Life Cycle Assessment for Flexible Pavements: Overview, Recent Results, Possible Future Directions

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54th Annual Illinois Bituminous Paving Conference
December 11, 2013

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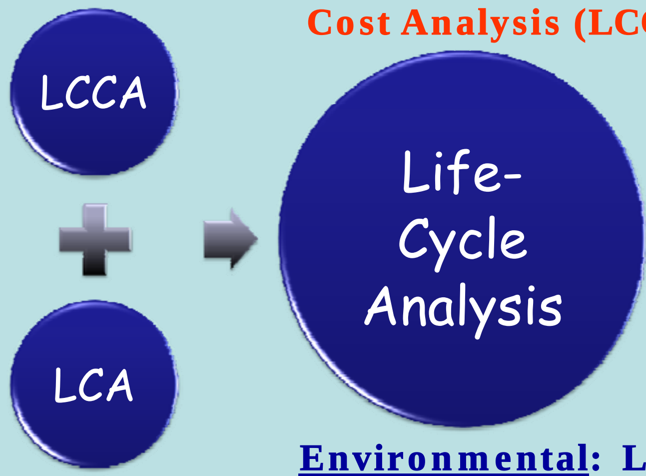
Outline

- Overview of Life Cycle Assessment (LCA)
- Some recent results of application of LCA to pavement
- Possible future directions

What is Life-Cycle Analysis?

Economics: Life-Cycle Cost Analysis (LCCA)



Environmental: Life-Cycle Assessment (LCA)

From Santero et al, AB 32 workshop, 2008

Life Cycle Assessment (LCA)

- Developed in 1960-70s
- A method for characterizing and quantifying environmental sustainability for specific performance criteria using a "cradle-to-grave" perspective
- Measures inputs and outputs, summarizes into *impact categories*
- ISO LCA Standards:
  - 14040 Principles and Framework
  - 14044 Requirements and Guidelines
  - 14047 Impact Assessment
- Provide general, but lack detailed information necessary for individual products and systems

ISO = International Organization for Standardization

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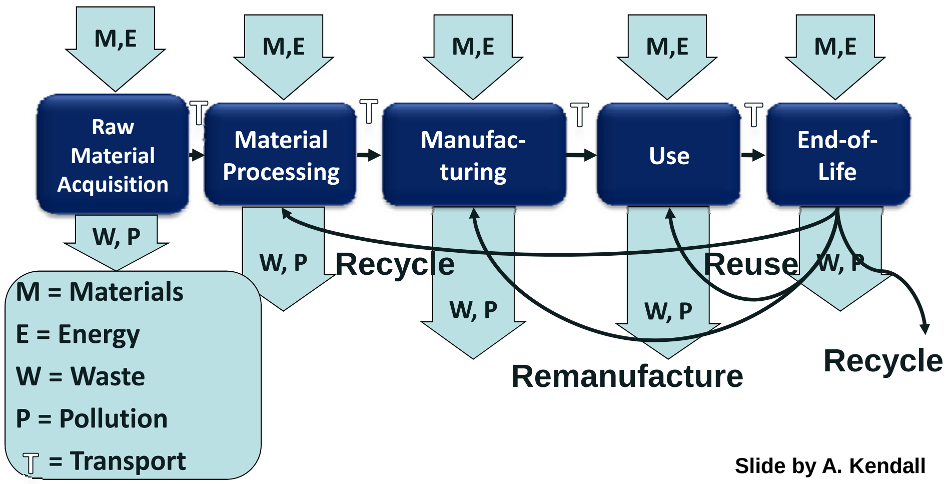
Generic Life Cycle Assessment

