

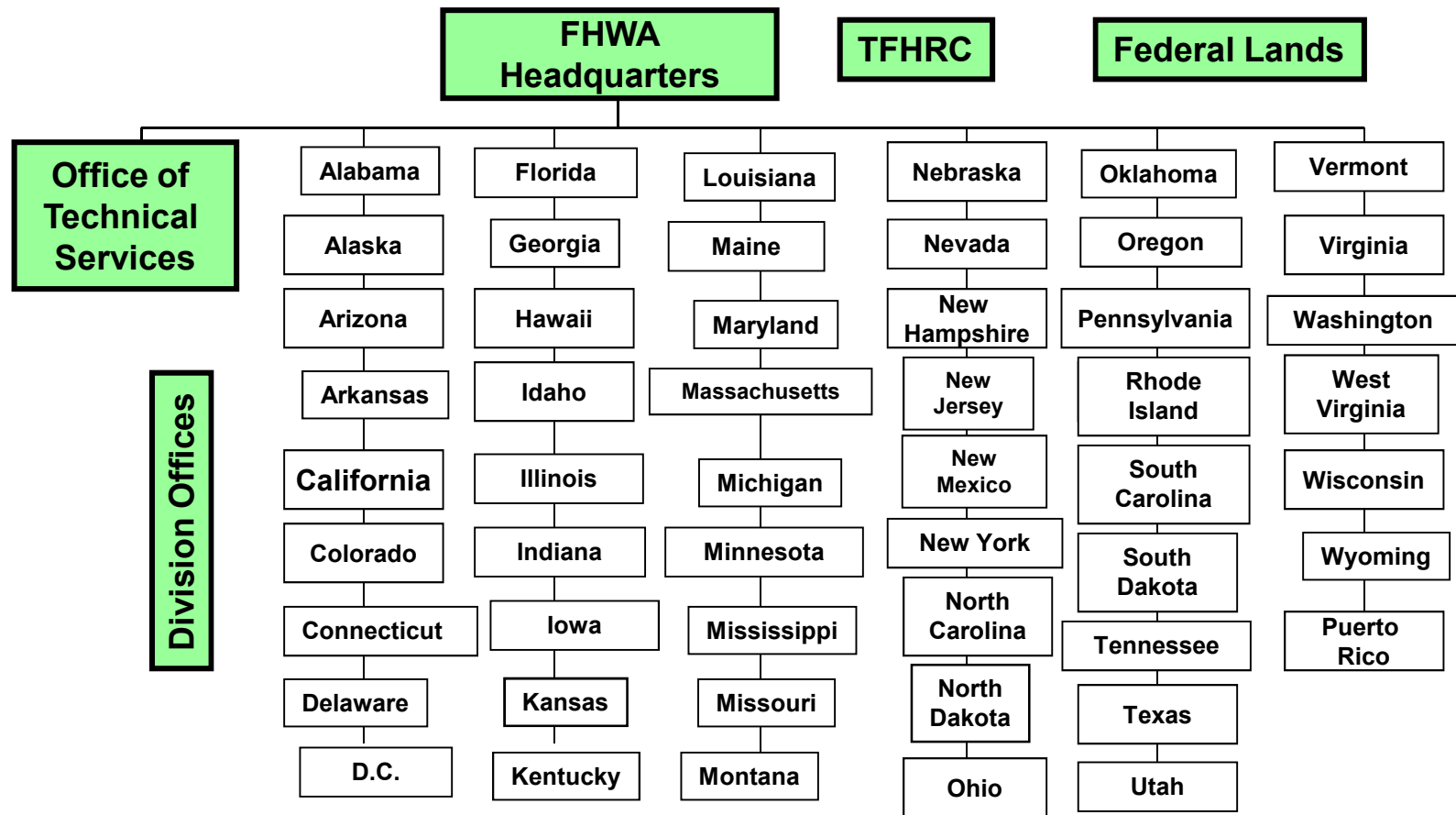
# Opportunities for Use of Industrial Materials in Highway/Road Construction

**Stephen R. Mueller, P.E.**  
**Pavement and Materials Engineer**  
**Federal Highway Administration**  
**[Steve.Mueller@fhwa.dot.gov](mailto:Steve.Mueller@fhwa.dot.gov)**

# Presentation Overview

- **Basic information about FHWA and the USA's Highway Transportation Network.**
- **FHWA's Recycling Policy**
- **Pavement and Materials Technology Opportunities in Transportation Applications:**
  - **Recycling**
  - **Reuse**
  - **Other Technologies**
- **Resources that might help your work!**

# FHWA Organization



# RC Technical Services Teams



# Office of Asset Management, Pavement and Construction

## 4 Teams

- **Design and Analysis**
- **Materials**
- **Construction**
- **Asset and Pavement Management**

**New –  
Office of Program Performance Management  
also with 4 New Teams**

# FHWA Asset Management, Pavement and Construction

## Points of Contact

**Butch Wlaschin, Director**

- **Suneel Vanikar**  
Design and Analysis Team Leader
- **John Bukowski**  
Materials Team Leader
- **Bryan Cawley**  
Construction and Construction Management Team Leader
- **Steve Gaj**  
Asset Management and Pavement Management Team Leader

# FHWA Recycling/Reuse Contacts

## FHWA Headquarters

**Lee Gallivan**  
**(317) 226-7493**  
**victor.gallivan@dot.gov**

**Gina Ahlstrom**  
**(202) 366-4612**  
**Gina.Ahlstrom@dot.gov**

## FHWA Resource Center

**Steve Mueller**  
**Resource Center, Lakewood**  
**(720) 963-3213**  
**steve.mueller@dot.gov**

**Mike Arasteh**  
**Resource Center, Baltimore**  
**(410) 962.0678**  
**Michael.Arasteh@dot.gov**

**Joe Huerta**  
**Resource Center, Baltimore**  
**(410) 962-2298**  
**Joseph.Huerta@dot.gov**

# Without Pavement, We Would Be Stuck in the Mud!



Washington-Richmond road, 1919  
NMAH, Archives Center, API Collection



# Society Depends on Infrastructure

***SOCIAL INTERACTIONS***

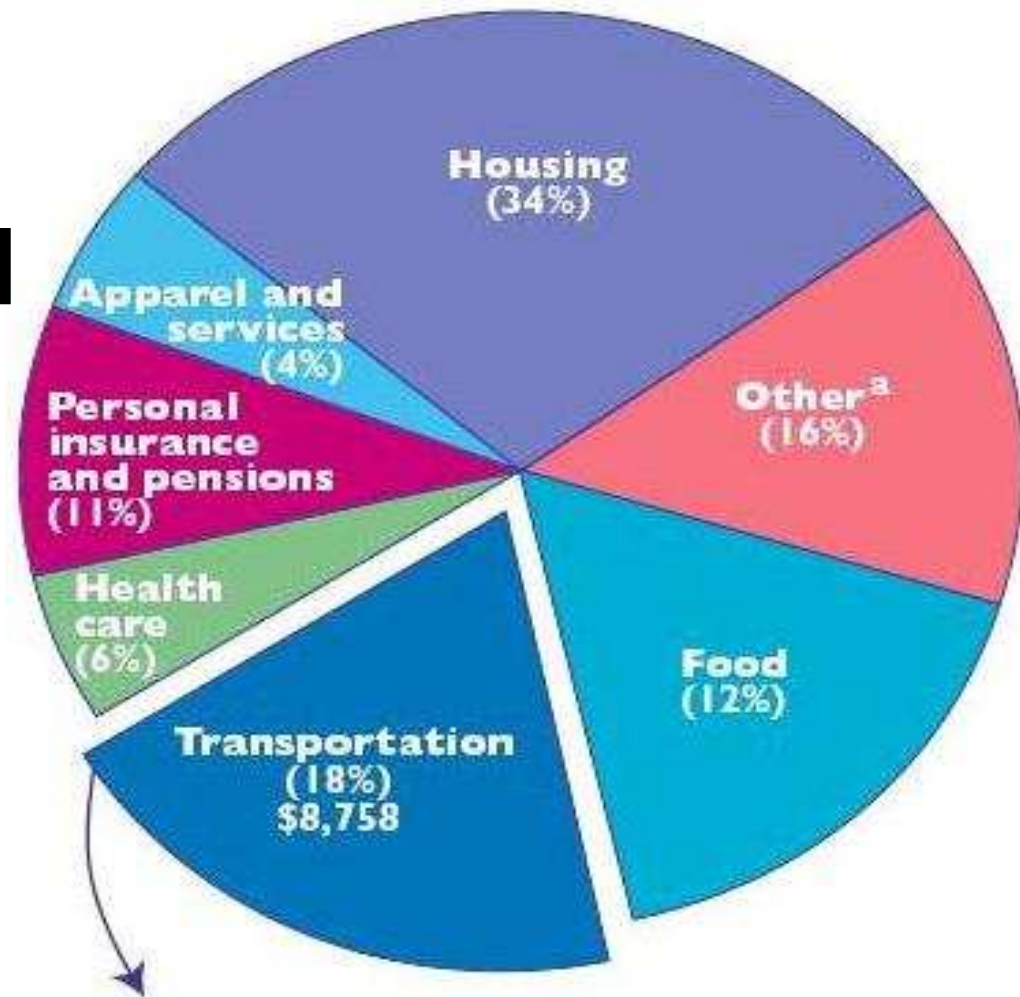
***ECONOMIC TRANSACTIONS***

**INFRASTRUCTURE**

**Roads, Bridges, Airports, Water Systems, Wastewater Systems,  
Gas, Electric, Telephones, Waterways, Coastal Facilities, Parks, Etc.**

