0.104
Eutrophication	[kg N-Equiv.]	0.00624
Smog Air	[kg 03-Equiv.]	1.89
Abiotic Depletion for Fossil Resources	[MJ surplus energy]	MND*

Source: NAPA

EPDs for Asphalt Binder: Previous Efforts

- Existing Cradle to Gate Industry Average LCA for Asphalt Binder
  - Published in 2019
  - Started in 2016
  - Contracted with Thinkstep, now Sphera
  - Collected “Foreground” (process) data from 12 refineries and 10 terminals
  - Used Sphera’s “Gabi” for background data
  - Declared Unit: 1 kg of Asphalt Binder
    - Without additives
    - SBS Modified
    - GTR Modified
    - PPA Modified
- Feeds into NAPA’s Mixture EPD Tool

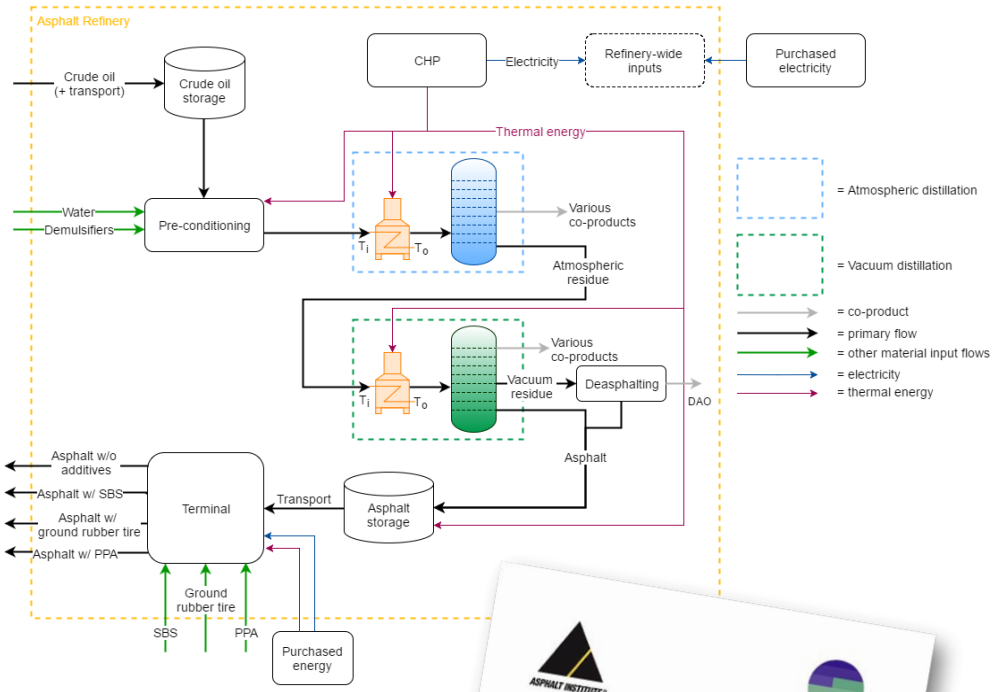


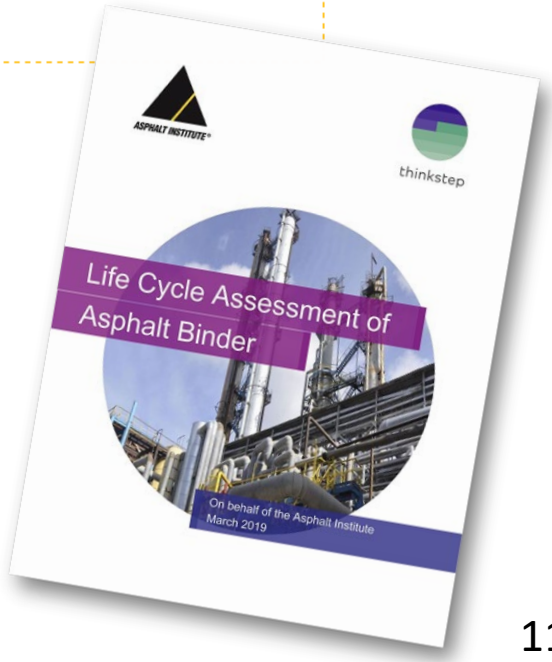
https://www.asphaltinstitute.org/engineering/sustainability/life-cycle-assessment-of-asphalt-binder/

EPDs for Asphalt Binder: Current Efforts

First of its kind EPD Taskforce provided path forward for:

- **Developing Product Category Rules (PCR) for asphalt binder using third-party Program Operator**
  - **Process includes including relevant external stakeholders**
- **Hired an LCA consultant to update AI's current Life Cycle Assessment (LCA) on asphalt binders in North America that was published in 2019**
  - **collect new foreground data from volunteer member company refineries and terminals (NDAs in place)**
  - **Incorporate newer background datasets**
- **Developing Environmental Product Declaration (EPD) web-based tool for product or facility specific EPDs**
  - **Support "Buy-Clean" policies**





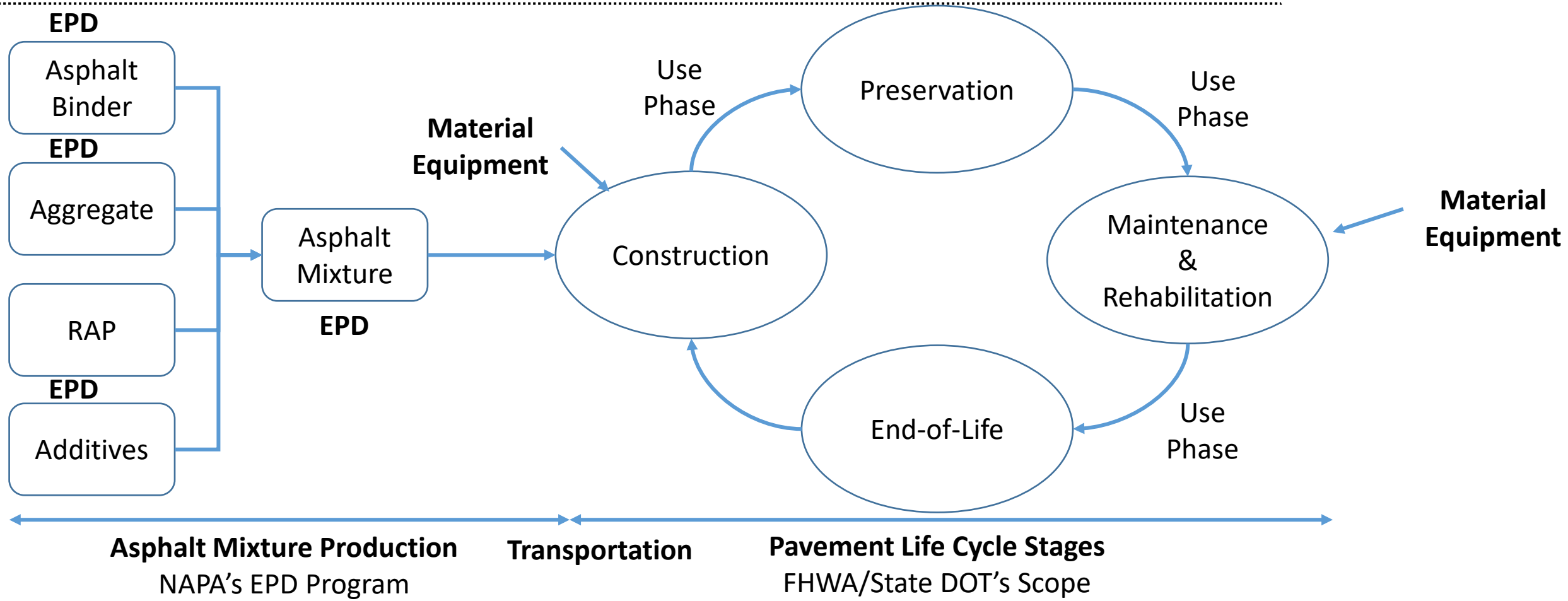
EPD for Asphalt Mixtures

- Program Operator - NAPA
- PCR –Committee Info and Review
  - Completed in 2022
  - www.asphaltpavement.org/uploads/documents/EPD_Program/NAPA_PCR_AsphaltMixtures_v2.pdf
- Asphalt Mixtures LCA
  - Published in 2016, updated in 2021
  - www.asphaltpavement.org/uploads/documents/EPD_Program/LCA_final.pdf
- Independent Verification
  - LCA, PCR and EPD Tool
- Emerald Eco-label EPD Tool
  - https://asphaltepd.org/

DECLARED PRODUCT	**221731**, an asphalt mix.
DECLARATION OWNER	
PROGRAM OPERATOR	National Asphalt Pavement Association 6406 Ivy Lane, Suite 350 Greenbelt, MD, 20770 Toll-free: (888) 468-6499 www.asphaltpavement.org/epd
LCA AND EPD TOOL DEVELOPER	Benjamin Ciavola, Ph.D., Trisight 322 Shelden Ave. Ste. 14, Houghton, MI 49931 http://trisightengineering.com
INDEPENDENT VERIFIERS	John Beath Environmental, LLC The data and declarations produced by the EPD tool was externally, independently verified in accordance with ISO14025, ISO21930, and the referenced PCR. Trisha Montalbo https://goaspha.lt/3u7MIqk
PRODUCT CATEGORY RULE	Product Category Rules (PCR) for Asphalt Mixtures, version 2.0 National Asphalt Pavement Association 6406 Ivy Lane, Suite 350 Greenbelt, MD, 20770 Toll-free: (888) 468-6499 www.asphaltpavement.org/epd
PCR REVIEW	PCR confirmed by PCR Review Panel Led by Joep Meijer, TheRightenvironment https://goaspha.lt/3NJbyVx

Considerations for Path Forward

Reliable Foreground Process Data: Promote Whole Pavement-Level EPDs



Link to an article on Pavement PCR

Guidance on "Who and What Level should Pavement PCR be developed?"

Next in the line: "Can All LCAs be Considered as EPDs?"