- Evaluates a product or system throughout its entire *life cycle*



Slide by A. Kendall

Three Key Steps of Life Cycle Assessment

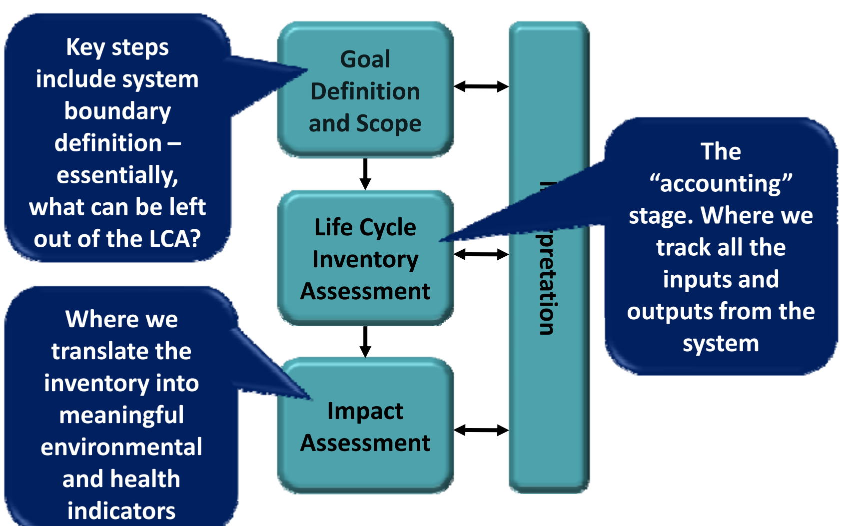


Figure based on ISO 14040

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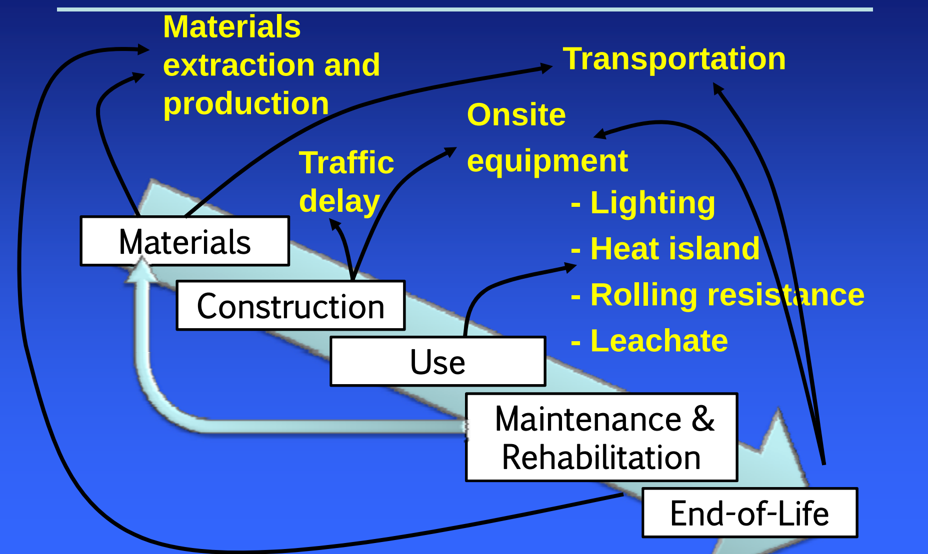
The Pavement Life Cycle



N. Santero, PhD thesis, UC Berkeley, 2009

Why use LCA for evaluating environmental performance?

- Quantifies outcomes:
  - GHG, energy, pollutants, finite resources
- for project-specific inputs:
  - materials, transport, construction, traffic levels, re-use
- Requires explicit prioritization of outcomes for decision-making
- Can account for regional and time variability, and other uncertainties in data sets and analysis

