Why RAP?

Adam Hand, PE, PhD
University of Nevada Reno

Why RAP - *Session Description*

- Benefits of RAP for Owners
- How RAP can enhance Sustainability, Reduce Cost & Improves Performance
- Share Insights highlighting Economic and Environmental advantages of incorporating RAP in pavement projects
- Learn about cost savings with RAP, including reduced material expenses and lower greenhouse gas emissions
- Best practices for utilizing RAP to achieve high-quality, durable pavements meeting modern performance standards
- Gain knowledge on how RAP can transform your pavement management strategies, making them more cost-effective and environmentally friendly

Why RAP?

- Is it the Right Thing to Do?
  - Engineering Performance
  - Economics
  - Environment

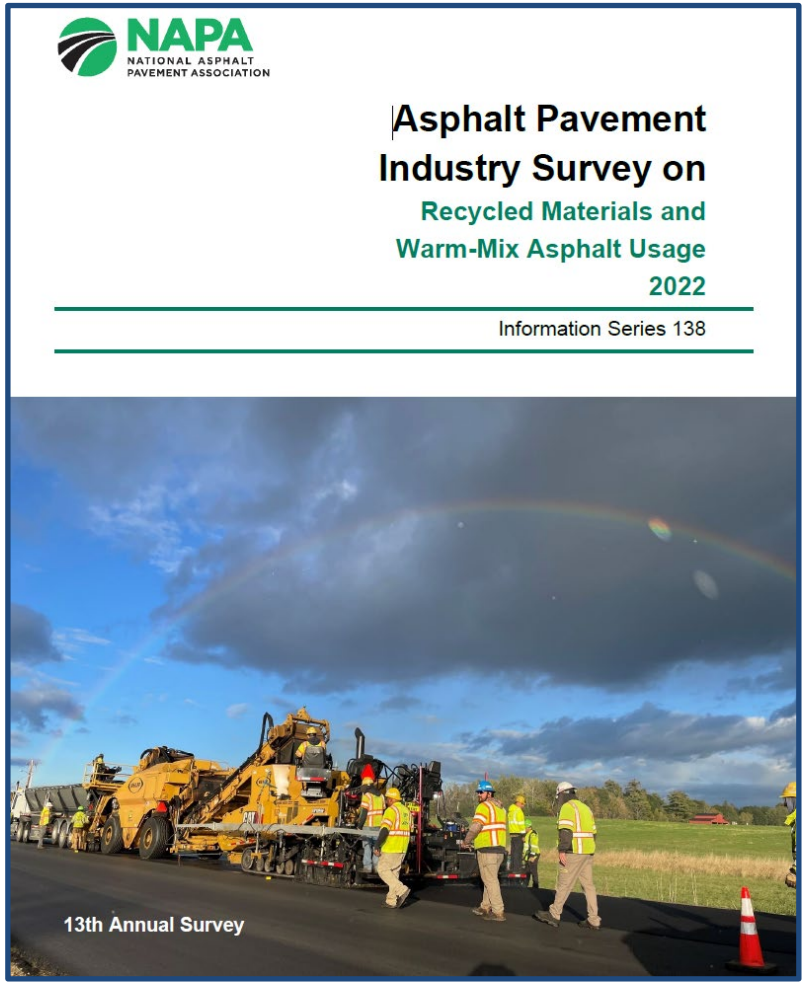
✓ Taxpayers, Agencies, Industry
✓ Our Children, Their Children
✓ Planet

- So What is Stopping Us?

Recycled & Other Materials Used in Asphalt Pavements

- Reclaimed Asphalt Pavement (RAP)
- Reclaimed Asphalt Shingles (RAS)
- Ground Tire Rubber (GTR)
- Warm Mix Asphalt Additives
- Anti-Strip Additives
- Recycling Agents
- Fillers
- Fibers
- Plastics
- …

- *Circularity of Recycled Materials*



Annual Mix Tonnage

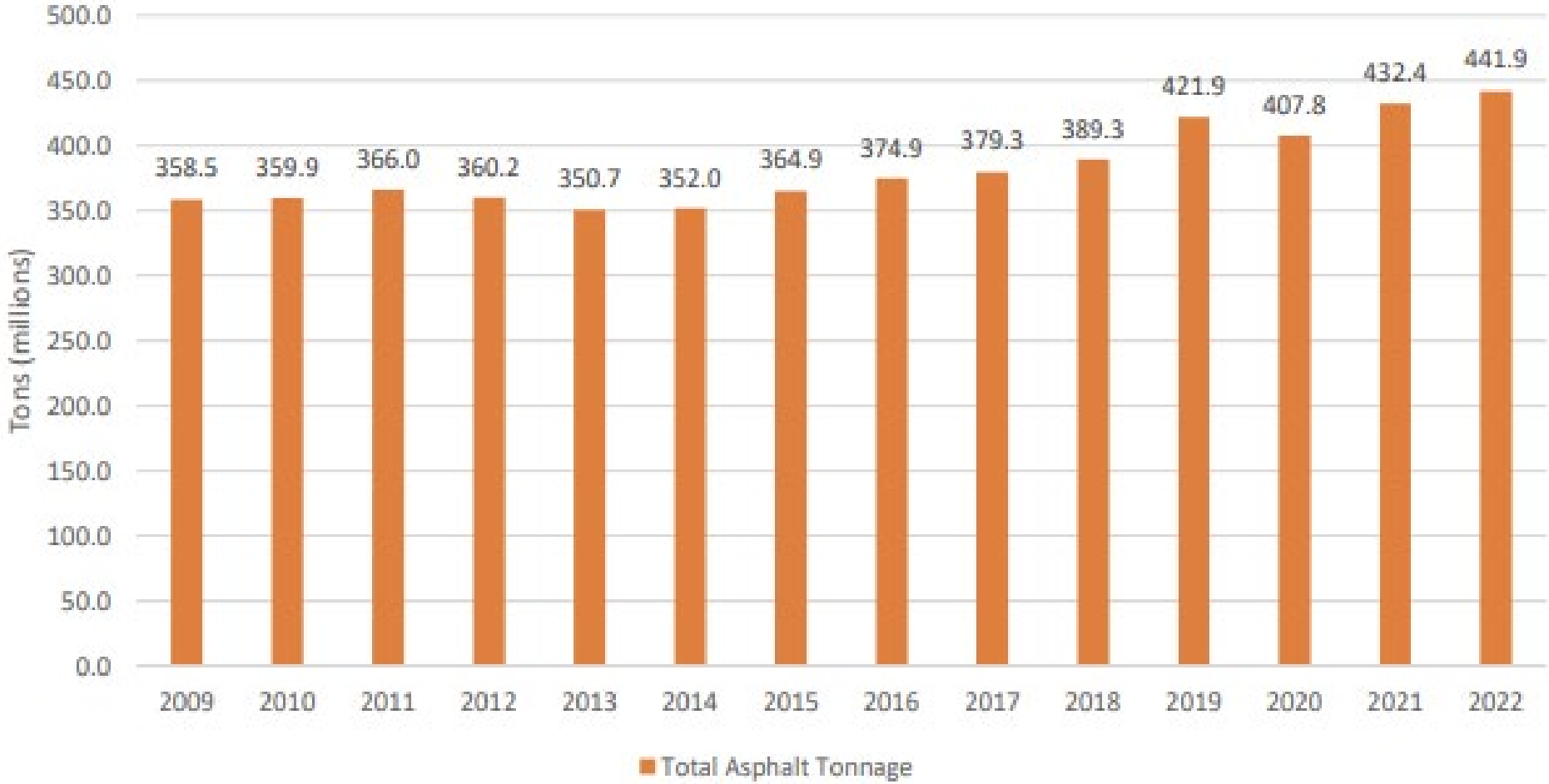


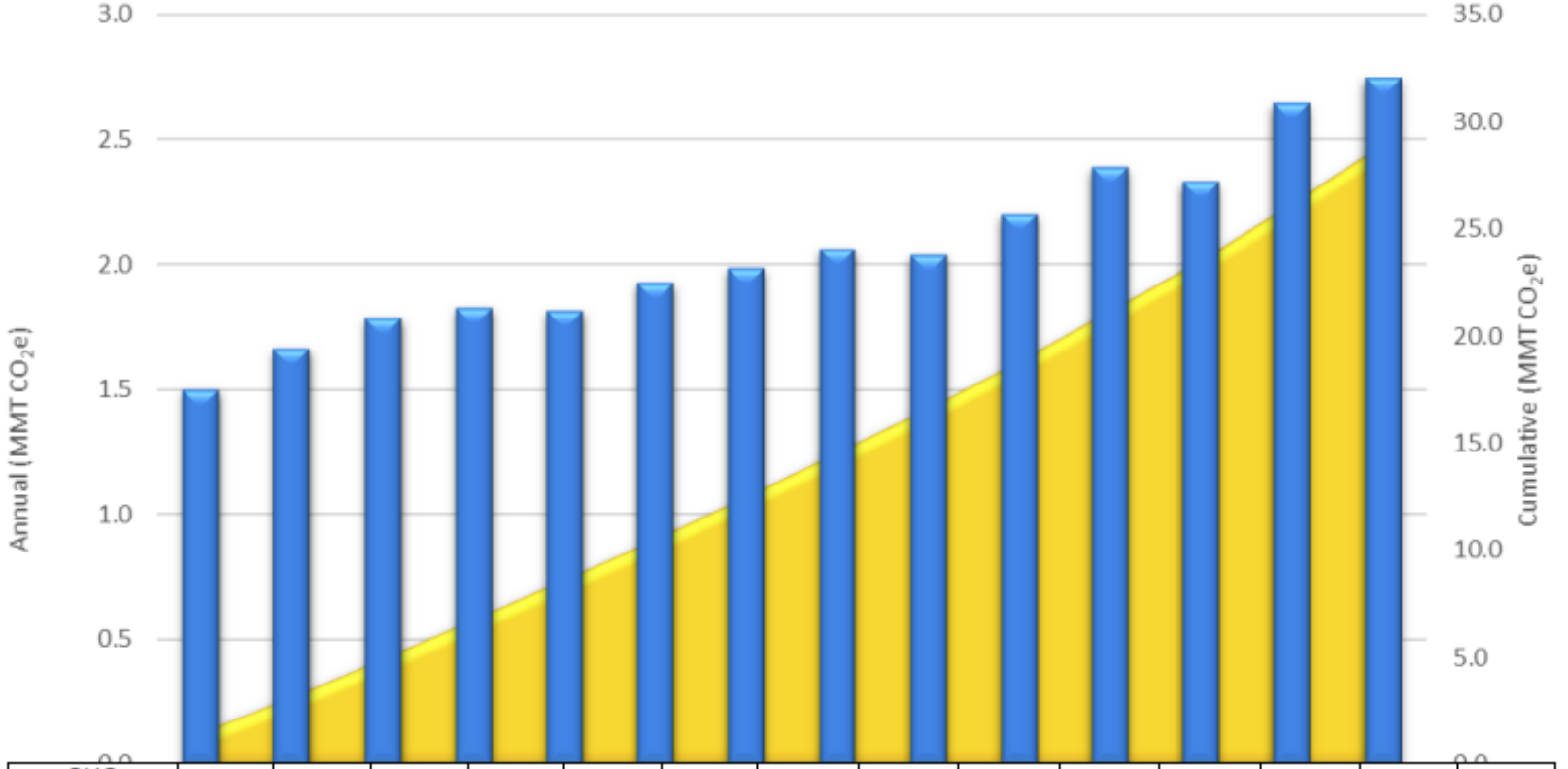
Figure 2b: Estimated Total Asphalt Mixture Production in Total, 2009–2022

Savings w/ RAP:

- **4.7** Million tons AC
- **90** Million tons Aggs
- **$3.4** Billion
- **2.6** Million MT CO2e

Examples RAP

- Industry is Succeeding - RAP
  - 98% gets Re-Recycled
  - Averaging ≈ 21% for Years
  - *Room to Improve*
- There Success Stories!
  - Spec Changes
  - GHG Reductions
  - BMD States
  - Nebraska, SC, IL, …
  - Others



GHG Emissions	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cumulative	1.5	3.2	4.9	6.8	8.6	10.5	12.5	14.5	16.6	18.8	21.2	23.5	26.1	28.9
Annual	1.5	1.7	1.8	1.8	1.8	1.9	2.0	2.1	2.0	2.2	2.4	2.3	2.6	2.7

Figure 19: GHG Emissions Reduction from Use of RAP in New Asphalt Mixtures, 2009–2022

Agency RAP Specifications Changes

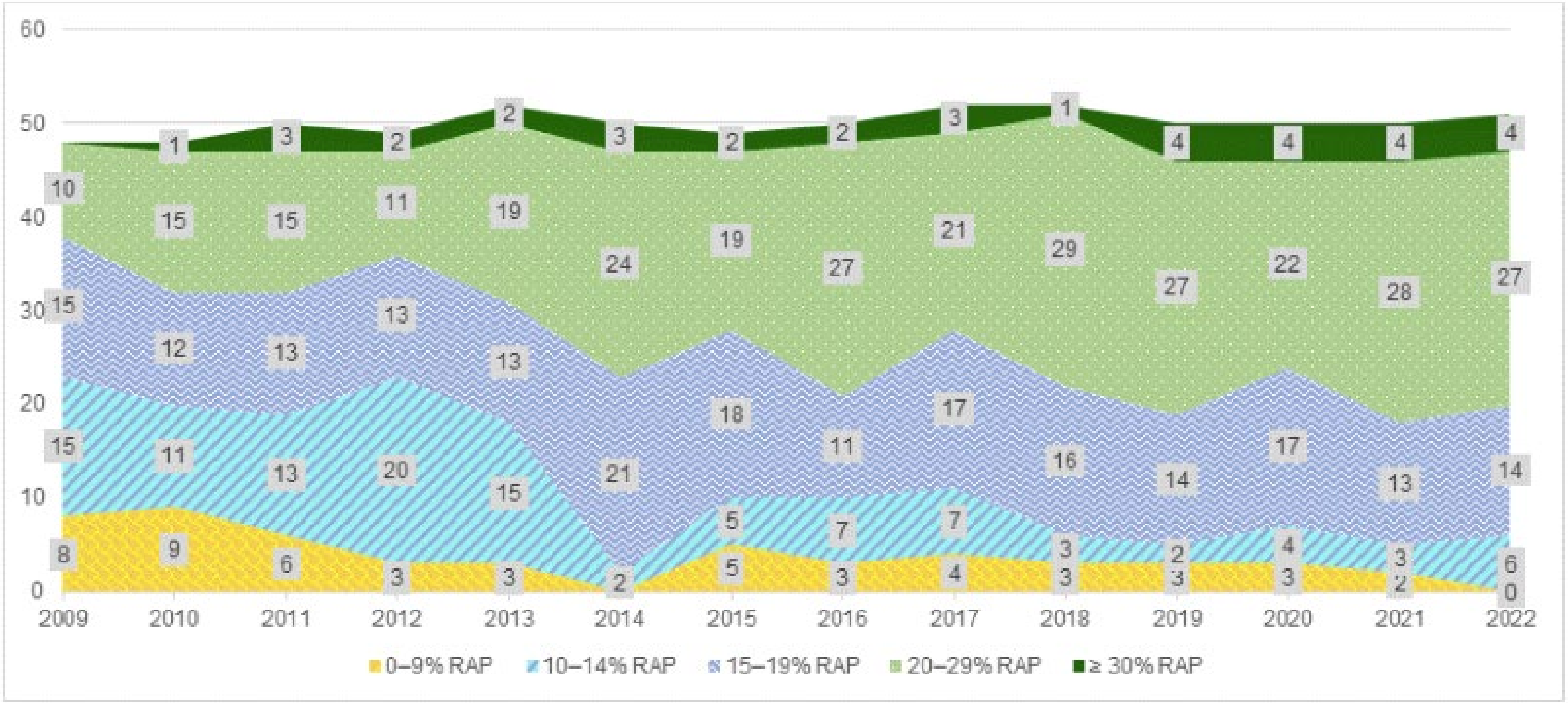
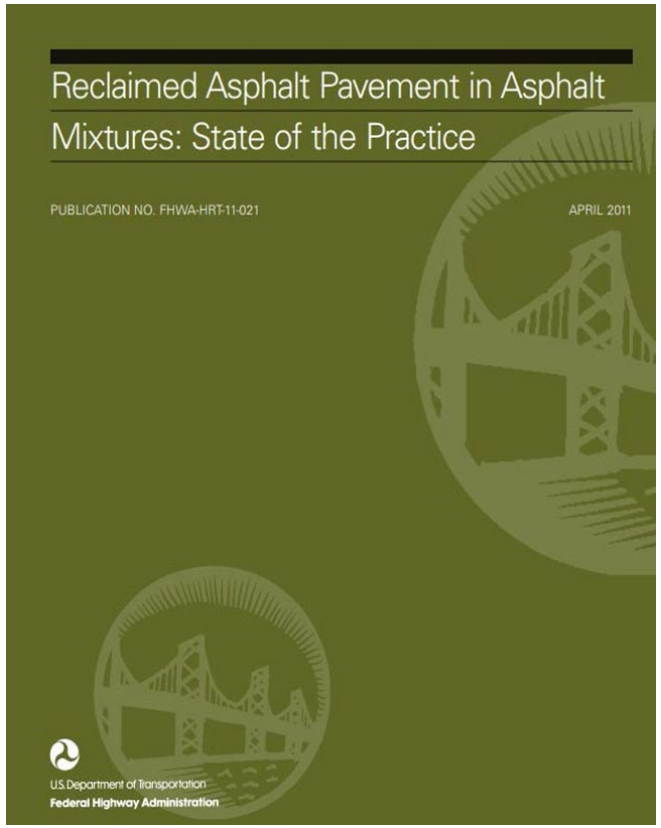


Figure 8: Number of States at Different Average Percentage of RAP Used in HMA/WMA Mixtures, 2009–2022

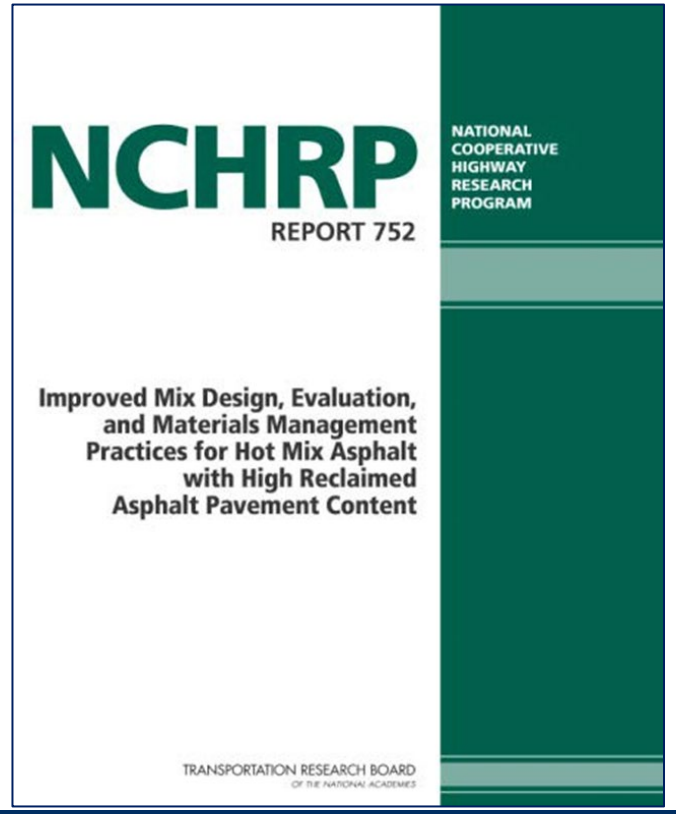
Positive High RAP Pavement Performance

- RAP in Asphalt Mixtures: State of the Practice

  FHWA-NRT-11-021

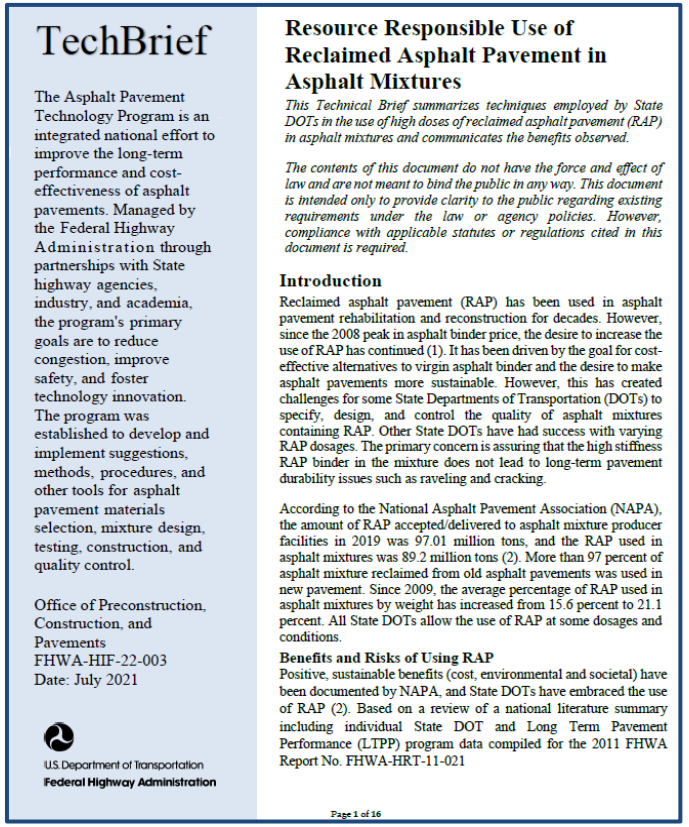


- NCHRP Report 752
- NCAT Test Track
- LTPP Studies



- RR use of RAP in Asphalt Mixtures

  FHWA-HIF-22-033



TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost-effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures, and other tools for asphalt pavement materials selection, mixture design, testing, construction, and quality control.

