# *Improving the Sustainability of Local Government Pavement: A Process and Practical Results*


Presented by

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Information from UCPRC, LBNL/UCPRC/USC team, Tom van Dam (NCE)

Capital Region Climate Readiness Collaborative
UCPRC tour, Davis,CA
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# What is the University of California Pavement Research Center?

UNIVERSITY of CALIFORNIA | PAVEMENT RESEARCH CENTER
Davis • Berkeley

- Mission
  - *Dedicated to providing knowledge, the UCPRC uses innovative research and sound engineering principles to improve pavement structures, materials, and technologies.*
- Pavement research begun in 1948 at UCB
- UCPRC begun in 1995
  - UCB 1995 – 2002
  - UCD & UCB – 2002 onwards

# Some Recent UCPRC Work

- Caltrans
  - Life Cycle Cost Analysis (LCCA)
  - Mechanistic-Empirical design methods
    - Long life rehabilitation, concrete and asphalt
  - Environmental Life Cycle Assessment (LCA)
  - Construction quality
  - Rapid Rehabilitation construction productivity and work zone traffic management
  - Pavement management
  - Recycling (asphalt, concrete, rubber, etc)
  - Noise, smoothness
  - Freight logistics decisions and pavement condition
- Caltrans and Interlocking Concrete Pave Institute
  - Permeable pavements for storm water infiltration

# Some Recent UCPRC Work

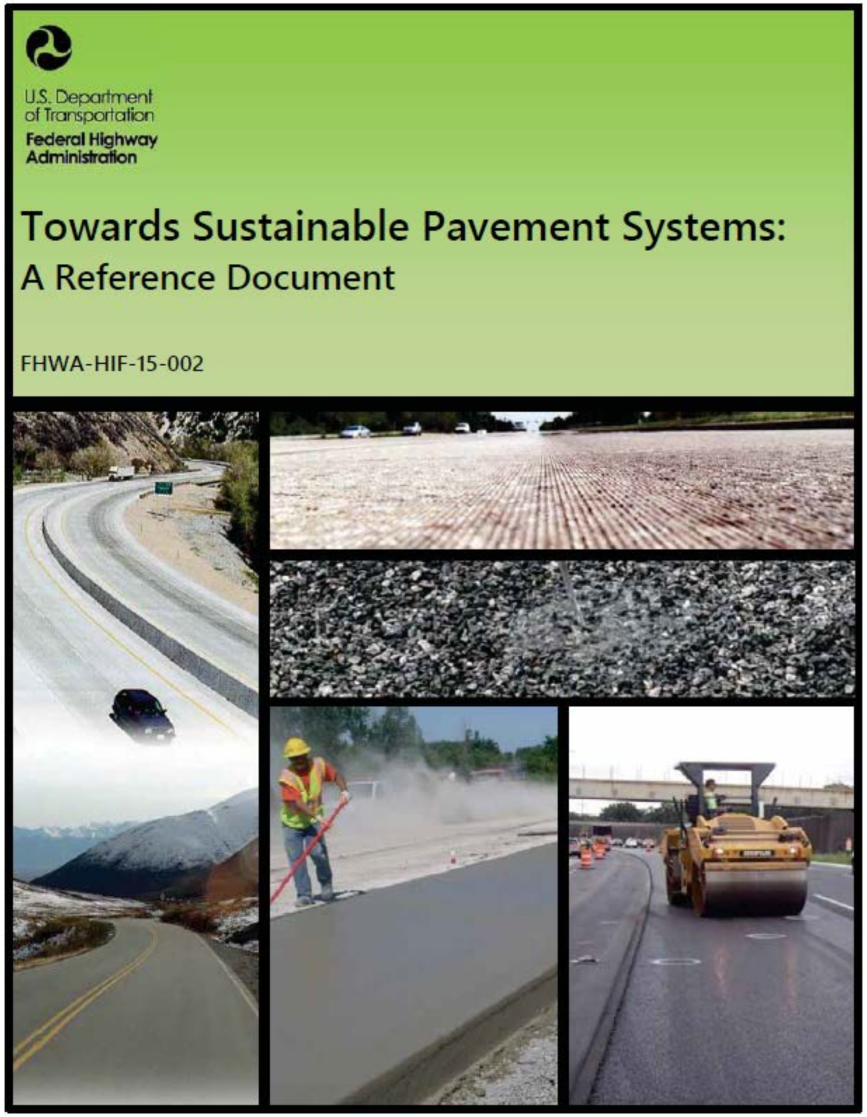
- California Air Resources Board
  - Urban heat island life cycle assessment
- CalRecycle
  - Rubber asphalt mix development and specifications
- Federal Highway Administration
  - Sustainability of pavement
  - Full-depth reclamation
  - Wide base single truck tires
- Federal Aviation Administration
  - Asphalt recycling
  - Mechanistic-empirical design methods
  - Airfield environmental life cycle assessment
- <u>This presentation does not reflect policy or recommendations of any of these sponsors</u>

# A Sustainable Pavement is an Aspirational Goal

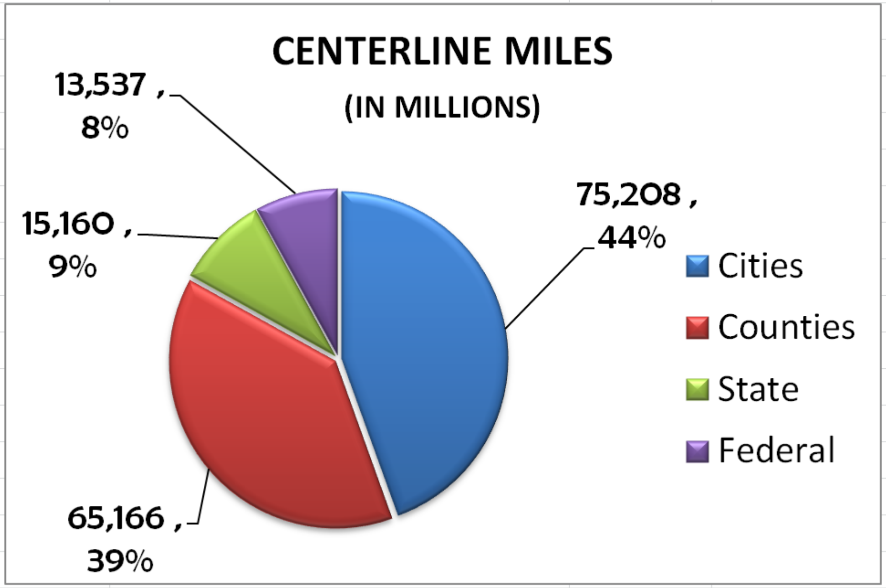
- Might not get there, but we can do a lot better than we are
- Lots of low hanging fruit

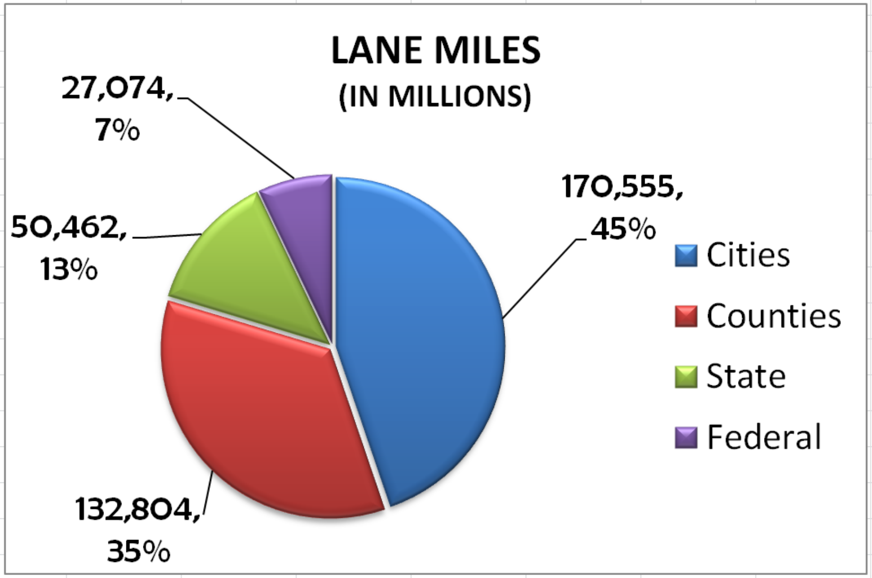
# FHWA Pavement Sustainability Reference Document

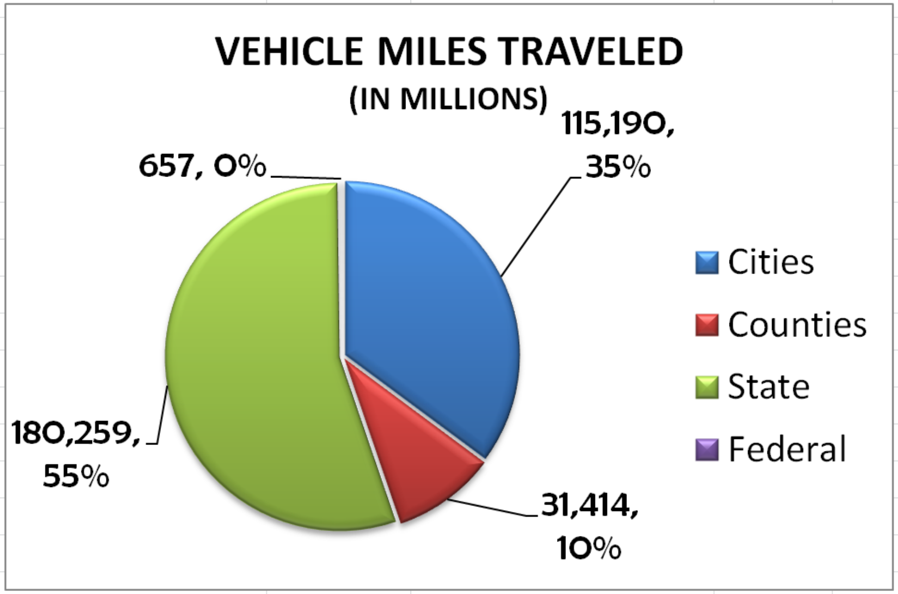
- State of the knowledge on improving pavement sustainability
- http://www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm
- Search:
  - "FHWA pavement sustainability"
  - "NCST pavement sustainability"
- Recommendations for improving sustainability across entire pavement life
- Organized around Life Cycle Assessment (LCA) framework
- Other information available at same web site
  - Tech briefs
  - Literature database