vement Life Cycle Assessment Workshop

Pavement Life Cycle Assessment Workshop

University of California, Davis
Davis, California
May 5-7, 2010

CSTB
IFSTTAR
SETAC
International Society for Industrial Ecology
rilem

July 10-12, 2012
Nantes, France

International Symposium on Life Cycle Assessment and Construction

Follow-up:
Pavement LCA 2014 Symposium
October 14-16, 2014 Davis, CA

Summary Document: Pavement LCA Tech Memo

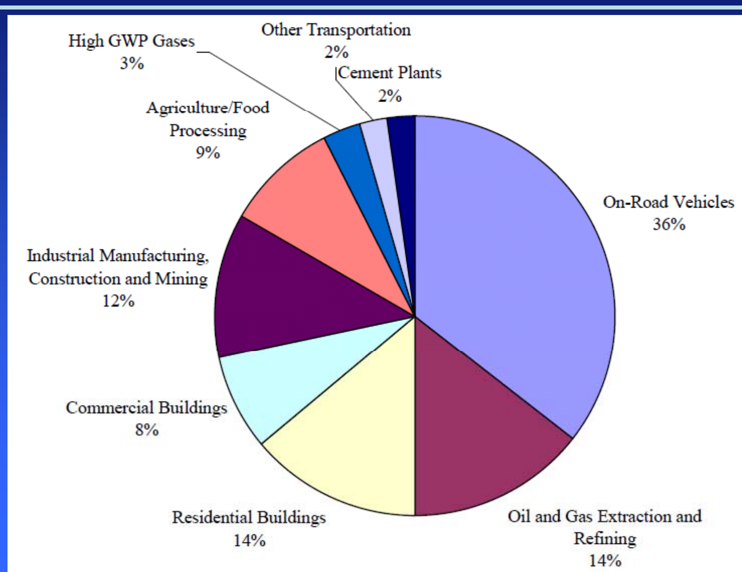
- LCA framework for pavements
- Summary of system boundaries, assumptions
- Assessment of models/data for each phase
- Transparency Document: Requirements for pavement LCA studies sufficient to permit comparison between studies.

LCA Workshop Documents at www.ucprc.ucdavis.edu/p-lca

Pavement Scenarios That Can Be Analyzed with LCA

- Network level
  - IRI maintenance/rehab trigger criteria for GHG
  - Funding for M&R of pavement versus other transportation investments
- Project level
  - Recycling strategies
  - Pavement type selection
  - Design life selection
  - Continuous vs night-time construction windows
- Innovation
  - New materials, structures, construction

Assembly Bill 32 (2006) requires 2020 GHG emissions at 1990 levels 2050 GHG emissions at 20% of 1990 levels



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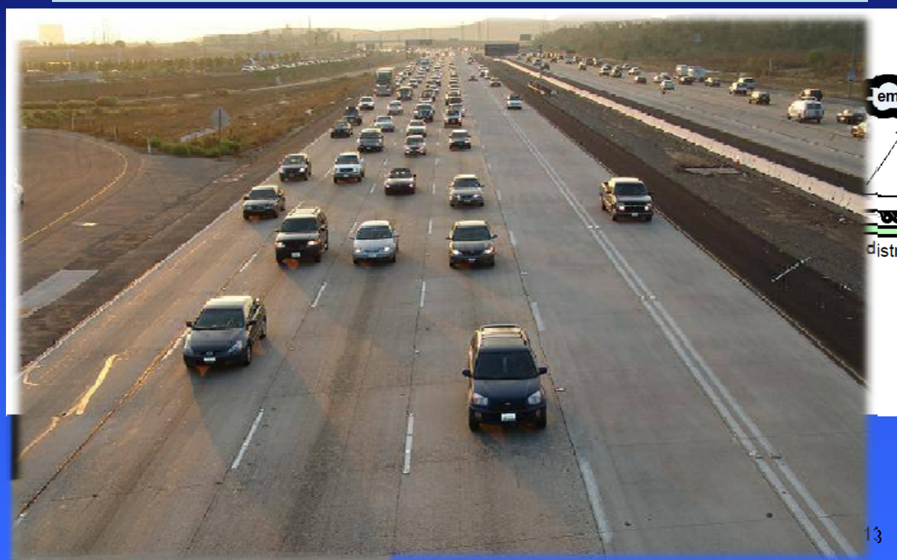
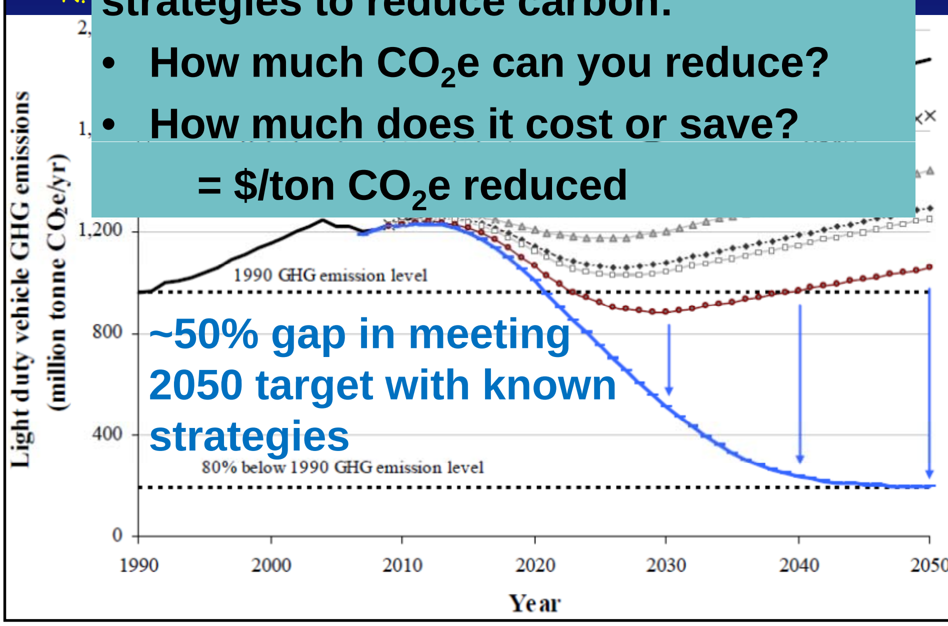
Current state approaches for meeting AB32 goals for transportation sector



