

# Regionalized Life Cycle Inventory

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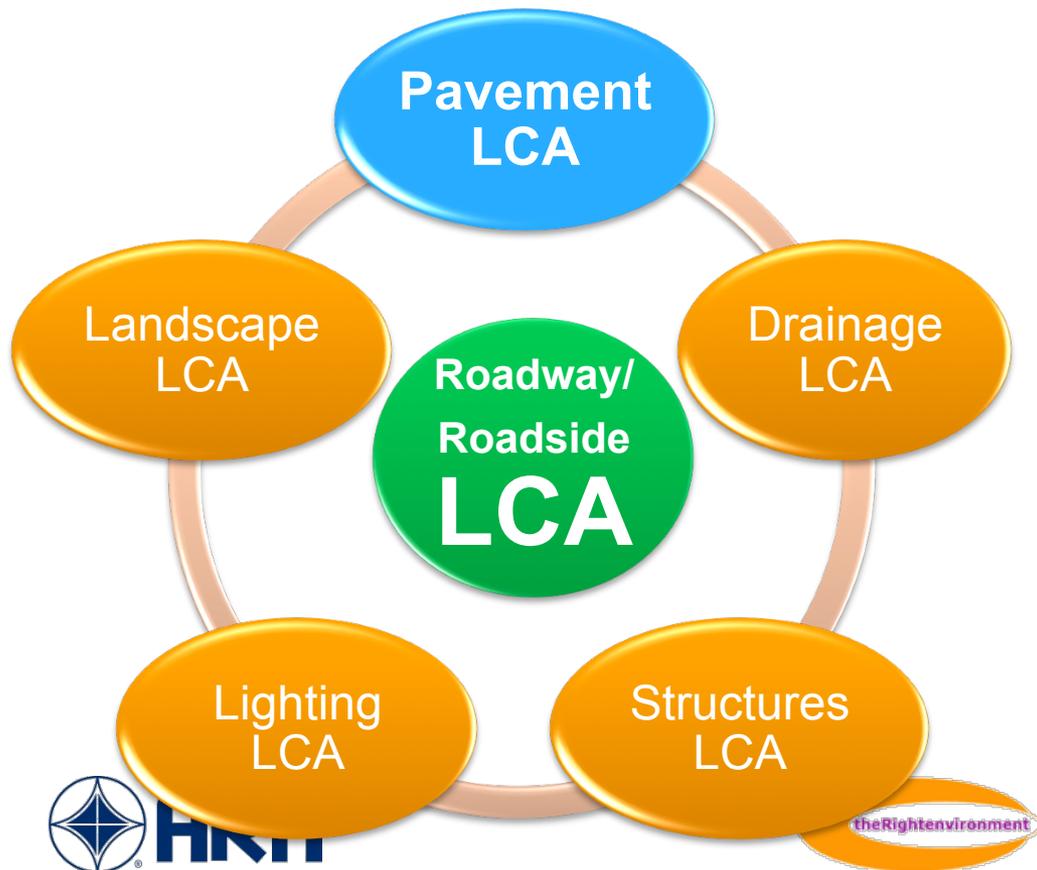
# Outline

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- **Introduction**
- **Life Cycle Inventory Database**
  - **Inventory Modeling Approach**
  - **Data Collection**
  - **Inventory Highlights**
- **Pavement LCA Tool**
- **Case Study**

# Overall Project Objective

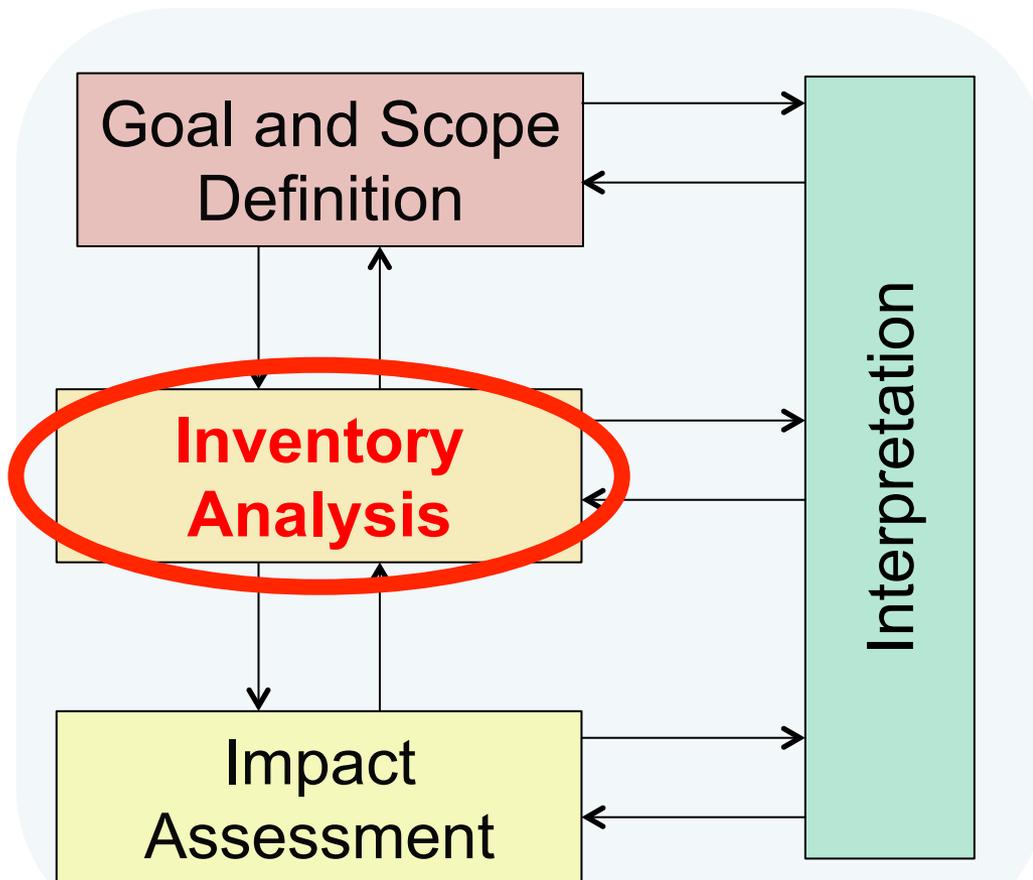
## Development of a roadway/roadside LCA toolkit



Illinois Tollway  
Network

# Life Cycle Inventory (LCI)

## Steps to Perform LCA (per ISO 14044)



An integral part  
of a data-driven  
LCA process

# LCI Database Motivation

- Existing databases may not be **temporally** and **regionally** appropriate for all situations
- Need a multi-tiered approach of **collecting** local information and **modeling** the processes to include upstream emissions
- Processes considered