# National Surface Transportation Financing Commission Report 2009

**2007 Average  
US Household  
Expenditures  
18% for  
Transportation**



# Less Than 100 Years Ago...



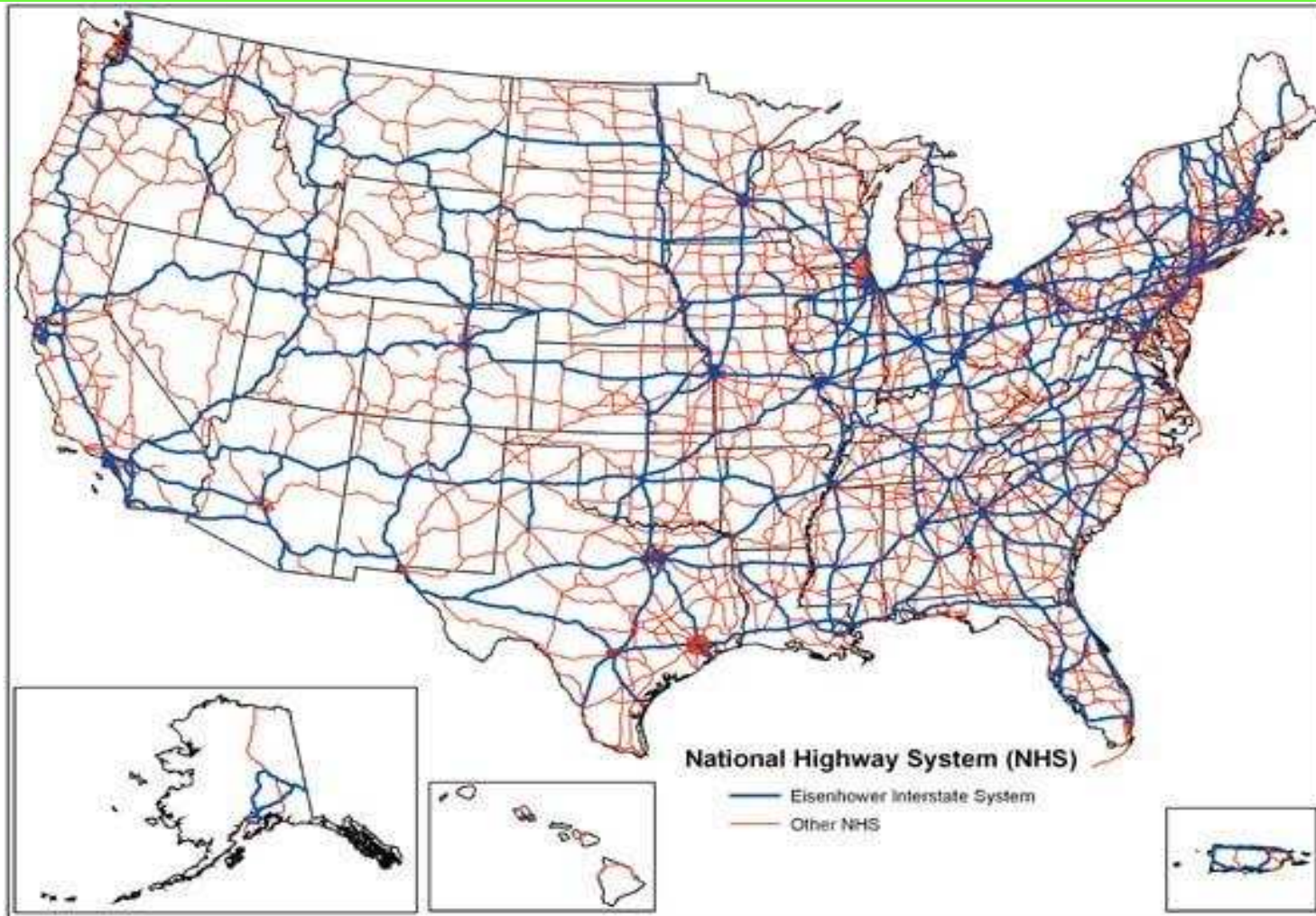


# We've Come a Long Way ...



# 4 Million Miles of Roads

600,000 Bridges



# Statistics We Should Know:

Federal = 3%

State = 20%

Local = 77%

2/3 are Paved (1/3 Unpaved)

94% of Paved have an Asphalt Surface

# FHWA's "3 E's"



## ● ENGINEERING

- Use Good Engineering Design to Assure Long-Life Pavements.

## ● ECONOMICS

- Use Life-Cycle Cost Analysis for Project Selection.

## ● ENVIRONMENT

- Consider Recycling First
- Be Good Stewards of the Environment

# FHWA Recycled Materials Policy

- **FHWA recognize the need to increase our highway industry's overall use of recycled materials**
- **Forge partnerships among government, industry, and academia**
- **Continue to strengthen the relationship between FHWA, US EPA, and State DOT/DEQ**
- **[www.fhwa.dot.gov/legsregs/directives/policy/recmatmemo.htm](http://www.fhwa.dot.gov/legsregs/directives/policy/recmatmemo.htm)**



# Key Points of FHWA Recycling Policy

- **Recycled materials should get first consideration in overall materials selection.**
- Recycling can offer engineering, economic and environmental benefits.
- Engineering and environmental properties are important.

# Key Points of FHWA Recycling Policy

- Life Cycle Cost benefits assessment is warranted for economic consideration.
- **Restrictions prohibiting recycled material that are without technical basis should be removed.**
- RCRA applies to Federal-Aid projects
  - Resource Conservation and Recovery Act
  - [www.epa.gov/epawaste/inforesources/online/index.htm](http://www.epa.gov/epawaste/inforesources/online/index.htm)

# WHY FHWA Promotes Recycling?

- **Environmental Enhancements and Stewardship**
- **Economic Savings Potential**
- **Performance Enhancements**
- **Saving “Non-Renewable” Resources**
- **Cooperative Partnerships with Industry**
- **Just “Darn Good” Practice**

# Presentation Overview

- Basic information about FHWA and the USA's Highway Transportation Network.
- FHWA's Recycling Policy
- **Pavement and Materials Technology Opportunities in Transportation Applications:**
  - Recycling
  - Reuse
  - Other Technologies
- **Resources that might help your work!**