Bang for your buck questions for strategies to reduce carbon:

- **How much CO_2e can you reduce?**
- **How much does it cost or save?**

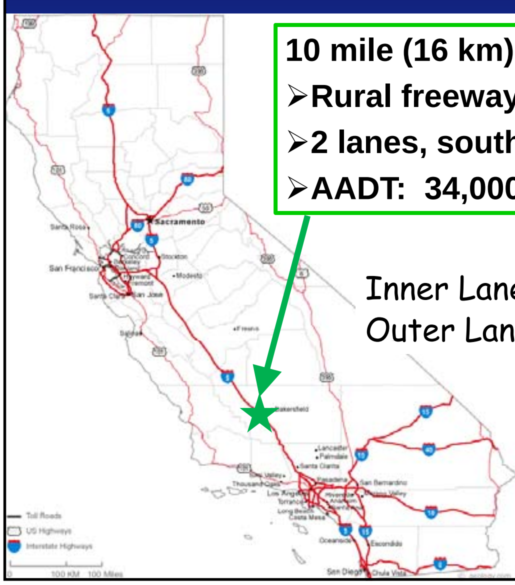
= \$/ton CO_2e reduced



Pavement Rolling Resistance

- Roughness (models available)
  - Measured with International Roughness Index (IRI)
  - Dissipates energy through suspension and tires
- Macrotexture (models available)
  - Dissipates energy through tire tread distortion
- Deflection (models under development)
  - Theory: dissipates energy through deflection of viscoelastic pavement materials (HMA)
  - Theory: larger deflection and viscoelasticity results in vehicle always running uphill

Case Study 1 (KER-5): Asphalt overlay on rural/flat freeway



10 mile (16 km) segment

- **Rural freeway**
- **2 lanes, southbound**
- **AADT: 34,000; ~35% trucks**

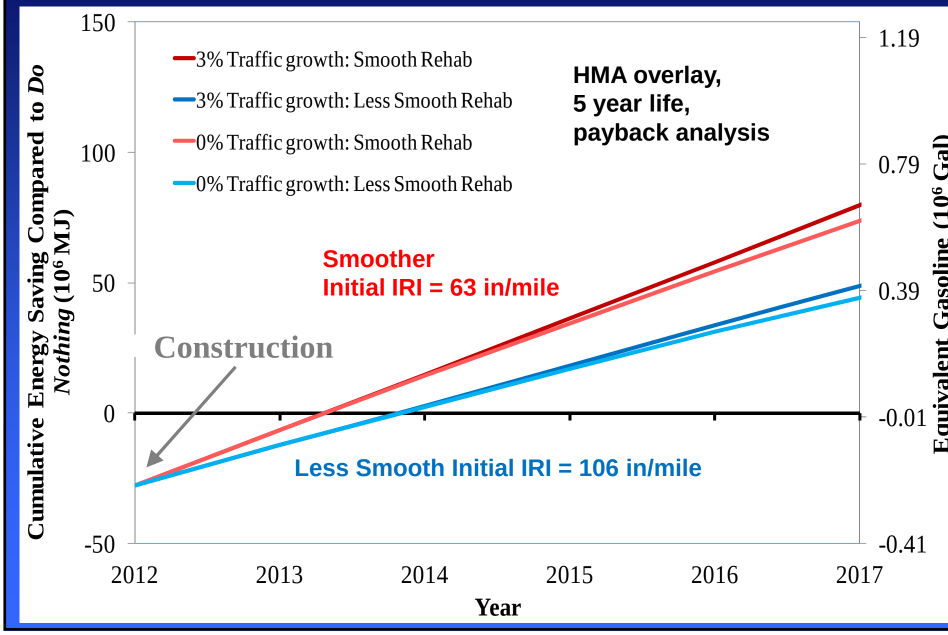
	Cars	Trucks	IRI
Inner Lane	77%	9%	158
Outer Lane	23%	91%	222