Relevant Scope for EPD Comparability

- Pavement-level EPD Process will need to be standardized
  - Functional unit
  - Definition of functionality “Scenarios”
  - Cradle to gate EPDs mostly use “Declared Unit” only
  - Involve multiple stakeholders
    - Program Operators
    - PCR Committee
  - Consensus Based and Third-Party Plus Public Verified
  - Accountability is key

Conclusions

- Incorporate principles of “Service Life Planning” (ISO 15686)
  - Meet or Exceed a Structure’s Design Life
  - Use Stage Performance: Structural Condition Evaluation using Advanced Mechanisms such as Traffic Speed Deflection Devices (TSDD)
- Innovative Contracting Mechanisms
  - “Buy-Clean” to “Design-Build-Operate-Preserve-Maintain Clean”
  - Transition to “Low-Carbon” Pavement Systems
- Data Quality Improvement = Systemic Improvement
  - Improving existing Pavement Management Systems
  - Feedback loop between PMS with Procurement and Design
  - High Quality Background Data

Thank You!

Sustainability and LCA for Concrete Pavement

August 17, 2023

National Concrete Pavement Technology Center

Leif G. Wathne, P.E.

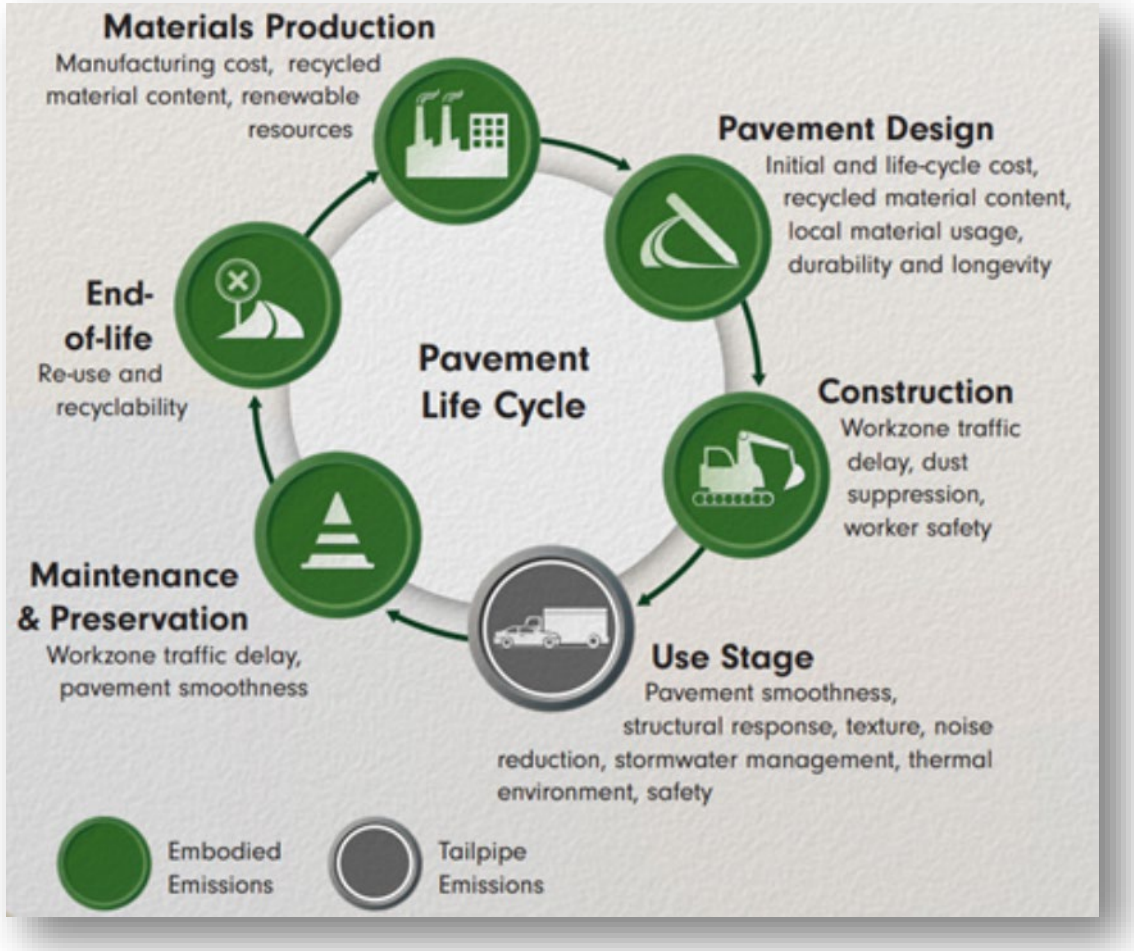
Tech Center

Life Cycle Assessment

A technique that can be used for analyzing and quantifying the environmental impacts of a product, system, or process. LCA provides a comprehensive approach to evaluating the total environmental burden of a product or process by examining all of the inputs and outputs over the life cycle, from raw material production to end of life.

Source: FHWA HIF-16-014

Life Cycle Assessment



- Systematic approach that identifies most relevant impacts and potential improvements while identifying potential trade-offs.
- Gives agencies the ability to investigate areas where they can improve.
- Rules defined by the International Organization for Standardization (ISO) in its 14040 family of standards.

Source: FHWA Sustainable Pavements Program

Tools

- LCA PAVE (FHWA)
- Athena Pavement LCA (North American)
- PaLATE V2.2 (UC Berkeley)
- eLCAP (UC Davis)
- MIT CSHub LCA Toolkit v1.1
  - Full life cycle (including use-phase)
  - Transparent/Accommodates uncertainty

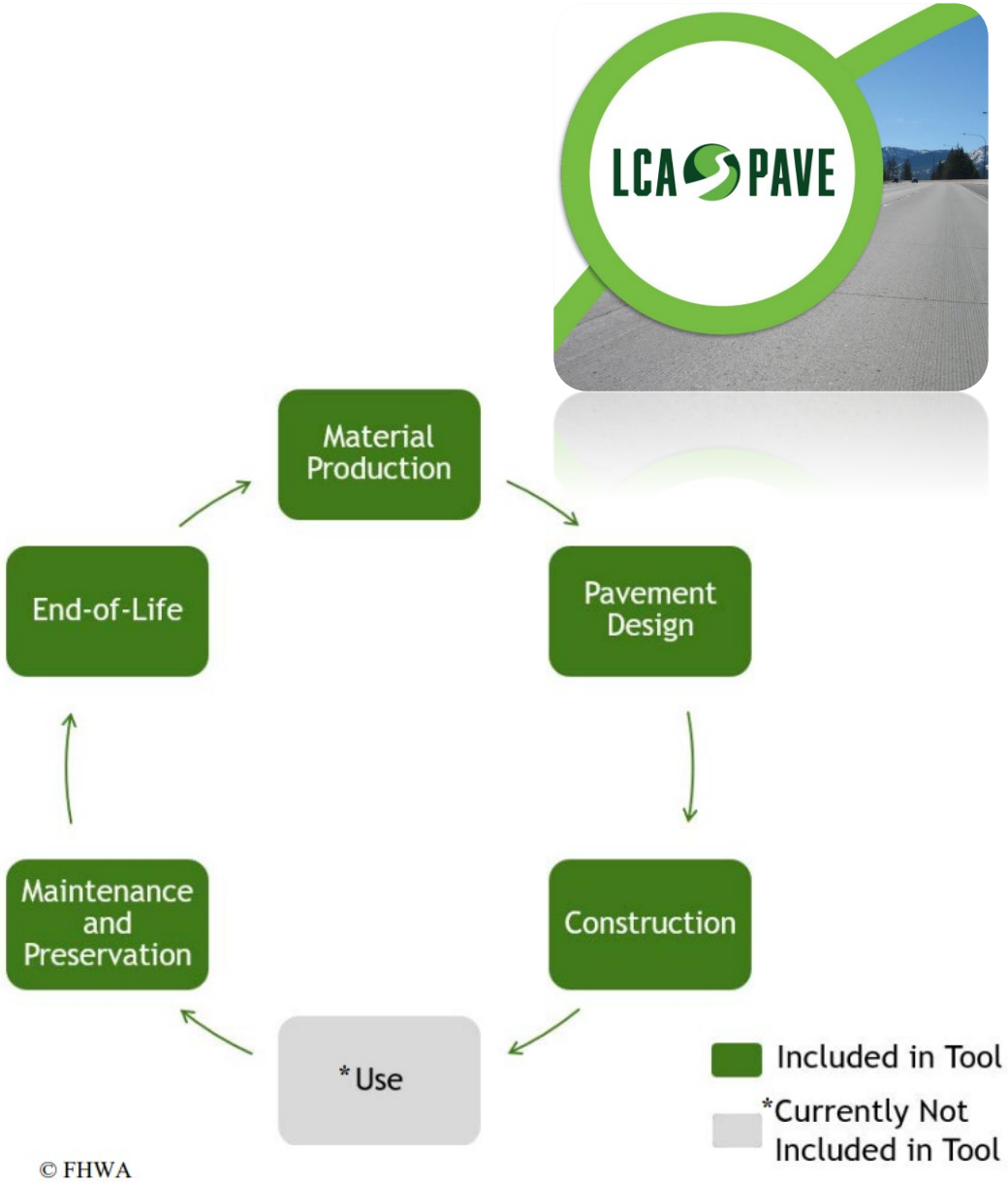


Figure 1-1. Life-cycle stages considered in the tool.

Current U.S. focus is on CARBON….