Office of Preconstruction, Construction, and Pavements
FHWA-HIF-22-003
Date: July 2021

U.S. Department of Transportation
Federal Highway Administration

Resource Responsible Use of Reclaimed Asphalt Pavement in Asphalt Mixtures

This Technical Brief summarizes techniques employed by State DOTs in the use of high doses of reclaimed asphalt pavement (RAP) in asphalt mixtures and communicates the benefits observed.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. However, compliance with applicable statutes or regulations cited in this document is required.

Introduction

Reclaimed asphalt pavement (RAP) has been used in asphalt pavement rehabilitation and reconstruction for decades. However, since the 2008 peak in asphalt binder price, the desire to increase the use of RAP has continued (1). It has been driven by the goal for cost-effective alternatives to virgin asphalt binder and the desire to make asphalt pavements more sustainable. However, this has created challenges for some State Departments of Transportation (DOTs) to specify, design, and control the quality of asphalt mixtures containing RAP. Other State DOTs have had success with varying RAP dosages. The primary concern is assuring that the high stiffness RAP binder in the mixture does not lead to long-term pavement durability issues such as raveling and cracking.

According to the National Asphalt Pavement Association (NAPA), the amount of RAP accepted/delivered to asphalt mixture producer facilities in 2019 was 97.01 million tons, and the RAP used in asphalt mixtures was 89.2 million tons (2). More than 97 percent of asphalt mixture reclaimed from old asphalt pavements was used in new pavement. Since 2009, the average percentage of RAP used in asphalt mixtures by weight has increased from 15.6 percent to 21.1 percent. All State DOTs allow the use of RAP at some dosages and conditions.

Benefits and Risks of Using RAP

Positive, sustainable benefits (cost, environmental and societal) have been documented by NAPA, and State DOTs have embraced the use of RAP (2). Based on a review of a national literature summary including individual State DOT and Long Term Pavement Performance (LTPP) program data compiled for the 2011 FHWA Report No. FHWA-HRT-11-021

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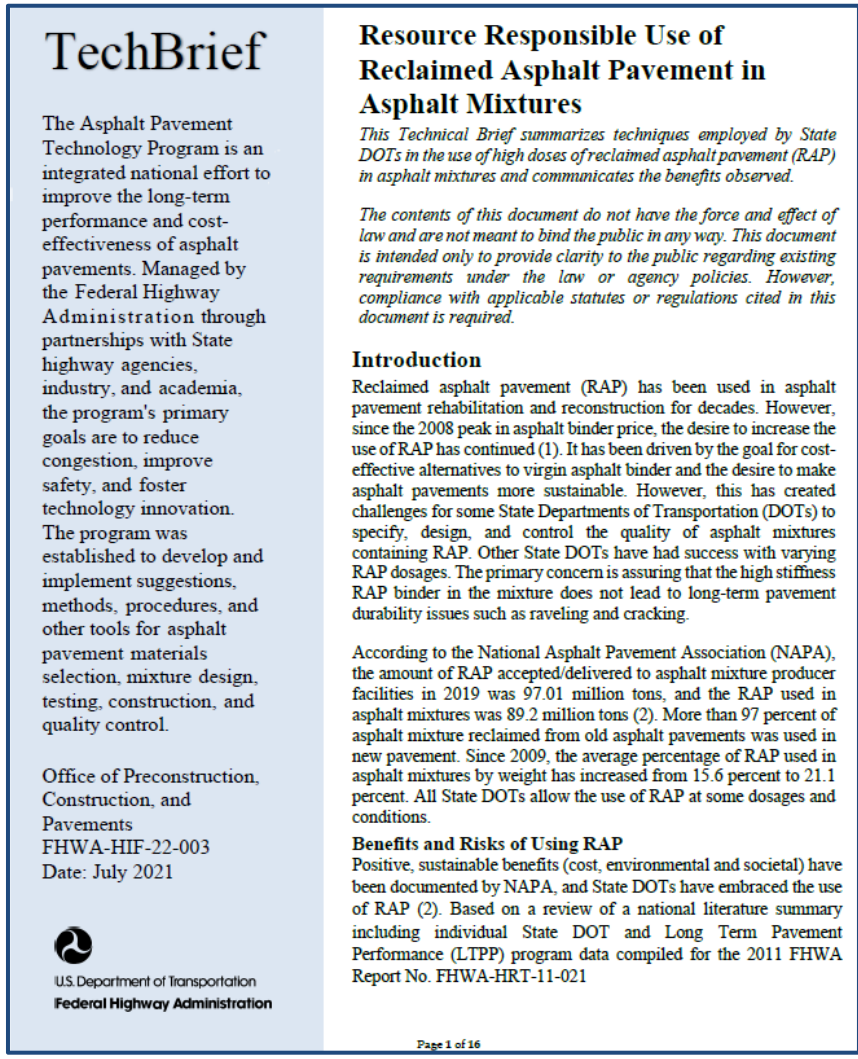
https://www.fhwa.dot.gov/pavement/recycling/rap.cfm

High RAP Success Stories

- **Florida DOT (FDOT):** RAP use unlimited for some mixes, some producers use 40% RAP, highest RAP used is 50% percent in unlimited RAP mixture type
- **Nebraska DOT (NDOT)**: Average RAP used in NDOT mixtures 39%, Typical RAP range of 35 to 50%
- **New Jersey (NJDOT):** Minimum RAP 20% for surface mixtures and 30% for intermediate and base mixtures with BMD specification
- **South Carolina DOT (SCDOT)**: specifies some mixtures with 25 to 35% RAP
- **Washington DOT (WSDOT):** allows up to 40% RBR (no more than 20% from RAS) with a BMD specification since 2013 (HWTT & ITS)
- **Wisconsin DOT (WisDOT):** > 95% of 2.8 million tons of asphalt used contains RAP, and 40% used in some mixtures



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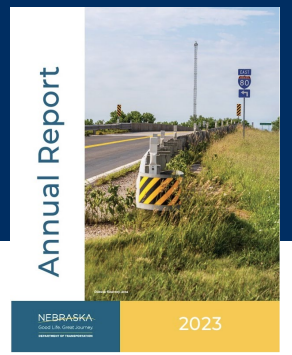
https://www.fhwa.dot.gov/pavement/recycling/rap.cfm

State DOT RAP use Requirements

DOT RAP Use Requirements	FDOT	NDOT	NJDOT	SCDOT	WisDOT	WSDOT
% RAP Criteria	X	X	X			X[7]
RBR Criteria	X[1]			X	X	X
% RAS Criteria			X	X	X	X
Specifications Used by Others	X	X		X	X	X
Lift Location Criteria	X	X	X	X	X	
Traffic Criteria	X			X	X	X
Specialty Mixture Criteria	X		X	X	X	X
Binder Type Criteria	X	X		X		X
Softer Binder by Grade Bump	X	X	X[5]			
Softer Binder by Blending Chart			X[5]		X	X
Softer Binder by PG of Blend			X[5]		X	X
Recycling Agent Additive		X	X[5]			X
WMA Additive	X	X	X[5]	X	X	X
Additional Asphalt at Design	X	X	X	X	X	
Additional Asphalt at Acceptance			X	X	X	
Gsb for RAP Aggregates					X	X
Mixture Performance Test(s)			X	X[4]		X
Pay for Binder Separately		X		X		
RAP Fractionation	X[2]			X[2]	X[2]	
RAP QC Plan	X		X	X		
Dedicated RAP Stockpiles	X[3]			X[6]		

[1]Contractor option for RAP over 20 percent, but RBR may not exceed 0.20;
[2]Contractor option, use may be greater for FRAP than RAP;
[3]Contractor option;
[4]APA rutting test only;
[5]Contractor option to meet performance test criteria;
[6]If not fractionated;
[7]RAS percent specified but overruled by RBR.

Nebraska DOT

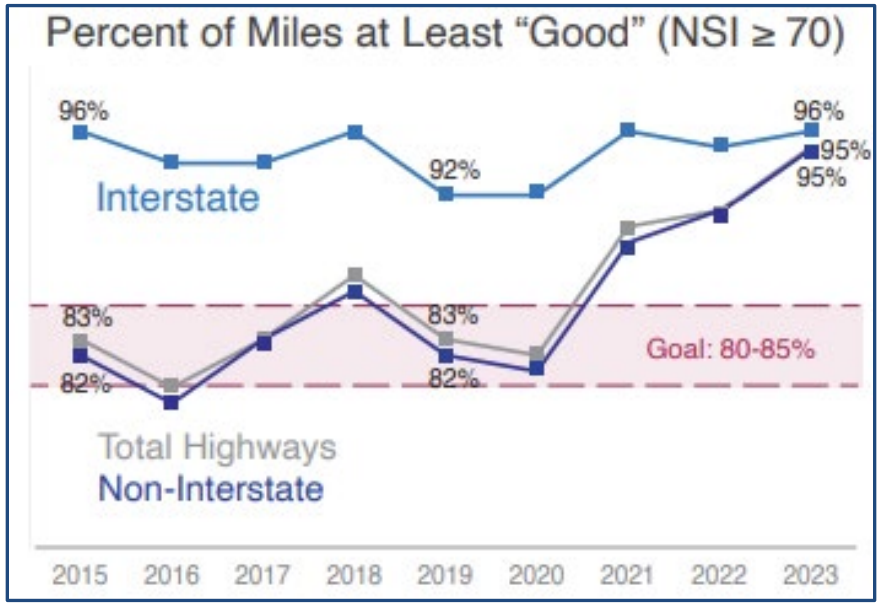


- **Nebraska DOT**
  - **Recycling Quantities, Cost Savings & Pavement Performance Improvement in Annual Report**
    - https://dot.nebraska.gov/media/3493/annual-report.pdf

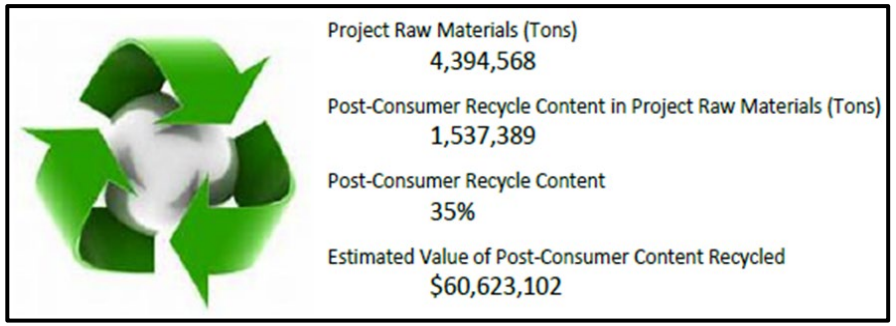
Post-Consumer Recycle Content

Overall Replacement Content

Fiscal Year	Raw Materials (tons)	Recycle Content Raw Materials (tons)	Est. Value Recycled
2014	3,796,902	1,350,476	$59,292,024
2015	3,215,669	1,246,427	$45,750,906
2016	3,717,875	1,250,980	$47,568,953
2017	4,346,961	1,534,604	$60,233,179
2018	2,993,035	1,088,647	$49,670,595
2019	3,243,560	1,104,208	$61,257,110
2020	3,506,284	1,175,577	$61,617,867
2021	3,530,896	1,230,025	$77,148,114
2022	3,033,886	1,041,155	$77,974,124

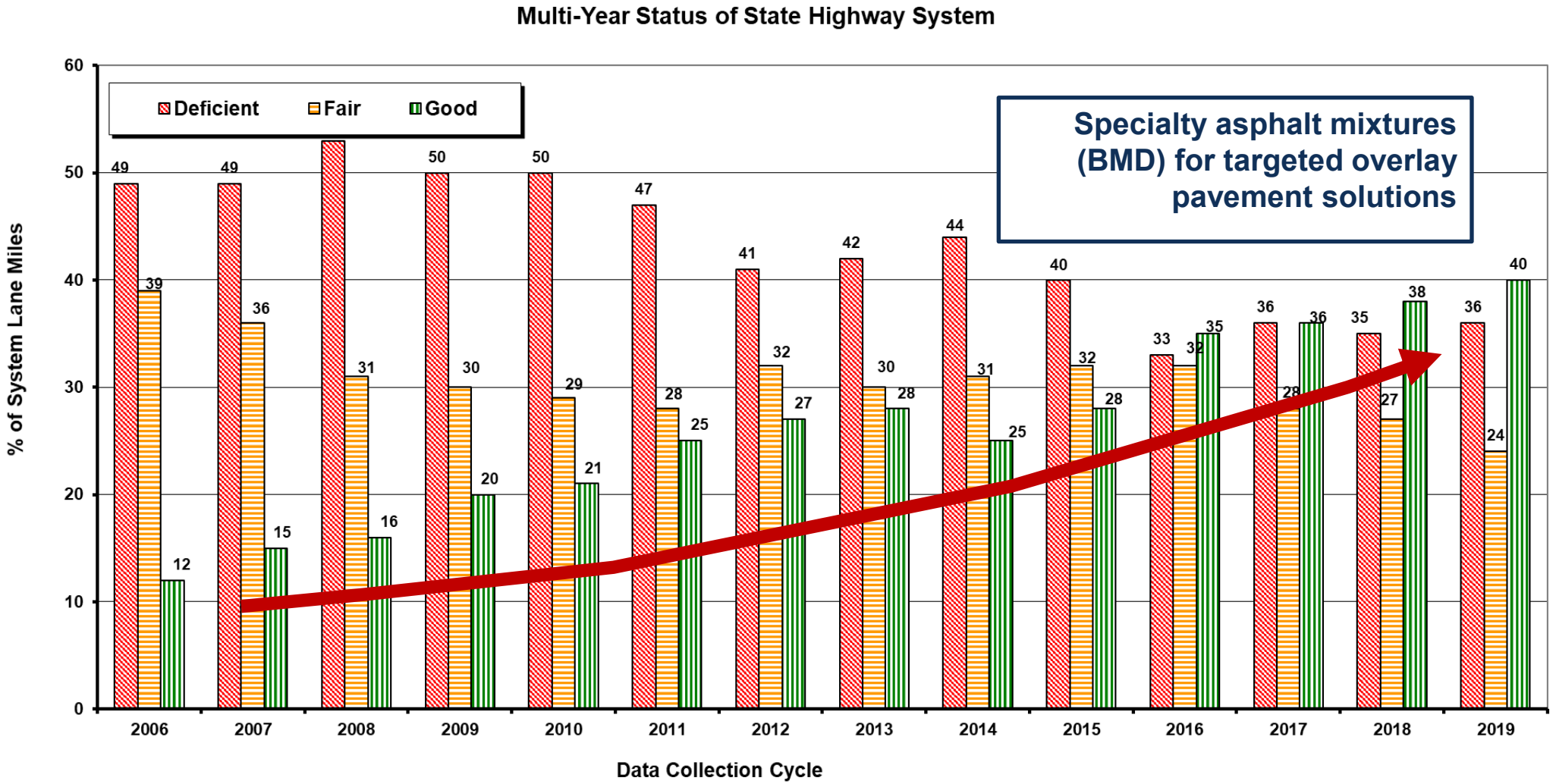


Post-Consumer Labeling Plan Sets Since 2014



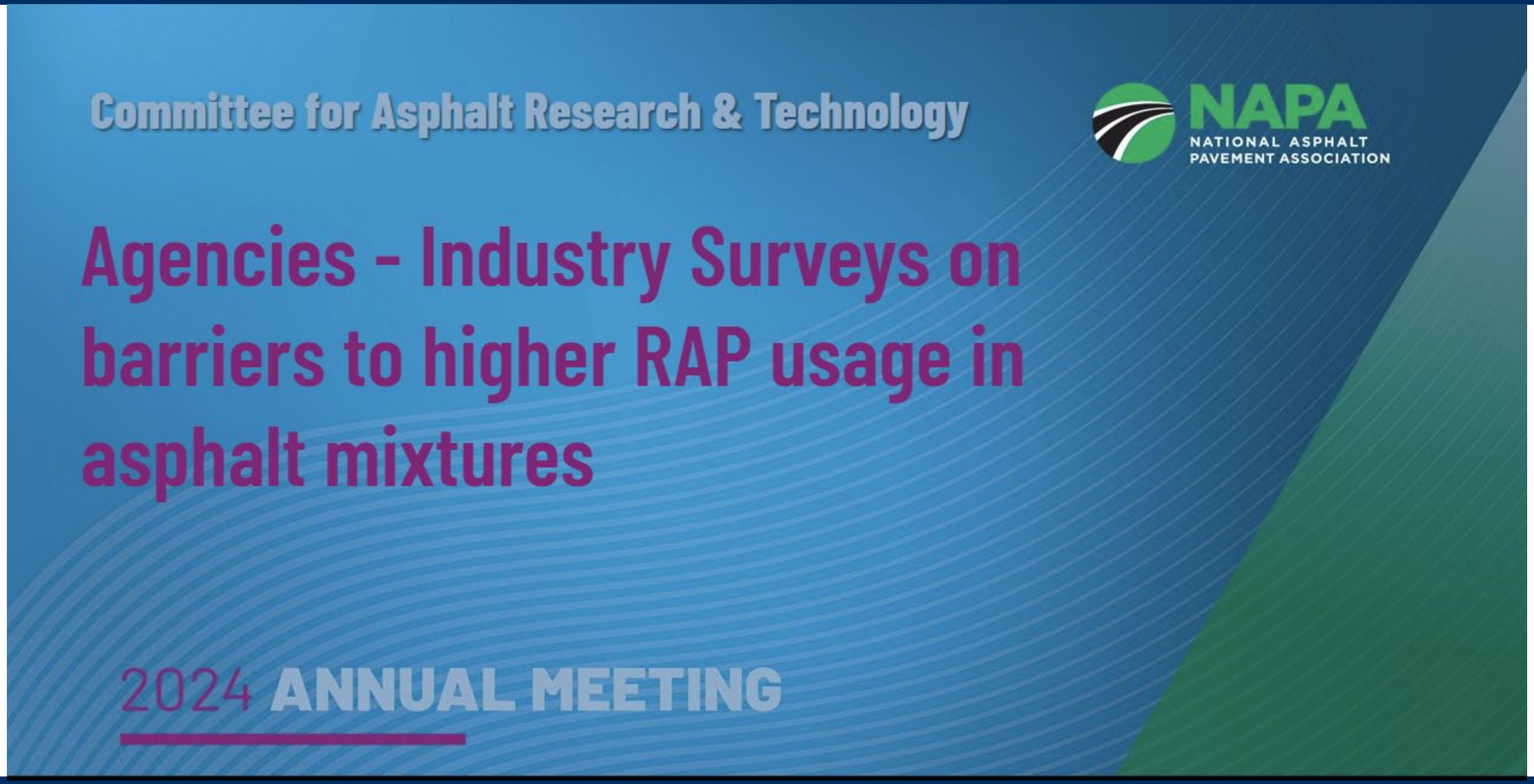
- **Nebraska Serviceability Index (NSI): Range = 0 to 100; "Good" ≥ 70%**
- **Goal 80 to 85% of Highway System "Good"**
  - **92% of Interstate System "Good; "83% of Total Highway System "Good;"**
- **NSI has Increased since High RAP Implementation in 2013**

BMD Benefits: *NJDOT Pavement Network Improvements*



Source: NJDOT Pavement Management System

Why not More RAP?