Compare:

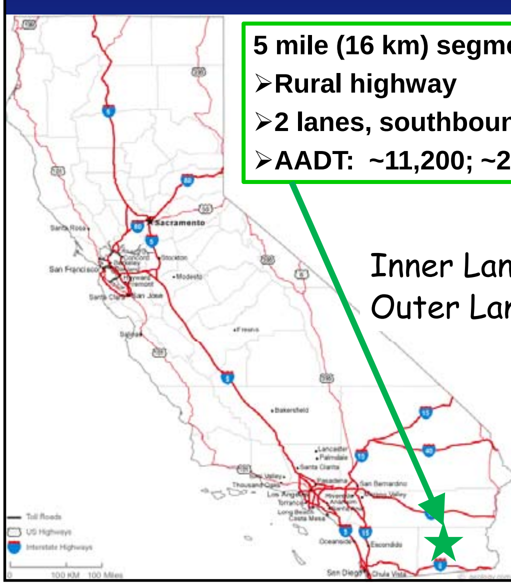
- Routine maintenance

-5 year overlay:
HMA or RHMA

Kern-5 (high traffic): Cumulative life cycle energy savings of HMA overlay compared to "Routine Maintenance"



Case Study 4 (IMP-86): Concrete CPR B on rural/flat highway

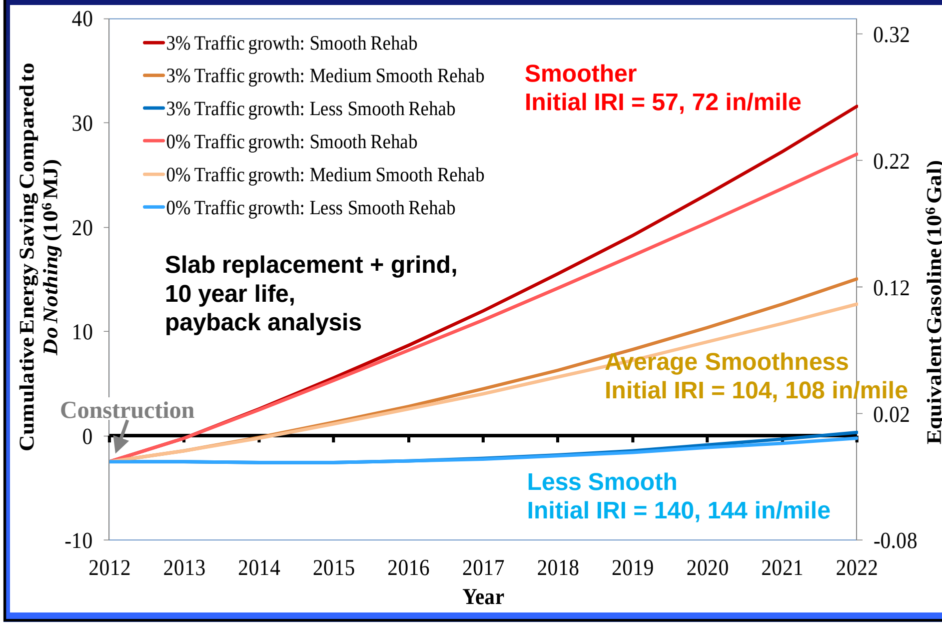


5 mile (16 km) segment in need of rehab
- **Rural highway**
- **2 lanes, southbound**
- **AADT: ~11,200; ~29% trucks**

