Sustainability and Pavements: Are We Focusing On the Right Things?

Arizona Pavements/Materials Conference

"Technology that makes a difference"

ASU Memorial Union

Tempe, Arizona

November 15, 2011

Leif G. Wathne, P.E.

Talking Points

- Sustainability – What do we mean?
- In the Context of Pavements?
- What are we focusing on today?
- What should we be focusing on?
  - Life Cycle Assessment
  - The Use Phase…?
- Parting Thoughts

[**VanDam** 2009]

Sustainability and Pavements: Are we Focusing on the Right Things?

SUSTAINABILITY?

What is Sustainability?

- **Sustainability** – derived from Latin: *sustinēre* (from *sus*, up and *tenēre*, to hold) Essentially the capacity to **endure**.
- Term applied very broadly to every facet of life, but increasingly in the context of human sustainability on Earth – particularly as causes of global warming and climate change are debated.

Sustainability?

- Highway Engineer will focus on
  - Structural design
  - Pavement materials
  - Construction
- Items such as:
  - Recycling
  - Industrial byproducts
  - Resource conservation
  - Energy use

Are we missing significant opportunities?

Are we missing the target?

Sustainability?

YES!

- Opportunities are missed by ignoring the operational or use-phase of the pavement!
- Research suggests the long-term, cumulative benefits are staggering *[Europe, North America]*
- Mostly relates to fuel use and surface reflectivity
- So, central question for engineers/administrators: In the context of sustainable practices…

  Are we focusing on the right things?

Sustainability and Roadways?

- Fundamentally, how do we balance

  Natural environment,

  Societal needs,

  Economic vitality,

  when talking about pavements?

- Lots of research, lots has been written… but, significant confusion remains!

Sustainability and Roadways?

- ACPA Special Report on Green Roadways…
  - Emphasizes **longevity** as the primary opportunity!!

Green Roadways

Environmentally and Economically Sustainable Concrete Pavements

concrete pavement research and technology *special report*

Contents

Introduction....1
Longevity....2
Beyond Longevity....3
Reduced Fuel Consumption and Emissions....4
Fuel Savings During Use....4
Fuel Savings During Construction....5
Lower Energy Footprint....6
Reduced Use of Natural Resources....7
Use of Industrial Byproducts....8
Pavement Renewal....9
Quiet Surface Textures....9
Improved Water Quality....10
Pavement Recycling....11
Light-Colored and Cool....12
Reduced Lighting Requirement....12
Heat Island Mitigation....13
Global Cooling....14
Conclusions....15
References....15

ACPA

American Concrete Pavement Association

June 2011

Introduction

The concepts of "sustainability" and "sustainable development" are receiving considerable attention as the causes of global warming and climate change are debated. The World Commission on Environment and Development has defined sustainable development as "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

In recent years it has been suggested that in order for human activity to meet present needs without compromising the prospects of future generations, we need to carefully balance economic, environmental, and societal demands. This concept is often referred to as the "three pillars of sustainability" or the "triple-bottom-line."

A major focus of this concept involves ensuring that sustainable practices in pavements go hand in hand with economic success. This is indeed true of concrete pavements.

Particularly because of its long life, concrete is an economical, cost-effective pavement solution that consumes minimal materials, energy, and other resources for construction, maintenance, and rehabilitation activities over its lifetime. Beyond longevity, other features of concrete pavement further enhance its sustainability:

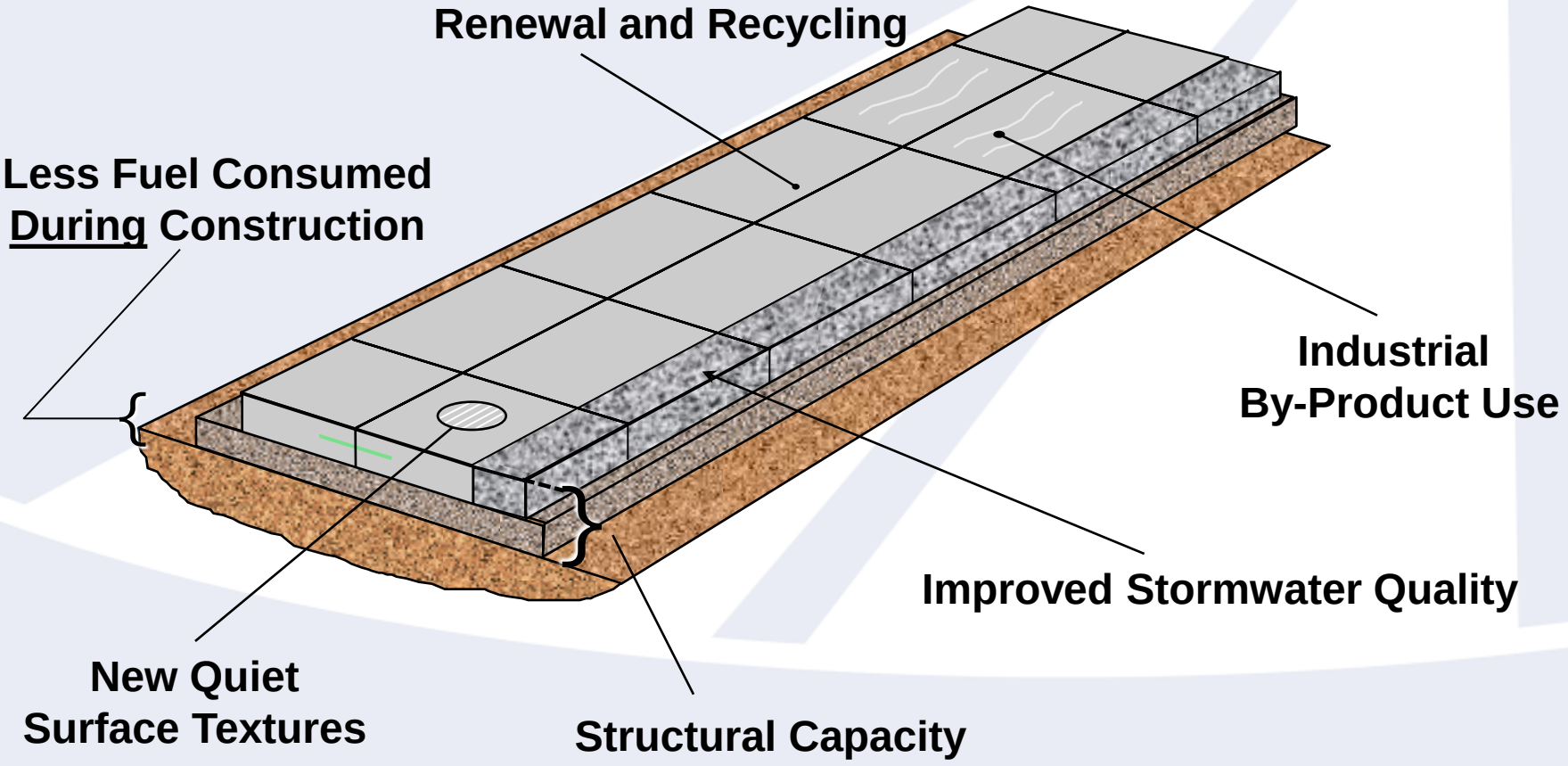
- Because of its rigidity, concrete pavement deflects less under vehicle loading, which results in reduced vehicle fuel consumption.
- The construction of concrete pavements consumes less fuel (particularly diesel) during materials production, transportation, and placement than the construction of asphalt pavements.
- Concrete pavements exhibit a lower energy footprint associated with their production, delivery, and maintenance than asphalt pavements do over a 50-year time period.
- Due to its inherent rigidity, concrete pavement requires less subbase aggregate materials for structural support than asphalt pavements.
- Concrete pavement mixtures incorporate industrial byproducts (i.e., fly ash and slag cement), which lowers the disposal needs, reduces the demand on virgin materials, and conserves natural resources.