Agencies – Industry RAP Barriers Surveys Takeaways

Agencies Barriers

- Reduced Service Life Concerns (cracking, raveling, PMB mixes)
- Impact of variability
- Plants Capacity
- Availability of soft binders
- RAP Availability
- Contractors' choice

Industry Barriers

- Specifications
- RAP Availability
- Plants Capacity
- Impact of variability

Best Practices to increase RAP use

- **Higher specs Limits**: 40% to 45% or none.
- **Variability control**: FRAP or % RAP allowed function of variability.
- **Binder control**:
  - Use of RBR (Recycled Binder Rate)
  - Use of RAP agg. Gsb
  - COAC
- **Innovations:**
  - WMA as a compaction aid
  - Use of Recycling Agents
  - BMD implementation
- **Contract provisions:**
  - Binder paid separately, w/RAP binder
  - Rebate on savings

Agencies' Innovations and Best Management Practices to Increase RAP Use

- **Binder Grade Adjustments**
- **Additives:**
  - WMA Technologies: predominantly as a compaction aid
  - Recycling Agents
- **Additional Asphalt Content:** 60% of states use various methods to adjust asphalt content
- **RAP Processing, Handling, and QC**
  - RAP% contingent to composition tolerances or fractionation
  - Captive stockpiles
- **Balanced Mix Design (BMD) Testing**
- **Contractual Provisions**

Key demands from Agencies to facilitate RAP Usage

Balanced Mix Design

- Correlating cracking tests with actual field performance

Quantifying Benefits

- Economic and environmental benefits of high RAP mixes

Recycling Agents

- Emphasis on research and use

Training Programs

For contractors and local agency personnel

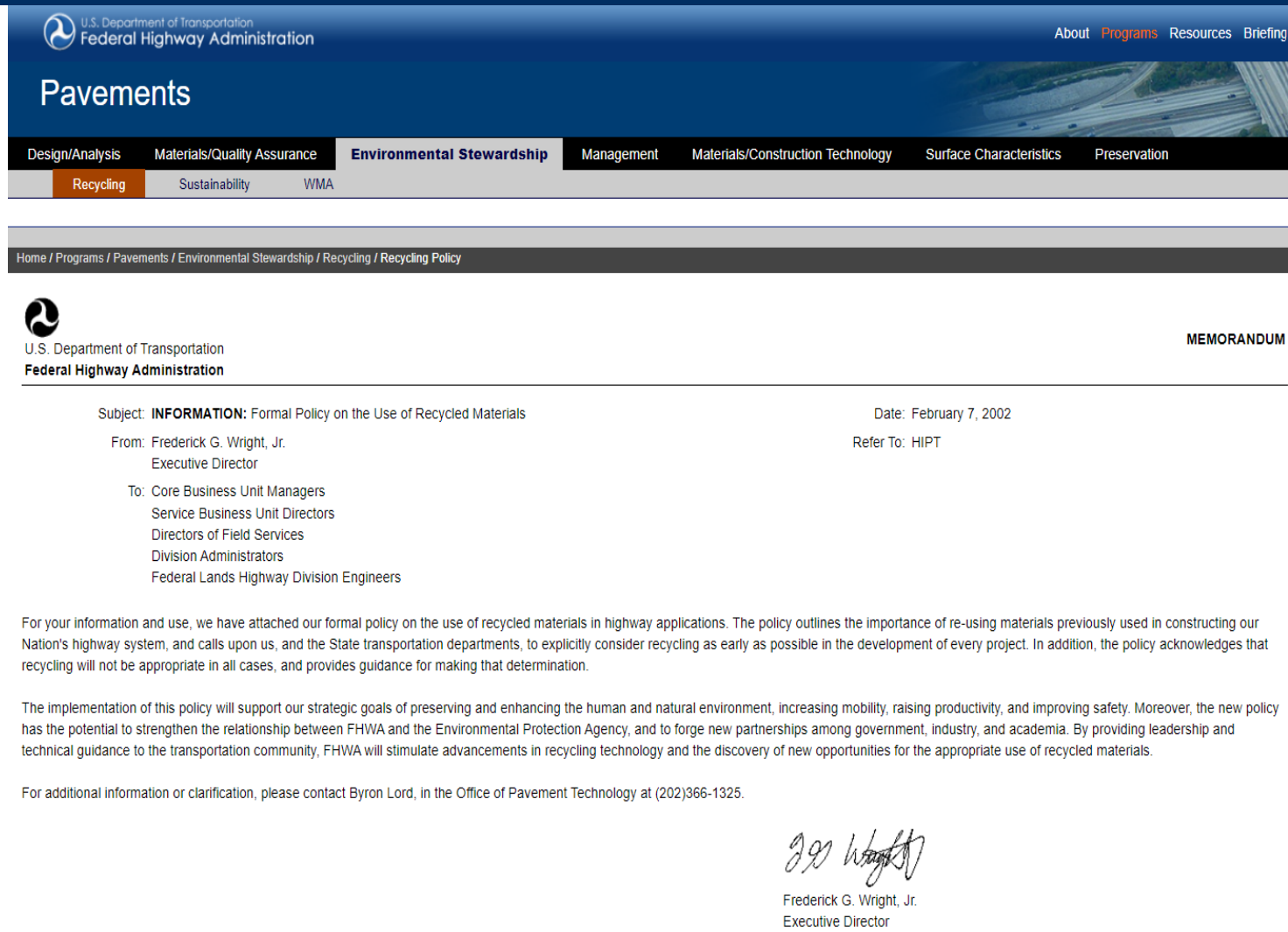
Performance – Recycling

FHWA Recycling Policy & the *Three E's*

- "*The policy acknowledges the importance of reusing materials previously used in constructing our Nations highway system, and calls upon us, and State transportation departments to explicitly consider recycling as early as possible in the development of every project.*"

- "*In addition the policy acknowledges that recycling will not be appropriate in all cases and provides guidance for making that determination*."

https://www.fhwa.dot.gov/legsregs/directives/policy/recmatmemo.htm



U.S. Department of Transportation
Federal Highway Administration

About Programs Resources Briefing

Pavements

Design/Analysis | Materials/Quality Assurance | **Environmental Stewardship** | Management | Materials/Construction Technology | Surface Characteristics | Preservation

Recycling | Sustainability | WMA

Home / Programs / Pavements / Environmental Stewardship / Recycling / **Recycling Policy**

U.S. Department of Transportation
Federal Highway Administration

MEMORANDUM

Subject: **INFORMATION:** Formal Policy on the Use of Recycled Materials
Date: February 7, 2002

From: Frederick G. Wright, Jr.
Executive Director
Refer To: HIPT

To: Core Business Unit Managers
Service Business Unit Directors
Directors of Field Services
Division Administrators
Federal Lands Highway Division Engineers

For your information and use, we have attached our formal policy on the use of recycled materials in highway applications. The policy outlines the importance of re-using materials previously used in constructing our Nation's highway system, and calls upon us, and the State transportation departments, to explicitly consider recycling as early as possible in the development of every project. In addition, the policy acknowledges that recycling will not be appropriate in all cases, and provides guidance for making that determination.

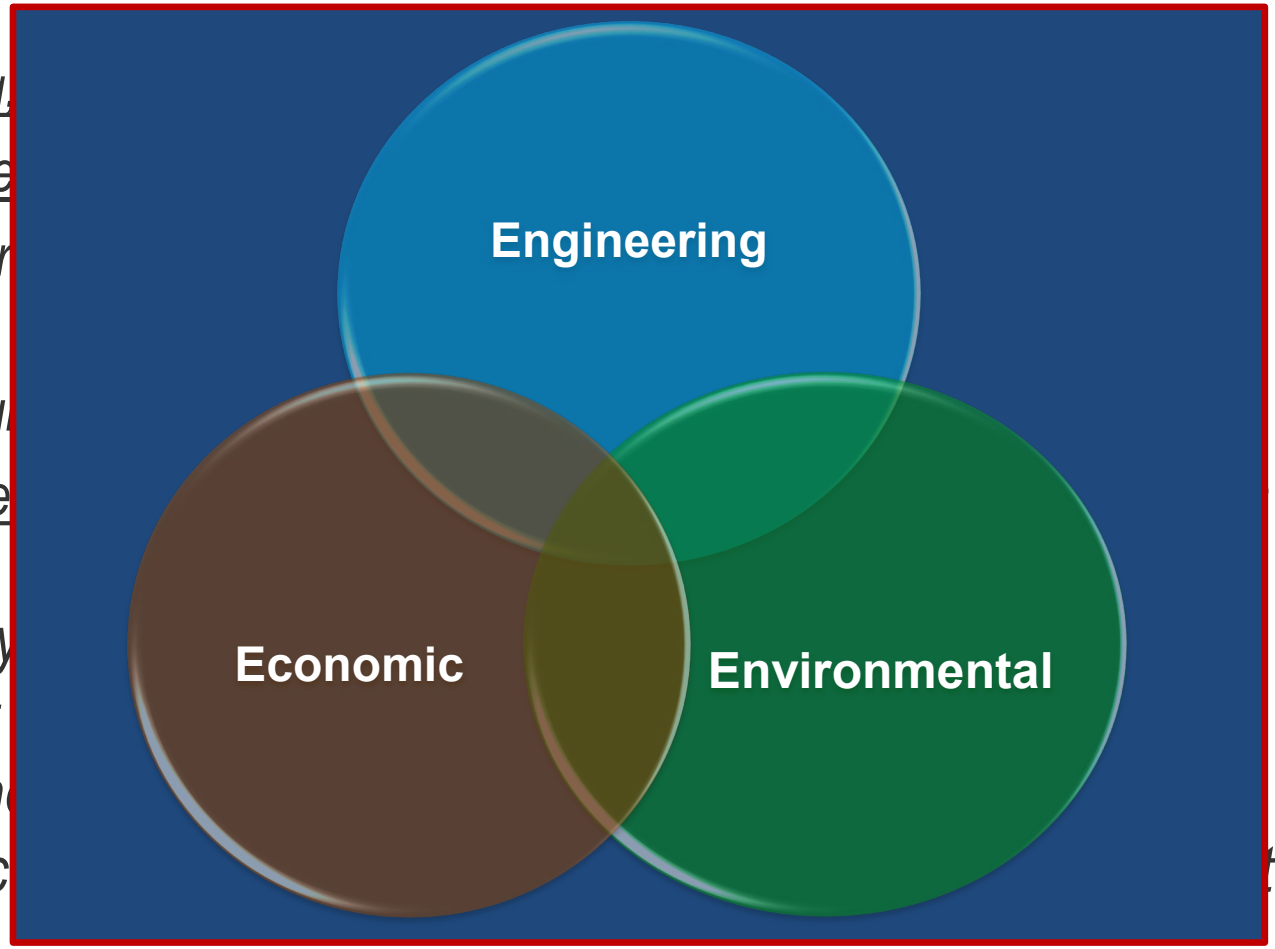
The implementation of this policy will support our strategic goals of preserving and enhancing the human and natural environment, increasing mobility, raising productivity, and improving safety. Moreover, the new policy has the potential to strengthen the relationship between FHWA and the Environmental Protection Agency, and to forge new partnerships among government, industry, and academia. By providing leadership and technical guidance to the transportation community, FHWA will stimulate advancements in recycling technology and the discovery of new opportunities for the appropriate use of recycled materials.

For additional information or clarification, please contact Byron Lord, in the Office of Pavement Technology at (202)366-1325.

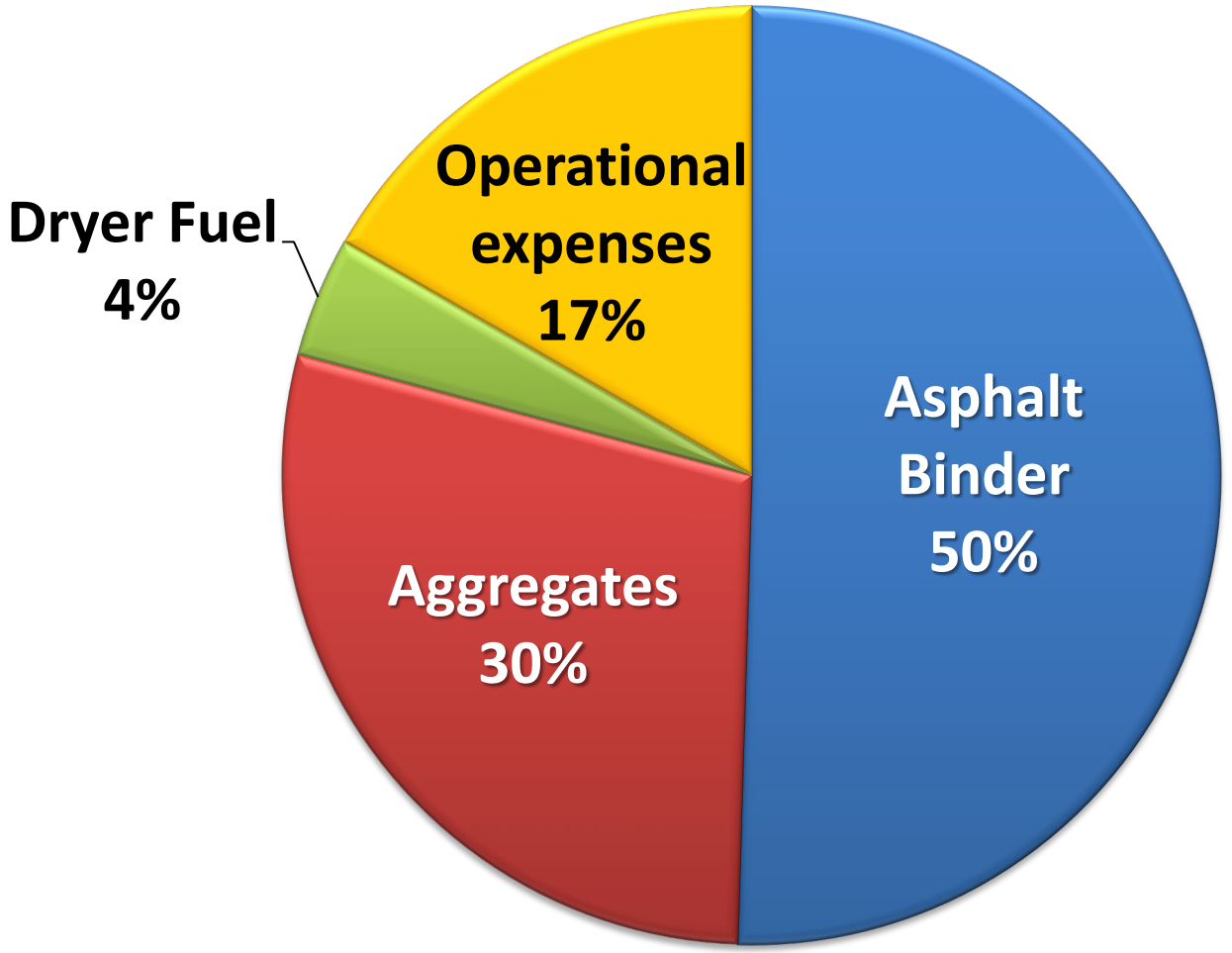
Frederick G. Wright, Jr.
Executive Director

Performance – Recycling
FHWA Recycling Policy - the *Three E's*

- "*The FHWA policy is*:
  1. *Recycling and reuse can offer engineering*
  2. *Recycled materials should get first conside*
  3. *Determination of the use of recycled mater environmental suitability.*
  4. *An assessment of economic benefits shou*
  5. *Restrictions that prohibit the use of recycle specifications."*
- *"FHWA has a longstanding position that any virgin or recycled, shall not adversely affect highway system. This remains a cornerston and future development we support researc findings."*



Mix Cost & RAP Economics



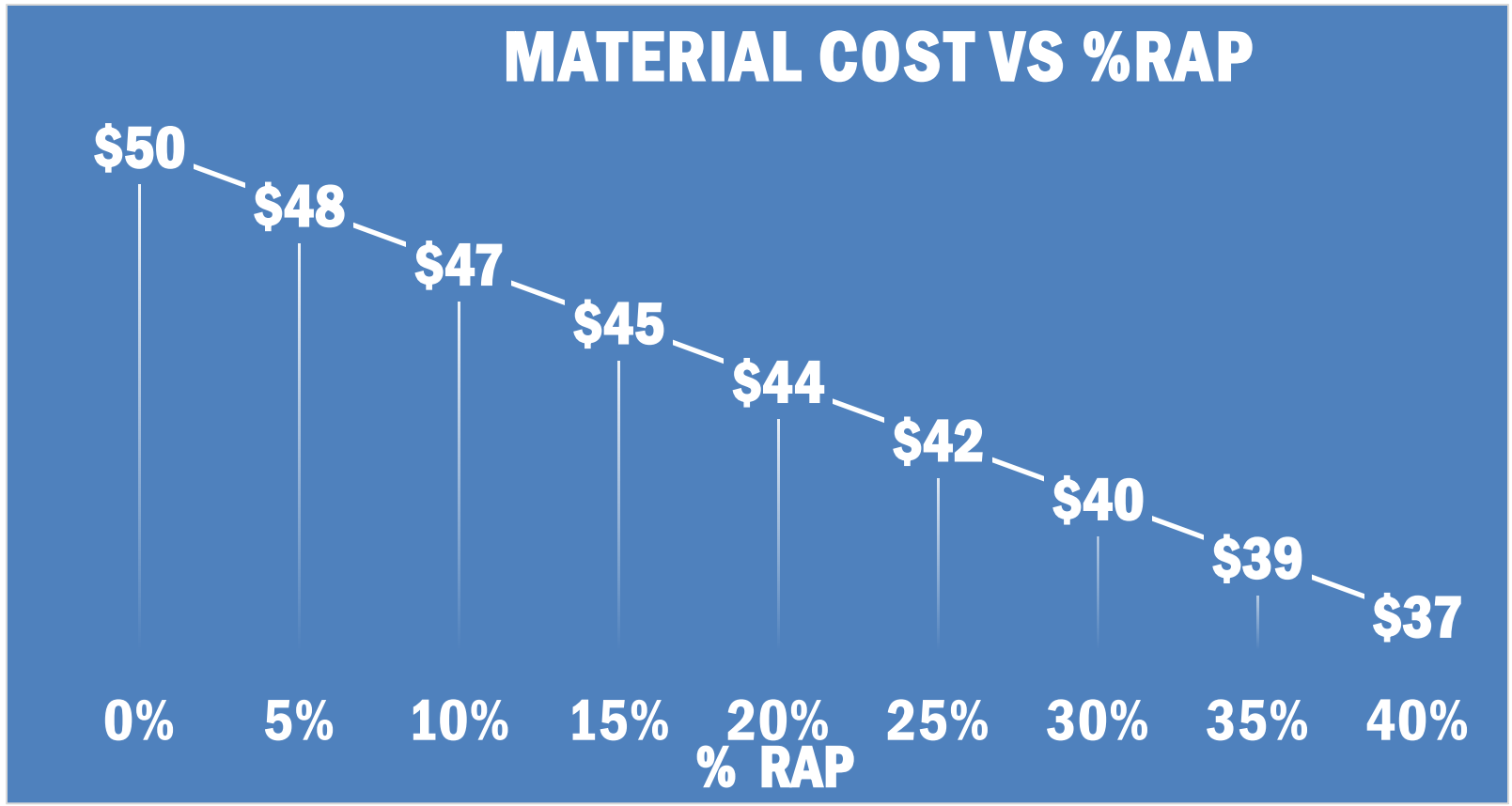
RAP Economics

RAP Economic *Ballpark* Benefits Estimate

RAP Costs:	$ / ton
Milling	$3.00
Hauling	$3.00
Processing	$4.00
RAP Cost:	$10.00

Virgin Mix	$/ton	%	$
Coarse Aggregates	$18.00	61%	$11.00
Fine aggregates	$15.00	33%	$5.00
Asphalt Cement	$600.00	5.7%	$34.00
		100%	$50.00