# EPA Mantra

- **REDUCE**

- **Consume Less If Possible.**

- **RECYCLE**

- **Reuse Previously Produced Materials.**

- **REUSE**

- **Incorporate Materials Used in Other Manufacturing Processes Into the Work.**

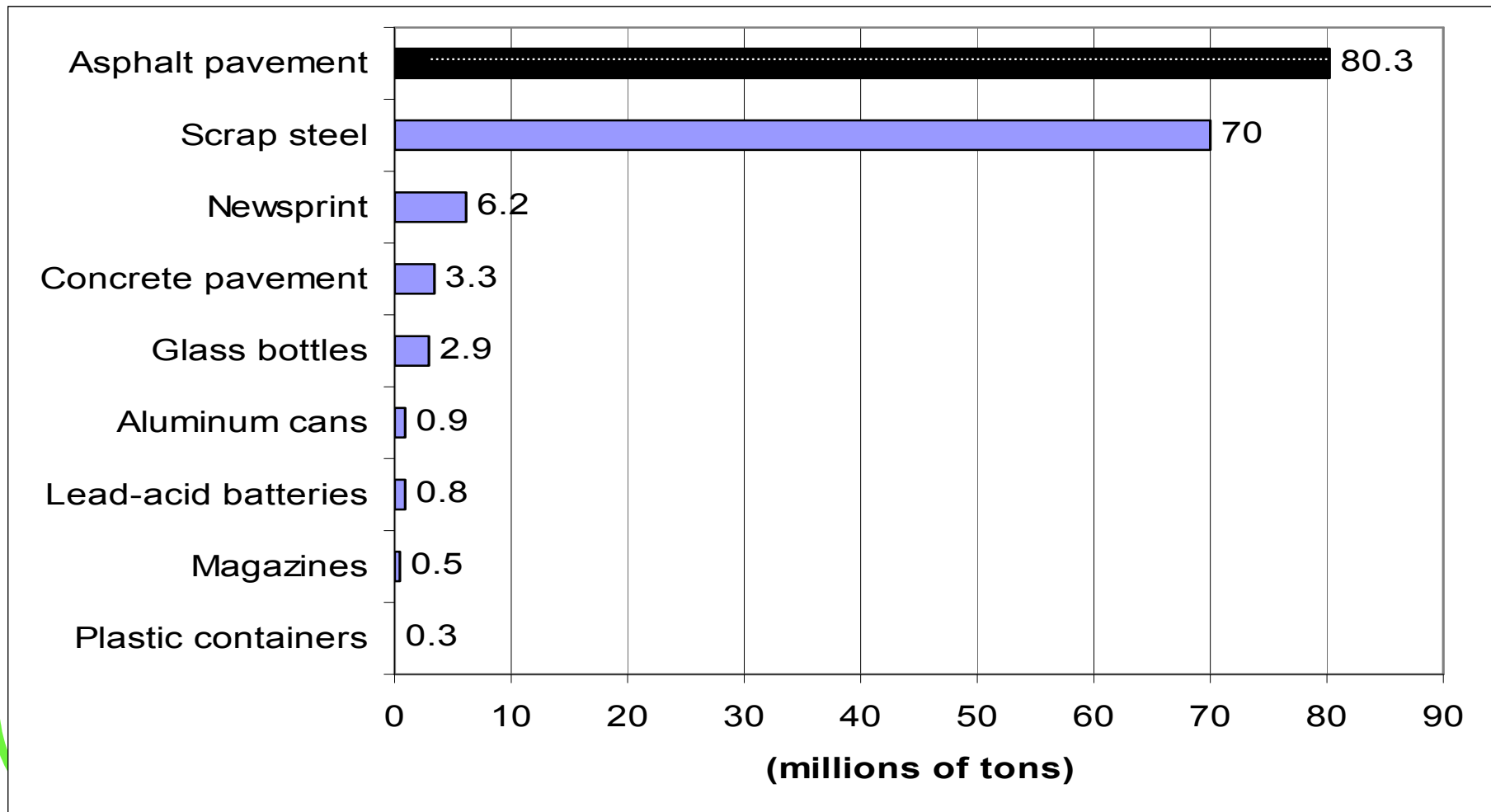
# TECHNOLOGY APPLICATIONS

- **RECYCLING**
  - Reclaimed Asphalt Pavement
  - Recycled Concrete Aggregate
  - In-Place Recycling
- **REUSE**
  - FLY ASH / COAL ASH
  - TIRE RUBBER
  - SHINGLES
  - SLAG
  - FOUNDRY SAND
- **Warm-Mix Asphalt**

# Recycling Applications

- **Reclaimed Asphalt Pavement**
- **Recycled Concrete Aggregate**
- **In-Place Recycling**

# Materials Recycling – Tons/Year





# Asphalt Pavement Recycling

**The volume of recycled asphalt pavement is....**

- **13 TIMES** greater than recycling of newsprint
- **27 TIMES** greater than recycling of glass bottles
- **89 TIMES** greater than recycling of aluminum cans
- **267 TIMES** greater than recycling of plastic containers