Material  
production &  
processing

Fuel &  
electricity  
production

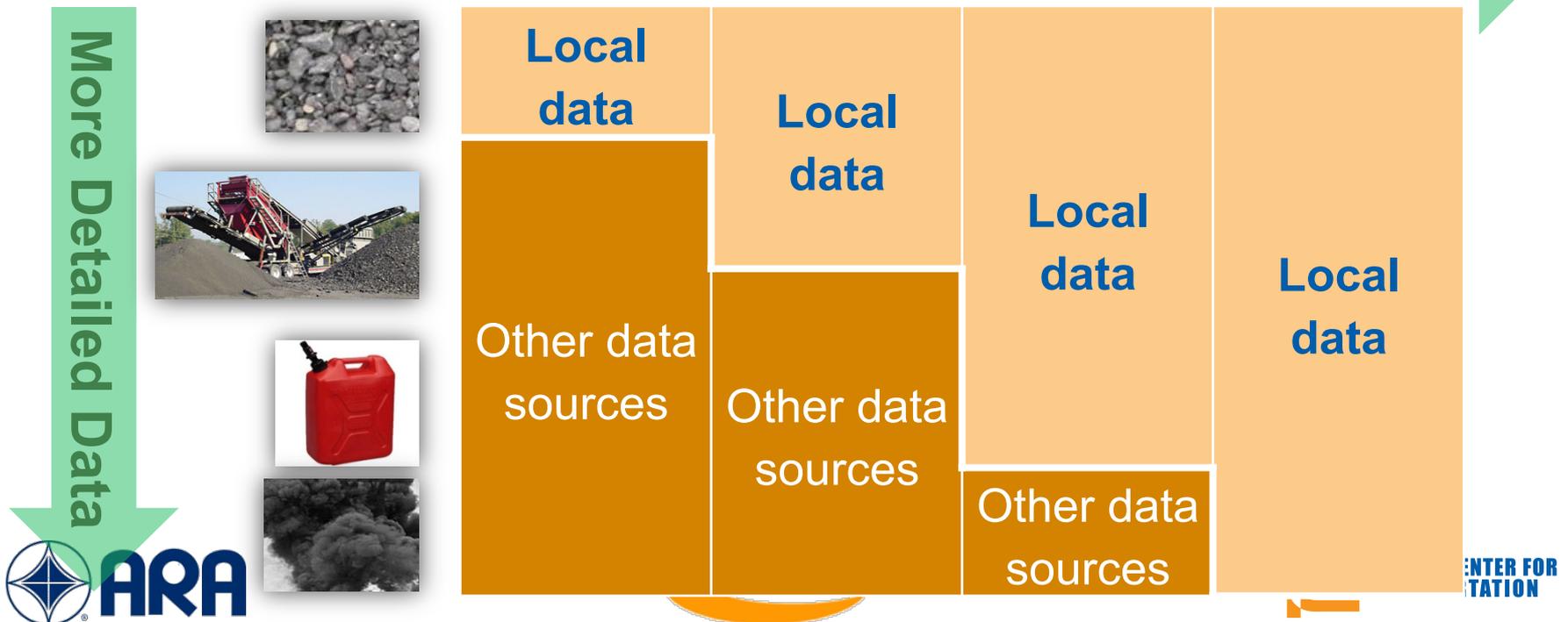
Hauling &  
transport

Equipment  
usage

# Modeling Approach

- **Regionalize** data relevant to the Tollway using commercial LCI databases and software with **comprehensive inventory data**

Higher Level of Regionalization



# Inventory Modeling Procedure

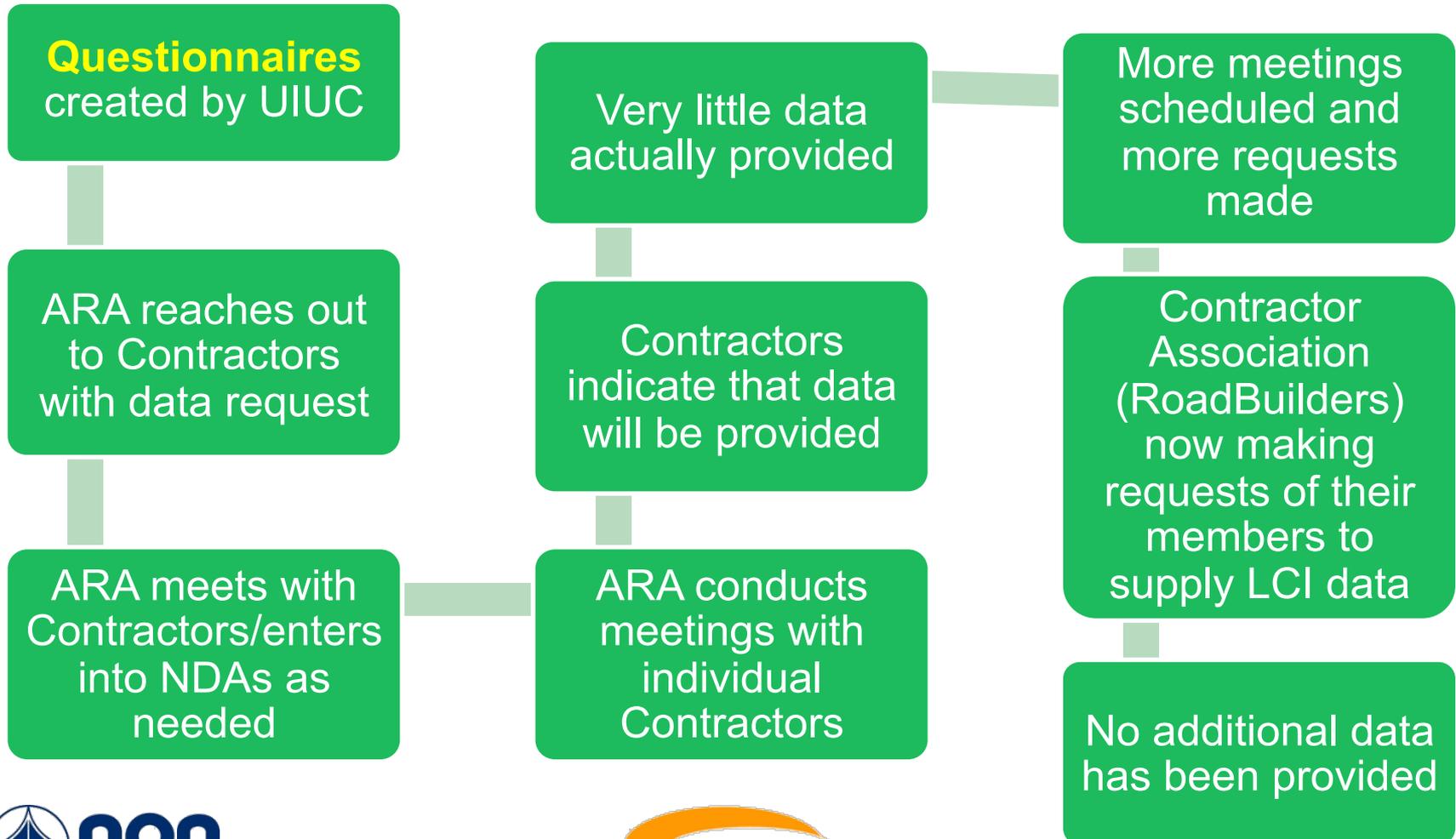
1) Distribute and collect **local questionnaires**

2) Analyze and screen collected data with literature

4) Benchmark with commercial data and literature

3) Model and develop regionalized database in **SimaPro software**

# LCI Data Request Process



# Contractor Involvement to Date

First Stakeholder Meeting  
(Open Hostility)

Aug  
2012

Individual meetings with  
Contractors to request  
operation specific LCI data  
(Indifference to Curiosity)

Aug  
2013

Presentation request  
by RoadBuilders  
(Seeing potential  
value)

Aug  
2014

# Hurdles to LCI Data Collection

- **No good time for Contractors to assemble and submit data**
  - **Spring (getting ready for summer construction season)**
  - **Summer (construction season)**
  - **Autumn (busy finishing up construction season)**
  - **Winter (preparing bids for next year's projects)**
- **No clear value to Contractors to provide data**
- **Protection of “proprietary” information**

# Future for LCI Data

- **LCA Tool users (in order of adoption):**
  - **Agency (Public Relations emphasis)**
  - **Agency (Designers, Construction Managers)**
  - **Agency (Contract Award criteria)**
  - **Contractors (only when contract award is on the line)**
- **Development of LCI data submittal as part of “pre-certification” requirement to do Tollway work**
- **Development of online system to make data submittal easier (similar to QC/QA test data submittal system)**

# Other Data Sources

- **Supplements and validates questionnaire data**

## LCI Databases

- US-Ecoinvent
- US-LCI (NREL)

## Government Software

- eGRID, GREET
- MOVES, NONROAD

## Reports, Literature

- Portland Cement Assn.
- Athena Institute, etc.

