More Durable, Cost-Effective, & Sustainable Pavement

John Harvey, PE

University of California Pavement Research Center

City and County Pavement Improvement Center

UC Davis

Alameda County
Green Purchasing Roundtable
10 December, 2019

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Welcome To CCPIC

ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

MTI MINETA TRANSPORTATION INSTITUTE

ITS Berkeley

CP² CENTER

TransGET National Center for Transportation, Green Technologies, and Education

CAL POLY

- 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

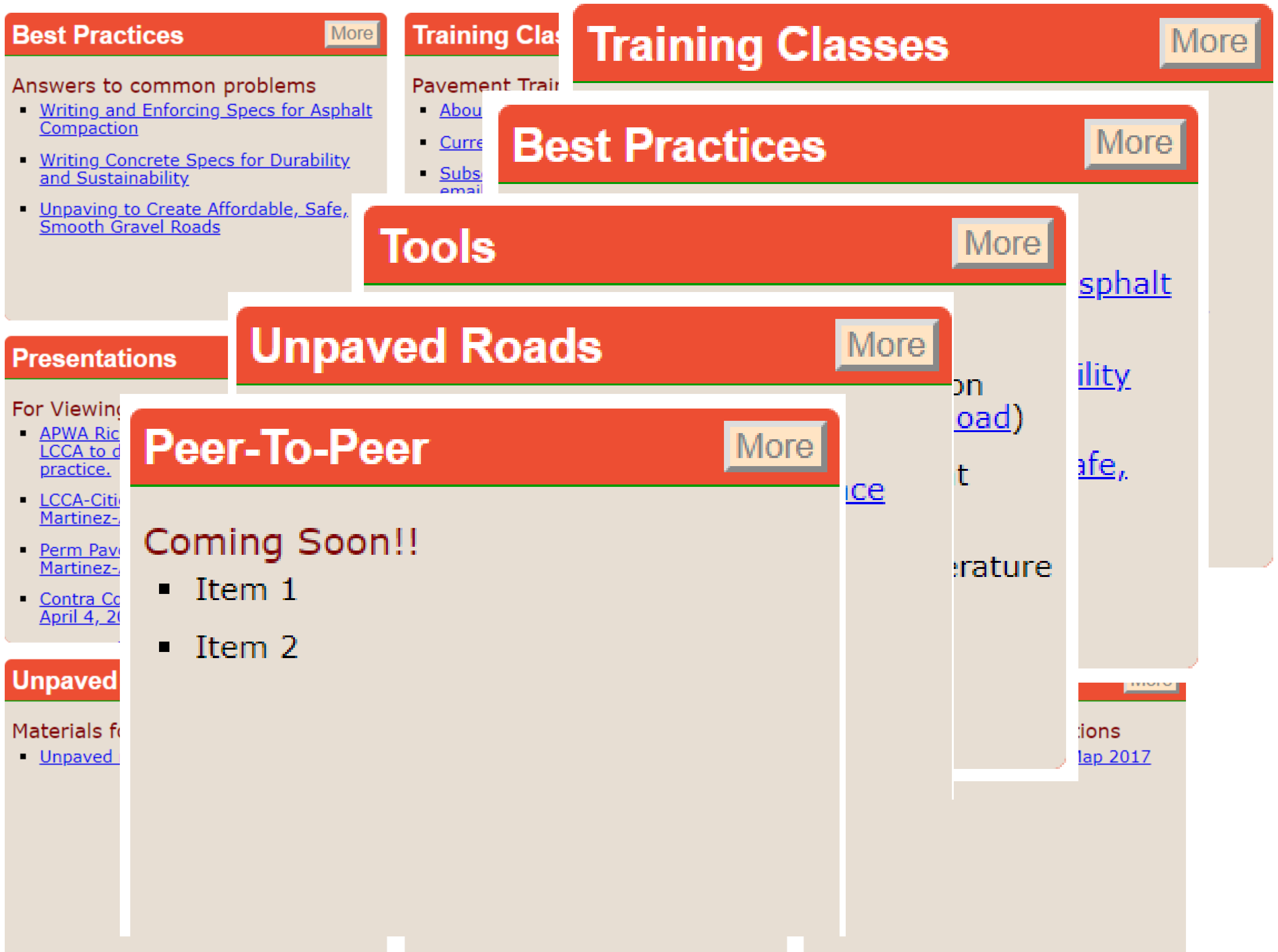
CCPIC Scope

- Provide <u>technology transfer</u> through on-line and in-person training, peer-to-peer exchanges, and dissemination of research results and best practices in a variety of formats for a variety of audiences (e.g., policy makers, engineers, planners, community members)
- Develop <u>technical briefs, guidance, sample specifications, tools, and other resources</u> based on the latest scientific findings and tested engineering solutions for local government pavement engineers, managers, and the consultants who support them

CCPIC Scope

- Establish a pavement engineering and management certificate program for working professionals through UC Berkeley ITS Tech Transfer
- Serve as a resource center for up-to-date information, regional in-person training, pilot study documentation, and forensic investigations
- Conduct research and development that produces technical solutions that respond to the pavement needs of both urban and rural local governments

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 =

Population X $\frac{\text{GDP*}}{\text{Person}}$ X $\frac{\text{Impact}}{\text{GDP*}}$

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

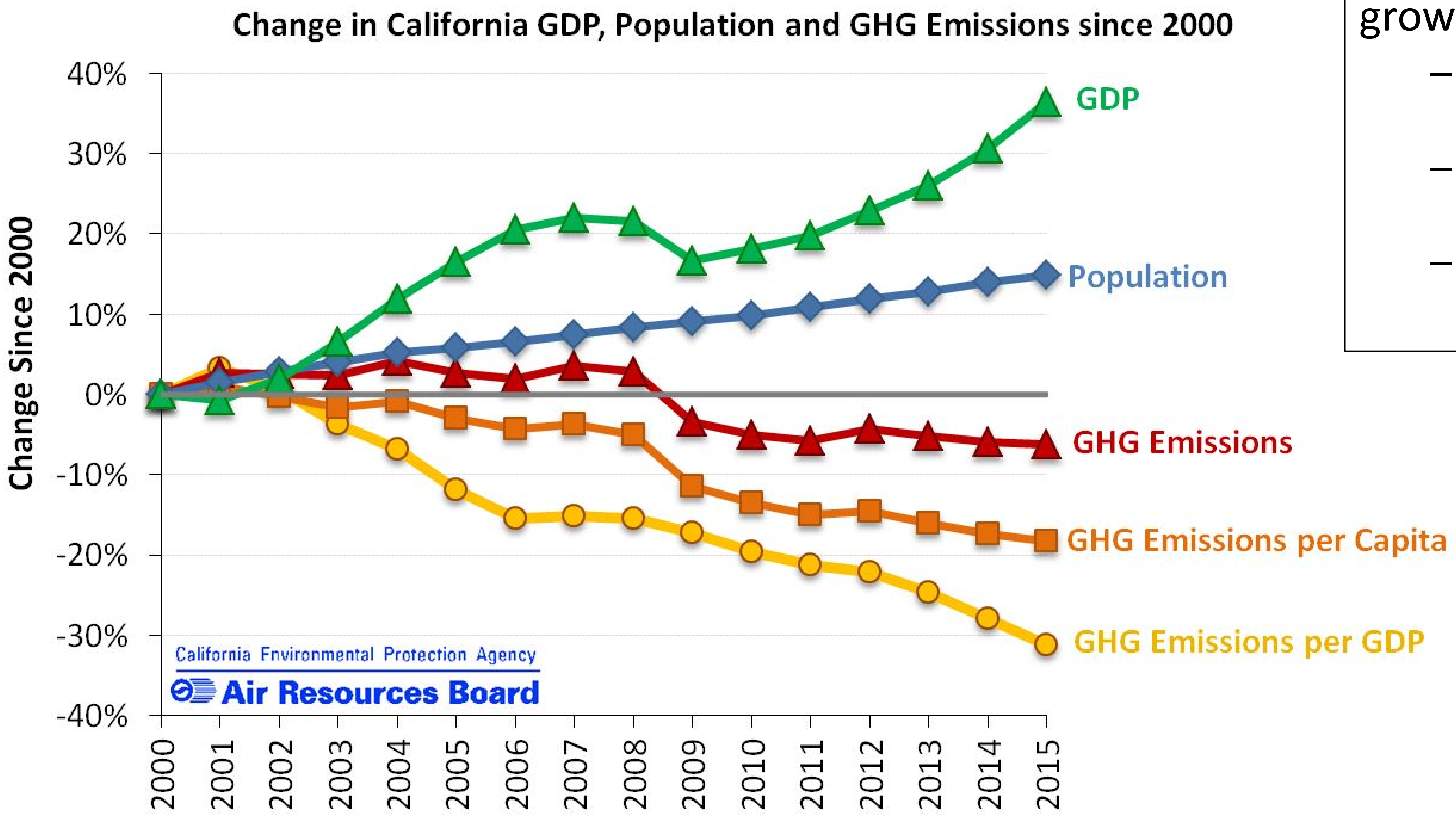
Population	GDP* / Person	Impact / GDP*
Need enough young people for social stability	Increase in wealth and economic activity	New technology, organization and implementation

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

Some Major California Legislation on GHG

- Governor's Executive Order S-3-05 (2005) required:
  - Reduction of GHG emissions to 1990 levels by 2020
  - Reduction to 80 percent below 1990 levels by 2050
- 2006 Climate Change Solutions Act (Assembly Bill 32)
  - Made 2020 reductions law
  - Tasked many government entities, including local governments and government agencies, with helping to meet those goals
- Governor's Executive Order B-30-15 (2015) requires:
  - Reduction of 40 percent below 1990 levels by 2030
- Senate Bill 32 in 2016
  - Made 40 percent reduction law
- Executive Order B-55-18 (2018) requires:
  - Carbon neutrality for the state by 2045

Climate Change and Economy: How Are We Doing? (2000 to 2015)



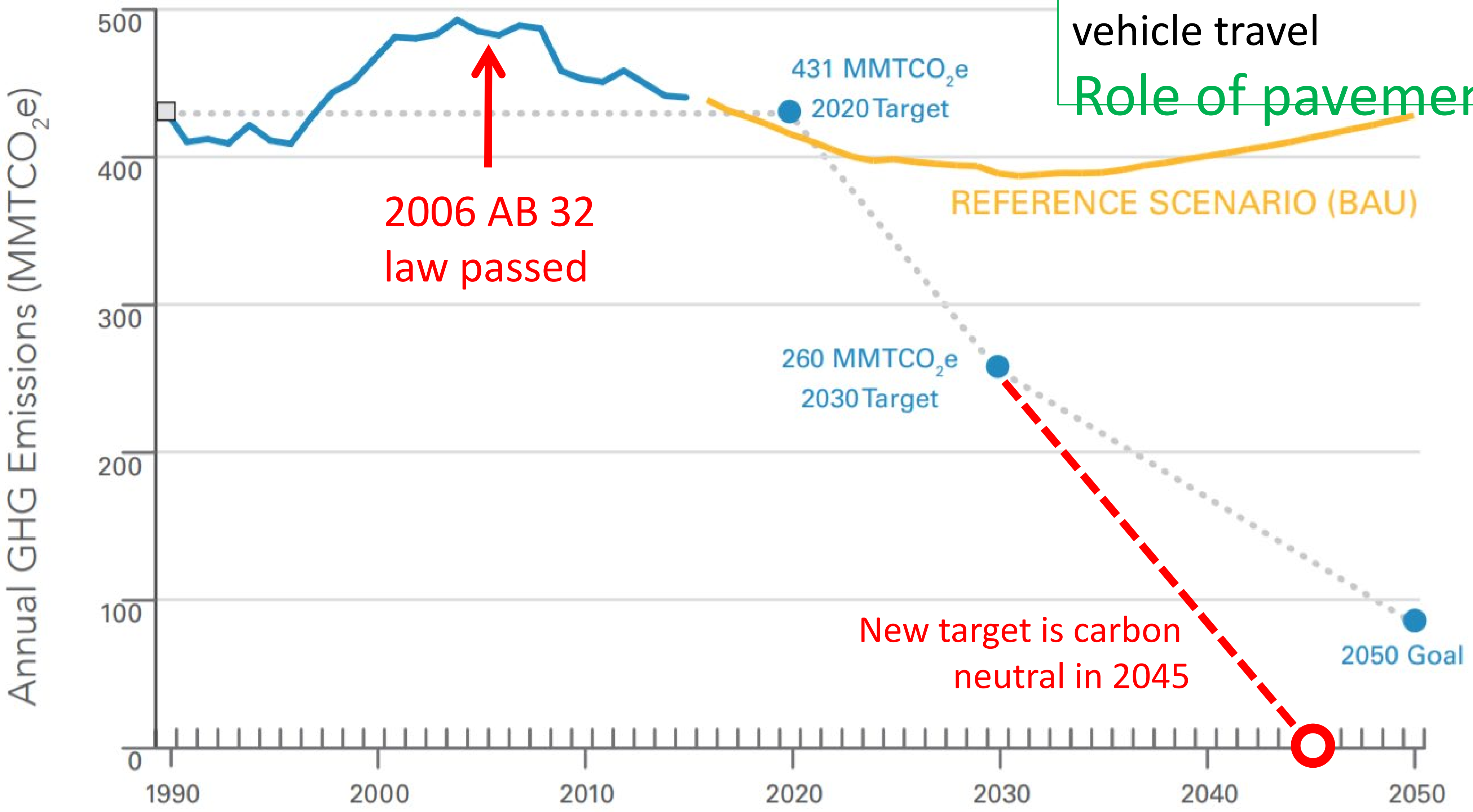
Population growth:

- 2000: 34 million
- 2017: 39 million
- 2055: 50 million

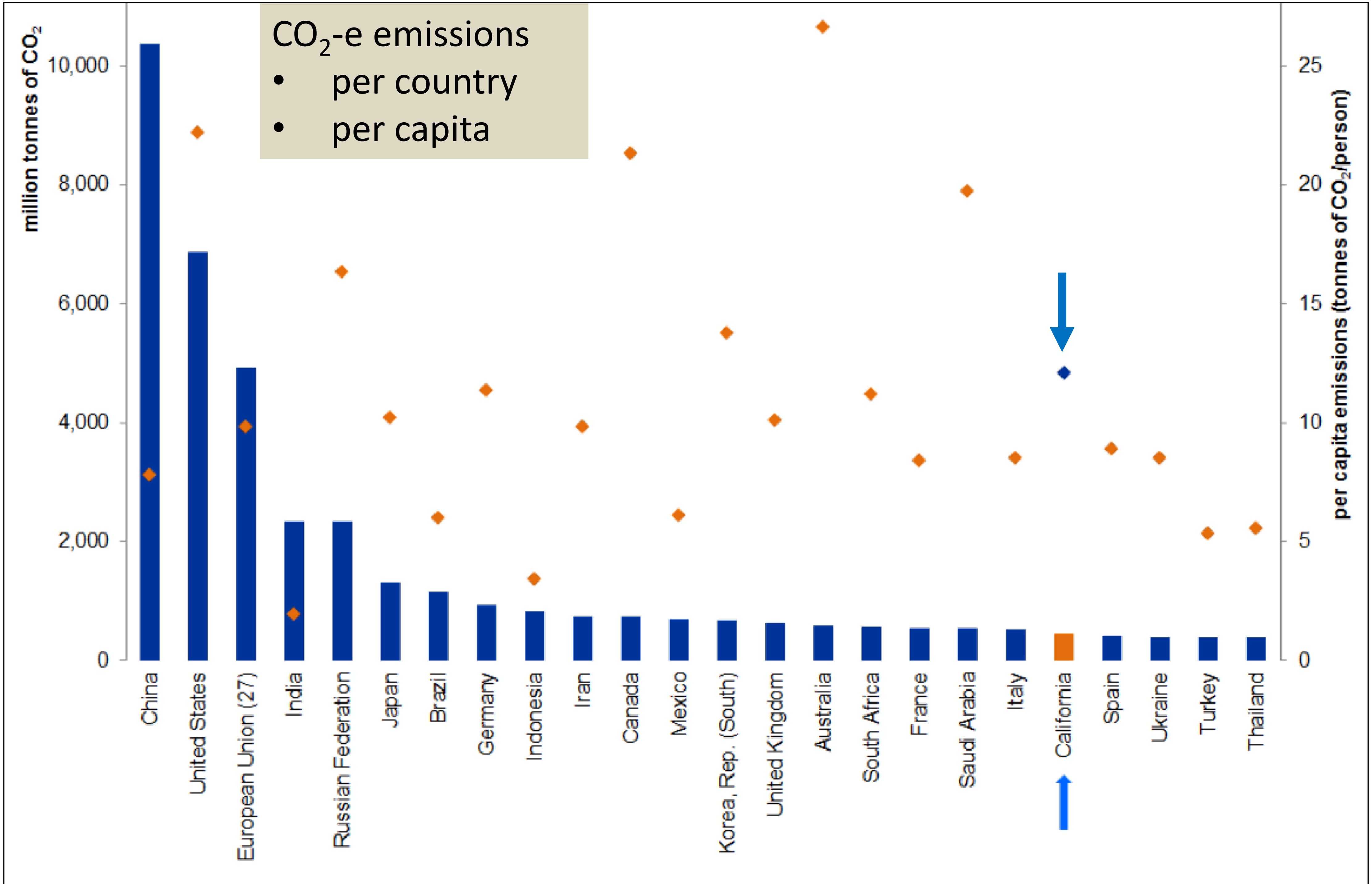
Climate Change Targets and Transportation Strategies (ref 2015)