# What is RAP?



**Aggregate ~ 95%**



**Asphalt Binder ~ 5%**

# Costs / Values of RAP

- **Value = Material it replaces - processing**

- **Aggregate - 95% at \$10/ton = \$9.50**

- **Asphalt - 5% at \$400/ton = \$20**

- **Minus the Processing = \$5/ton**

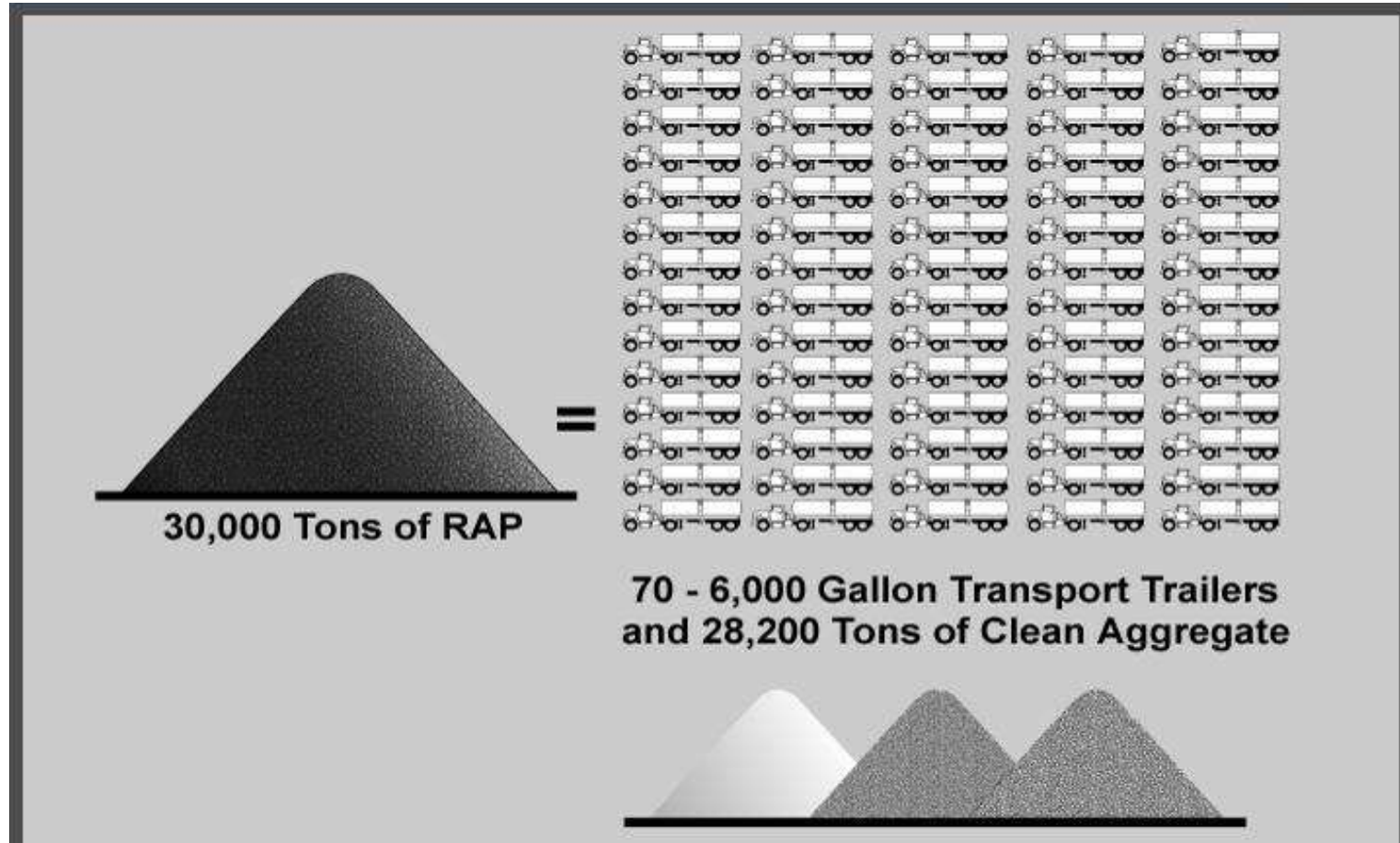
**Total Value = \$24.50 per ton**

- **10% RAP saves \$2.45/ton**

- **20% RAP saves \$4.90/ton**

- **40% RAP saves \$9.80/ton**

# Sustainability Considerations



Courtesy: Astec Industries



# Recycled Concrete Aggregate



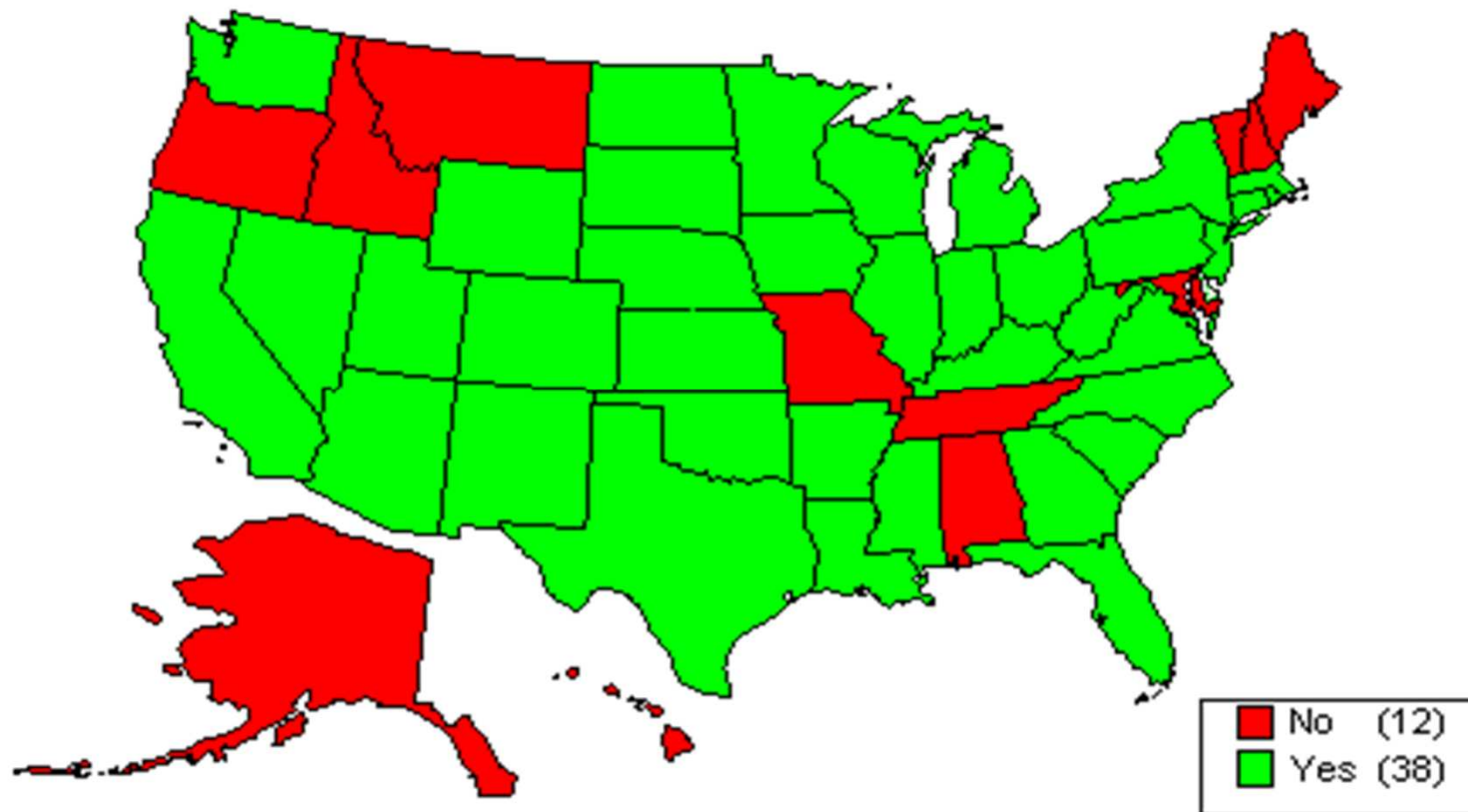
# 2004 FHWA RCA Review

## Survey and In-Depth Review of:

- Texas
- Virginia
- Michigan
- Minnesota
- California

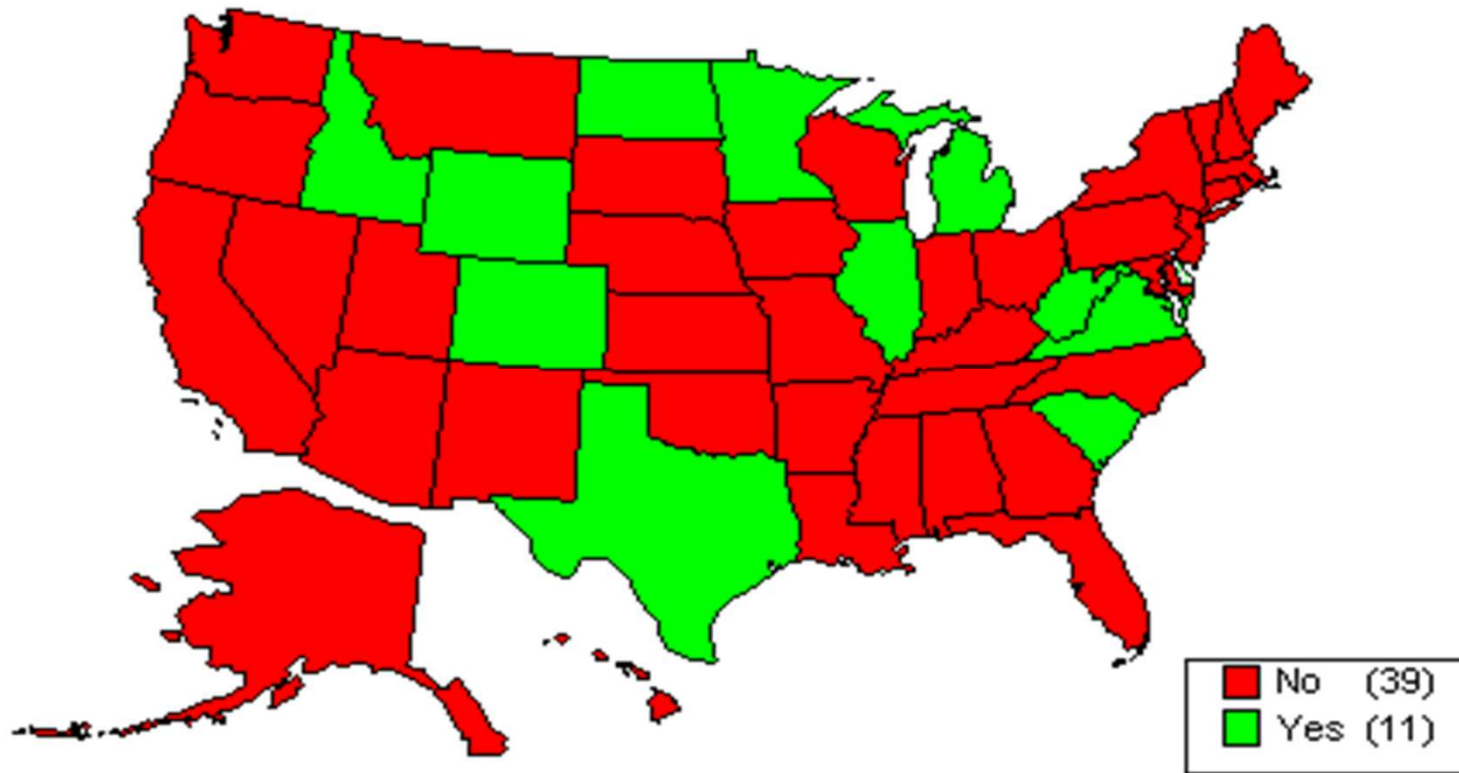


# States using RCA as Base





# States using RCA in PCCP





# Worlds Largest “Urban Quarry”

Denver 8.5 miles



Courtesy of Recycled Materials, Inc.

# World's 2<sup>nd</sup> Largest Recycle Project!

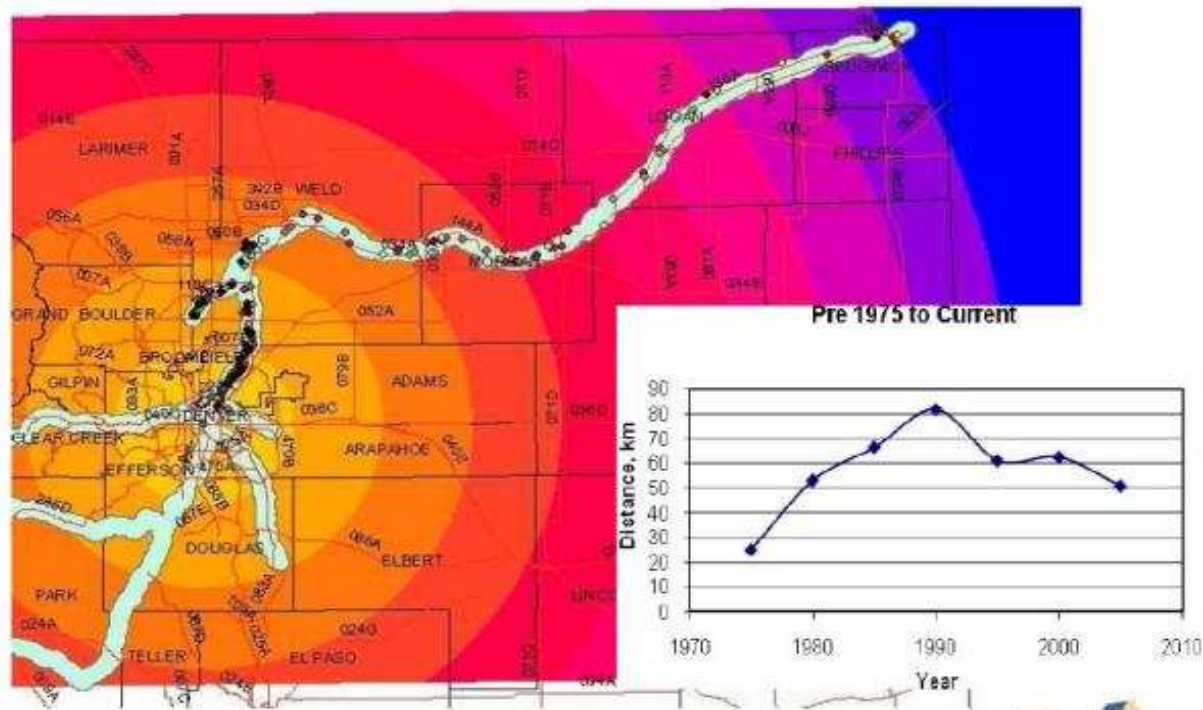


**El Toro MCAS**  
Irvine, California

Courtesy of  
Recycled Materials, Inc.