	Cars	Trucks	IRI
Inner Lane	76%	8%	158
Outer Lane	24%	92%	183

Compare:
- **Do Nothing**
- **10 year CPR B**
  - **Grind**
  - **3% slab replacement**

IMP-86 (**lower traffic**): Cumulative life cycle energy savings of CPR compared to "Routine Maintenance"



Conclusions from project-level case studies

- Smoothing rough pavement has great potential to reduce energy consumption and GHG emission.
- Emissions from construction and materials for high traffic volume roads can be paid back very quickly (in less than 1 year at extreme).
- For low traffic volume roads, material production and construction emissions will never be paid back with use phase savings.

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Application of models to Caltrans network

- LCA used to identify optimal IRI values to trigger 5 to 10 year treatments to quickly improve smoothness
  - Optimized for different traffic levels
- Applied to 48,000 lane-mile network
- Life cycle cost to determine $/metric-ton of CO_2-e saved compared to previous IRI trigger values
- Models implemented in Caltrans PMS

10 year Results of Optimal vs Previous IRI Trigger (214 in/mile)

Average Daily Traffic Pass Car Equivalents/ Direction	Optimal IRI triggering value (inches/ mile)	Total lane-miles in the network	GHG reductions (MMT CO_2-e)	Agency cost-effectiveness ($/metric ton CO_2-e)
< 2,517	-----	12,068	0.24	-5,127
2,517 to 11,704	152	12,068	0.28	3,818
11,704 to 19,108	127	4,827	0.29	2,420
19,108 to 33,908	127	4,827	0.52	1,283
33,908 to 64,656	101	4,827	1.68	1,030
64,656 to 95,184	101	4,827	2.03	638
> 95,184	101	4,827	3.11	441
Total			**8.15**	**688**

Conclusions from network-level calculations

- Use of optimized IRI triggering values can contribute to the statewide GHG emission reduction target (reduction of 0.2 percent compared to current trigger).
- Performing M&R on segments with a very low daily traffic in the network does not lead to net GHG or energy benefits.
- The optimal IRI triggering values and the resultant GHG reduction are very sensitive to construction smoothness.

Caltrans Deflection Energy Dissipation Study

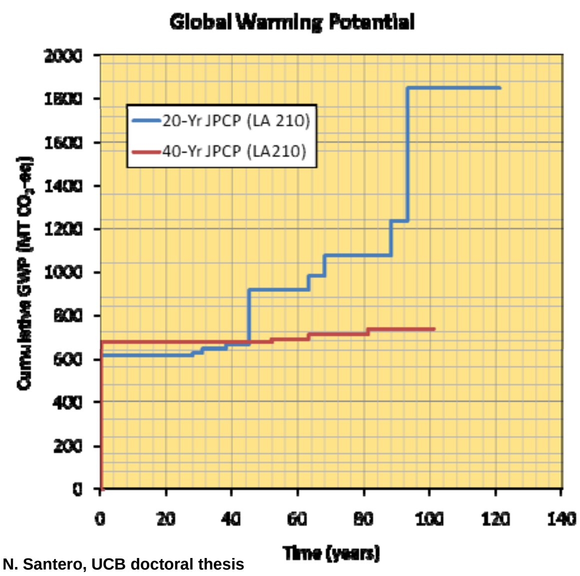
Start October 2013

Phase I model comparison for different pavement types, climates, vehicles
Phase II field validation

German Heavy Vehicle
Rolling Resistance Measurement Device on test road in Nantes, France
(sensitive to texture, deflection)

Long-life rehabilitation of heavy duty concrete and asphalt pavements

- LCCA studies show longer rehab design lives (30-40 years) reduce costs where high traffic
- Initial results indicate long-term GHG savings also



N. Santero, UCB doctoral thesis

Typical AC Long-life Rehab Structure Designed with ME

	Existing grade
Rubberized OGFC – safety, noise	*25-50 mm*
Top layer – rutting, cracking, 6% AV*	*75-100 mm*
Middle layer – cracking, rutting 6% AV, 25% RAP	*Varying thickness*
*Rich Bottom layer** – cracking, 0-3% AV*	*50-75 mm*
Variable base granular, CTB, PCC	*0 or 150 mm*
subgrade	

**15% RAP, polymer binder*

*** 15% RAP*

What is happening now with Pavement LCA?