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

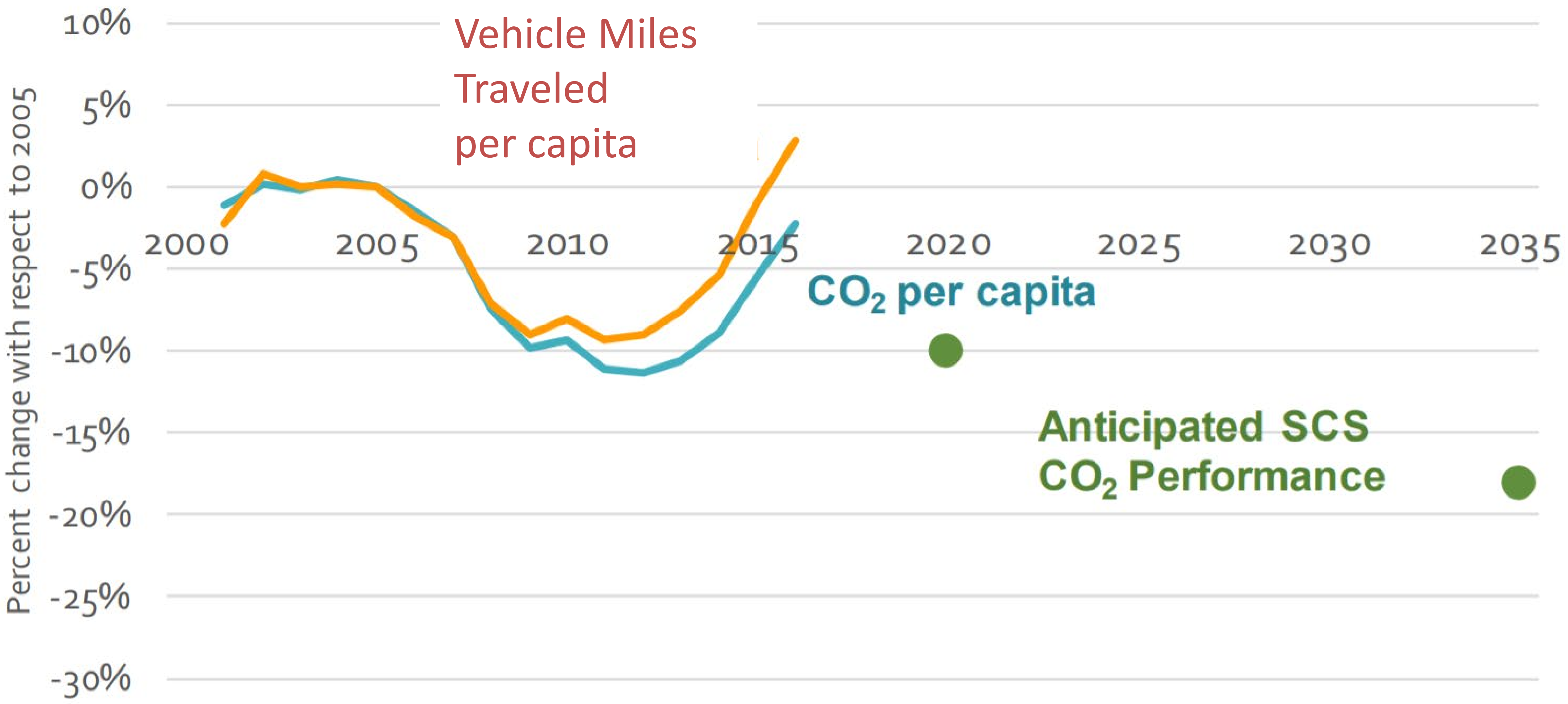


2012 data

California Air Resources Board report

How Are We Doing? New data to 2016

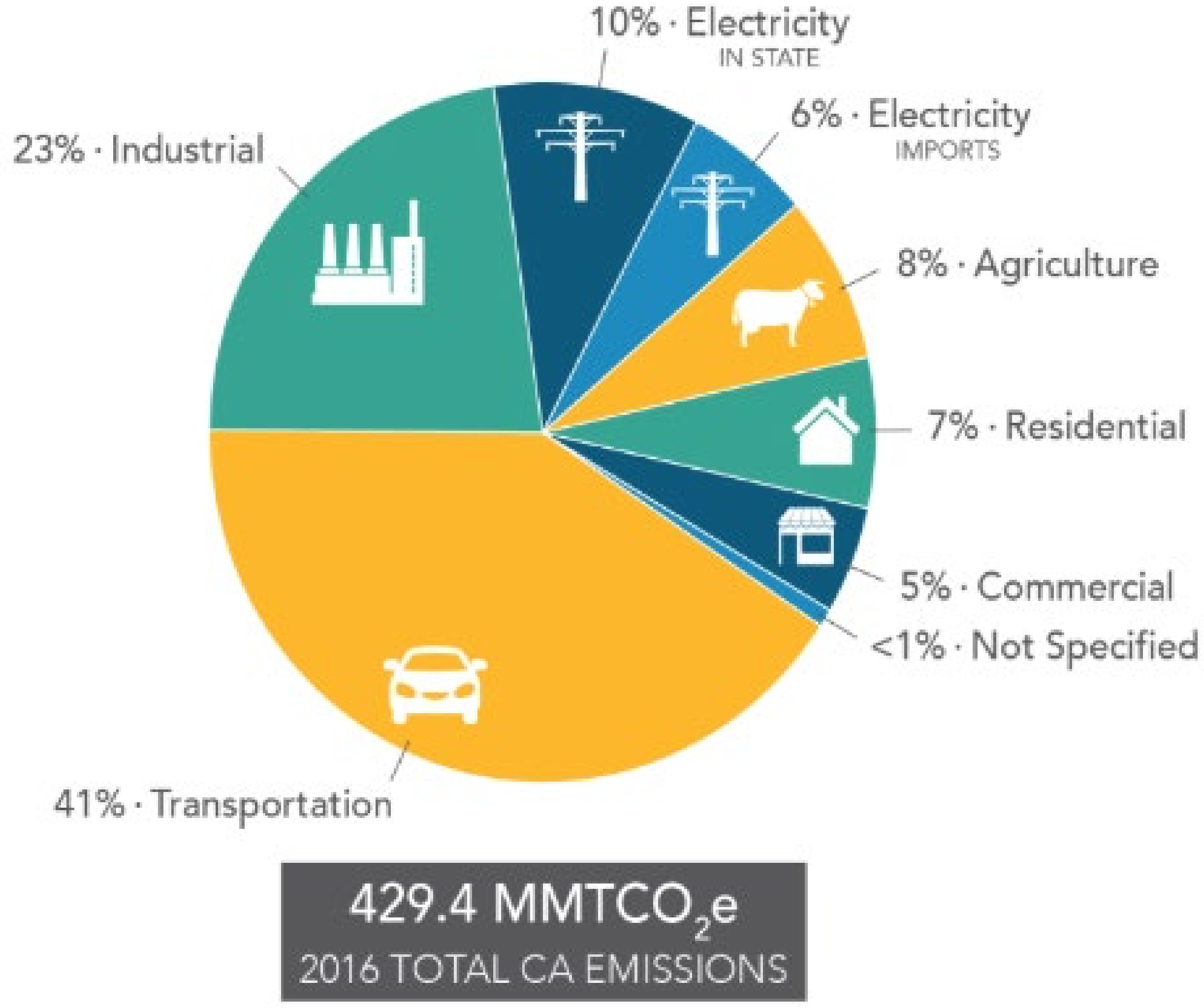
Changes since 2005



Estimated Potential Pavement-Related Reductions to 2016 California GHG Emissions

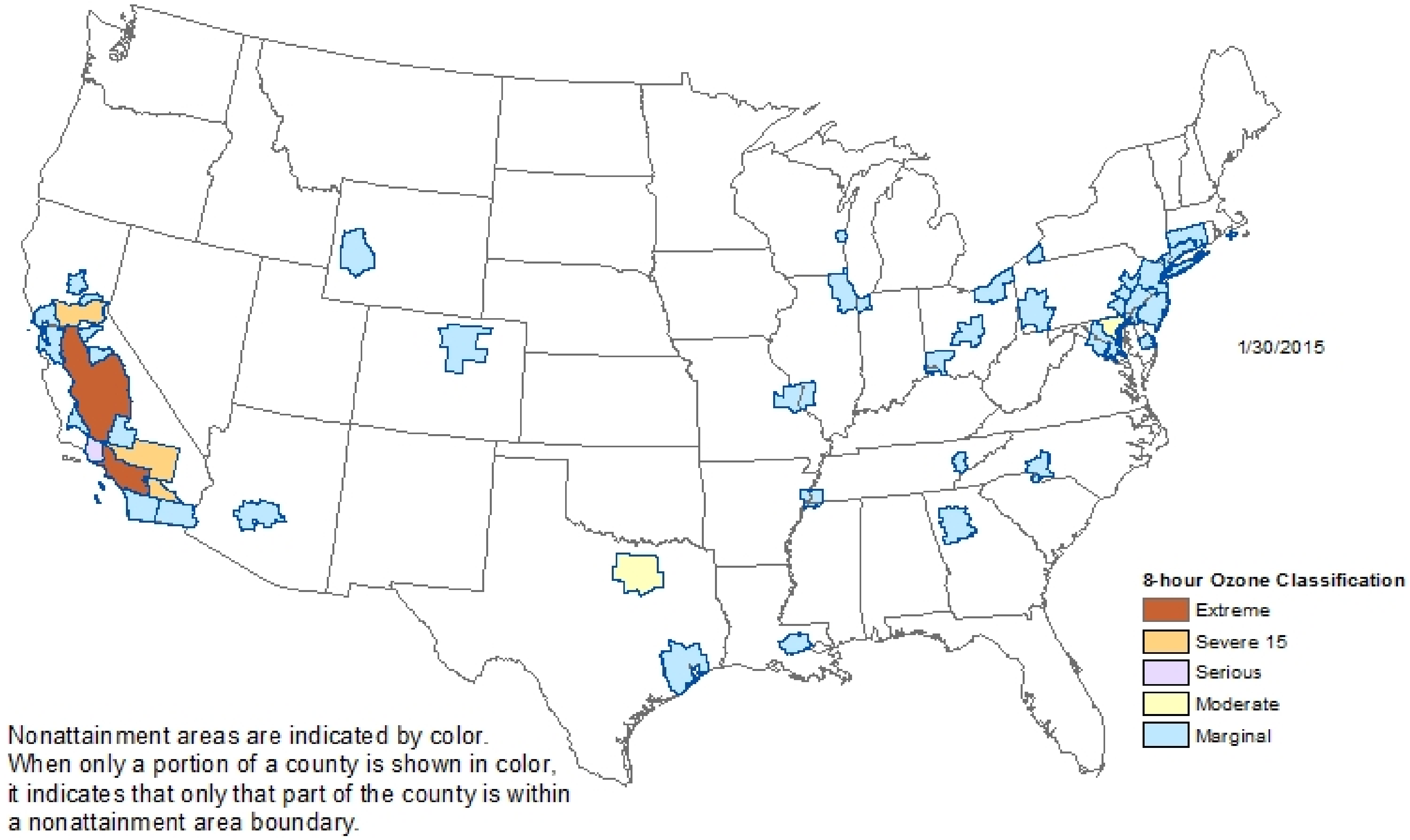
Possible Pavement Reductions	MMT/ year
Rolling resist to optimum	1.5 to 3.0
Reduce cement use 50%	0.2
Reduce virgin asphalt use 50%	0.7
Reduce hauling demolition, oil, stone haul 10%	0.6
TOTAL	**3.0 to 4.5**

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)



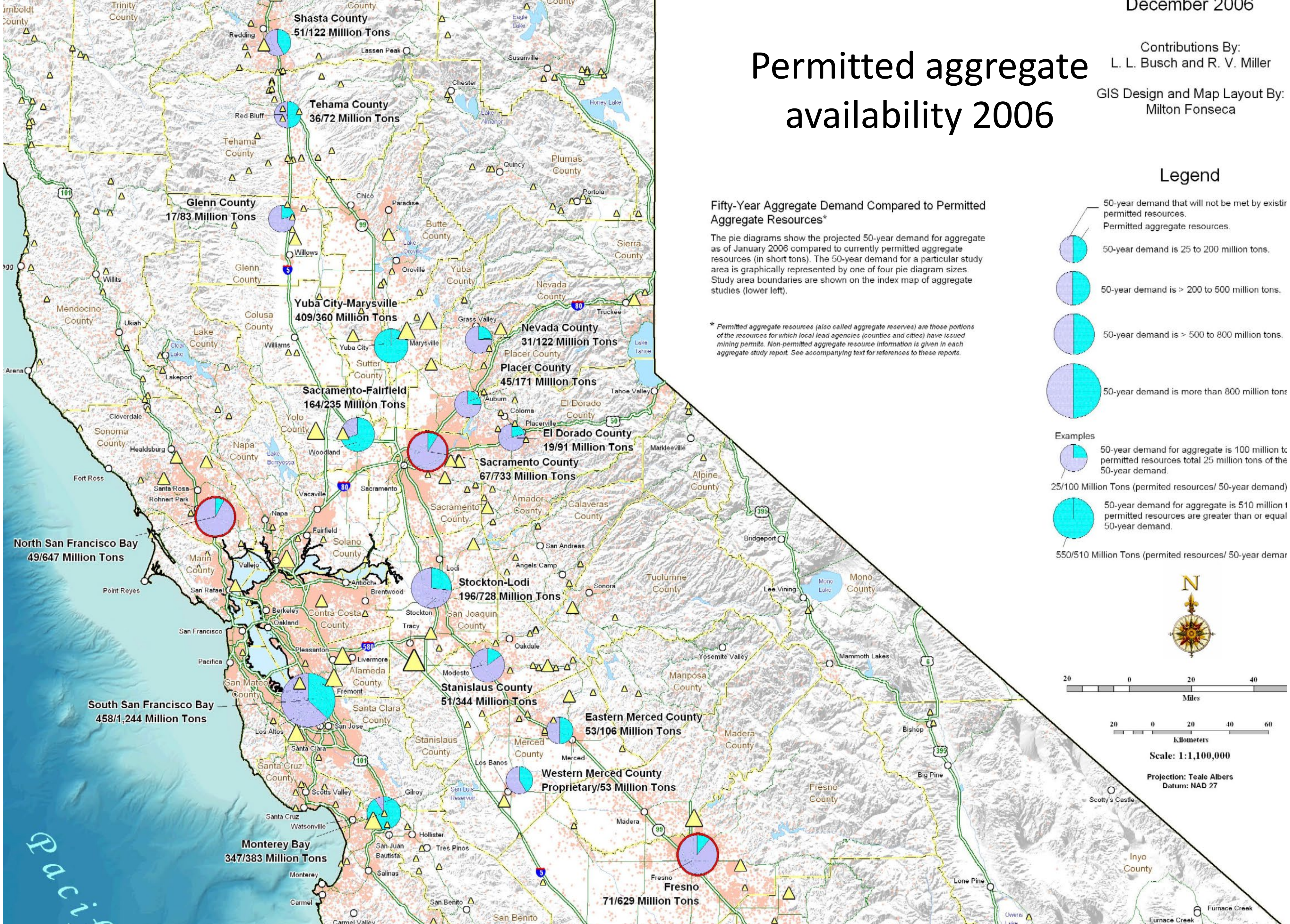
http://www.epa.gov/oaqps001/greenbk/map8hr_2008.html

Pavement Materials Resource Depletion and Replacement

- Aggregate:
  - Local future shortages and quality issues
  - Large quantities of aggregate moved on the roads, burns fuel, high levels of damage to pavement
  - In-place recycling of aggregate

- Bitumen:
  - California importing asphalt because largest refineries are coking for liquid fuels
  - If oil demand for transportation fuel diminishes, there is a nearly infinite future supply of asphalt, will there be a business to refine it?
- Potential partial solution:
  - Mine existing roads for asphalt and aggregate = RAP, FDR, CCPR, CIR

Permitted aggregate availability 2006

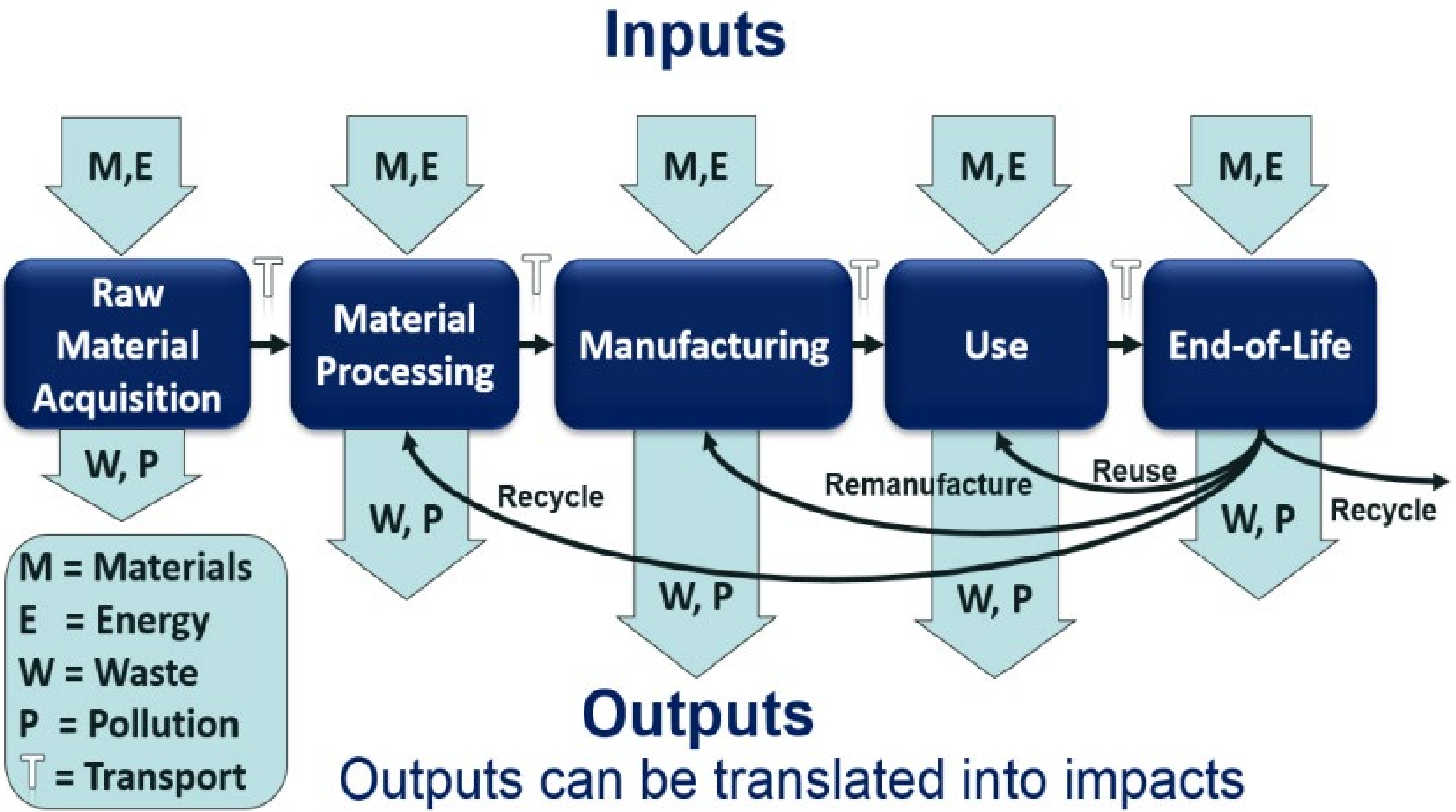


FHWA Sustainable Pavements Technical Working Group

- https://www.fhwa.dot.gov/pavement/sustainability/
- Begun in 2009
- Brings together
  - Federal and state DOTs, Industries, Academia, Consultants
- Meets every 6 months around the country
- Next meeting is in Sacramento, June 2-3, 2020

