More Durable, Cost-Effective, & Sustainable Pavement

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University of California Pavement Research Center

City and County Pavement Improvement Center

UC Davis

Contra Costa County
Sustainability Exchange
14 April, 2020

UCPRC | City and County Pavement Improvement Center

- Sponsored by League of California Cities, County Engineers of California, and California State Association of Counties
- Chartered 28 September 2018

www.ucprc.ucdavis.edu/ccpic

CCPIC Mission and Vision

- Mission
  - CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research
- Vision
  - Making local government-managed pavement last longer, cost less, and be more sustainable

CCPIC Organization

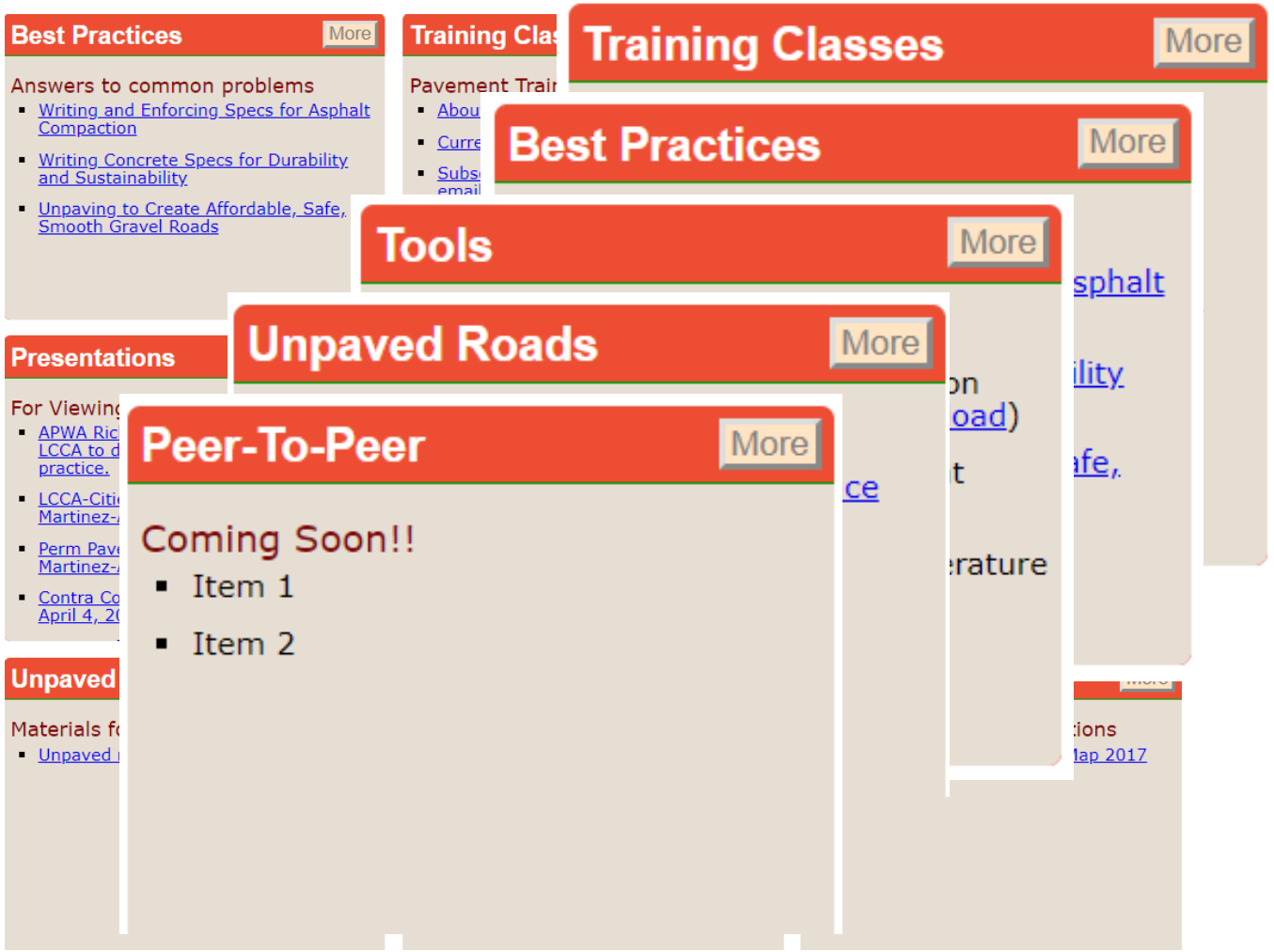
- University of California Partners
  - University of California Pavement Research Center (lead), administered and funded by ITS Davis
  - UC Berkeley ITS Tech Transfer, administered and funded by ITS Berkeley
- California State University Partners
  - CSU-Chico, CSU-Long Beach, Cal Poly San Luis Obispo
  - Funding partner: Mineta Transportation Institute, San Jose State University

CCPIC Organization

- Governance:
  - Chartered by League of California Cities, California State Association of Counties, County Engineers Association of California, also provide staff support
  - Governance Board consisting of 6 city and 6 county transportation professionals
- Current Funding
  - Seed funding for CCPIC set up and initial activities from SB1 funding through the ITS at UC Davis and UC Berkeley, and Mineta Transportation Institute at San Jose State University

CCPIC Website

www.ucprc.ucdavis.edu/ccpic



- Pavement training
- Best practices technical briefs
- Tools
- Unpaved roads
- Peer-to-peer

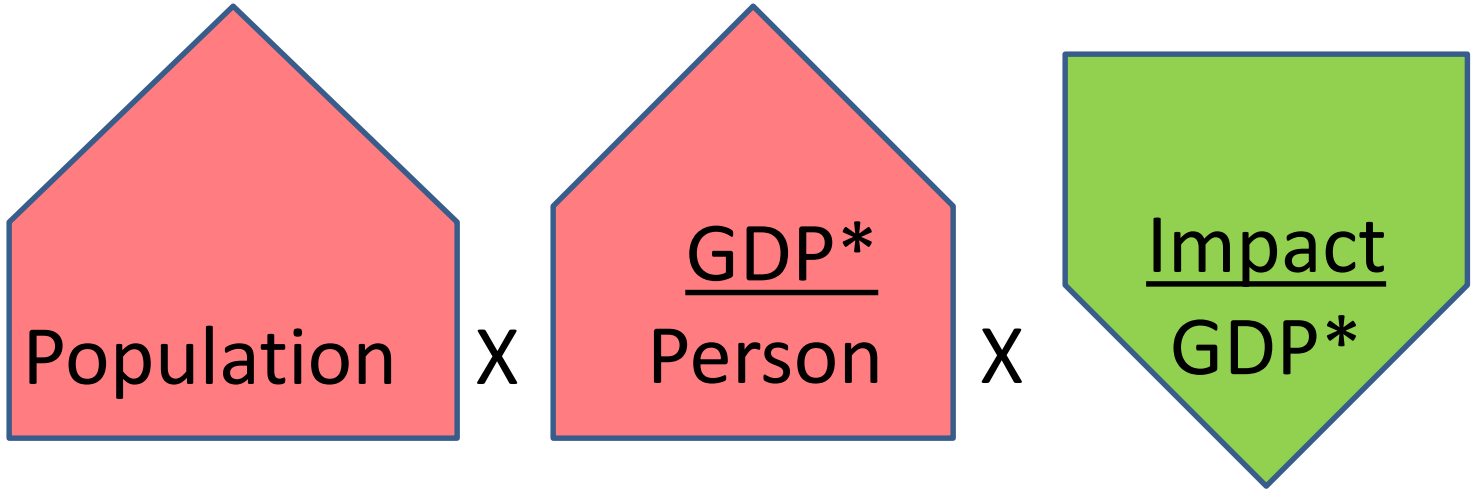
How to get involved in CCPIC activities?

- Get training
- Get your organization to take training
- Host in-person training classes
- Read the tech briefs and see if your agency can make improvements
  - See the draft specification language
  - We can support you
- Get involved with governance board
- Start a peer-to-peer chat group
- Take a look at the tools on the website

Sustainability:
Master equation for environmental impacts

Environmental impact =

*Is GDP the best measure for economic activity producing happiness?



Need enough young people for social stability

Increase in wealth and economic activity

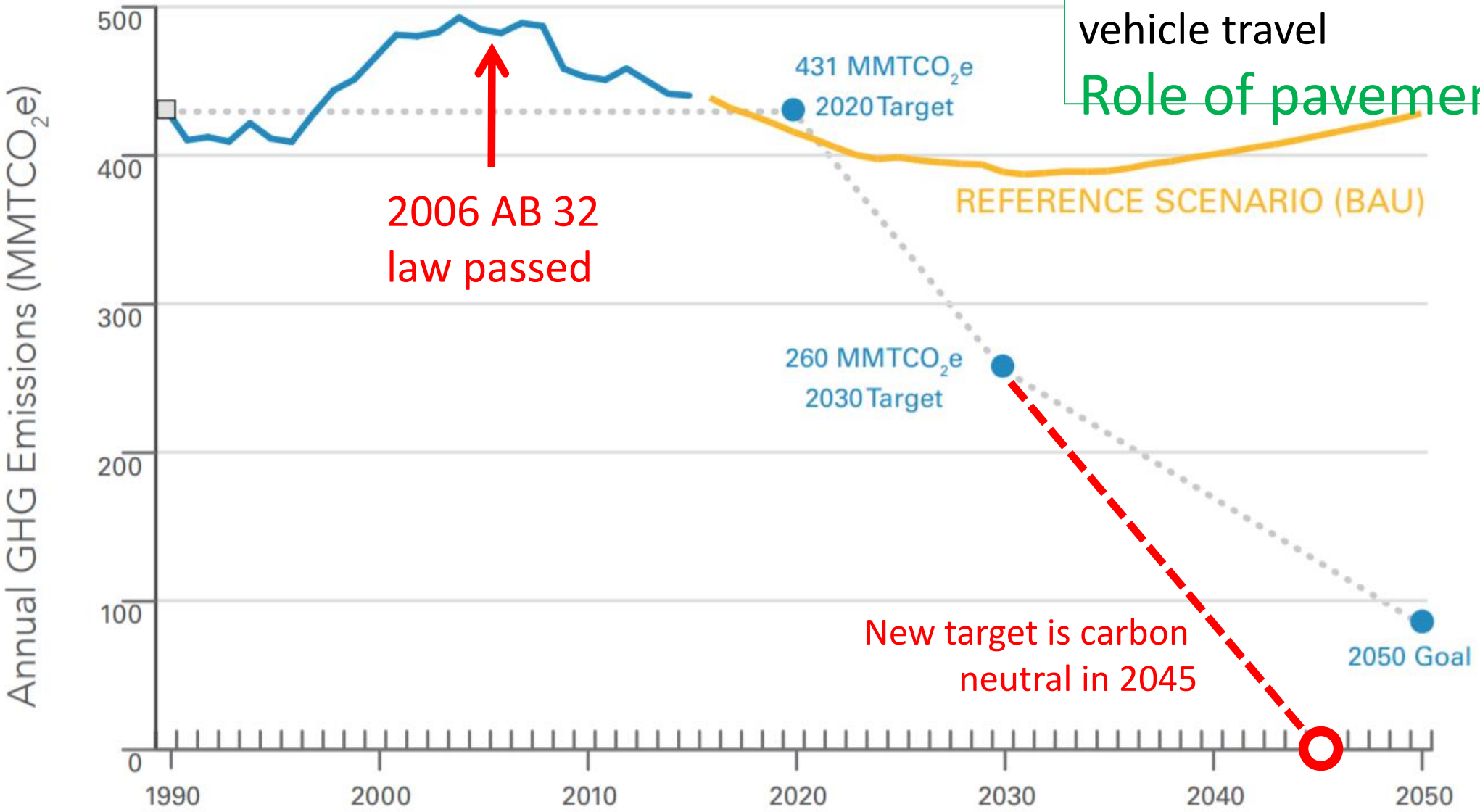
New technology, organization and implementation