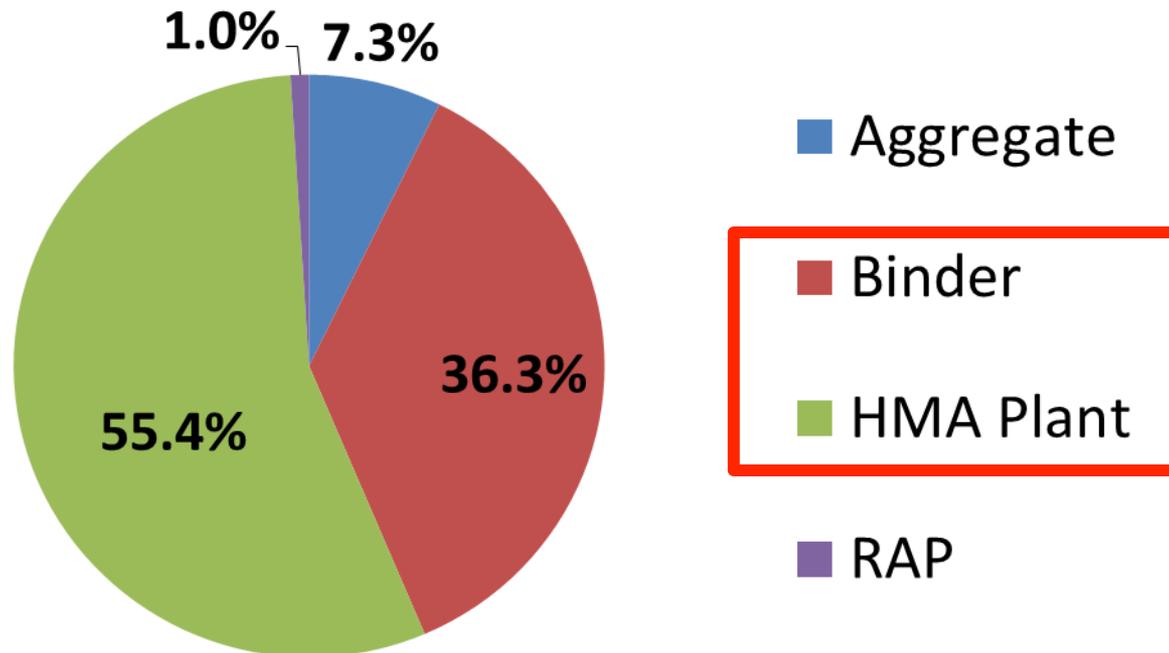
Data modeled in commercial LCA software



# Creating Inventory Models

- Focus on processes that **contribute significantly** to the overall environmental impacts

## Energy Consumption for a Flexible Pavement



# Asphalt Binder Model

Crude Extraction &  
Flaring (*Foreign/  
Domestic*)

Transport

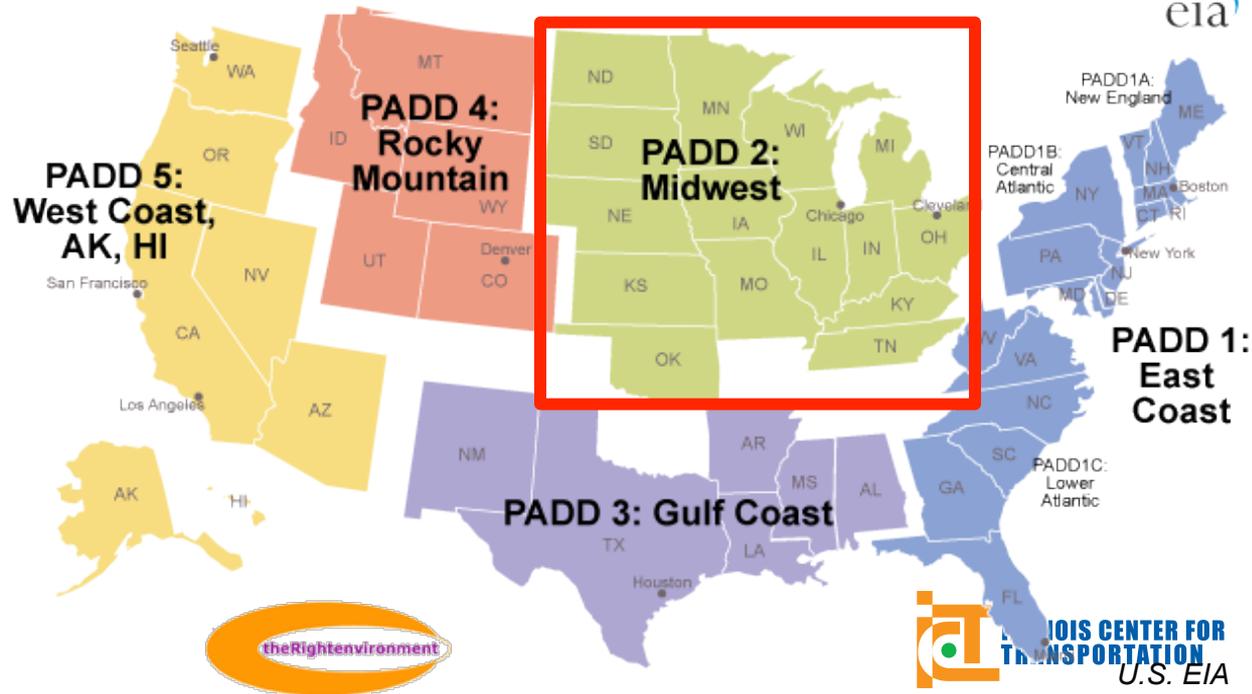
Petroleum Refining  
(*Domestic*)

Transport

Asphalt Blending &  
Storage  
(*Domestic*)

- **Five U.S. Regions**
  - **Data from U.S. Energy Information Administration**

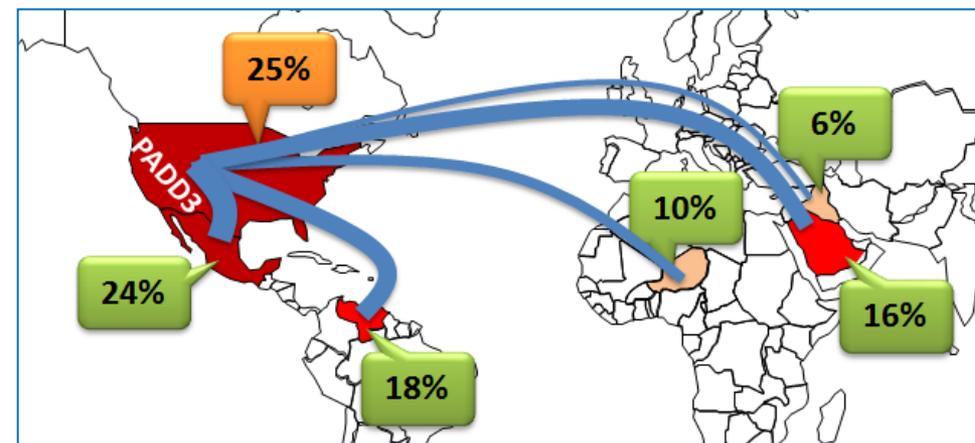
Petroleum Administration for Defense Districts



# Crude Distribution & Transport

Crude Extraction & Flaring

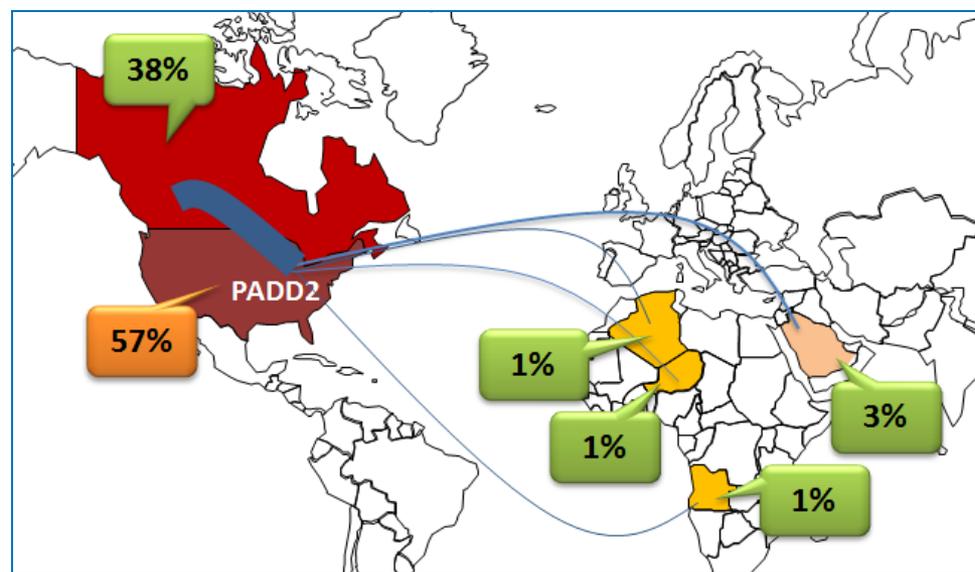
Transport



PADD3  
(Gulf Coast)

