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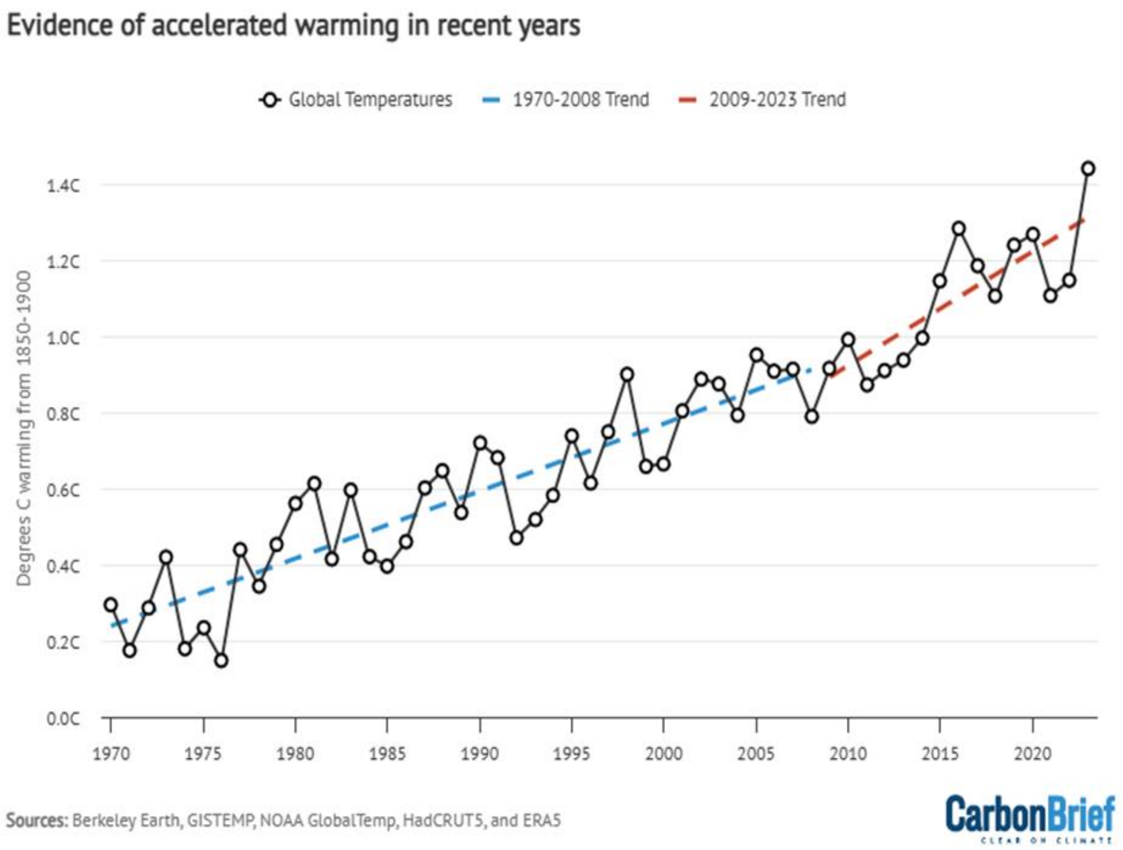
2024 FALL ASPHALT SEMINAR NOVEMBER 28 – 2024

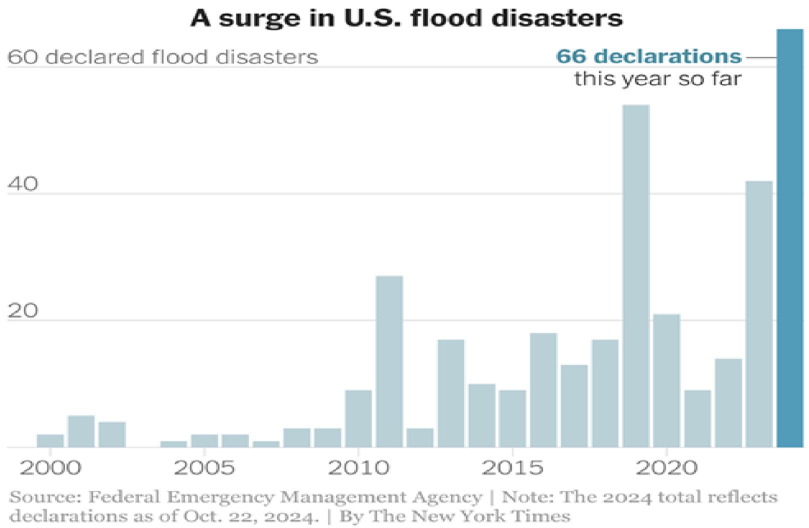
PATHWAYS TO A SUSTAINABLE FUTURE FOR ASPHALT TECHNOLOGY

Decarbonizing the Asphalt Industry: Paving the Way to a Sustainable Future

Jean-Paul Fort
Director of Pavement Engineering & Innovation
National Asphalt Pavement Association (NAPA)

Why Decarbonization Matters





- **Hurricane Katrina (2005):** $160 billion
- **California Wildfires (2018):** $16 billion
- **Fort McMurray Wildfires (2016):** CAD 9 billion

Mitigation (reducing emissions) and Adaptation (building resilient systems) yield a 6-to-1 return *(World Bank)*

Industry Decarbonization Initiative

NAPA National Asphalt Pavement Association

The Road Forward

A Vision for Net Zero Carbon Emissions for the Asphalt Pavement Industry

www.asphaltpavement.org/climate

Strategy towards Net Zero

1. Production & Construction
2. Eco-efficient pavements
3. Supply Chain
4. Electricity

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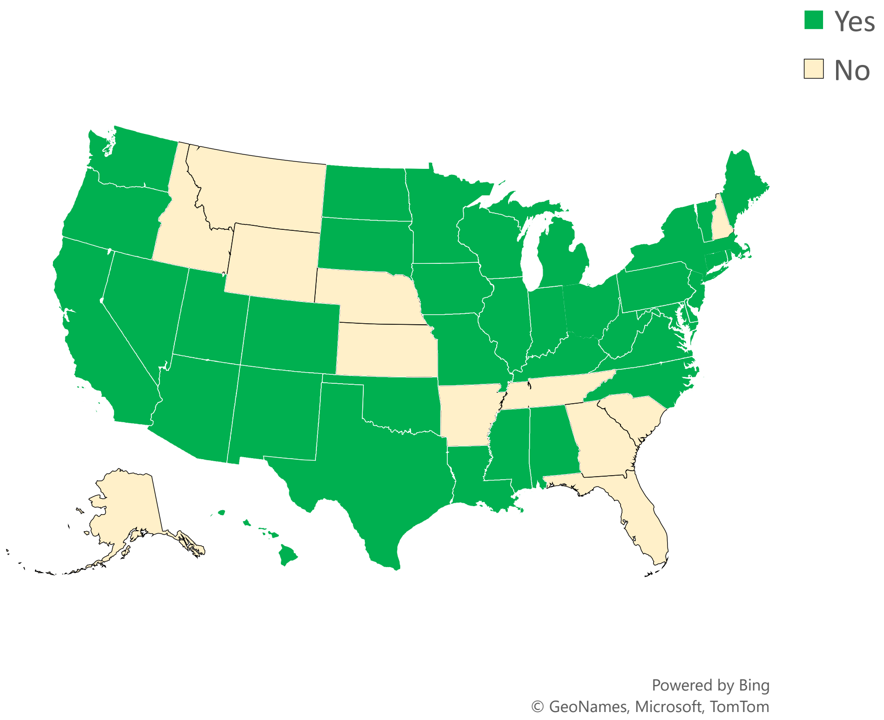
Legislative Decarbonization Initiatives

Federal Initiative:

- U.S. federal government is world's largest purchaser of goods and services ($650B+/year - 2.5% of US GDP)
- ~32% of U.S. construction emissions come from federally funded projects

2022 **$4.5B** IRA funding through GSA **($2.15B)**, FHWA **($2B)**, EPA **($350M)** to fund and promote **Low Carbon Transportation Materials (LCTM).**



39 States engaged in:

- State Buy Clean Programs
- Federal-State Buy Clean Partnerships
- U.S. Climate Alliance
- EDC-7, EPDs for sustainable projects
- FHWA Climate Challenge

Programs require Quantification Tools to Benchmark Low-Carbon Transportation Materials (LCTM)

Path Towards Net Zero Emissions

- **Quantification Tools and Benchmarking Challenges**
- Reducing A1-A3 Production Emissions and Boosting Profitability
- Decarbonizing Subsequent Life Cycle Phases
- Wrap up: Key Steps and Research Needs

The Asphalt Pavement Life Cycle

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A1-A3	• **Materials Production:** Raw materials extraction, processing and asphalt mix production
A4-A5	• **Construction**: Transport to site, paving operations
B1-B7	• **Use Phase:** service life, traffic related emissions
B2-B5	• **Maintenance & Rehabilitation:**, repairs, rehabilitation operations work zone congestion emissions
C1-C4	• **End-of-Life**: Demolition, recycling, or disposal

Cradle-to-Grave

Asphalt Life Cycle Assessment Tools

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Underlying Life Cycle Assessment (LCA)

Update to the Life Cycle Assessment for Asphalt Mixtures in Support of the Emerald Eco Label Environmental Product Declaration Program

April 2022

Environmental Product Declaration — NAPA VERIFIED

Amlan Mukherjee, PhD, PE
Professor
Department of Civil, Environmental & Geospatial Engineering
Michigan Technological University
Houghton, MI 49931

Michigan Tech

For:
National Asphalt Pavement Association
6406 Ivy Lane, Suite 350
Greenbelt, MD 20770-1441

ISO 14040 - 14044

Product Category Rules (PCR)

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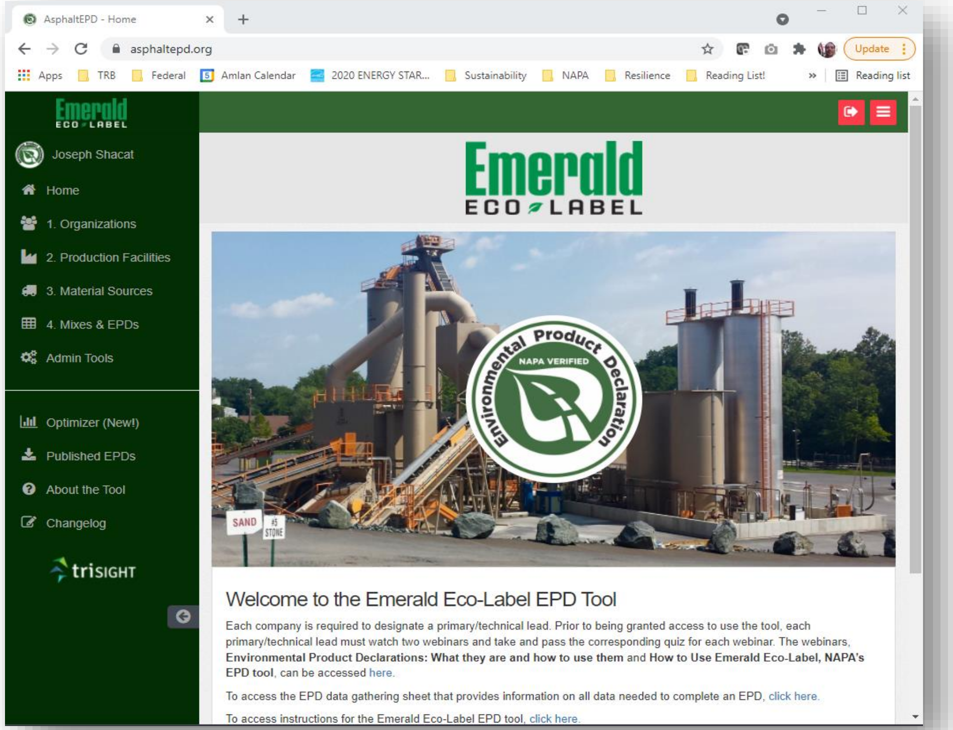
Product Category Rules (PCR)
For Asphalt Mixtures

Version 2.0
Effective Date: April 2022
Validity Period: Through March 2027

6406 Ivy Lane, Suite 350 | Greenbelt, MD 20770 | 301-731-4748
www.AsphaltPavement.org/EPD

ISO 14025 - 21930

Environmental Product Declaration (EPD)



www.asphaltpavement.org/epd

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Environmental Product Declaration Metrics

TABLE 4. LIFE CYCLE IMPACT INDICATORS

ACRONYM	INDICATOR	UNIT	QUANTITY PER METRIC TONNE ASPHALT MIXTURE (PER SHORT TON ASPHALT MIXTURE)			
			MATERIALS (A1)	TRANSPORT (A2)	PRODUCTION (A3)	TOTAL (A1-A3)
GWP-100	Global warming potential, incl. biogenic CO2	kg CO2 Equiv.	33.16 (30.08)	1.69 (1.53)	35.40 (32.11)	70.25 (63.73)
ODP	Ozone depletion potential	kg CFC-11 Equiv.	1.49e-08 (1.35e-08)	1.02e-08 (9.24e-09)	2.22e-07 (2.01e-07)	2.47e-07 (2.24e-07)
EP	Eutrophication potential	kg N Equiv.	8.93e-03 (8.10e-03)	5.03e-04 (4.56e-04)	4.87e-03 (4.42e-03)	1.43e-02 (1.30e-02)
AP	Acidification potential	kg SO2 Equiv.	9.59e-02 (8.70e-02)	8.60e-03 (7.80e-03)	1.29e-01 (1.17e-01)	2.33e-01 (2.11e-01)
POCP	Photochemical ozone creation potential	kg O3 Equiv.	2.00 (1.82)	0.28 (0.25)	2.57 (2.33)	4.85 (4.40)

Plant Specific, Mix Specific:

- Raw materials: A1
- Transport: A2
- Production: A3

Cradle-to-Gate:

- Aligns with the procurement process
- Other stages outside producer control
- Used in LCA studies for subsequent stages

ISO 21930: To be comparable, products shall meet the function i.e., **the same specification**.