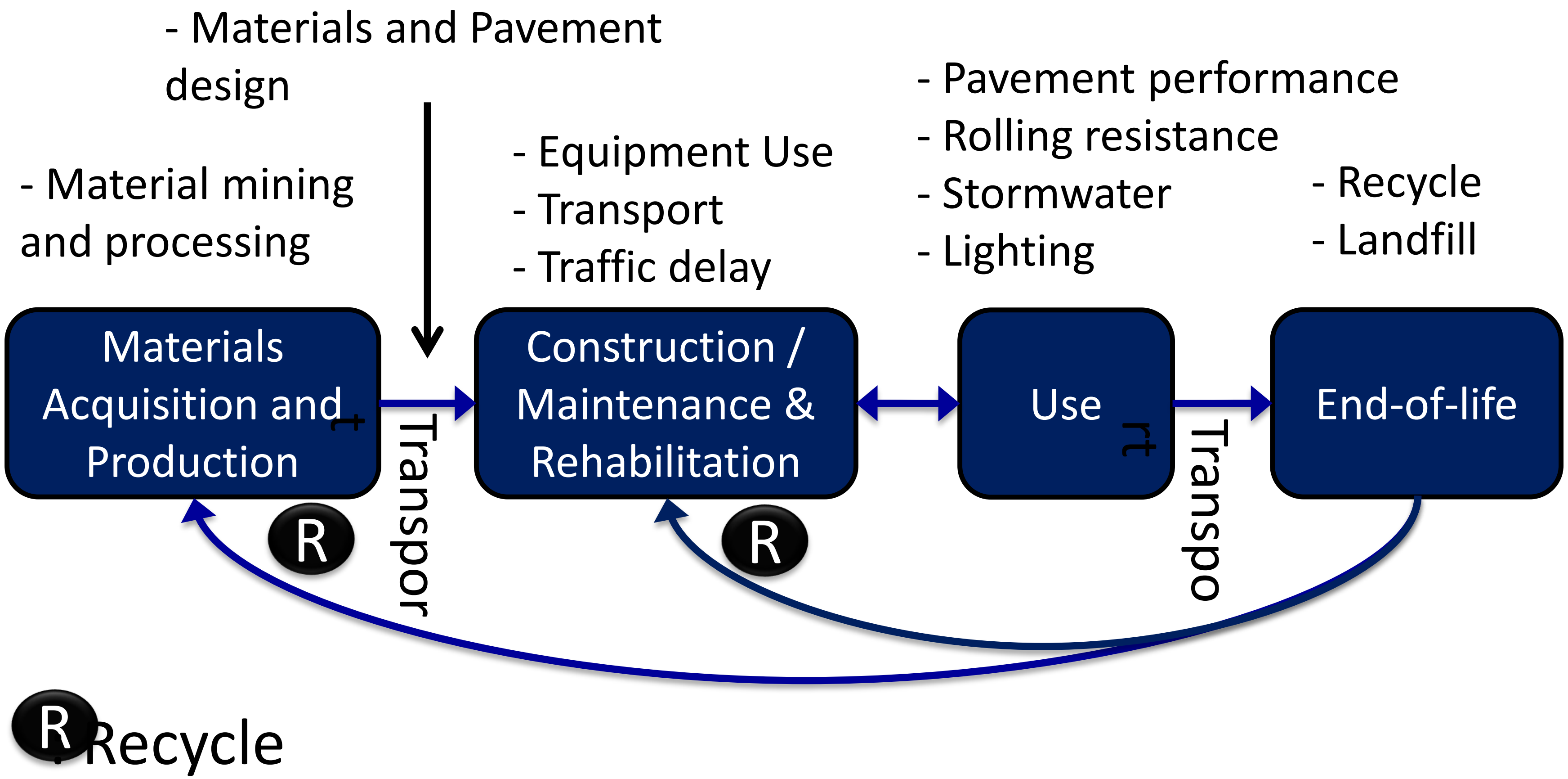
Product Life Cycle and Flows

Kendall (2012)



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

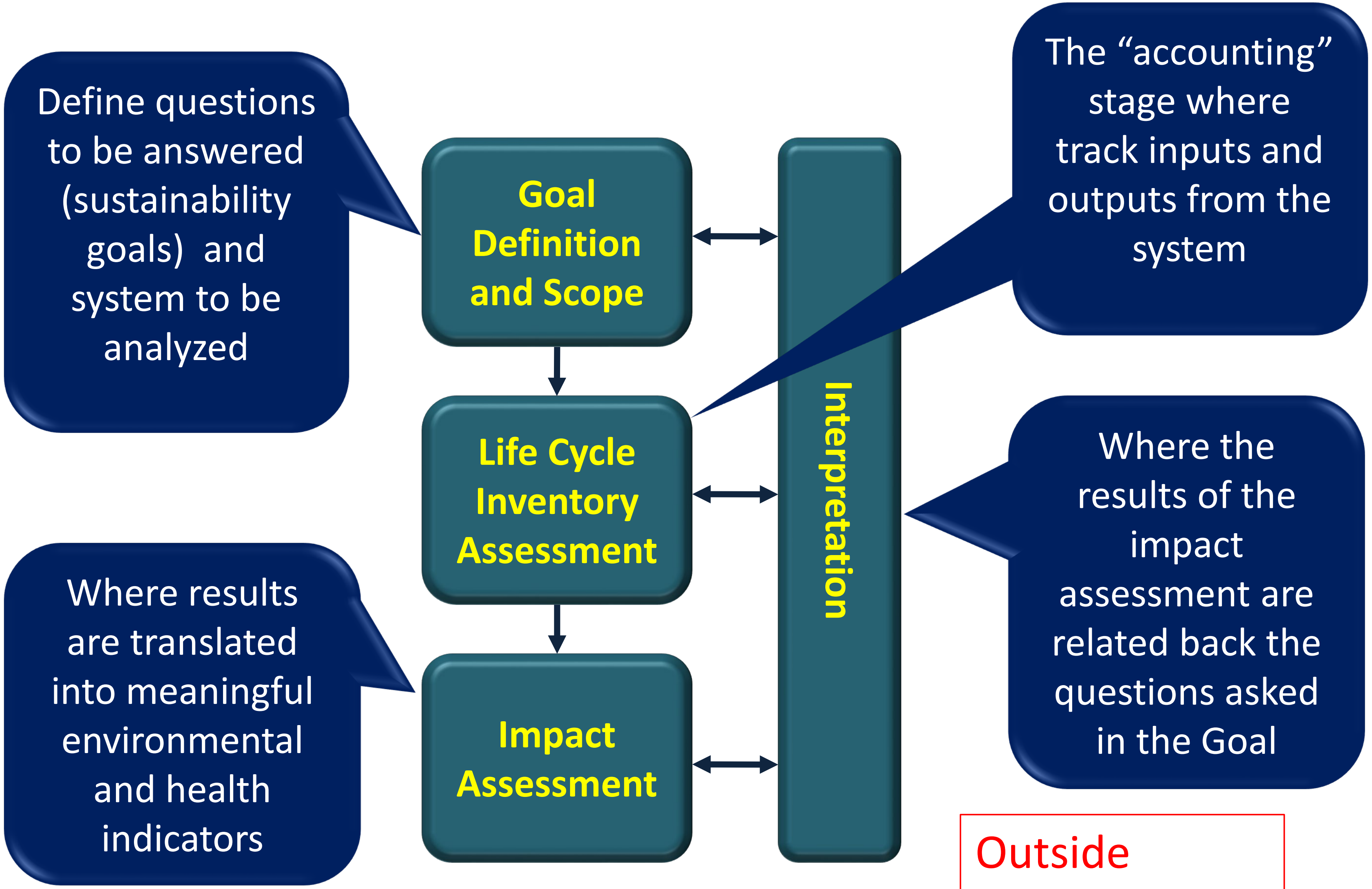
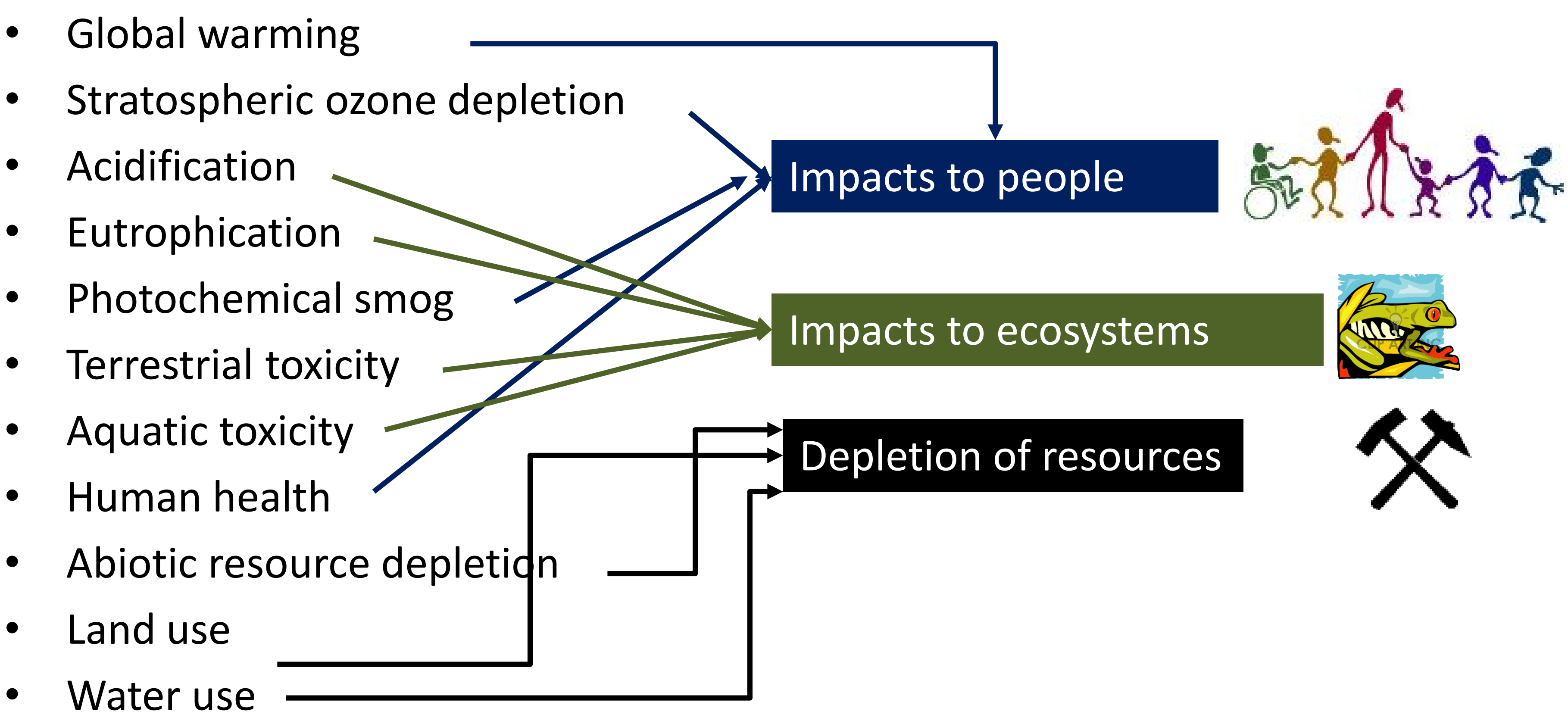


Figure based on ISO 14040, adopted from Kendall

Outside Critical Review

US EPA Impact Assessment Categories

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



From Saboori   *Image sources: Google*

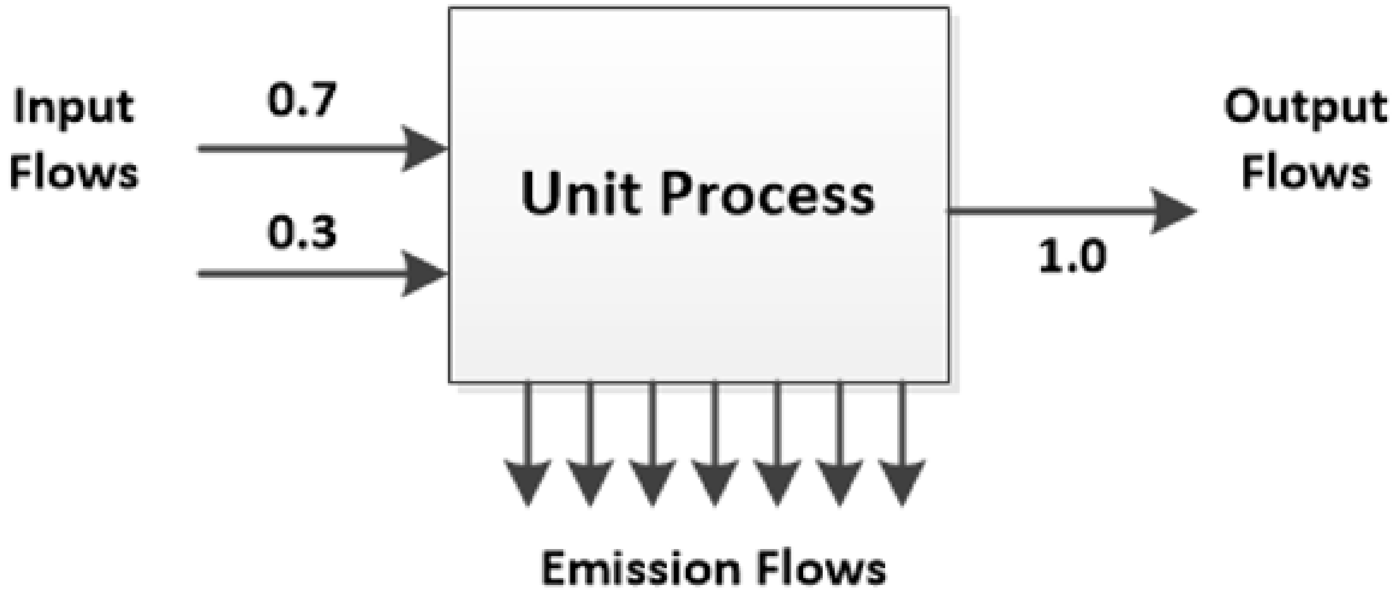
Why LCA?

- **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

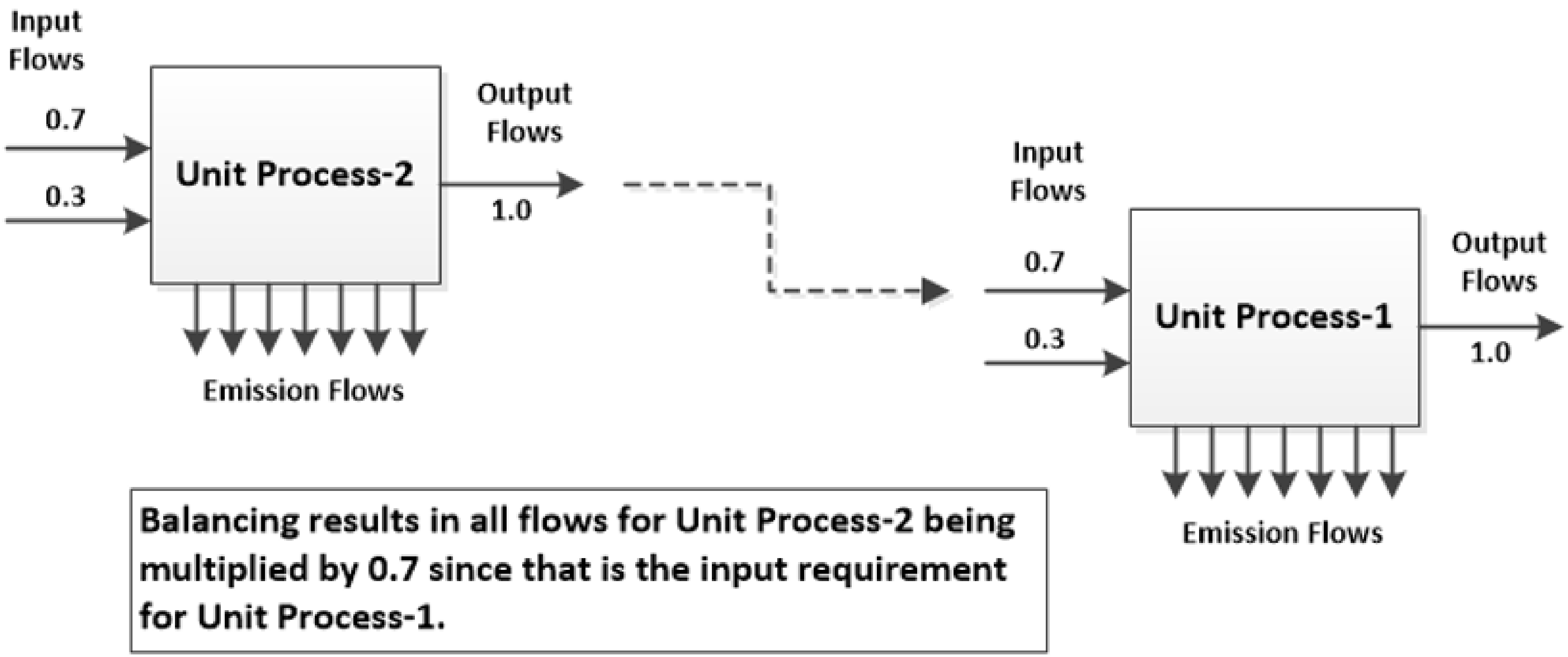
Why LCA?