# Aggregate Hauling is longer...

## South Platte Virgin Aggregate Sources



Urban Sustainable Infrastructure Engineering Project (USIEP), CU Denver  
<http://carbon.cudenver.edu/engineering>





# FHWA / ARRA WORKSHOPS



- **2008 – Salt Lake City, UT**
- **2009 – Minneapolis, MN**
- **2010 – Harrisburg, PA**
- **2011 – Atlanta, GA**

<http://www.pavementpreservation.org/conferences/regional-in-place-recycling-conferences/>

# Cold In-Place Recycling

## Description

Milling, rejuvenating, and replacement of the top portion of the HMA surface (performed without heat)

## Purpose

**Rework HMA to depth of 2 – 4 inches.**

**Correct surface distresses.**

**Improve profile, crown, and cross-slope.**



# Nevada DOT CIR



**Lime Slurry**



**CIR Train**



**Milling**



**Milling Teeth**



**Vibratory Roller**



**Processed Material**



# Hot In-Place Recycling

## Description

Milling, rejuvenating, and replacement of the top portion of the HMA surface (performed with heat)



## Purpose

Rework HMA to depth of 1 to 2 inches.

Correct surface distresses.

Improve profile, crown, and cross-slope.

# TECHNOLOGY APPLICATIONS

- ✓ **Reclaimed Asphalt Pavement**
- ✓ **Recycled Concrete Aggregate**
- ✓ **In-Place Recycling**
- **REUSE APPLICATIONS**
  - **FLY ASH / COAL ASH**
  - **TIRE RUBBER**
  - **SHINGLES**
  - **SLAG**
  - **FOUNDRY SAND**
- **Use of Emulsions / Warm-Mix Asphalt**



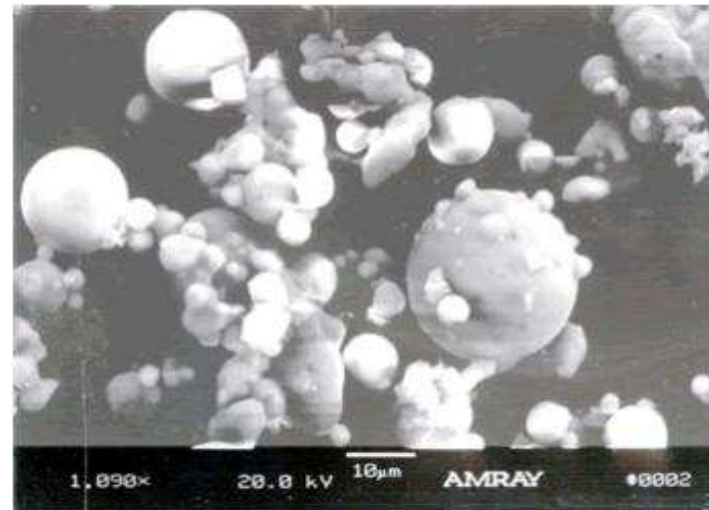
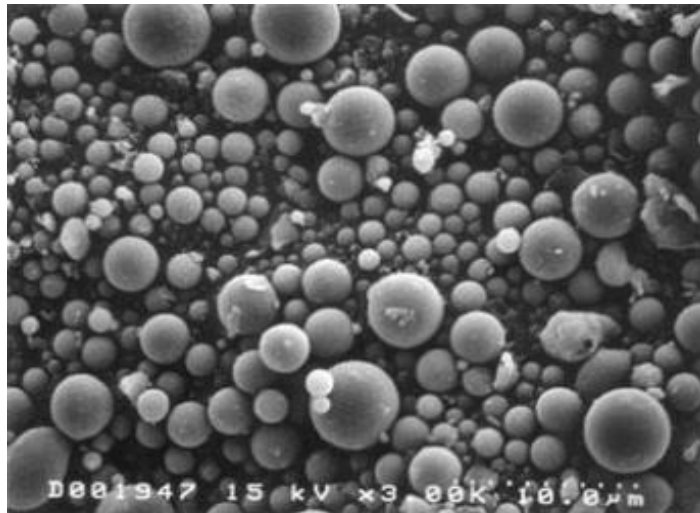
# Fly Ash – Substitute for Cement

## Essential Component for Durable Concrete



# Fly Ash – Substitute for Cement

- **Approximately 50% of US electricity is generated by coal-fueled power plants**
- **In 2003, over 110 million metric tons of CCP were produced**
- **38% beneficially used (42 mill. metric tons)**



# Controlled Low Strength Material



**CLSM using Class F fly ash**



**CLSM using Class C fly ash and sand**



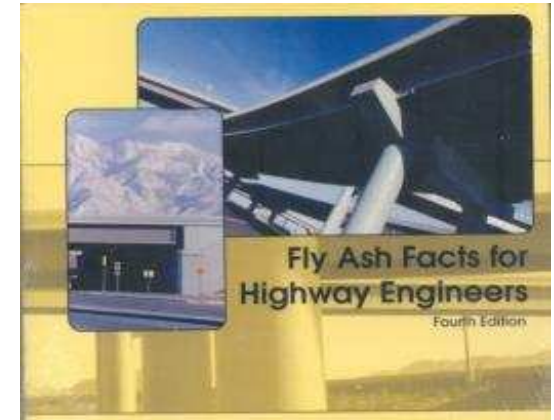
# Soil Stabilization



**Increase the structural capacity of sub-grades and road base.**

# Coal Combustion Products (CCP)

- **Fly Ash in:**
  - PCC
  - Stabilization of base course
  - Flowable fill
  - Structural fills/Embankments
  - Soil improvements
  - Asphalt pavements
- **Flue Gas Desulphurization (FGD)**
- **Bottom Ash**



# TIRES

- **What Can We Do With This ~~Mess~~ Resource?**
  - 300 million more are added annually.
  - 87% currently going to an end-use market





# Tire Bales

- **Block of Rubber**
  - 2.5'x 4.5'x 5'
  - 2000 pounds
- 60% weight reduction over soil
- Permeable
- **USES:**
  - Embankments.
  - Slope repair and rock fall barriers.



# Ground Tire Rubber

- **Performance Properties**
  - Cost effectiveness
  - Added Benefit
- **User Demands**
  - Noise abatement
- **Sustainability**
  - Recyclable in HMA?



# Asphalt Roofing Shingles

- **Factory rejects are recycled into high-quality pavements.**
- **Approved for use by North Carolina and Minnesota DOTs.**
- ***10 MILLION TONS/YR REMOVED FROM ROOFS – MOST ARE LANDFILL***



# Slag - Reuse

- **A by-product of steel production**
  - **Works especially well as Aggregate for high-volume roadways and/or**
  - **High skid-resistance applications**
    - **Indianapolis Motor Speedway**
    - **Automobile manufacturers' test tracks**
  - **Meets requirements for use in Superpave Aggregates**

# Foundry Sand - Reuse

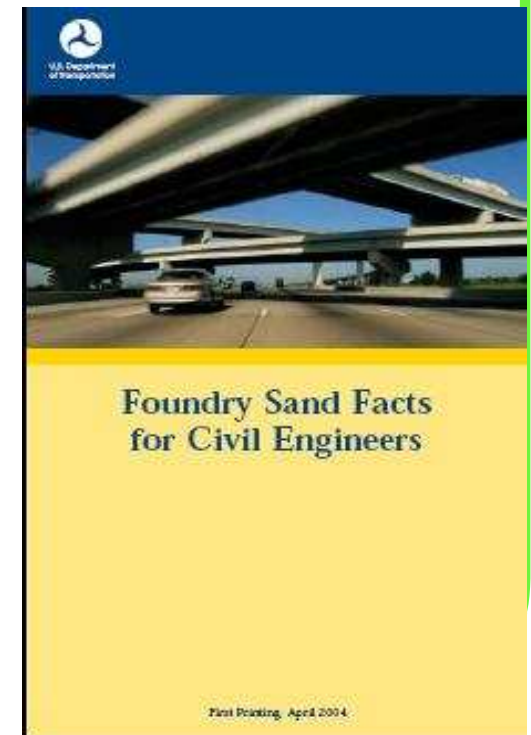
- **Already screened, blended and ready to use in Hot Mix Asphalt**
  - **Reduces cost of sand by about 40%**
  - **100,000 tons used in HMA per year**