$4.5B

*" … that have substantially lower levels of embodied greenhouse gas emissions associated with all relevant stages of **production, use, and disposal** …"*

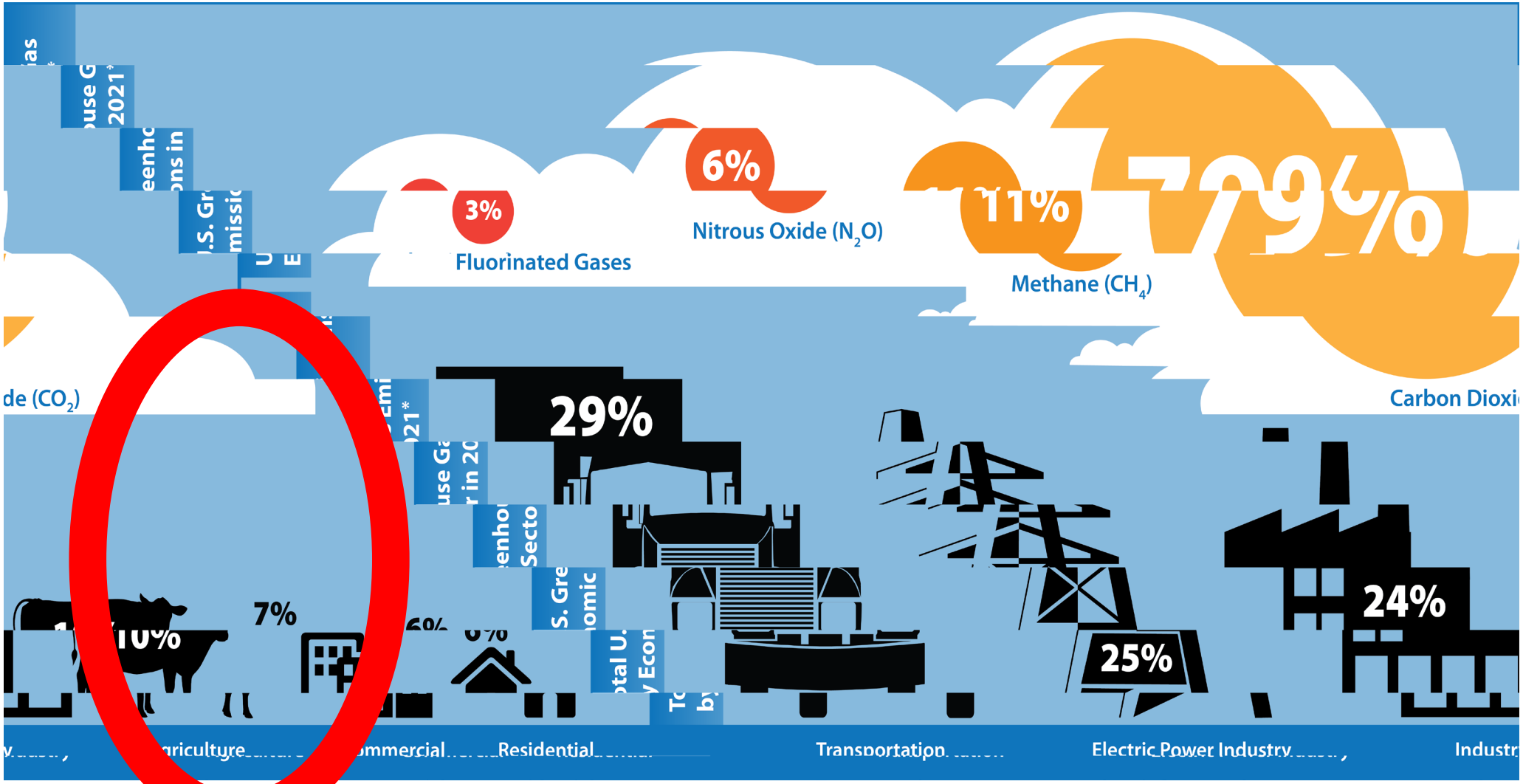
PUBLIC LAW 117–169—AUG. 16, 2022

- $250 Million for Environmental Product Declarations (EPD) Assistance
- $100 Million for **Low-Embodied Carbon** Labeling for Construction Materials
- $2.15 Billion for Use of **Low-Carbon** Buildings
- $2 Billion for **Low-Carbon Transportation** Grants

2022 Inflation Reduction Act

U.S. GHG Emissions…

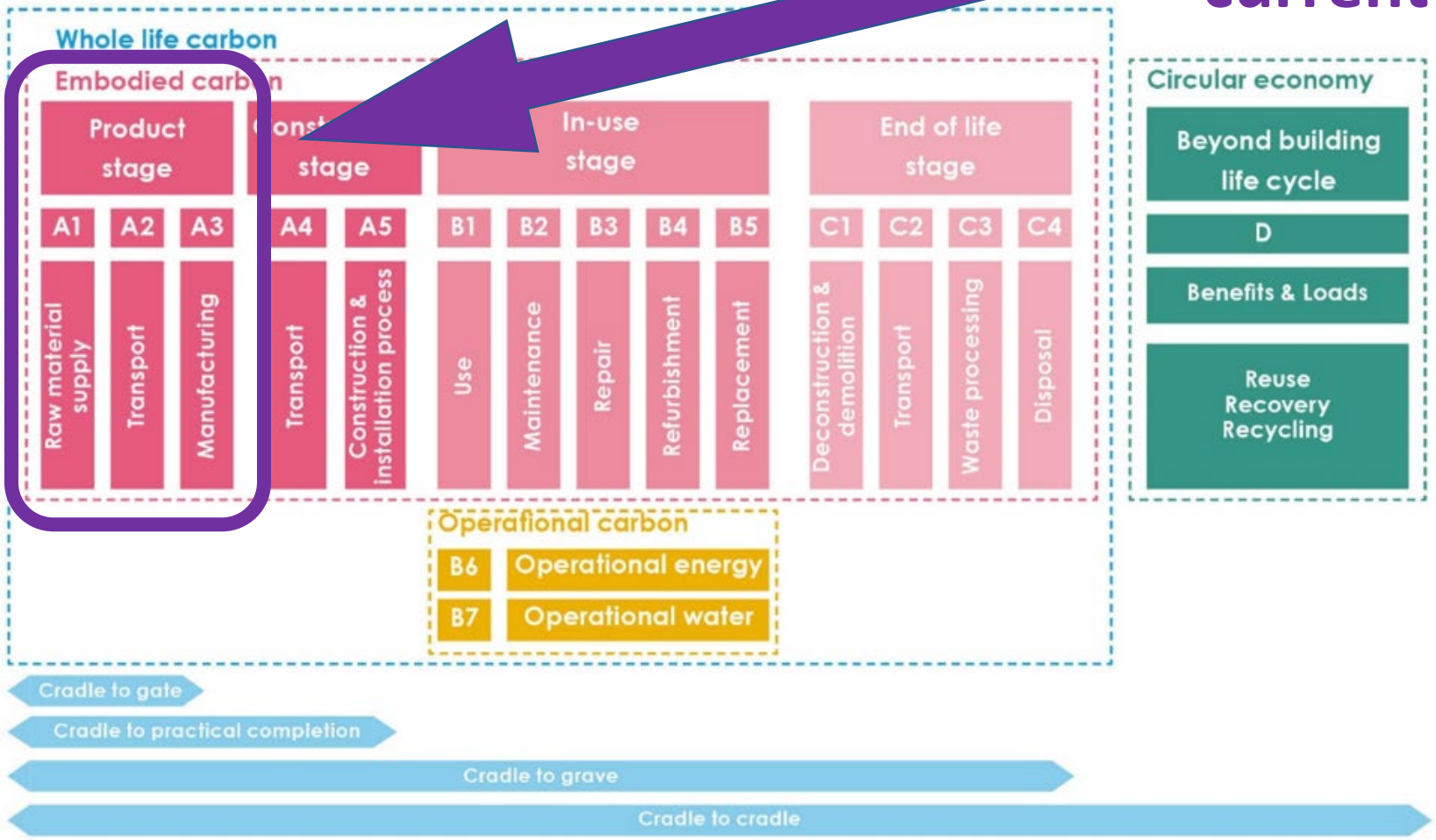
CONTEXT



Source: EPA Greenhouse Gas Inventory Report 2021

Life Cycle Stages…

A large part of current focus…



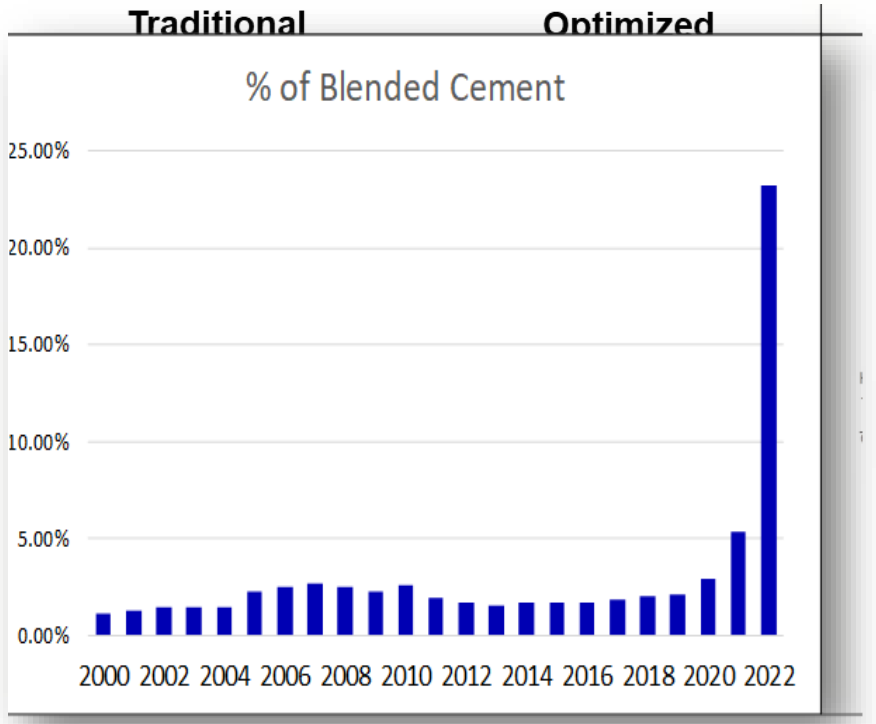
- LCA allows the practitioner to quantify emissions from each of these stages
- Help inform better decisions

Adapted from ISO 21930

Specific levers to reduce EMBODIED CO_2...

1) Consume **less concrete** for new structures:
   - Be efficient with our pavement designs
2) Consume **less cement** in concrete mixtures:
   - Optimizing our concrete paving mixtures
3) Consume **less clinker** for making cements:
   - Embrace lower carbon cements

Come a long way already…. will continue to improve!