- **What is a vision for use of LCA in transportation?**
- To use LCA wherever appropriate, and to use LCA principles in hybrid forms where appropriate (such as urban metabolism-LCA),
- considering full system and full life cycle
- with data that are accurate, transparent, comprehensive, regionally applicable, up-to-date,
- indicators that provide relevant information for answering questions, decision-making and reporting by transportation producers/providers, consumers and operators,
- in a science-based culture of honesty, transparency, critical peer review and fairness leading to continuous process improvement

Basic Unit Process Used in LCA

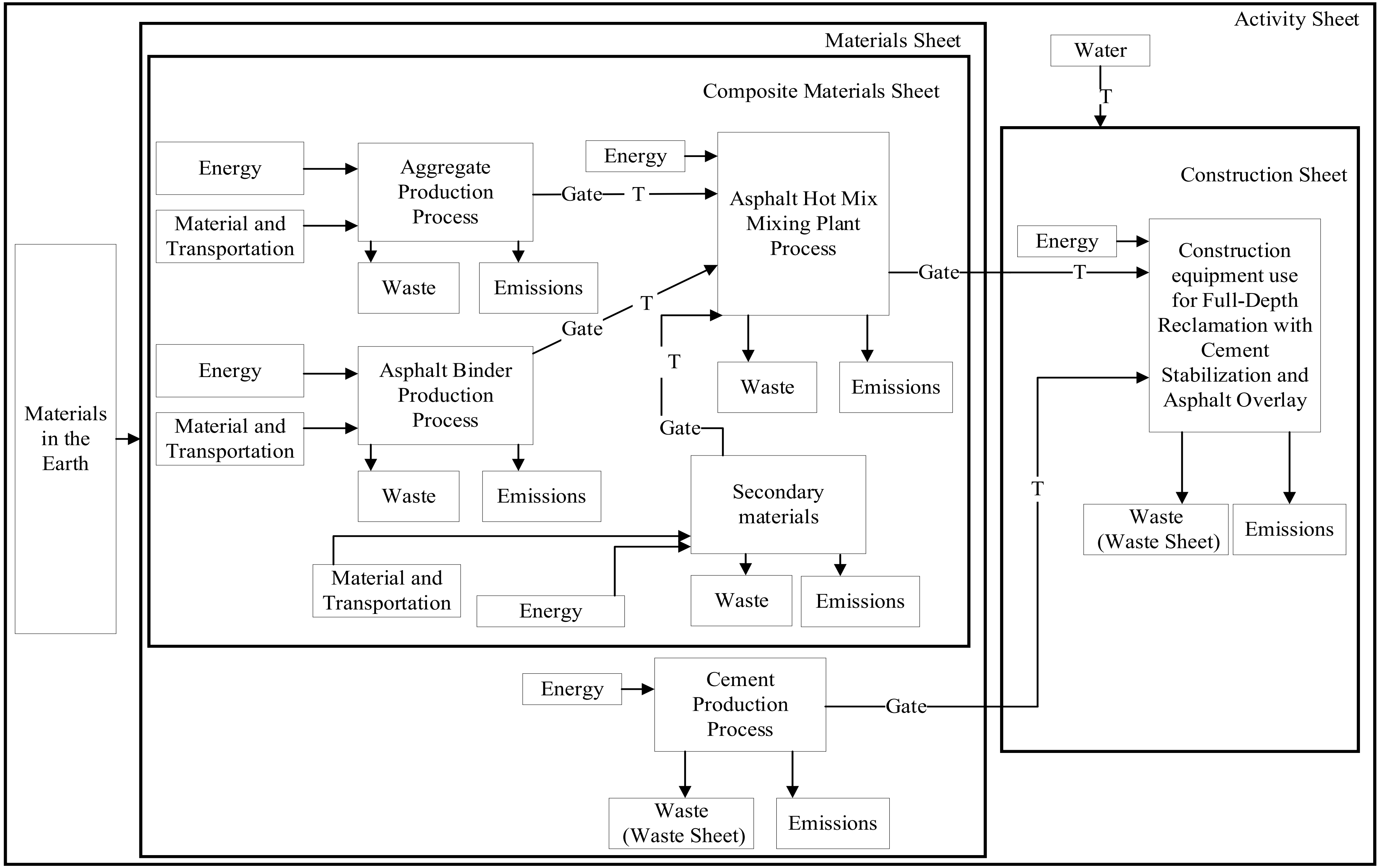


“Balancing” with Multiple Unit Processes



- Multiple unit processes represent the “Model” of a pavement project
- A Typical pavement project (new construction, rehab, minor/major treatments, etc.) will have hundreds of unit processes: HMA, AB, electricity, diesel, construction equipment use
- “Balancing” the LCA model results in the life cycle inventory of the pavement project

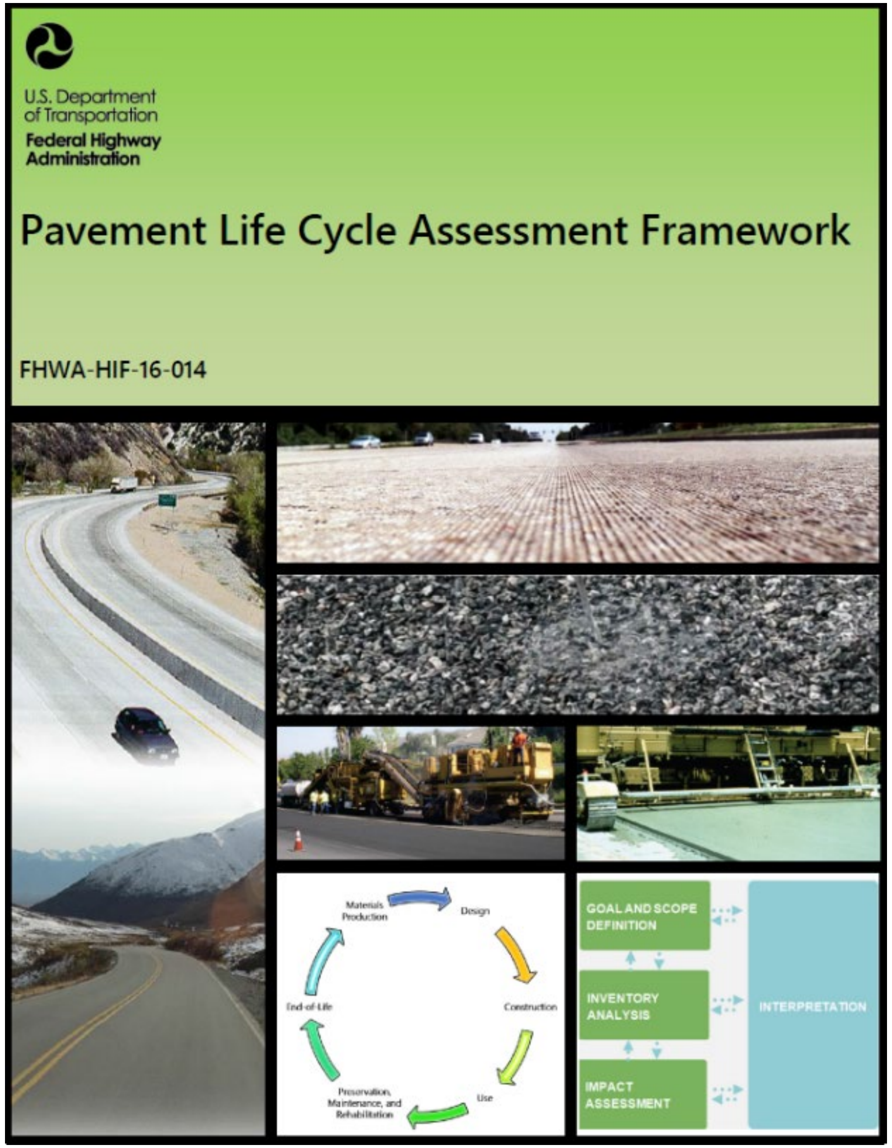
Activity Sheet, Materials Sheet, Composite Material Sheet, Construction Sheet
Example: FDR-Cement, Asphalt Overlay



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

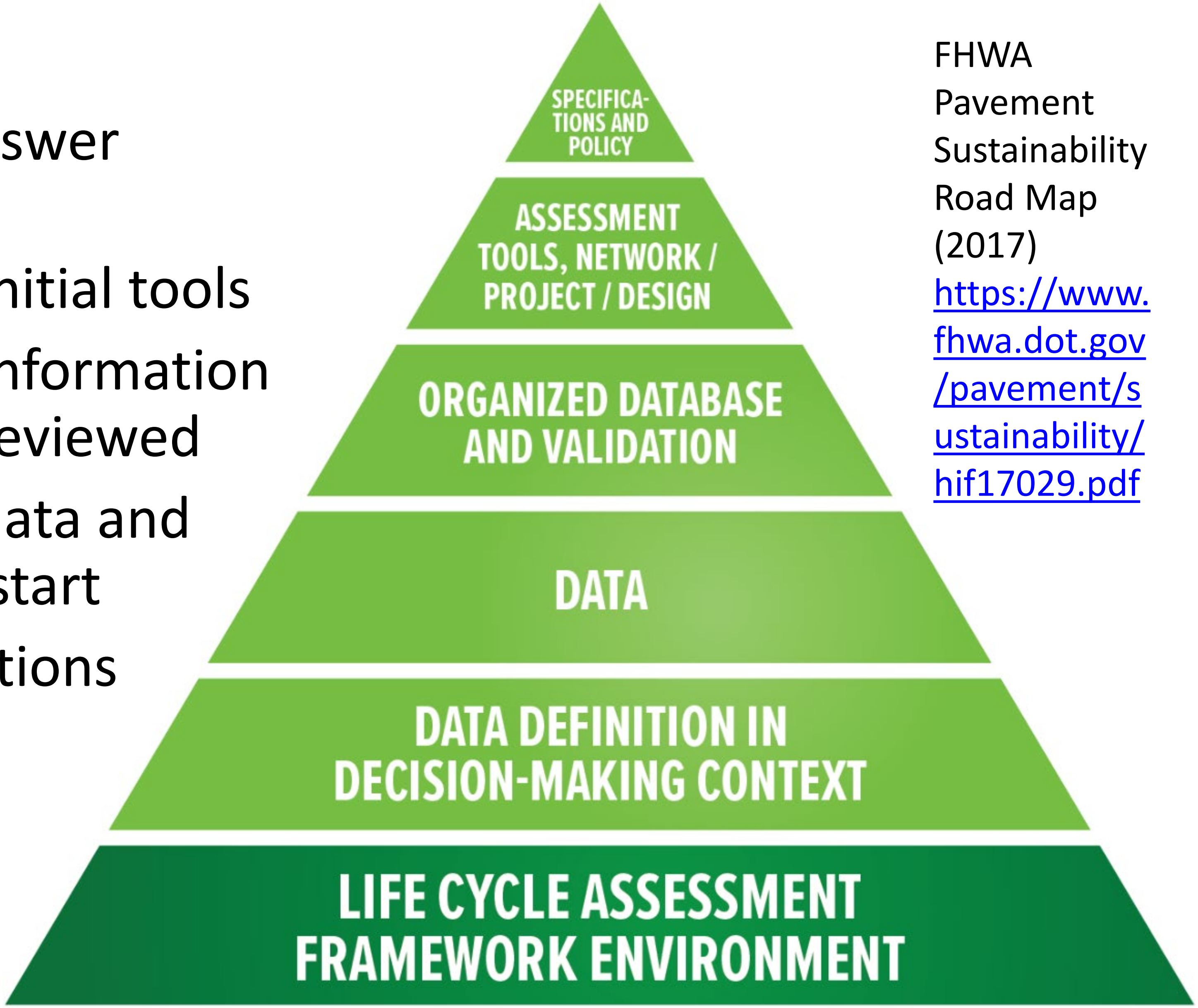
FHWA Pavement LCA Framework Document

- 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"



Are we ready to produce pavement LCA tools?

- Want to answer questions
- Ready for initial tools
- Inventory information available, reviewed
- Sufficient data and models to start
- Data definitions ready
- FHWA framework



FHWA Pavement Sustainability Road Map (2017) https://www.fhwa.dot.gov/pavement/sustainability/hif17029.pdf

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

What are the appropriate places to use LCA?

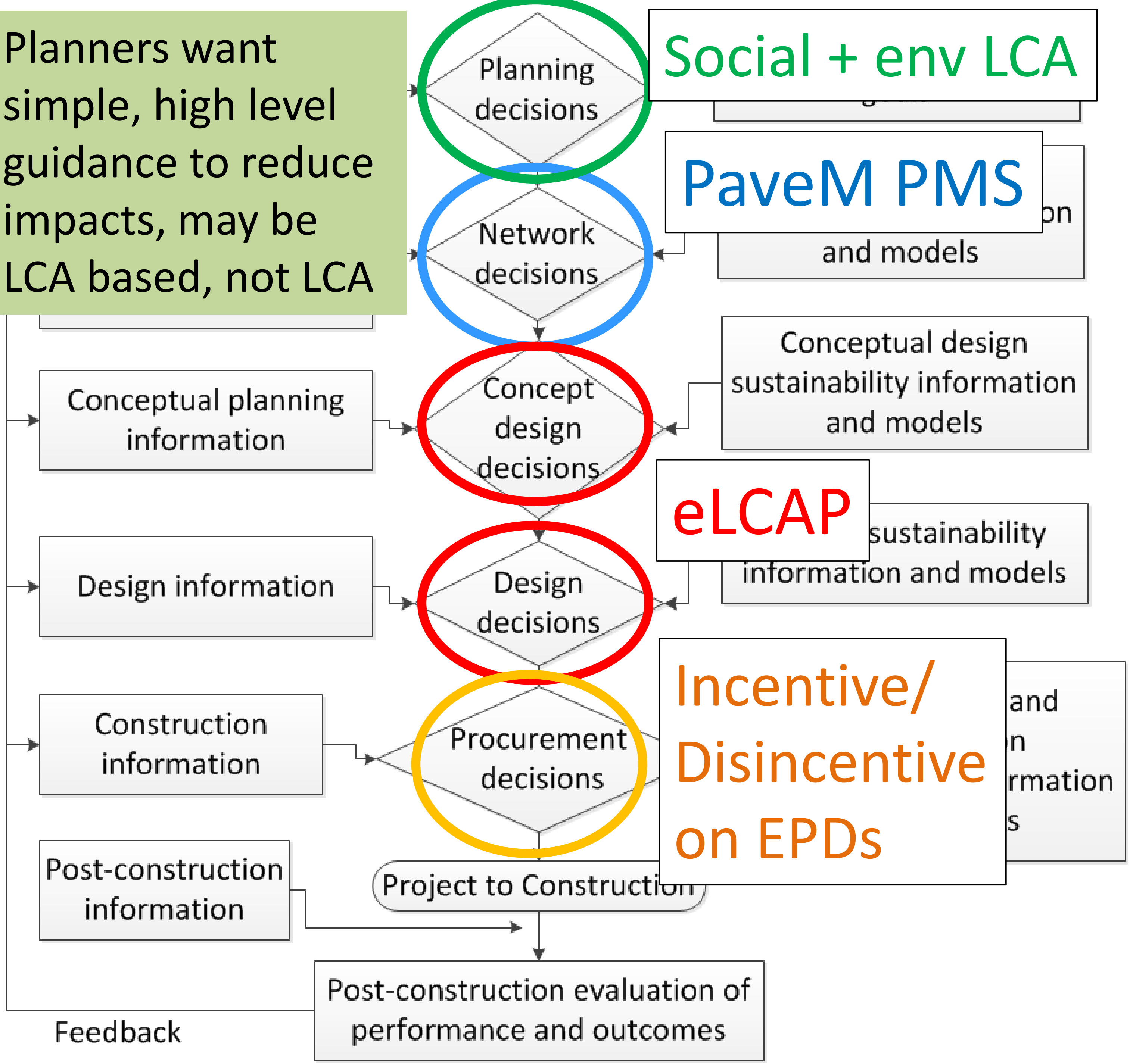
- Policy
  - Specifications, design methods, mandates, regulations
- Asset management
- Planning
- Conceptual Design
- Design
- Procurement
  - In design-bid-build (low-bid) assess incentive/disincentive payments against baseline for critical impacts
  - A+B+C+D: Contractors and agencies already know how to do this for construction quality, schedule, smoothness
  - Periodically raise the bar

Objective: web-based integrated tools for:

- Planning
- Network
- Concept
- Design
- Procurement

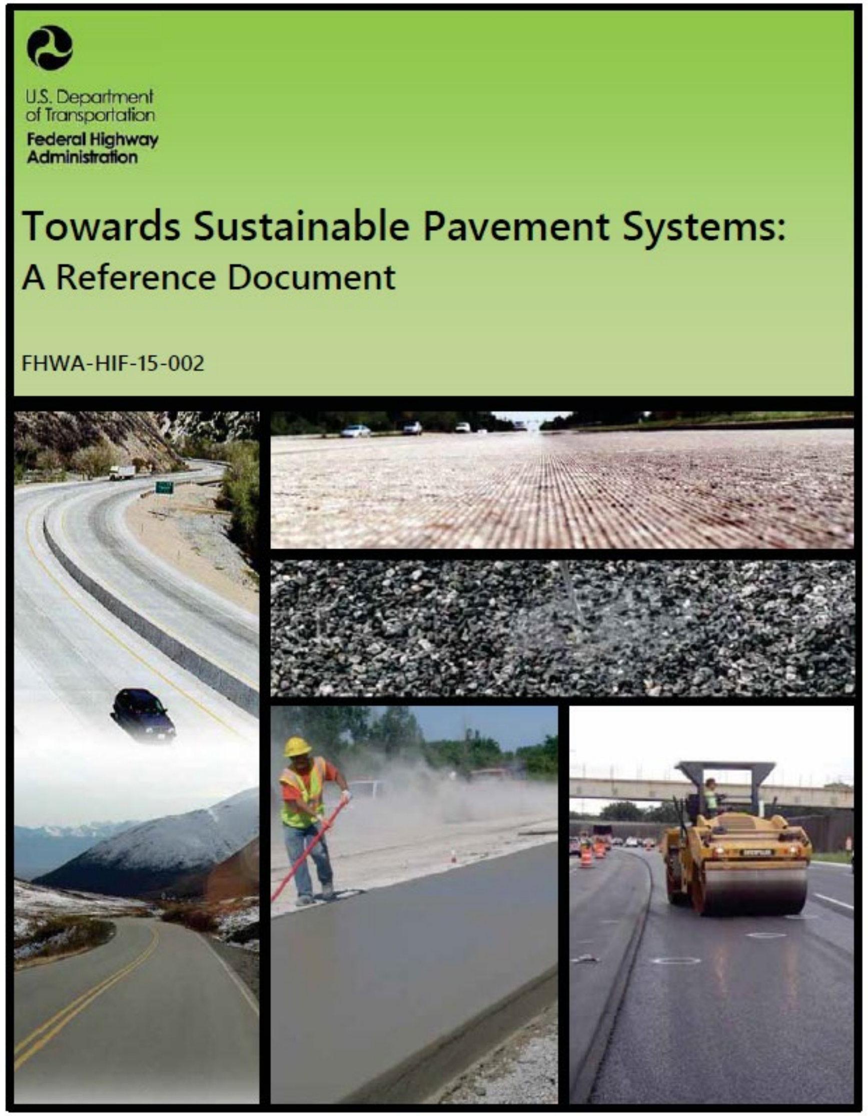
With complete life cycle data regionally applicable data

Planners want simple, high level guidance to reduce impacts, may be LCA based, not LCA