Ehrlich and Holdren (1971) Impact of population growth. e.g. via LCA *Science* 171, 1211-1217
Slide adapted from R. Rosenbaum, Pavement LCA 2014 keynote address

Climate Change Targets and Transportation Strategies (ref 2015)

1. Land use planning; 2. Change trucks and cars to natural gas, electric, fuel cell; 3. Reduce vehicle travel

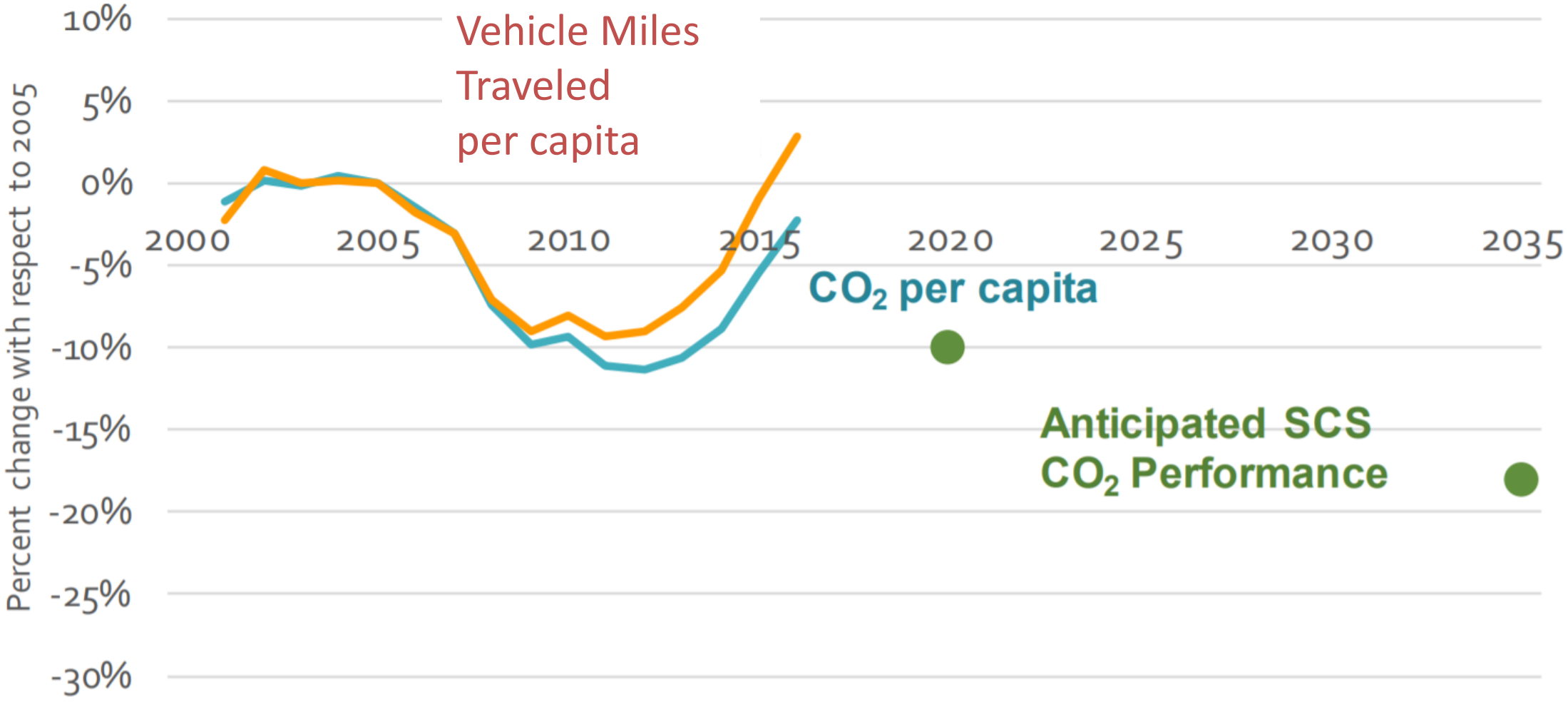
Role of pavement?



https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf

How Are We Doing? New data to 2016

Changes since 2005

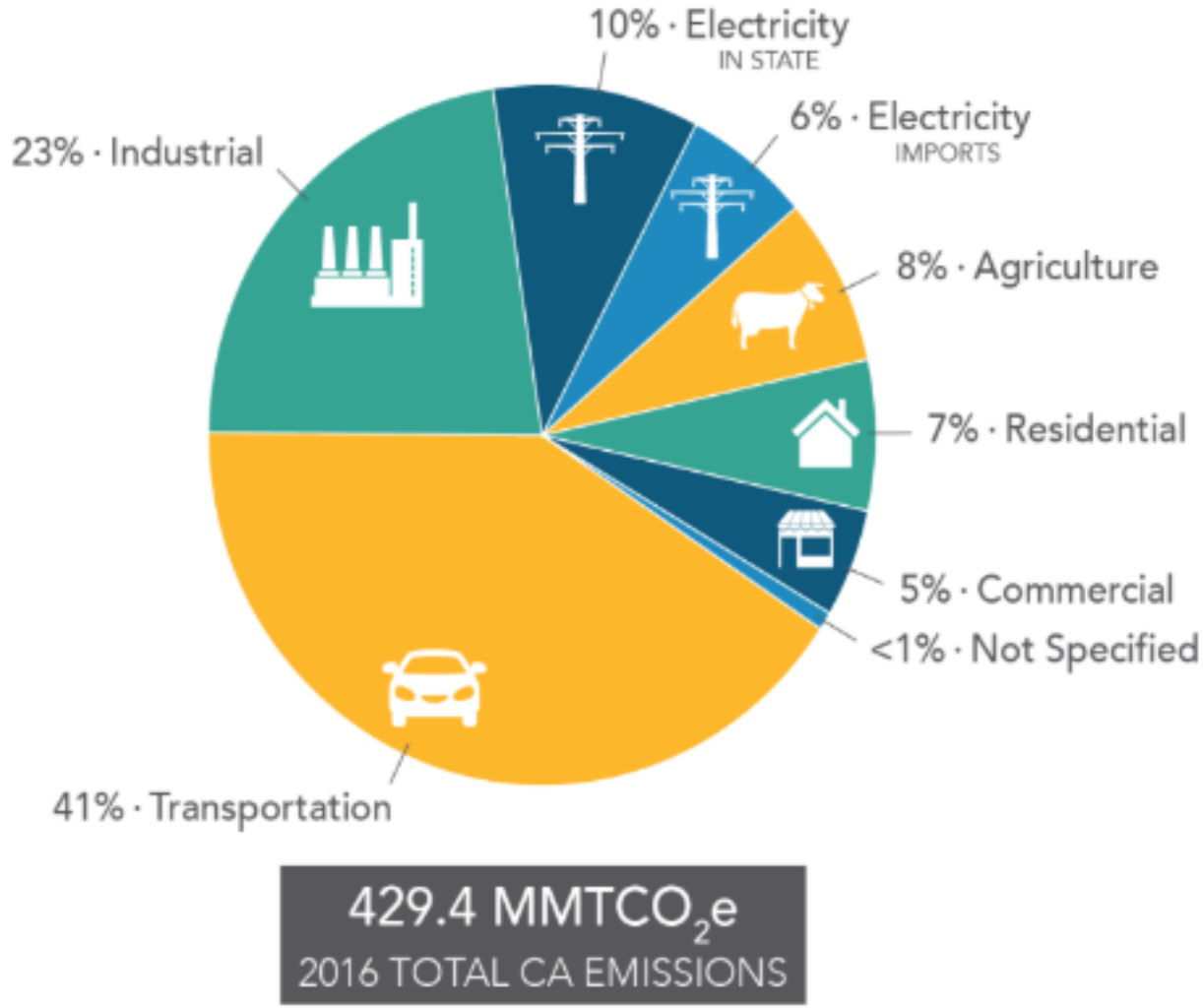


Estimated Potential Pavement-Related Reductions to 2016 California GHG Emissions

Possible Pavement Reductions	MMT/ year
Rolling resist to optimum	1.5 to 3.0
Reduce cement use 50%	0.2
Reduce virgin asphalt use 50%	0.7
Reduce hauling demolition, oil, stone haul 10%	0.6
TOTAL	**3.0 to 4.5**