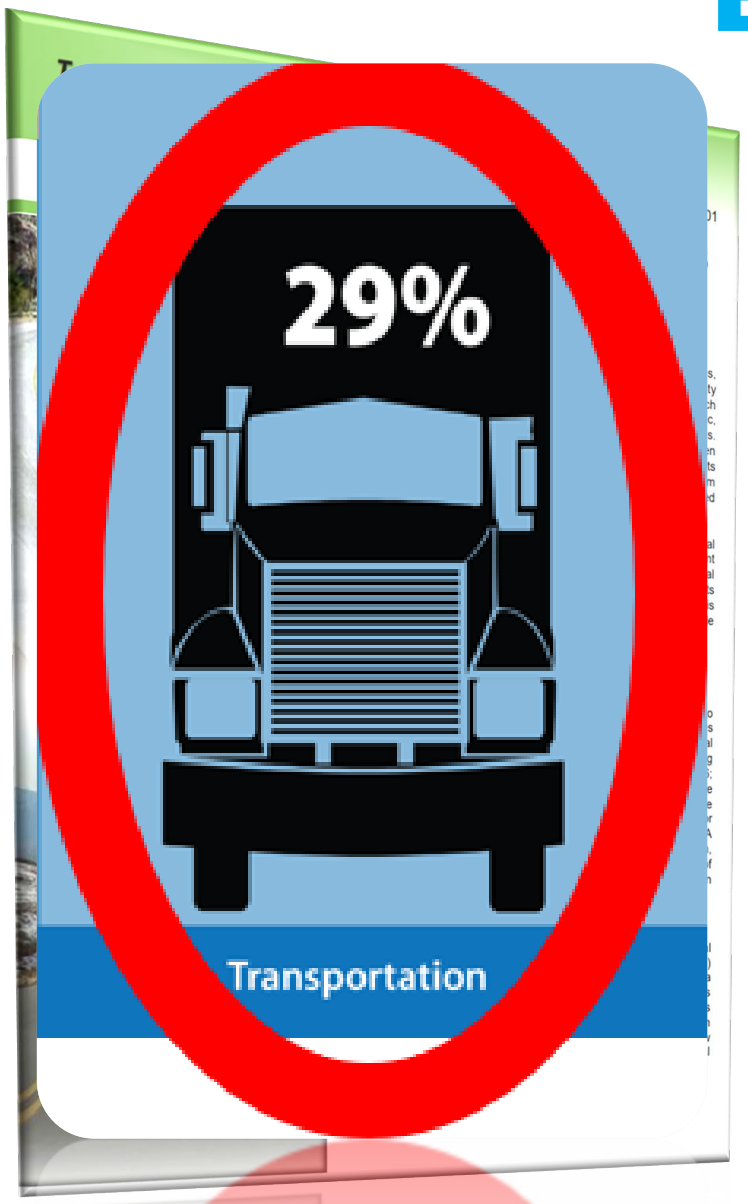


Reduces initial GWP by 22%
and life cycle GWP by 14%

[Source: Mehta, CI February 2009]

BEYOND embodied emissions

Beyond Embodied Emissions…



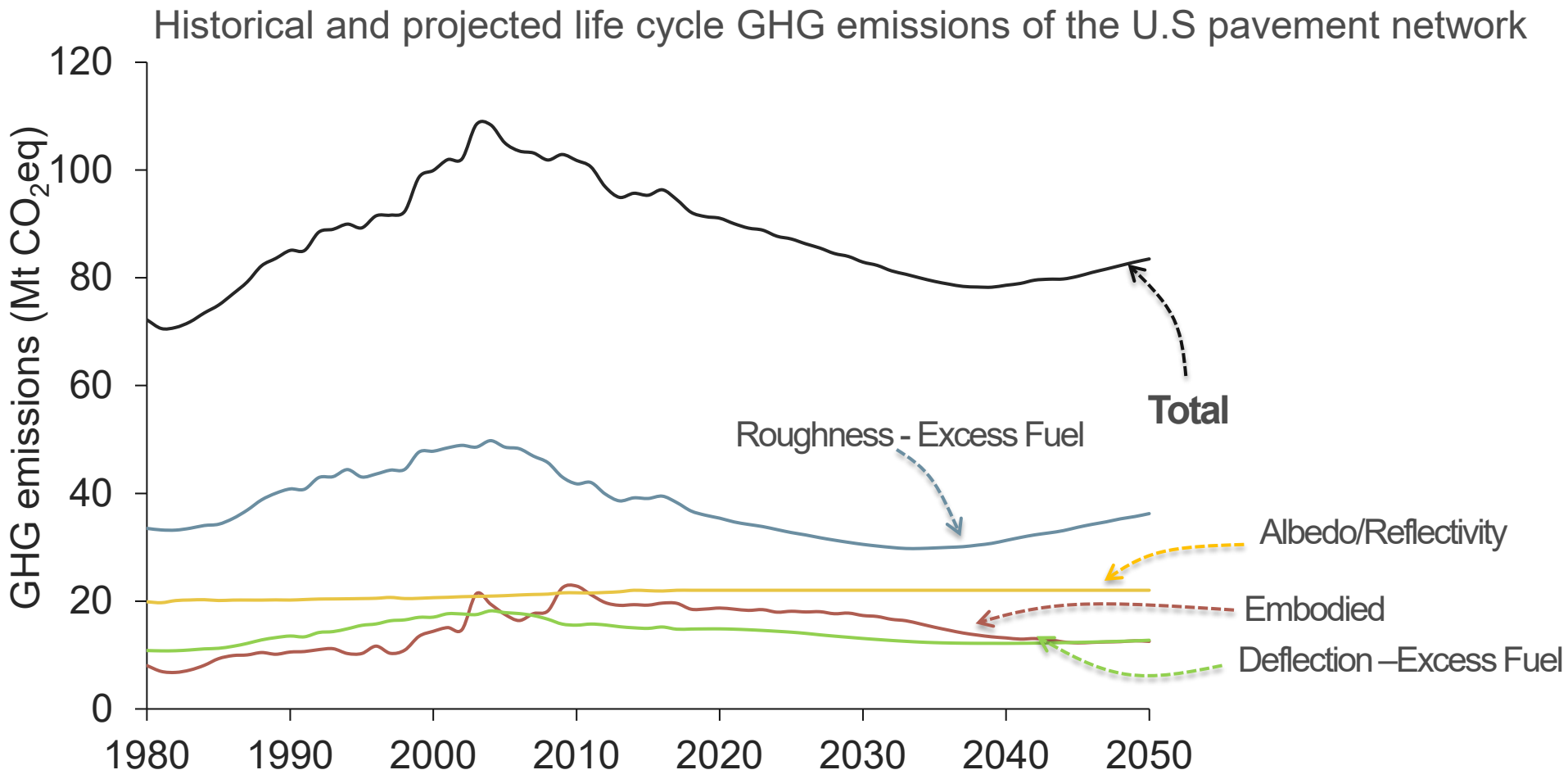
- Use-phase impacts that relate to excess CO_2 emissions:
  - Pavement **Roughness**
  - Pavement **Macrotexture**
  - Pavement **Deflection** (structural response)

  These "*can all affect vehicle fuel consumption and, as a result, have potentially significant environmental impacts*".
  - Pavement **Albedo** (reflectance)
- Focus of much past and ongoing research

NOTE: ***Uncertainty ≠ insignificance***

Source: FHWA HIF-16-014

Relative significance of impacts



Source: Gregory, Jeremy, et al. Proceedings of the National Academy of Sciences 118.37 (2021)

Concluding Thoughts…

- As engineers we need to understand where the biggest opportunities are…
- Things we can do to reduce **embodied** impacts (EPDs) **and** things we can do to reduce **use-phase** impacts
- **LCA is the key to understand the relative importance of each**
- Focus on the big reduction opportunities first. Don't let uncertainty paralyze us!

Thank you!

Useful Resources

- FHWA SP Program
- ACPA White Paper
- PCA Roadmap
- NRMCA EPD
- MIT CSHub

National Concrete Pavement Technology Center

Tech Center

Life Cycle Assessment for Pavements and Transportation Infrastructure

Integrating Pavement Performance

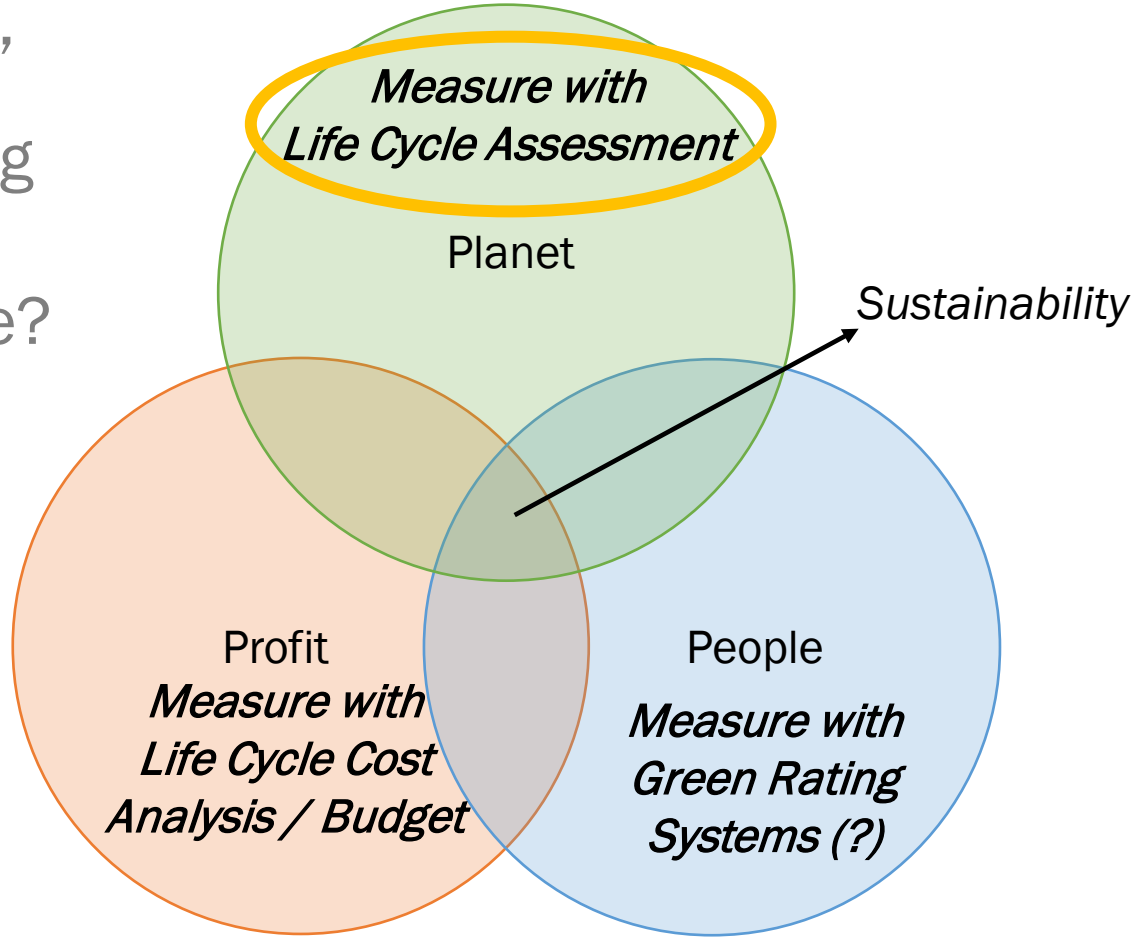
Benjamin F. Bowers, PhD, PE
Assistant Professor
Auburn University
National Center for Asphalt Technology

You might be asking:
“Where does performance fit into all of this?”