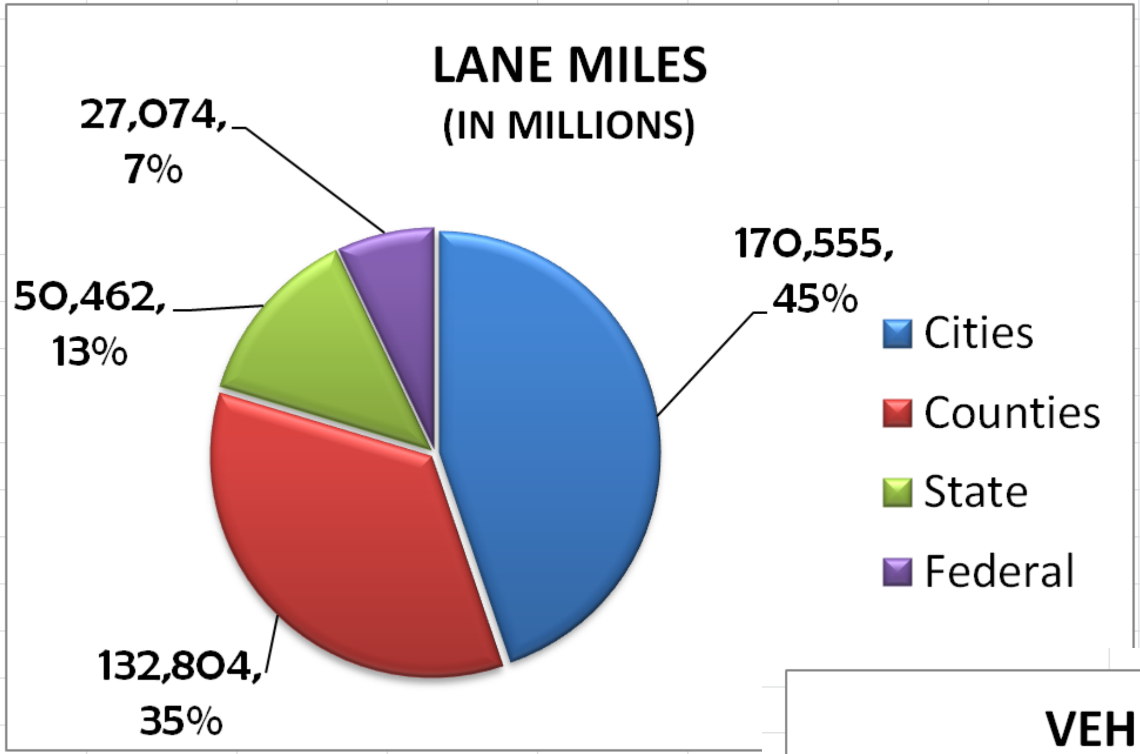


FHWA Reference Document: Towards More Sustainable Pavement

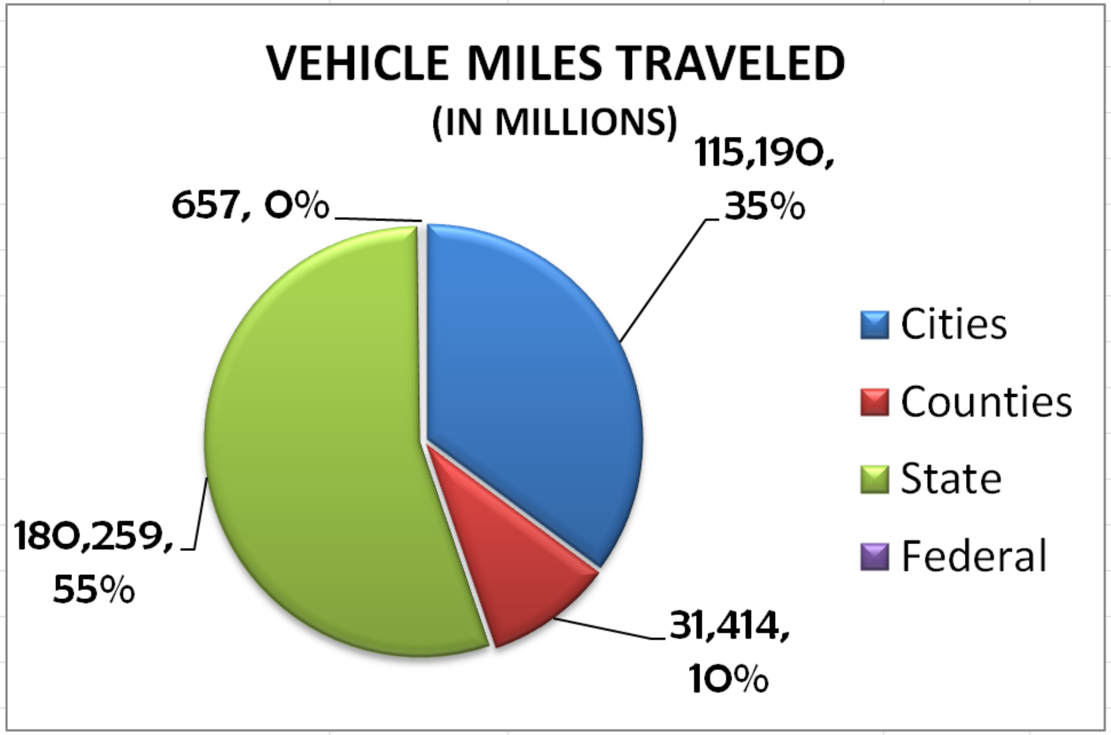
- Published in 2015
- Written with full system, complete life cycle perspective
- Summarizes basics of each step in pavement life cycle
- Presents strategies for reducing environmental impact through each stage of life cycle
- Summarizes life cycle assessment, life cycle cost analysis



Why is Local Government Pavement Important to Sustainability?

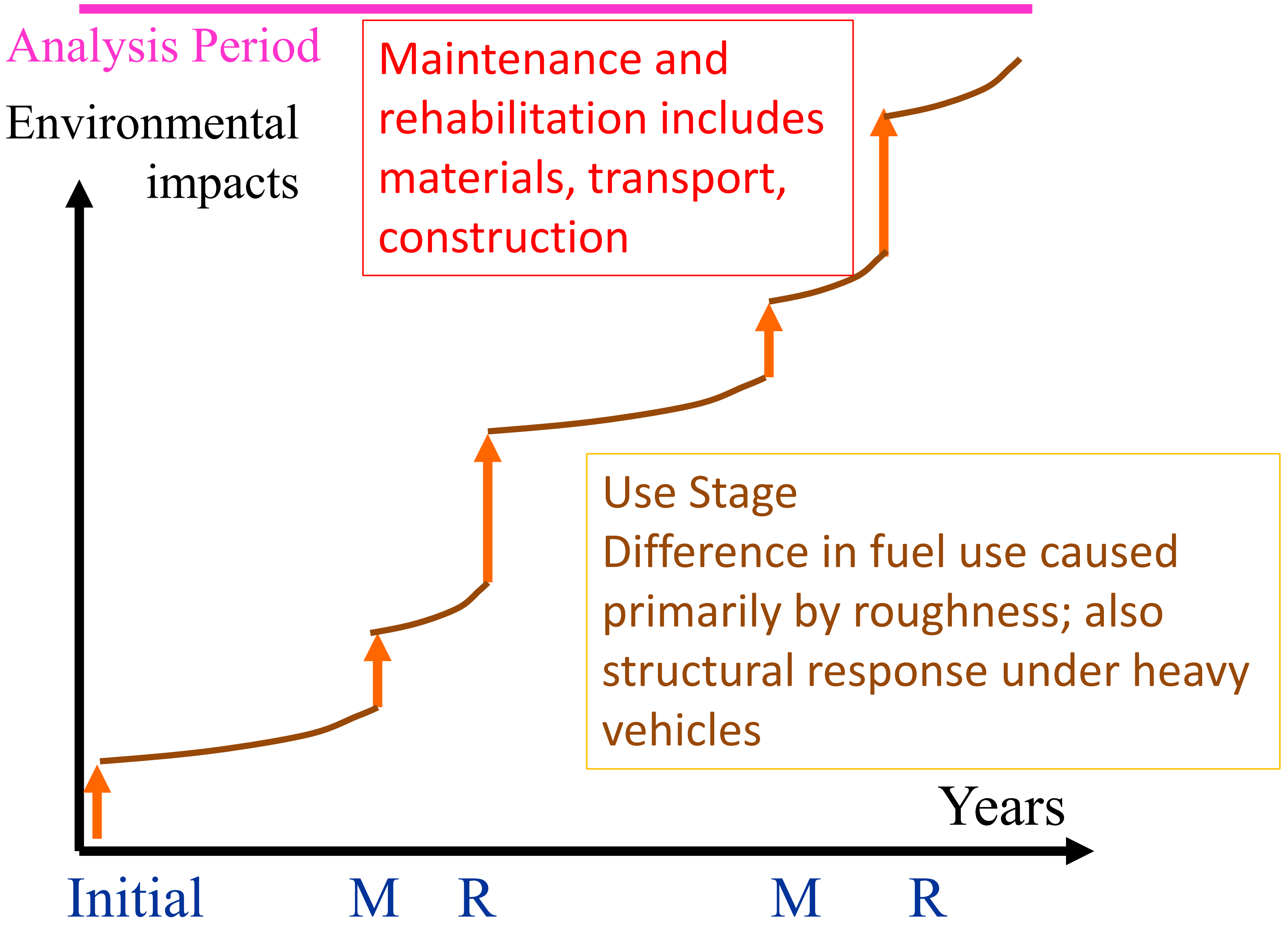


State and local governments have similar amounts of:
- Spending
- Materials use

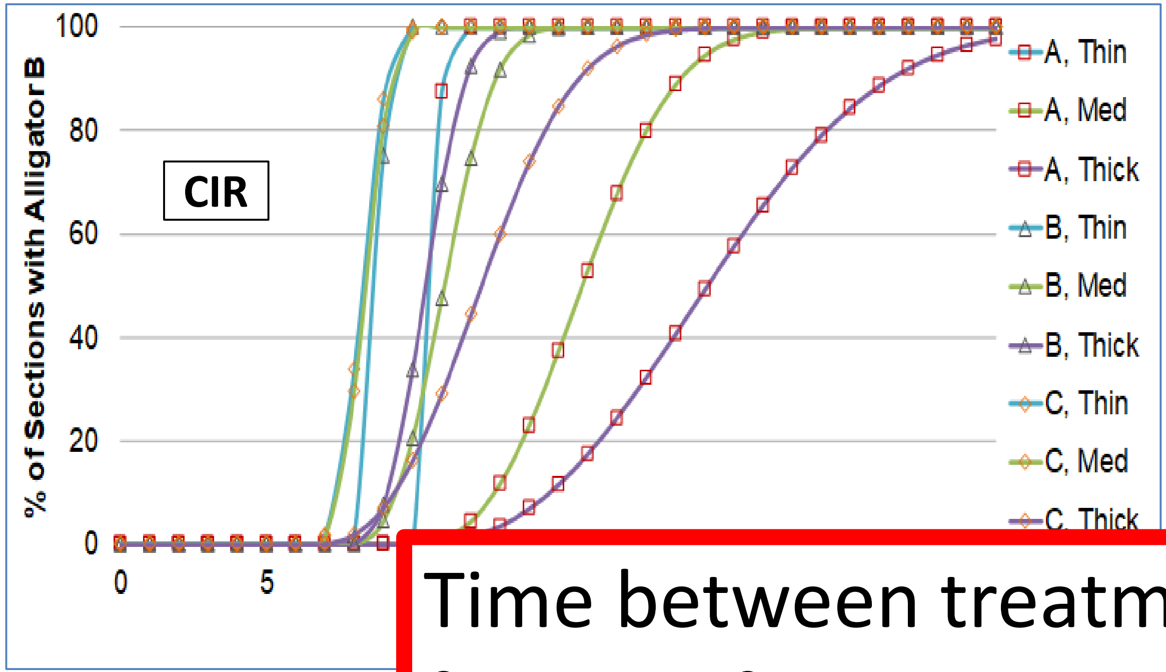


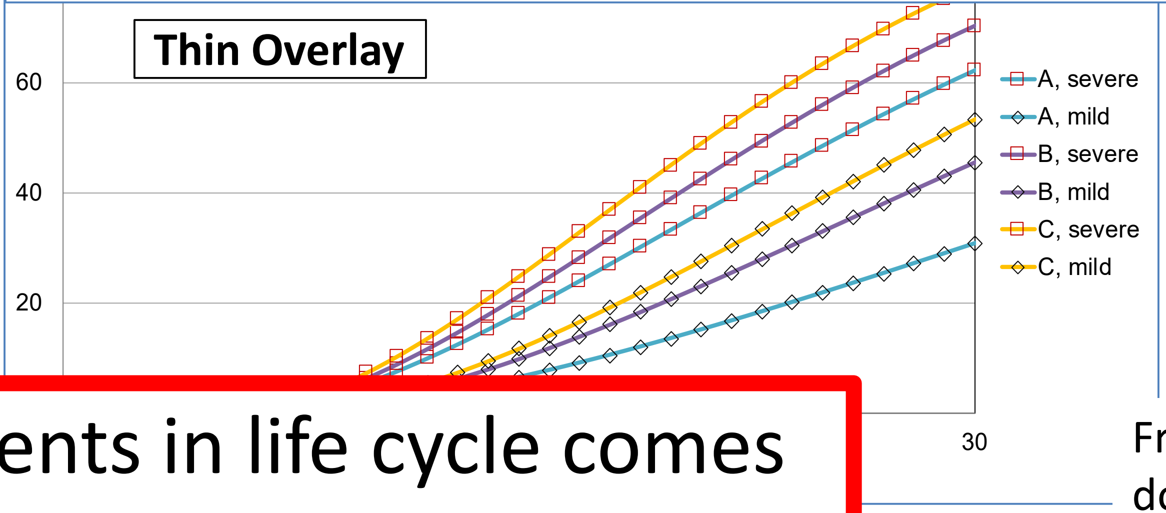
Environmental Impacts over the Pavement Life Cycle

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



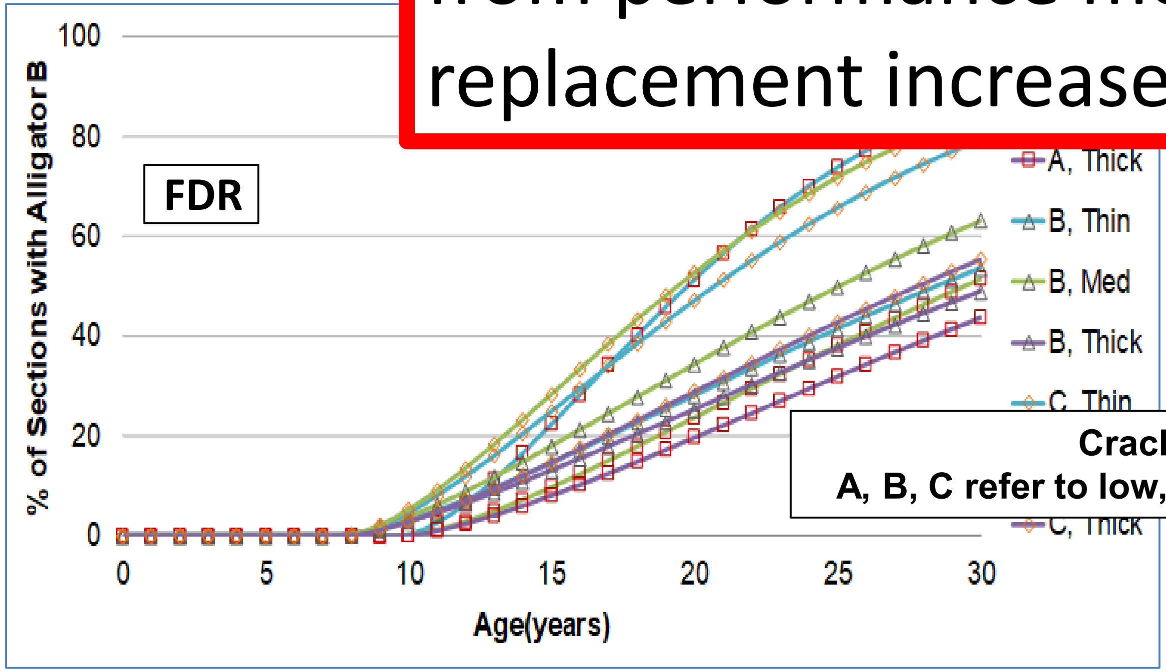
Performance models for wheelpath cracking from Caltrans PMS data, similar for IRI for Use Stage

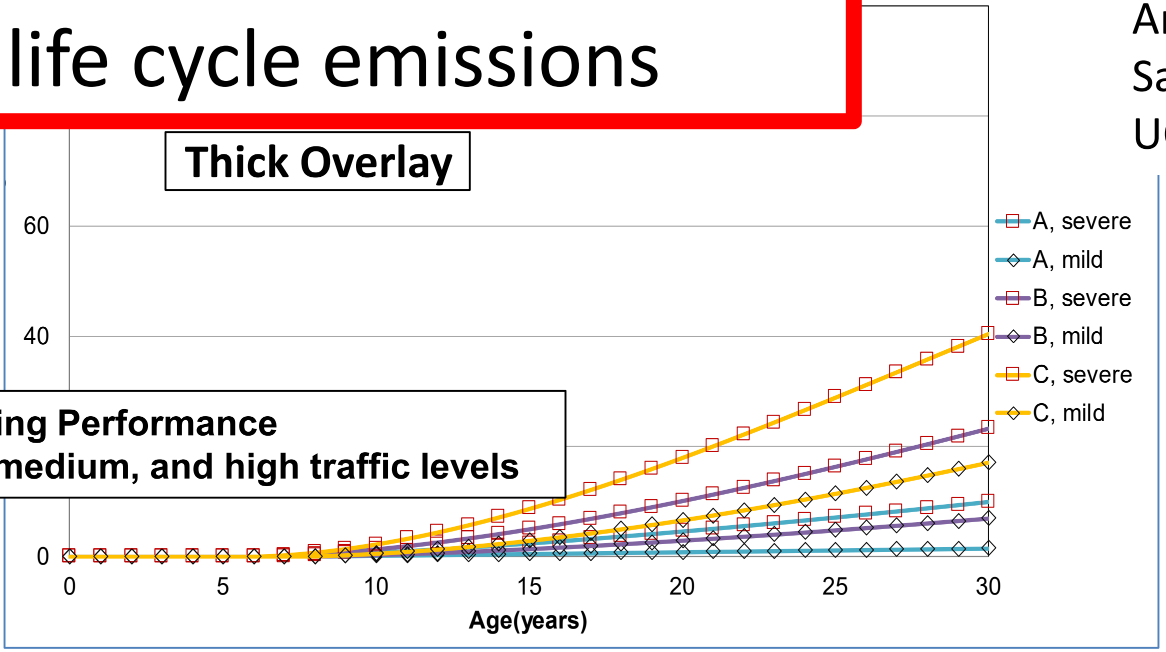




Time between treatments in life cycle comes from performance models; more frequent replacement increase life cycle emissions