# Foundry Sand

- **Structural Fills & Embankments**
- **Flowable Fills – pipe/trench backfill**
- **Roadway Base material**
- **Cement feed stock**
  - **Fine Aggregate for PCC**
- **Hot Mix Asphalt aggregate**
- **Soil Amendment**



# Reuse of Industrial Byproducts

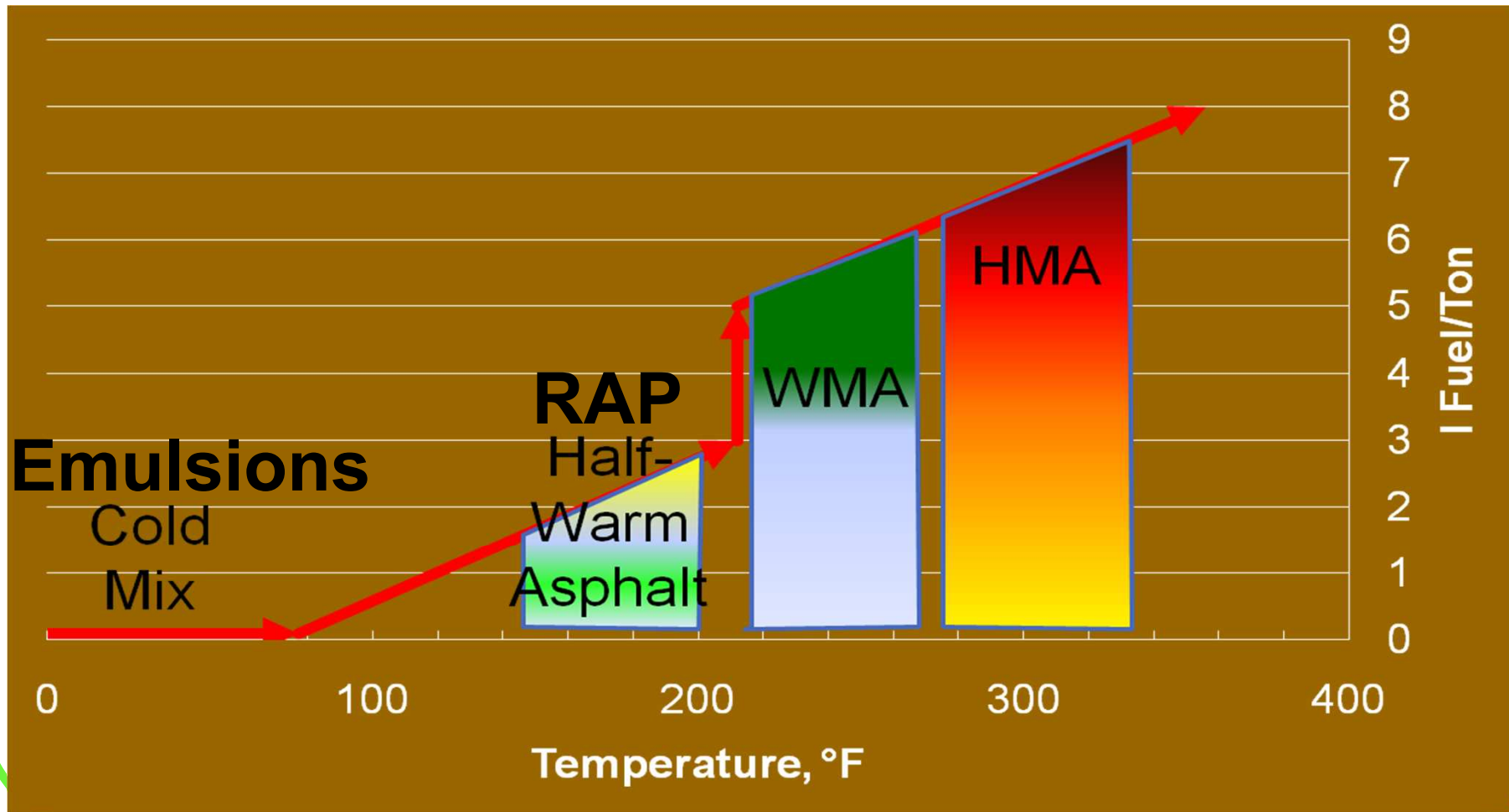
**Millions of Tons per Year used in Highway Applications**

Byproduct Materials Produced	Production (million metric tons)	Recycled in Highway Applications (million metric tons)	Applications
Blast Furnace Slag	14	12.6	Concrete
Coal Bottom Ash	14.5	4.4	Asphalt, Base
Coal Fly Ash	53.5	14.6	Cement Production, Structural Fill
Foundry Sands	9 to 13.6	?	Flowable Fill, Asphalt
Cement Kiln Dust	12.9	8.3	Stabilizer
Bottom Ash	8	Small Amounts	Asphalt, Base
Nonferrous Slags	8.1	?	Base, Asphalt
Steel Slags	?	7.5	Base, Asphalt, Concrete
Recycled Asphalt Pavement	41	33	Asphalt, Base
Reclaimed Concrete	?	?	Base, Concrete

# Technology Applications

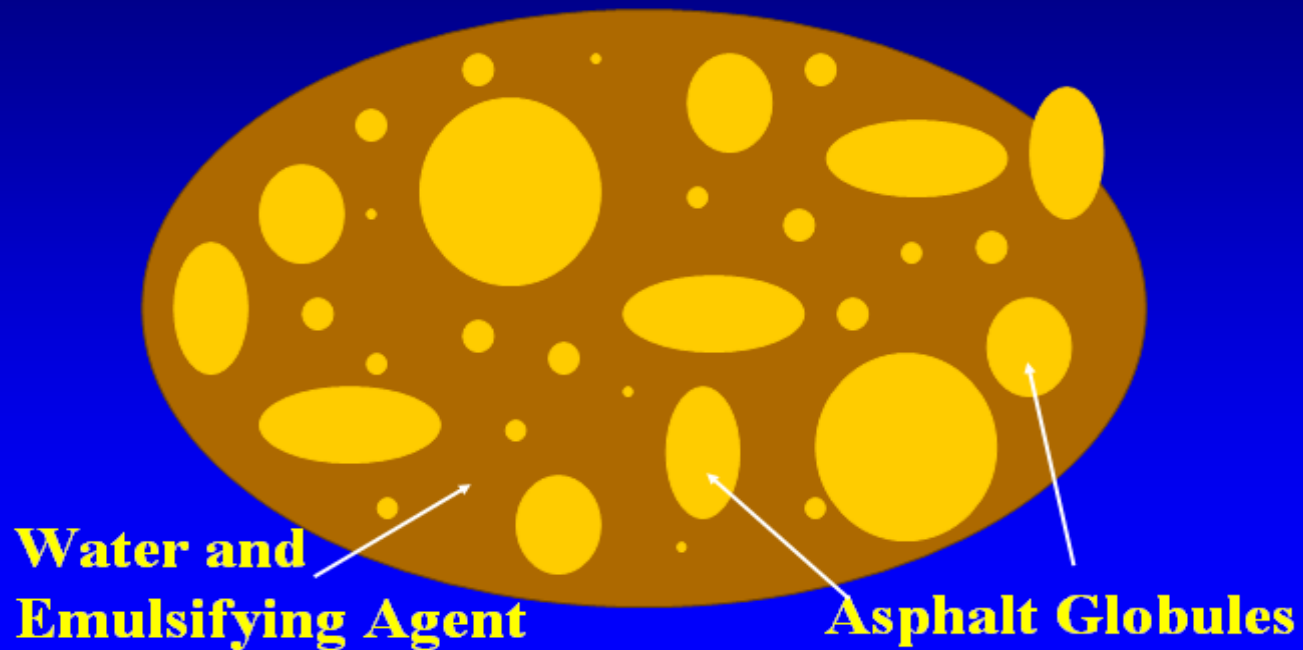
- ✓ Reclaimed Asphalt Pavement
- ✓ Recycled Concrete Aggregate
- ✓ In-Place Recycling
- ✓ REUSE APPLICATIONS
  - ✓ TIRE RUBBER
  - ✓ SHINGLES
  - ✓ SLAG
  - ✓ FOUNDRY SAND
- **Use of Emulsions and Warm-Mix Asphalt**