Petroleum Refining

Transport



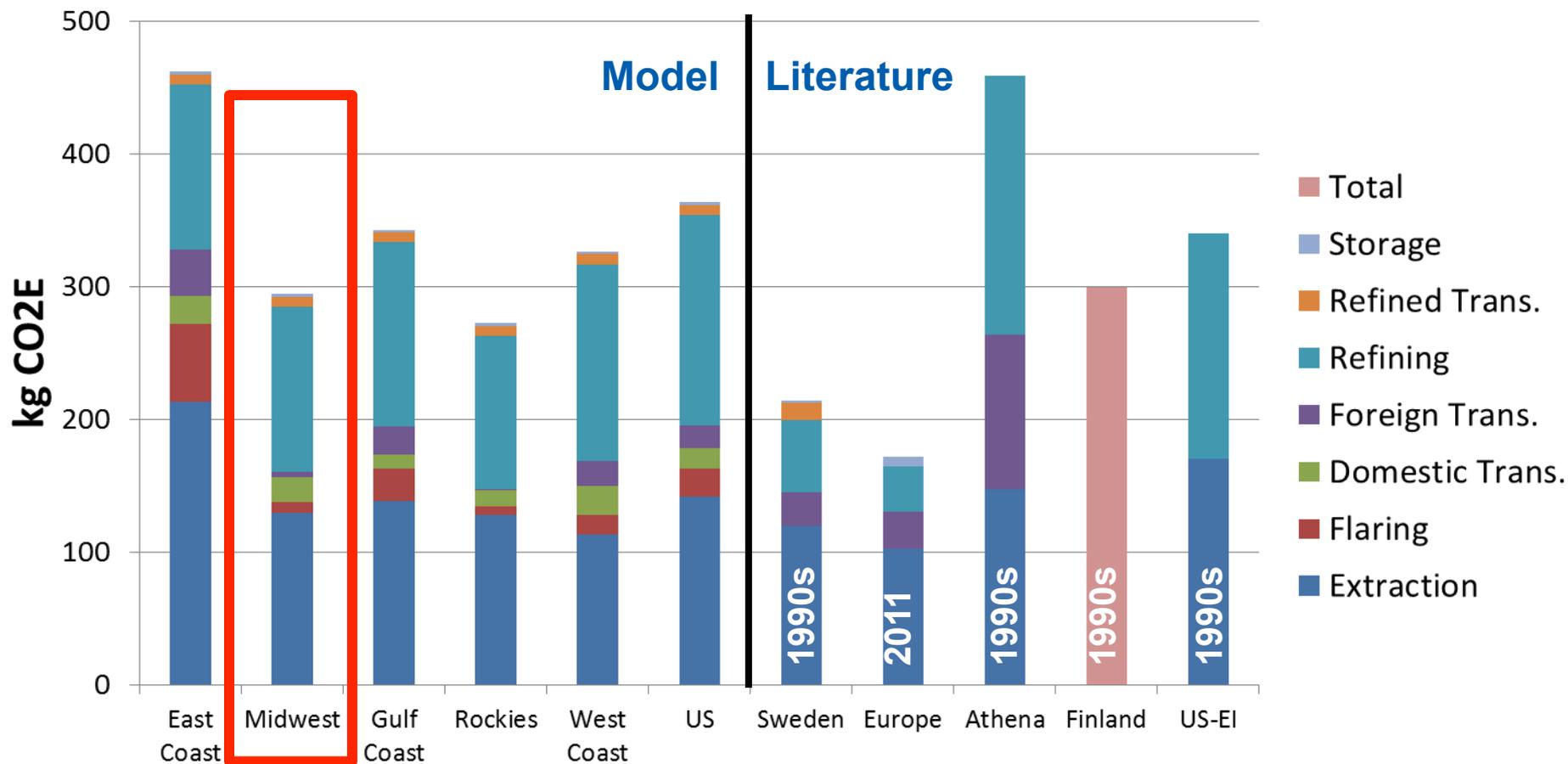
PADD2  
(Mid-west)

Asphalt Blending & Storage



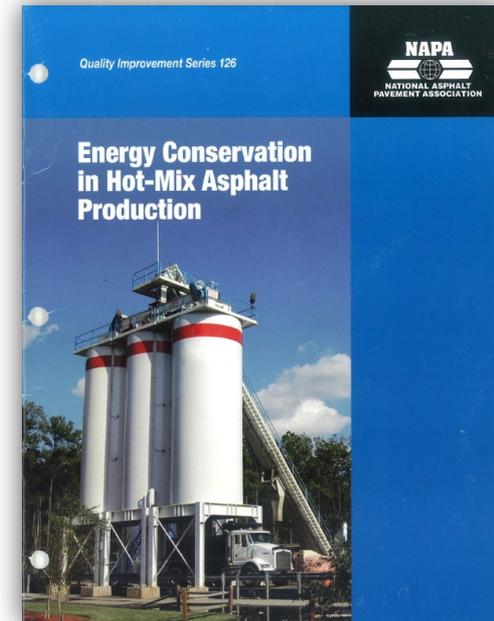
# Asphalt Binder: Results

## Greenhouse Gases per short ton binder production



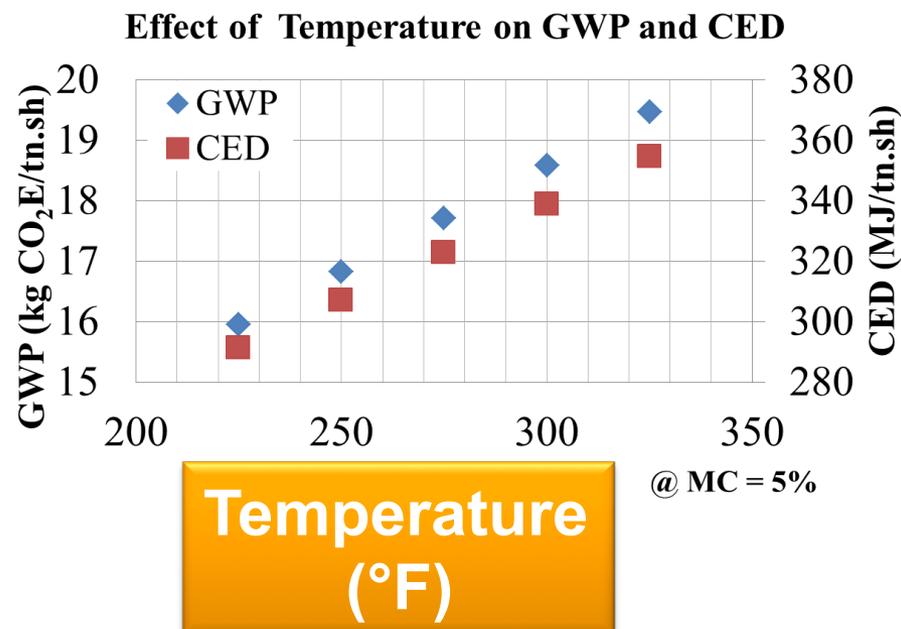
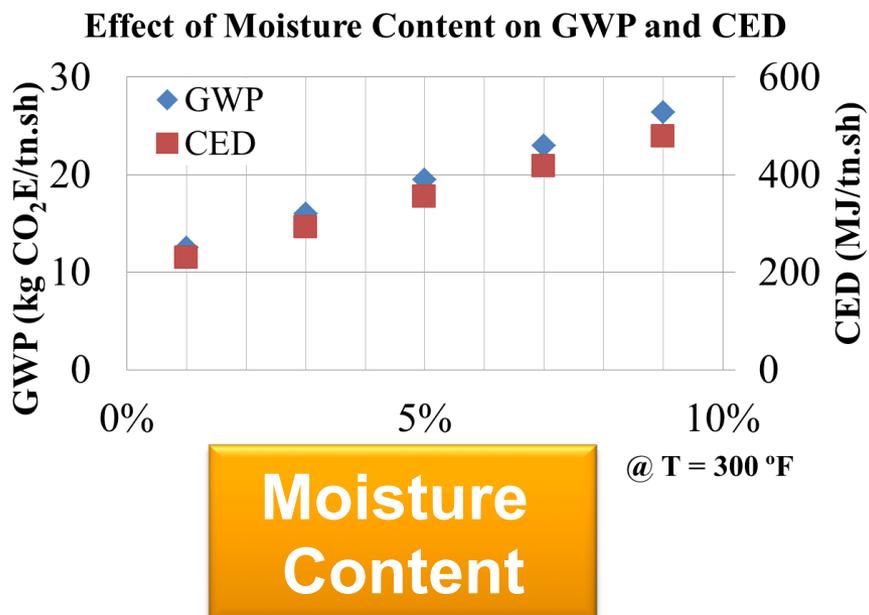
# HMA Plant Model