Figure 1. An example of a green, sustainable concrete pavement; see ACPA's QD025P-1, "Nall Avenue: A Green Street," for details on the sustainability-related benefits of this project (photo courtesy of The City of Overland Park, Kansas).

- Countless examples worldwide!

Sustainable Benefits *Beyond* Longevity

Can be achieved through selection design and mixture optimization!



Sustainability and Roadways…

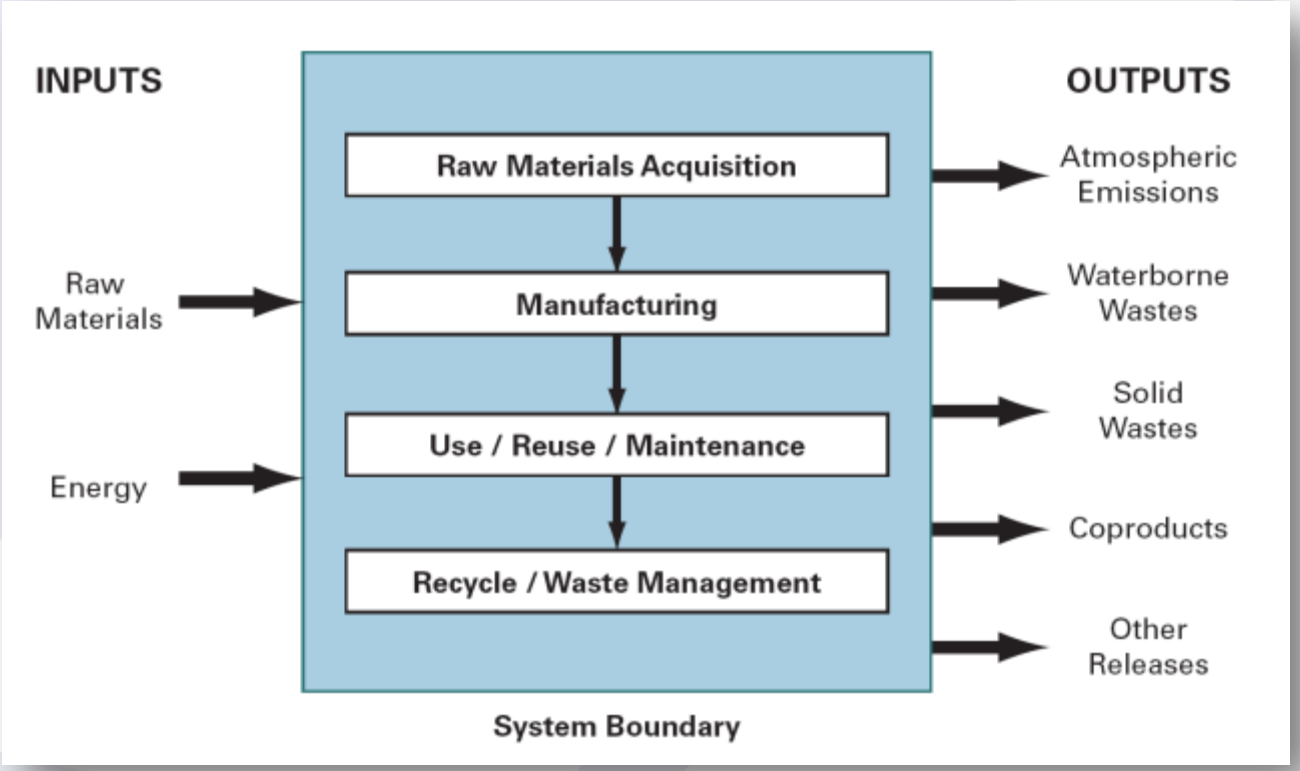
What to make of all these opportunities?

- ***Cradle-to-grave*** or ***end-to-end*** analysis has emerged…
- Life Cycle Assessment (LCA) (***not LCCA***)

  ISO 14040 series of standards
- Involves a "***cumulative analysis of impacts throughout <u>all</u> stages of the life cycle***"

Sustainability and Roadways…

- LCA concept *[EPA 2006]*



- Captures ”use-phase” (traffic impact etc.)