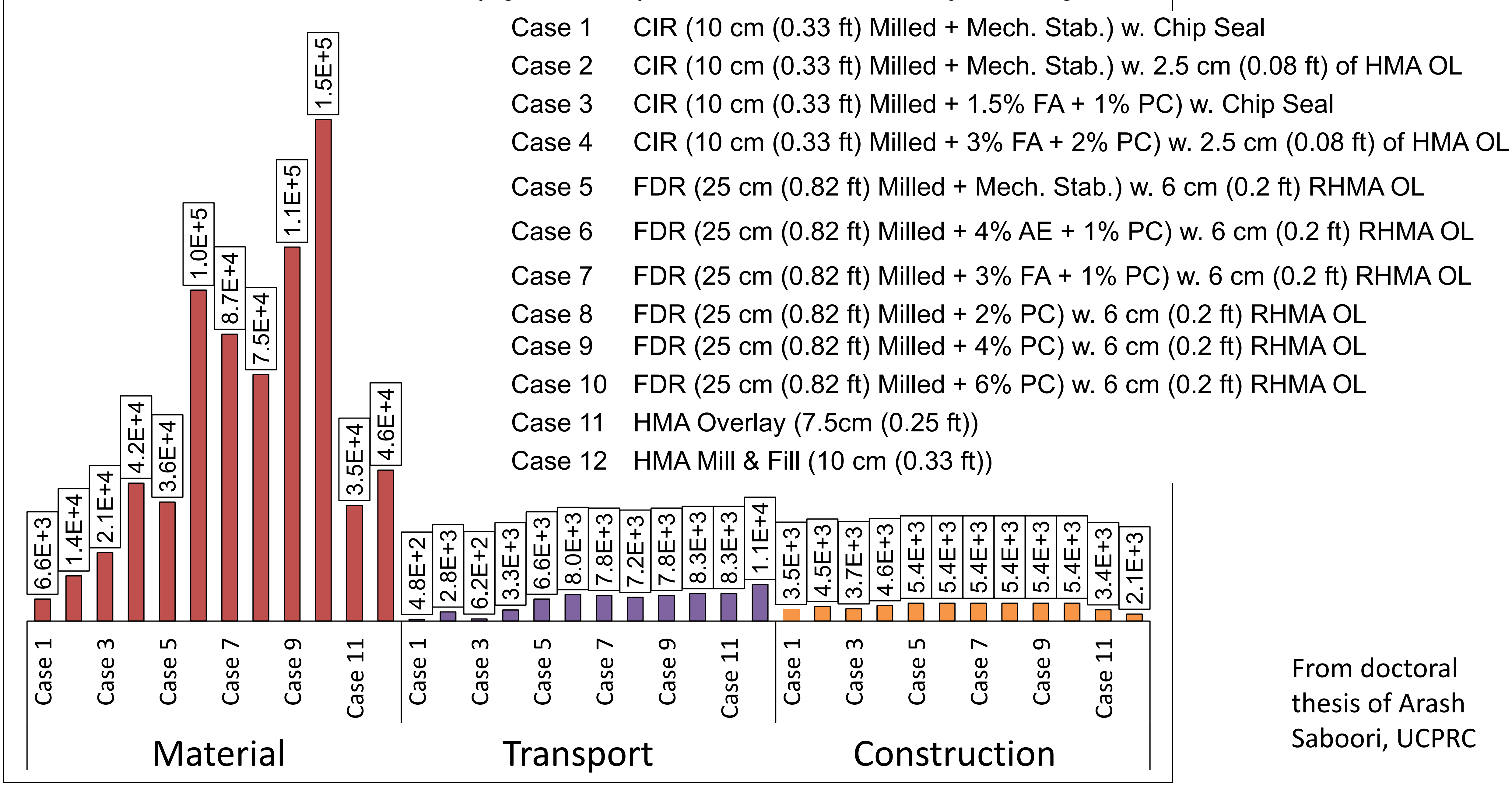
From doctoral thesis of Arash Saboori, UCPRC





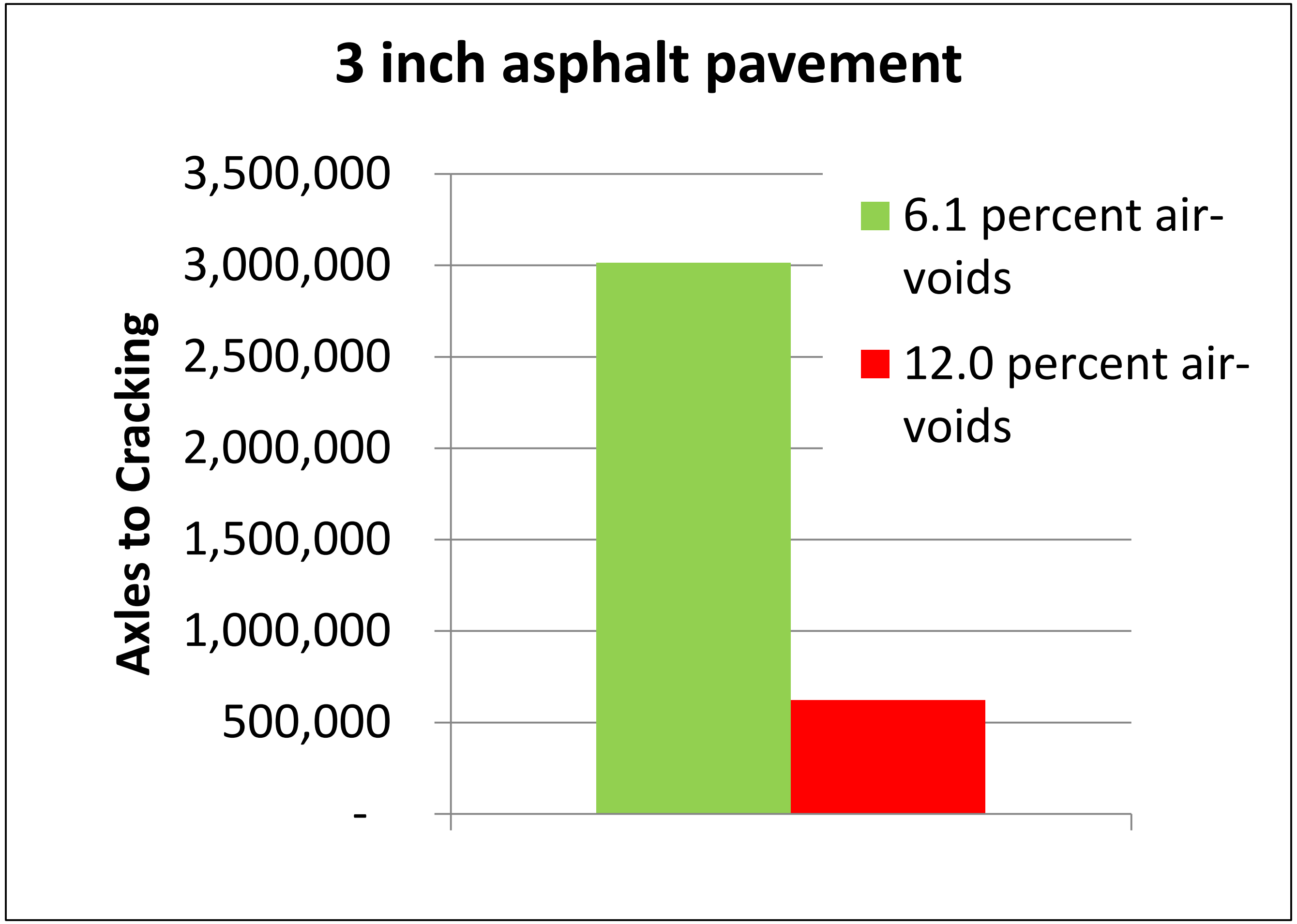
Cracking Performance
A, B, C refer to low, medium, and high traffic levels

Comparison of Materials & Construction GHG Emissions (kg of CO2e) for 1 ln-km per Life Cycle Stage



From doctoral thesis of Arash Saboori, UCPRC

Effect of asphalt construction compaction on axle loads to cracking



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

Simulation based on FHWA Westrack project field results

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!


Best Practices for Pavement

Is your asphalt only living half as long as it could?

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Writing and enforcing specifications for asphalt compaction

May 2017

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!

Best Practices for Pavement

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When did you last review your concrete specifications?

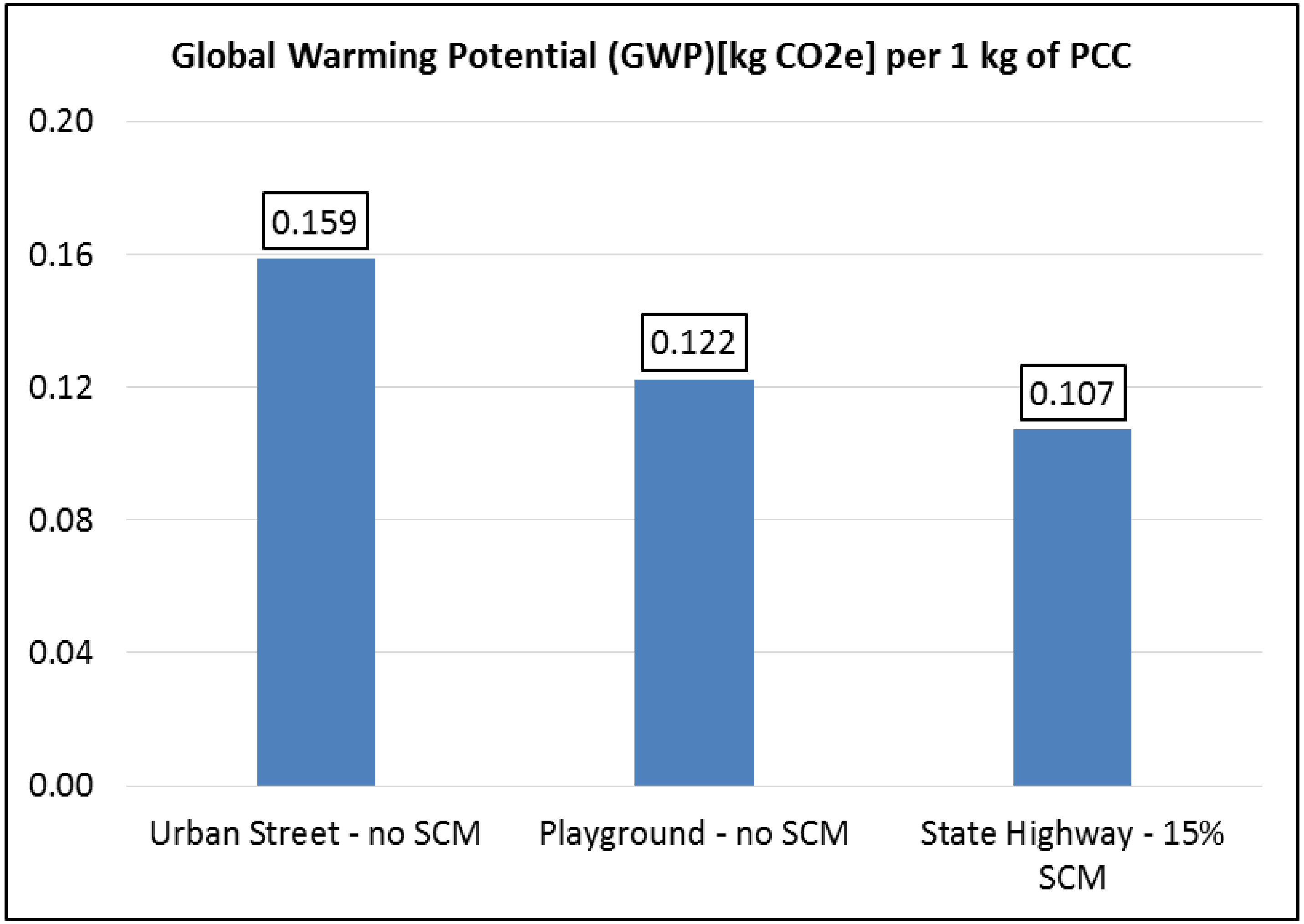
City and County Pavement Improvement Center

Writing concrete mix specifications to improve durability and sustainability

June 2019

Effects on greenhouse gas emissions

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

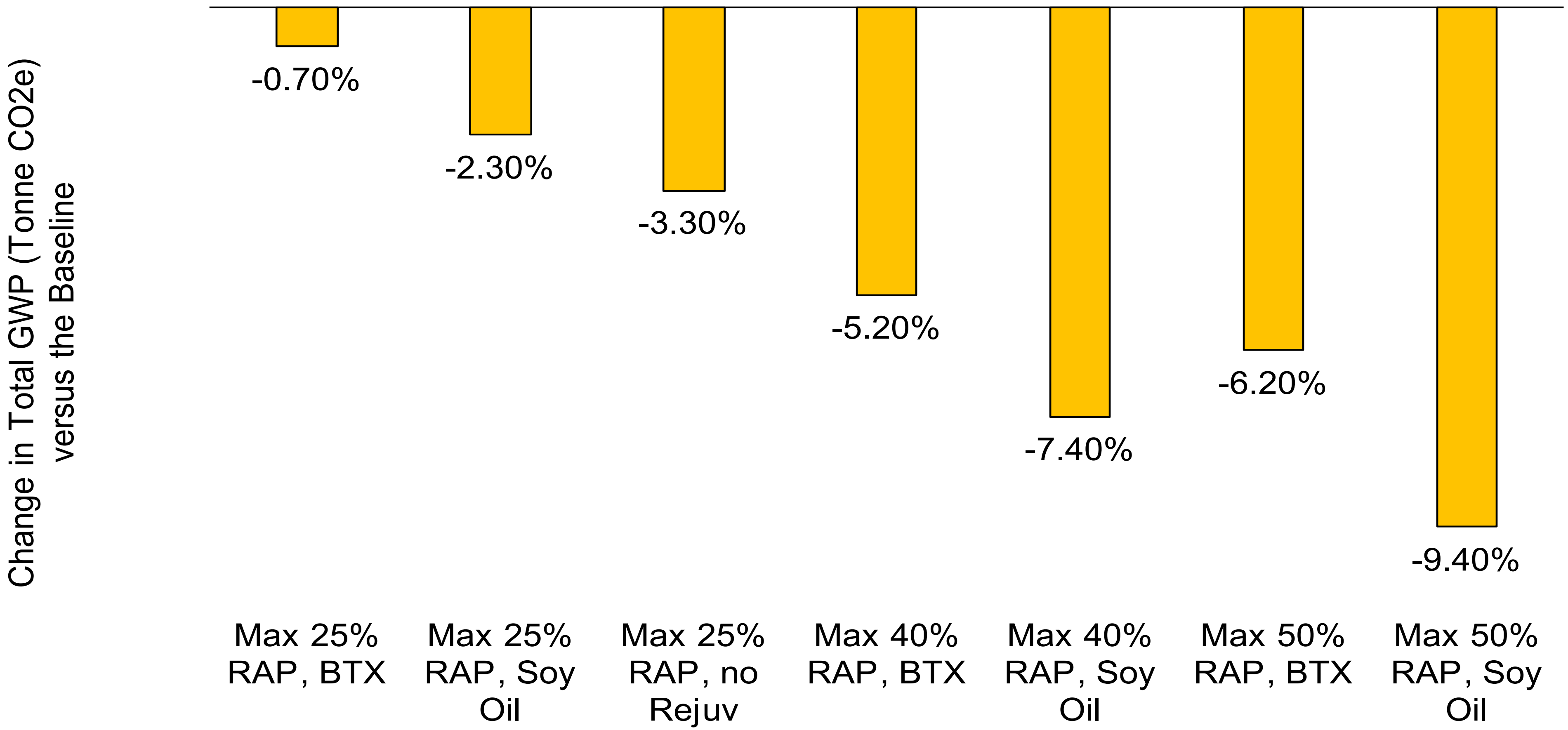


Greenhouse Gases HMA vs RHMA

- 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

Use of Rubberized RAP in HMA

- Early RHMA-G projects are starting to be rehabilitated, showing up in RAP
- Study compared mixes with RAP and R-RAP
  - R-RAP mixes had equal or slightly better performance to HMA with no RAP in laboratory
  - No requirement to have separate RAP and R-RAP piles

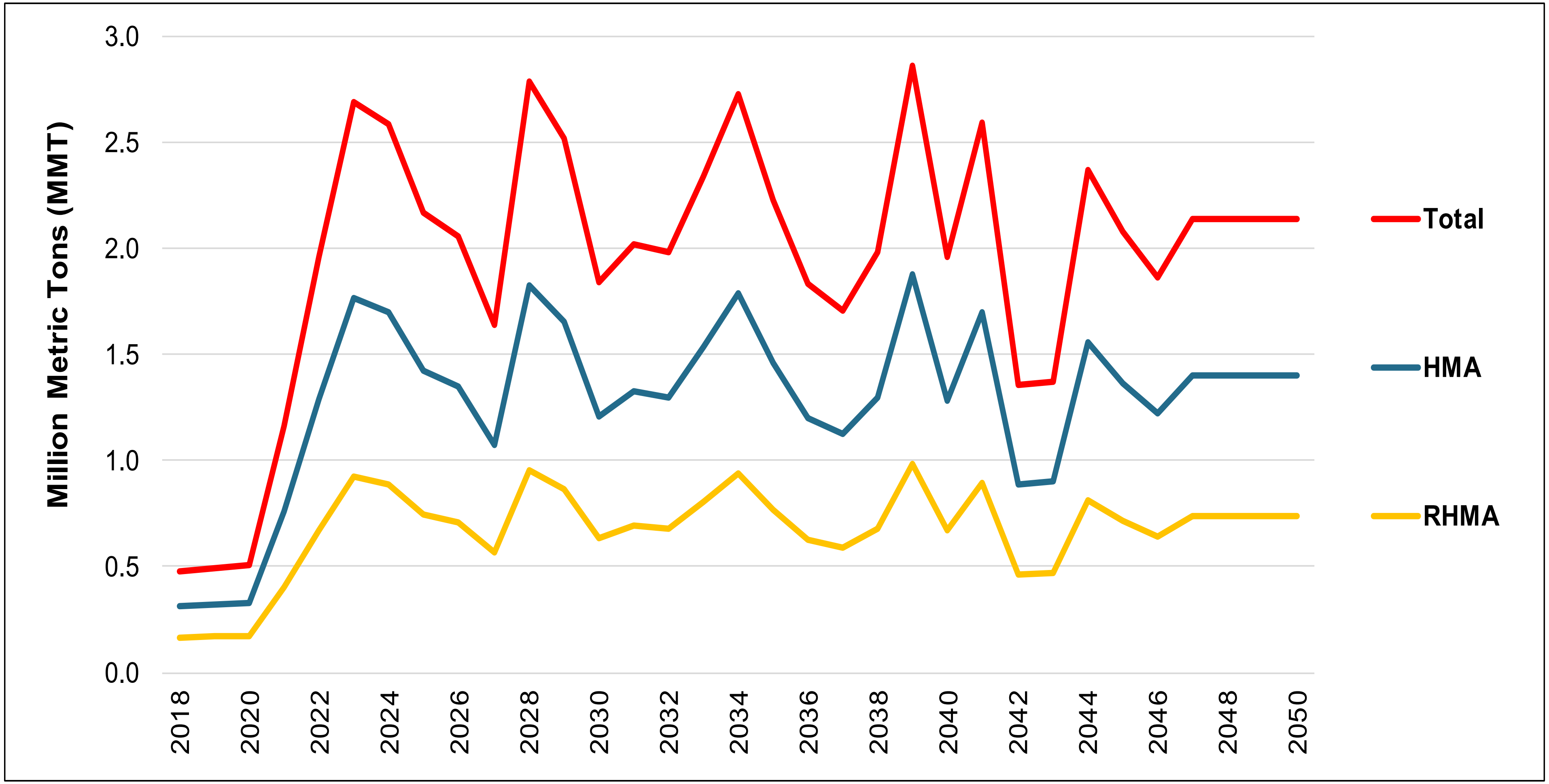
Caltrans Network: Use of Optimized IRI Triggers for Maintenance and Rehabilitation in Pavement Management System

Daily Passenger Car Equivalent traffic of lane-segments range	Total lane-miles	Percentile of lane-mile	Optimal IRI triggering value m/km, (inch/mile)
<2,517	12,068	<25	-----
2,517 to 11,704	12,068	25-50	2.8 (177)
11,704 to 19,108	4,827	50-60	2.0 (127)
19,108 to 33,908	4,827	60-70	2.0 (127)
33,908 to 64,656	4,827	70-80	1.6 (101)
64,656 to 95,184	4,827	80-90	1.6 (101)
>95,184	4,827	90-100	1.6 (101)