Regionally specific

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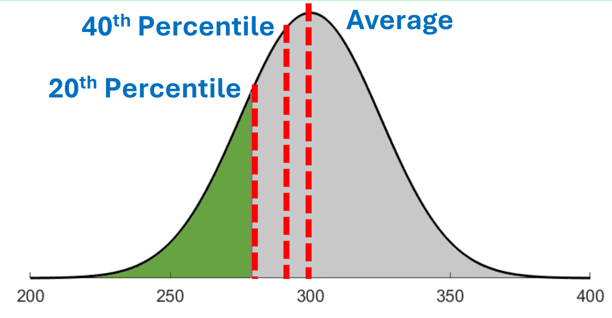
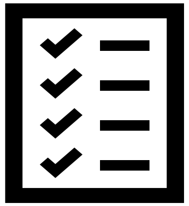
Benchmarking Challenges

EPA Interim Determination

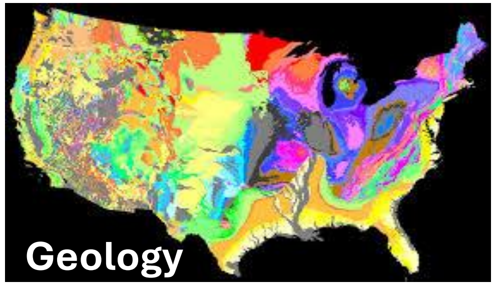
- **Top 20%**: Materials with lowest GWP first
- **Next 40%:** If top 20% materials unavailable
- **Then better than industry average**



Factors beyond Control:



Specifications



GSA – Lower Embodied Carbon Materials

($2.15B – 154 Pilot Projects)

GSA IRA Limits for Low Embodied Carbon Asphalt - May 16, 2023 (EPD-Reported GWPs, in kilograms of carbon dioxide equivalent per metric ton - $kgCO_2e$/ t)		
Top 20% Limit	Top 40% Limit	Better Than Average Limit
55.4	64.8	72.6

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Impact of Factors Beyond Control

Examples of GWP-100 of 3 Unmodified Surface Mixes Binders

3 Plants Locations	Kg CO2e / METRIC TONNE ASPHALT MIXTURE			
	MATERIALS (A1)	TRANSPORT (A2)	PRODUCTION (A3)	TOTAL (A1-A3)
Midwest Plant @ Quarry, 24% RAP	33.16	1.69	35.40	**70.25**
Specification Impact on A1: Western State 20% RAP + 1% $CaOH_2$	48.95	18.39	25.51	**92.86**
Geology Impact on A2: Central Florida 20% RAP	26.16	73.27	22.98	**122.42**

GSA Maximum: 72.6 kg CO2e / Ton

- **$CaOH_2$:** 1,388 kg CO2e / ton → 1% equates to = + 14 kg CO2e / ton of mix.
- **Florida**: need to ship aggregates from Georgia, Alabama, or Nova Scotia

State-Specific Benchmarking

FHWA supports industry-driven regional benchmarks

Emerald ECO LABEL

GWP for A3

GWP for A2

GWP for A1

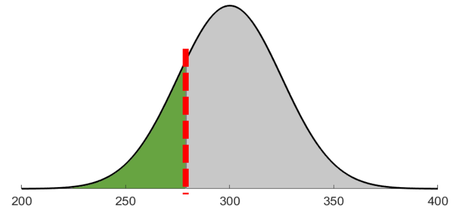
A3 Production & Climate impact: BM data → State-specific GWP thresholds

A2 Geology Impact: BM data → State-specific GWP thresholds

A1 Design Specifications Impact → National Level GWP thresholds based on key categories - BM and EPD data

National Level Benchmarks Regionalized by State.

$$[\sum_1^n (A1 + A2 + A3)]_{State}$$



https://go.asphaltpavement.org/sip-108

Credit: Ben Ciavola - WAP

Benchmarking Asphalt Mixes

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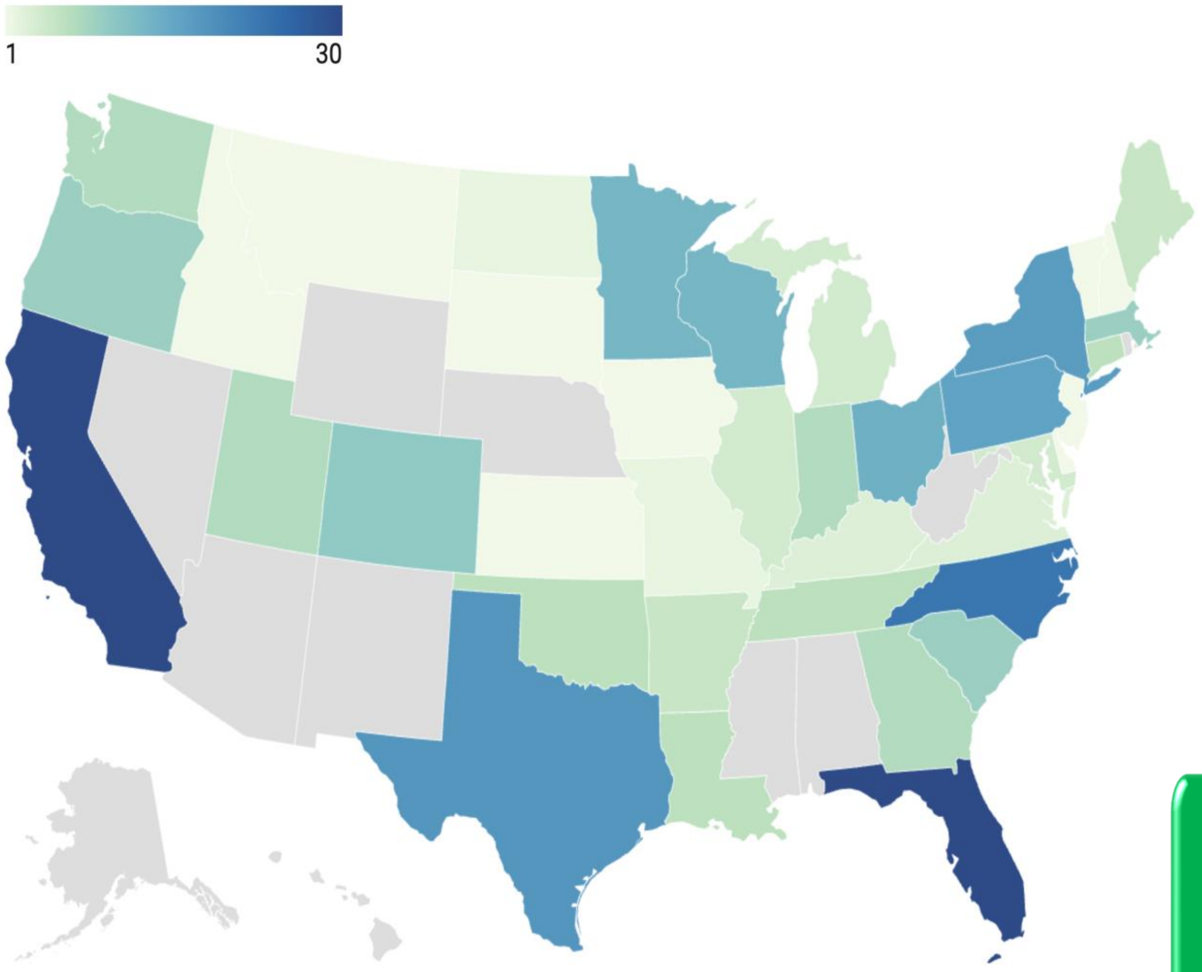
47 States

161 Organizations

526 Plants

2510 Mixes



https://go.asphaltpavement.org/sip-108

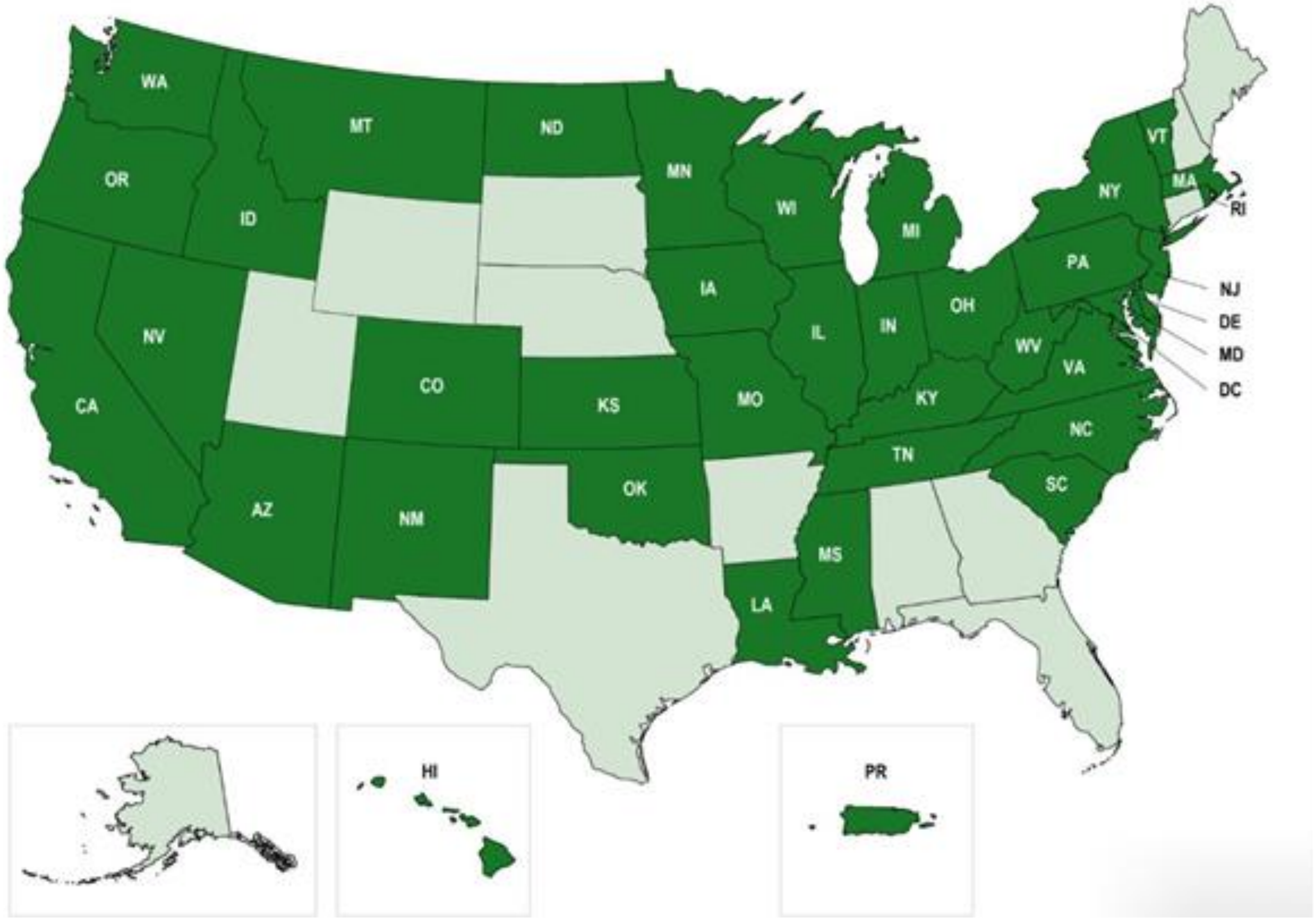
Industry Efforts

Emerald ECO LABEL

Equitable GWP Thresholds for $2B LCTM Grant Program for DOTs.