Sustainability and Roadways…

Only via this kind of comprehensive Life Cycle Assessment will highway administrators be able to consider and properly account for the cumulative impacts of their decisions!

What are we doing?

What are we currently focusing on?

- Material Production & Construction!
  - **Recycled materials (RCA, RAP, rubber, shingles)**

  - **Industrial by-products (slag, flyash…)**

[Image PCA]

  - **Energy use and emissions (new cements, warm-mix)**

[Image Oldcastle]

What are we currently focusing on?

- Sustainability programs and rating systems have emerged for pavements.
  - GreenRoads (rate roadways, not an LCA)
  - FHWA Self Evaluation Tool (rating)
  - FHWA Sustainable Pavements TWG
  - ISI Envision (rating)
- Relate to production/construction phases
- Little is focused on the long-term use or operational phase of its life-cycle!

Sustainability and Pavements: Are we Focusing on the Right Things?

What should we be doing?

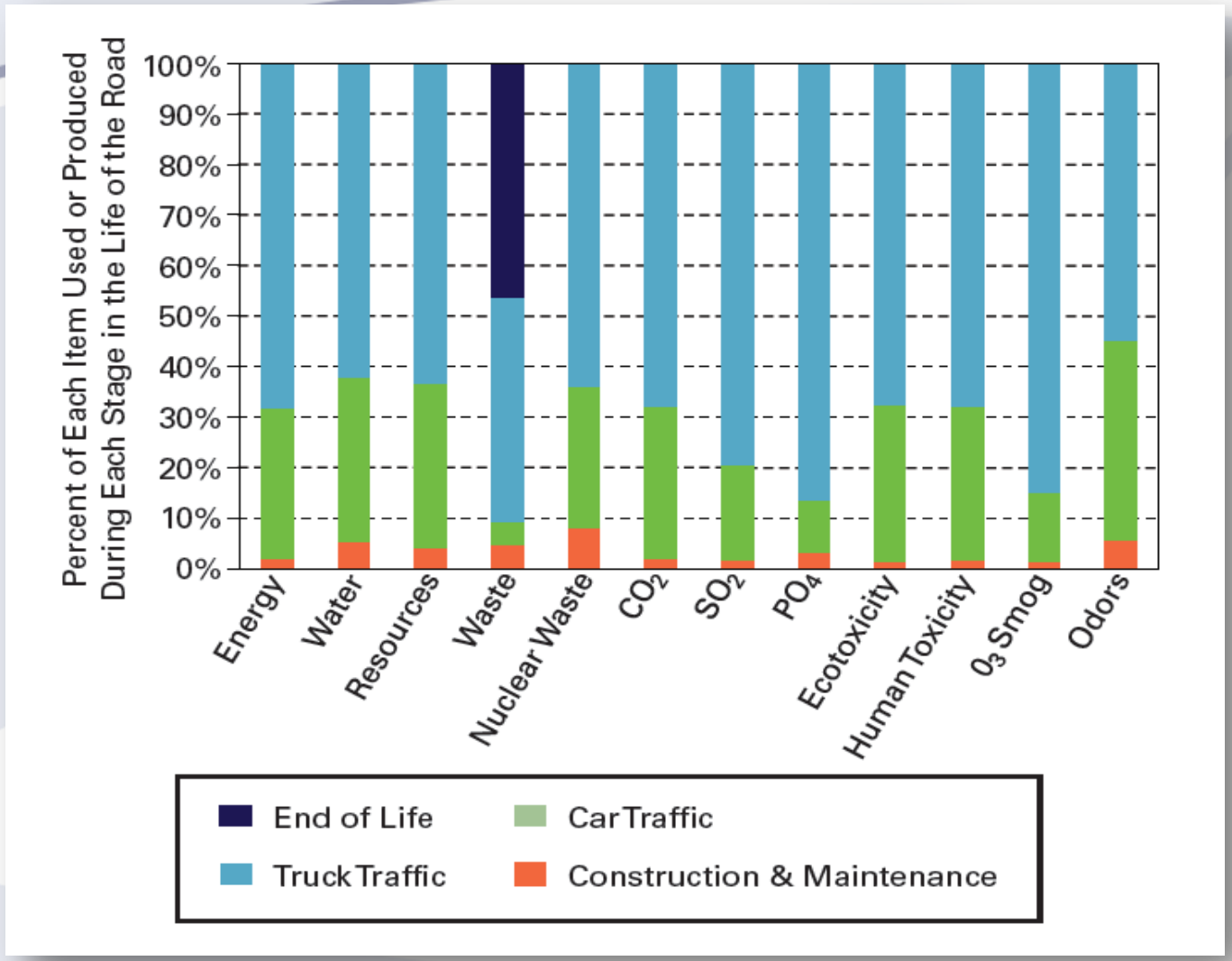
What should we be doing?

- Clarification:

  All the commonly adopted sustainability strategies are important and should be embraced!

- …though, it is useful to know where we can be most impactful.
- Recent comprehensive LCA studies are giving us clues as to where that is...

What should we be doing?