# Why is Local Government Pavement Sustainability Important?




**National $1000 Spent on Transportation in 2008 (US Census Bureau)**

| STATE GOVERNMENT | LOCAL GOVERNMENT |
|---|---|
| 97,508,989 | 61,053,150 |

# Measuring Sustainability

- Life Cycle Cost Analysis (LCCA)
  - Economic
- Life Cycle Assessment (LCA)
  - Range of environmental impacts
  - Emerging area
- Sustainability Rating Systems (e.g., INVEST)
  - Environmental and social impacts

**Reasons to Meaure**

**Accounting**

**Decision support**

**Establish baseline/process improvement**

# Four Key Stages of Life Cycle Assessment

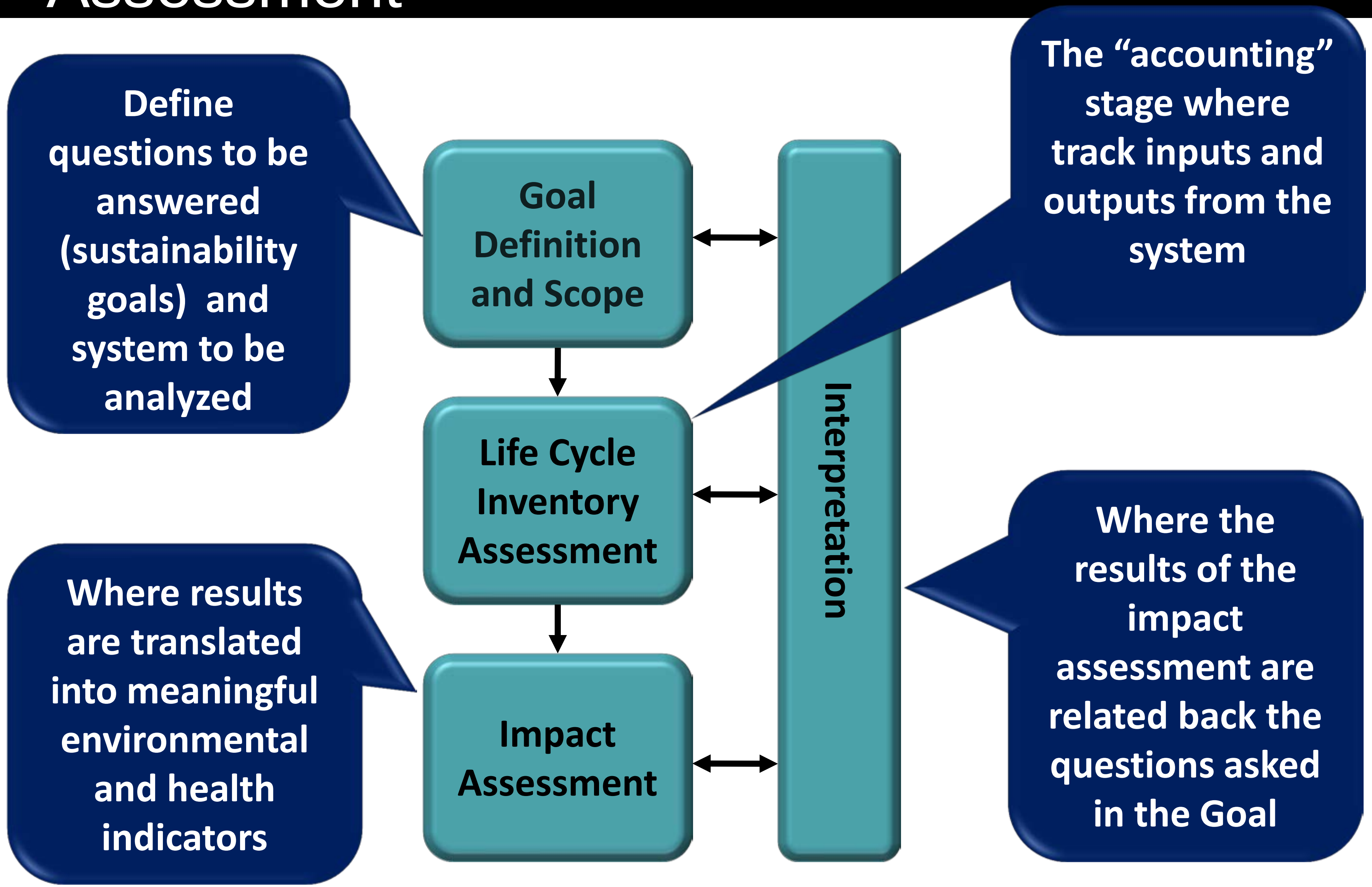



Figure based on ISO 14040, adopted from Kendall

# US EPA Impact Assessment Categories

(TRACI – Tool for the Reduction and Assessment of Chemical and other environmental Impacts)

- Global warming
- Stratospheric ozone depletion
- Acidification
- Eutrophication
- Photochemical smog
- Terrestrial toxicity
- Aquatic toxicity
- Human health
- Abiotic resource depletion
- Land use
- Water use