FHWA LCTM Grants Current Status

- 39 state DOTs are receiving the combined $1.2B LCTM Grants.
- These grants will enable state DOTs to purchase LCTMs
  - Benchmarking to define LCTM GWP thresholds
  - Conduct training and outreach with Industry
  - Align Benchmarking and State Specifications
  - Monitoring Performance

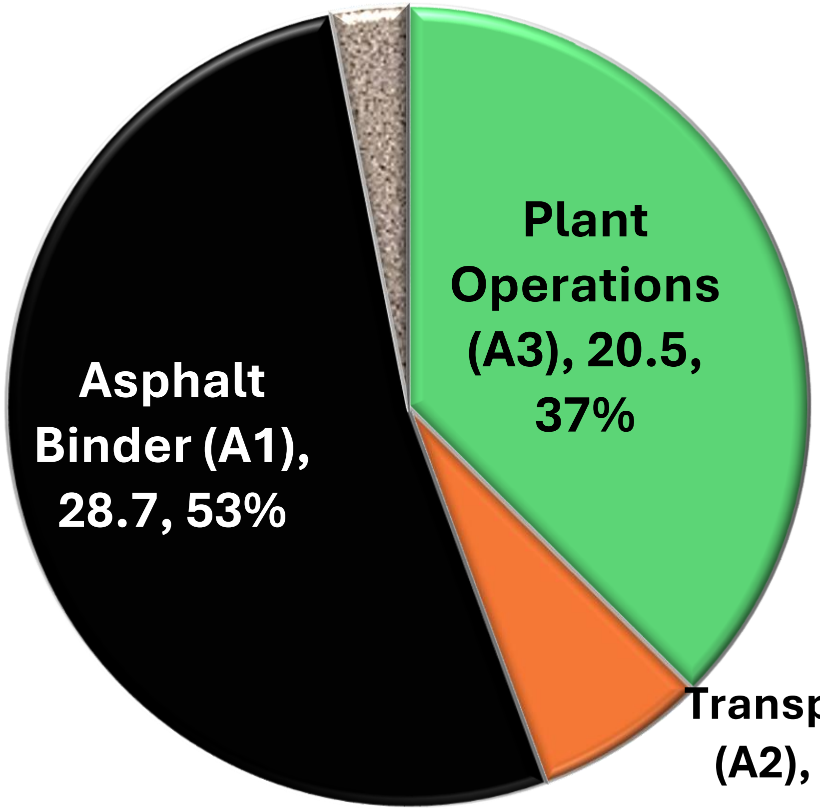


https://www.fhwa.dot.gov/lowcarbon/statedotgrants_fy22.cfm

Path Towards Net Zero Emissions

- Quantification Tools and Benchmarking Challenges
- **Reducing A1-A3 Emissions, and Boosting Profitability**
- Decarbonizing Subsequent Life Cycle Phases
- Wrap up: Key Steps and Research Needs

Cradle-to-Gate Emissions Breakdown



Reference Asphalt Mix: standard mix, no RAP, 5% AC

The bulk of emissions are generated by:

1. A1 (56%), especially AC (53%)
2. A3 Burner ~ 30%

Primary GWP Reduction Levers:

- **Raw Materials (A1):** Increase % of Recycled
- **Burner Emissions (A3):** Materials Moisture, Plant Efficiency, Production T°

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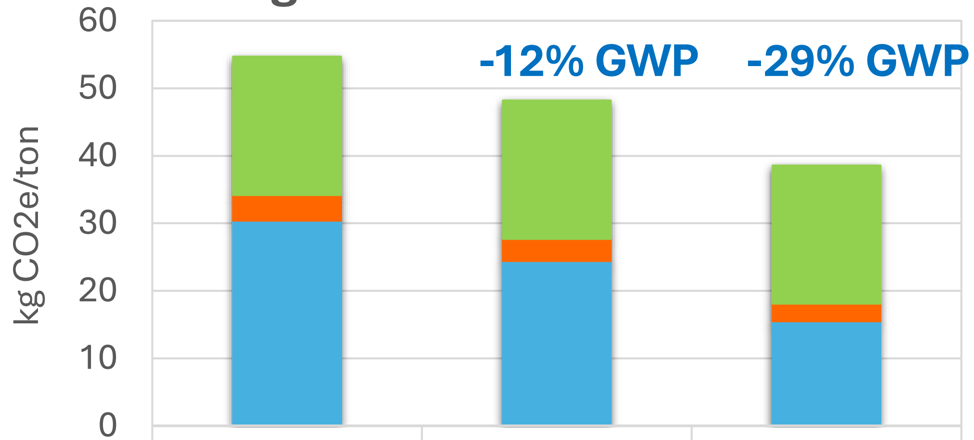
A1 : Benefits of Using RAP

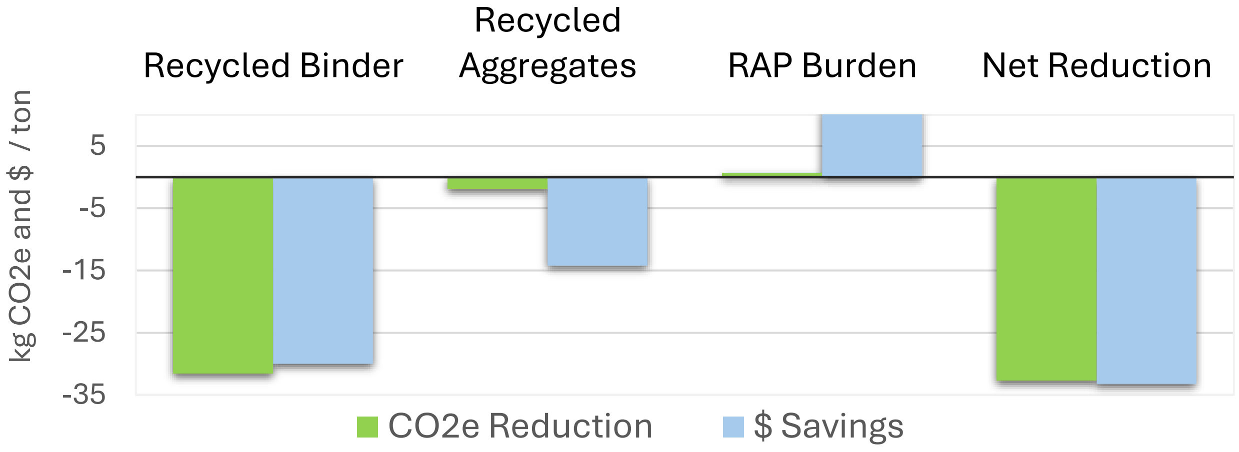
Kg CO2e / ton vs. % RAP



	0%	20%	50%
Total (A1-A3)	54.7	48.2	38.6
Plant Operations (A3)	20.5	20.5	20.5
Transport (A2)	3.8	3.30	2.6
Binder & Aggregates (A1)	30.4	24.40	15.5

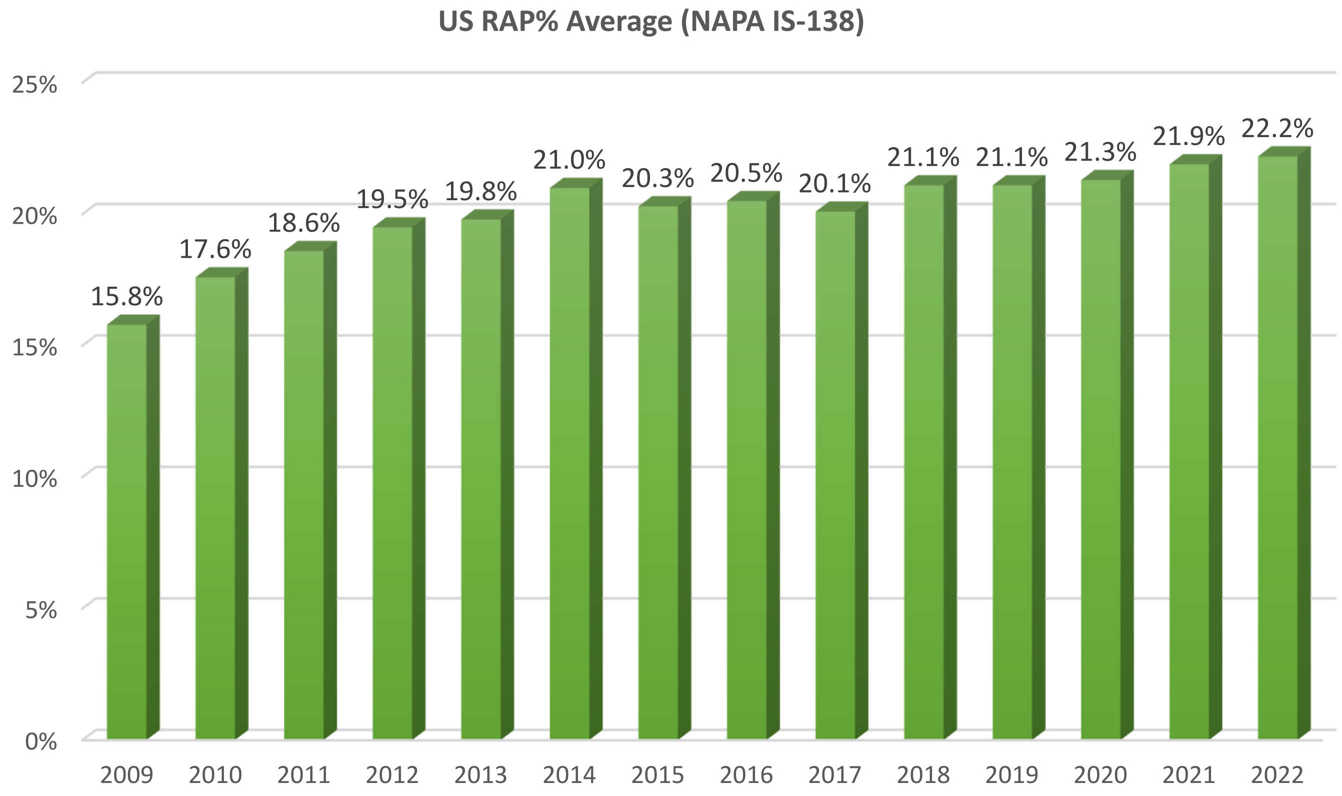
+1% RAP: ~ -0.33 kg CO_2 & ~ -$0.33 / mix ton

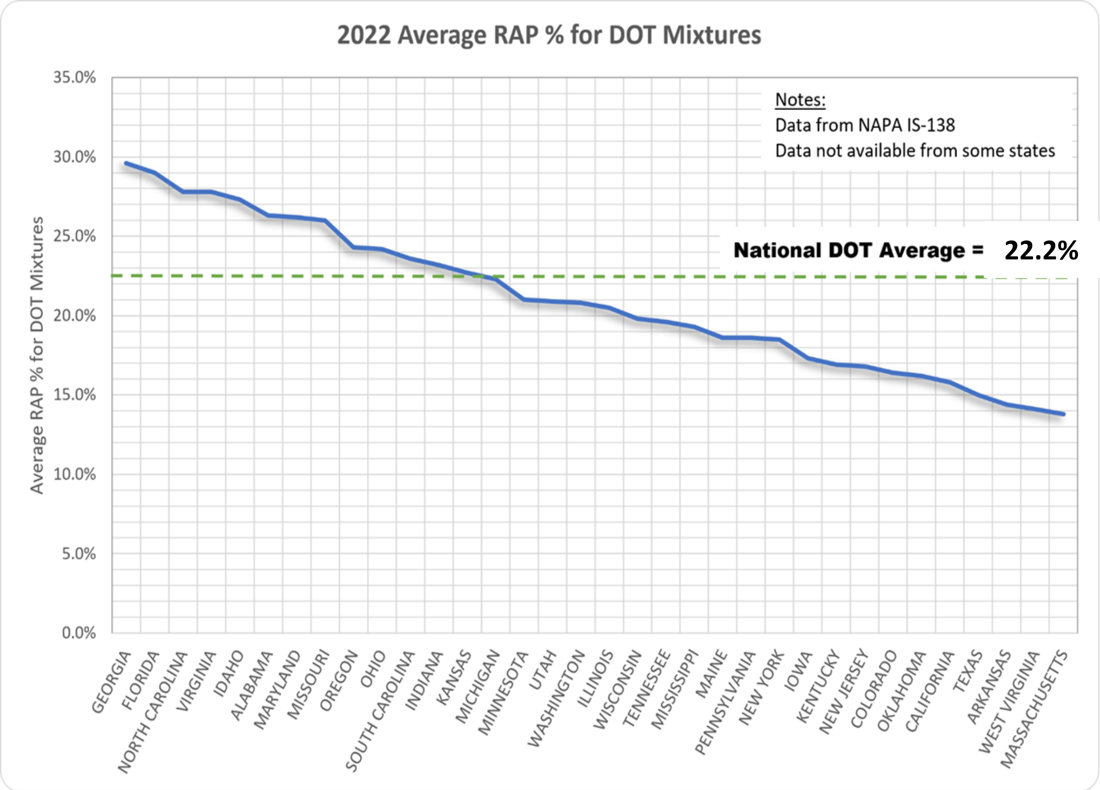
CO2e Reduction and $ Savings with RAP



	5% Recycled Binder	95% Recycled Aggregates	Processing Burden	Net Reduction per ton of RAP
kgCO2e/ton	-632 * 5% = **-31.6 kg**	-1.94 * 95% = **-1.84 kg**	**+ 0.71 kg**	**-32.7 kg CO2e**
$	-$600 * 5% = **-$30**	-$15 * 95% = **-$14.25**	**+ $11.0**	**-$33.3**