# Energy Use Comparisons



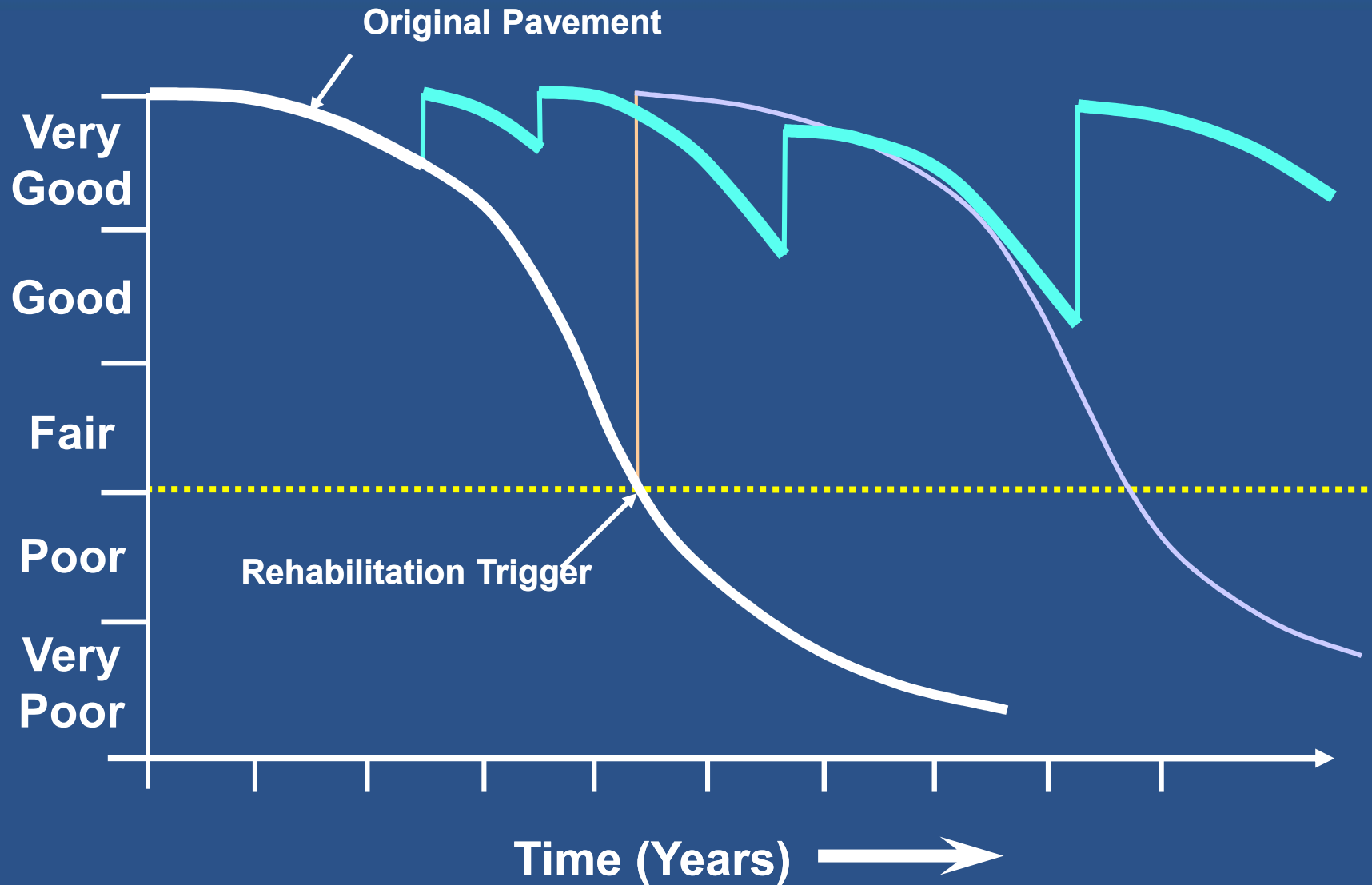
# Emulsions

## Asphalt Emulsions





# The Pavement Preservation Concept

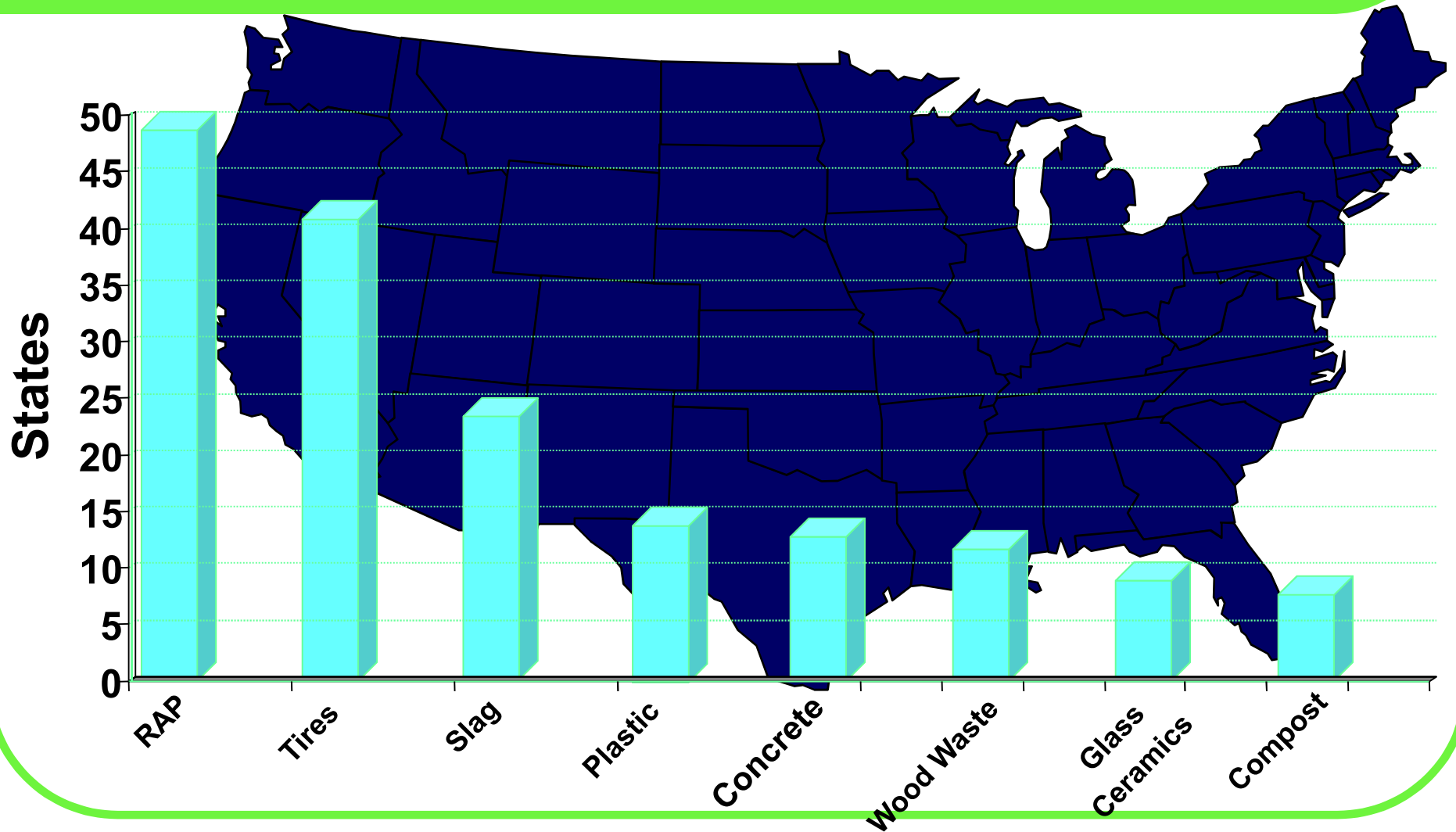


# Warm Mix Asphalt Benefits

- Savings in energy
- Decreased plant emissions
- Reduced exposure to fumes
- Low/No odor
- Improved compaction
- Extended haul distances
- Extended paving season
- Higher RAP incorporation
- SAFETY
- Longer binder life?

[www.warmmixasphalt.com](http://www.warmmixasphalt.com)

# States Using Recycled Materials




# Resources for Agencies

- ✓ **FHWA**
- ✓ **OTHER ORGANIZATIONS**
- ✓ **WEBSITES**
- ✓ **READING RECOMMENDATIONS**
- ✓ **COLLEAGUES / PARTNERS**

# FHWA Web-Based Resources

- [www.fhwa.dot.gov/pavement/recycle](http://www.fhwa.dot.gov/pavement/recycle)
- [www.fhwa.dot.gov/preservation](http://www.fhwa.dot.gov/preservation)



The screenshot displays the FHWA Pavements website interface. At the top, it features the U.S. Department of Transportation Federal Highway Administration logo and the title "Pavements". Below the title is a navigation menu with tabs for Research, Design, Construction, Preservation (which is highlighted), Maintenance, Management, and Rehabilitation. The main content area is divided into a left sidebar and a right main panel. The sidebar lists various categories: Pavement Design and Analysis, Materials and Construction Technology, Pavement Management and Preservation, Pavement Surface Characteristics, Construction and Materials Quality Assurance, and Environmental Stewardship. The main panel is titled "General Pavement Preservation Information" and contains three sub-sections: "Preservation", "Asphalt", and "Concrete". Each sub-section lists relevant resources and documents.