- Predicting energy use in HMA plant based on **moisture** content of aggregate and mixing **temperature**
- Based on **local questionnaires** and literature from **NAPA** report (2007)
- Operation Types
  - Drying/mixing (natural gas)
  - Fans, drum motors (electricity)
  - In-plant transportation (gas/diesel)

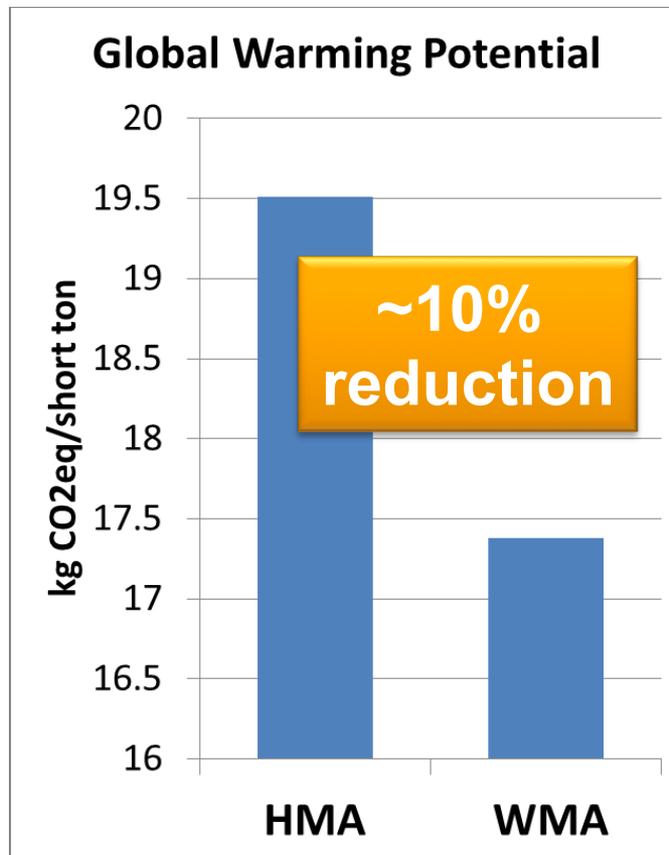
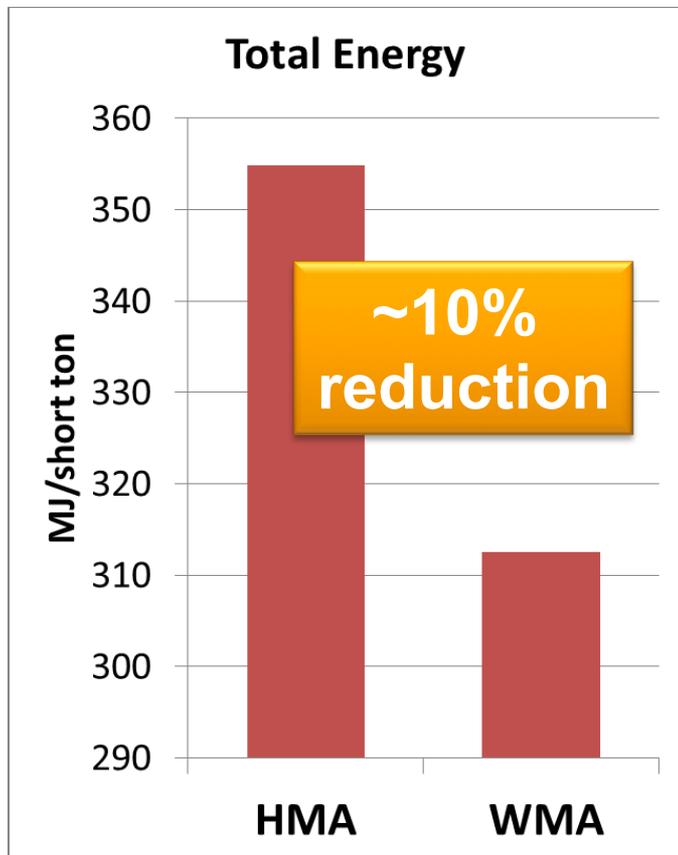