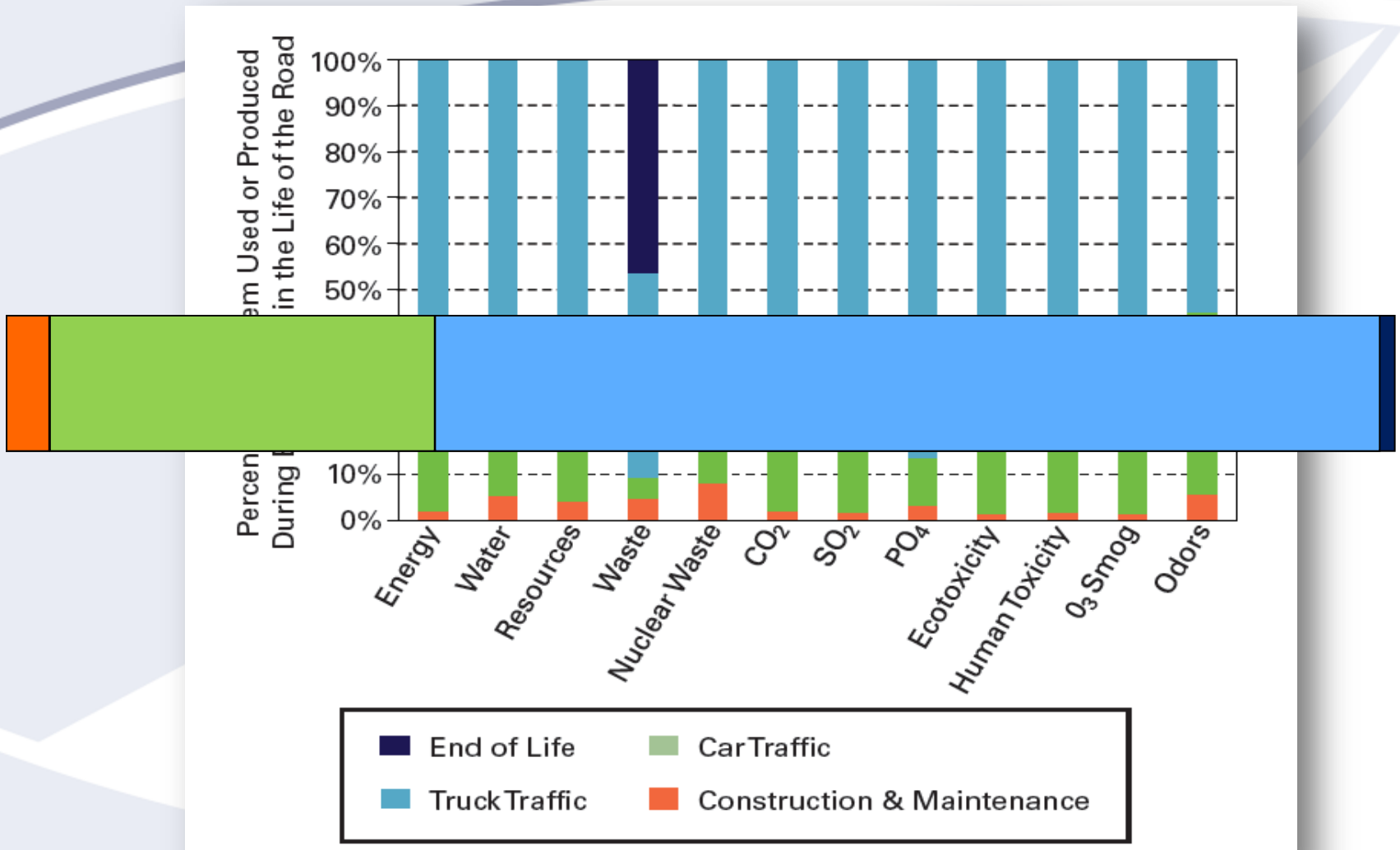
[Centre d'Energetique de l'Ecole des Mines de Paris]

Ecoprofile of different life cycle stages of a typical road.

What should we be doing?

- From this LCA we see:
  - Overall impacts from use-phase dwarfs impacts from ALL other phases of the roadway life cycle
  - From energy perspective… construction and maintenance accounts for less than 2% of the entire energy footprint *[EAPA 2004]*
- Therefore (as an example):
  - Just a **2-3%** improvement in the truck/car portion of the ecoprofile could offset the entire construction and maintenance ecoprofile!

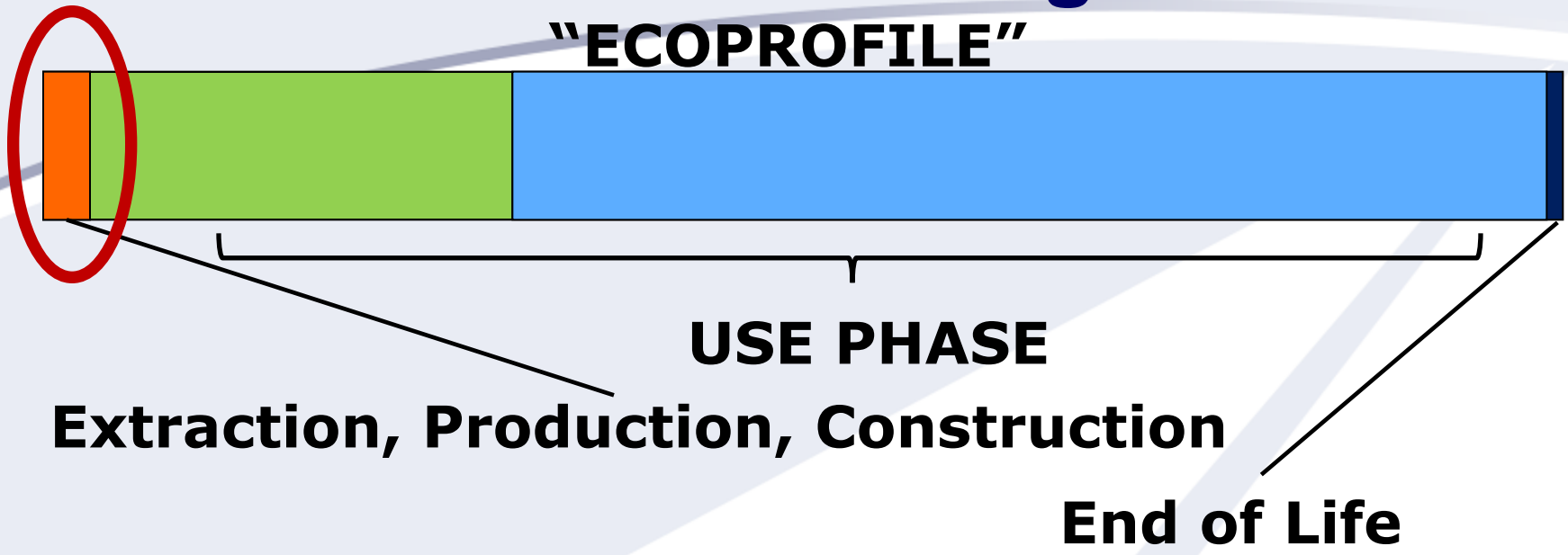
What should we be doing?