RAP Value* :	%	AC%	$ / ton
Coarse RAP	35%	2.2%	$ 30.80
Fine RAP	65%	5.7%	$ 48.60
	100%	4.5%	$ 42.40

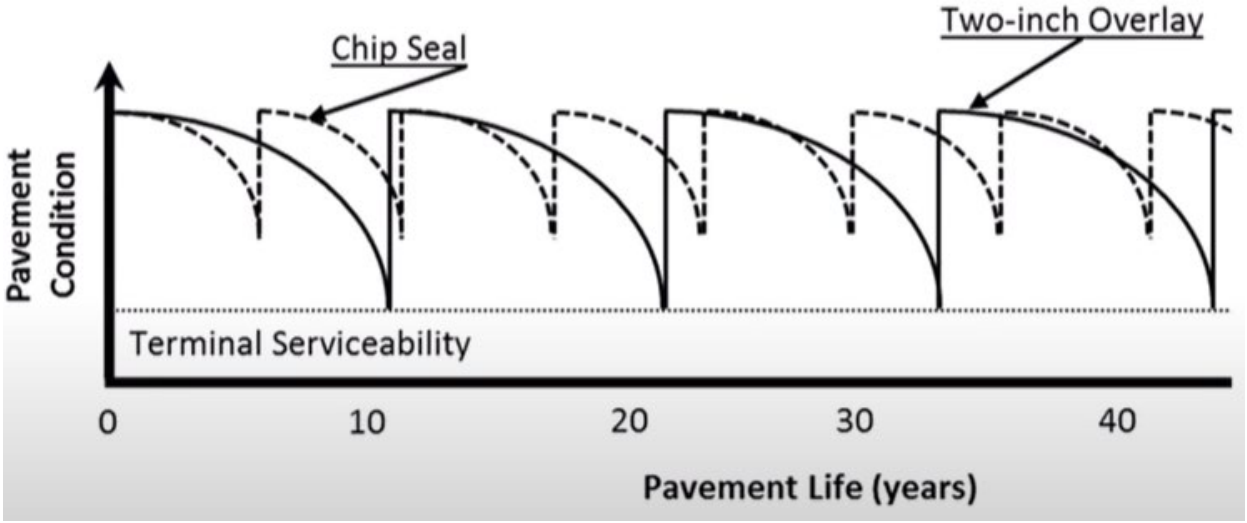


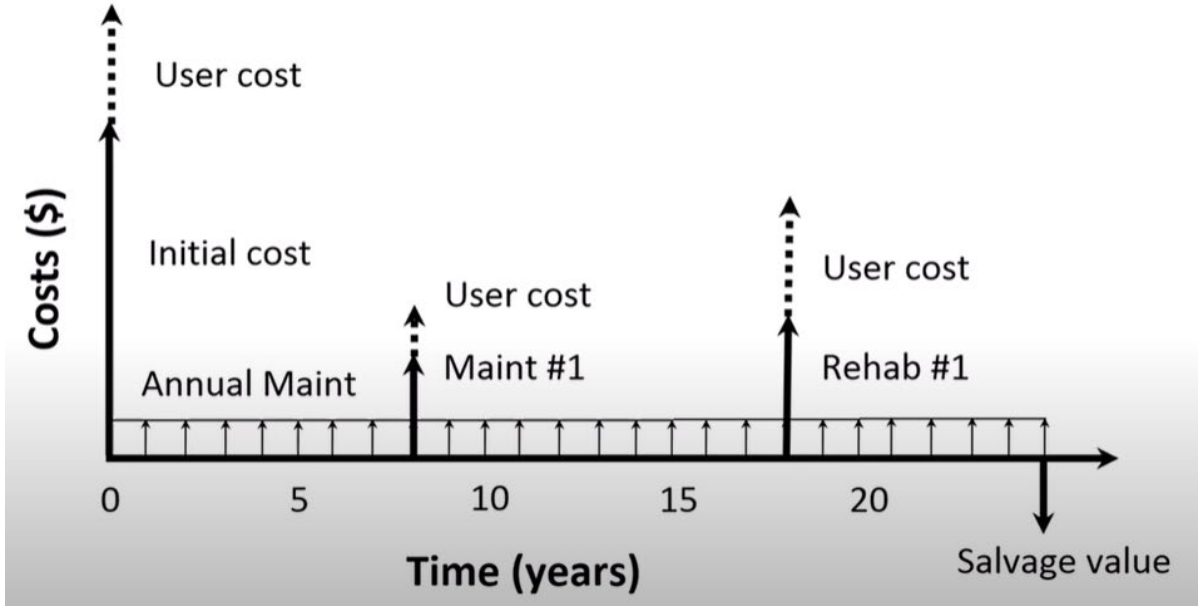
Life Cycle Cost Analysis (LCCA)

- An economic evaluation method for determining the total cost of owning and operating a facility over a period of time
- Can be used to compare alternatives

REAL COST

https://www.fhwa.dot.gov/pavement/lcca/lccasoft/





Pavinar, Andrew Braham, University of Arkansas

Life Cycle Assessment (LCA)

- LCA is a environment assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service

LCA PAVE

https://www.fhwa.dot.gov/pavement/lcatool/

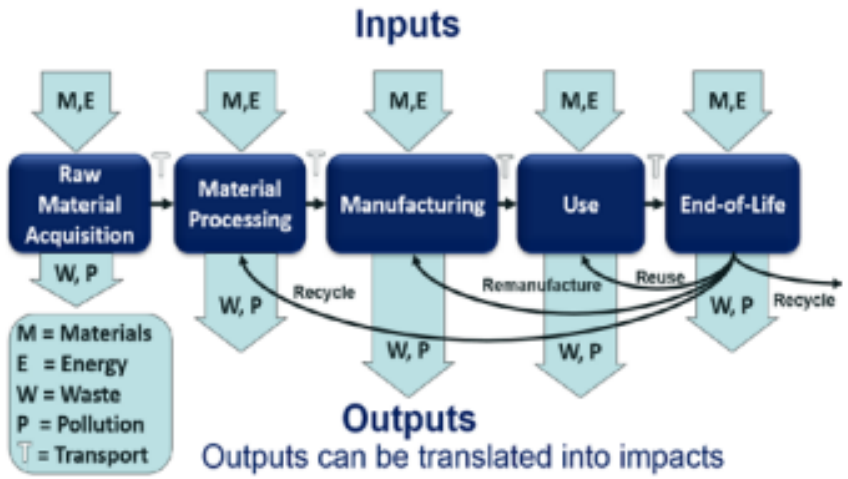


Figure 1. Generic life cycle of a production system for LCA (Kendall 2012).

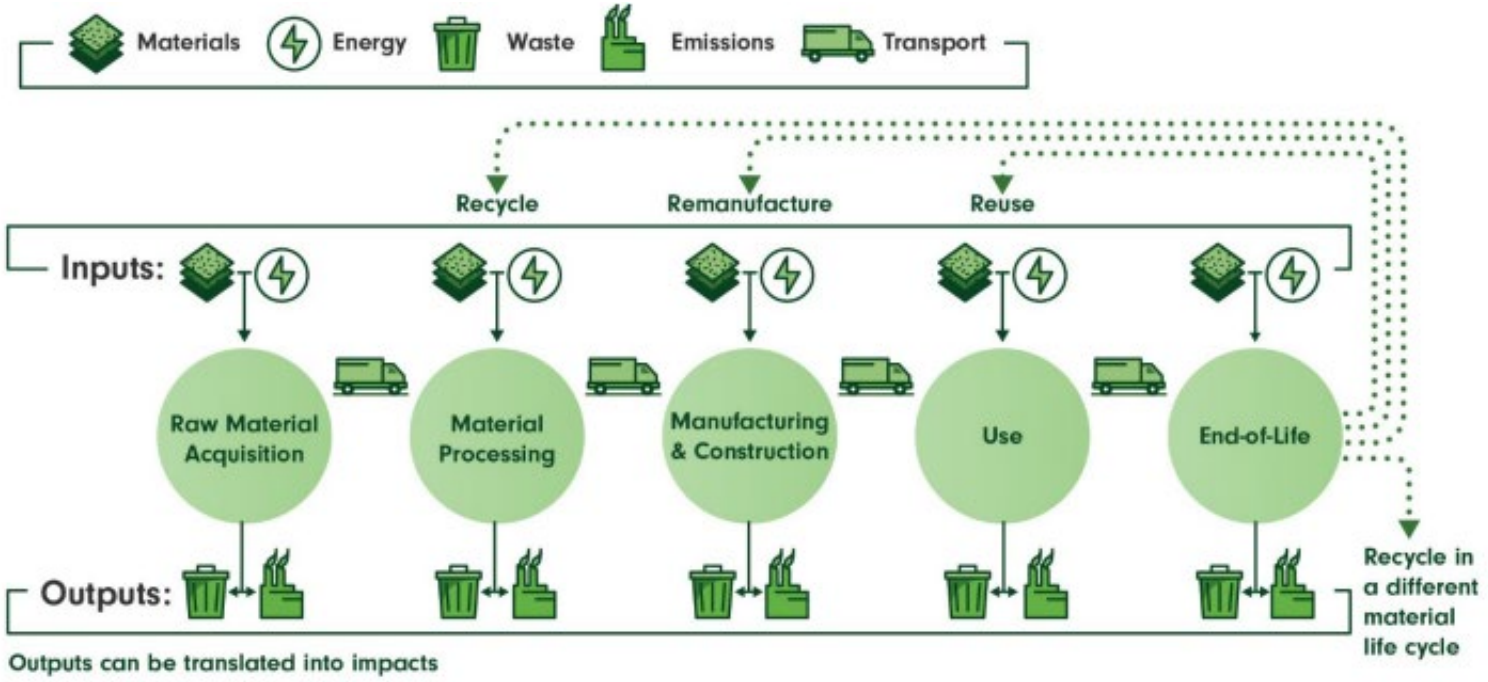


Figure 1. Generic life cycle of a production system for LCA.

https://www.fhwa.dot.gov/pavement/sustainability/hif15001.pdf

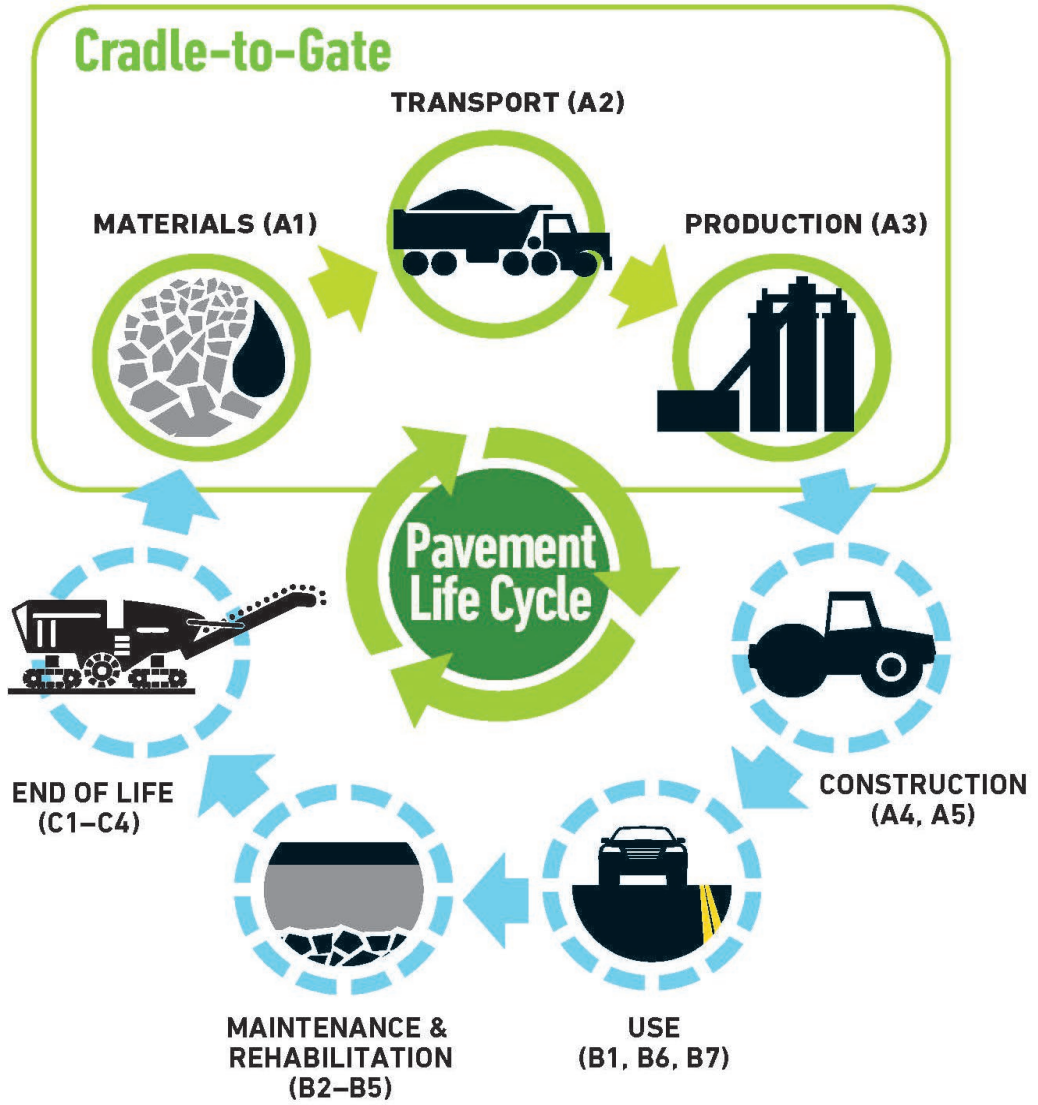
Life Cycle Assessment and EPDs

Cradle-To-Grave LCA

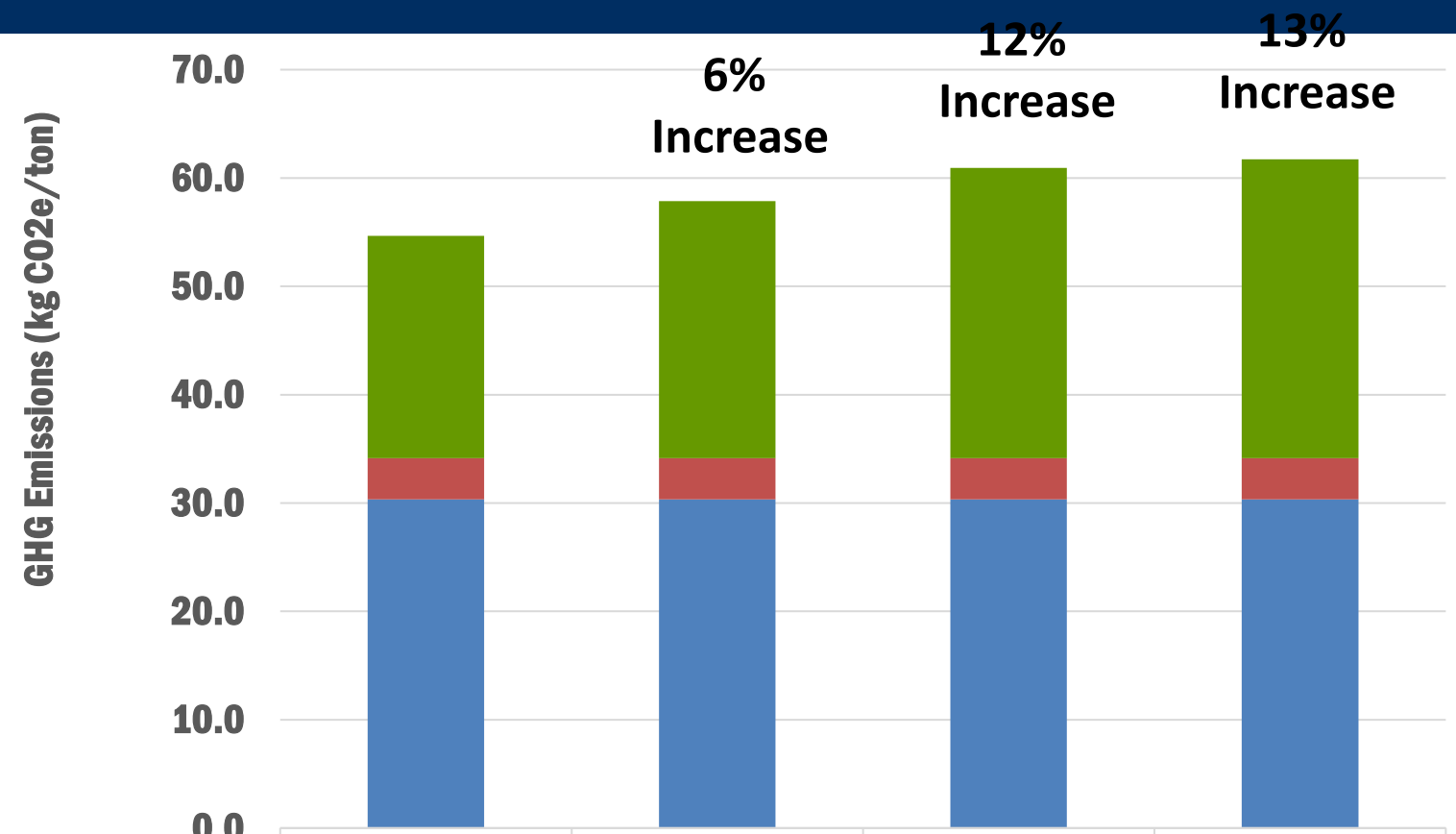
LCA PAVE

EPDs

Emerald ECO LABEL

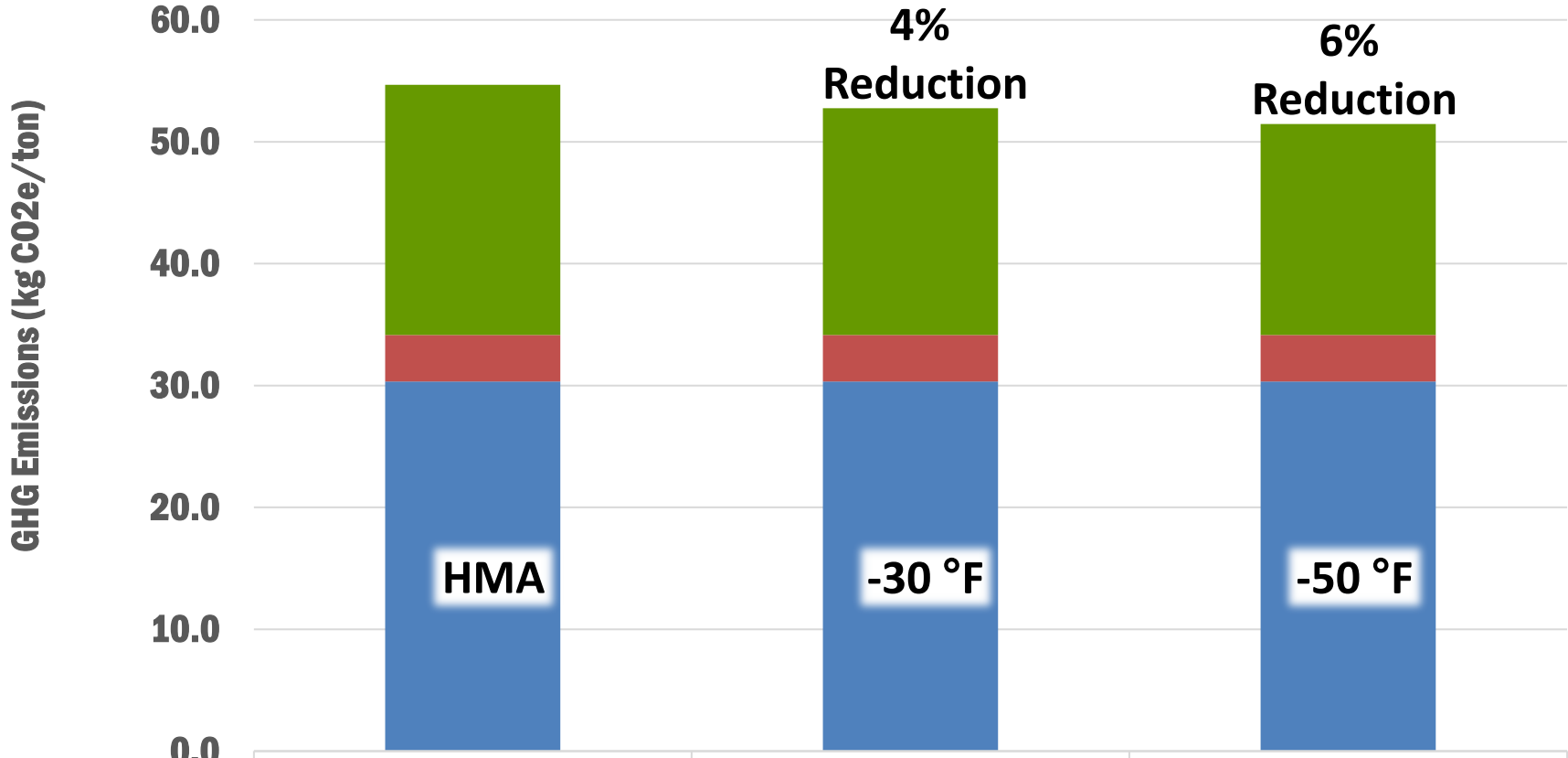


Burner Fuel Type



	Natural Gas	Used Oil	Propane	Diesel
Total (A1-A3)	54.7	57.9	60.9	61.7
Plant Operations (A3)	20.5	23.7	26.8	27.6
Transportation (A2)	3.8	3.8	3.8	3.8
Materials (A1)	30.3	30.3	30.3	30.3