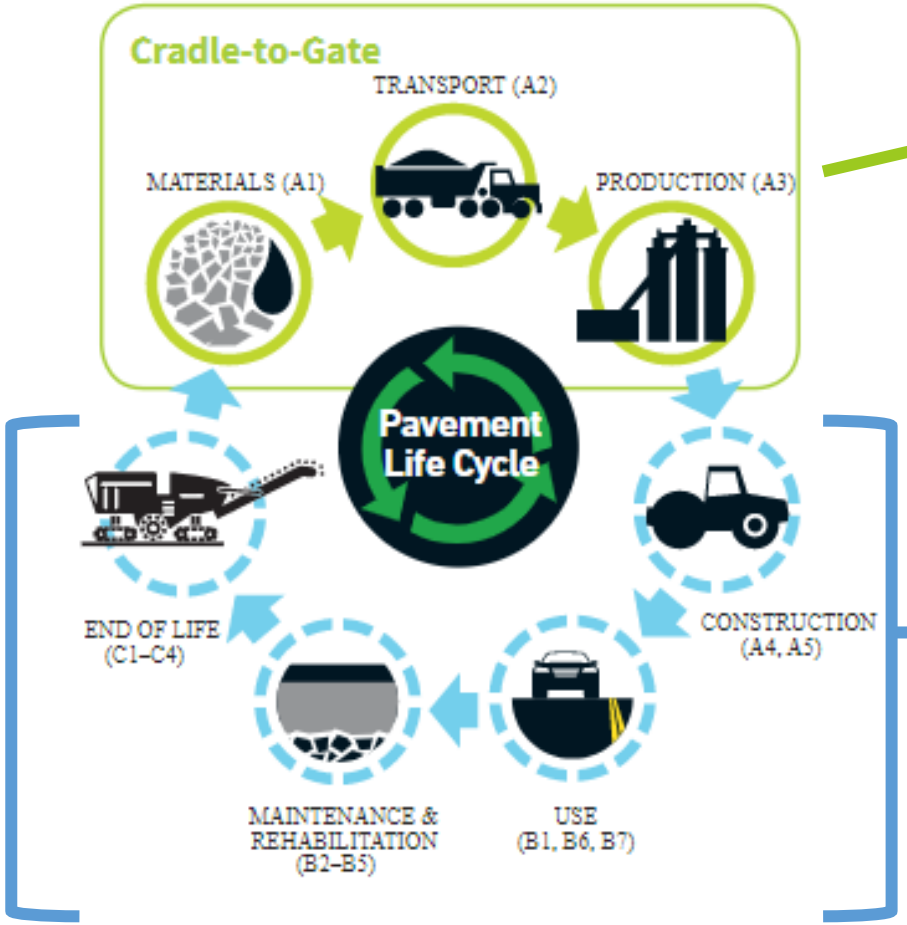
Performance is a key tenet of sustainability

- Remember the “triple bottom line”
  - **Profit** – are we maintaining / growing the economy?
  - **People** – are we caring for all people?
  - **Planet** – are we taking care of our environment?

- *Each part of the triple bottom line relies on **performance**.*



How do we actually use this?



Environmental Product Declarations

We're doing this!

Everything else…

We're working on this…

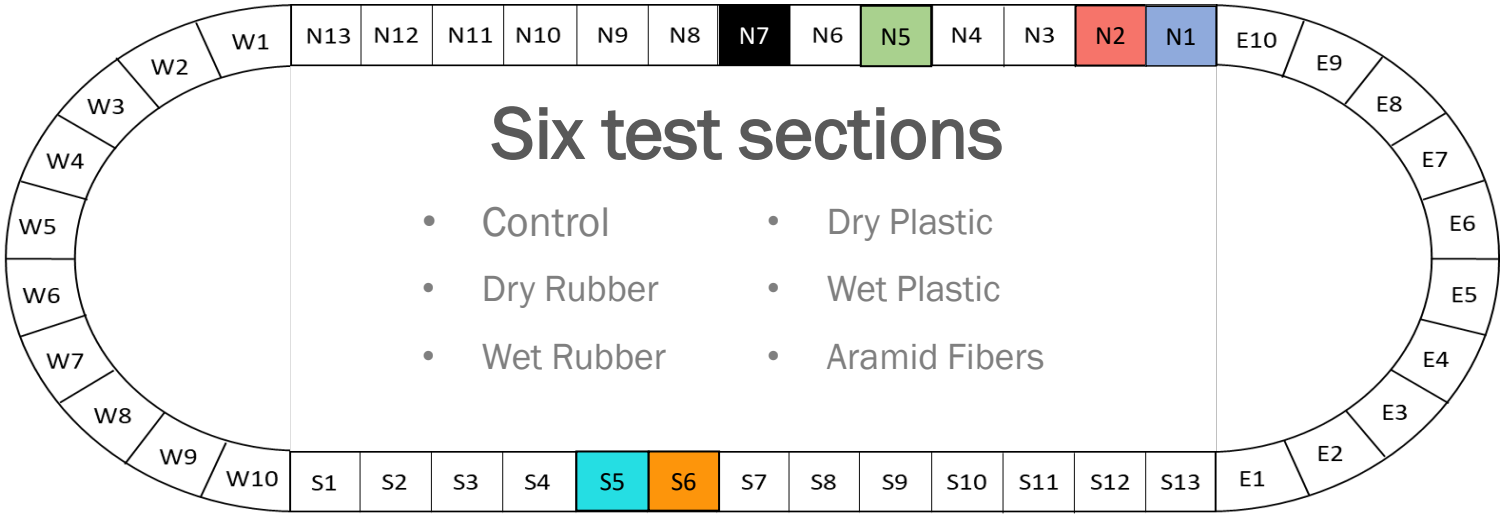
Mukherjee, A., 2016. Life cycle assessment of asphalt mixtures in support of an environmental product declaration. *National Asphalt Pavement Institute: Lanham, MD, USA*.

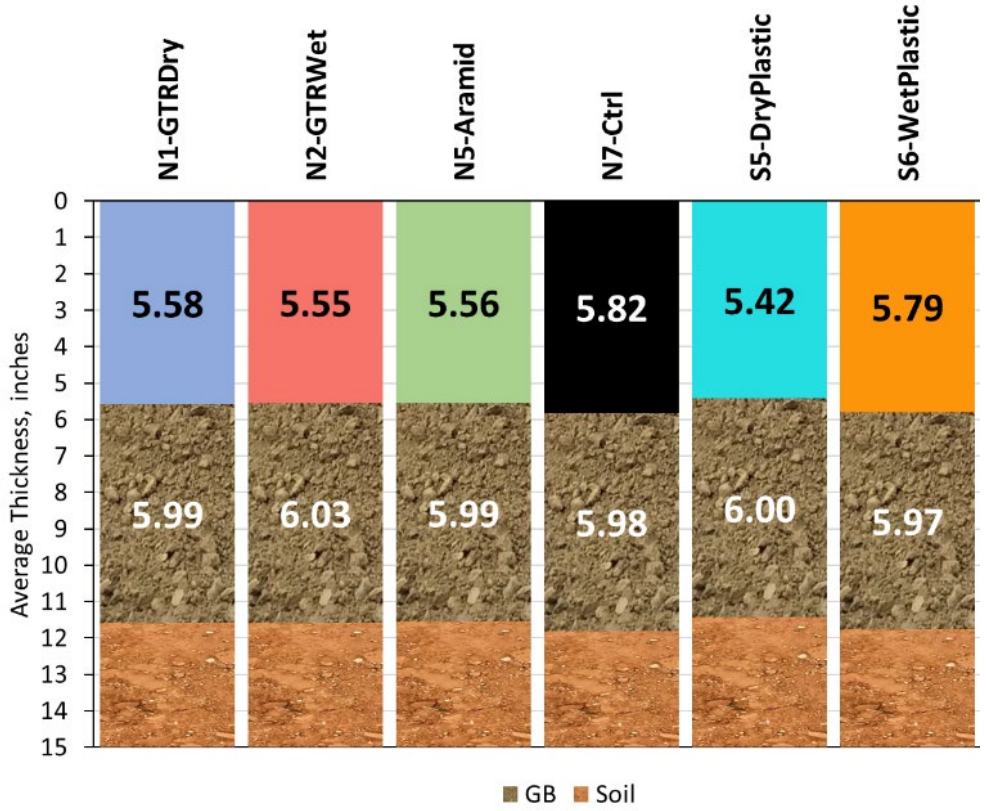
Setting the stage…

- A comparative life cycle assessment is being performed at the NCAT Pavement Test Track
- Five different asphalt additive technologies + a control are being tested with all variables controlled as closely as possible
  - Designed to fail in fatigue
- EPD and/or aggregated datasets are being gathered for materials
- The entire pavement life is being modelled…
  - This is required to perform a comparative LCA because the additives will likely change the performance of the asphalt mixture