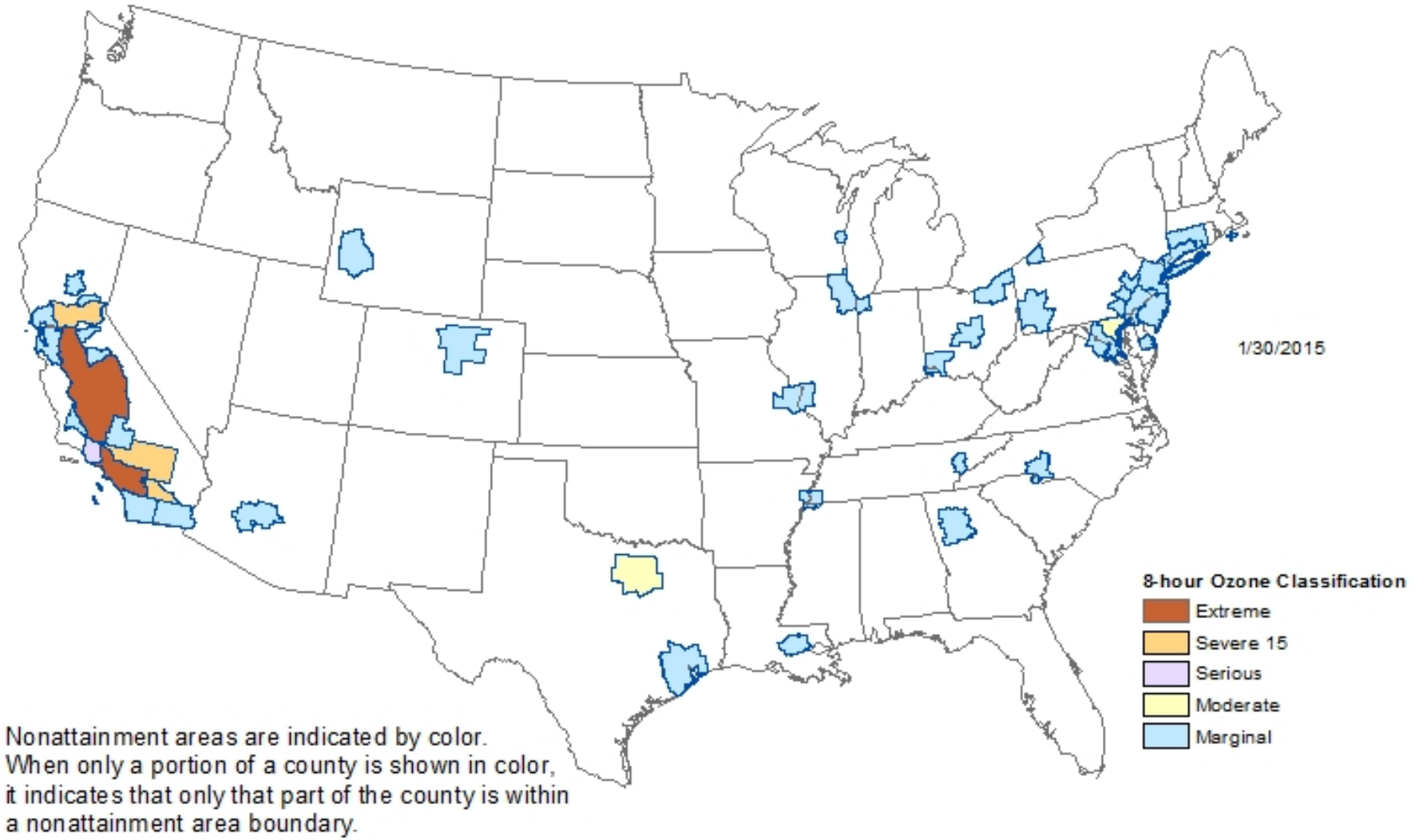
0.7 to 1.0 % of 429 MMT state total

1.0 to 3.6 % of 126 MMT transportation total



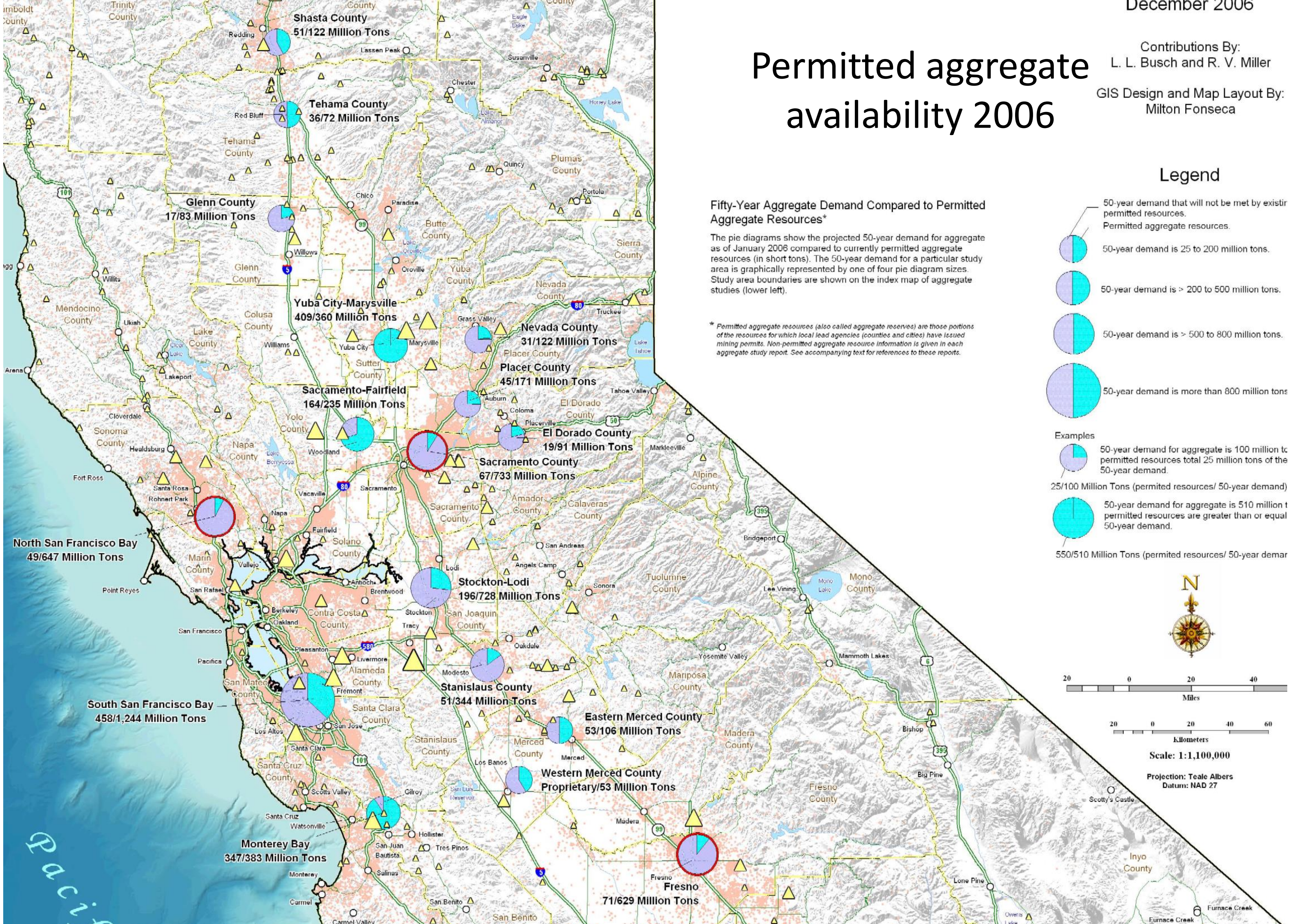
http://www.arb.ca.gov/cc/inventory/data/data.htm

Other types of environmental impact:
8 hour ozone non-attainment by county (2008)



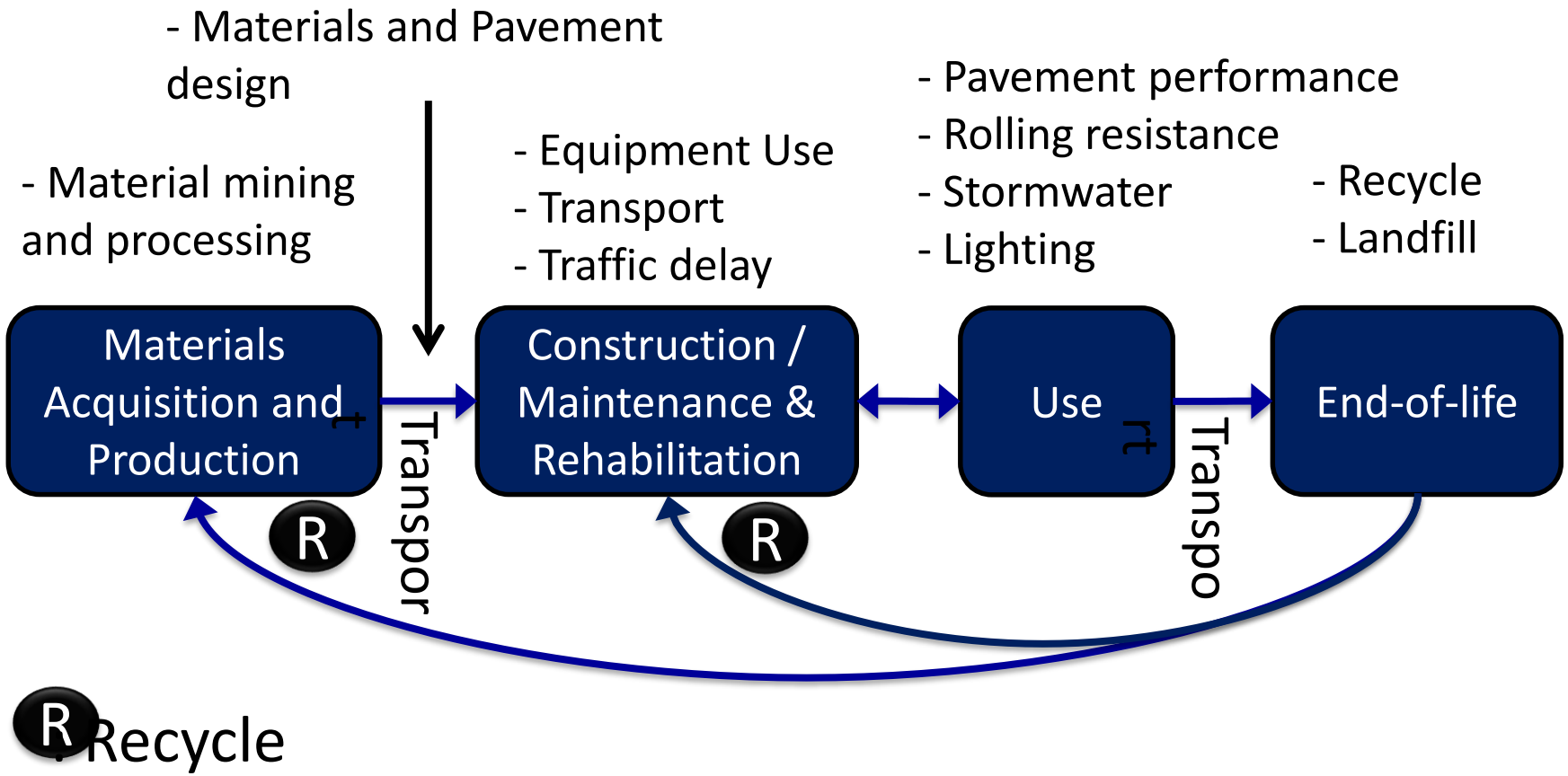
http://www.epa.gov/oaqps001/greenbk/map8hr_2008.html