# Drying and Mixing

- Relationship between energy consumption and GWP



# Total HMA Plant Operations



**HMA:**

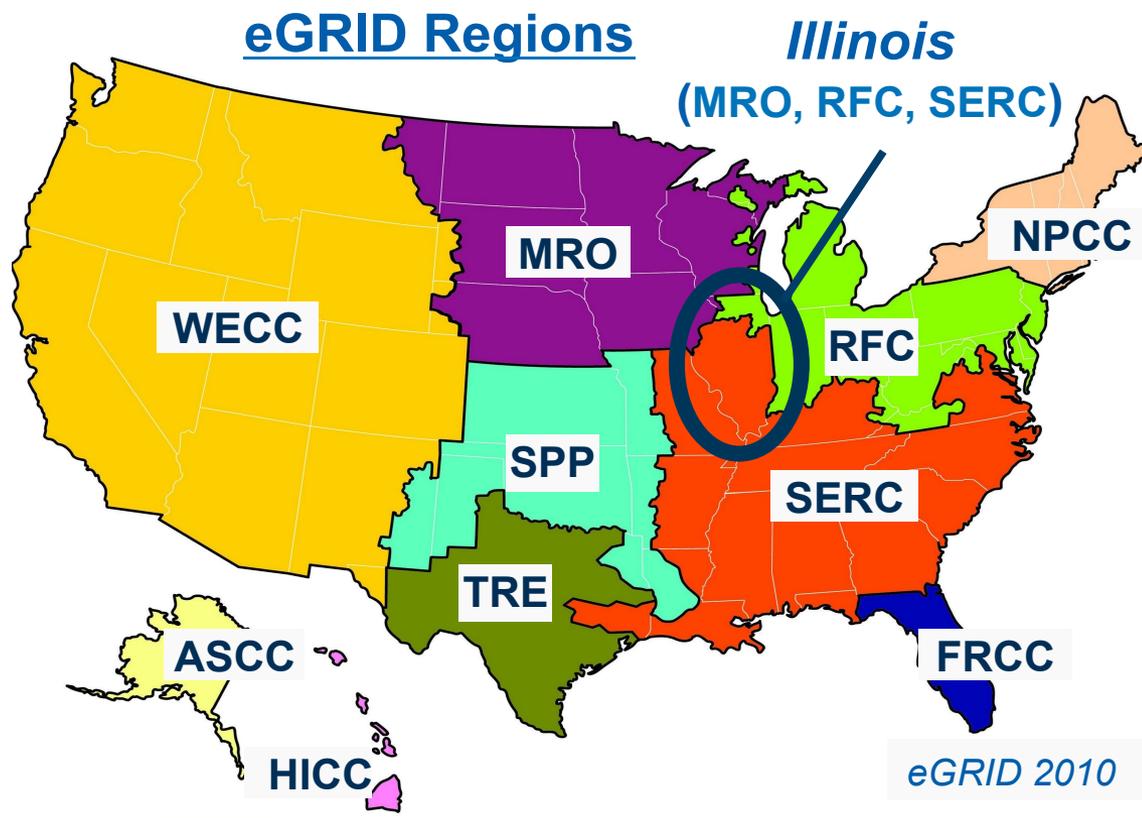
- MC = 5%
- T = 325 °F

**WMA:**

- MC = 5%
- T = 240 °F

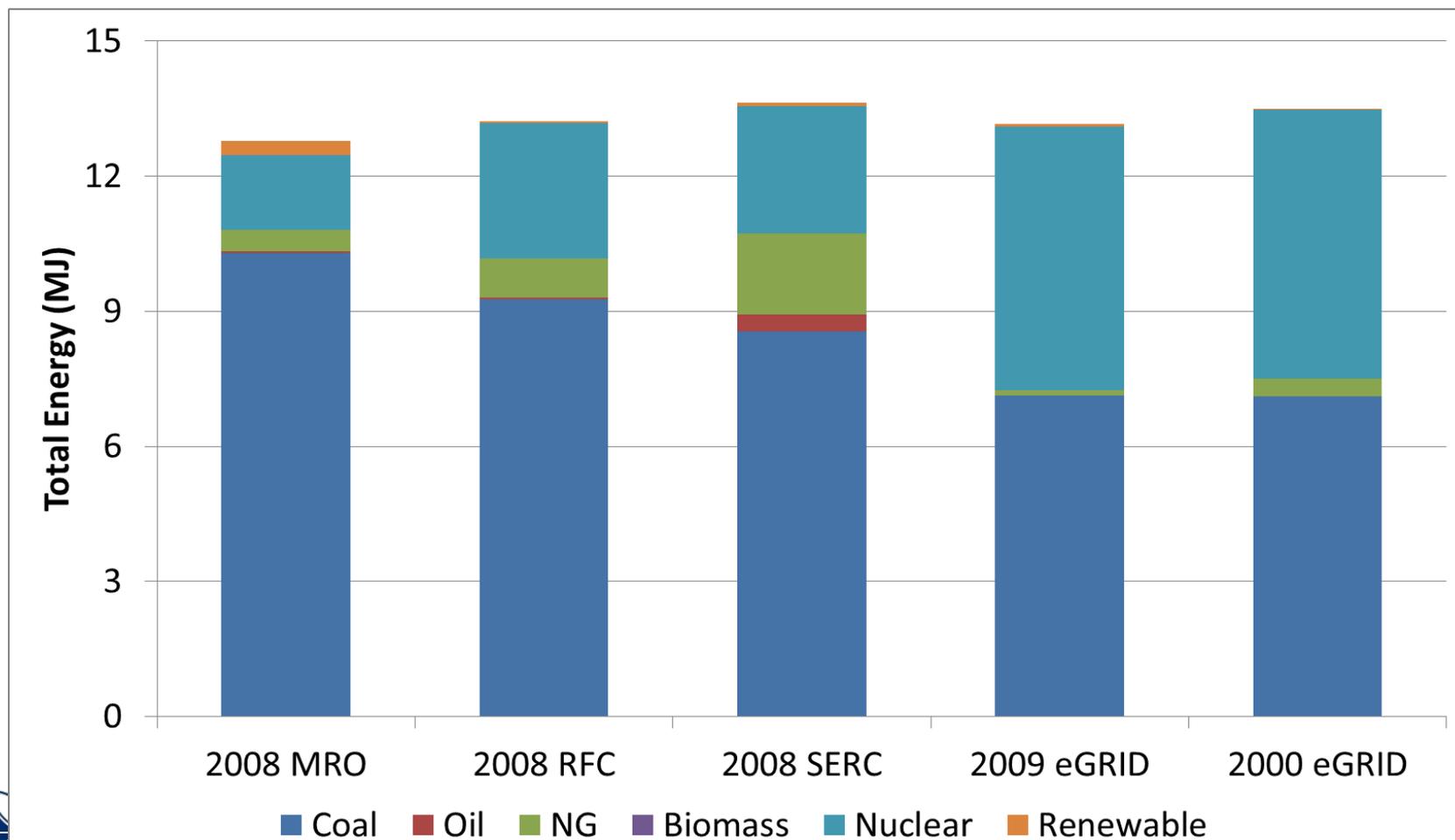
# Electricity Generation Model

- Influences most unit processes in the **material** phase
- Plant fuel mixes, efficiencies, emissions vary with regions and years
- **Region-year-specific** models developed for **Illinois** using EPA's **eGRID**



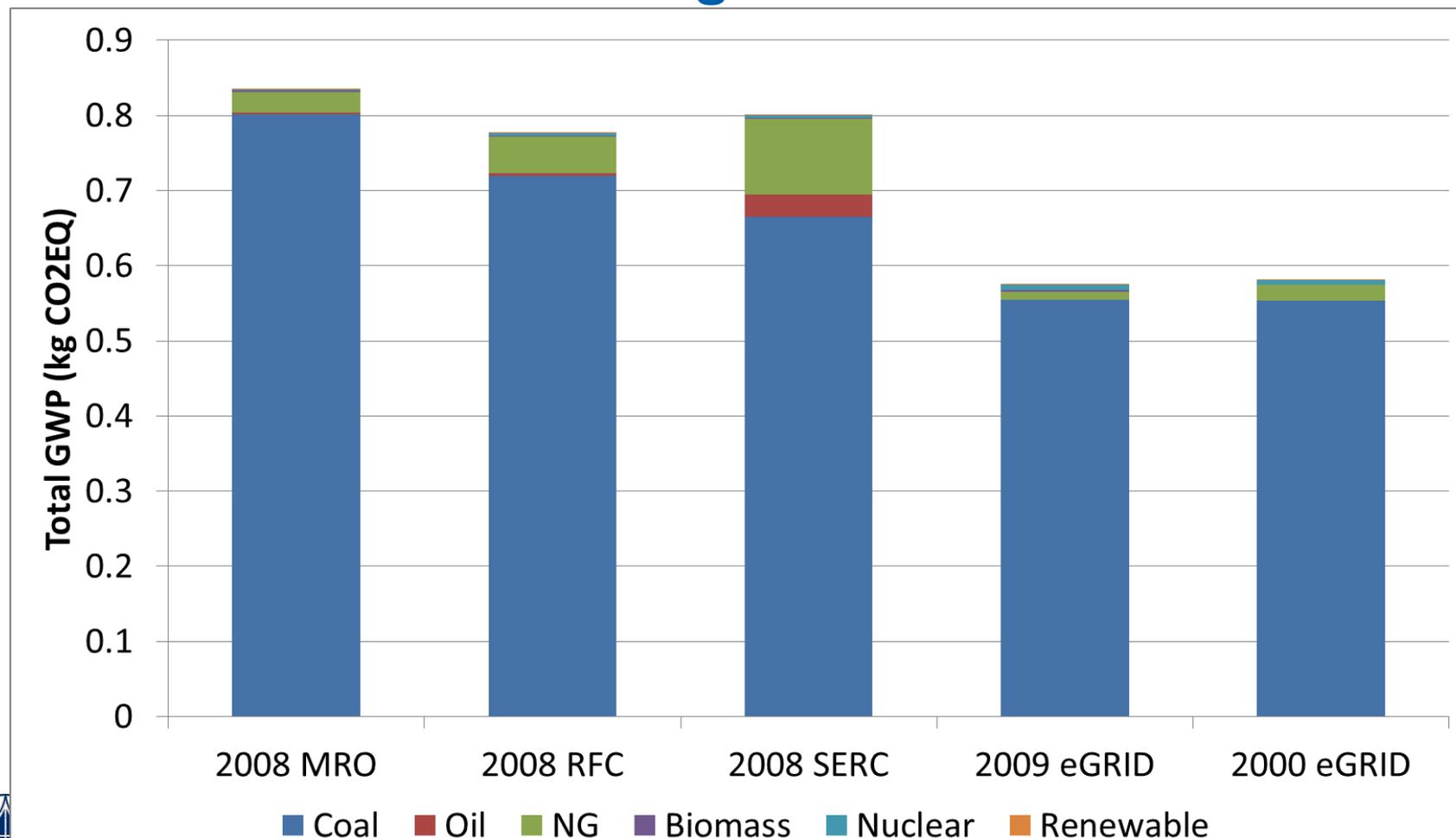
# Electricity Model: Energy

## □ Proportion of plant fuel mixes



# Electricity Model: GWP

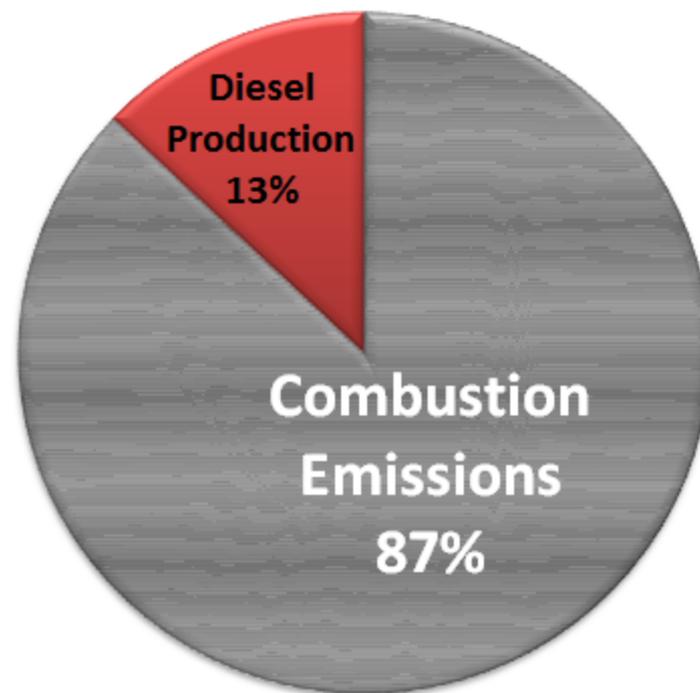
- Lower GWP from a high ratio of nuclear