U.S. Department of Transportation  
Federal Highway Administration

## Pavements

Research Design Construction **Preservation** Maintenance Management Rehabilitation

Pavement Design and Analysis

Materials and Construction Technology

Pavement Management and Preservation

Pavement Surface Characteristics

Construction and Materials Quality Assurance

Environmental Stewardship

### General Pavement Preservation Information

#### Preservation

- [2007 PPETG Meeting Minutes](#) **NEW!**
- [Transportation System Preservation Technical Services Program \(TSP<sup>2</sup>\)](#)
  - [Transportation System Preservation Technical Services Program \(TSP<sup>2</sup>\) Announcement](#)
- [Pavement Preservation Definitions](#) (09/12/05)
- [Pavement Preservation Technical Assistance Review and Evaluation](#) (05/12/05)
- [NCHRP 14-14. Guide for Optimal Timing of Pavement Preventive Maintenance Treatment Applications](#)
- [Pavement Preservation: A Road Map to the Future](#) (pdf, 888 kb)
- [Michigan Department of Transportation Pavement Preservation Study](#)
- [Pavement Preservation Research Problem Statements](#)
- [Pavement Preservation Scanning Tour Status Report \(7/2002\)](#)
- [Slurry/Micro-Surface Mix Design Procedure](#)
- [Pavement Preservation Concepts and Techniques](#) (pdf version 0.1 mb)

#### Asphalt

- [Slurry/Micro-Surface Mix Design Procedure Project](#)
- [Spray Applied Polymer Emulsion Field Studies \(GSB-88\)](#)
- [High Volume/High Speed Asphalt Roadway Preventative Maintenance Surface Treatments](#)

#### Concrete

- [CPTP Products](#)



# FHWA Supports Pavement Preservation!



Left to right: Associate Administrator for Infrastructure King Gee; Administrator Tom Madison; James B. Sorenson, Highway Engineer; and Executive Director Jeff Paniati.

# FHWA Supports Pavement Recycling!



# Key Websites – 1/2

- **FHWA Pavement Recycling –**  
<http://www.fhwa.dot.gov/pavement/recycling/index.cfm>
- **FHWA INVEST Tool: “Infrastructure Voluntary Evaluation Sustainability Tool”**  
<http://www.sustainablehighways.org/>
- **Asphalt Recycling and Reclaiming Association**  
<http://www.arra.org>
- **Pavement Recycling and Reclaiming Center**  
<http://prrcenter.org> (Cal Poly Pomona)

## Key Websites – 2/2

- **FHWA Every Day Counts Warm Mix Asphalt**  
<http://www.fhwa.dot.gov/everydaycounts/technology/asphalt>
- **Recycled Materials Resource Center -**  
<http://www.recycledmaterials.org>
- **Green Highways Partnership**  
<http://www.greenhighways.org>
- **USEPA Resource Conservation Challenge**  
<http://www.epa.gov/osw/consERVE/rrr/imr/index.htm>

# Recommended Reading

- <http://www.recycledmaterials.org/tools/uguidelines/index.asp>

## **User Guidelines for Byproducts and Secondary Use Materials in Pavement Construction**

- <http://www.dot.state.co.us/Publications/PDFFiles/epagrant.pdf>

## **MATERIALS RECYCLING AND REUSE – FINDING OPPORTUNITIES IN COLORADO HIGHWAYS, October 2007**



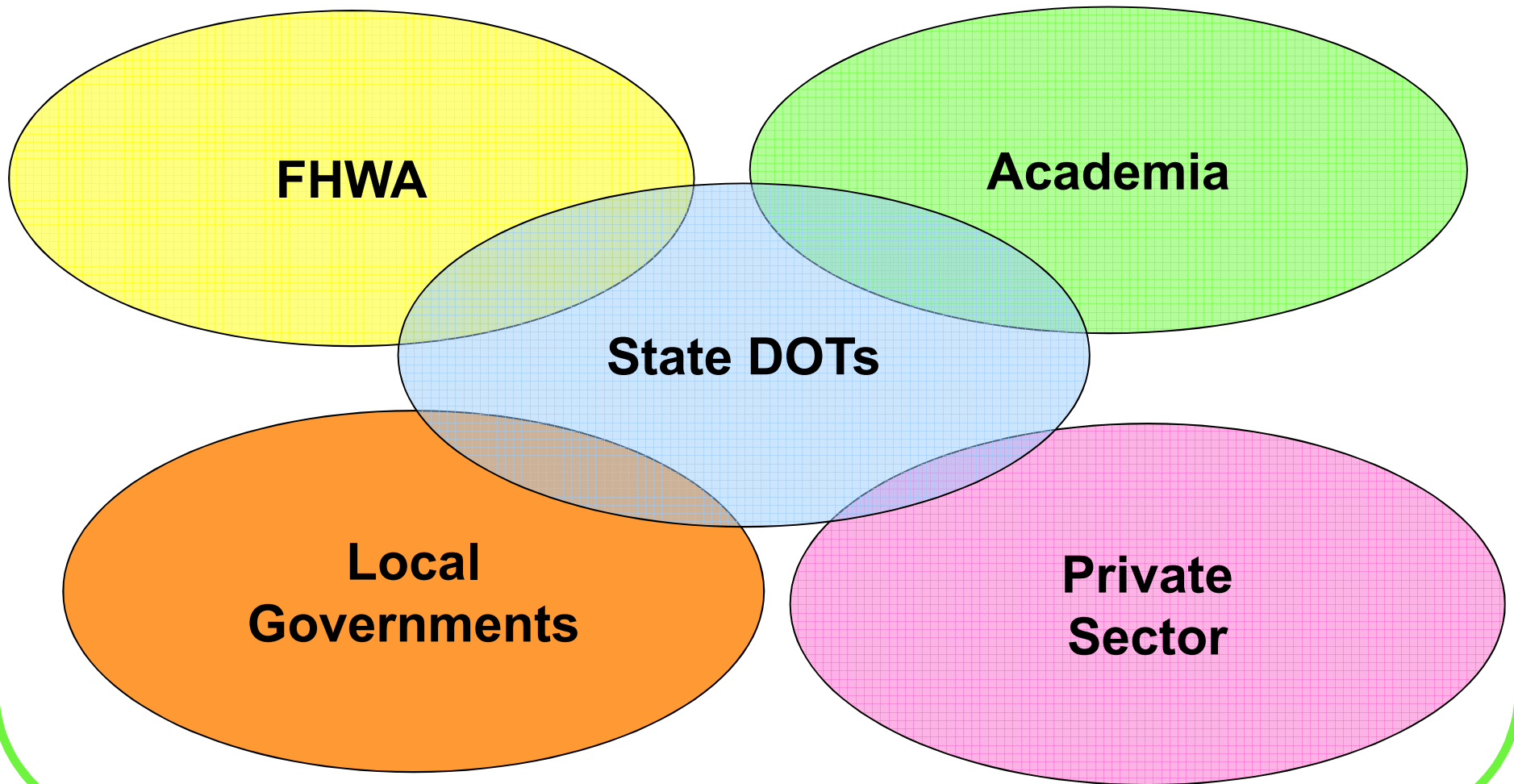
# Concluding Comments

- **Resources for State and Local Agencies**
  - **Industry Associations: AEMA, ARRA, ISSA, FP2**
  - **National Center for Pavement Preservation**
  - **Recycled Materials Resource Center**
  - **FHWA websites, publications, products, training**
  - **TRB, NCHRP, AASHTO**
  - **Webinars**
  - **Training: NHI, Workshops**
- **How do we measure success?**

# Challenge for YOU!

- **Do**
  - **Look at your current specs/regulations**
  - **Overcome your own hurdles**
- **Act**
  - **Partner with DOT/ DNR / EPA & Industry**
  - **Create reuse/recycle programs**
  - **Make use of the resources noted in this presentation!**

# Partnerships Are Required



# Partnerships are Required

- **1 FHWA**
- **52 State DOTs (including DC and PR)**
- **3,034 County governments;**
- **35,933 Municipal, Town and Township governments.**
- **4,140 Colleges and Universities**
- **\_\_\_\_\_ contractors/industry reps.**

**UNITED WE STAND....**

*It's Good to be GREEN!*