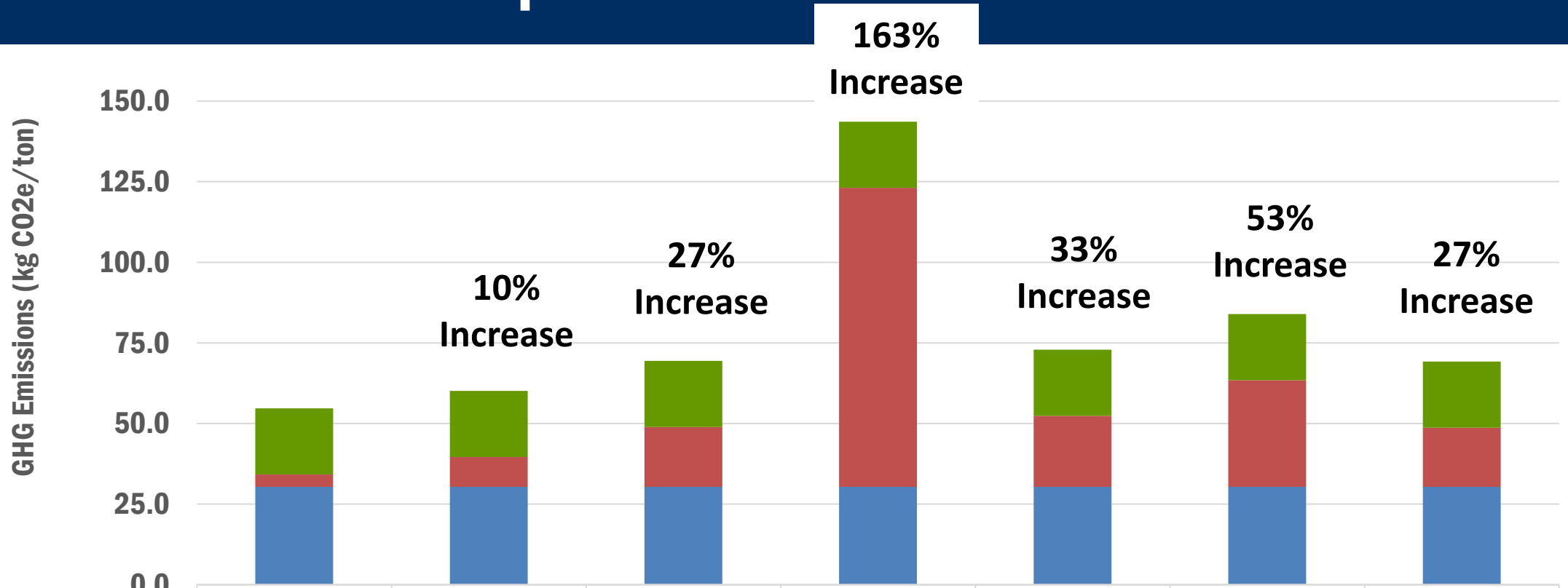
WMA – Reduced Mix Production Temp



	HMA	WMA -30°F	WMA -50°F
Total (A1-A3)	53.7	51.8	50.5
Plant Operations (A3)	20.5	18.6	17.3
Transportation (A2)	3.8	3.8	3.8
Materials (A1)	30.3	30.3	30.3

Assume 1,000 Btu/°F/ton fuel savings

A2 Transport Distance and Mode



	Average Truck	50 Miles Truck	100 Miles Truck	500 Miles Truck	500 Miles Train	500 Miles Inland Barge	500 Miles Ocean Vessel
Total (A1-A3)	54.7	60.1	69.4	143.6	72.9	83.9	69.2
Plant Operations (A3)	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Transportation (A2)	3.8	9.3	18.5	92.7	22.0	33.1	18.3
Materials (A1)	30.3	30.3	30.3	30.3	30.3	30.3	30.3

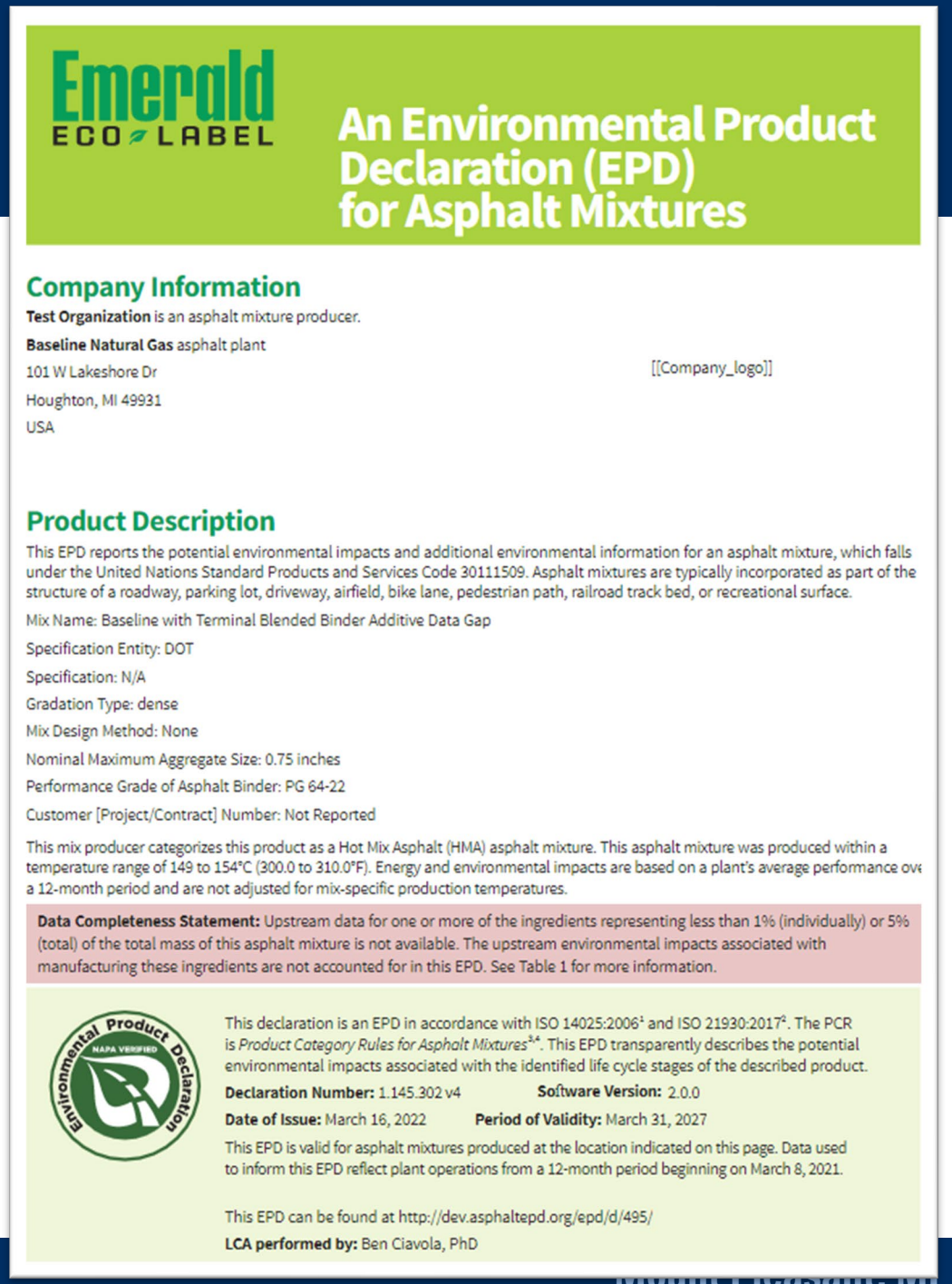
EPD Cover

Company and Plant Information →

Product Description →

Red box indicates a data gap →

Green box has info about the EPD →



Emerald ECO LABEL

An Environmental Product Declaration (EPD) for Asphalt Mixtures

Company Information

Test Organization is an asphalt mixture producer.

Baseline Natural Gas asphalt plant

101 W Lakeshore Dr

Houghton, MI 49931

USA

[[Company_logo]]

Product Description

This EPD reports the potential environmental impacts and additional environmental information for an asphalt mixture, which falls under the United Nations Standard Products and Services Code 30111509. Asphalt mixtures are typically incorporated as part of the structure of a roadway, parking lot, driveway, airfield, bike lane, pedestrian path, railroad track bed, or recreational surface.

Mix Name: Baseline with Terminal Blended Binder Additive Data Gap

Specification Entity: DOT

Specification: N/A

Gradation Type: dense

Mix Design Method: None

Nominal Maximum Aggregate Size: 0.75 inches

Performance Grade of Asphalt Binder: PG 64-22

Customer [Project/Contract] Number: Not Reported

This mix producer categorizes this product as a Hot Mix Asphalt (HMA) asphalt mixture. This asphalt mixture was produced within a temperature range of 149 to 154°C (300.0 to 310.0°F). Energy and environmental impacts are based on a plant's average performance ove a 12-month period and are not adjusted for mix-specific production temperatures.

Data Completeness Statement: Upstream data for one or more of the ingredients representing less than 1% (individually) or 5% (total) of the total mass of this asphalt mixture is not available. The upstream environmental impacts associated with manufacturing these ingredients are not accounted for in this EPD. See Table 1 for more information.

Environmental Product Declaration — NAPA VERIFIED

This declaration is an EPD in accordance with ISO 14025:2006[1] and ISO 21930:2017[2]. The PCR is *Product Category Rules for Asphalt Mixtures*[3,4]. This EPD transparently describes the potential environmental impacts associated with the identified life cycle stages of the described product.

Declaration Number: 1.145.302 v4 **Software Version:** 2.0.0

Date of Issue: March 16, 2022 **Period of Validity:** March 31, 2027

This EPD is valid for asphalt mixtures produced at the location indicated on this page. Data used to inform this EPD reflect plant operations from a 12-month period beginning on March 8, 2021.

This EPD can be found at http://dev.asphaltepd.org/epd/d/495/

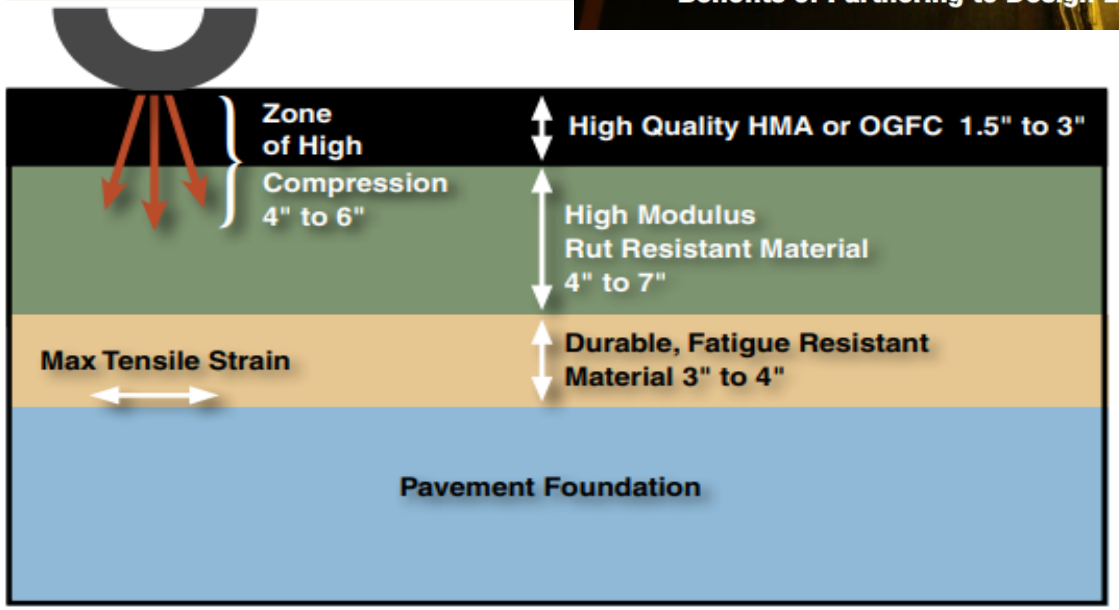
LCA performed by: Ben Ciavola, PhD

Structural Performance – Perpetual Pavements

- Perpetual Asphalt Pavement
  - "Long-Life Pavements"
  - Designed and constructed to lasts 50+ years
  - No major structural rehabilitation or reconstruction
  - Periodic surface renewal
  - Structural Design

PAVEXpress

http://app.pavexpress.com/#/

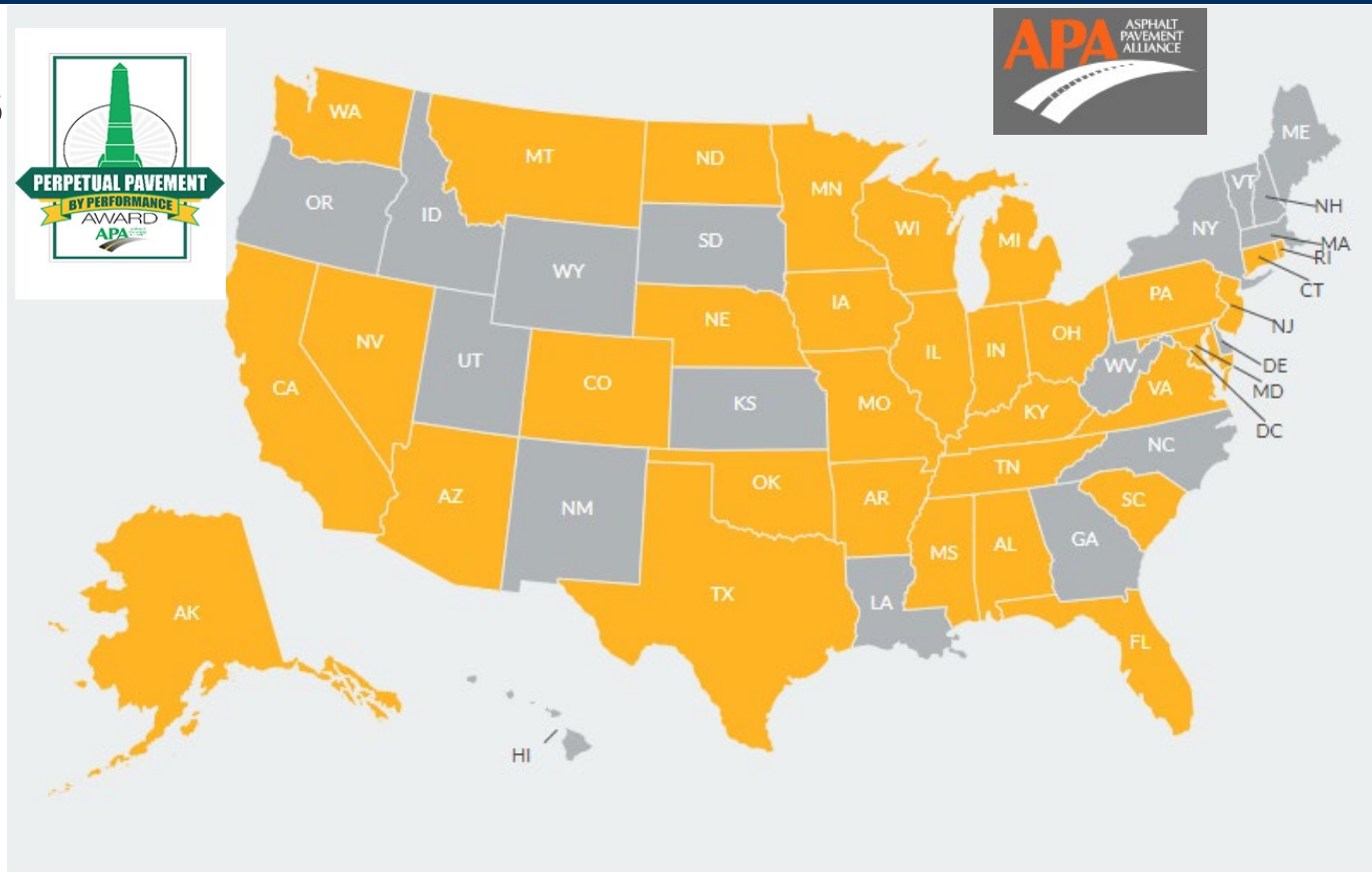


Structural Performance - Perpetual Pavement Awards

- APA Recognized 181 Long-Life Pavements
  - 32 U.S. State, 1 Canadian Province
  - Ages: 32 to 91 years, ***Average = 46 years***

- 3 Methods
  - Perpetual By Design
  - Perpetual by Performance
  - Perpetual by Conversion

- *How many in Michigan?*



Caltrans Recent I-5 Long Life Pavement Project

A LCCA for the new and existing lanes indicates that using a *Perpetual Pavement design saves Caltrans approximately $40 million in undiscounted direct asphalt paving costs over the next 60 years when compared to conventional rehabilitation strategies* methodology. The Perpetual Pavement design approach has a 4 percent higher initial cost, but no rehabilitation costs over the analysis period.

Performance – Lower Cost & Lower LCA

Iowa DOT Perpetual Designs – Lower Cost & Lower Carbon

U.S. Department of Transportation
Federal Highway Administration

IMPROVED ASPHALT PAVEMENT SUSTAINABILITY THROUGH PERPETUAL PAVEMENT DESIGN

FHWA-HIF-19-080

SUSTAINABLE PAVEMENTS PROGRAM

The Iowa Department of Transportation constructed an innovative asphalt pavement project featuring perpetual pavement long-life design concepts in 2016. The award-winning project, located on a 3.5-mile stretch of State Highway 100 near Cedar Rapids, provided reduced life-cycle costs and reduced environmental impacts as compared to conventional design approaches.

WHAT WAS THE MOTIVATION?

The Iowa Department of Transportation (Iowa DOT) is continuously looking for ways to improve the performance of its highway network while also reducing costs. The short service lives associated with many conventional asphalt pavements, along with their recurring maintenance and rehabilitation requirements and associated traffic disruptions, have led the Department to evaluate perpetual asphalt pavement designs offering extended service lives, lower life-cycle costs, and increased sustainability. With the perpetual pavement, the Iowa DOT expects to be able to limit future rehabilitation activities to the surface course while preserving the base and foundation. This will minimize the impacts to traffic by limiting long-term work zones and costly reconstruction alternatives in the future.

WHAT WAS DONE?

In 2016, the Iowa DOT constructed a perpetual pavement on a stretch of Iowa State Highway 100 (Iowa 100), a four-lane divided highway that loops around Cedar Rapids from Edgewood Road on the north and westward to Covington Road (see figures 1a and 1b). Perpetual pavements make use of a fatigue-resistant lower asphalt layer coupled with rut-resistant surface layers to produce a long-lasting pavement that can last for decades with only minimal maintenance to the surface layer (NAPA 2018). In the proper application, the enhanced performance and durability associated with perpetual pavements can result in significant economic (lower life-cycle costs), environmental (less material usage/production), and social (fewer lane closures) benefits.