Permitted aggregate availability 2006



Where can cost and 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*

Four Key Stages of Life Cycle Assessment

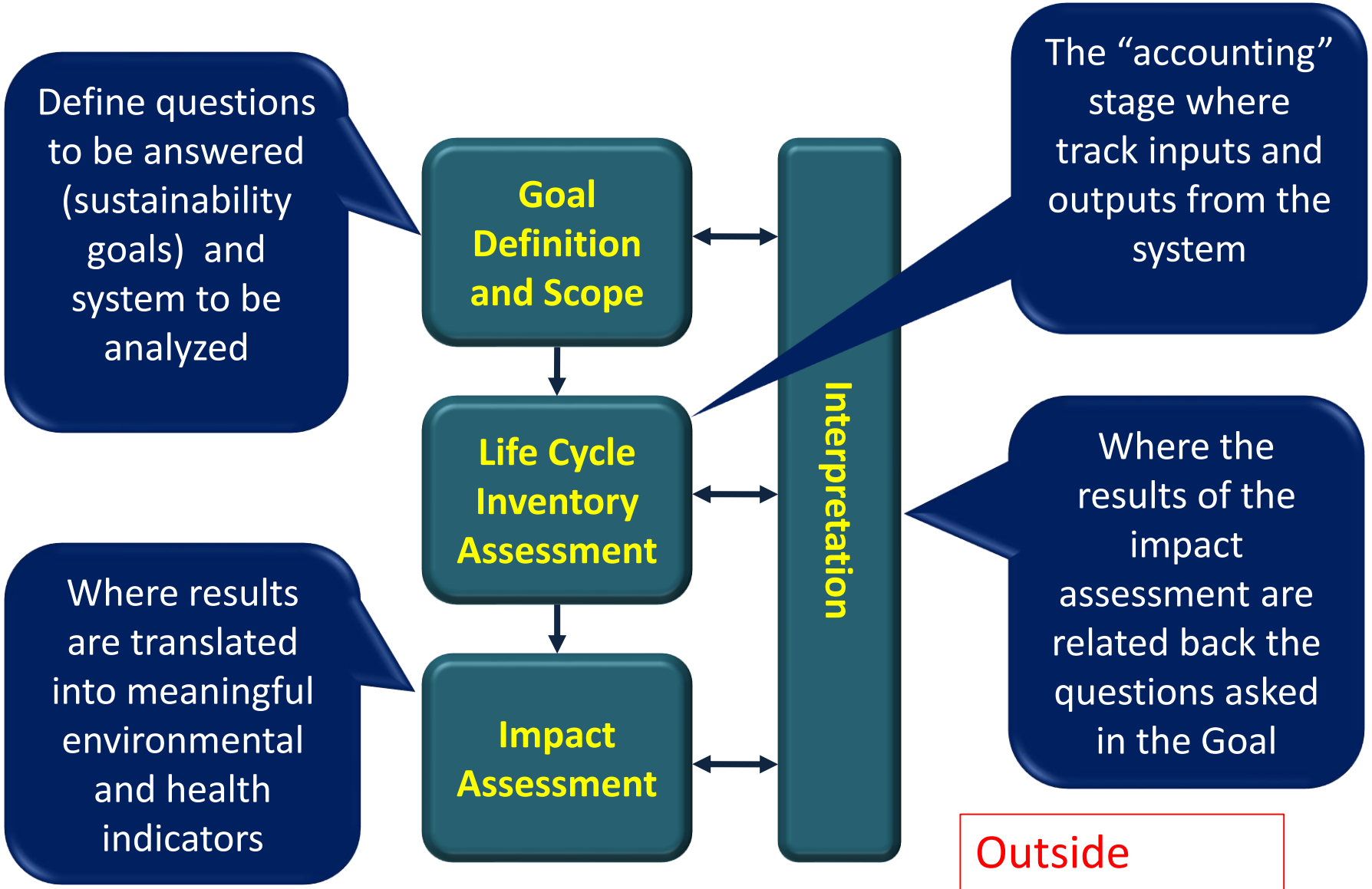
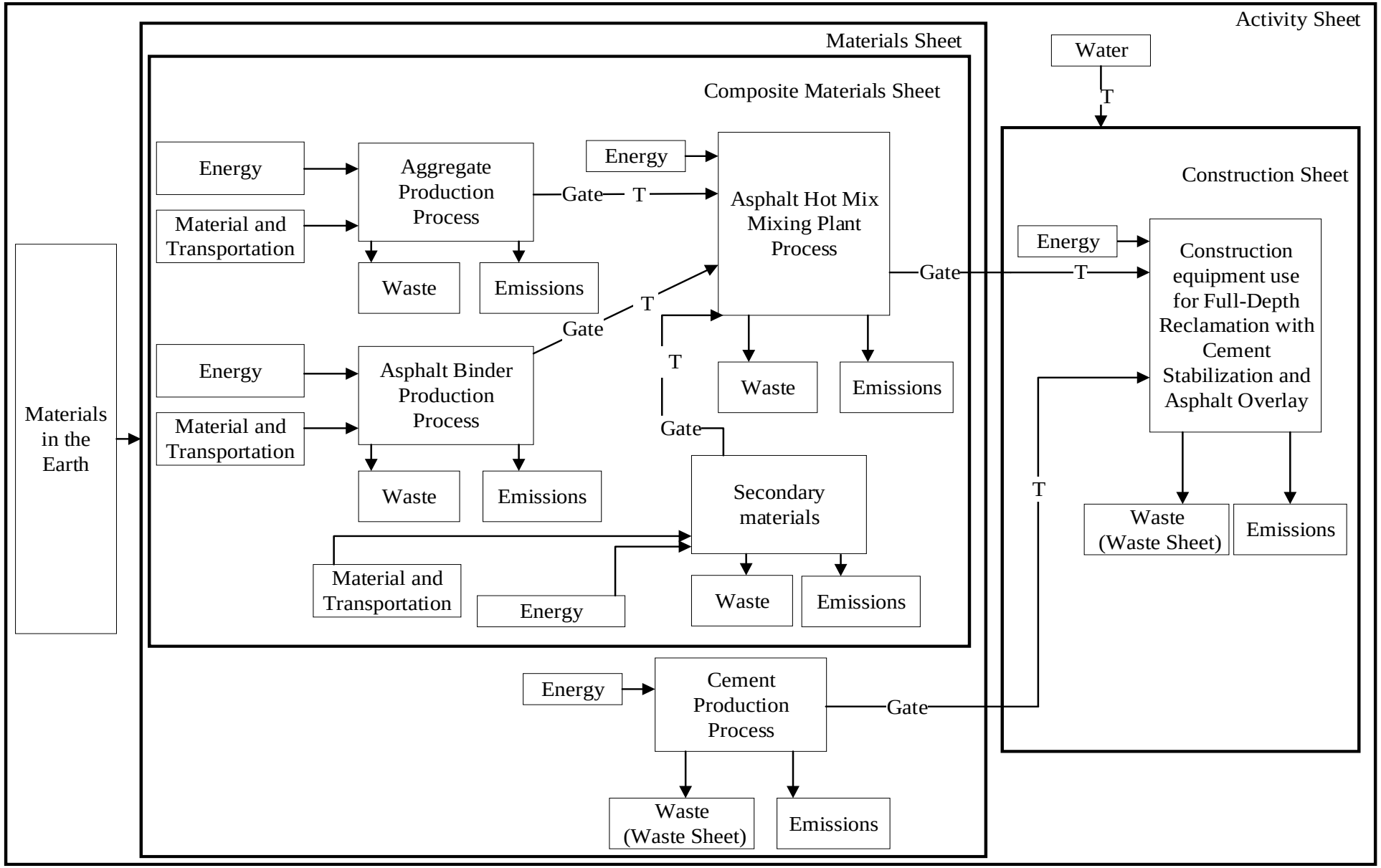


Figure based on ISO 14040, adopted from Kendall

Outside Critical Review

Activity Sheet, Materials Sheet, Composite Material Sheet, Construction Sheet
Example: FDR-Cement, Asphalt Overlay

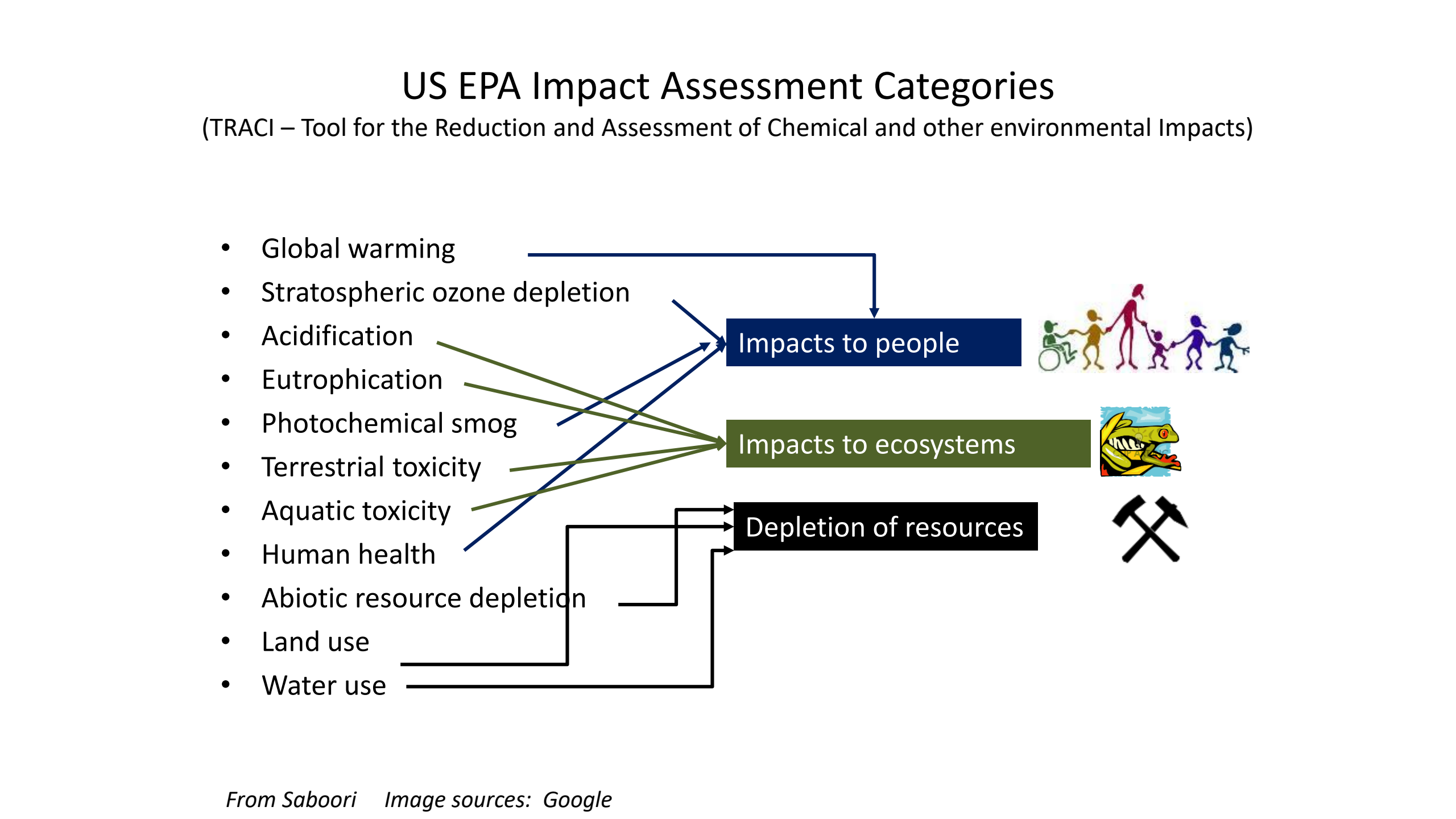


Material Processes can be replaced with EPDs
Each Process and Transportation Has Emissions
T=Transportation