- LCA is the framework for new FHWA Sustainable Pavement Guidelines
- Model and software development in universities and institutes
- LCA + LCCA used to select contractors for Design-Build-Maintain projects in Netherlands and France
- Future trends
  - More standardization, better data
  - More implementation, but how??

One possible next step

Product Category Rules

Slides prepared by
Nick Santero – PE INTERNATIONAL
John Harvey – UC Davis
Joep Meijer – The Right Environment
Tom Van Dam – CTL Group (now with Nichols Consulting Engineers)

Definitions and Relationships

PCRs, LCAs, and EPDs

PCR: the framework

Product Category Rule (PCR)

"Set of specific rules, requirements, and guidelines for developing Type III environmental product declarations for one or more product categories" (ISO 14025)

LCA: the analysis

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040)

EPD: the declaration

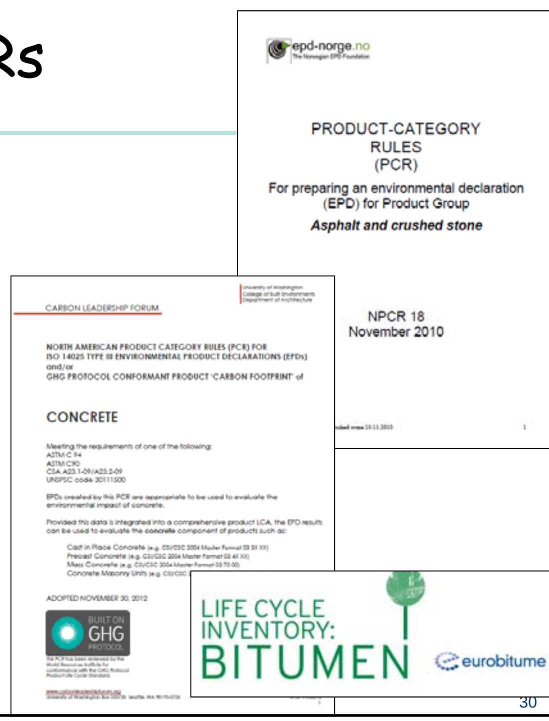
Environmental Product Declaration (EPD)

"Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information" (ISO 14025)

Types of PCRs

Material Focused

- **Material-Focused PCRs**
  - **Specific to a material**
  - Typically cradle-to-gate (i.e., excludes use and/or end-of-life)
- **Materials-Focused PCRs are prevalent**
  - PCRs (and EPDs) are available for many basic materials
  - Few North American PCRs available
  - Credits for EPDs in LEED v4



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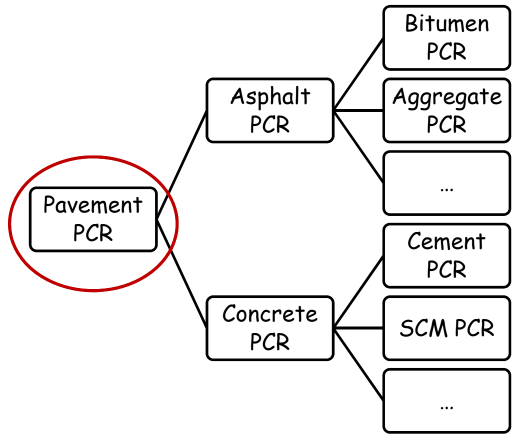
Types of PCRs

Systems

- **Systems PCRs**
  - Build on product-focused PCRs
  - Typically cradle-to-grave (i.e., includes use and end-of-life)
- **Systems PCRs are not prevalent**
  - More complicated than product-focused
  - Whole-building LCA standard under development by ASTM