The portion of the Iowa 100 paving project featured in this case study was completed in 2016 and included a 12.5-inch asphalt pavement over a 15.5-inch modified subbase (see figure 2 [Schram 2018]), a design that is expected to carry the traffic on this stretch of highway for over 60 years with only minor periodic milling and resurfacing. The initial cost of the project was $15.1 million (including safety features and project management), with the pavement construction accounting for approximately $6.5 million. The $15.1 million cost was about $5 million less than the original engineer's estimate.

JANUARY 2020
FHWA-HIF-19-080

Table 4. LCCA computations for perpetual and conventional pavements.

Economic Indicator	Discount Rate, %	Cost of Perpetual Pavement, $	Cost of Conventional Pavement, $	Cost Savings with Perpetual, $ (%)
NPV	2	5,273,053	7,366,294	2,093,241 (28)
EUAC	2	105,461	147,326	41,895 (28)
NPV	4	4,769,182	5,746,767	977,585 (17)
EUAC	4	95,384	114,935	19,552 (17)

IMPROVED ASPHALT PAVEMENT SUSTAINABILITY THROUGH PERPETUAL PAVEMENT DESIGN

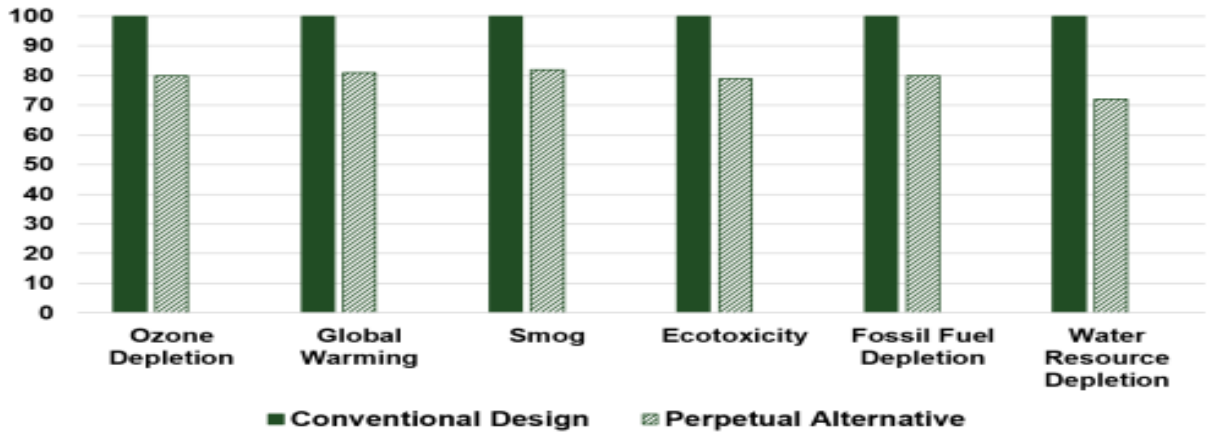


Figure 4. LCA results for the conventional design and the perpetual alternative.

https://www.fhwa.dot.gov/pavement/sustainability/case_studies/hif19080.pdf

U.S. Department of Transportation
Federal Highway Administration

IMPROVED ASPHALT PAVEMENT SUSTAINABILITY THROUGH PERPETUAL PAVEMENT DESIGN

FHWA-HIF-19-080

Perpetual Pavement – Rubblized PCC, Crack & Seat

Functional Performance - Congestion Costs - User Delays


I-405 Los Angeles, CA

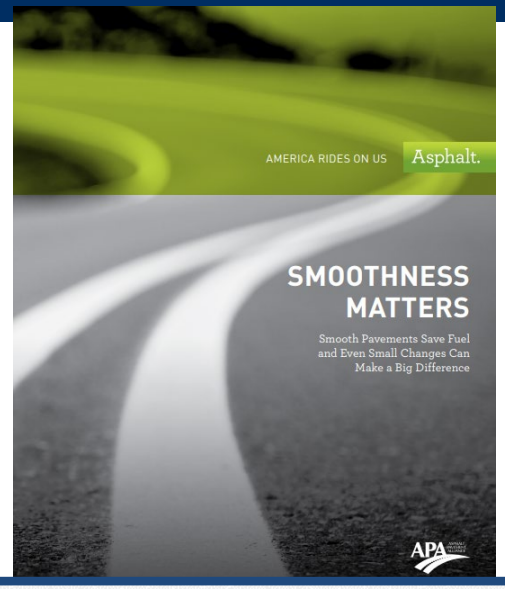
Morning News – Reno, NV

2022: $81 Billion https://www.govtech.com/question-of-the-day/how-much-did-traffic-congestion-cost-the-u-s-last-year

2023 Trucking Industry : $95 Billion https://www.truckersnews.com/home/article/15637165/traffic-congestion-cost-trucking-industry-946-billion-in-2021-new-record

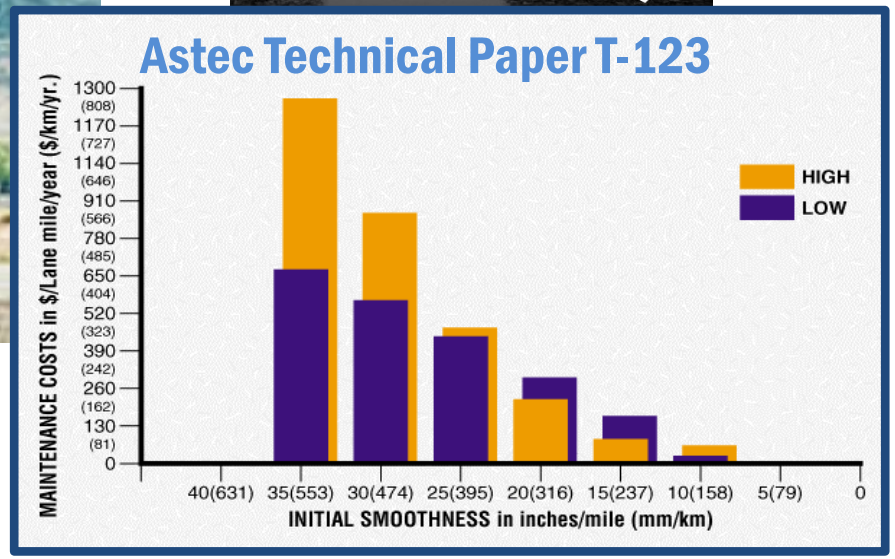
Functional Performance - Pavement Smoothness

- Pavement Smoothness Significantly Impacts Fuel Consumption
  - Pavement Smoothness ≈ 5%
  - Rolling Resistance ≈ 1%
  - Pavement Stiffness ? (low)



- WesTrack
  - Mid 1990's
  - FHWA Sponsored
  - 4.5% Reduction in Fuel Consumption from Rough to Smooth

https://highways.dot.gov/public-roads/fall-1996/westrack-road-solutions



Durability Performance - Balanced Mix Design (BMD)

NAPA NATIONAL ASPHALT PAVEMENT ASSOCIATION

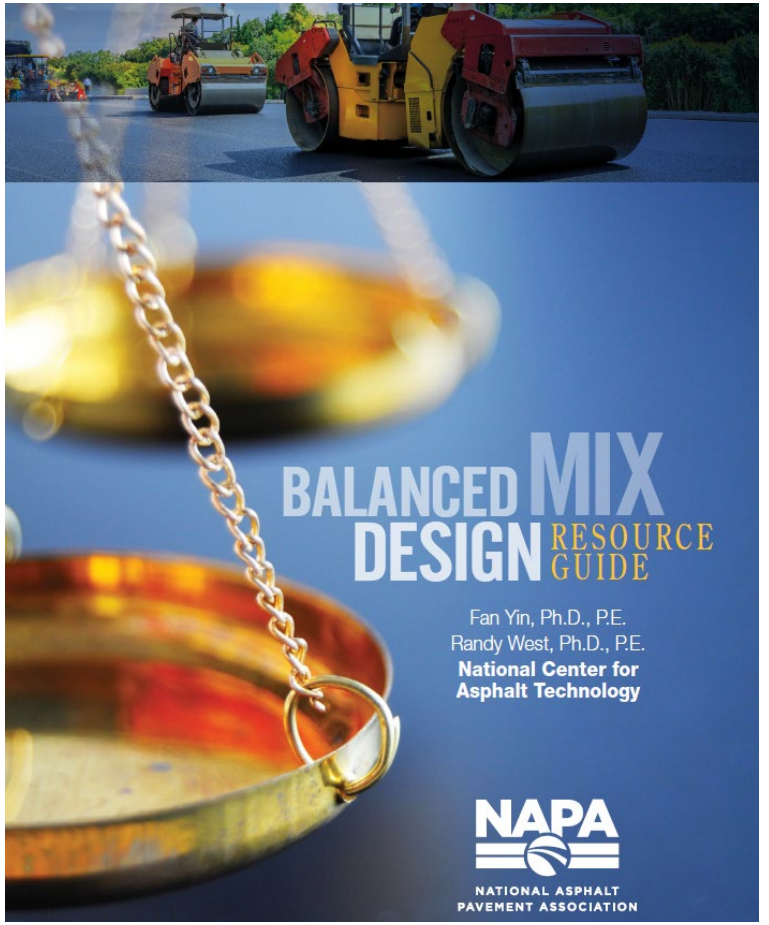
HOME | EXPERTISE | ENGINEERING | RESOURCES | BALANCED MIX DESIGN RESOURCE GUIDE

BALANCED MIX DESIGN RESOURCE GUIDE

APPROACHES | PERFORMANCE TESTS | IMPLEMENTATION EFFORTS | TRAINING & RESOURCES | TOOLS

What is Balanced Mix Design?

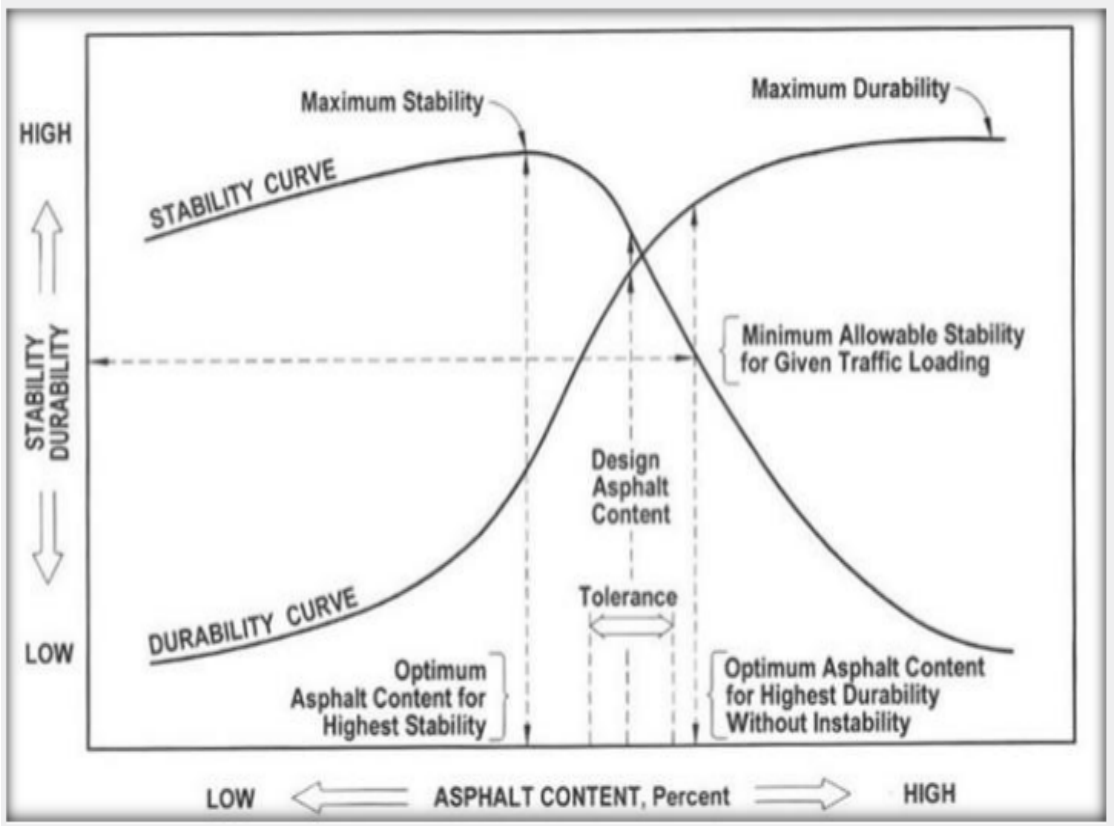
Balanced Mix Design (BMD) is defined as "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure" per AASHTO PP 105-20. This definition was initially established by the former Federal Highway Administration (FHWA) Expert Task Group (ETG) Balanced Mix Design Task Force in 2015.



https://www.asphaltpavement.org/expertise/engineering/resources/bmd-resource-guide

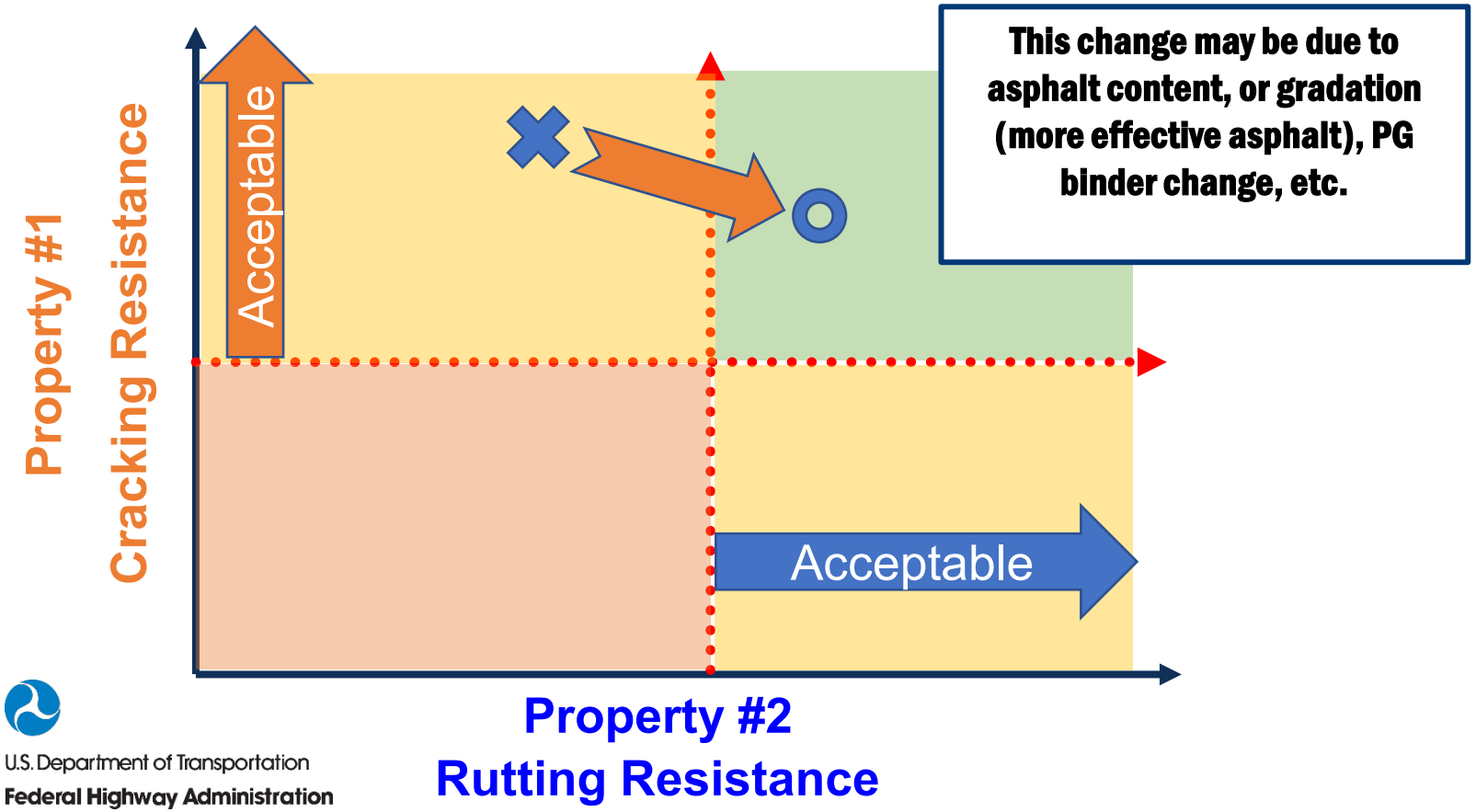
Performance – Balanced Mix Design

- Balanced Mix Design ≈100 years Ago
  - Balance Stability & Durability
- Industry Reported Benefits
  - Use of Innovative & Sustainable Additives
  - Relaxed Volumetric Properties
  - More Robust Methods for Mix Design & Acceptance
  - Improved In-place Density



Reality of BMD

- Reality of BMD Approach

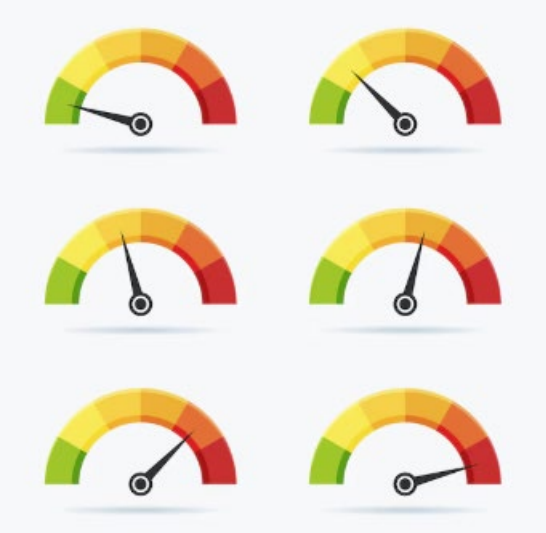


U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration RESOURCE CENTER

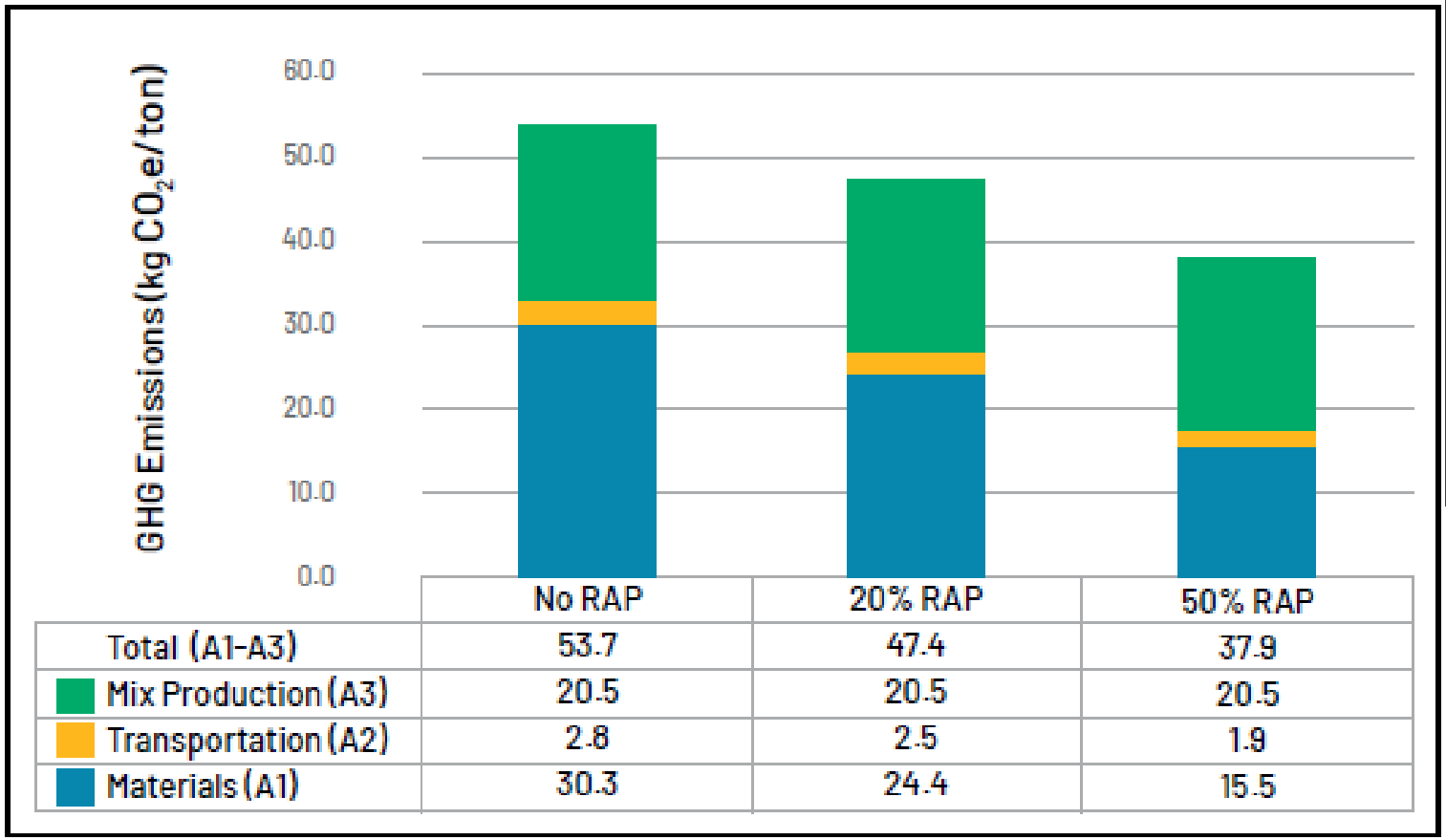
What Levers do we Have?