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



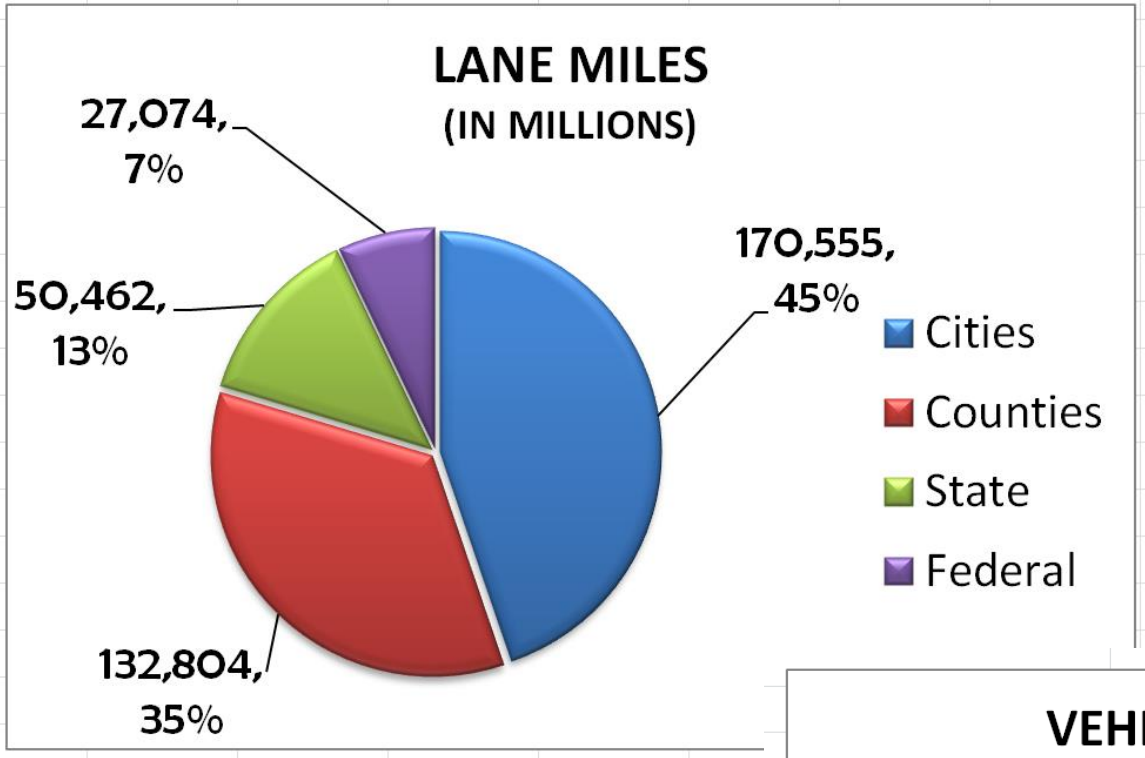
From Saboori Image sources: Google

Why LCA?

- **What is the goal of LCA?**
- Quantification of the environmental, energy and material resource use impacts
- Full life cycle of production, consumption/use/maintenance/ rehabilitation and end of life of products and services
- Considering system boundaries that are sufficiently defined to capture important interactions and potential unintended consequences
- This is being extended more recently to include social and economic impacts

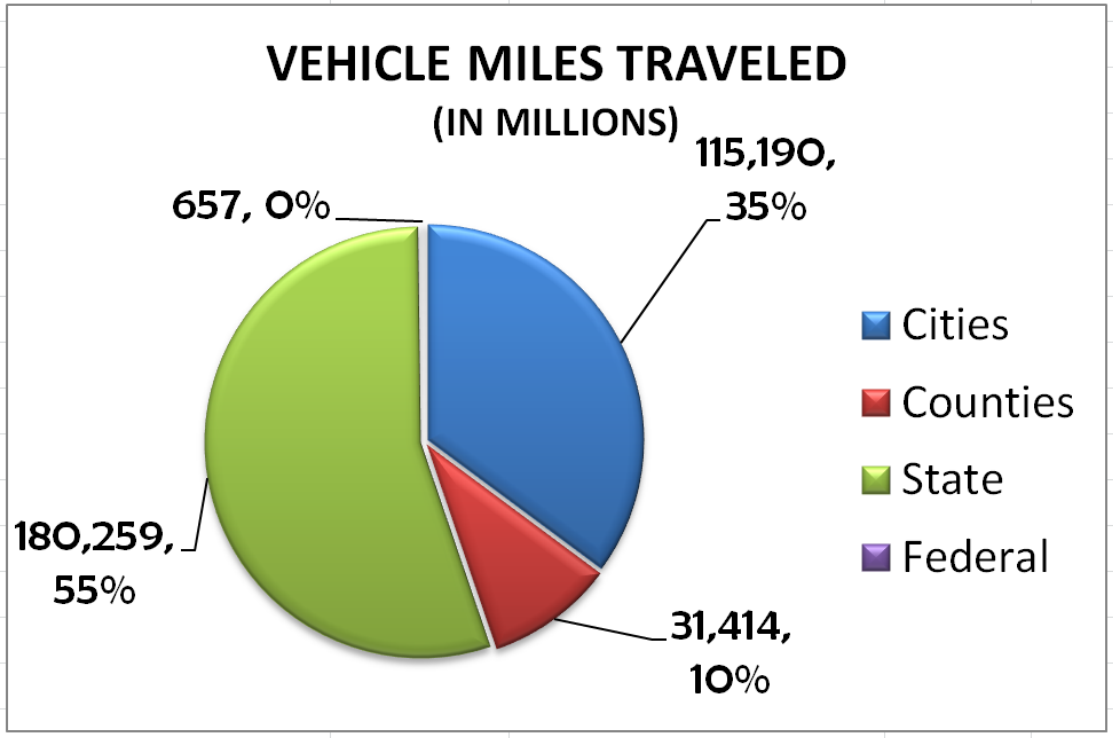
Using LCA, soon

- At state level
  - LCA has been implemented in the Caltrans PMS
  - Used to assess GHG for different state-wide network master work plans
  - Used to evaluate new policies, specifications, designs
- Tools for everyday use by local agencies under development
  - UCPRC is working on both of these
  - eLCAP, developed for Caltrans
    - Web based
    - Currently being updated and user interface converted to local government use
  - Should be available in summer 2020



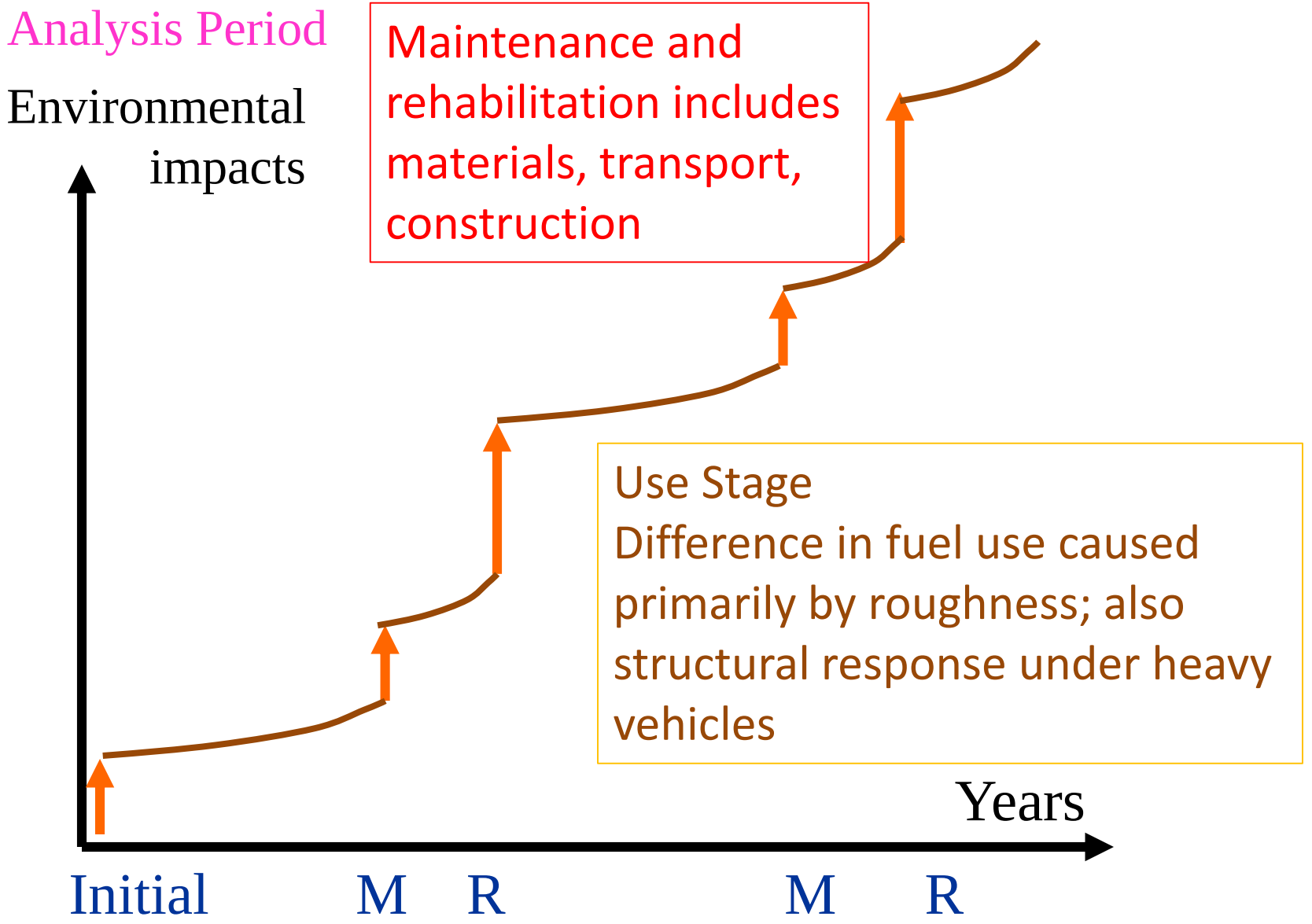
Why is Local Government Pavement Important to Sustainability?