RAP usage Evolution in the USA





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Barriers to Higher RAP usage

Agencies Concerns (2023 Survey)

Reduced Service Life

- RAP binder stiffness & availability
- RAP gradation & binder consistency
- PM binders' contribution

Production Factors

- Batch plant limitations. Drum Plants Heat Transfer Capacity....
- Dust control Systems
- Accessibility to Softer PG

Outdated Specs

- Viscosity-based blending charts
- Volumetrics-only Specifications

Sourcing Constraints

- Significant local constraint

Actions to Increase RAP usage

What High RAP States Specify:

- Supplement Virgin Binder
- RAP Processing & Fractionation
- Stringent Quality Testing
- Contractual Incentives

What they Consider:

- Specifications Updates (PG blending charts, Balanced Mix Design)
- Use of Recycling Agents
- Green Public Procurement (EPDs)

Industry Best Practices:

- **Optimize Production for RAP Binder Activation**: adjust production T°, TPH, to RAP%
- **Stockpiles Moisture Control**: paved grade, covers
- **Accessibility to Softer Binders:** tanks, inline blending
- **Plant Upgrades**
- Evaluate **Recycling Agents** use and their introduction method.

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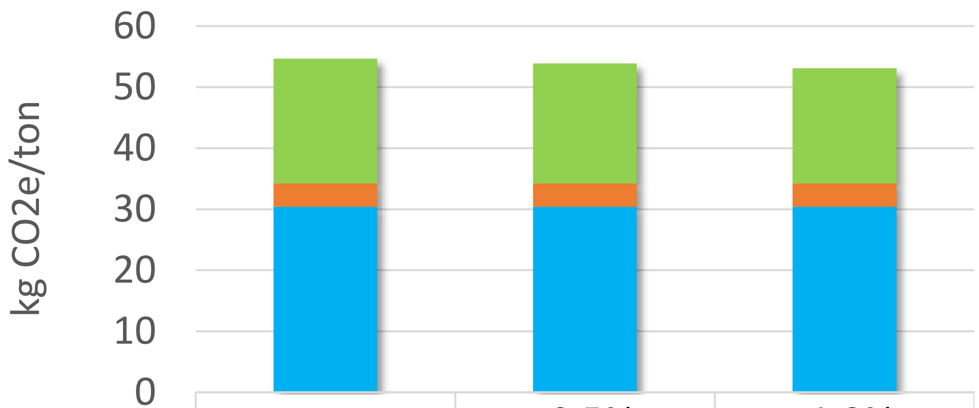
A3 : Benefits of Controlling Moisture

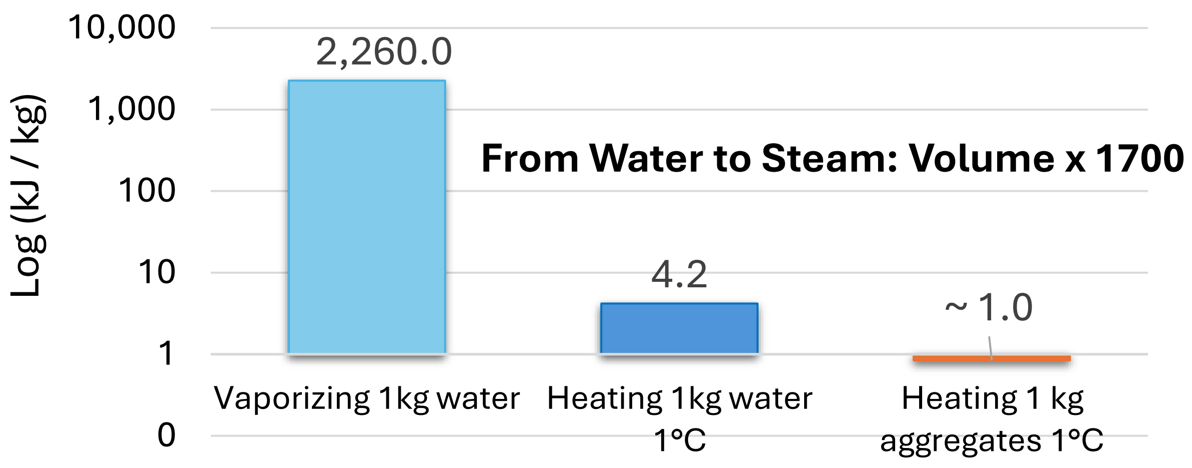
Kg CO2e / ton vs. % Moisture



		-0.5%	-1.0%
Total (A1-A3)	54.7	53.9	53.1
Plant Operations (A3)	20.5	19.7	18.9
Transportation (A2)	3.8	3.8	3.8
Materials (A1)	30.4	30.4	30.4

- 1% H_2O: ~ -1.6 kg CO_2e / ton (NG)

Impact of Moisture



~50% Plant Energy used to Dry Materials

- 1% H_20 = -11% Energy + 11% Production

Materials must be dried before be heated

A3 : Benefits of Controlling Moisture

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Stockpile Moisture Mitigation Payback Evaluator						
INPUT						
Item	As-Is	Mitigation	Mitigation Total Cost, $		10,000	
Annual Production, Tons	80,000					
Agg. Composite Moisture, %	5.2	4.6				
Plant Burner Fuel (Drop Down)	Natural Gas					
ANALYSIS						
BTU/ Ton Reduction	14,400		Savings, $		Payback	
Plant Burner Fuel	Natural Gas		Per Ton	Per Year	Years	Months
			0.13	10,164.71	1.0	11.8

Case Study: Michigan Paving (CRH)

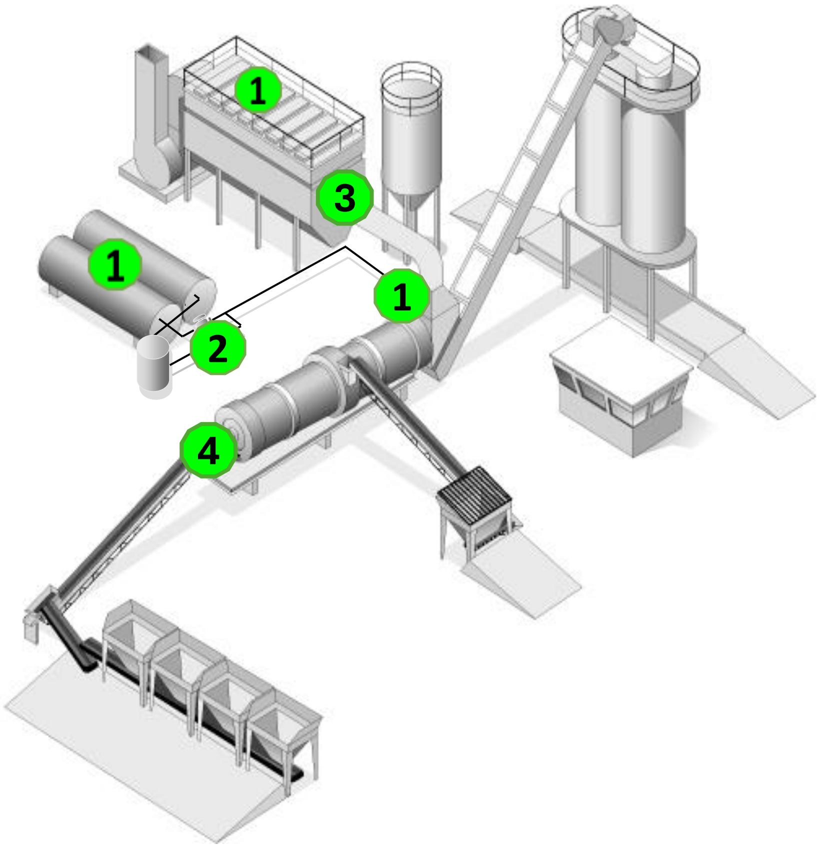
Paved pad below Fine Agg. Pile (20% plant tonnage)

- **Annual Composite Moisture Reduction:** 0.6%
- **Energy Savings:** - 17 MJ/MT (Natural Gas)
- **Cost Savings:** $0.13/ton of mix, totaling over $10,000 annually, fully offsetting paving cost.

~ - 28 MJ / MT mix by % H_2O Reduction

- $0.22/ ton mix by % H_2O Reduction

A3 : Benefits of Improving Plant Efficiency



Plant Improvements

	Measure	Btus Savings
1	**Insulation:** tanks, lines, dryer , ducts, baghouse…	5% to 10%
2	**Air leaks:** drum inlet, burner assembly, seals..	5% to 10%
3	**Reduce Stack T° :** adjust flighting, VFD	~ 1% per 10°F
4	**Burner:** Regular tune-up, fuels types	~ 3%

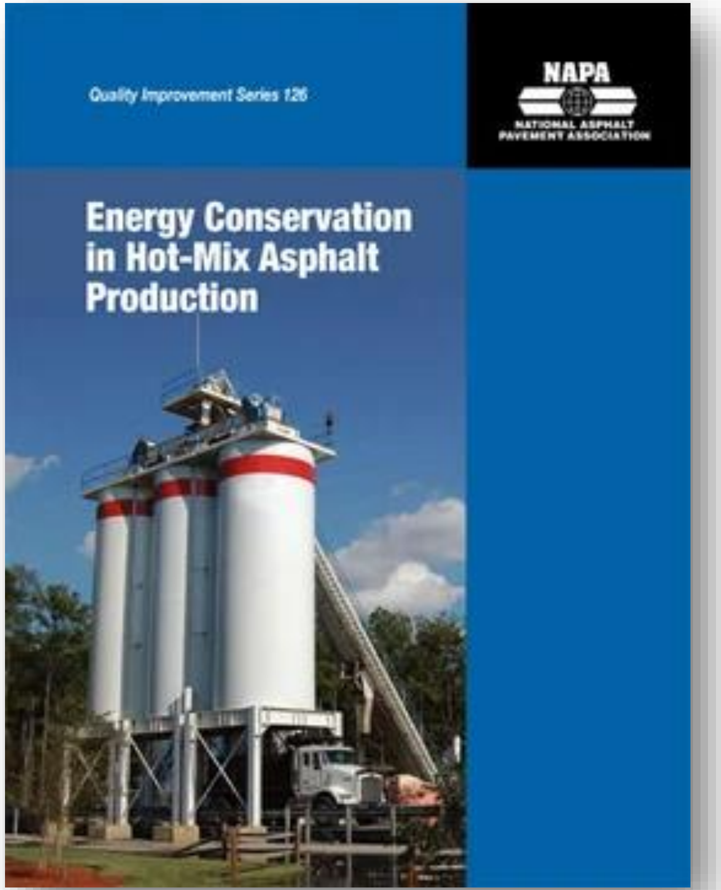
10 - 20%, Energy savings and A3 Emissions reduction.