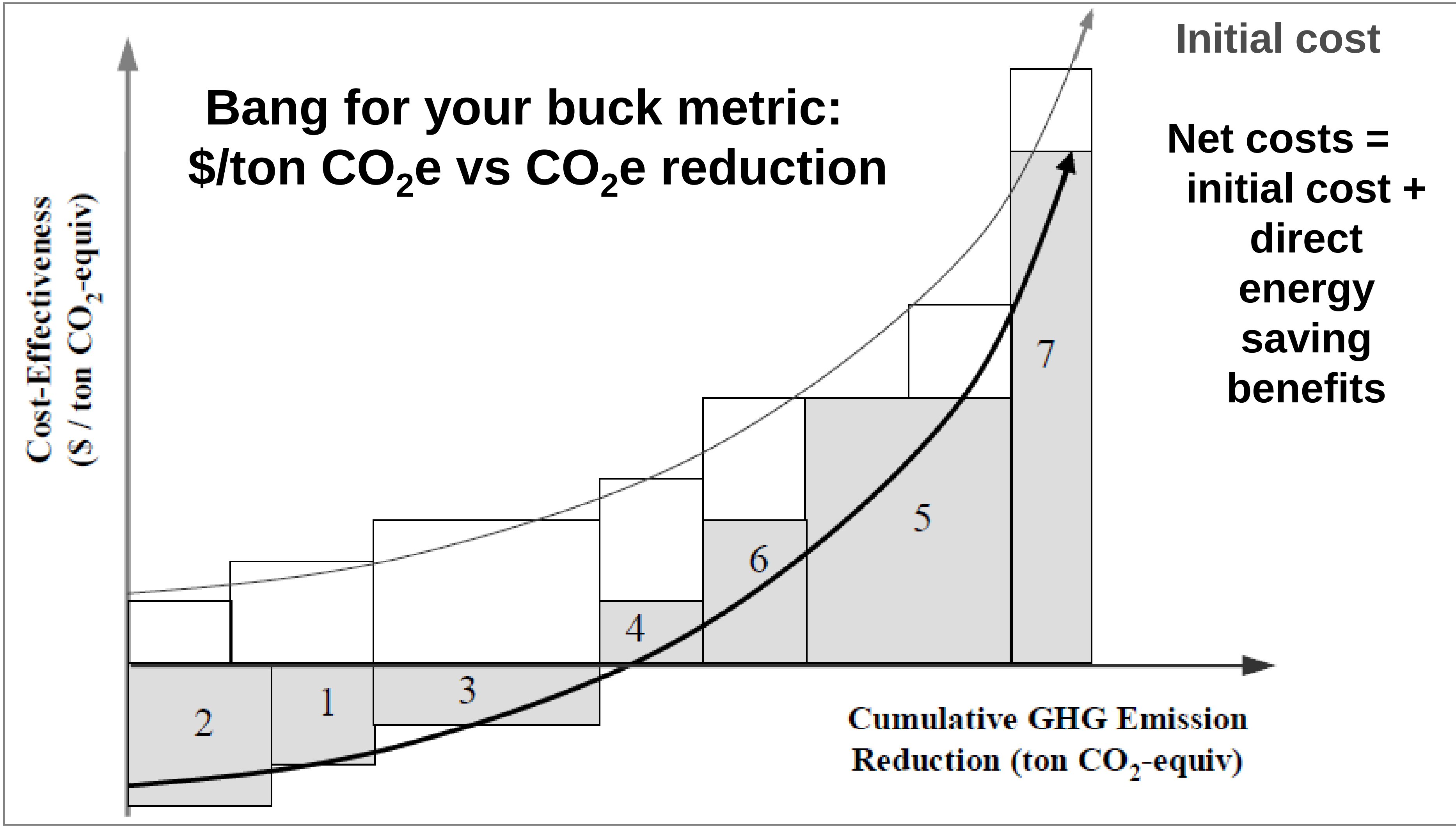
**Impacts to people**

**Impacts to ecosystems**

**Depletion of resources**

**Sustainability indices can be used for non-quantitative assessment including social**

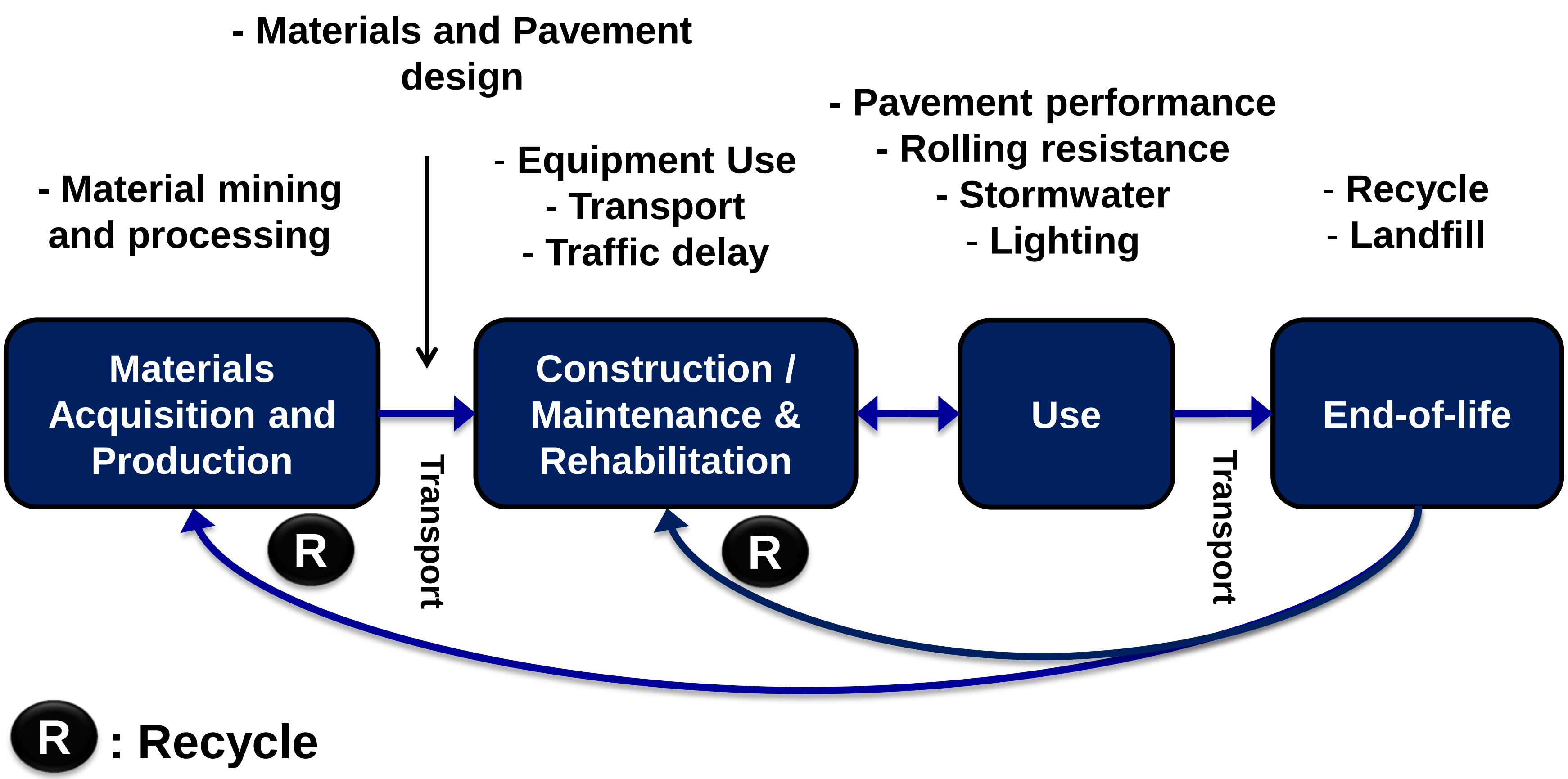
***From Saboori     Image sources:  Google***




- **Lutsey, N. (2008)**
  **Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-15**

# Where can environmental impacts be reduced?

- **Use Life Cycle Assessment (LCA) to find out**
- **Use Life Cycle Cost Analysis (LCCA) to prioritize based on improvement per $ spent**

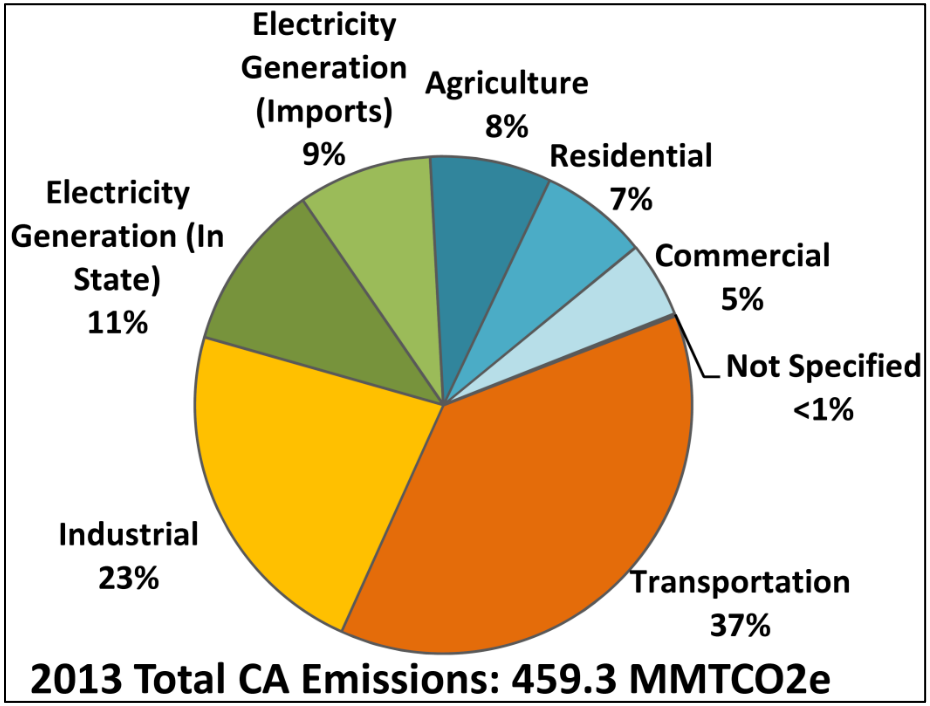



*From:* **Kendall et al.,** ***2010***

# How do Pavements Contribute to California GHG Emissions?

Out of 459 MMT CO2e

- On road vehicles 155 MMT
  - Pavement roughness and other effects can change vehicle fuel use by about 0 to 4 %
- Refineries 29 MMT
  - Paving asphalt about 1 % of refinery production
- Cement plants 7 MMT
  - Paving cement about 5 % of cement plant production
- Commercial gas use 13 MMT
  - Very small amounts for asphalt mixing plants
- Mining 0.2 MMT
  - Large portion for aggregate mining




http://www.arb.ca.gov/cc/inventory/data/data.htm

# Materials and Construction Stages

- Important for all roads
- More important than use stage for low and medium traffic volume roads

# Pavement Management to Improve Sustainability of Network

- To optimize M&R for the network, requires:
    1. Initial funding to reach sustainable maintenance condition
        a. Catch up on rehabilitation and reconstruction
        b. Preserve segments in good condition
    2. Steady funding afterward for preservation, with few needing rehab or reconstruction
    3. Asset management to program treatments based on predicted condition, not after failure occurs
- UCPRC research indicates that <u>annual cost of maintaining network can be reduced by up to 20 %</u> if this path is followed
- Preservation treatments have less environmental impact than rehabilitation

# Local Government Check List for Asphalt

- Construction quality
  - ✓ 1% decrease air-voids = about 10% more cracking life
  - ✓ Maintain and enforce strict compaction requirements
- Does your agency have a compaction requirement (% of maximum density) in your standard specifications?
  - ✓ If yes, do you enforce it?
  - ✓ If you are relying on the contractor, you are potentially getting <u>HALF</u> the possible life out of your asphalt overlays!
- Do you allow use of?
  - ✓ Rubberized asphalt
  - ✓ Recycled asphalt pavement
  - ✓ Warm mix
- Do you all utilities under the pavement?

# Local Government Checklist for Concrete

- Reduce cement content in concrete
  - ✓ Does your agency allow for high volumes of cement replacing materials?
  - ✓ Does your agency allow for the use of cement with lower environmental impact?
  - ✓ Do you have a minimum cement content requirement?
- Make it last longer
  - ✓ Do you consider shrinkage? Durability?
- Use less
  - ✓ Do you allow for design of thinner concrete pavement for local roads?