- Materials
  - Reclaimed Asphalt Pavement (RAP)
  - Reclaimed Asphalt Shingles (RAS)
  - Warm Mix Asphalt (WMA)
  - Recycling Agents
  - Others, ….
  - Locally Available Aggregates?
- Plants
  - Variable Frequency Drives
  - Insulation
  - Drying Efficiency
  - Fuel Selection
  - Manage Agg/RAP Moisture
- Construction
  - Mat Density
  - Joint Density
  - Smoothness
- Pavement Design
  - Perpetual Pavements
  - Long-Life Pavements

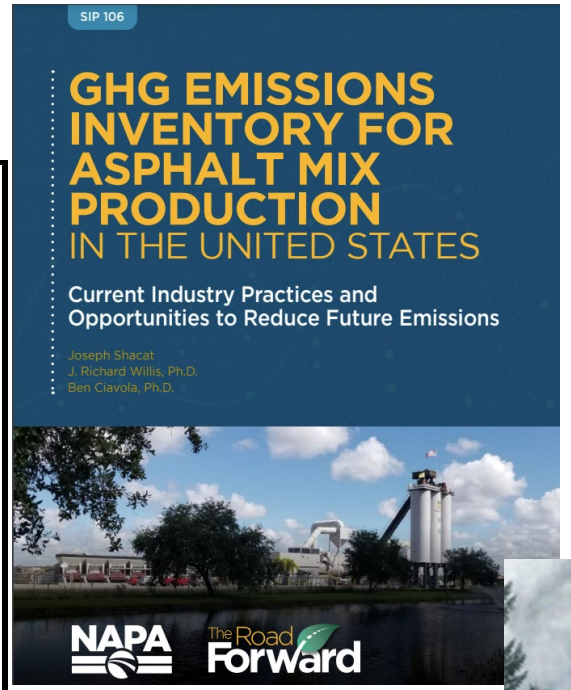


What Levers do we have – RAP?

- Materials
  - Reclaimed Asphalt Pavement (RAP)



	No RAP	20% RAP	50% RAP
Total (A1-A3)	53.7	47.4	37.9
Mix Production (A3)	20.5	20.5	20.5
Transportation (A2)	2.8	2.5	1.9
Materials (A1)	30.3	24.4	15.5



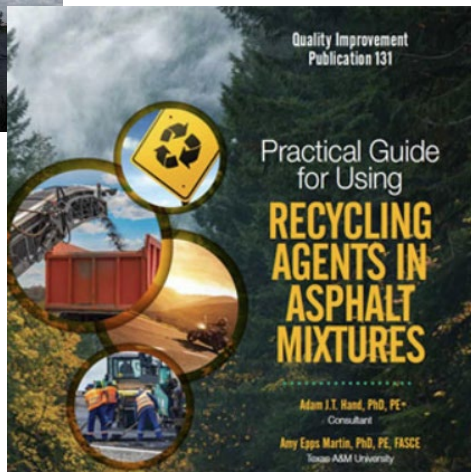


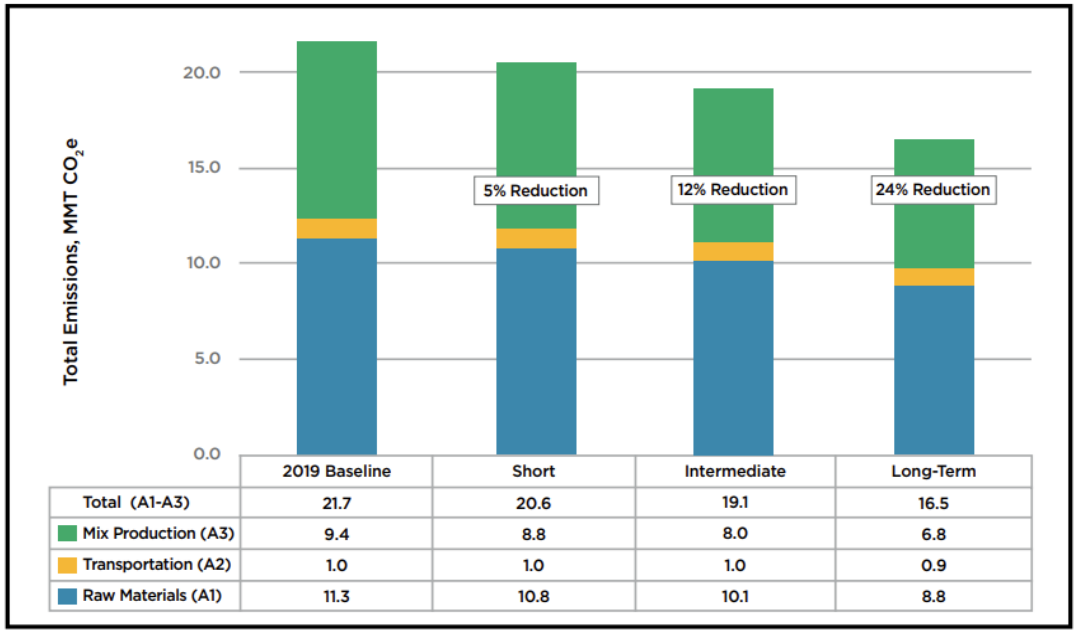
Figure 7. Impact of RAP on cradle-to-gate (A1-A3) GHG emissions of an asphalt mixture. Total asphalt binder content for each mix is 5%. RAP is assumed to also have a 5% asphalt binder content and to offset the virgin binder content accordingly (e.g., a mix with 20% RAP would have a virgin binder content of 4% and a recycled binder content of 1%). Units in the data table are in kg CO_2e/ton of mix. The sum of individual life cycle stages may not equal the total due to rounding effects.

What Levers do we have RAP, WMA, Moisture?

- Materials
- **Reclaimed Asphalt Pavement (RAP)**
- Reclaimed Asphalt Shingles (RAS)
- **Warm Mix Asphalt (WMA)**
- Recycling Agents
- Other: rubber, plastics, ….
- Locally Available Aggregates?
- **Moisture Management**

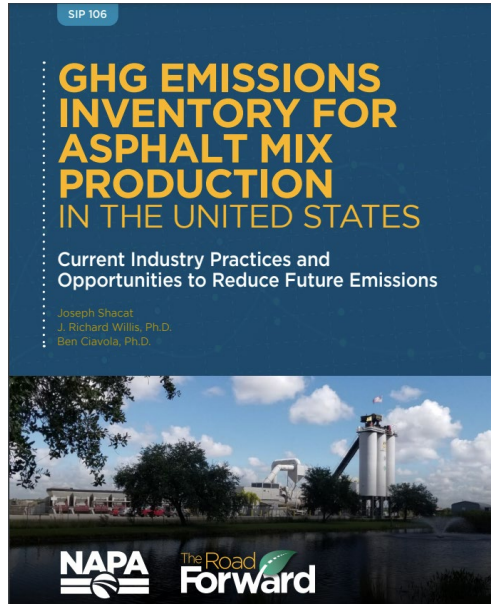
Table 3. **General parameters for GHG emission reduction scenarios.**

Parameter	2019 Baseline	Short-Term	Intermediate	Long-Term
RAP Content	21%	25%	30%	40%
Natural Gas Consumption as Percentage of Fuel Combusted	69%	72%	75%	90%
Aggregate Moisture Content Reduction	N/A	0.25%	0.50%	1.0%
Asphalt Mix Production Temperature Reduction	N/A	10 °F	25 °F	40 °F
Reduction in Electricity Consumption Intensity	3.32 kWh/ton	5%	10%	20%



	2019 Baseline	Short	Intermediate	Long-Term
Total (A1-A3)	21.7	20.6	19.1	16.5
Mix Production (A3)	9.4	8.8	8.0	6.8
Transportation (A2)	1.0	1.0	1.0	0.9
Raw Materials (A1)	11.3	10.8	10.1	8.8

Figure 5. **Potential cradle-to-gate GHG emissions associated with achieving short-term, intermediate, and long-term goals.**



What Levers do we have at the Asphalt Plant?

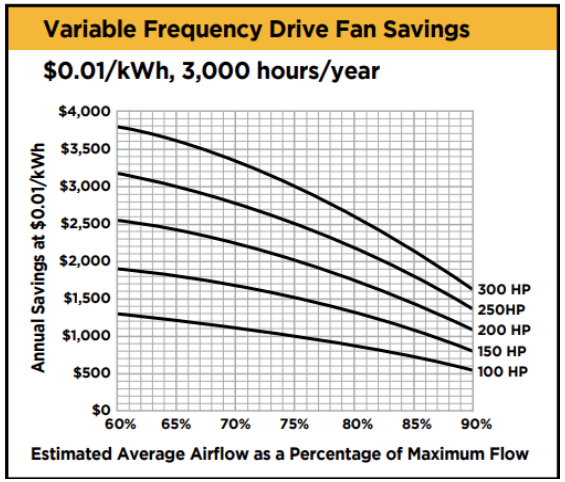
- Plants
- Variable Frequency Drives
- Insulation
- Drying Efficiency
- Fuel Selection
- Manage Agg/RAP Moisture

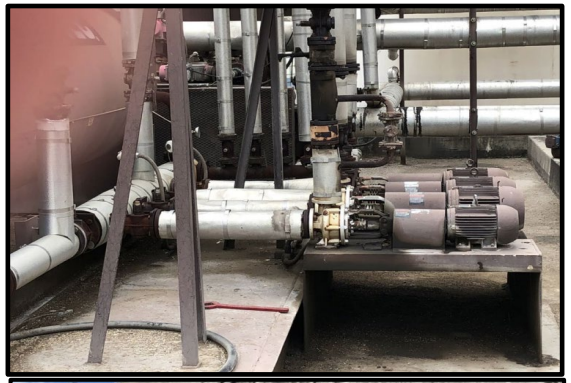
Type of Energy	Heating Value (Net or LHV)		Billing Units	Cost Comparisons Based on Heating Values						
No. 2 Fuel Oil	BTU/gal.	132,000	Per Gallon	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60
No. 5 Fuel Oil	BTU/gal.	143,250	Per Gallon	$1.09	$1.19	$1.30	$1.41	$1.52	$1.63	$1.74
Propane (LPG)	BTU/gal.	84,345	Per Gallon	$0.64	$0.70	$0.77	$0.83	$0.89	$.096	$1.02
Natural Gas	BTU/CCF (see note)	90,500	Per CCF	$0.69	$0.75	$0.82	$0.89	$0.96	$1.03	$1.10
Gas	BTU/Therm	100,000	Per Therm	$0.76	$0.83	$0.91	$0.98	$1.06	$1.14	$1.21
Electricity	BTU/kWh	3,413	Per kWh	$0.03	$0.03	$0.03	$0.03	$0.04	$0.04	$0.04
Coal	BTU/lb	12,000	Per Ton	$182	$200	$218	$236	$255	$273	$291

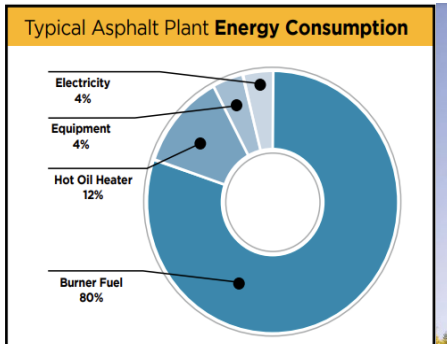
Each column of cost comparisons relates the costs of various types of energy to each other based on heating values. For example, the cost of No. 2 fuel oil at $1.00 per gallion is equivalent to a cost of $1.09 for No. 5 fuel oil for the same BTU. Thus, if No. 2 fuel is $1.00 per gallon it doesn't pay to choose No. 5 fuel oil unless it is less than $1.09. Likewise, it wouldn't pay to use electricity unless it is less than $0.03 per kWh.

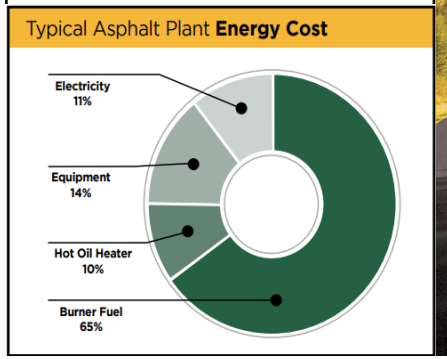
Type of Energy	Cost Comparisons Based on Heating Values (continued)													
No. 2 Fuel Oil	$1.70	$1.80	$1.90	$2.00	$2.10	$2.20	$2.30	$2.40	$2.50	$2.60	$2.70	$2.80	$2.90	$3.00
No. 5 Fuel Oil	$1.84	$1.95	$2.06	$2.17	$2.28	$2.39	$2.50	$2.60	$2.71	$2.82	$2.93	$3.04	$3.15	$3.26
Propane (LPG)	$1.09	$1.15	$1.21	$1.28	$1.34	$1.41	$1.47	$1.53	$1.60	$1.66	$1.73	$1.79	$1.85	$1.92
Natural Gas	$1.17	$1.23	$1.30	$1.37	$1.44	$1.51	$1.58	$1.65	$1.71	$1.78	$1.85	$1.92	$1.99	$2.06
Gas	$1.29	$1.36	$1.44	$1.52	$1.59	$1.67	$1.74	$1.82	$1.89	$1.97	$2.05	$2.12	$2.20	$2.27
Electricity	$0.04	$0.05	$0.05	$0.05	$0.05	$0.06	$0.06	$0.06	$0.06	$0.07	$0.07	$0.07	$0.07	$0.08
Coal	$309	$327	$345	$364	$382	$400	$418	$436	$455	$473	$491	$509	$527	$545

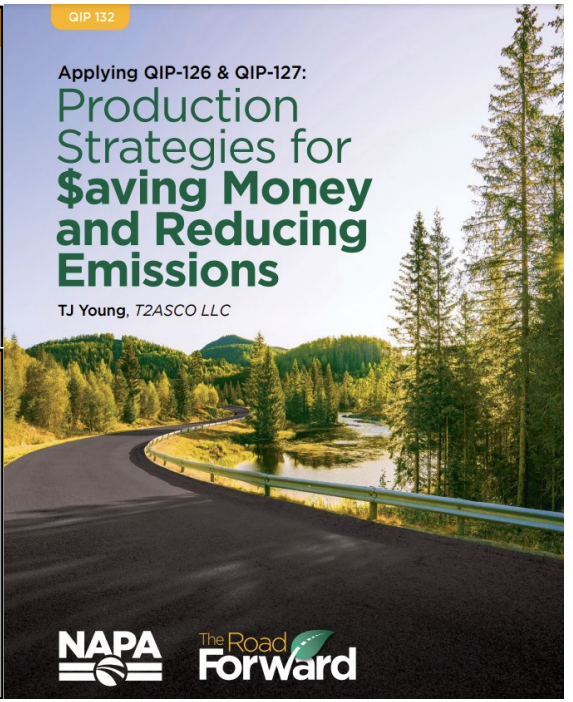
When No. 2 fuel oil is $1.00 per gallon. The actual heating values of various fuels vary somewhat from one region to another. However, the values used here are for fuels commonly used in the United States. CCF stands for 100 cubic feet. The net heating value of one cubic foot of natural gas is 905 BTU. However, natural gas is normally billed at its gross heating value, which is approximately 1,000 BTU per cubic foot.





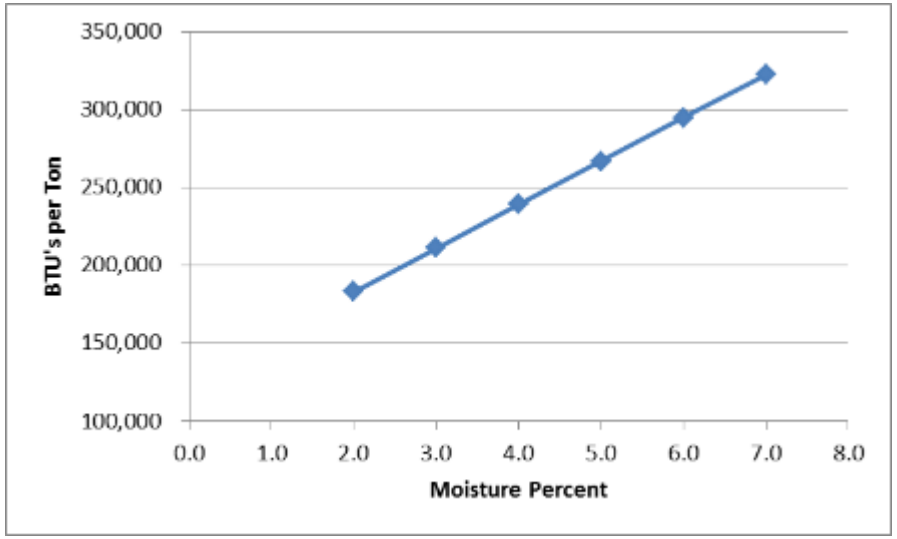






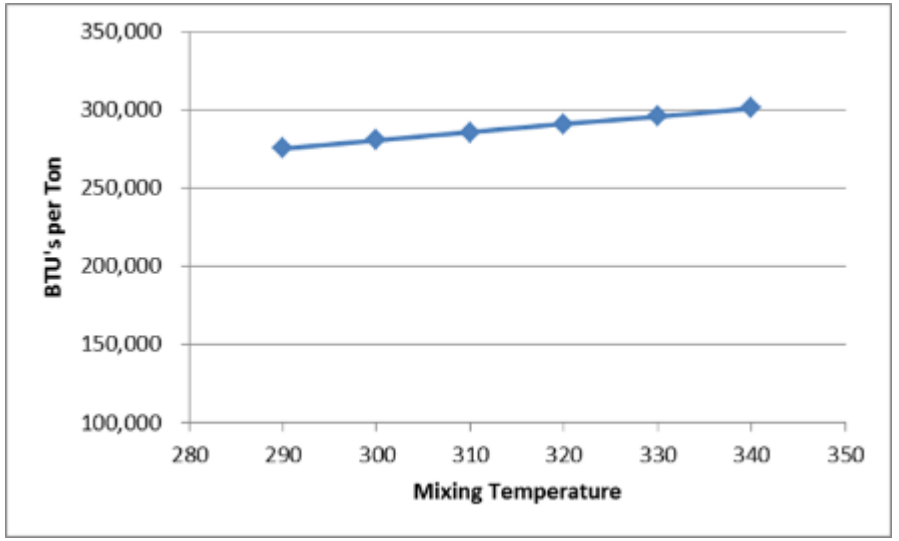
What levers do we have in asphalt plants