Additive Group Test Sections

- Constructed in September 2021
- Open to traffic in November 2021





Performance Goal 1: Mix Performance

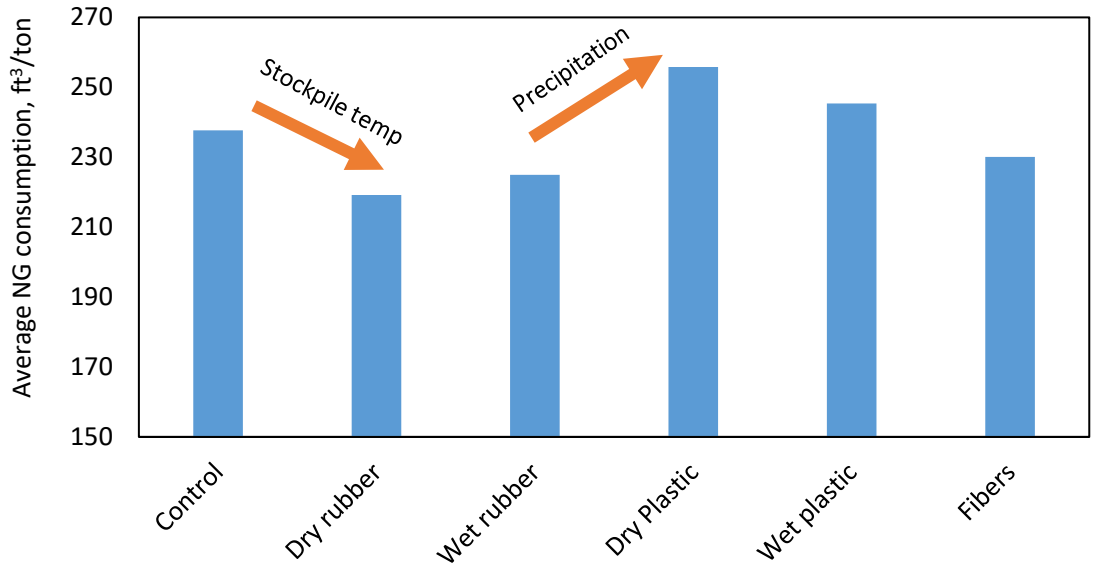
- All mixes are designed using a Balanced Mix Design Approach
  - **Cracking:** CTindex > 50 after 4 hours of short-term oven aging
  - **Rutting:** Hamburg Wheel Tracking Test < 12.5 mm at 20,000 passes
- Benefit: Use of local materials, recycling…
- *Remember: Don't compare EPD's for materials that are not expected to perform the same or equal*

Performance Goal 2: Production

	Control	Dry rubber	Wet rubber	Dry Plastic	Wet plastic	Fibers
Section	**N7**	**N1**	**N2**	**S5**	**S6**	**N5**
Avg temp during production	85.8	80.4	76.8	86.3	73.9	74.1
Average stockpile temp., F (6hrs prior production)	73.0	85.5	85.3	85.8	77.7	67.2
Cumulative precipitation 24 hrs. prior to production, in.	0.00	0.03	0.03	0.13	0.02	0.00
Avg energy used, ft^3/ton	237.7	219.2	225.0	255.8	245.4	230.1

Takeaways

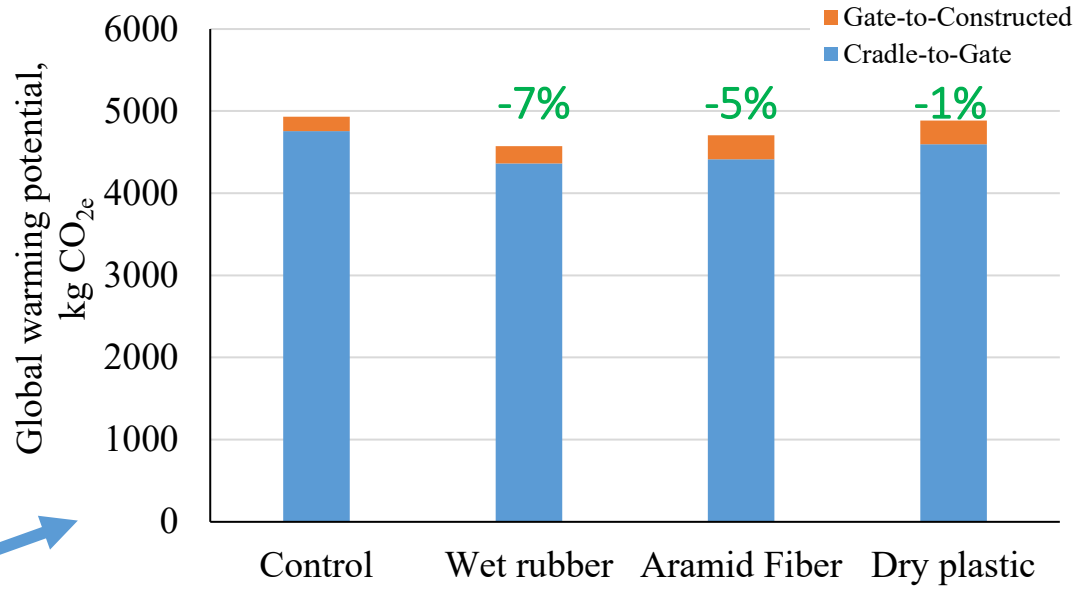
- Stockpile temperature and moisture play a role
- Benefit: More justification to implement good practices!
- *Be careful using one day's production*



Performance Goal 3: Construction

- We need to ensure good quality compaction
- Can a low-carbon technology also reduce the number of roller passes required?
  - Benefit: Saves time and money
  - Benefit: Allows contractor to move down the road more quickly
- *Need: Develop specifications and gain consensus for doing this…*

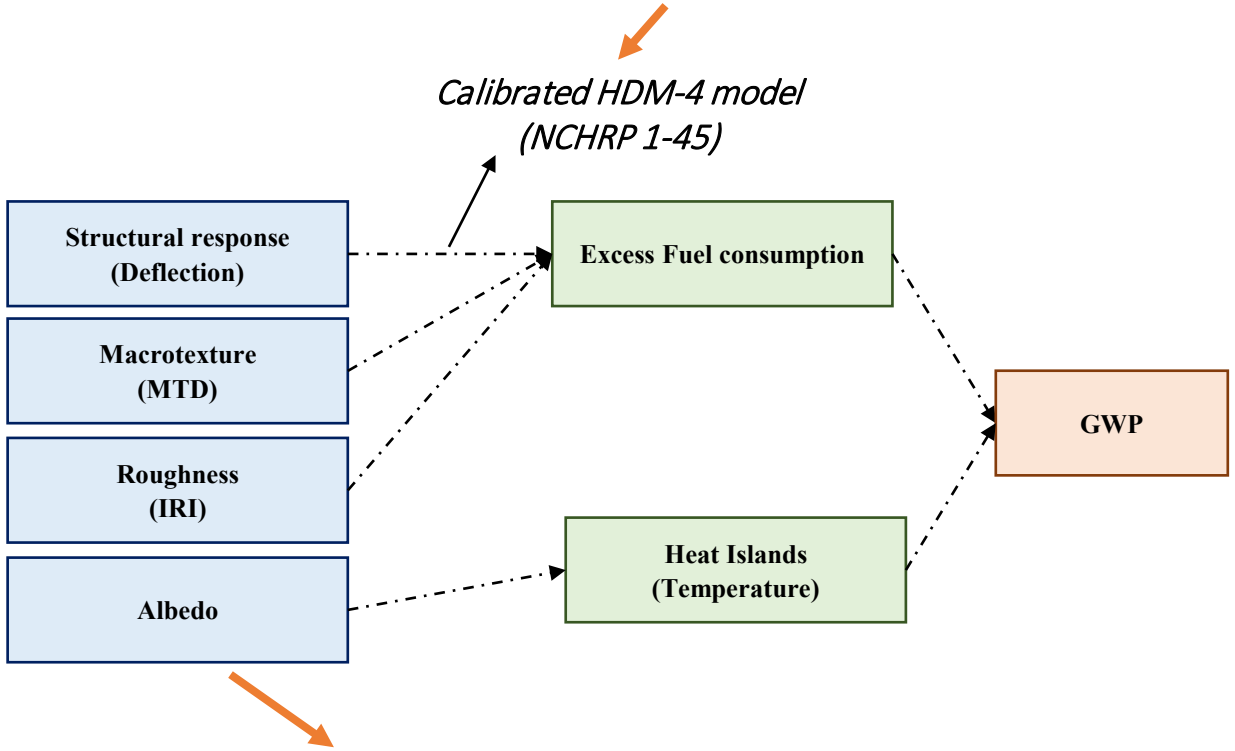
Declared Unit: test track section
(200 ft long, 12 ft wide)



Performance Goal 4: Use Phase

- Use phase can be a challenge as there are *lots* of models and data inputs
- Pavement Vehicle Interaction
  - *FHWA is putting together a group to discuss PVI and develop consensus*
- Benefit: Enhanced maintenance and rehabilitation schedules, reduced fuel consumption

Calibrated HDM-4 model yielded about 3.42 MPG and NCAT trucks consumes about 4.0 MPG

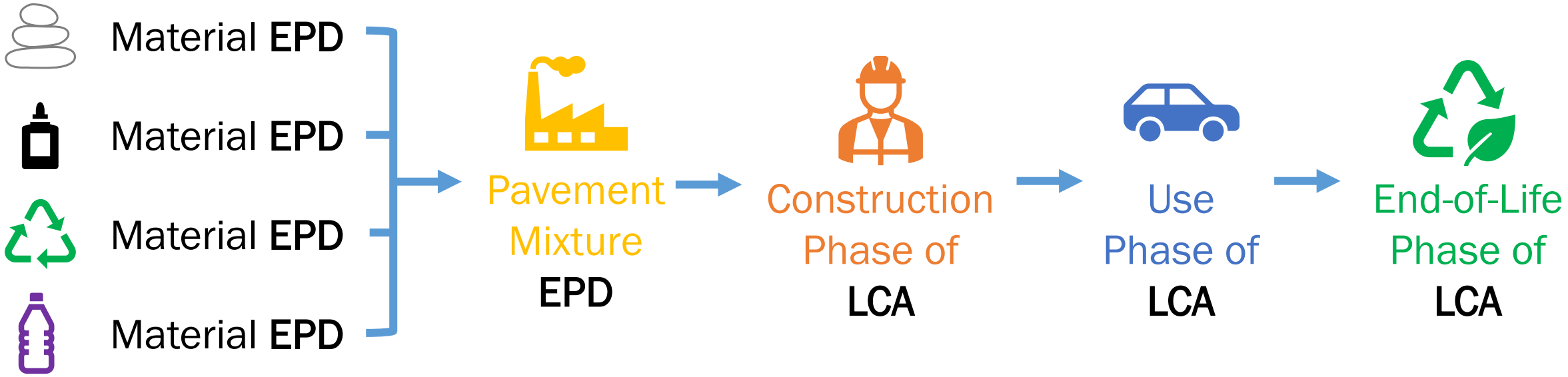


All the sections were subjected to diamond grinding, not expecting to see a lot of change in the Albedo over time