# Environmental Product Declaration (EPD)

- Results of an LCA for a product
  - Produced by industry
  - Most pavement industries working on EPDs now

**Environmental Facts**

Functional unit: 1 metric ton **of** asphalt concrete

| | |
|---|---|
| Primary Energy Demand [MJ] | $4.0x10^3$ |
| *Non-renewable [MJ]* | $3.9x10^3$ |
| *Renewable [MJ]* | $3.5x10^2$ |
| Global Warming Potential [kg $CO_2$-eq] | 79 |
| Acidification Potential [kg $SO_2$-eq] | 0.23 |
| Eutrophication Potential [kg N-eq] | 0.012 |
| Ozone Depletion Potential [kg CFC-11-eq] | $7.3x10^{-9}$ |
| Smog Potential [kg $O_3$-eq] | 4.4 |

**Boundaries: Cradle-to-Gate**
**Company: XYZ Asphalt**
**RAP: 10%**

**Example LCA results**

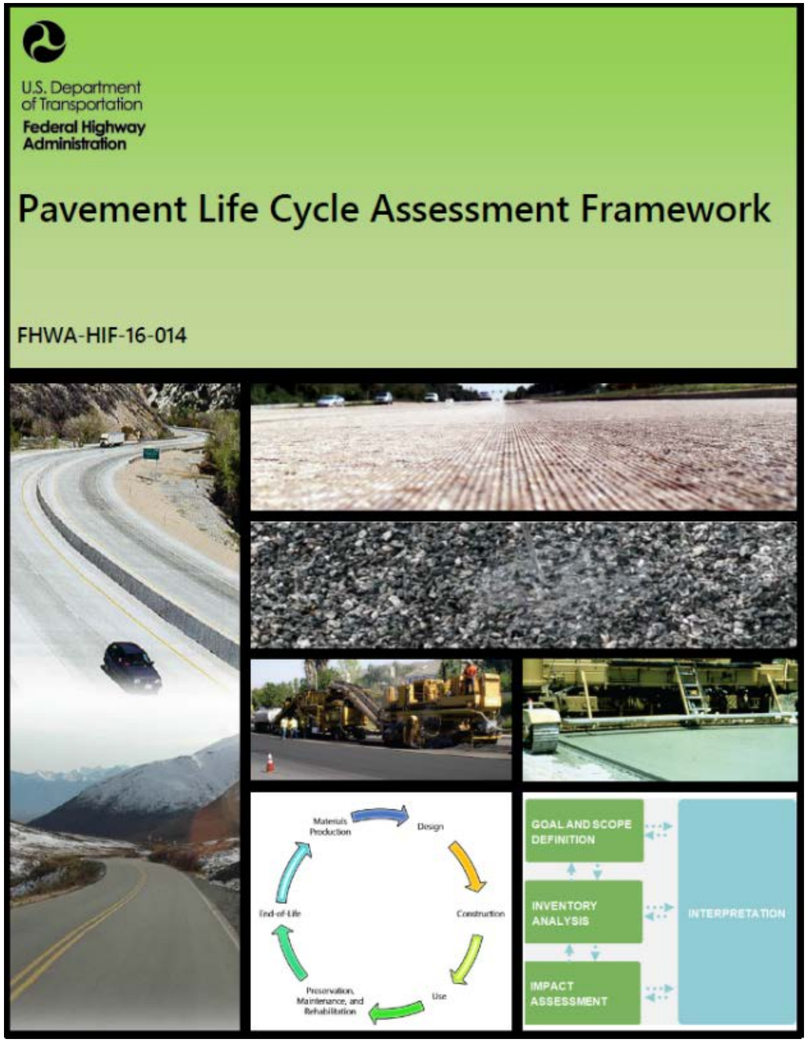
**Adapted from N. Santero**

# EPDs: What's Happening?

- Cement and concrete industries starting to produce EPDs
- Asphalt and asphalt concrete industries are currently working to produce EPDs
- Customers are starting to ask for EPDs
  - High Speed Rail is requiring EPDs for reporting
  - LEED4 is giving points for EPDs
  - Oregon and Illinois Tollway will soon be requiring them for information purposes
- How will they be used?
  - Caltrans/UCPRC participated in September 2016 TRB/FHWA Workshop to discuss obstacles and possible paths forward for EPDs
  - Procurement? Guidelines? Unintended consequences?
  - Stay tuned!

# FHWA Pavement LCA Framework Document

- Published January 2016
- Guidance on uses, overall approach, methodology, system boundaries, and current knowledge gaps
- Specific to pavements
- Includes guidelines for EPDs
- Search for information:
  - "FHWA pavement LCA"
  - "NCST Pavement LCA"




**https://www.fhwa.dot.gov/pavement/pub_details.cfm?id=998**

# Preservation and Bicycle Riders

- Objective: Develop guidelines for design of preservation treatments suitable for bicycle routes on state highways and local streets in California
- Measurements
  - Pavement textures for chip seals, slurries, HMA
  - Bicycle vibration

- Surveys of bicycle ride quality
  - 6 bicycle clubs
  - General public in Davis, Richmond, Chico, Sacramento, Reno
- Correlations between pavement texture, bicycle vibration and ride quality

# Conclusions from Bicycle Studies

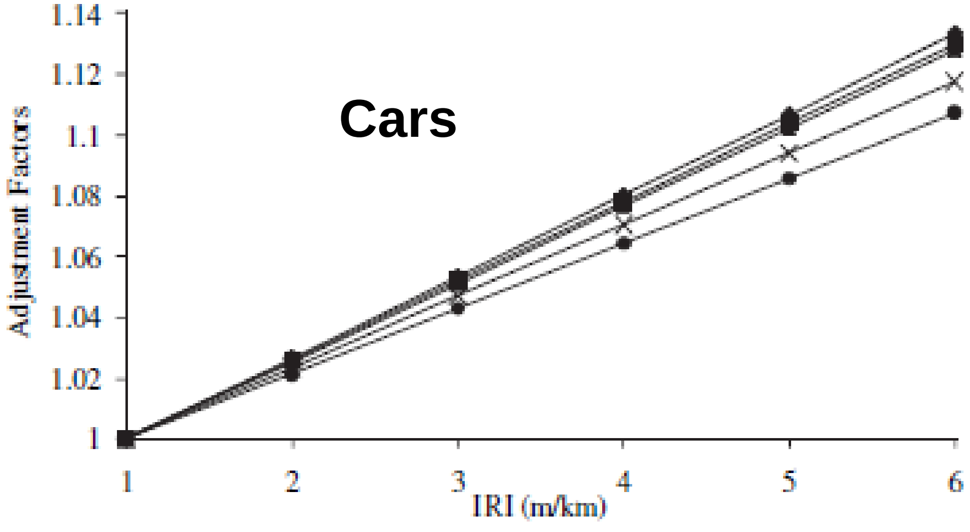
- 80% of riders rate pavements with Mean Profile Depth values 1.8 mm or less as acceptable
  - Limit chip seal stone size
- Most HMA, slurries on city streets have high acceptability
- Surface distresses, particularly transverse cracking, reduce ride quality
- Chip seal specification recommendations in Caltrans report
- Can be considered in PMS

- Consider "Complete Pavement", restripe to add wider bike lanes and safer turning lanes when paving,
  - Search on "complete streets and preservation ASCE webinar"

# Use Stage

- Pavement rolling resistance
  - Important for more than 2500 vehicles per day
- Heat Island
- Storm water
- Bicycle ride quality

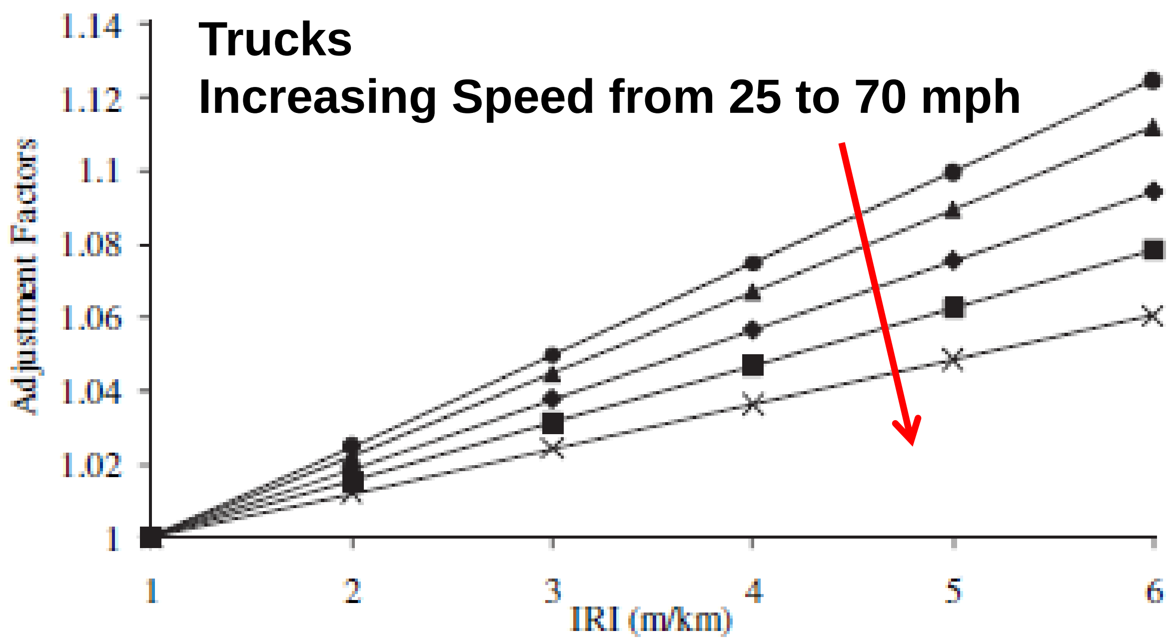
# Use Phase: Fuel Use, Speed, IRI



(a) Passenger car

- Cars more sensitive at faster speeds
- Trucks at slower speeds

- Roughness increases vehicle fuel use 0 to 8 percent across range of typical IRI
- Can be some offset from faster driving on smoother pavement