[Centre d'Energetique de l'Ecole des Mines de Paris]

Ecoprofile of different life cycle stages of a typical road.

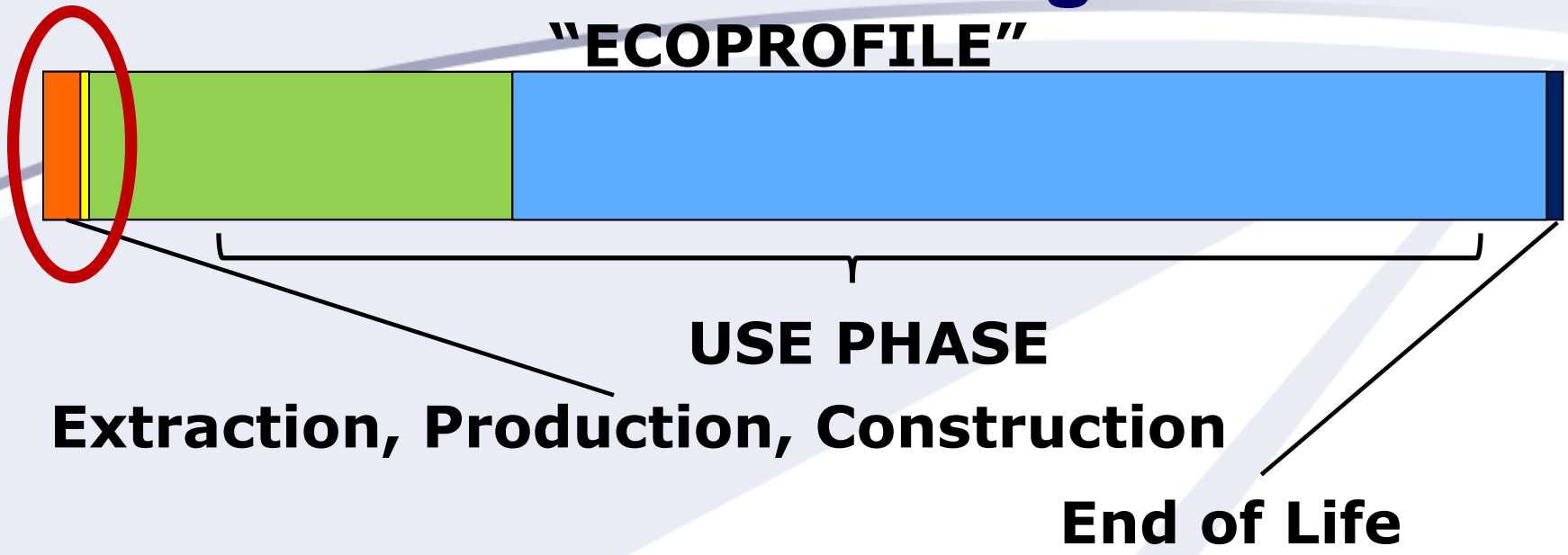
What should we be doing?



Where do our "conventional" sustainability tools fit in this ecoprofile?

RCA, RAP, Flyash, Slag, Warm Mix?

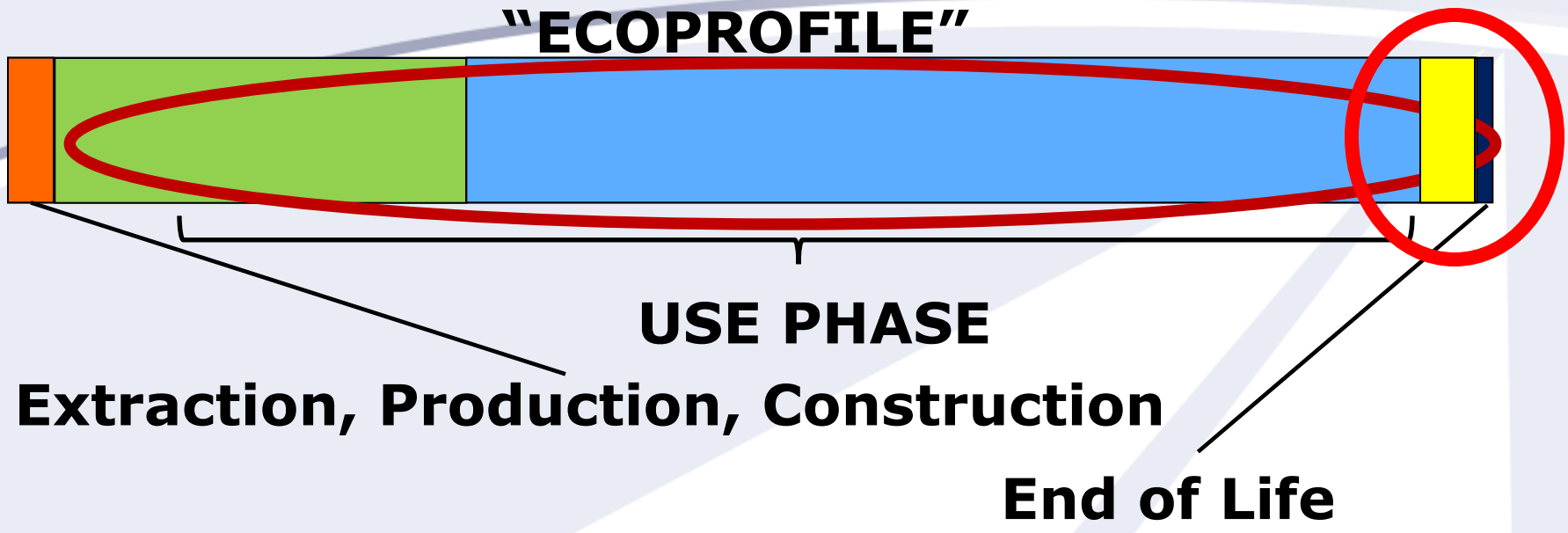
What should we be doing?