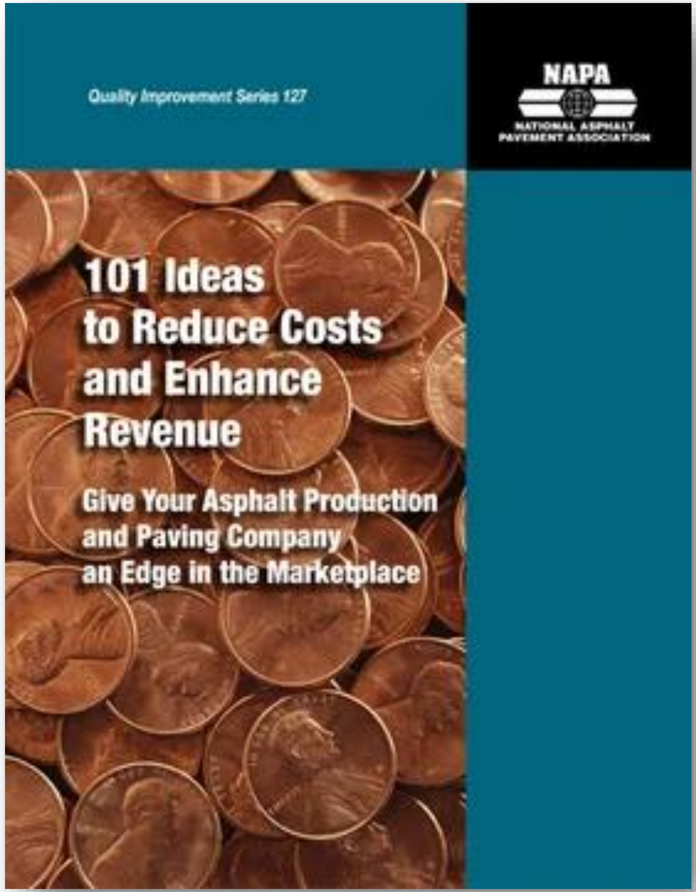
Plant Operations

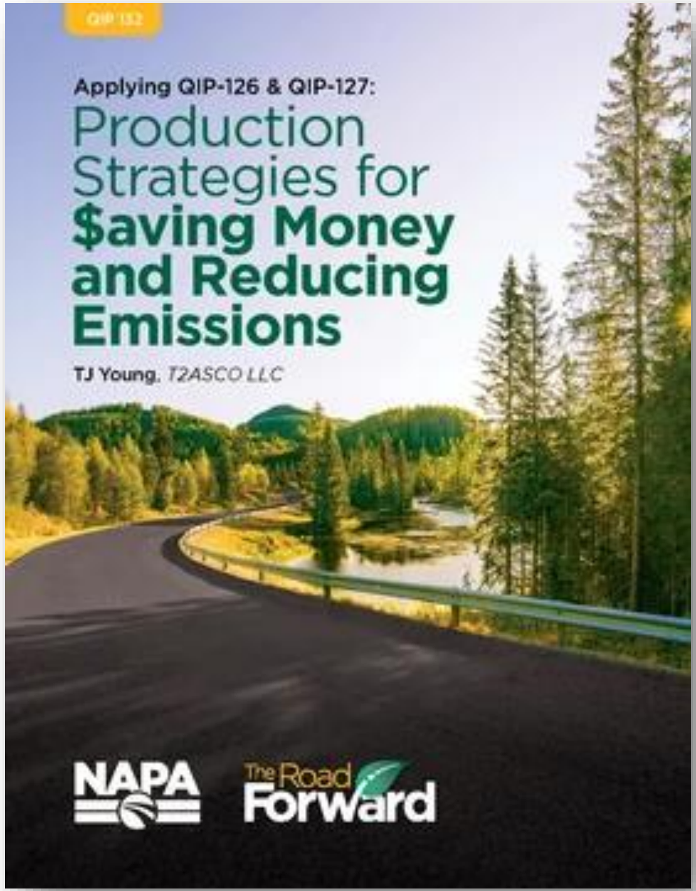
- *Reducing start and stops*: Silos, Scheduling
- *Waste:* start & stops, mix transition, leftovers, rejected loads…
- *New Technologies:* Automation, Moisture & T° Probes

Plant Efficiency Improvement reduces Emissions and Saves Money

A3 : Plant Efficiency Resources







https://go.asphaltpavement.org/production-strategies-for-saving-money-and-reducing-emissions-lp

A3 : Benefits of reducing Production T°

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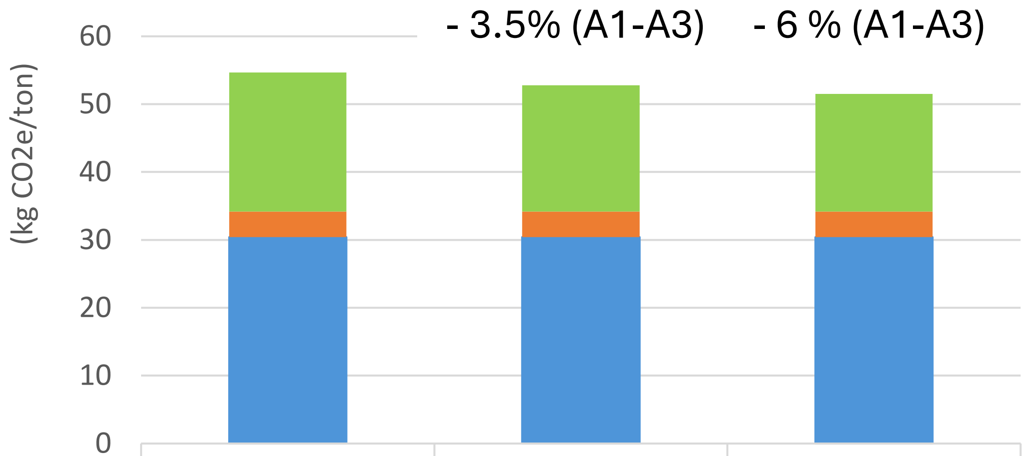
kg CO2e/ton vs. Production Temperature



		-17C	-28C
Total (A1-A3)	54.7	52.8	51.5
Plant Operations (A3)	20.5	18.6	17.3
Transportation (A2)	3.8	3.8	3.8
Materials (A1)	30.4	30.4	30.4

Assuming ~ 0.002MJ/°C/ MT Energy Savings (NCHRP 9-47A)

Impact of Production T° Reduction

- 30°C reduction → 15% ~ 20% Energy Savings
- Reduced Binder aging
- Below 135°C,
  - ~ 75% VOC emissions reduction
  - ~ 90% PM10 and PM2.5 reduction

Reduced Workers' Exposure

2023 WMA barriers Survey:

- Low in place density
- Moisture-induced performance issues
- Limiting RAP usage
- cost

Lowest Feasible T° that ensures Aggregate Drying, RAP Activation and Target in-place Density

*

A3 : Benefits of reducing Production T°


Credit COLAS


Credit COLAS

Case Study: DELTA Missouri (COLAS)

2009 -2010 Rehabilitation of I-55 (over PCC)

Project: 234,000 MT - 106 lane-km

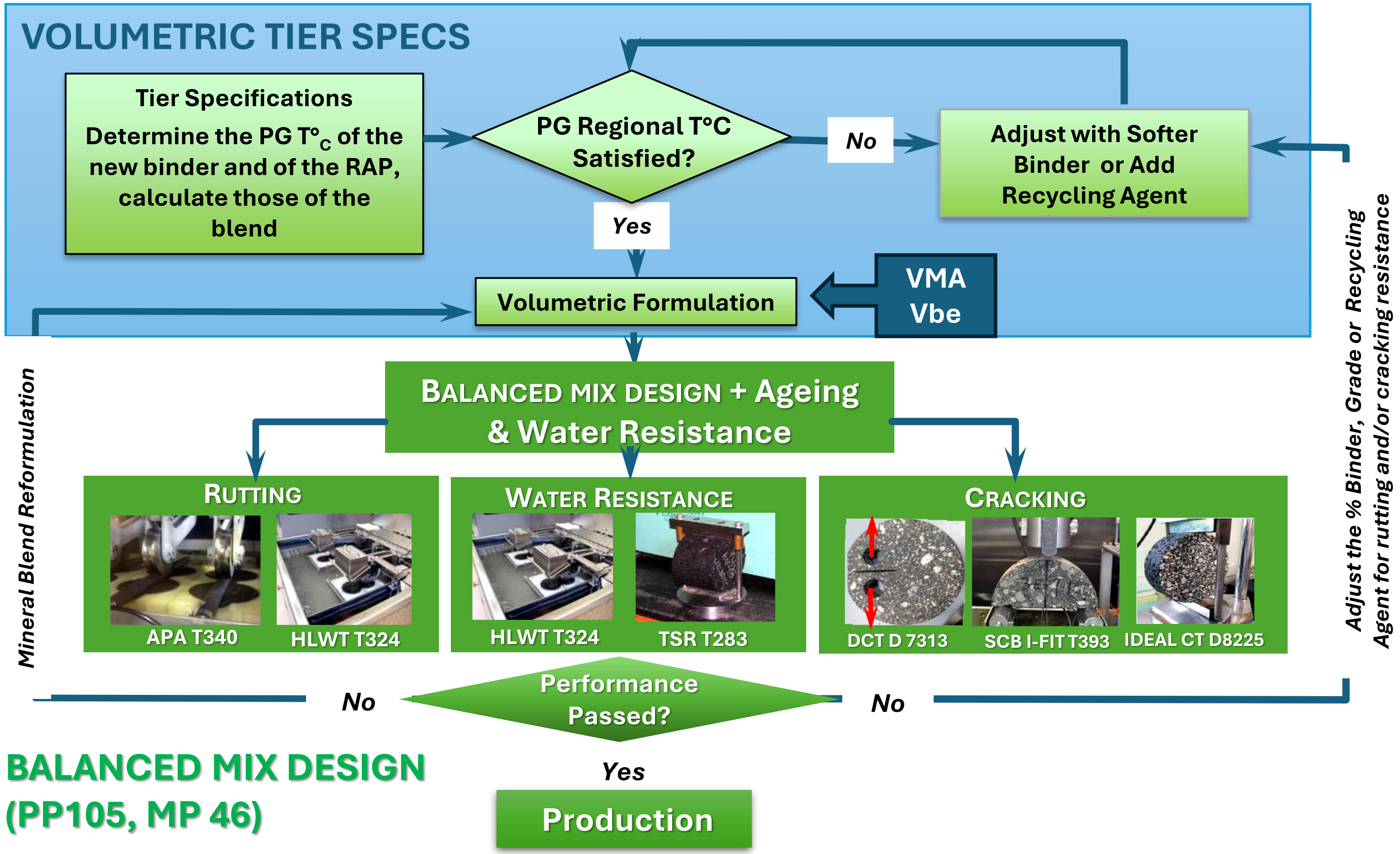
- **Plant**: 400 t/h mobile parallel flow with foam device
- **Fuel**: RFO / Diesel
- **Base**: 5-cm SP19-mm, PG 76-22,0% RAP, 125-Gyr - **HMA** vs. **WMA**
- SMA Surface & Marshall shoulders

Base: Jun.-Dec. 09	**HMA Base**	**WMA Base**	
Tonnes (metric)	**77,000**	**64,000**	**141,000**
Av. Production T°	**175°C**	**145°C**	**-30°C**
S/P Av. H_2O %	**1.8%**	**1.7%**	
MJ/MT (kBtus/t)	**280 (241)**	**238 (205)**	**- 15%**
A3* (kgCO2e /MT)	**25.3**	**21.4**	**- 3.9**

* Carbon Intensity RFO/Diesel: ~90kg CO2e/GJ

- **Mix Performance:** Improved rutting and cracking resistance, with preserved SBS properties from reduced aging at lower temperatures.
- **Field Compaction**: 94% Gmm compaction achieved @ -20°C

Balanced Mix Design Benefits



1. **Blending Chart Limitations:**
   Lab and extraction blending assume full RAP binder activation which does not reflect (variable) field conditions.

2. **Volumetric Design Limitations:**
   - Effective binder volume (Vbe) indicates RAP binder contribution but relies on unreliable Gsb measurements.
   - Blind to PMBs, Additives, WMA…etc.