# Hauling Truck Model

- Necessary to transport:
  - Raw/ recycled materials to processing plants
  - Materials and equipment to construction sites
  
- **MOVES 2014**
  - Regional emission inventory via **simulations** for the Illinois region
  - Added **upstream energy/ emissions** of diesel production

Contribution to GWP



# Construction Equipment Model

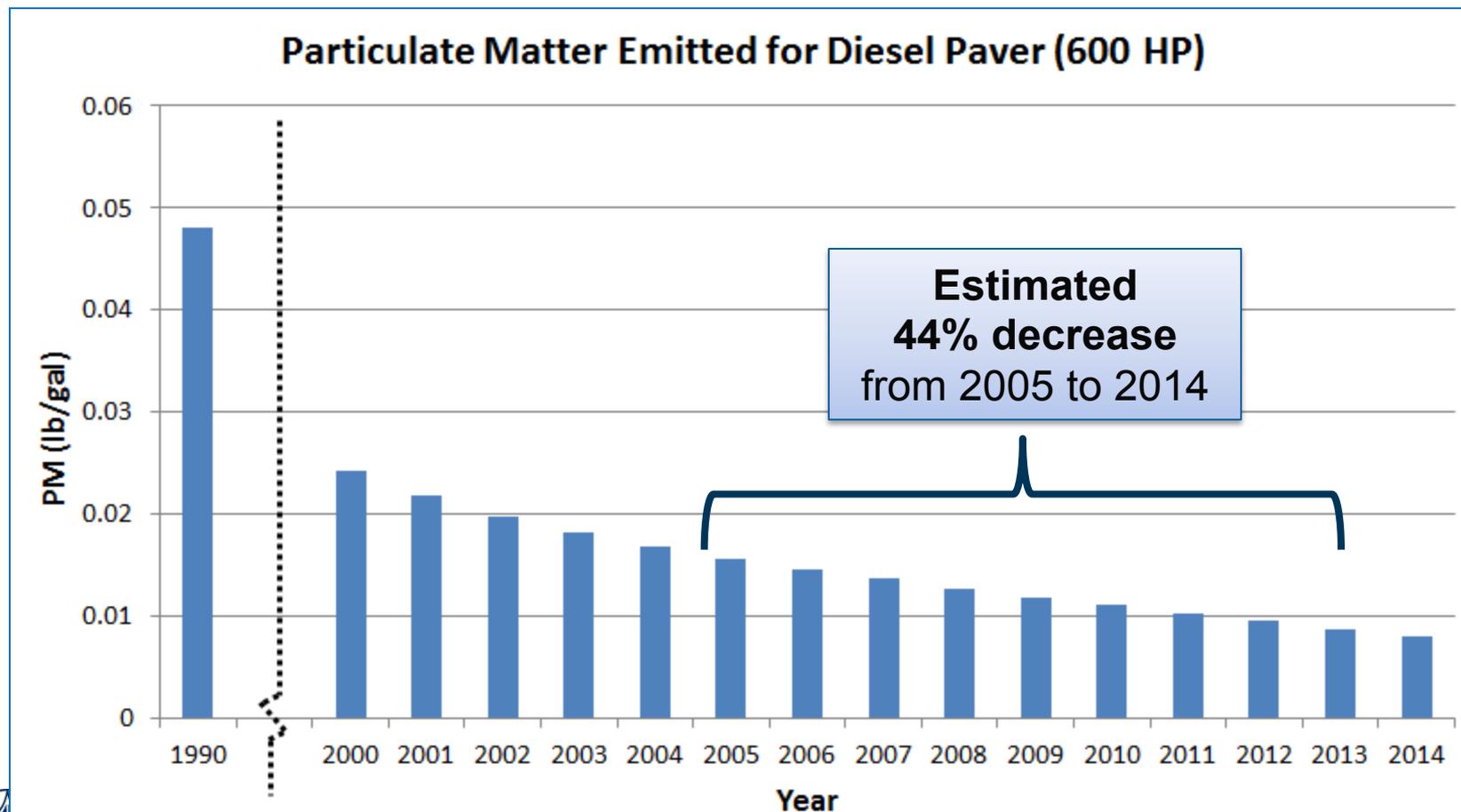
- EPA's **NONROAD** software models emissions from off-road vehicles at the county level
- Federal emission standards

General Lookup for Non-Road Diesel Engine PM Emission Standards  
(may vary for some manufacturers)

Horsepower range	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015+	
<25																						
25≤hp<50	Tier 0																					Tier 4
50≤hp<75																						
75≤hp<100																						
100≤hp<175																						
175≤hp<300																						
300≤hp<600																						
600≤hp<750																						
>750 hp																						

# Equipment Model: Results

- Implementation of emission tiers over time



# Summary of Inventory Database

## Material Production & Processing

HMA	PCC	Aggregate	Other
Straight Binder GTR Mod. Binder SBR Mod. Binder Sealant Emulsion HMA/WMA Plants	Cement Type I GGBF Slag Reinforcing Steel Ready Mix	Natural Agg. Crushed Agg.	RAP RAS RCA Fly Ash Steel Slag

## Fuel & Electricity

Electricity  
 Coal  
 Natural gas  
 Petroleum fuels

## Transportation

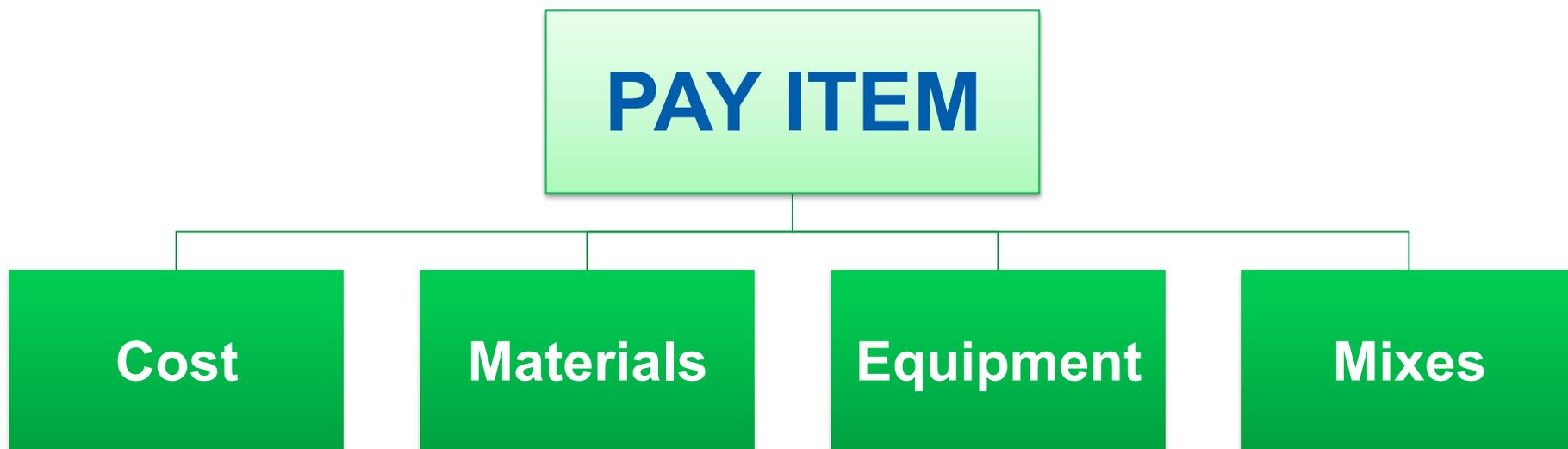
Hauling Truck  
 Barge  
 Rail

## Equipment

Various equipment  
 and nonroad vehicles

# Pavement LCA Tool

- Based on **pay items** for user friendliness and uniformity
- Full **life cycle** including use phase and various EOL scenarios



# Screenshots of Inputs

**Main Inputs**

**Main Pavements Inputs (ONE DIRECTION)**

Type of Pavement: (HMAC) Full Depth Asphalt Pavement, Rubblized PCC

Length of Section (mi): 4.5

Number of Lanes: 3

	Thickness (in)	Width (ft)
Lane 1	12	12
Lane 2	12	12
Lane 3	12	12
Lane 4		
Lane 5		
Lane 6		
Total Mainline		36

Paved Shoulders?