SO… if we make a 30% improvement in the production energy footprint (Warm Mix)…

…that small sliver would be the impact on the entire life-cycle "ecoprofile"!

What should we be doing?



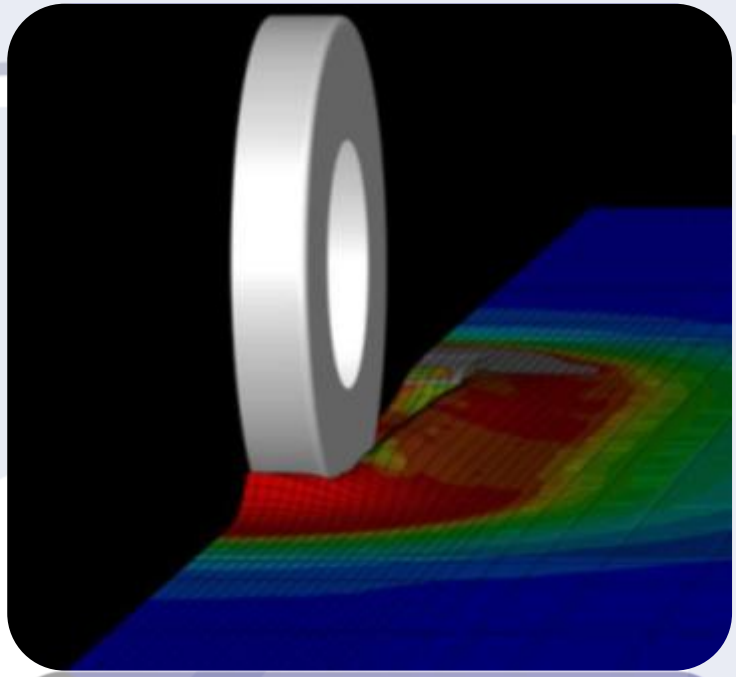
However, what if we can find a way to reduce the use-phase portion by, say 5%?

This yellow area would represent the overall impact…

What should we be doing?

What are these use/operational-phase impacts?

- **Vehicle fuel consumption rates**
  - Pavement rigidity
  - Pavement smoothness
- **Pavement surface reflectivity (albedo)**
  - Urban heat island mitigation
  - Lighting need
  - Global cooling potential

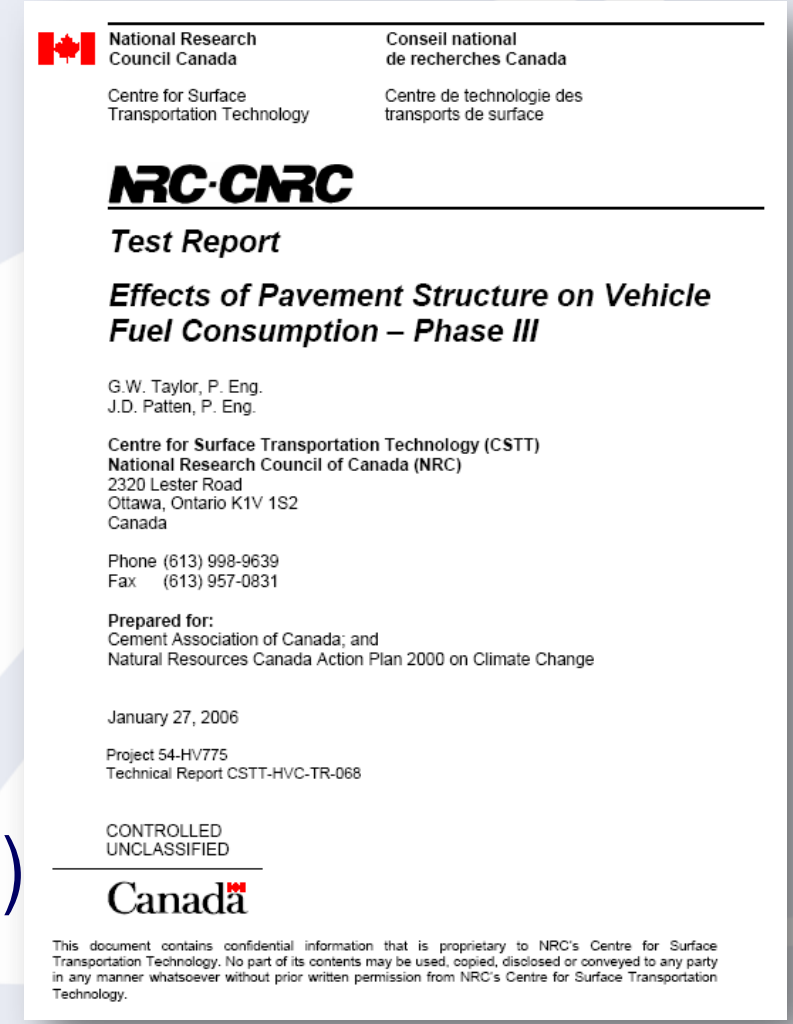


Sustainability and Pavements: Are we Focusing on the Right Things?

Vehicle Fuel Economy

Vehicle Fuel Economy

- Rigid Surface
  - →Lower Deflection
    - →**Less Loss**
- In-depth study by *National Research Council Canada*
- Significant fuel consumption reductions for trucks on concrete pavement (**0.8-6.9%**)
- Sweden, UTA, NCHRP, MIT



National Research Council Canada
Conseil national de recherches Canada

Centre for Surface Transportation Technology
Centre de technologie des transports de surface

NRC·CNRC

Test Report

Effects of Pavement Structure on Vehicle Fuel Consumption – Phase III

G.W. Taylor, P. Eng.
J.D. Patten, P. Eng.