BMD Tests (HWTT, IDEAL CT, SCB IFIT…)

- Sensitive to Vbe changes in real-time under varying production conditions.
- Reflect Binders & Additives performances

Balanced Mix Design Resources

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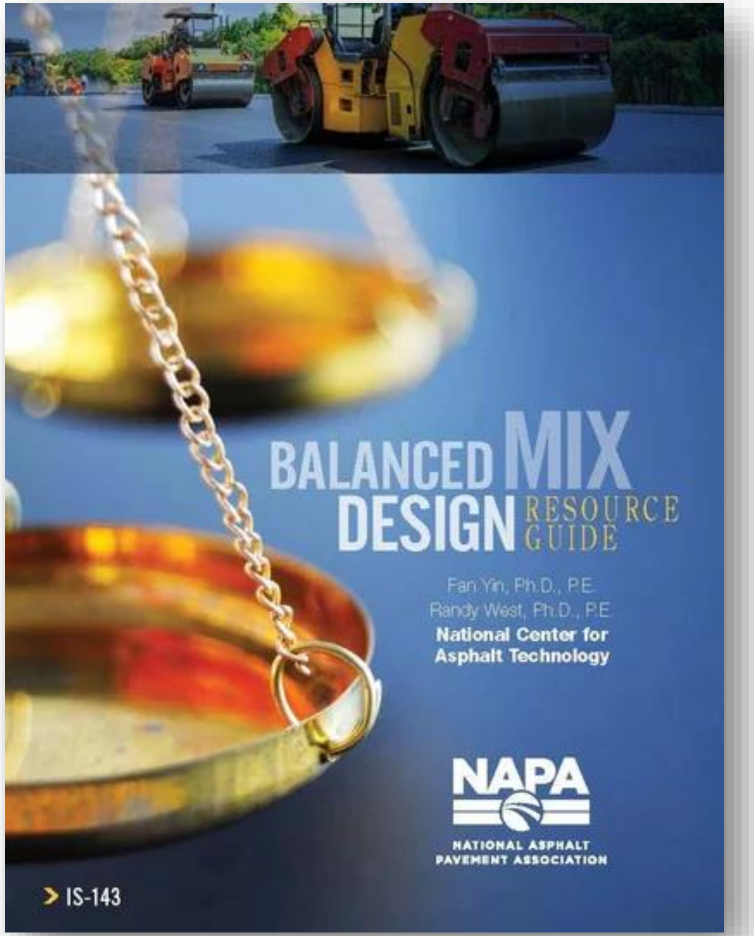

[balanced-mix-design-resource-guide]

Balanced Mix Design, Special Report 228

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GUIDANCE ON PROGRESSING THROUGH
BMD APPROACHES

Randy West and Fan Yin

INTRODUCTION

Balanced Mix Design (BMD) continues to be one of the most talked about topics in the asphalt pavement industry. As the State Departments of Transportation (DOTs) work toward BMD implementation, one of the important early decisions is how to approach BMD for mix design approval. This guide presents the pros and cons of different approaches in AASHTO PP 105 to implement the new BMD performance tests that DOTs should consider in this decision. Other relevant guide documents for implementing BMD specifications and conducting field validation of performance test criteria can be found on the National Asphalt Pavement Association (NAPA's) Balanced Mix Design Resource Guide website.

WHY CHANGE?

The motives for any change are typically rooted in dissatisfaction with the status quo. Feedback from BMD Peer Exchanges in 2023 (Bittner et al., 2023a; Bittner et al., 2023b; Bittner et al., 2023c) indicates that the most common reasons why state DOTs want to implement BMD include:

- Improving the service lives of asphalt pavements
- Eliminating premature failures of some asphalt pavements
- Reducing the carbon footprint of asphalt pavements
- Optimizing asphalt mixtures for specific applications

Most stakeholders realize that it is not possible to accomplish the above goals by continuing to use existing specifications, mix design practices, and construction methods. Although tweaks to existing Superpave specifications and methods, such as with Superpave 5, regressed air voids, and the corrected optimum asphalt content (COAC) concept, can provide some performance improvements, they do not fix the underlying limitations of a volumetric mix design system.

There are two recognized deficiencies of mix design systems based on volumetric properties: (1) the reliability and accuracy of VMA are challenging because of the difficulties in accurately determining the bulk specific gravity (G_{sb}) of aggregates, and (2) there is no way to determine the interaction effects of virgin binders, recycled binders, and other additives such as recycling agents. These issues are further discussed below.

Concerns regarding VMA

The two primary volumetric properties used in asphalt mix design and QA specifications are air voids (V_a) and voids in the mineral aggregate (VMA). Air voids represent the volume of void space within a compacted specimen at a specific compactive effort, which has been related to rutting resistance (Brown and Cross, 1992). VMA is defined as the volume of the intergranular void space between the aggregate particles of a compacted asphalt mixture that includes the air voids and the effective binder content. A minimum VMA is important to ensure a mixture contains an adequate volume of effective asphalt. Although many asphalt technologists know that the minimum VMA criteria were established by Norman McLeod in the late 1950s, some are surprised to know that he provided no mix performance data to support the criteria (Kandhal et al., 1998). Numerous other researchers have also discussed the weakness of VMA as a mix design criterion (Coree & Hislop, 2000).

[BMD approaches]

NAPA BMD Resource Guide

NCAT BMD Webpage:

CAPRI BMD Webpage:

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oapc ontario asphalt pavement council

PATHWAYS TO A SUSTAINABLE FUTURE FOR ASPHALT TECHNOLOGY

Strategy for A1-A3 Emissions Reduction, & Profitability

	Moisture	RAP Content			Production T° (C)	
unit per ton mix	-1%	1%	20%	50%	- 14°C	-28°C
Energy	~ -30 MJ/T				~ -29 MJ/T	-58 MJ/T
kg CO2 e /MT	-1.60	-0.33	-6.5	-16.4	-1.45	-2.90
$ / Ton mix (NG)	-$0.10 > -$0.20	-$0.33	-$6.9	-$17.1	-$0.10	-$0.17

All estimates based on Natural Gas with:

- *NG carbon Intensity: 0.058 kgCO2e/kBtu*
- *NG cost (5Y average): $3.40/ Million Btu*

Boost profitability and reduce A1-A3 CO_2 Emissions by:

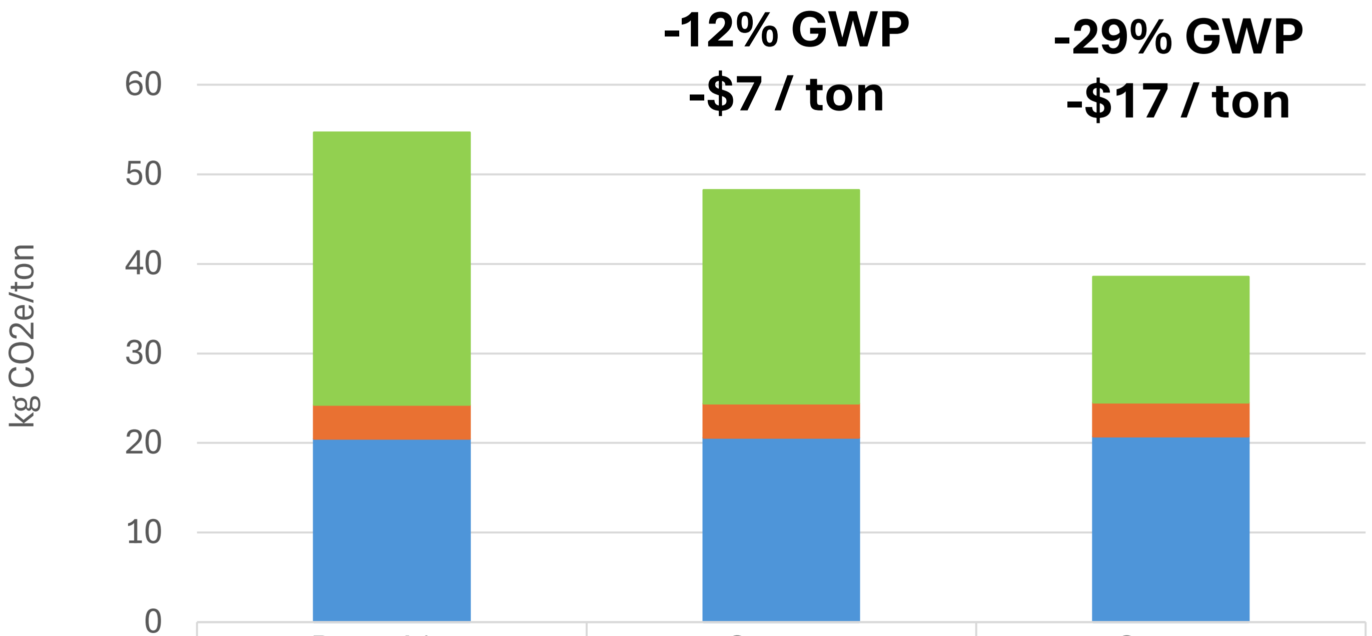
(1) Controlling Materials' Moisture,

(2) Increasing RAP

(3) Adjusting Production Temperatures

Strategy for A1-A3 Emissions Reduction, & Profitability

- **Base Line**: 0% RAP
- **Case 1:** -1% H_2O, +20%RAP, -14°C
- **Case 2:** -2% H_2O, +50%RAP, -28°C



	Base Line	Case 1	Case 2
Total (A1-A3)	54.7	48.3	38.6
Plant Operations (A3)	30.4	23.86	14.05
Transportation (A2)	3.8	3.8	3.8
Materials (A1)	20.5	20.6	20.7

Strategy for A1-A3 Emissions Reduction, Profitability & Performance

1. Control Materials Moisture

- Boosts profitability: **-$0.10 to -$0.20 per %/T**
- Reduces CO_2 emissions**: -1.6 kg CO_2 per %/T**
- Improves performance
- Supports RAP increase and lower Production Temperatures

1. Plant Operations Efficiency: ~15% Energy & A3 Emissions savings

- Insulate tanks, lines, drum, ducts, baghouse
- Seal air leaks (drum inlet, burner, seals)
- Optimize burner (tune-up, fuel type)
- Lower exhaust air temperature (flighting, VFD)
- Minimize waste

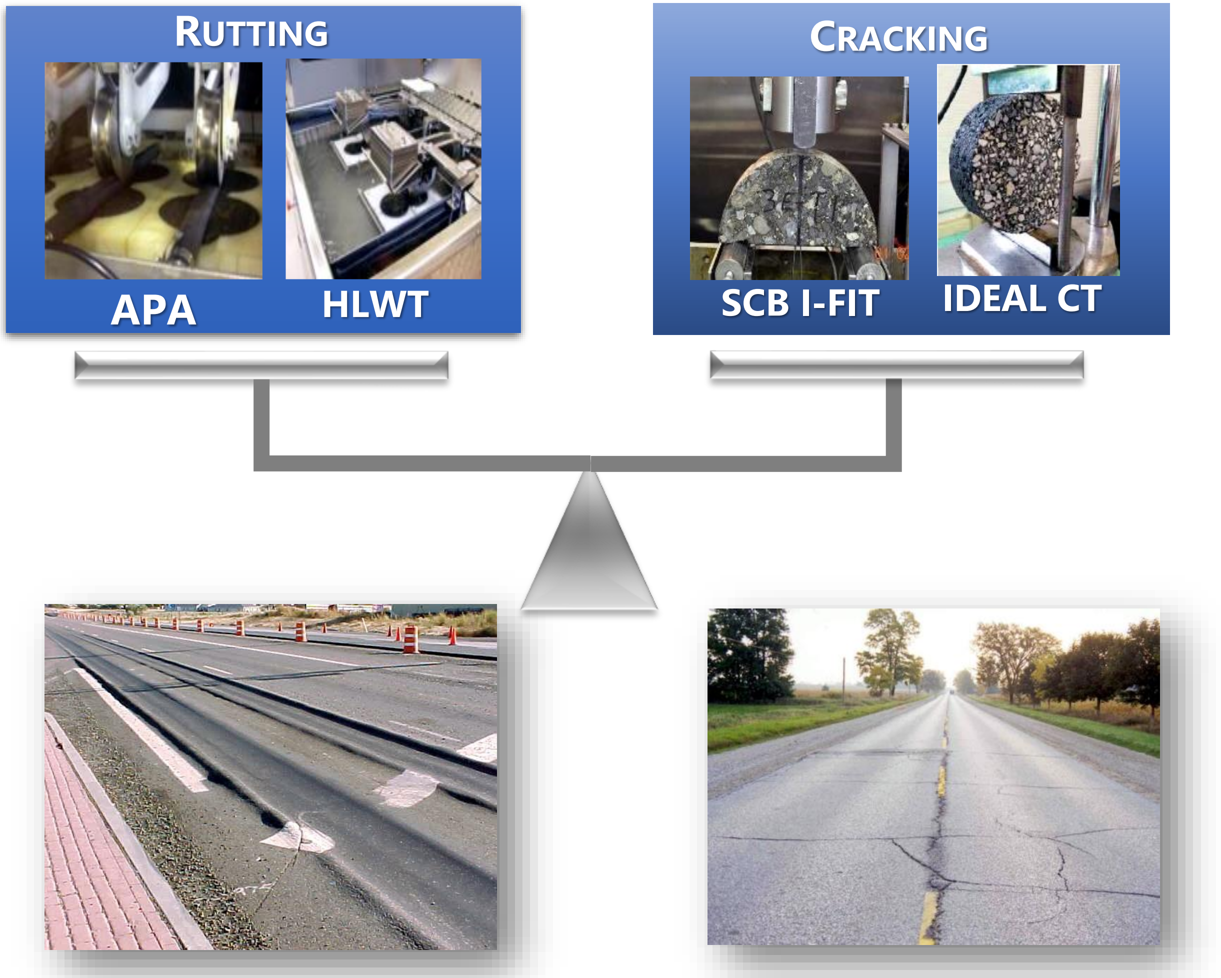
2. Increasing Recycled Asphalt Materials %