State and local governments have similar amounts of:
- Spending
- Materials use

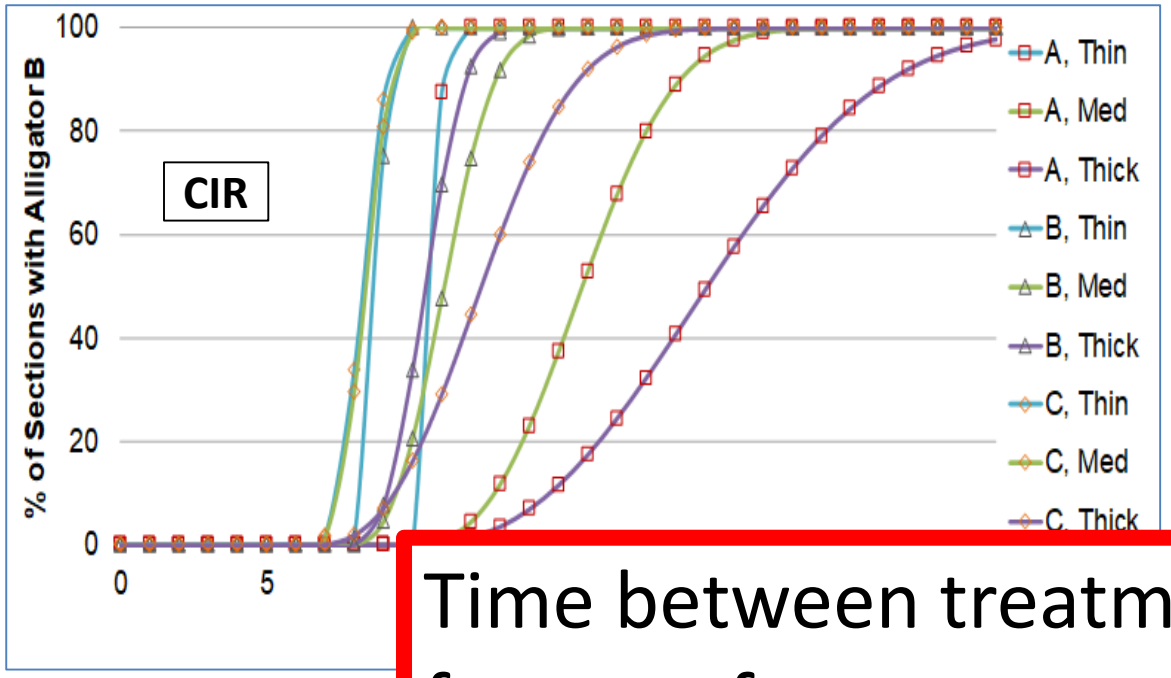


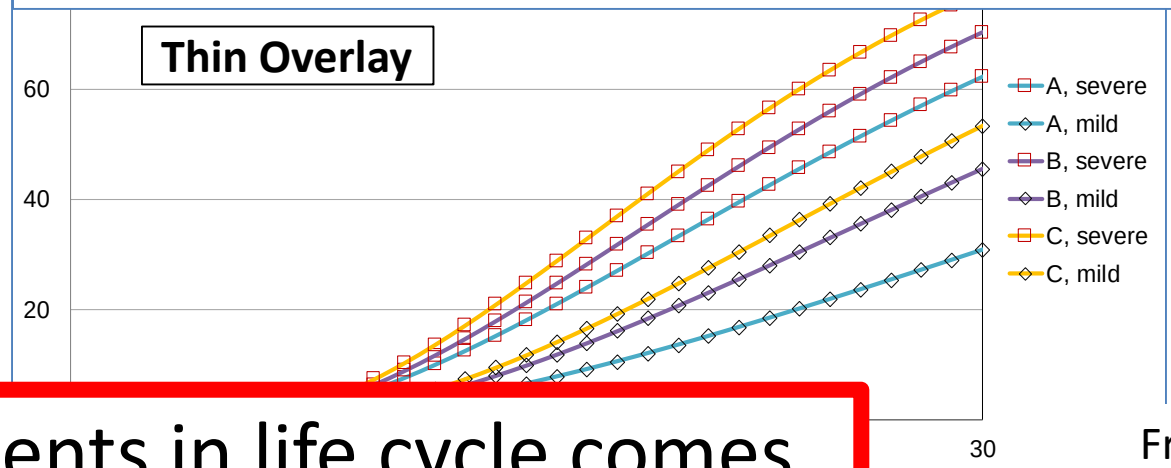
Environmental Impacts over the Pavement Life Cycle

- Where to focus
  - Lower traffic volume routes: most impacts are materials, transportation, construction
  - Higher traffic routes: bigger impacts from rolling resistance (roughness mostly)



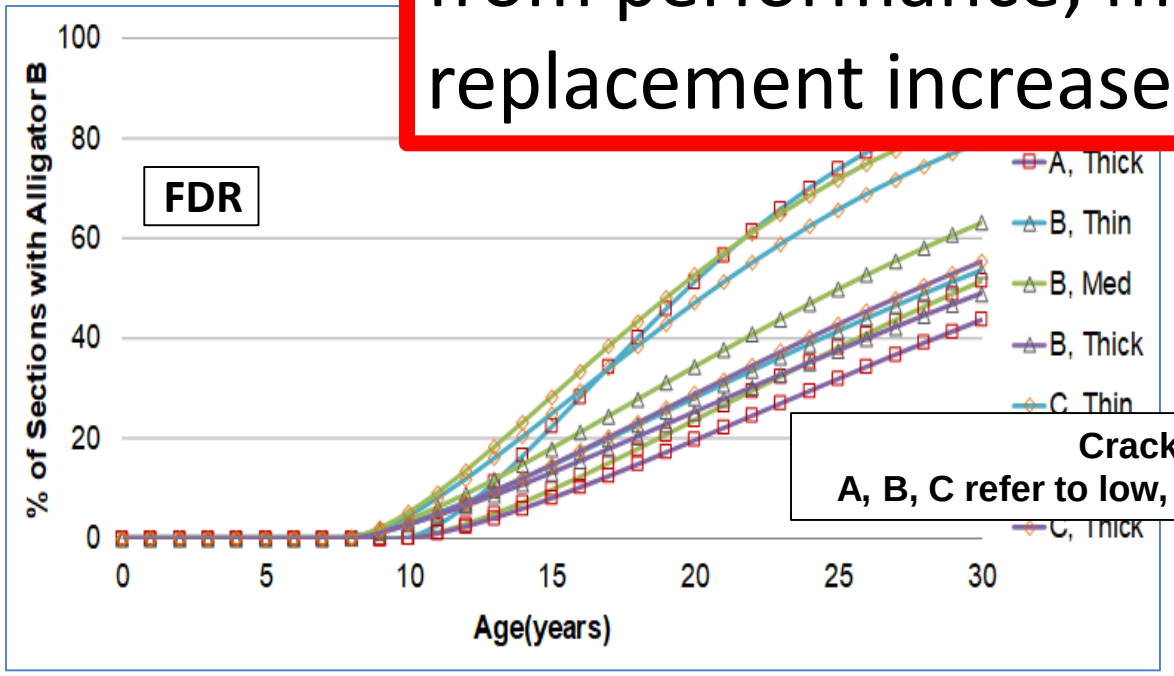
Performance models for wheelpath cracking from Caltrans PMS data, similar for IRI for Use Stage

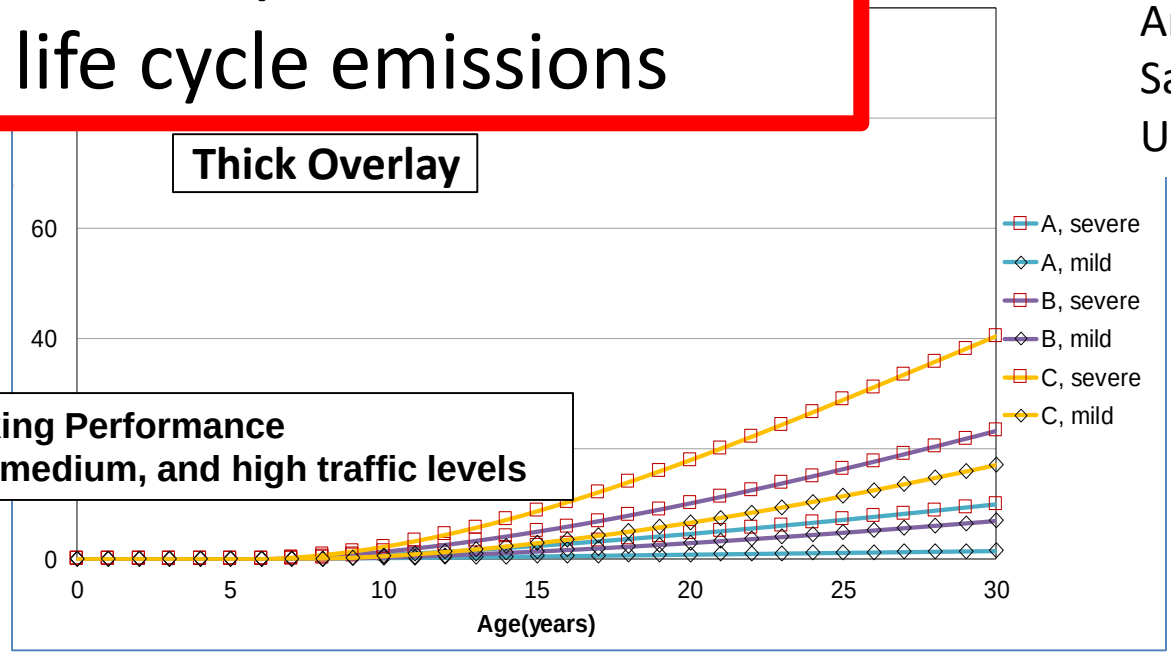




Time between treatments in life cycle comes from performance; more frequent replacement increase life cycle emissions