Centre for Surface Transportation Technology (CSTT)
National Research Council of Canada (NRC)
2320 Lester Road
Ottawa, Ontario K1V 1S2
Canada

Phone (613) 998-9639
Fax (613) 957-0831

Prepared for:
Cement Association of Canada; and
Natural Resources Canada Action Plan 2000 on Climate Change

January 27, 2006

Project 54-HV775
Technical Report CSTT-HVC-TR-068

CONTROLLED
UNCLASSIFIED

Canada

Vehicle Fuel Economy: Rigidity

- US DOT data
  - US truck fuel consumption ~ 39 billion gallons per year
  - With just a 3% improvement on roughly 70% of the network, savings would amount to…

    … approx **820 million gallons of diesel/yr**

    (19 billion lbs CO_2 eq. and $3 billion)
  - Additional savings from lighter vans, cars, etc.

Improved Fuel Economy: Smoothness

- Smoothness – smooth roads are fuel efficient roads.
  - Should **specify** and **construct** smooth concrete pavements
  - FHWA reported a **4.5%** improvement in fuel economy (trucks) with smoothness (IRI) improving from 152in/mile to 76in/mile (’00).
  - Ongoing work as well at MIT and NCHRP.
  - Applies not just to new pavements – must maintain smoothness. Pavement renewal!

Sustainability and Pavements: Are we Focusing on the Right Things?

Surface Reflectivity

Surface Reflectivity - Lighting

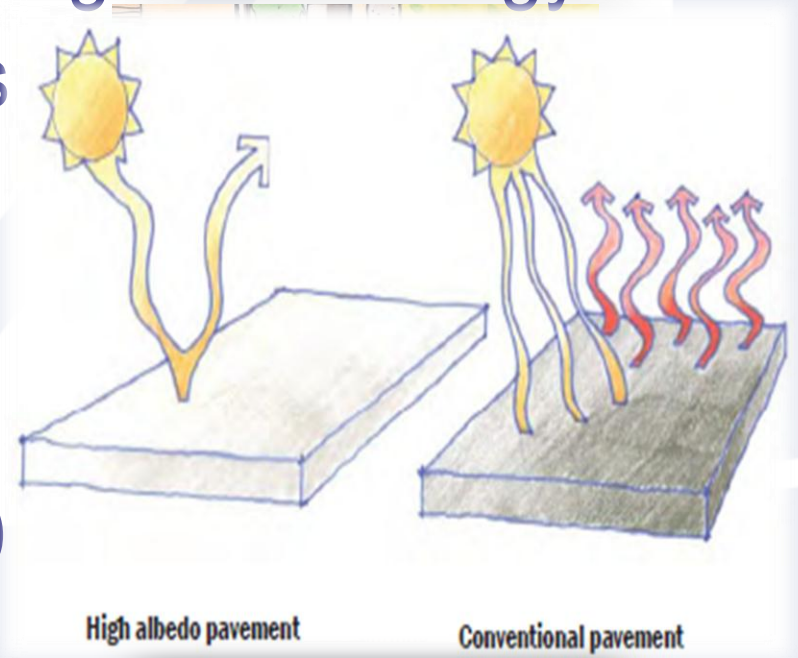
Enhanced Nighttime Visibility:

- Improved pedestrian and vehicle safety
- Reduced lighting & energy requirement:
  - Fewer fixtures/watts
  - Up to 33% reduction
  - AASHTO - 40% lower
  - Huge budget impact!

Surface Reflectivity – Urban Heat

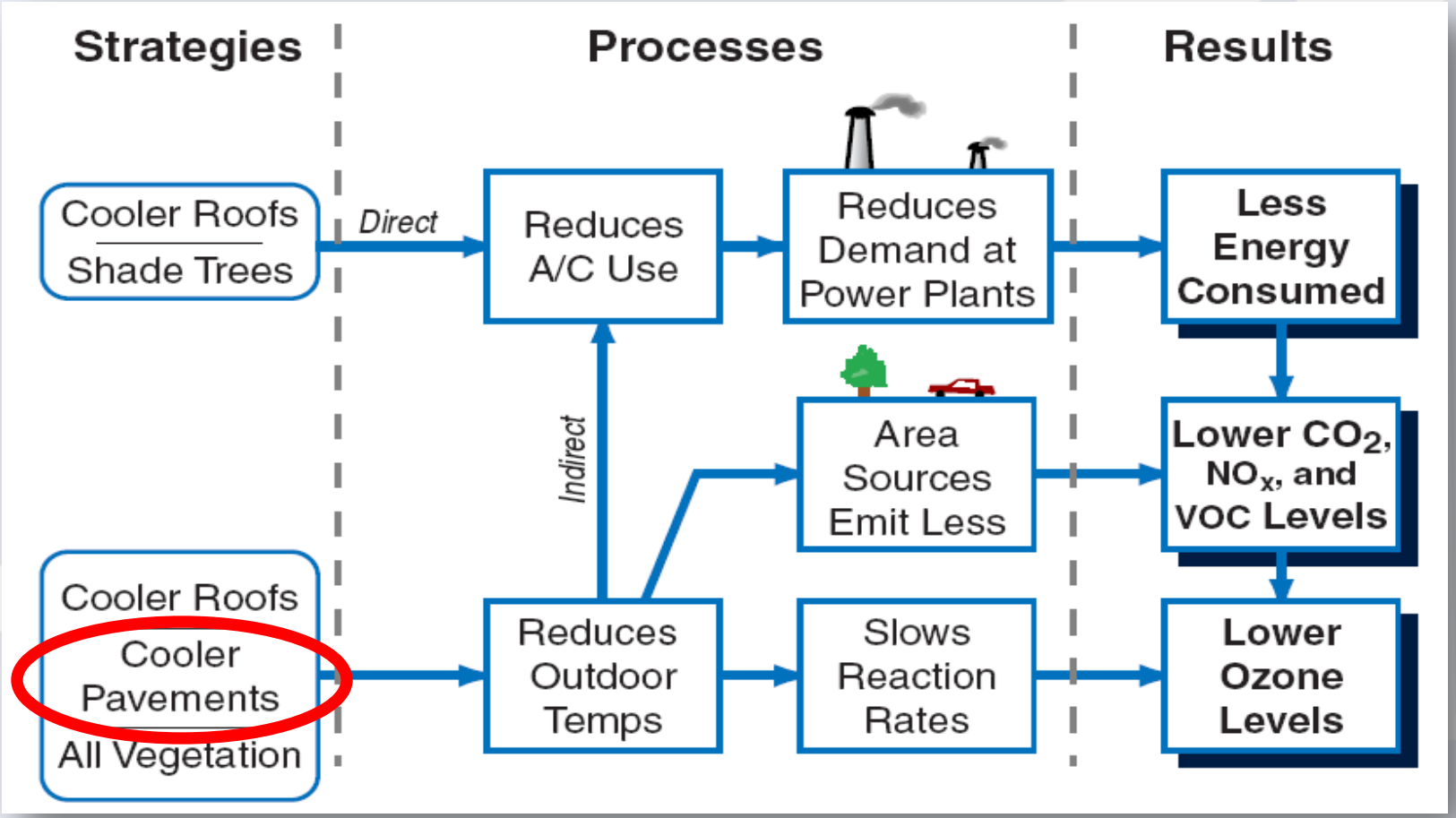
Urban Heat Island Mitigation:

- Urban areas up to 9°F warmer due to UHI
  → greater energy use and resulting pollution
- PCCP is an effective mitigation strategy
  - lower city temperatures
  - lower cooling costs
  - reduce smog formation
- Pot. energy savings
  $2B in US alone *(LBNL'08)*



Surface Reflectivity – Global Cooling

- 5th CA Climate Change Conf (*LBNL and CEC*)



Surface Reflectivity – Global Cooling

- Concept is that earth is not a closed system

- Reflective materials on earth's surface (snow, ice, concrete) return more of sun's energy back into space – reducing temperatures
- This amounts to the equivalent of CO_2 reduction (offset)

Global Cooling

- Cities 1% of global land area
- 60% cities=roofs/pavements
- Cool roofs and pavements (concrete) can increase urban albedo by 0.1, and in turn induce negative radiative forcing….
- If implemented in 100 largest cities in world, this can offset **44Gt** of emitted CO_2 ($1.1 trillion at $25/ton) – proposal to UN considered.

Sustainability and Pavements

Parting Thoughts

Early Experiments in Transportation

Parting Thoughts

- Lots of sustainability opportunities with concrete pavement construction – opt for longevity!
  - Recycling, SCM's, Pervious, Optimized Design…
- Industry committed to sustainable approaches in all aspects of pavement construction
- **But**, we may be missing enormous opportunities by focusing solely on the production and construction aspects (less than 5% of footprint)
- Must consider the use-phase (dwarfs all else)!!!

Parting Thoughts

- **The use-phase has an enormous impact!**

  Long service life - exposed every hour of every day, supporting millions of cars/trucks

  - **Vehicle fuel consumption(rigid and smooth)**
  - **Surface reflectivity (light, UHI, global cooling)**

- Not much different than the challenge with project costs and LCCA…

Parting Thoughts

- Great thing is that we **can** control what we consider – focus on the right things!
- From what we know today, **rigid**, **smooth** and **light-reflective** pavement surfaces will be a major focus of sustainable roadway practices moving forward.
- Focusing on the things that actually matter will better enable us to sustain our experience here on earth – i.e. to **endure**!

Resources…

- Recently published Special Report →
- Available at: ***www.acpa.org***
- Much work ongoing:

National Concrete Pavement Technology Center

Tech Center

Massachusetts Institute of Technology
CONCRETE SUSTAINIBILITY HUB

Sustainability Opportunities with Pavements: Focusing on the Right Things

concrete pavement research and technology *special report*

Contents

1 Introduction
2 Sustainability in the Context of Pavements
3 Current U.S. Sustainability Initiatives
4 Green Highways Partnership
4 Greenroads Rating System
5 Green Pavement Technologies Program
5 What We Should be Focusing on
6 Vehicle Fuel Consumption
9 Pavement Albedo
9 Pavement Illumination
9 Urban Heat Island
11 Global Cooling
11 Conclusion
12 References

ACPA
American Concrete Pavement Association

May 2010

Introduction

Sustainability is essentially the capacity to endure. The word is derived from the Latin sustinēre (from sus, up and tenēre, to hold), and there are numerous definitions provided in the dictionary, including "to give support," "prolong," and "withstand" (Merriam Webster 2010). Today the term is applied very broadly to almost every facet of life, although it is increasingly being used in the context of human sustainability on Earth - particularly so, as the causes of global warming and climate change are debated. In 1987, The World Commission on Environment and Development defined sustainable development as "*meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987), while an ancient Native American proverb captures the concept of sustainability in the following way: "*We do not inherit the earth from our ancestors; we borrow it from our children*".

In recent years it has been suggested that in order for human activity to meet present needs without compromising the prospects of future generations, we need to carefully balance environmental, societal and economic demands. This concept is often referred to as the "three pillars" of sustainability" or the "triple-bottom-line" (Figure 1).

For the roadway engineer, consideration of sustainability or sustainable practices often leads to a focus on the structural design, the pavement materials, or the construction operation because these are items that are largely within the roadway engineer's control. Items such as recycling, use of industrial by-products (fly ash, slag cement, etc.), resource conservation, CO_2 footprint and even embodied energy

Figure 1. Graphical representation of the three pillars of sustainability

tend to get a fair amount of attention in this context. There may, however, be significant sustainability opportunities missed by ignoring the operational or use-phase of a pavement's life.

Recent research suggests that the long-term cumulative benefits derived from a sustainable pavement design can be absolutely staggering. Specifying a rigid pavement in order to realize improved vehicle fuel efficiency can have enormous benefits over the life of the pavement. Likewise, specifying a smooth pavement can result in similar cumulative benefits. The energy savings realized during the entire operational phase of an urban pavement's life associated with reduced lighting needs for a high-albedo pavement can also be significant. Moreover, the long-term energy and CO_2 savings associated with mitigating the urban heat island effect through the use of high-albedo, cool pavements are quite large.

THANK YOU!

lwathne@acpa.org

ACPA

www.acpa.org

International Society

ISCP

for Concrete Pavements