Moisture

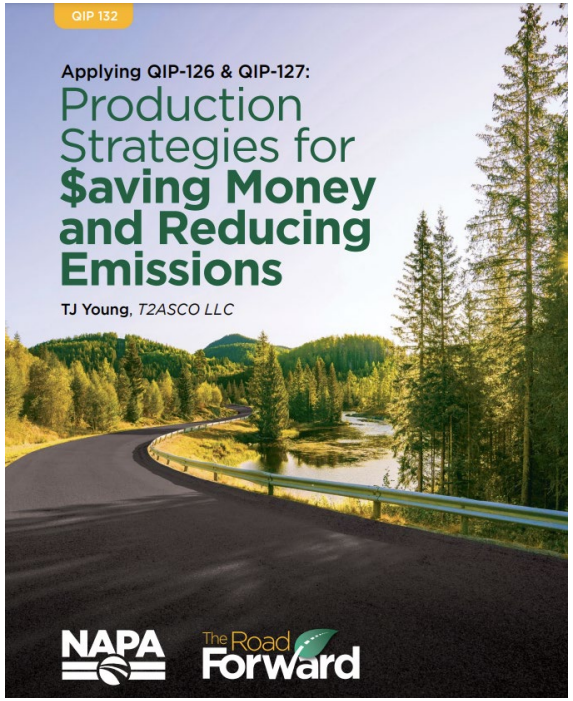


- *1% change in moisture equals a ~24,000 BTU change per ton of mix*

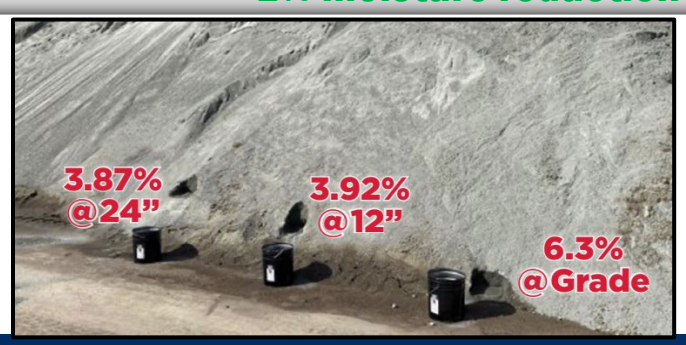
Temperature



- *Every 5 degree change equals a ~2,200 BTU change per ton of mix*



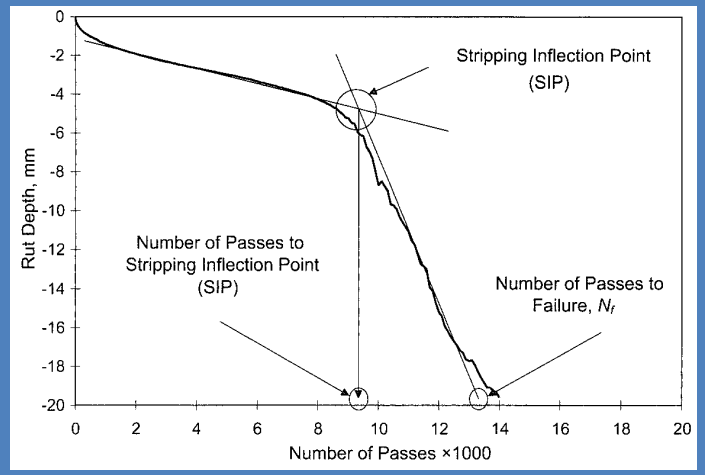
1% moisture reduction = ~55F temperature reduction



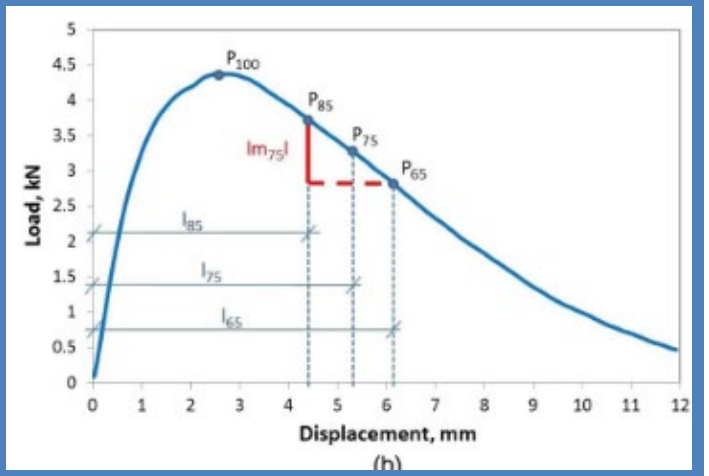
BMD Performance Tests can Assess Effective of "Levers"

BMD Tests – Right for the Climate & Distresses Observed

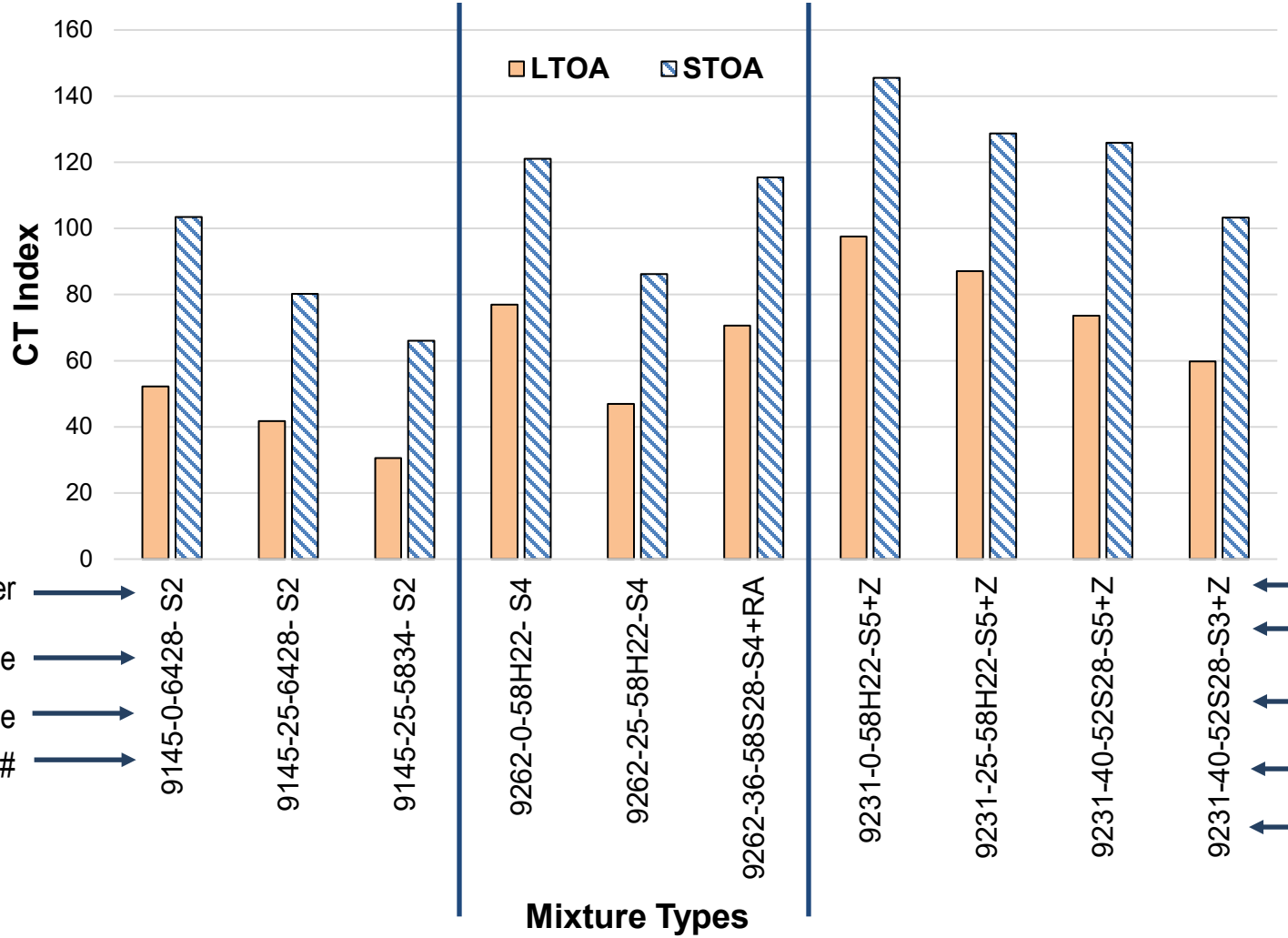
Rutting – HWTT?

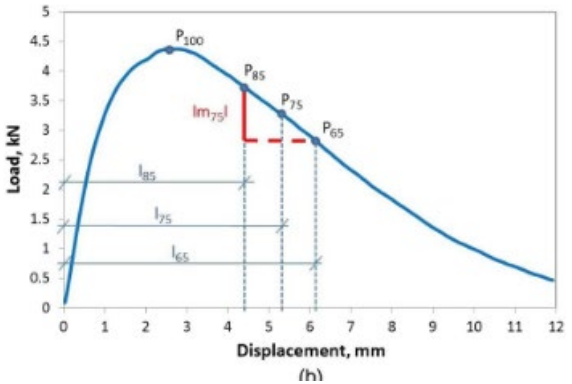


Cracking – CT_{Index}?



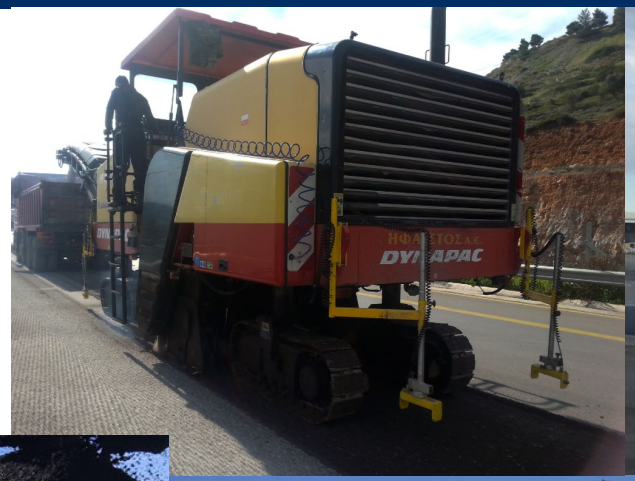
Same Source – Grade Bumping Down & Recycling Agents

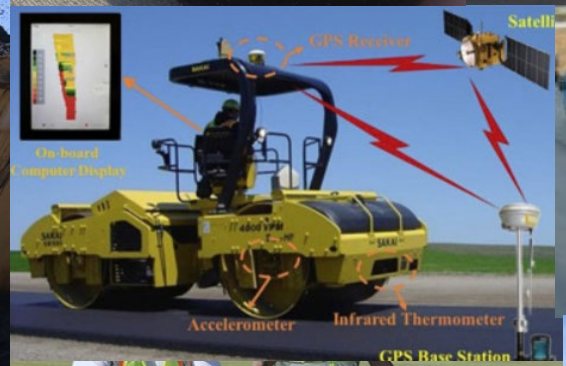




What Levers do we have Construction?

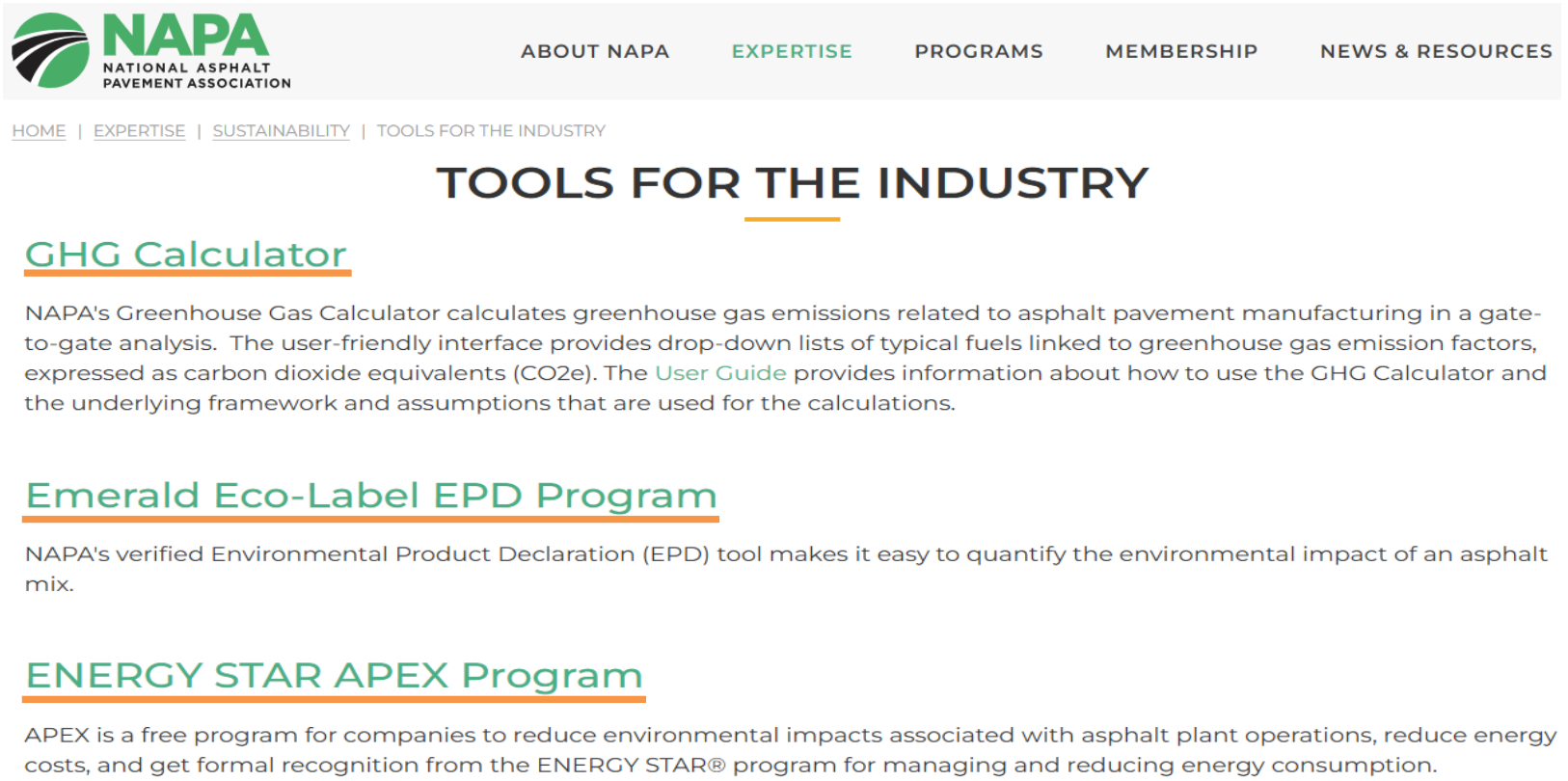
- Construction
  - Mat Density
  - Joint Density
  - Smoothness





NAPA Sustainability & Resilience Resources

- Technical Publications
- Webinars
- Technical Meetings
- Training & Education
- Talented Staff
- Tools for Industry
- Videos
- Pave it Black Podcasts
- NAPA Magazine



NAPA NATIONAL ASPHALT PAVEMENT ASSOCIATION

ABOUT NAPA | EXPERTISE | PROGRAMS | MEMBERSHIP | NEWS & RESOURCES

HOME | EXPERTISE | SUSTAINABILITY | TOOLS FOR THE INDUSTRY

TOOLS FOR THE INDUSTRY

GHG Calculator

NAPA's Greenhouse Gas Calculator calculates greenhouse gas emissions related to asphalt pavement manufacturing in a gate-to-gate analysis. The user-friendly interface provides drop-down lists of typical fuels linked to greenhouse gas emission factors, expressed as carbon dioxide equivalents (CO_2e). The User Guide provides information about how to use the GHG Calculator and the underlying framework and assumptions that are used for the calculations.

Emerald Eco-Label EPD Program

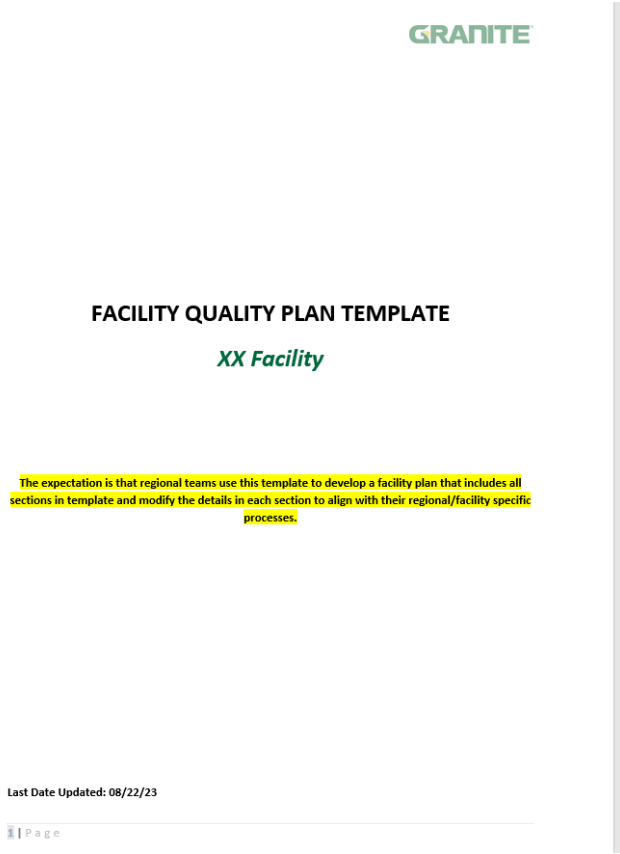
NAPA's verified Environmental Product Declaration (EPD) tool makes it easy to quantify the environmental impact of an asphalt mix.

ENERGY STAR APEX Program

APEX is a free program for companies to reduce environmental impacts associated with asphalt plant operations, reduce energy costs, and get formal recognition from the ENERGY STAR® program for managing and reducing energy consumption.

Community Engagement Helps

- Goals: Education and Partnering on RAP Use
- Customers
  - DOT
  - Other Agencies
  - Private Companies
- Share Goals & Benefits
- Plant & Lab Tours
- Pavement Association
- Change Management isn't Easy…
- Open & Honest Partnering



GRANITE

FACILITY QUALITY PLAN TEMPLATE

XX Facility

The expectation is that regional teams use this template to develop a facility plan that includes all sections in template and modify the details in each section to align with their regional/facility specific processes.

Last Date Updated: 08/22/23

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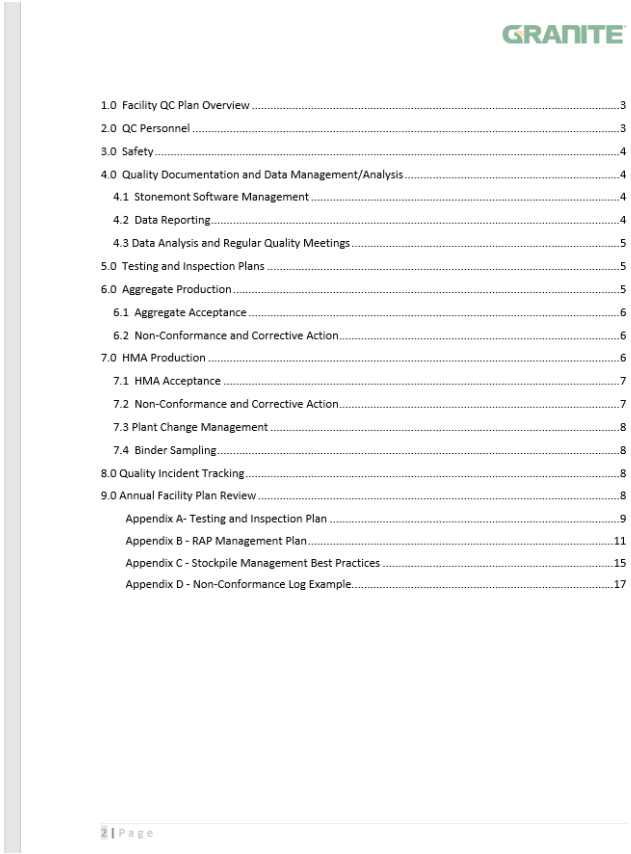

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Why RAP - *Session Description*

- Benefits of RAP for Owners
- How RAP can enhance Sustainability, Reduce Cost & Improves Performance
- Share Insights highlighting Economic and Environmental advantages of incorporating RAP in pavement projects
- Learn about cost savings with RAP, including reduced material expenses and lower greenhouse gas emissions
- Best practices for utilizing RAP to achieve high-quality, durable pavements meeting modern performance standards
- Gain knowledge on how RAP can transform your pavement management strategies, making them more cost-effective and environmentally friendly

Why RAP?

NAPA presented Gerken Paving, Inc. with a 2024 Larry H. Lemon Quality in Construction Award for work on M-34 and Industrial Highway in Lenawee County, Michigan

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