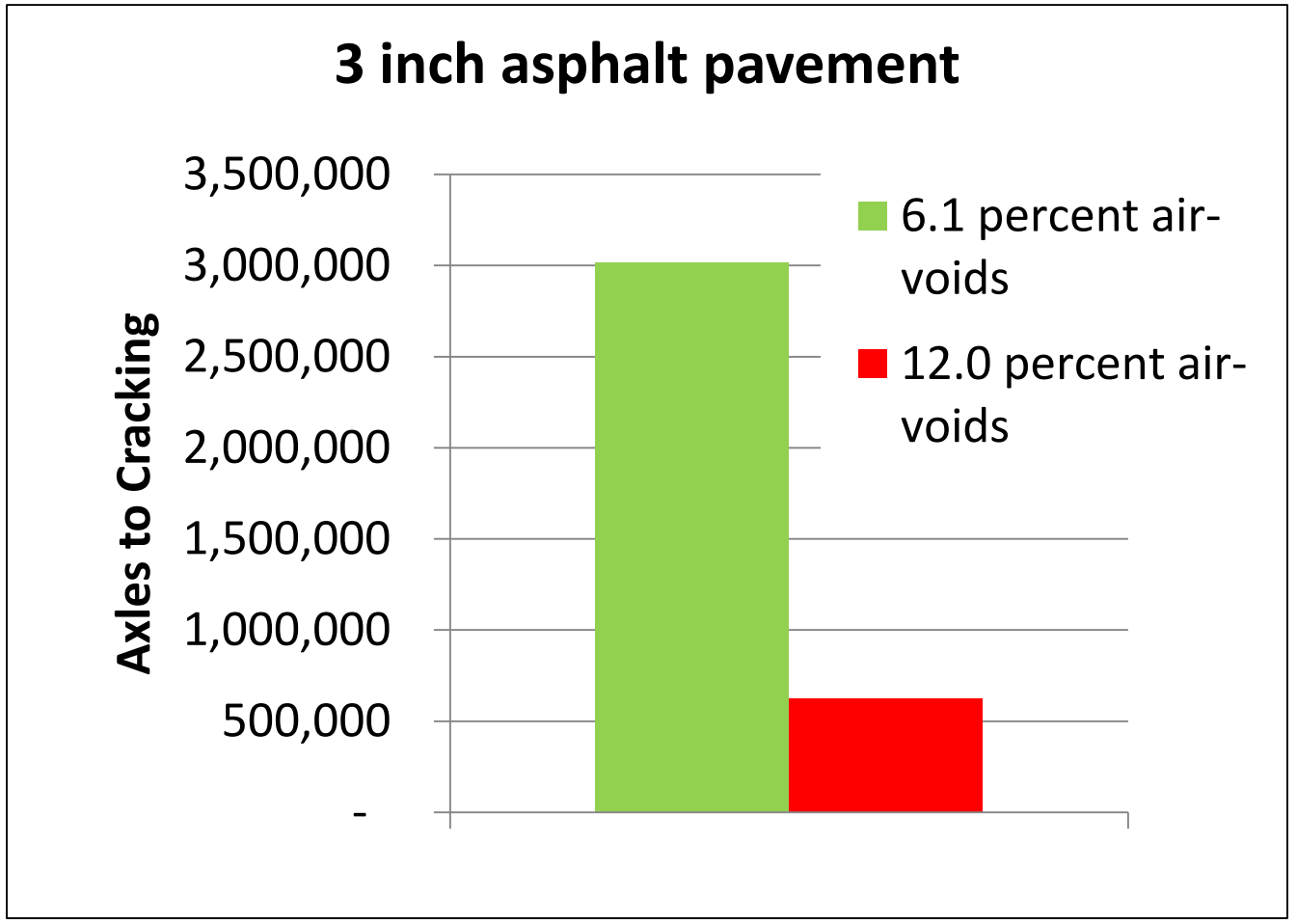
From doctoral thesis of Arash Saboori, UCPRC





Cracking Performance
A, B, C refer to low, medium, and high traffic levels

Effect of asphalt construction compaction on axle loads to cracking



Simulation based on FHWA Westrack project field results

General rule:
1% increase in constructed air-voids = 10% reduction in fatigue life under heavy loads

Similar effects on residential routes; more air voids = faster aging

Local Government LCCA and LCA example: Asphalt Compaction 8% vs 12% air-voids

- Assumptions:
  - 4 miles of two-lane rural county road
  - Pulverize cracked HMA, compact, 100 mm HMA overlay
  - $26/sy
  - 12% air-voids = 12 year life
  - 8% air-voids = 18 year life
- Net present cost* over 50 year period:
  - 12% air-voids = $4.36 million
  - 8% air-voids = $3.09 million = **29 % less cost**
- Greenhouse gas emissions are **34% less**

*2% discount rate

Getting Good Asphalt Compaction

- Include QC/QA construction air-void content specification in each contract
- Measure air voids as % of Theoretical Maximum Density
  - Not laboratory test maximum density
- Have contractor prove they can achieve spec
- Measure every day
- Look at the data
- Communicate with contractor

On CCPIC web site!

Concrete mix specifications

- Older concrete specifications
  - Written to ensure enough cement to meet strength and durability requirements
  - Often included minimum cement content
- Modern concrete mix designs
  - Minimize need for portland cement
  - Replace with supplementary cementitious materials (SCM
  - Minimize amount of cement paste in the mix:
    dense aggregate gradations
  - Reduces shrinkage in dry California environment
    = longer life

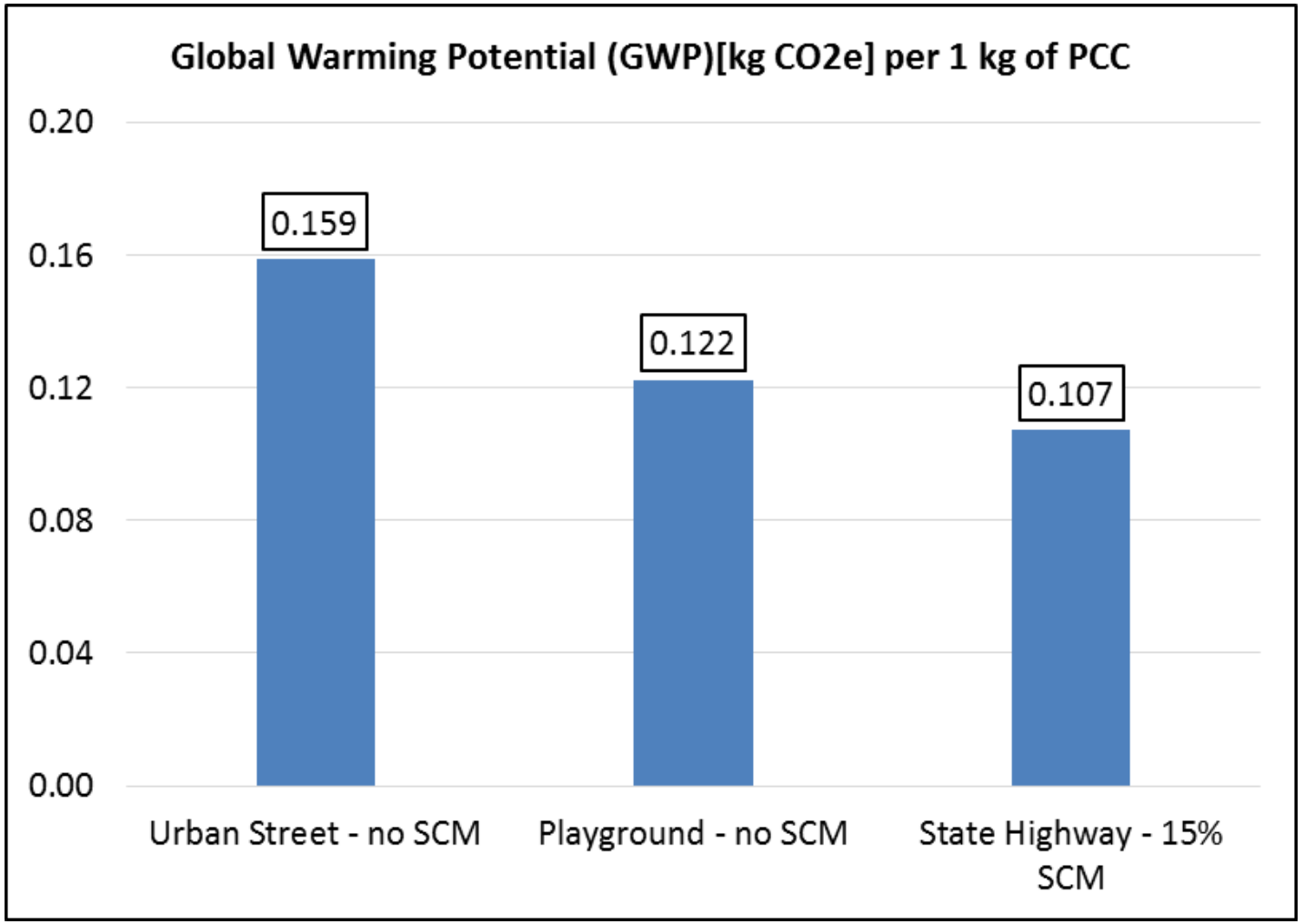
Concrete mix specifications

- What are SCMs?
  - Fly ash, natural pozzolans, slag cement
  - These can come pre-blended (new ASTM specs)
  - Caltrans also allows 5% replacement with ground limestone
    - Agencies are evaluating up to 15%
- These changes to mix design specs
  - Decrease cost
  - Decrease environmental impact
  - Increase durability of the concrete
- Many local agencies have not reviewed concrete and minor concrete specs in a long time

On CCPIC web site!

Effects on greenhouse gas emissions

- Mix designs from a city that hasn't reviewed specs and Caltrans highway mixes

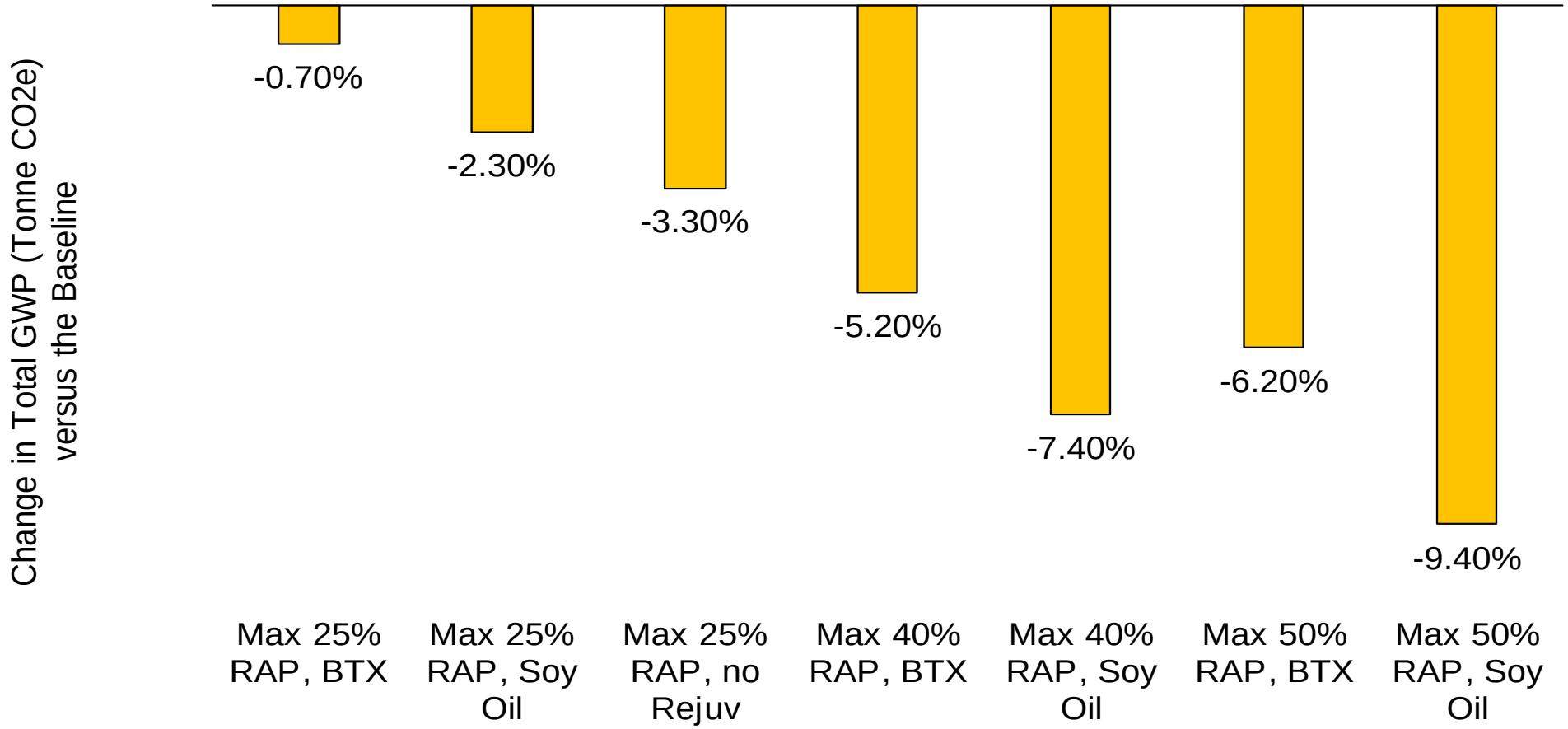


Greenhouse Gases HMA vs RHMA

- Same design for 10 year overlay on highway
- HMA strategy emits 26% more CO2e because of increased thickness