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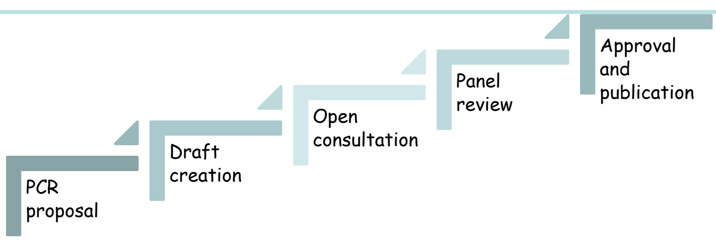
PCR Development Steps



- Stakeholder engagement
  - Industry associations (e.g., ACPA, NAPA)
  - Manufacturers (e.g., companies)
  - LCA practitioners (e.g., LCA consultants)
  - Government agencies (e.g., FHWA, Caltrans, Illinois DOT, Illinois Tollway)
  - NGOs

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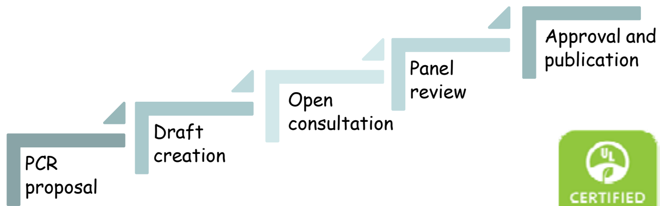
PCR Development Steps



- Facilitated by a program operator
  - Hosts the PCR
  - Verifies EPDs
  - Registers EPDs

Example North American program operators →

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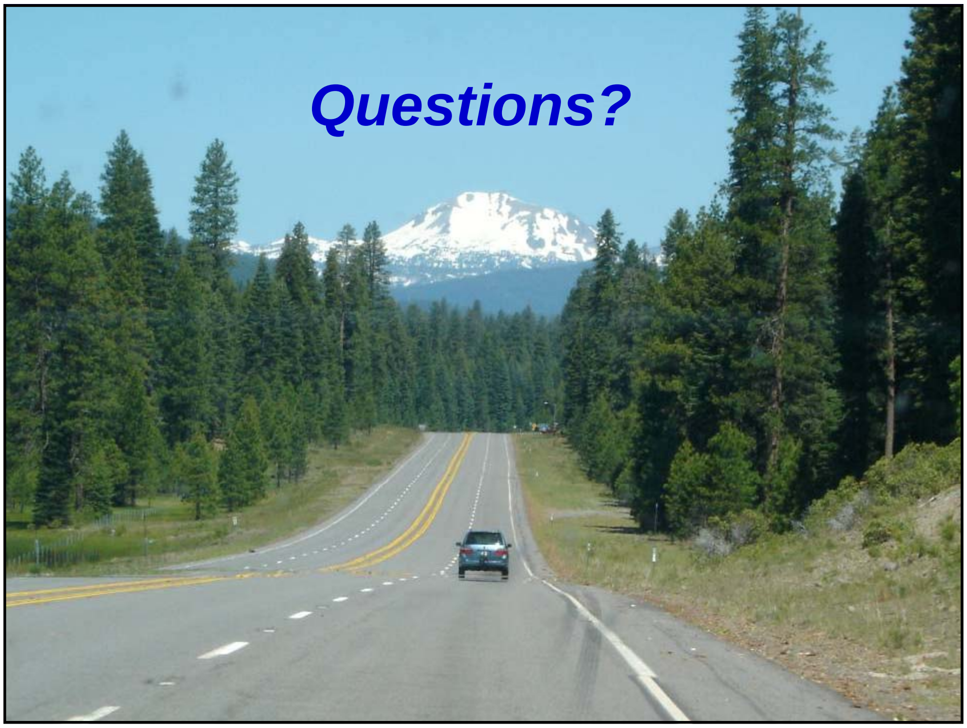
Expectations for Transportation Segment of the Economy

S. David Freeman

UCLA Seminar: Infrastructure Investment for Sustainable Growth (October, 2010)

- Transportation sector about to enter a period of profound change similar to energy sector in 1970s and 1980s
- Regulations will be implemented requiring increasing energy efficiency and environmental performance
- Transformation necessary to maintain economic competitiveness of US
- We don't have enough money to make many mistakes


Questions?