(e) Articulated truck

# Caltrans Network: Optimal trigger by traffic group

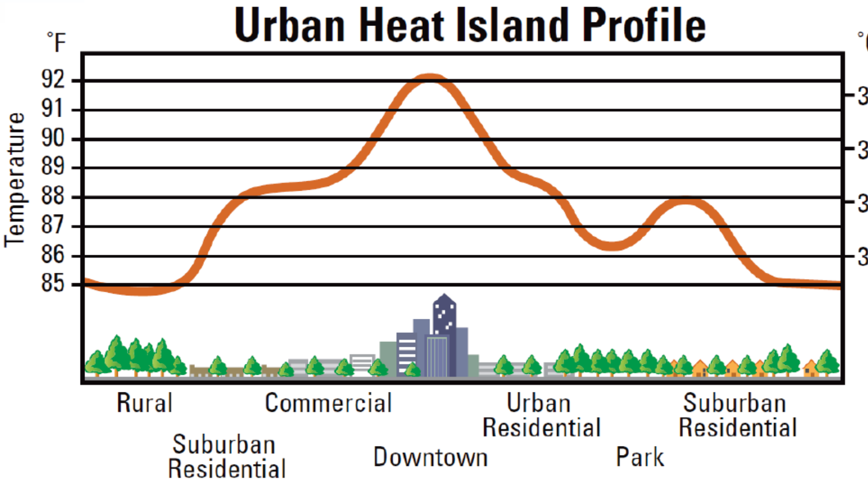
| Traffic group | Daily PCE of lane-segments range | Total lane-miles | Percentile of lane-mile | Optimal IRI triggering value (m/km, inch/mile in parentheses) | Annualized $CO_2$-e reductions (MMT) | Modified total cost-effectiveness ($/t$CO_2$-e) |
|---|---|---|---|---|---|---|
| 1 | <2,517 | 12,068 | <25 | ----- | 0 | N/A |
| 2 | 2,517 to 11,704 | 12,068 | 25~50 | 2.8 (177) | 0.141 | 1,169 |
| 3 | 11,704 to 19,108 | 4,827 | 50~60 | 2.0 (127) | 0.096 | 857 |
| 4 | 19,108 to 33,908 | 4,827 | 60~70 | 2.0 (127) | 0.128 | 503 |
| 5 | 33,908 to 64,656 | 4,827 | 70~80 | 1.6 (101) | 0.264 | 516 |
| 6 | 64,656 to 95,184 | 4,827 | 80~90 | 1.6 (101) | 0.297 | 259 |
| 7 | >95,184 | 4,827 | 90~100 | 1.6 (101) | 0.45 | 104 |
| **Total** | | | | | **1.38** | **416** |

# Conclusions Regarding Roughness

- There are reasons for local government pavements to measure and manage roughness on high volume and truck routes
- Currently no commercially available methods to measure under low speeds and stop-start conditions
  - Viable alternative technologies have been used in past
  - Cost per vehicle is about $500 plus certification cost
  - Can use for identifying locations with maintenance needs
- Cannot get IRI from PCI
  - Pavements can have good PCI and be rough and vice/versa

# Urban Heat Island Effect

- The formation of urban heat islands is well documented
  - Created, at least in part, by the presence of dark, dry surfaces in heavily urbanized areas
- Exist at many different levels
  - Ground/pavement surface
  - Near-surface (3 – 6 ft)
  - Above street level
  - Atmospheric
- Affects
  - Human thermal comfort
  - Air quality (ground-level ozone, i.e. smog)
  - Cooling energy consumption

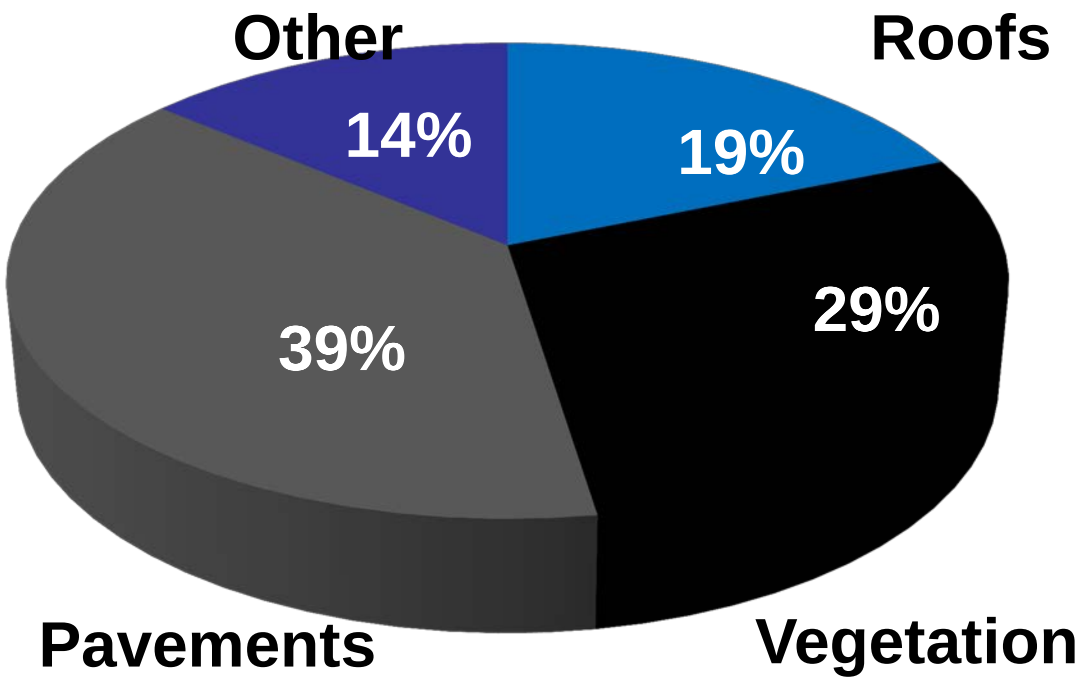



**EPA 2003**

# LBNL/USC/UCPRC Study Currently Recently Completed: Life Cycle Assessment and Co-benefits of Cool Pavements

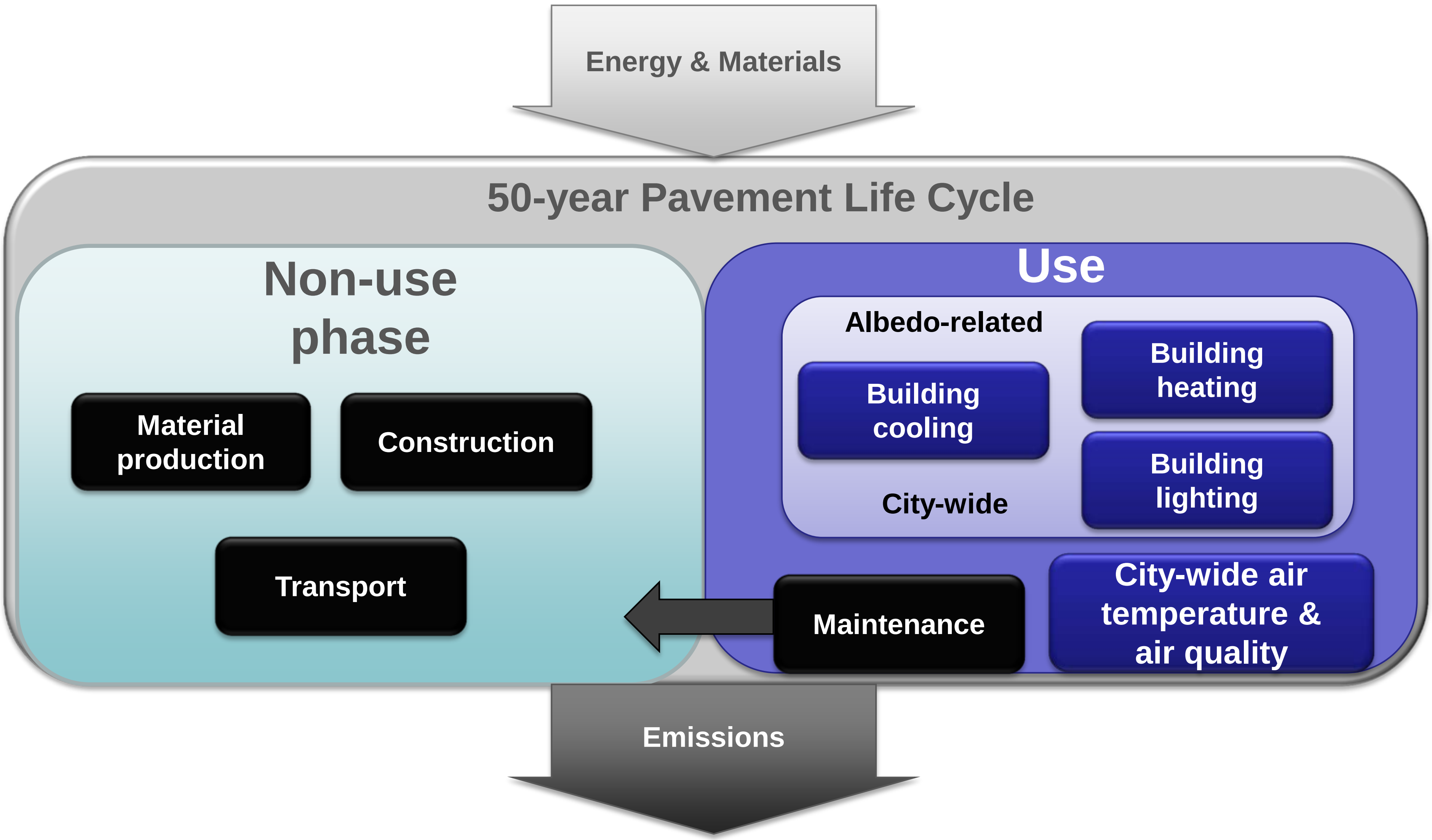
- Sponsored by CARB, Caltrans, response to AB 296
- Albedo is solar radiation reflectivity
  - 0 is completely absorptive
  - 1 is completely reflective
- Modeled 50 year GHG emissions
  - Change of urban pavements to higher reflectivity materials
  - Change of urban temperatures
  - Change in building energy use
- Report to be published in Fall 2016
- Journal paper also submitted