Wang et al 2014

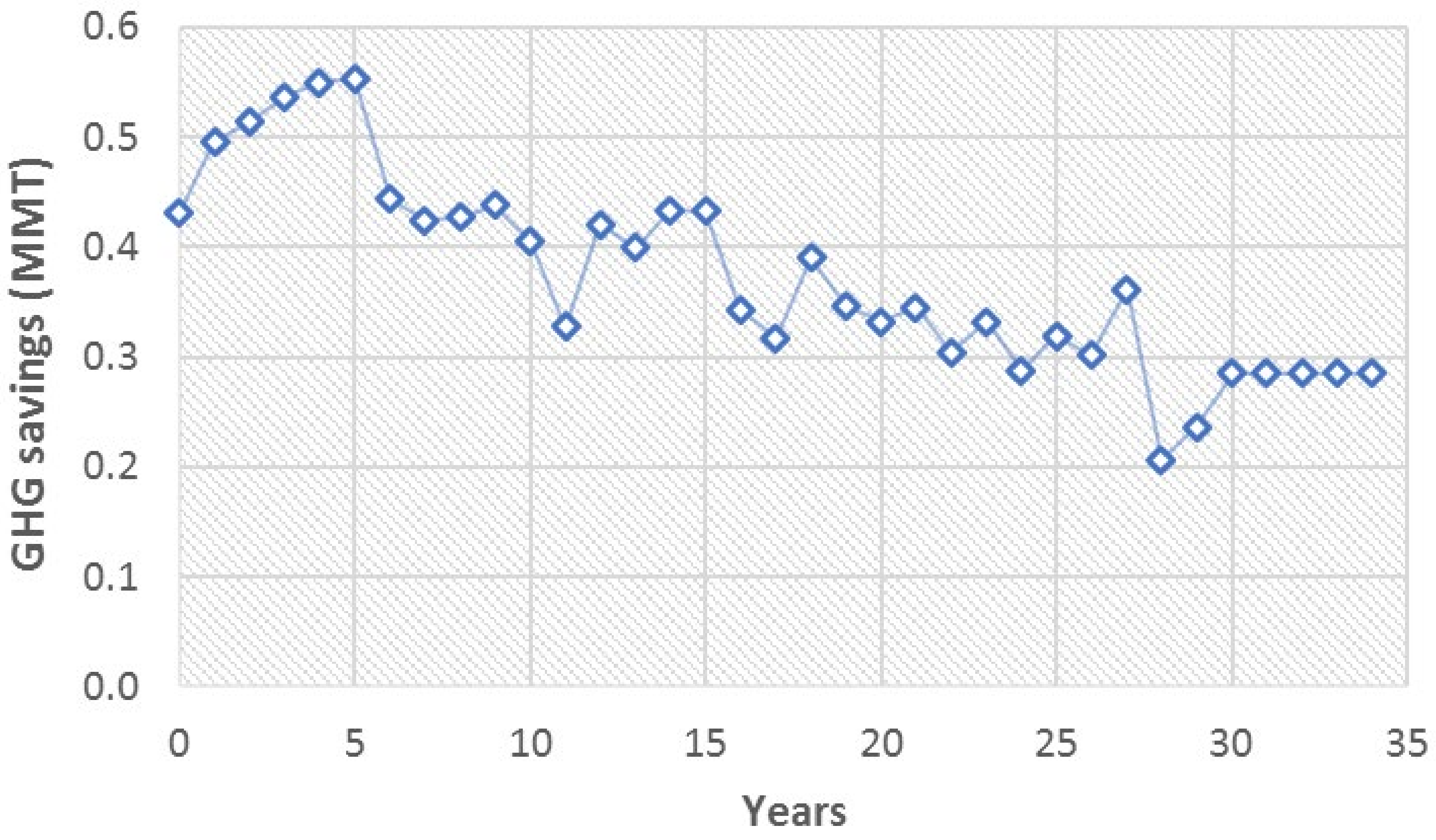
Estimated Asphalt Quantities on State Highways

- Increased production of HMA and RHMA
- New fuel tax
  - $2.5 billion more for state highways
  - $2.0 billion more for local roads



PMS Calculations of GHG Reductions from Use of Optimized IRI Triggers

(this analysis now run for every network work plan Caltrans considers)



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™

Caltrans EPD Requirements

- Caltrans is requiring EPDs for pavement and bridge materials on pilot projects in 2019
  - Hot mix asphalt
  - Concrete
  - Aggregate
  - Structural steel, Rebar per AB262
- For use in LCA and for reporting of GHG emissions
- https://dot.ca.gov/programs/engineering-services/environmental-product-declarations

Caltrans

Pilot Project Updates

Pilot Projects Requiring EPDs (updated 07/22/2019, a

Project EA	Estimated Advertise Date
01-0F960	May 5, 2019
01-0E040	July 25, 2019
02-1H110	July 22, 2019
02-4G500	July 15, 2019
05-1F740	December 28, 2018
07-31040	September 30, 2019
08-0K121	October 1, 2019
08-1F690	August 15, 2019
12-0N490	July 1, 2019

Recommendations from FHWA/Industry EPD Workshop, Michigan, 2016

- Develop rules and reporting, standardization of EPDs (1-2 years)
- Require use of standardized PCRs (3 to 5 years)
  - Need single operator or consortium
  - Produce a single PCR, appendices for specific materials
  - Fill gaps in public databases
  - Develop characterization of performance, must have for procurement
  - Implement reward system for plant specific vs average data
- If desirable, and sufficient progress, consider using for procurement
- Mukherjee et al, http://www.ucprc.ucdavis.edu/PDF/FHWA_EPD_Workshop_Report.pdf

PCR and EPD Harmonization from Caltrans Pilots

- Between PCRs
  - Inconsistencies in units, methods, common background data, allocation (in supply chain and between competitors), reporting
- Between EPDs within PCRs
  - Different interpretations of the same PCR rules

Issues with current approach to urban pavement

- Active transportation
  - Street geometric and surface designs generally don’t consider it
  - Bike path and trails are scaled down highway pavement designs
- Urban forests
  - Impermeability
  - Pavement and root growth
- Noise
  - Tire pavement noise at higher speeds
  - Non-absorptive for noise

Land8.com

Pavements = urban hardscape
not just roads and streets

- Stormwater management, groundwater infiltration
- Tire pavement noise
- Human thermal comfort
- Pedestrian and bicycle functionality
- Better interaction with urban forestry

HEAT ISLAND GROUP

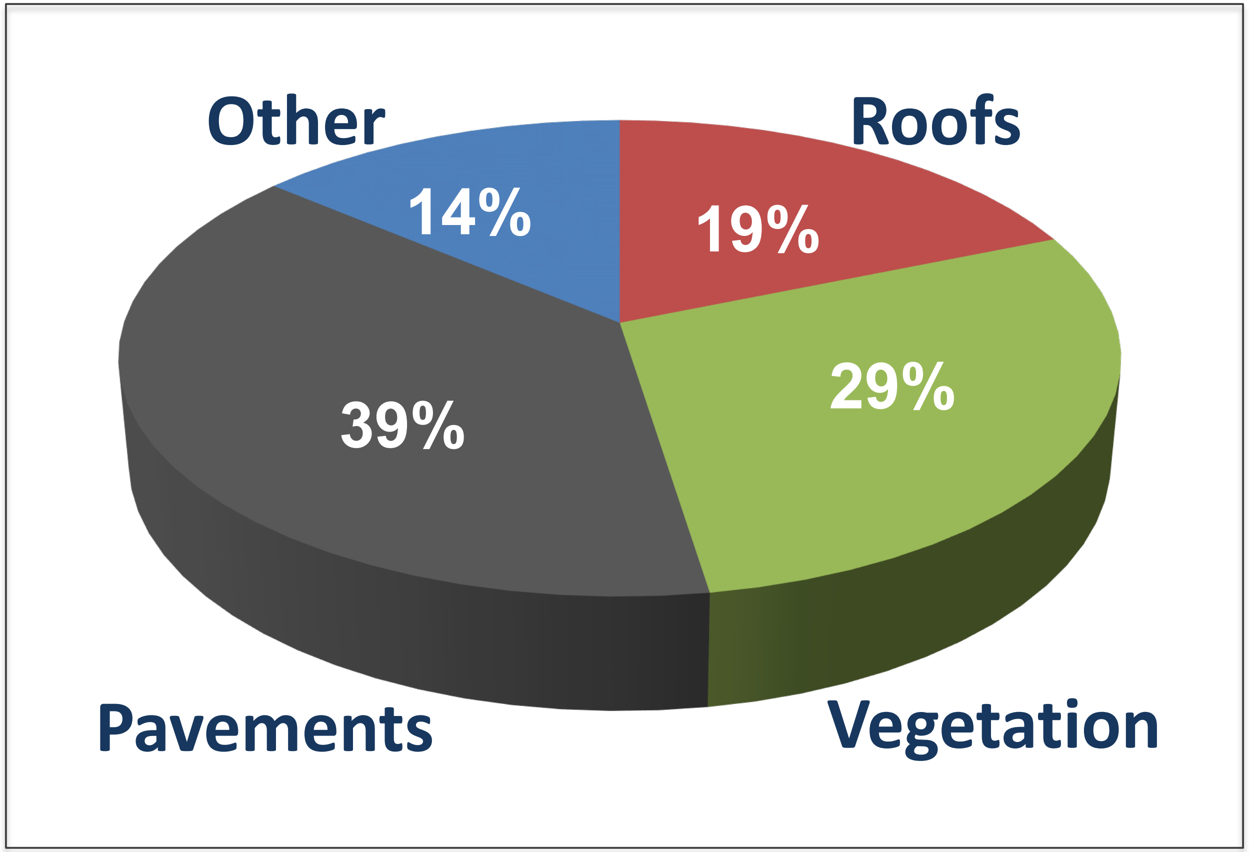
Life-Cycle Assessment and Co-benefits of Cool Pavements

Lawrence Berkeley National Laboratory
University of California Pavement Research Center
University of Southern California
thinkstep, Inc.

CalAPA, Sacramento, 25 Oct 2017

Abridged from
ARB Research Seminar
May 3, 2017
Sacramento, CA

Pavements are an important part of the urban environment

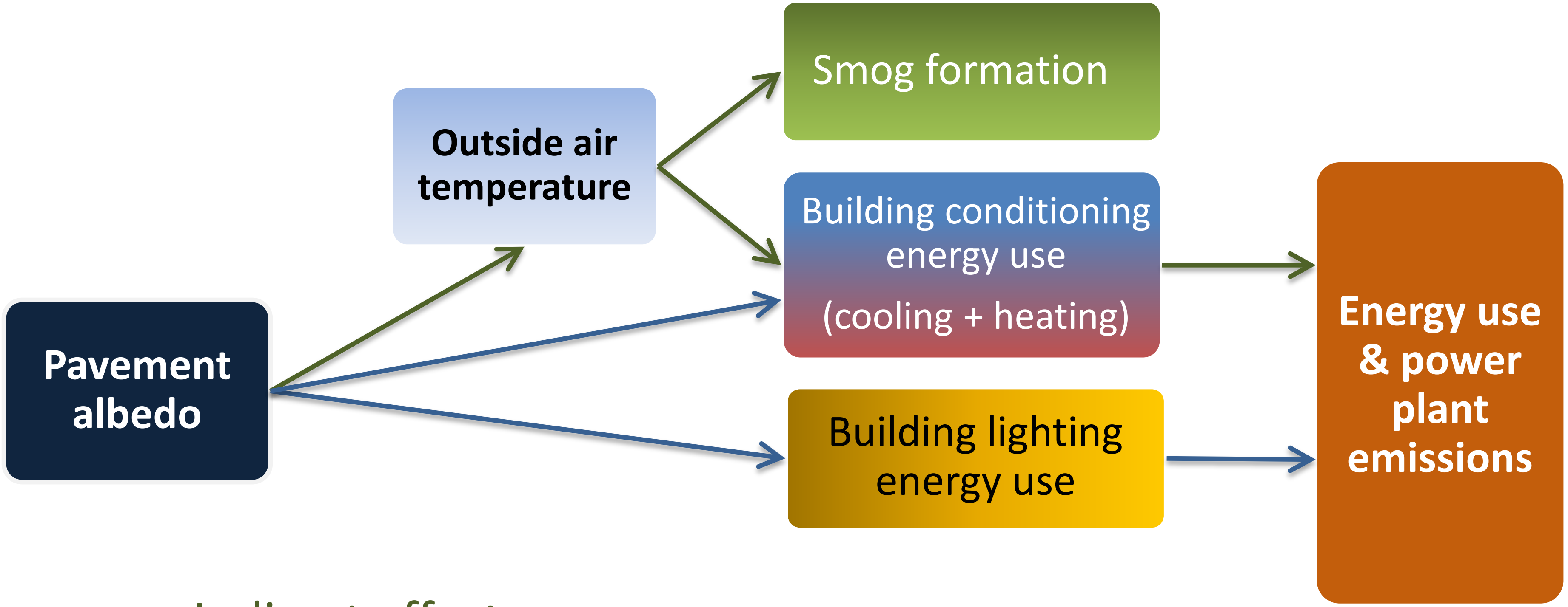


Sacramento

Fractions of land area were measured above tree canopy

Akbari et al. 2003 <doi:10.1016/S01692046(02)00165-2>

We analyzed use-stage effects that result from change in pavement albedo



- Indirect effect
- Direct effect

3 pavement scenarios: routine maintenance, rehabilitation, and long-life rehabilitation (ii)

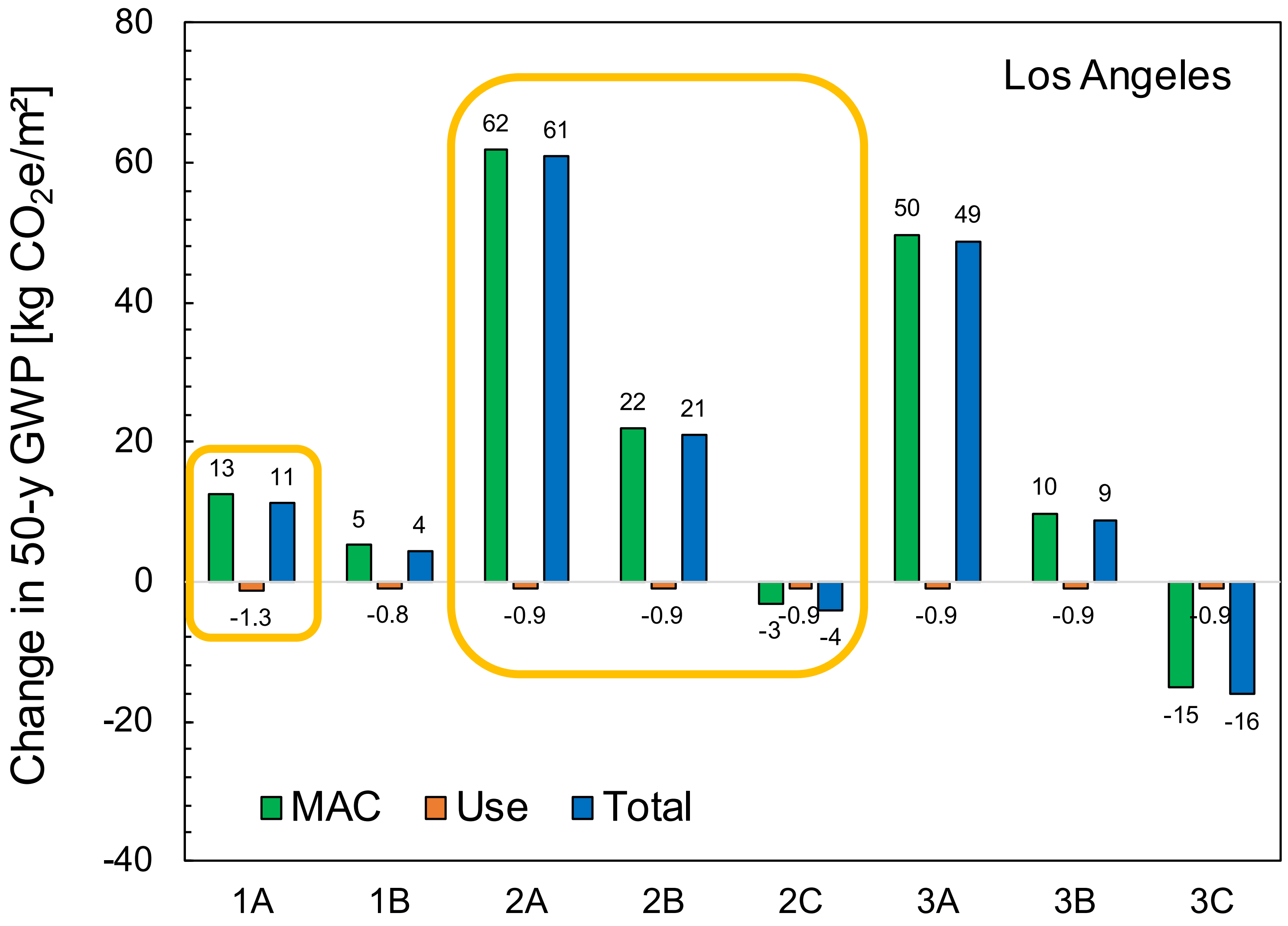
Rehabilitation case study

Treatment	Composition
Mill-and-fill AC	38% coarse aggregate, 57% fine aggregate, 5% dust, 4% asphalt binder, and 15% reclaimed asphalt pavement by mass
Bonded Concrete Overlay on Asphalt (no SCM)	1071 kg coarse aggregate, 598 kg fine aggregate, 448 kg cement, 1.8 kg polypropylene fibers, 1.9 kg water reducer (Daracern 65 at 390 mL per 100 kg of cement), 1.6 kg retarder (Daratard 17 at 325 mL per 100 kg of cement), 0.6 kg air entraining admixture (Daravair 1400 at 120 mL per 100 kg of cement), and 161 kg water per m^3 wet concrete
BCOA (low SCM)	1085 kg coarse aggregate, 764 kg fine aggregate, 267 kg cement, 71 kg fly ash, 1.8 kg polypropylene fibers, and 145 kg water per m^3 wet concrete
BCOA (high SCM)	1038 kg coarse aggregate, 817 kg fine aggregate, 139 kg cement, 56 kg slag, 84 kg of fly ash, and 173 kg water per m^3 wet concrete

Case study	Typical treatment	Less-typical treatment	Aged albedo	Albedo increase	Service life (y)	Thickness per installation (cm)	Thickness installed over 50 y (cm)
1. Routine maintenance	Slurry seal		0.10	-	7	-	-
		1A: Styrene acrylate reflective coating	0.30	0.20	5	-	-
2. Rehabilitation	Mill-and-fill AC		0.10	-	10	6	30
		2A: BCOA (no SCM)	0.25	0.15	20	10	25
		2B: BCOA (low SCM)	0.25	0.15	20	10	25
		2C: BCOA (high SCM)	0.25	0.15	20	10	25