	Thickness (in)	Width (ft)
Inner	8	6
Outer	8	6

Unpaved Shoulders?

	Thickness (in)	Width (ft)	Slope (%)
Inner	6	6	4
Outer	6	6	4

Longitudinal Joints (number of joints): 4

Transverse Joints (spacing, ft): 15

Ok Cancel

**Modify Mix Design**

**Mix Design** Status (Default/User-modified): D

Date Created: Aug 2014

Mix Design ID: 90BIT0934

Mix Type: HMA Plant

Mix Description: Sample mix

Load inputs from an existing mix design: Choose Existing ID

**Asphalt Mix Volumetrics**

Gmb (design)	2.663
Gmm	2.663
Voids (%)	4.0
Asphalt Content (%)	5.1

	Material	Recycled Binder (%)	Amount (% mix)	Transportation Mode	Source-to-Plant Distance (mi)
1	FRAP - #4		35	Hauling Truck	5
2	FMM02 (HMA)		20	Hauling Truck	20
3	PG 64-22		5.1	Hauling Truck	60
4	CMM13 (HMA)		45	Hauling Truck	20
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
		Total	105.1		

OK Cancel

# Tollway Case Study

- **1 Full depth HMA** and **6 PCC** reconstruction projects performed by Tollway in 2013
- Included **Materials, Construction, Maintenance**
- **Effects of improvements from 2000s to 2013**

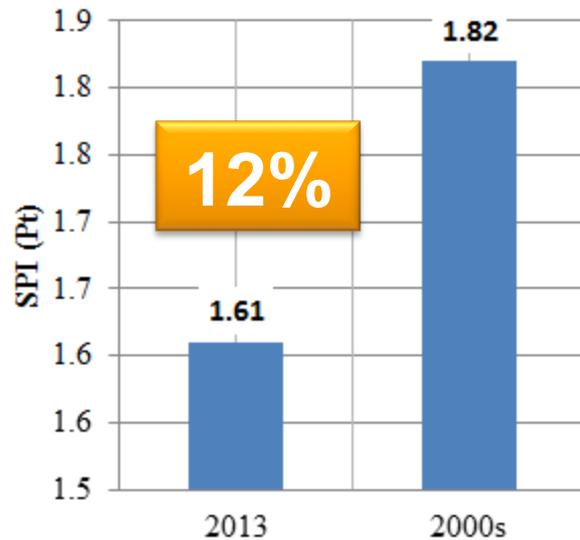
## Materials & Design

- Increase of **RAP, RAS**
- Replace HMA with **WMA**; virgin aggregates with **RCA** in shoulders/base layers
- Using composite mixes with **fly ash**
- **Layer thickness** changes
- Increased **design life** for PCC pavements

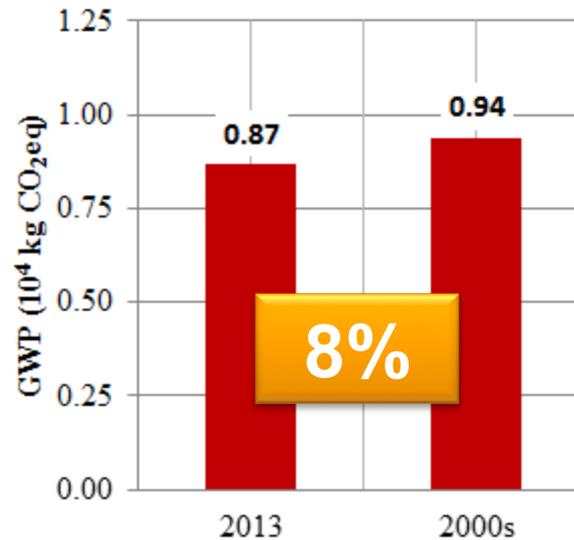
# Full Depth HMA Results

## □ Results per lane-mi-yr

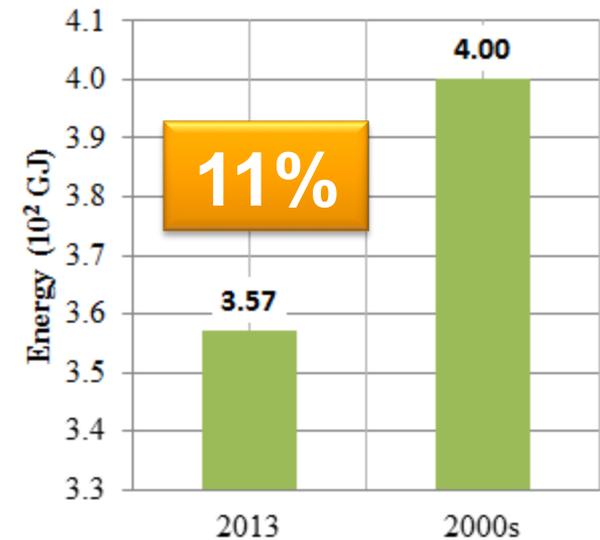
### Sustainable Performance Indicator



### Global Warming Potential



### Cumulative Energy Demand



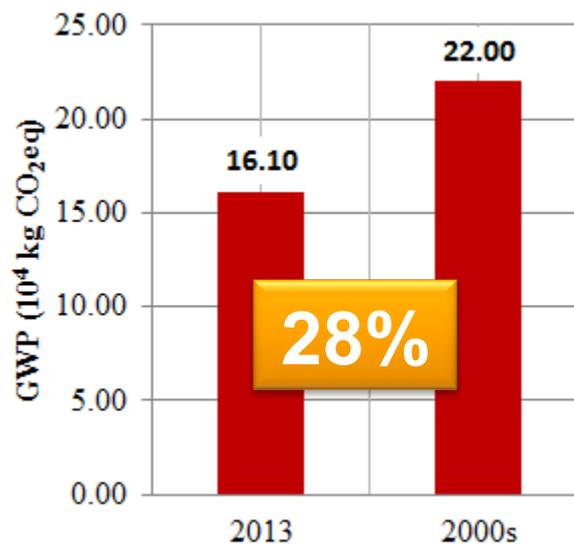
# PCC Pavement Results

## □ Results per lane-mi-yr

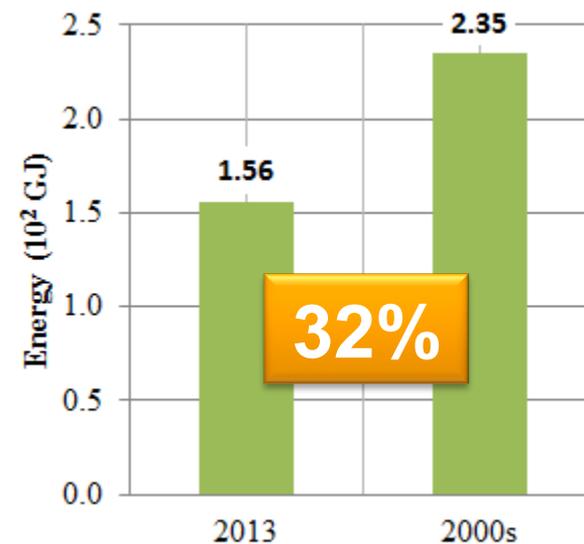
### Sustainable Performance Indicator



### Global Warming Potential



### Cumulative Energy Demand



# Acknowledgements

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- This project is funded by the Illinois Tollway through the Illinois Center for Transportation.
- **Tollway:** Steve Gillen
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- **UIUC** Team