# Pavements are an important part of the urban environment

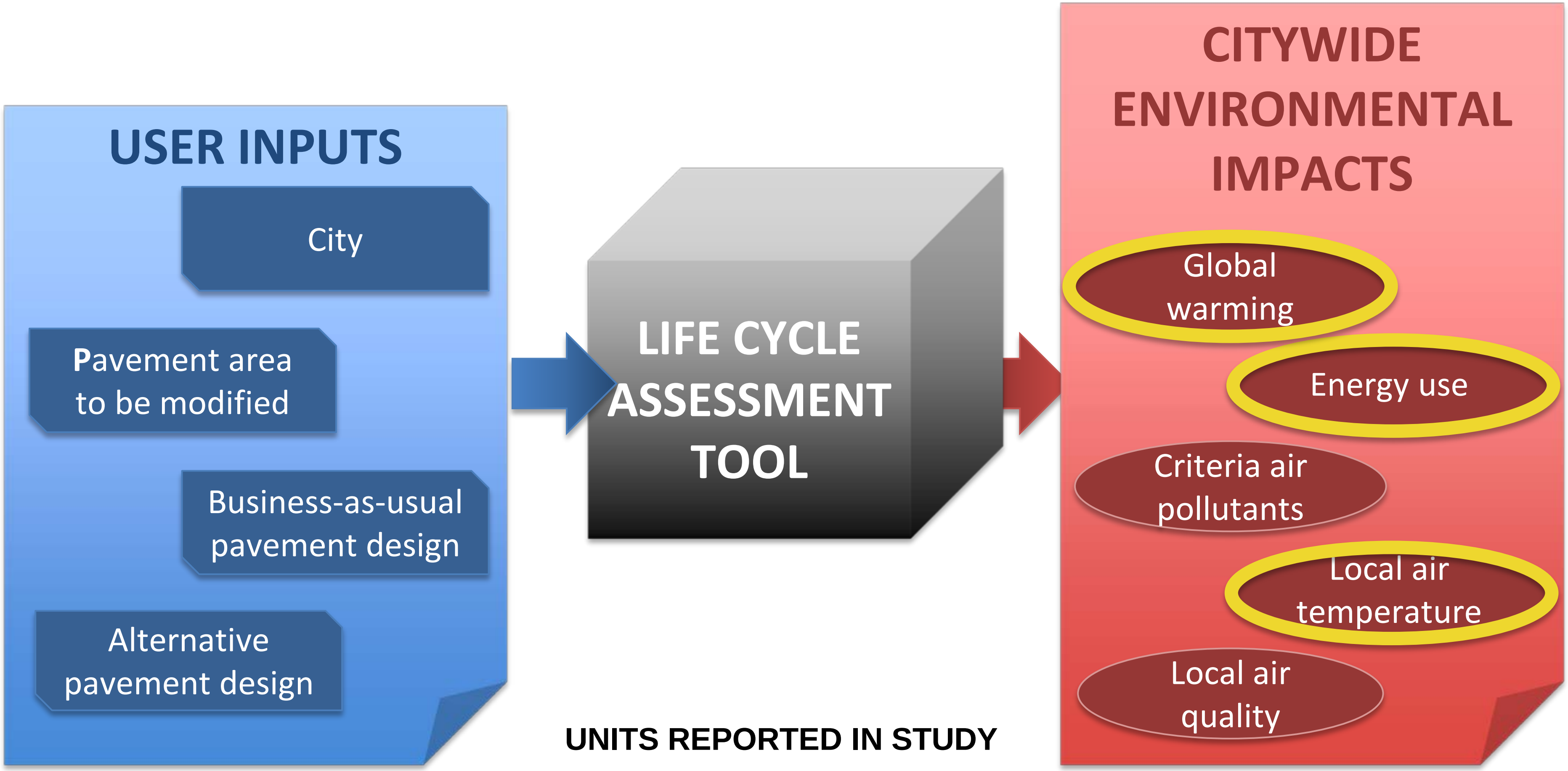



**Urban fabric above tree canopy in Sacramento, California**

# The scope of the pLCA tool includes the non-use and use phases of the pavement life cycle



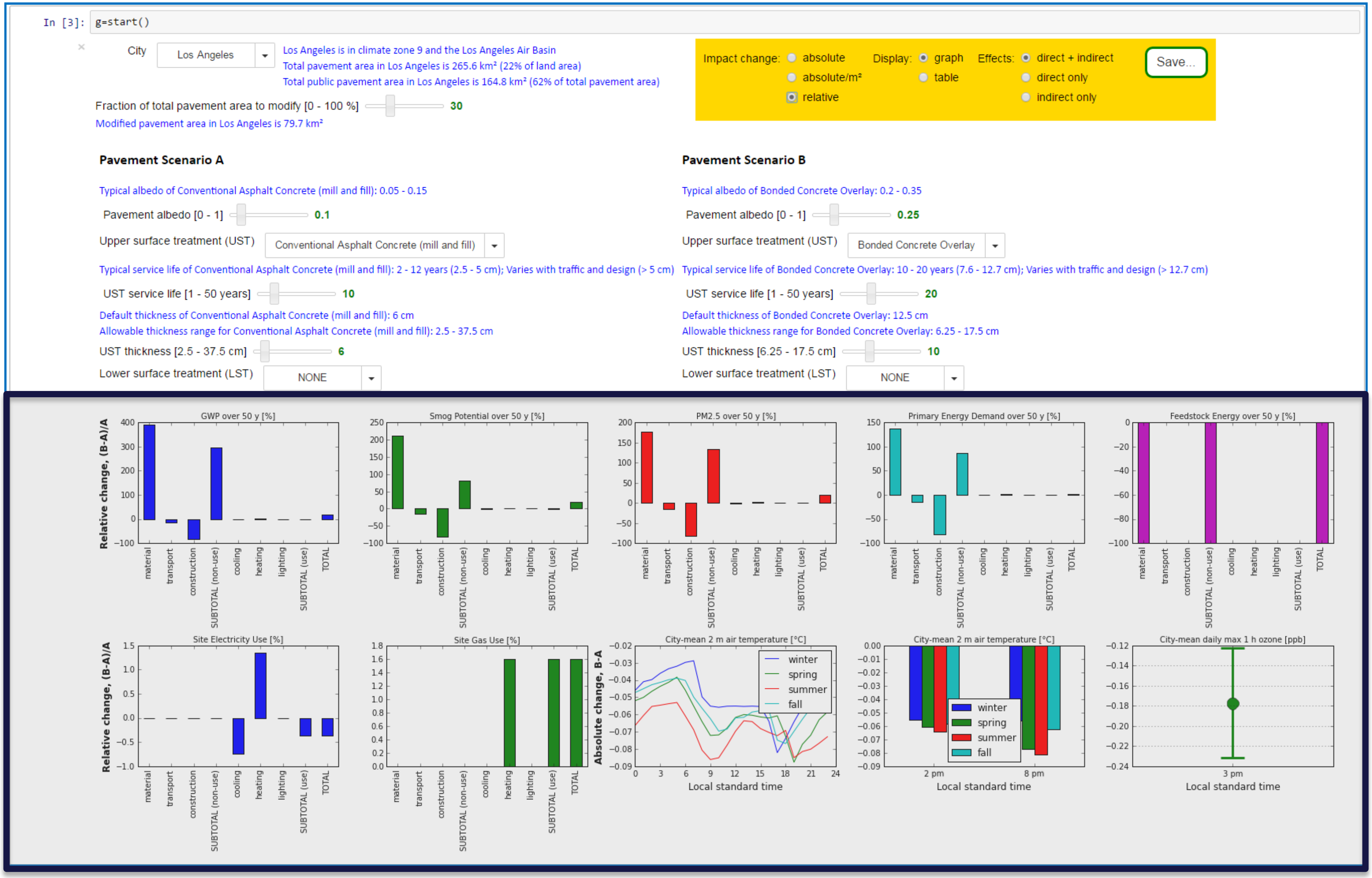
# This study evaluates a subset of results from the pLCA tool