Strategy for Overlays	Materials (MT GHG)	Construction (MT GHG)	Total (MT GHG)
45 mm mill + 75 mm HMA with 15% RAP	1,650	505	2,155
30 mm mill + 60 mm RHMA	1,310	396	1,706
HMA/RHMA	1.26	1.28	1.26

High Reclaimed Asphalt Pavement (RAP) Mixes
Percent Change in Total GHGs
vs. Baseline Assuming Same Performance



High RAP benefit canceled by need for high impact rejuvenating agents

If life is decreased by 10% then no reduction in GWP

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]	4.0×10^3
Non-renewable [MJ]	*3.9×10^3*
Renewable [MJ]	*3.5×10^2*
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]	7.3×10^{-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, Pavement Interactive, Steve Meunch

Why Would a Local Government Ask for EPDs? Can Industry Deliver Them?

- EPDs are produced by industry and provide LCA results for their product from “cradle to gate” of their plant
- EPDs provide a means for agencies to quantify their emissions and impacts
- Materials EPDs do not account for how long the material will last in a given application
- Asphalt and concrete producers have set up systems to produce verifiable EPDs

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

NRMCA™

Conclusions

- Pavement can play its role in reducing climate change, and often also reduce cost
- LCA and LCCA are tools to be used to quantify and prioritize
- There are no magic bullets, every sector needs to prioritize what it can do to both reduce environmental damage and cost
- Think full system and life cycle
- There are strategies that you can be implementing now!

Recommendations for What You Can Do Now

- Improve asphalt pavement life
  - Include asphalt compaction specifications
    - % of Theoretical Maximum Density, not % of Laboratory Test Max Density
  - Enforce asphalt compaction specifications
    - Review and communicate with contractor daily
  - Consider use of rubberized hot mix
- Improve concrete specifications
  - Use strength and shrinkage specifications
  - Remove minimum cement contents
  - Allow use of supplementary cementitious materials
- Keep heavy traffic routes smooth

Recommendations for What You Can Do Now

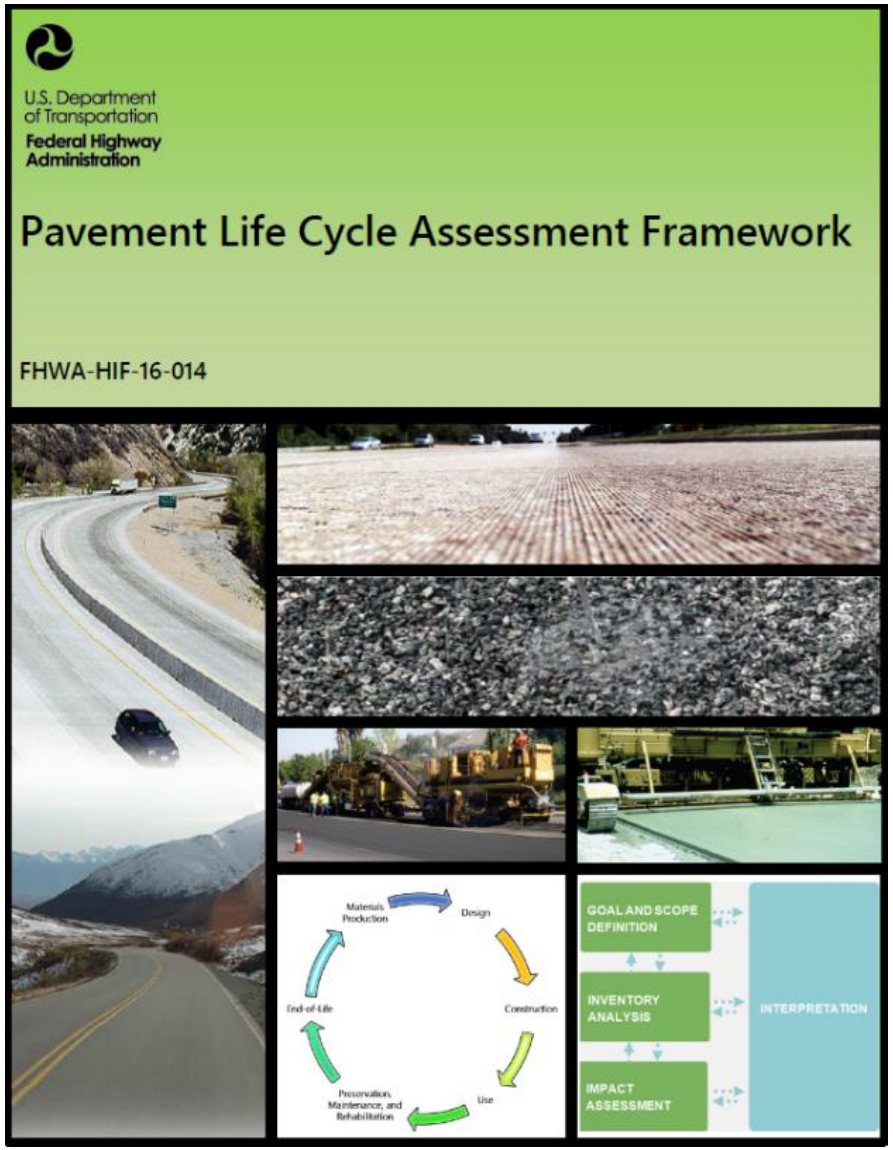
- Be careful of high RAP mixes until performance is proven
- Practice timely pavement preservation
  - Seal coats before cracks and significant aging occur, especially for routes without heavy traffic
  - Optimize decision trees
- Consider full-depth reclamation where severe full-depth cracking
- Minimize trucking of materials in construction projects
- Get ready to use LCA in design and to evaluate other questions
- Consider asking for Environmental Product Declarations
  - Monitor steps Caltrans is taking towards using for procurement
  - Consider use of EPDs in future procurement for materials meeting same specification;
  - Use incentive/disincentive, not go/no go against an arbitrary baseline

Some Items that Have Come Up in Introductions

- Permeable pavement
- Complete streets and bicycles
- PMS strategies
- Cool pavement
  - CARB study
  - No carbon black in concrete
- Utilities

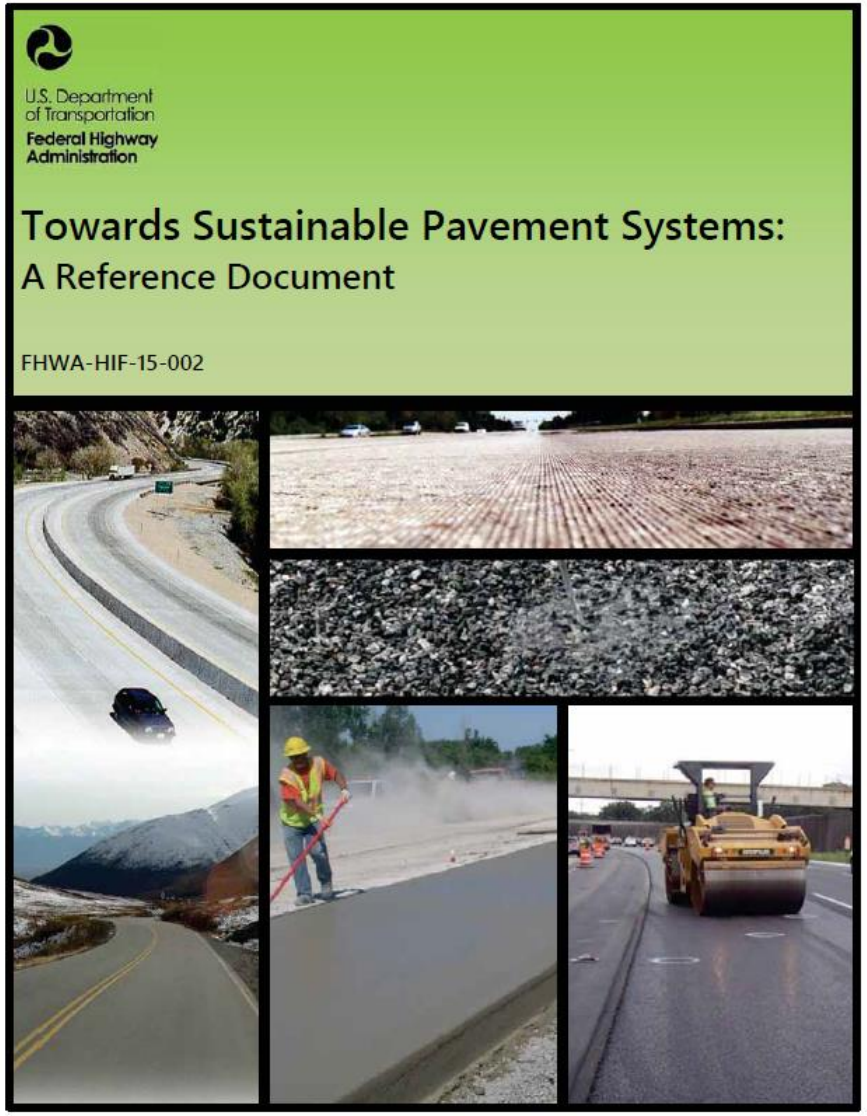
FHWA Pavement LCA Framework Document

- Published January 2016
- Guidance on uses, overall approach, methodology, system boundaries, and current knowledge gaps
- Specific to pavements
- Includes guidelines for EPDs
- Search on “FHWA LCA framework”



FHWA Reference Document: Towards More Sustainable Pavement

- Published in 2015
- Written with full system, complete life cycle perspective
- Summarizes basics of each step in pavement life cycle
- Presents strategies for reducing environmental impact through each stage of life cycle
- Summarizes life cycle assessment, life cycle cost analysis



Thank You!

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International Symposium on Pavement, Roadway, and Bridge Life Cycle Assessment 2020

Sacramento, California, USA
June 3-6, 2020

www.ucprc.ucdavis.edu/lca2020

Search on “pavement LCA 2020”