- High profitability : **-$0.33 per %/T**
- Strong impact on CO2e reduction **: -0.33kg CO2e per %/T**

3. Production T° reduction

- Profitability: **~ -$0.01/ per °C/T (NG)**
- Contributes to CO2e reduction: **-0.10 kg CO2e per °C/T**
- Reduction of VOC, PM emissions & ageing , **workers exposure**

Balanced Mix Design

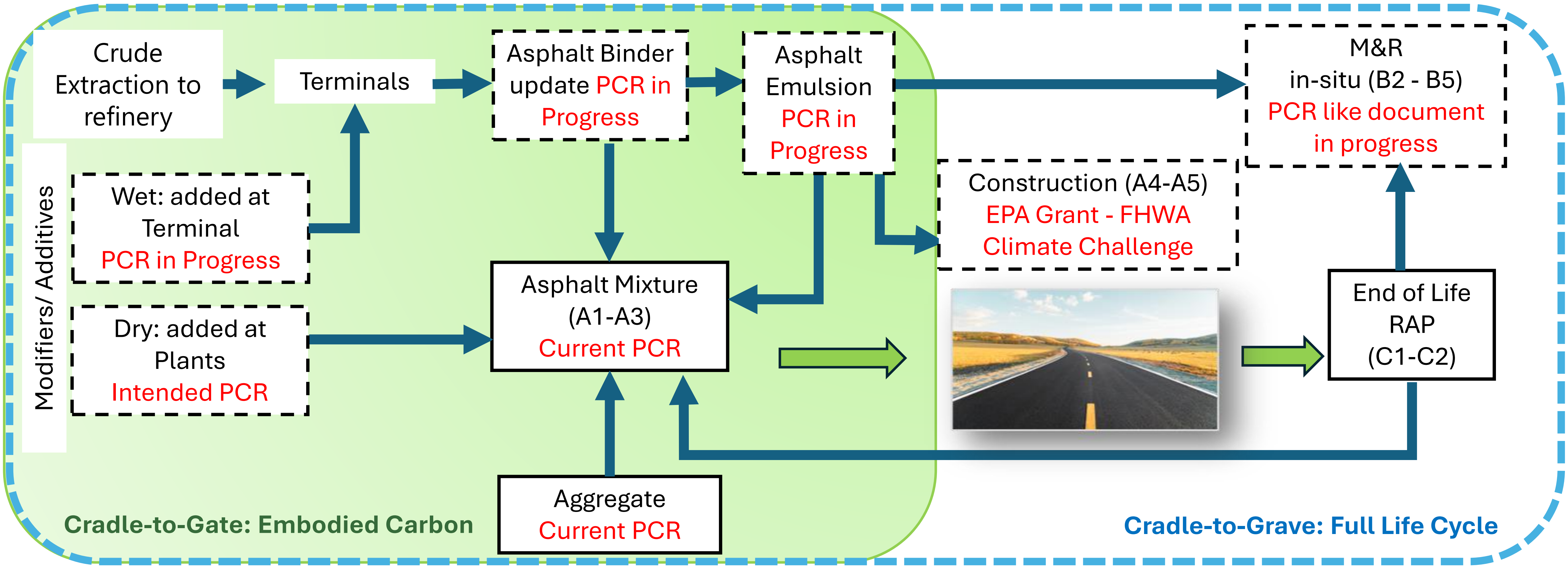


asphaltpavement.org/bmd-resource-guide

Path Towards Net Zero Emissions

- Quantification Tools and Benchmarking
- Reducing A1-A3 Production GWP and Boosting Profitability
- **Decarbonizing Subsequent Life Cycle Phases**
- Wrap up: Key Steps and Research Needs

LCAs & PCRs Development Status



Legend

Pavement Life
Material flow

FHWA – Pavement PCR including Use ((B1, B6, B7)
PCR like document in discussion
Incentives to adopt GPP: FHWA - LCTM

Credit Amlan Mukherjee - WAP

New Pavement Construction (A4-A5)

- **Transport to Jobsite (A4)**
  - Project-specific, no national benchmark
  - Probably ~3-5 kg CO_2e/ton mix in most cases
- **Pavement Construction (A5)**
  - Pavers, rollers, milling machines, MTVs...
  - Probably ~5-7 kg CO_2e/ton mix in most cases
- **Decarbonization Levers:**
  - Operations optimization
  - Alternative fuels, electrification...

Credit COLAS

Maintenance, Rehabilitation & Reconstruction (B2-B5)

- **Direct Emissions (A1-A5)**
  - Construction equipment
  - Temporary infrastructure (e.g., extra travel lanes)
  - Work zone congestion
  - End-of-Life considerations (C1 – C4)
- **Indirect Emissions**
  - Impact of smoothness on vehicle fuel consumption
  - Impact of construction quality on pavement life and future maintenance

LCAs for each M&R activities to be developed and integrated into whole pavement LCA.


Crack Sealing


Chip Seal


Microsurfacing Credit COLAS


Ultrathin Bonded Wearing Course


Cold-in-Place Recycling / FDR

Use Phase (B1 – B6)

- **Traffic emissions exceed construction and maintenance by 10 to 400 times**
- **Factors:**
  - Traffic volume and congestion (urban vs highway, work zone congestions …)
  - Vehicles types and efficiency (engines, EVs…)
  - Rolling Resistance : Smoothness (IRI), Macrotexture, Structural response…..
  - IRI is in relation with initial smoothness and Pavement Condition

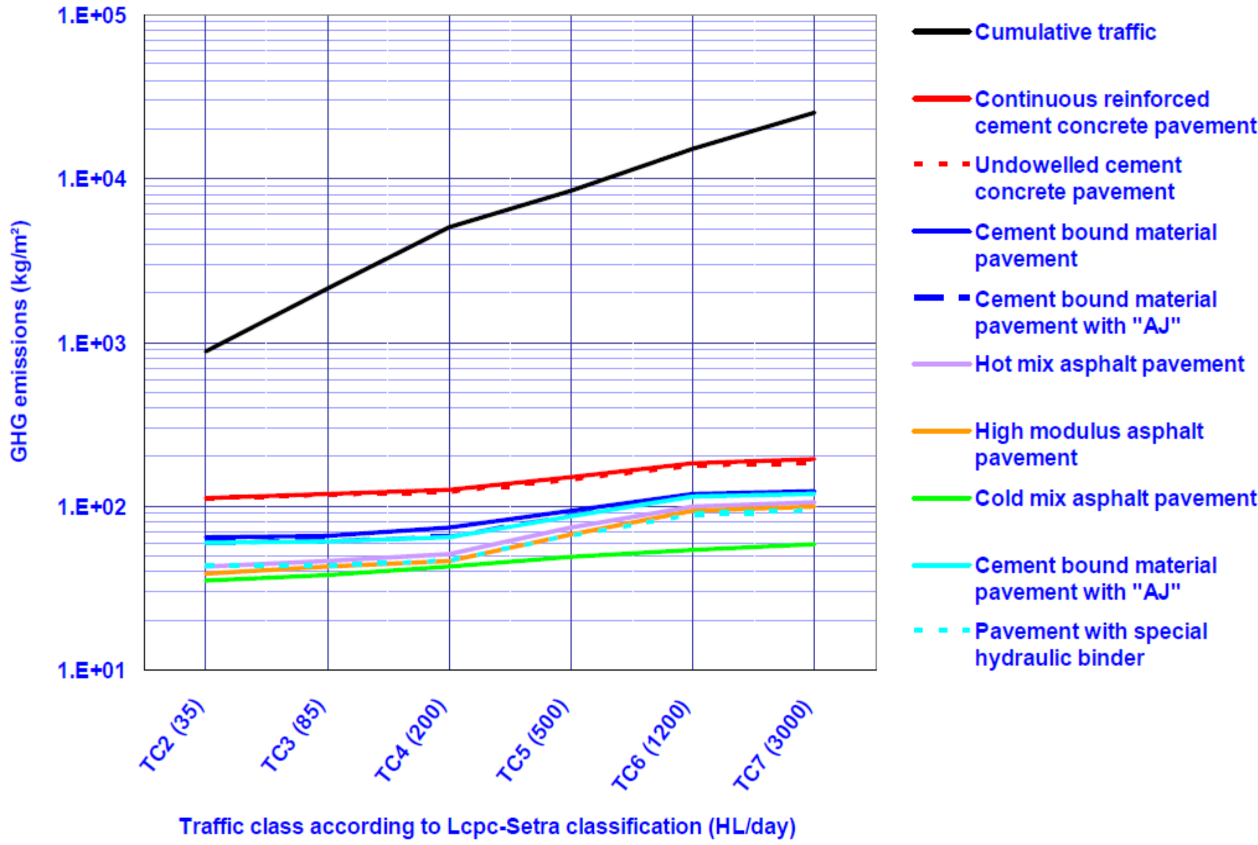


Figure 15: GHG emissions for each type of pavement structure (construction + maintenance of the pavement and safety barriers), compared to total cumulative traffic

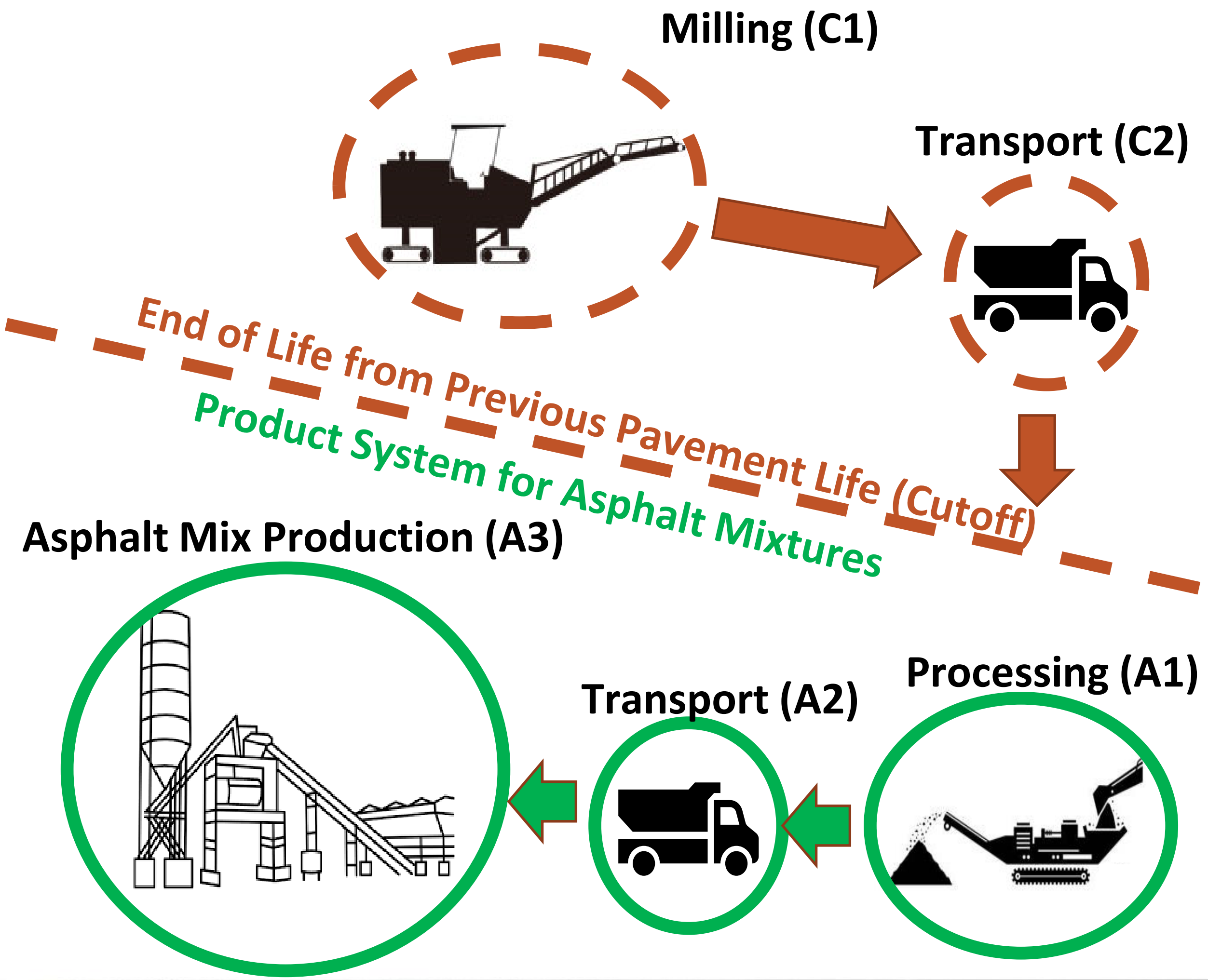
* *M. Chappat; J. Bilal (2003), The Environmental Road of the Future - Colas*

End-of-Life (C1-C4) to New Production (A1-A3)

- **End-of-Life (Previous Pavement Cycle)**
  - **C1:** Milling + Sweeper + Work zone congestion ~2-3 kg CO_2e/ton RAP
  - **C2:** Haul millings to storage or processing location ~4-5 kg CO_2e/ton RAP (53 km average distance)

  C1 and C2 used as data input for a Pavement LCA

- **New Asphalt Mix Product System:**
  - **C3 / A1:** 0.1Gal diesel /ton of RAP processed ~ 0.71 kg CO2e/ ton RAP
  - **C4: ~ 0** 99% Asphalt Pavement Recycled Close-Loop System.