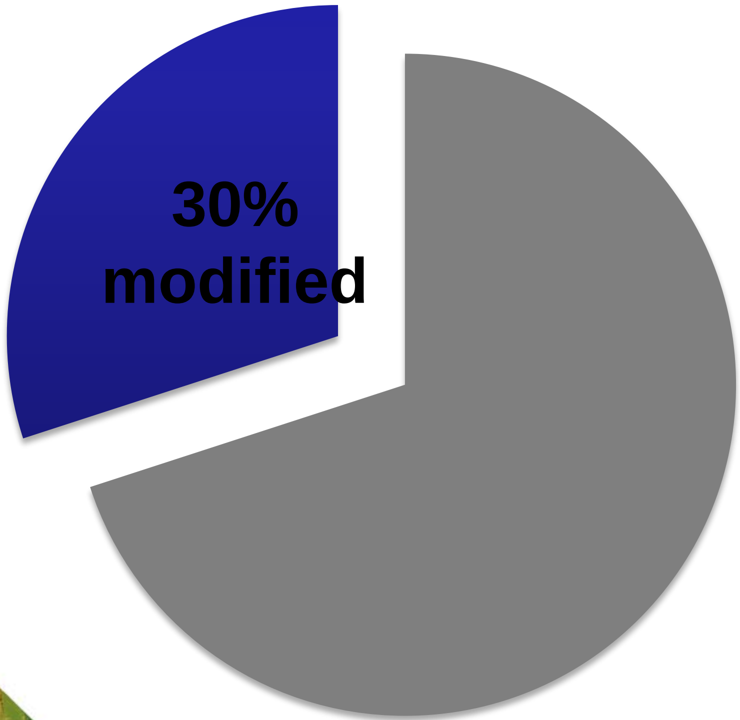

**UNITS REPORTED IN STUDY**

| | | |
|---|---|---|
| **Global Warming Potential (GWP), kg of $CO_2e$** | **Primary Energy Demand (PED), MJ** | **Outdoor Air Temperature, °C** |

# The pLCA tool has an easy-to-use interface



# The case studies evaluate cool pavement campaigns in two California cities

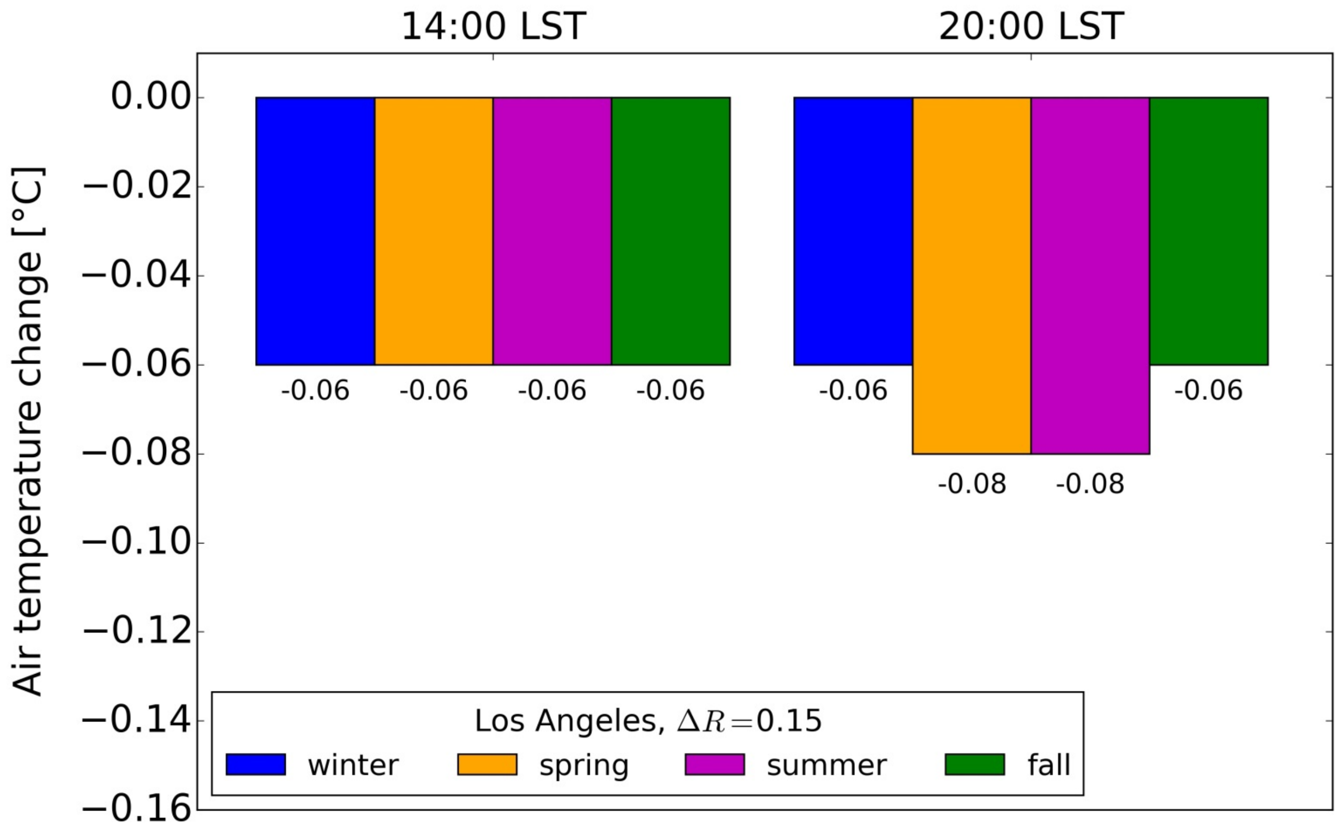

**Total city paved area**

# Second case study evaluates rehabilitation pavement treatment options


**Mill-and-fill conventional asphalt concrete**


**Bonded cement concrete overlay**

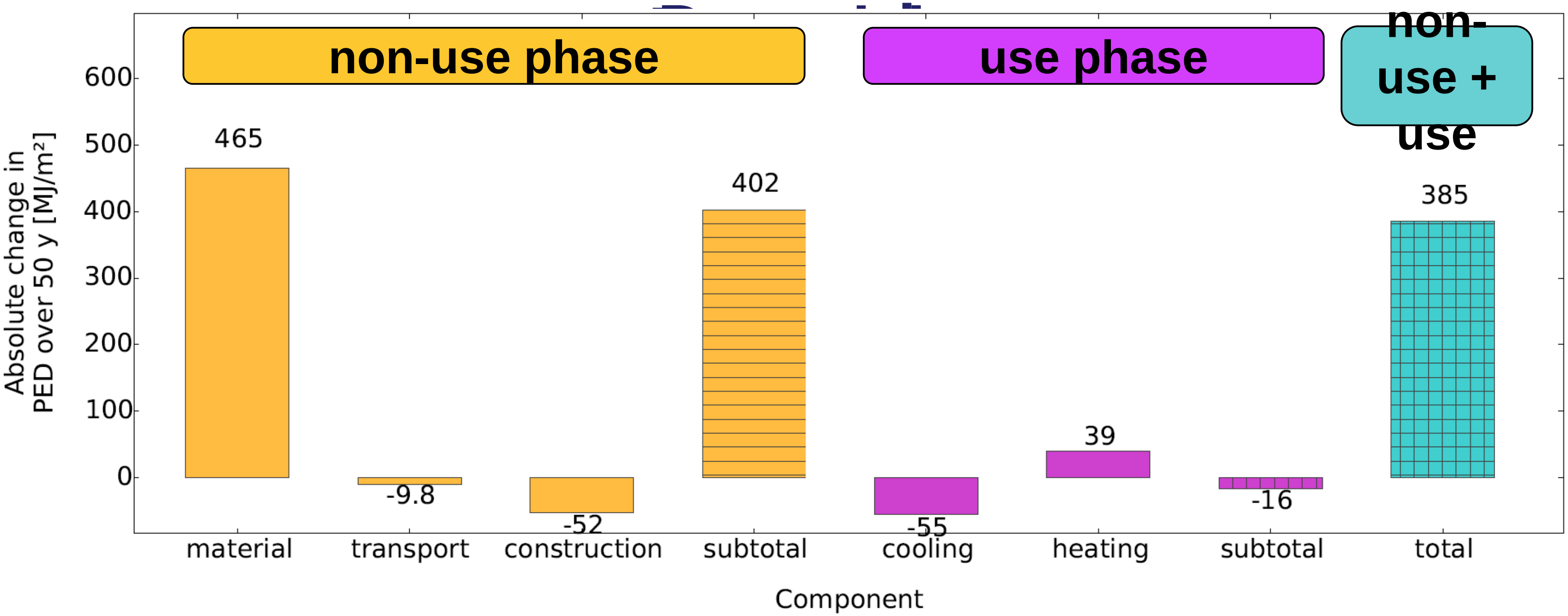
# Raising pavement albedo by 0.15 lowers outside air temperature by ~0.08 °C




**Rehabilitation: Substituting cement concrete overlay (aged albedo 0.25) for asphalt concrete mill-and-fill (aged albedo 0.10)**