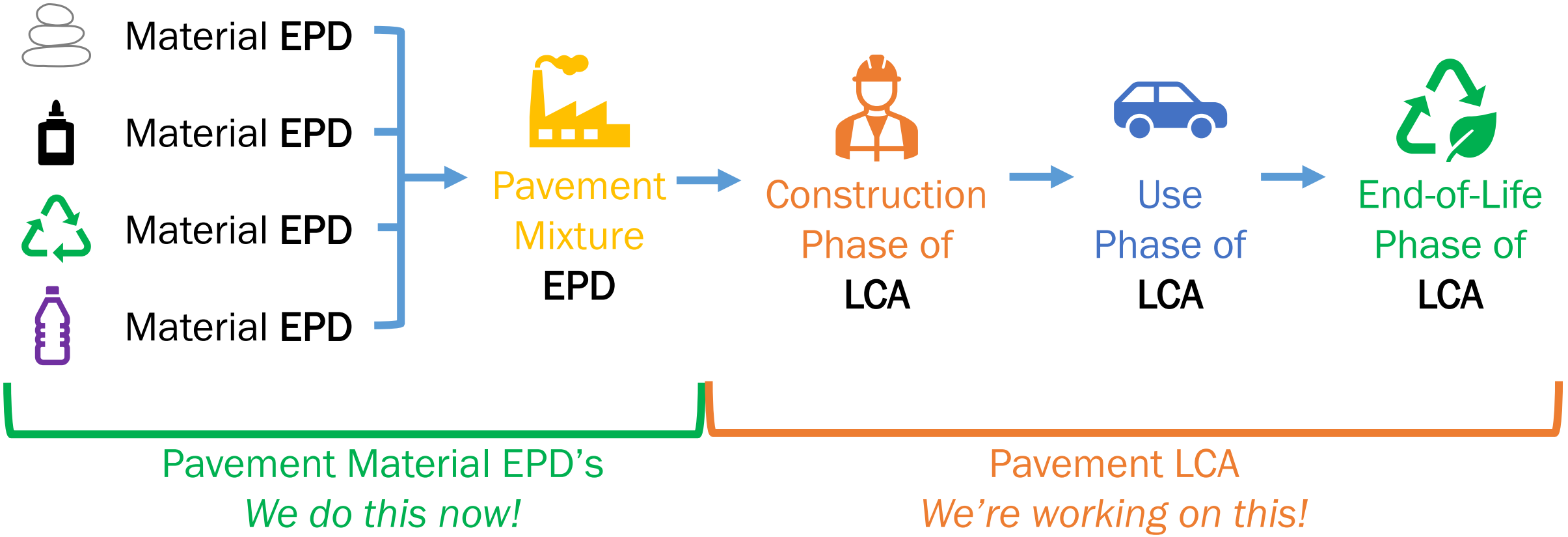
Performance Goal 5: End of Life

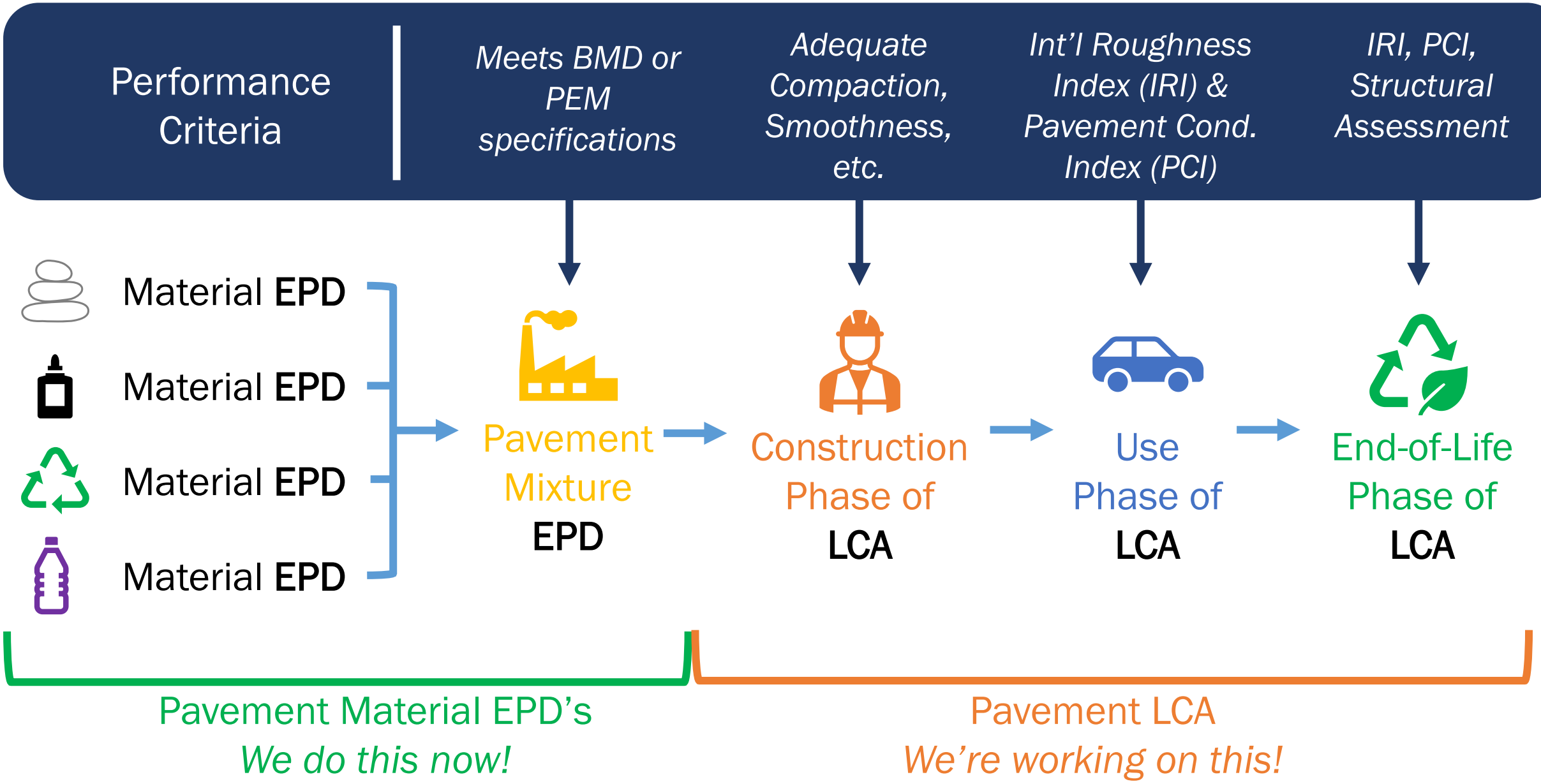
- What do we do at the end of our pavement life?
  - Use as foundation of a new pavement?
  - Recycle the materials in place?
  - Recover and reuse as RAP or recycled concrete aggregate?

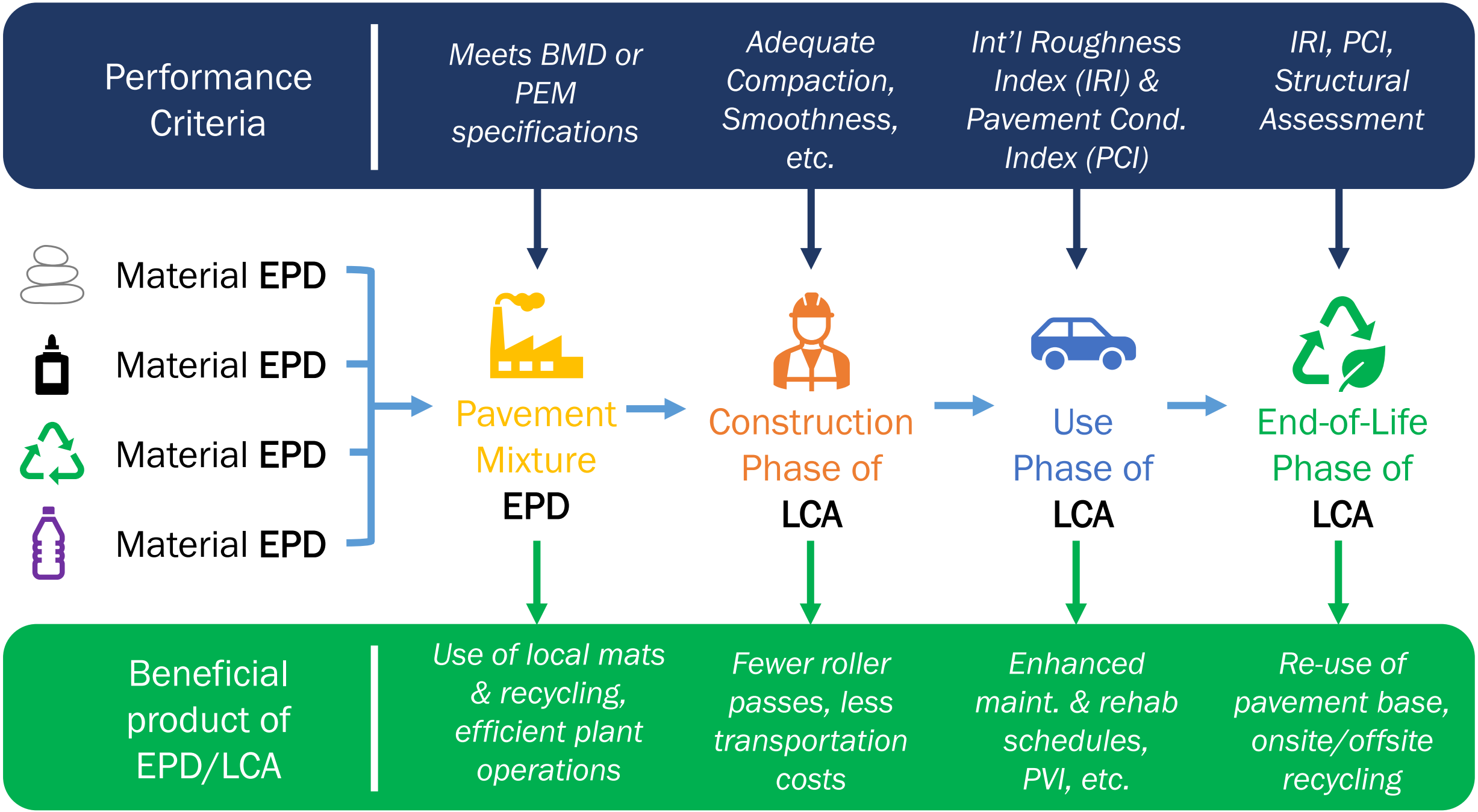
...in summary


Material EPD
Material EPD
Material EPD
Material EPD
Pavement Mixture EPD
Construction Phase of LCA
Use Phase of LCA
End-of-Life Phase of LCA

...in summary


Material EPD
Material EPD
Material EPD
Material EPD
Pavement Mixture EPD
Construction Phase of LCA
Use Phase of LCA
End-of-Life Phase of LCA
Pavement Material EPD's
We do this now!
Pavement LCA
We're working on this!