Path Towards Net Zero Emissions

- Quantification Tools and Benchmarking
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- Decarbonizing Subsequent Life Cycle Phases
- **Wrap up: Key Steps and Research Needs**

NAPA EPA Grant Program

Reducing Embodied Greenhouse Gas Emissions in Construction.

- $160M awarded to 38 organizations
- NAPA leads a $10M grant and partners on another

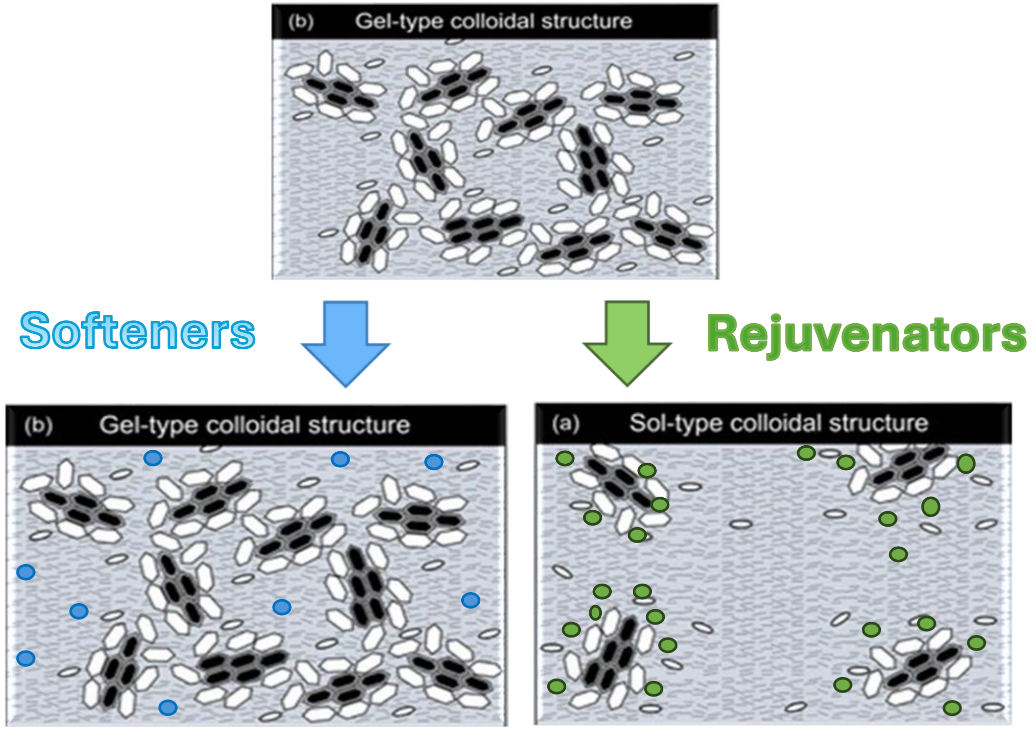
NAPA's 5-Year Program Objectives:

1. **Enhancing EPDs for Asphalt Mixtures**
   - Improve Environmental Product Declarations (EPDs)
   - Provide rebates to increase adoption and availability
2. **Life Cycle Assessment for Flexible Pavements :** Develop a PCR and LCA standard and create tools for full life cycle assessment: (A4-A5), (B2-B5), (B1-B6), (C1-C4)
3. **Workforce Development:** Educate and train industry professionals on EPDs and LCAs

Partners: 5 universities, 2 asphalt producers.

Recycling Agents

- **Key Barrier to increase RAP (2023 Survey):** Uncertainty about RAP Binder Availability
- **Agencies' Response:** Limit RAP% or Increase Virgin Binder – Limited Recycling Agents use
- **Recycling Agents work by Interacting with Aged Binders**



- **Factors considered for RAs use:** Current selection and dosage protocols are based on blending charts and aging considerations.
- **3 Critical Factors to be considered:** Dispersion, Diffusion, Compatibility of RAs in RAP
- **And introduction Method:** Research and production trials have focused on pre-blending because of its practicality.

→ Plant-level trials are needed to compare Preblending and Pretreatment methods

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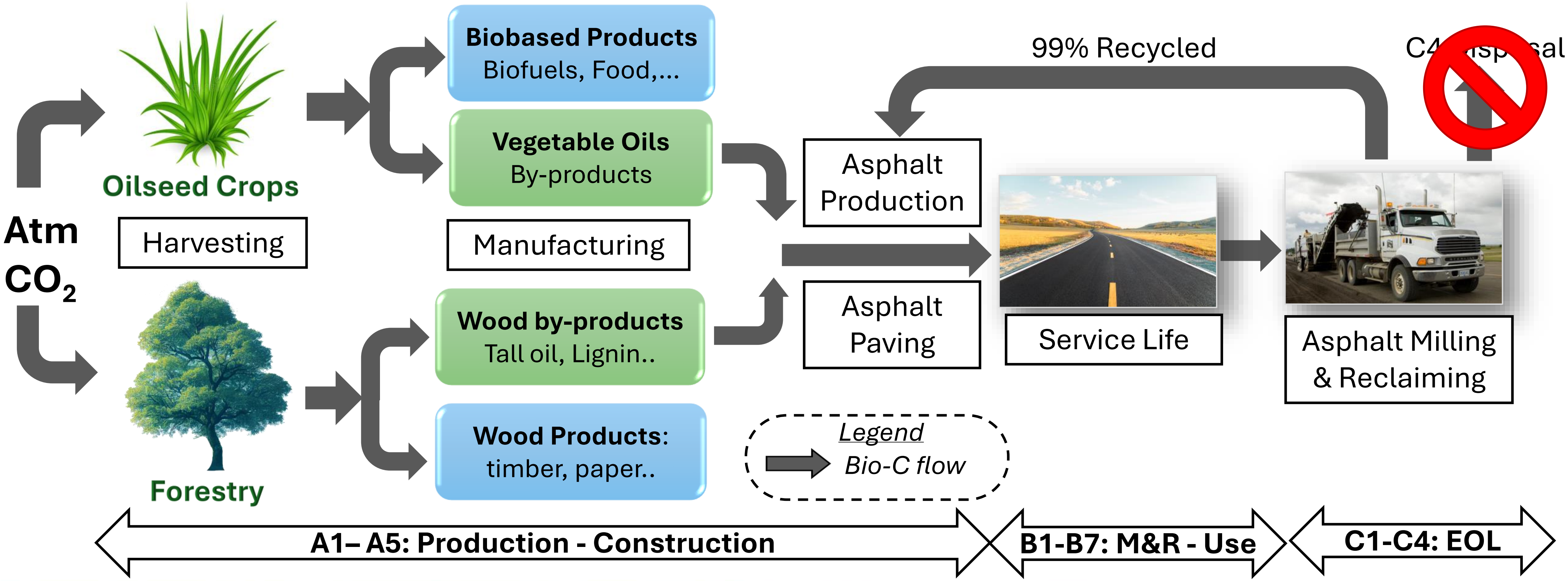
Biobinders



Cold Central Plant Recycling (CCPR)

100% RAP mixed with emulsion or foamed asphalt at ambient temperatures in a central or mobile plant.

- **Cost-Effective and Sustainable**
  - Eliminates heating requirements, minimizing energy consumption
  - Reduces new material needs, hauling costs, and emissions

  → **Reduces GHG emissions up to 50%**
- **Performance Benefits:**
  - Supports heavy traffic applications (30+ million ESALs in trials) **SN ~ 0.37**
  - Mitigates cracking and rutting in flexible pavement designs
- **Construction Efficiency:**
  - Versatile: ~ 24 h stockpiling,
  - Suitable for various project scales and traffic level

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Path Towards Net Zero Emissions

- **Industry Driven Opportunities**
  - ✓ Reduce Emissions and Boost Profitability : (1) **Optimize Plant Operations** (moisture control, plant efficiency), (2) **Increase RAP use**, and (3) **Adjust Production Temperatures**.
  - ✓ Implement **Balanced Mix Design** and **Innovative Technologies**: Recycling Agents, Biobinders and CCPR.
- **Agency Driven Opportunities:**
  - ✓ Adopt **Performance Based Specifications** (e.g., BMD) and **Bridge the Gaps,** integrate materials, structural design, construction, and maintenance to achieve perpetual pavements.
  - ✓ **Green Public Procurement:** Include embodied carbon emissions in material specs and ensure regulations and specifications support decarbonization e.g., when LCTMs are not at the lowest-cost option in low-bid markets.
- **Cooperation:**
  - ✓ **Agency-Industry Partnership:** cooperation between transportation agencies and the industry to align priorities and accelerate sustainable practices (e.g., LCTM benchmarking)
  - ✓ **Collaboration across the Asphalt Industry** to establish unified LCA, PCR, and EPD frameworks for consistent cradle-to-grave assessments.

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Thank you to our PARTNERS

The Road Forward

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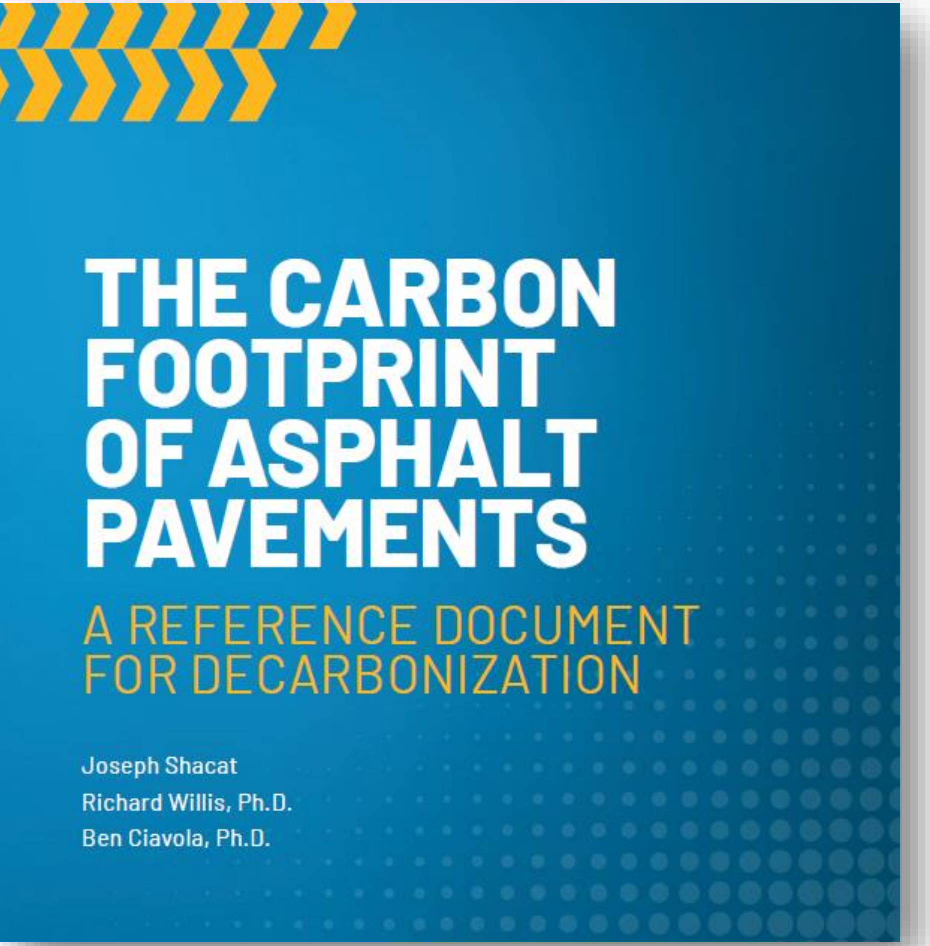
SUMMIT Materials

Path Towards Net Zero Emissions



- SIP-109 Report published by NAPA in April 2024

www.asphaltpavement.org/climate

Thank You!

Jean-Paul Fort
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OAPC -2024 -JP Fort Decarbonizing the Asphalt Industry.pdf