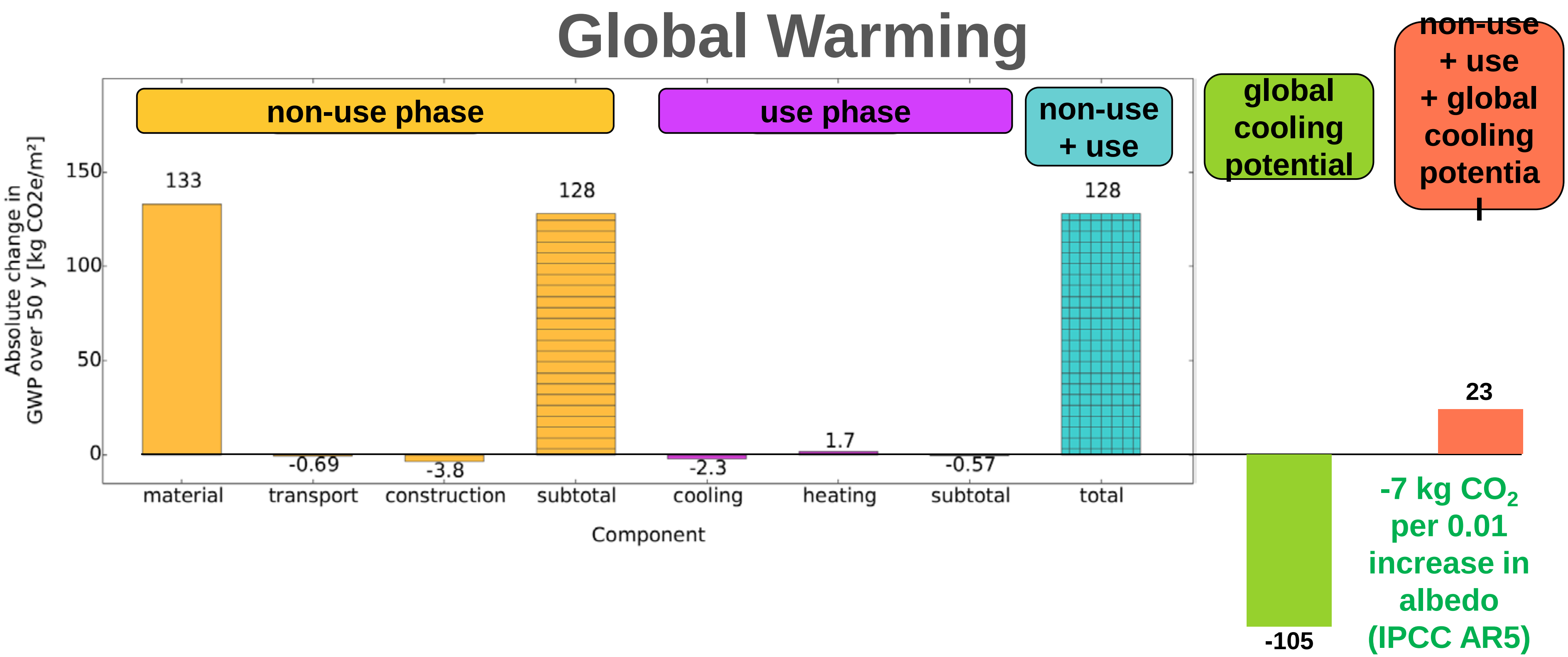
# What are the life cycle environmental changes from the pavement change?

## Primary Energy



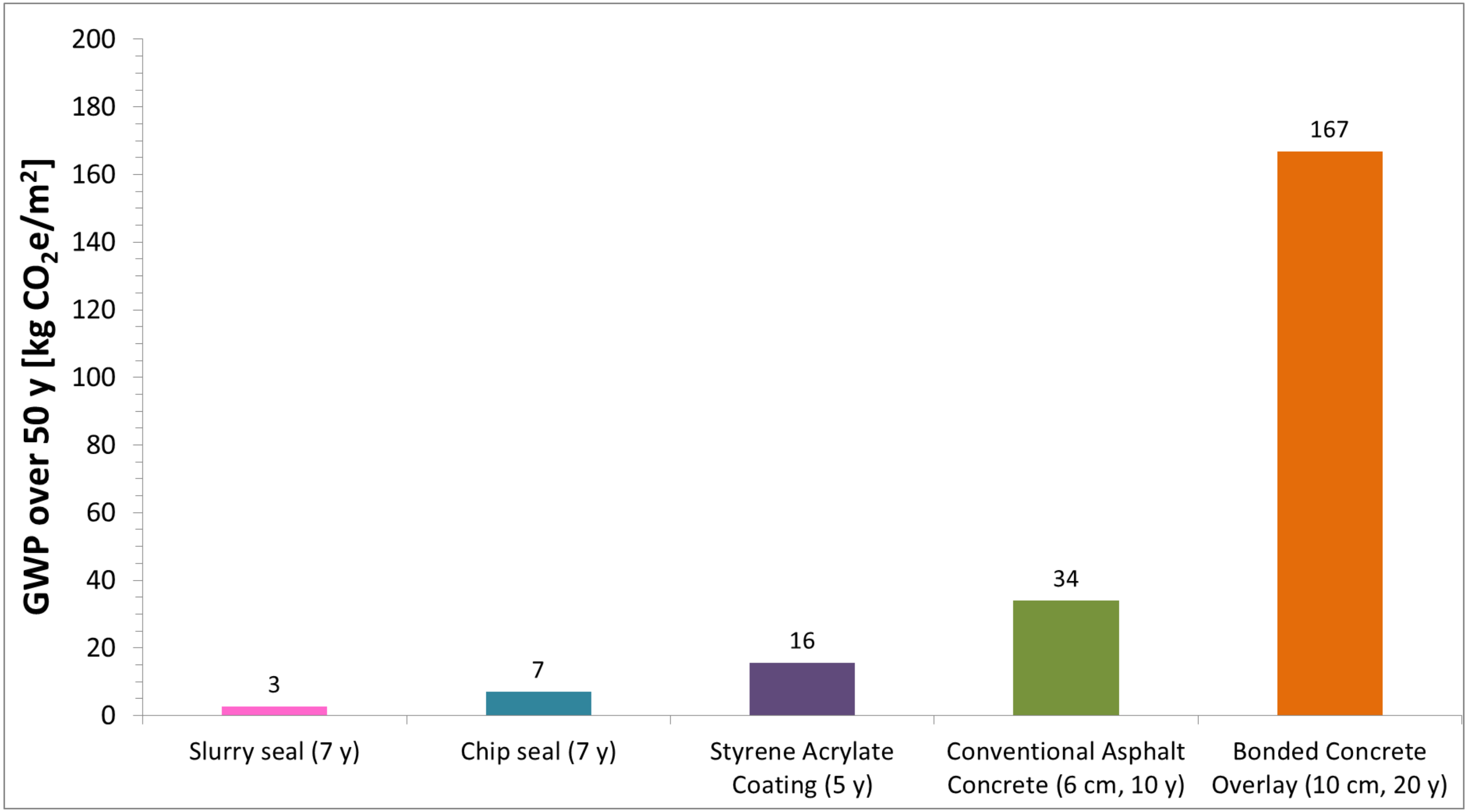

**Fresno, Rehabilitation: Substituting cement concrete overlay (aged albedo 0.25) for asphalt concrete mill-and-fill (aged albedo 0.10)**

# 50-year life-cycle increase in GWP




**Los Angeles, Rehabilitation: Substituting cement concrete overlay (aged albedo 0.25) for asphalt concrete mill-and-fill (aged albedo 0.10)**

# Los Angeles, GWP, materials component



# Permeable Pavement for Stormwater Management

- Impervious pavement in urban areas contributes to
  - Water pollution (*oil, metal, etc*.)
  - Reduced groundwater recharge
  - Increased risk of flooding
  - Local heat island effect (*less evaporation*)


- Permeable pavement could help address the issues related to stormwater runoff volume and quality
- Initial analysis indicates that can have lower life cycle cost than other BMPs

# Getting the Permeable Pavement Results

- Pervious Concrete and Porous Asphalt for Heavy Traffic
  - Preliminary permeable pavement designs that can be tested in pilot studies under typical California traffic and environmental conditions
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2010-01.pdf
- Permeable Interlocking Concrete Pavement for Heavy Traffic
  - Design method and validation results
  - Being incorporated into ICPI and ASCE designs
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2014-04.pdf

Caltrans

LABORATORY TESTING AND MODELING FOR STRUCTURAL PERFORMANCE OF FULLY PERMEABLE PAVEMENTS: FINAL REPORT

RESEARCH REPORT

CALTRANS DOCUMENT NO.: CTSW-RT-10-249.04
UCPRC DOCUMENT NO.: UCPRC-RR-2010-01

November 30, 2010

California Department of Transportation
Division of Environmental Analysis
Storm Water Program
1120 N Street, Sacramento, California, 95814
http://www.dot.ca.gov/hq/env/stormwater/index.ht

# Pavement and Bicycle Riders

- Develop guidelines for design of preservation treatments suitable for bicycle routes on state highways (Phase I) and local streets (Phase II) in California
- Tasks
  - Pavement texture measurements
  - Bicycle vibration measurements
  - Surveys of bicycle ride quality
    - 6 bicycle clubs
    - General public in Davis, Richmond, Chico, Sacramento, Reno
  - Correlations between pavement texture, bicycle vibration and ride quality

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- Limit chip seal stone size
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- Can be considered in PMS
- Consider “Complete Pavement”, restripe to add wider bike lanes and safer turning lanes when paving, search ASCE webinar “complete streets and pavement preservation”

# Conclusions

- “State of the Knowledge” recommendations for improving pavement sustainability are available
  - Cost
  - Environment
- Improving environmental sustainability often also brings lower life cycle cost
  - Agency cost and user cost
- Improvements become permanent from reviewing and changing standard practices
- Everyone focused on getting sufficient funding
  - Sustainability discussion can help get funding
  - Sustainability can also often decrease life cycle cost

# Upcoming studies

- Life Cycle Assessment of Complete Streets
  - NCST
  - Includes development of “pavement justice” social and economic indicators
- Urban Metabolism
  - NCST
- Sustainable Freight Movement
  - NCST
- Surveys
  - Local government pavement needs survey (NCST)
  - Permeable pavement obstacles to implementation (Caltrans)

# Local Government Pavement Improvement Center

- How do we get the Caltrans and FHWA content to local government in an implementable form?
- Working on securing funding ($500k/year), working with LOCC, CSAC
- Organization
  - Local government board of directors
  - Research, pilot project support, model specs and procedures, training
  - Leverage existing resources: ITS Tech Transfer, LAP, APWA, CSUs (LB, SLO, Chico, Sac) for regional support
- If you think this is worthwhile, please let your organizations know


Questions?
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