Performance Criteria
Meets BMD or PEM specifications
Adequate Compaction, Smoothness, etc.
Int'l Roughness Index (IRI) & Pavement Cond. Index (PCI)
IRI, PCI, Structural Assessment
Material EPD
Material EPD
Material EPD
Material EPD
Pavement Mixture EPD
Construction Phase of LCA
Use Phase of LCA
End-of-Life Phase of LCA
Pavement Material EPD's
We do this now!
Pavement LCA
We're working on this!


Performance Criteria
Meets BMD or PEM specifications
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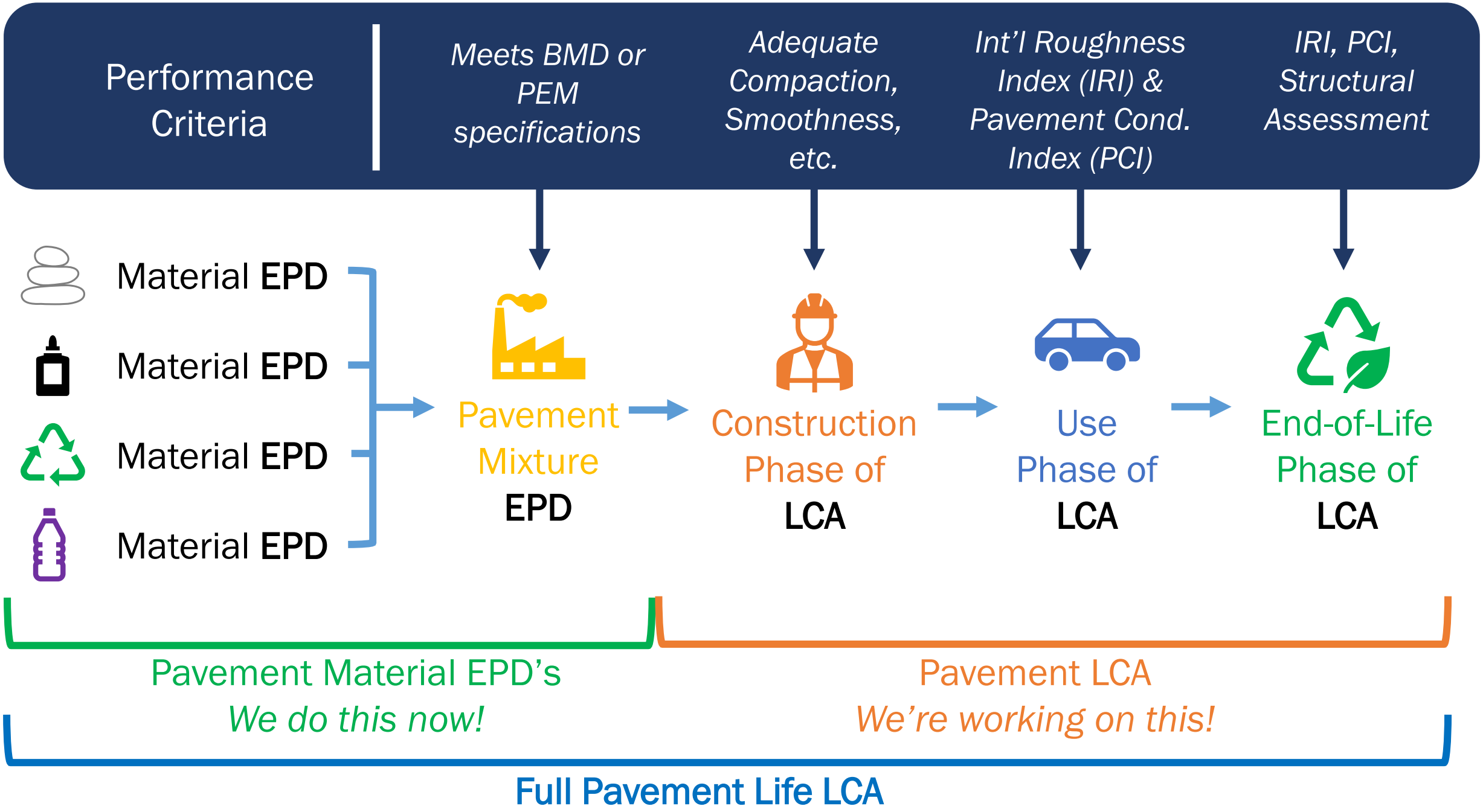
Int'l Roughness Index (IRI) & Pavement Cond. Index (PCI)
IRI, PCI, Structural Assessment
Material EPD
Material EPD
Material EPD
Material EPD
Pavement Mixture EPD
Construction Phase of LCA
Use Phase of LCA
End-of-Life Phase of LCA
Beneficial product of EPD/LCA
Use of local mats & recycling, efficient plant operations
Fewer roller passes, less transportation costs
Enhanced maint. & rehab schedules, PVI, etc.
Re-use of pavement base, onsite/offsite recycling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End-of-Life Phase of LCA
Pavement Material EPD's
We do this now!
Pavement LCA
We're working on this!
Full Pavement Life LCA

Questions?

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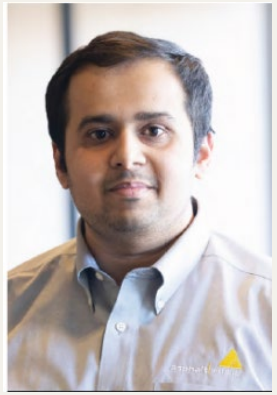
Federal Highway Administration



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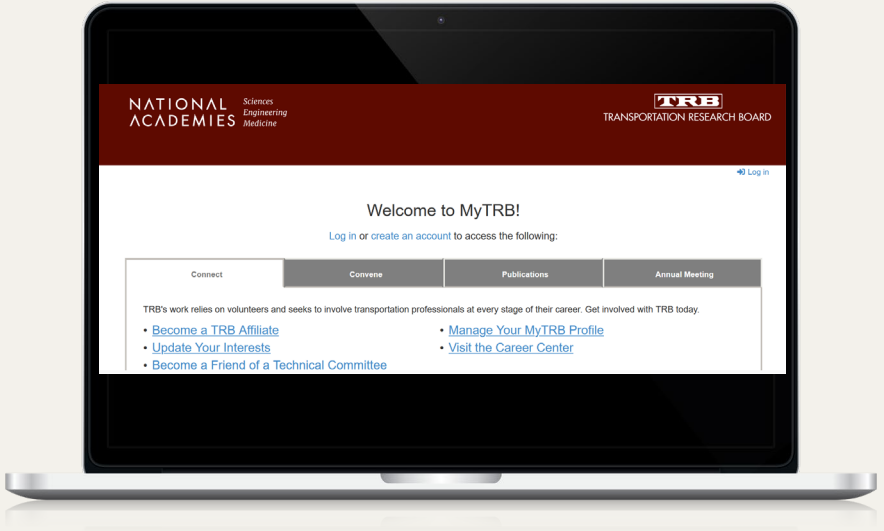

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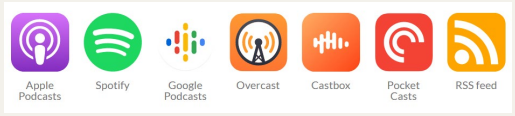

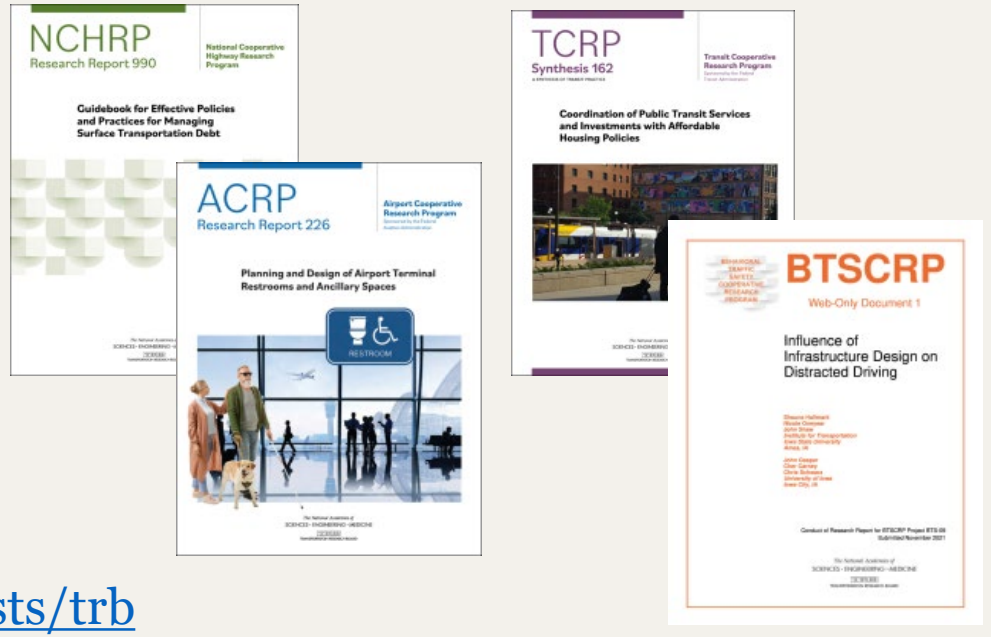

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