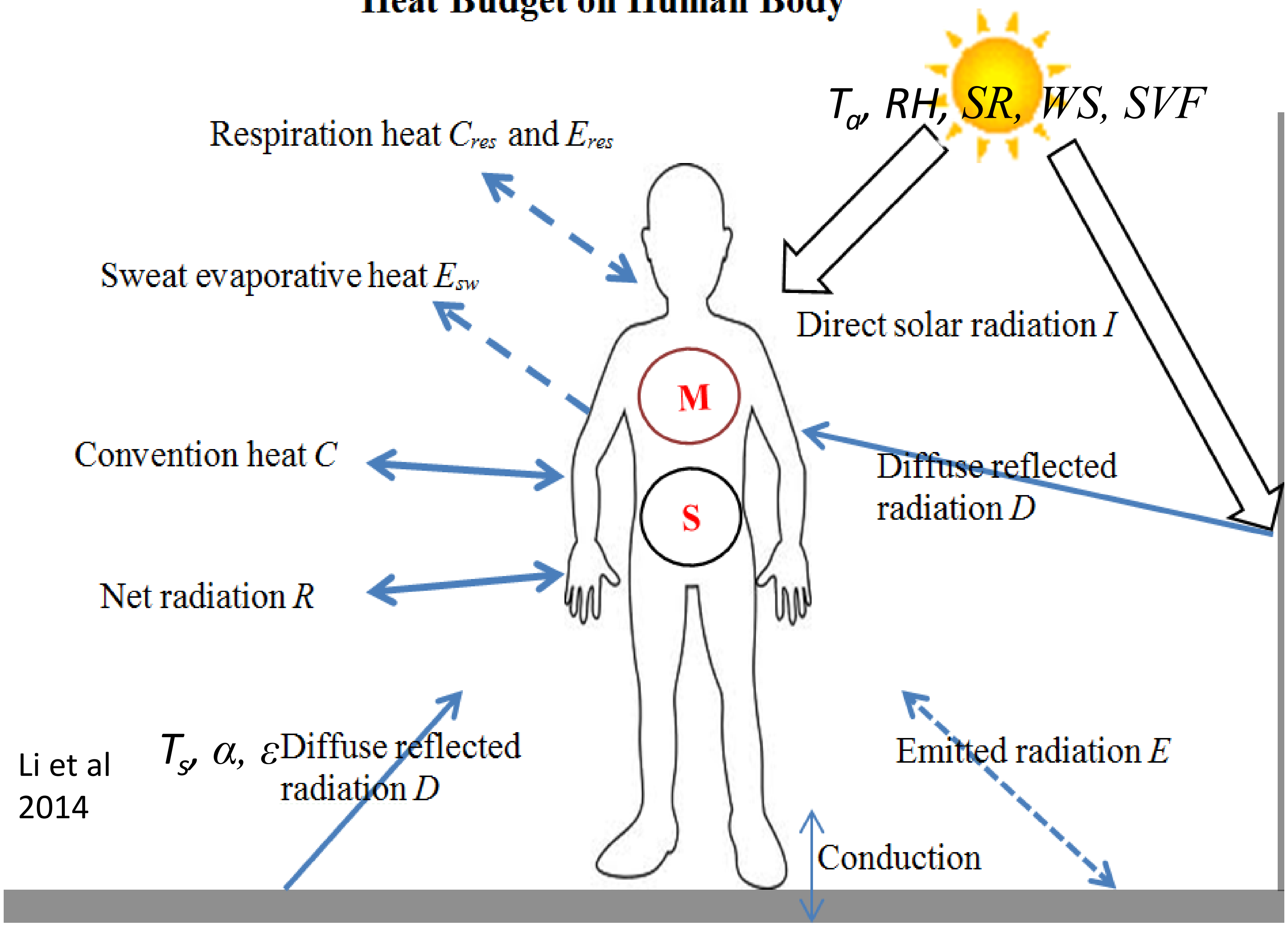
Case study	Typical treatment	Less-typical treatment	Aged albedo	Albedo increase	Service life (y)	Thickness per installation (cm)	Thickness installed over 50 y (cm)
3. Long-life rehabilitation	Mill-and-fill AC		0.10	-	20	15	37.5
		3A: BCOA (no SCM)	0.25	0.15	30	15	25
		3B: BCOA (low SCM)	0.25	0.15	30	15	25
		3C: BCOA (high SCM)	0.25	0.15	30	15	25

The Materials and Construction (MAC)-stage global warming potential changes exceed use-stage changes in LA



1A = slurry seal → reflective coating; 2A, 2B, 2C = mill-and-fill AC → no-, low-, or high-SCM BCOA

Heat Budget on Human Body



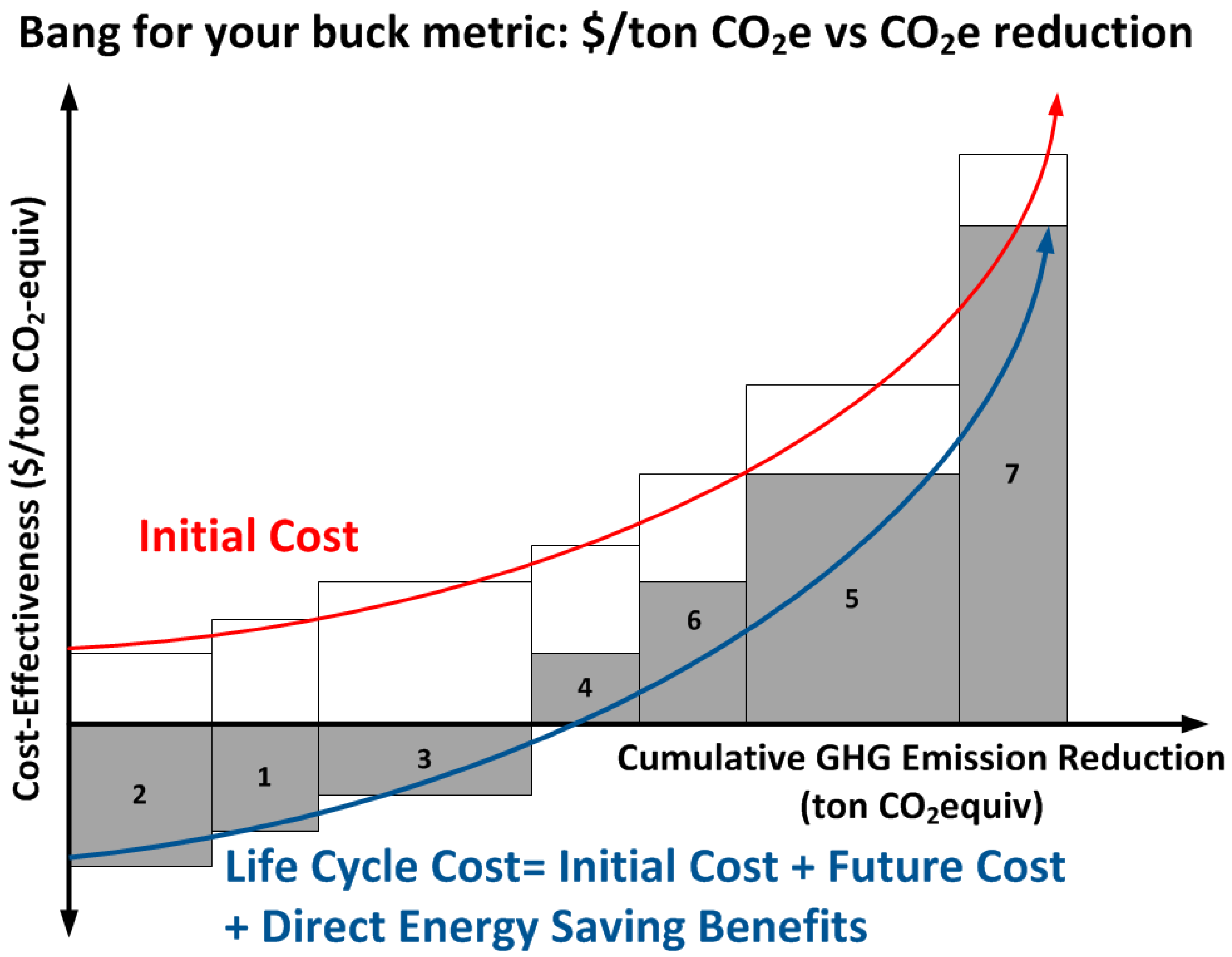
Li et al 2014

M is the metabolic rate (W/m^2). W is the rate of mechanical work (W/m^2). S (W/m^2) is the total storage heat flow in the body.

Evaluation of Alternative GHG Reduction Strategies Using LCA and LCCA

- Many proposed ideas to achieve environmental goals
  - Limited resources, need to not damage economy
- Need first-order analysis to determine which ideas to further investigate
  - Regulation, laws by state government
  - Specifications, policies by state and local agencies
  - New technologies to pursue
- Uses “supply curve” combining:
  - Environmental impact from Life Cycle Assessment
  - Cost impact from Life Cycle Cost Analysis
- Pilot projects at UCPRC
  - Caltrans changes to internal operations
  - Local government review of climate action plans

Supply Curve



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

Caltrans alternatives initially being looked at

Initial preliminary results

Strategy	MMT change 2015-2050	Cost/MT	Ready to Implement
Efficient maintenance of pavement roughness	13.2	$17-24	Very high
Energy harvesting through piezoelectric technology	0.7	-$165 to $530	Medium
Automating bridge tolling systems	0.4	$260	Very high
Increased use of reclaimed asphalt pavement	0.1 to 1.33	-$2500 to -$730	Medium
Electrification for light vehicles and bio-based diesel as alternative fuels for the Caltrans fleet	0.03 to 0.14	$511 to $6120	High
Installing solar and wind energy technologies within the state highway network right-of-ways	2.2 to 2.3	-$1285 to $305	Low (wind and roadside solar) to Very high (solar over parking)

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

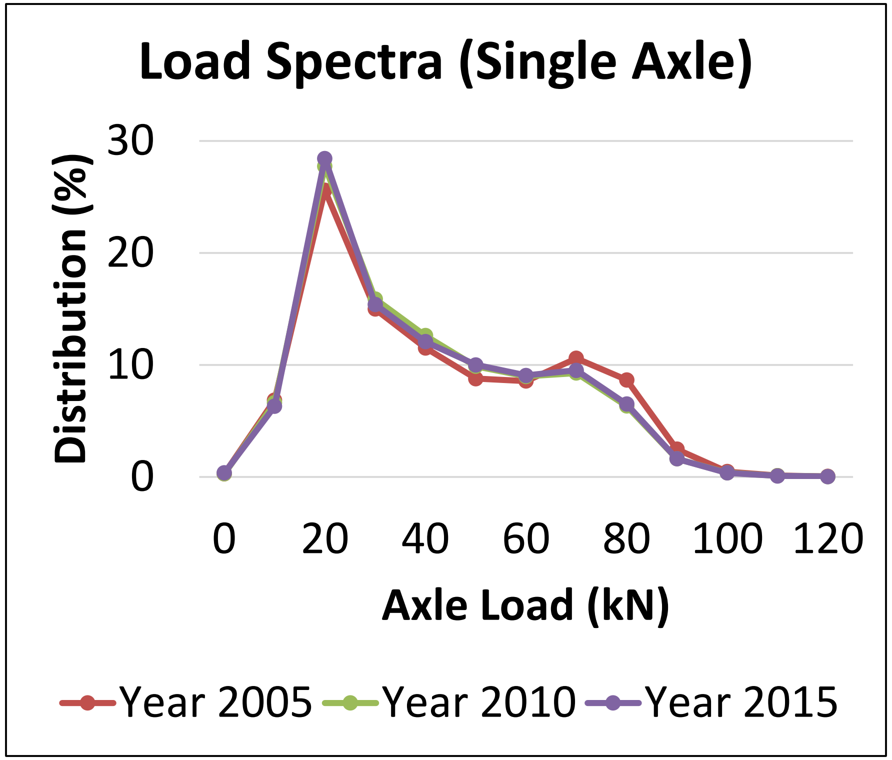
- Improve asphalt pavement life
  - Include asphalt compaction specifications
    - % of Theoretical Maximum Density, <u>not</u> % of Laboratory Test Max Density
  - Enforce asphalt compaction specifications
    - Review and communicate with contractor daily
  - Consider use of rubberized hot mix
- Improve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

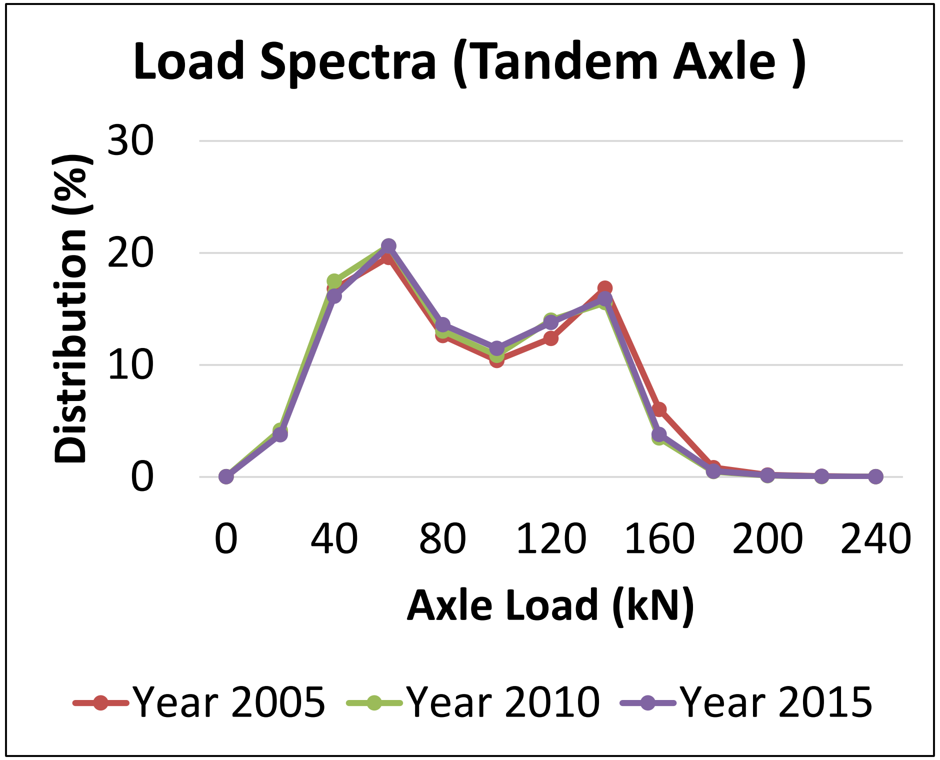
Recommendations for What You Can Do Now

- Practice timely pavement preservation
  - Seal coats before cracks and signficiant aging occur, especially for routes without heavy traffic
  - Optimize decision trees
- Consider full-depth reclamation where pavements have 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

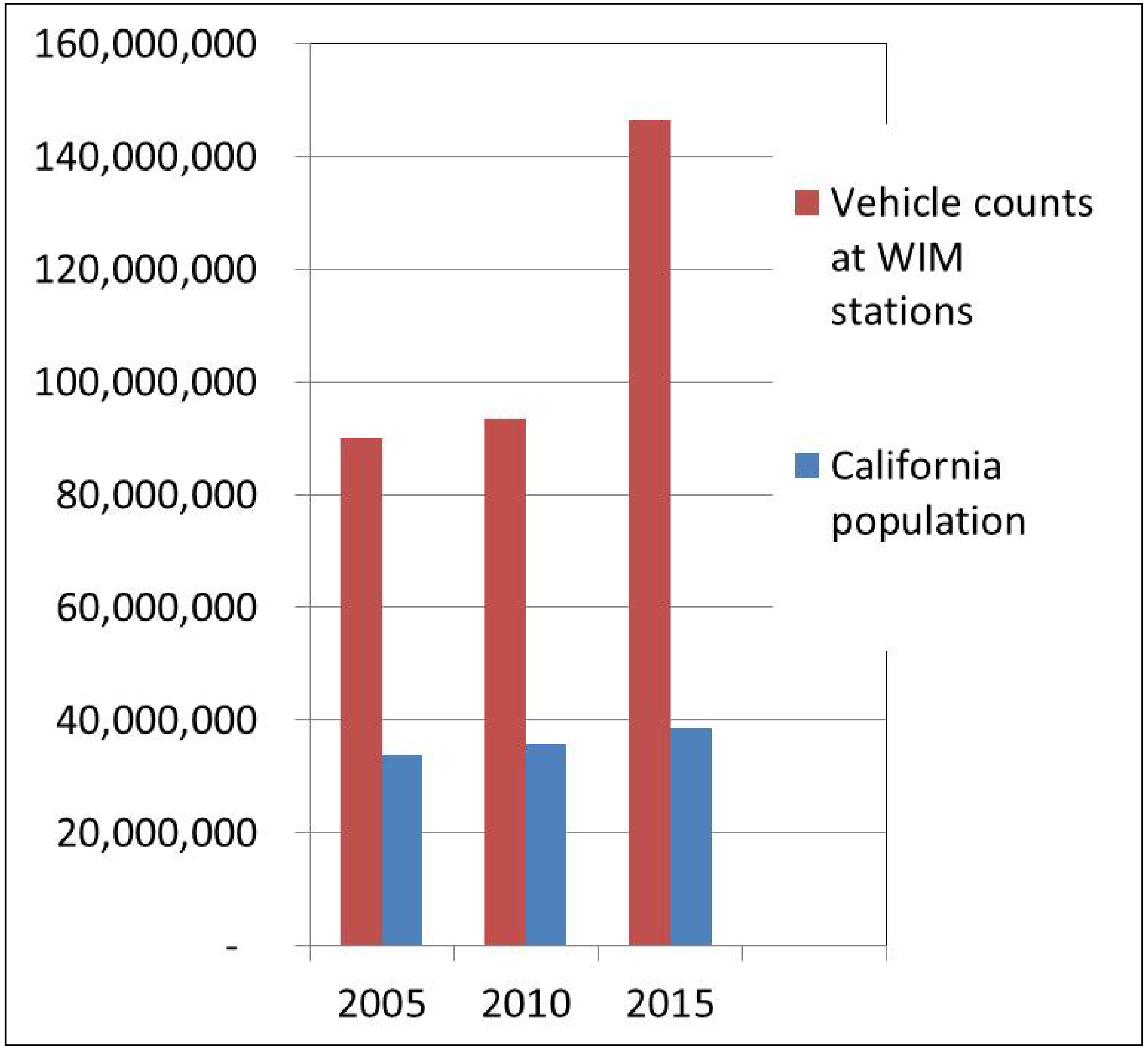
Truck traffic axle weights increasing?

- State-wide average axle loads (115 WIM stations) virtually unchanged in 10 years
- Gross vehicle weights slightly reduced





Freight growth: more trucks



- 62% increase in truck counts vs 14% growth in population
- Short-haul: 69% increase
- Long-haul: 59% increase

UCPRC/Caltrans WIM data

Thank You!

PAVEMENT
ROADWAYS
BRIDGES
LCA 2020
June 3-6, 2020 • Sacramento, California, USA

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”