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Life-Cycle Assessment (LCA) – A Primer



Old Concept for New Times

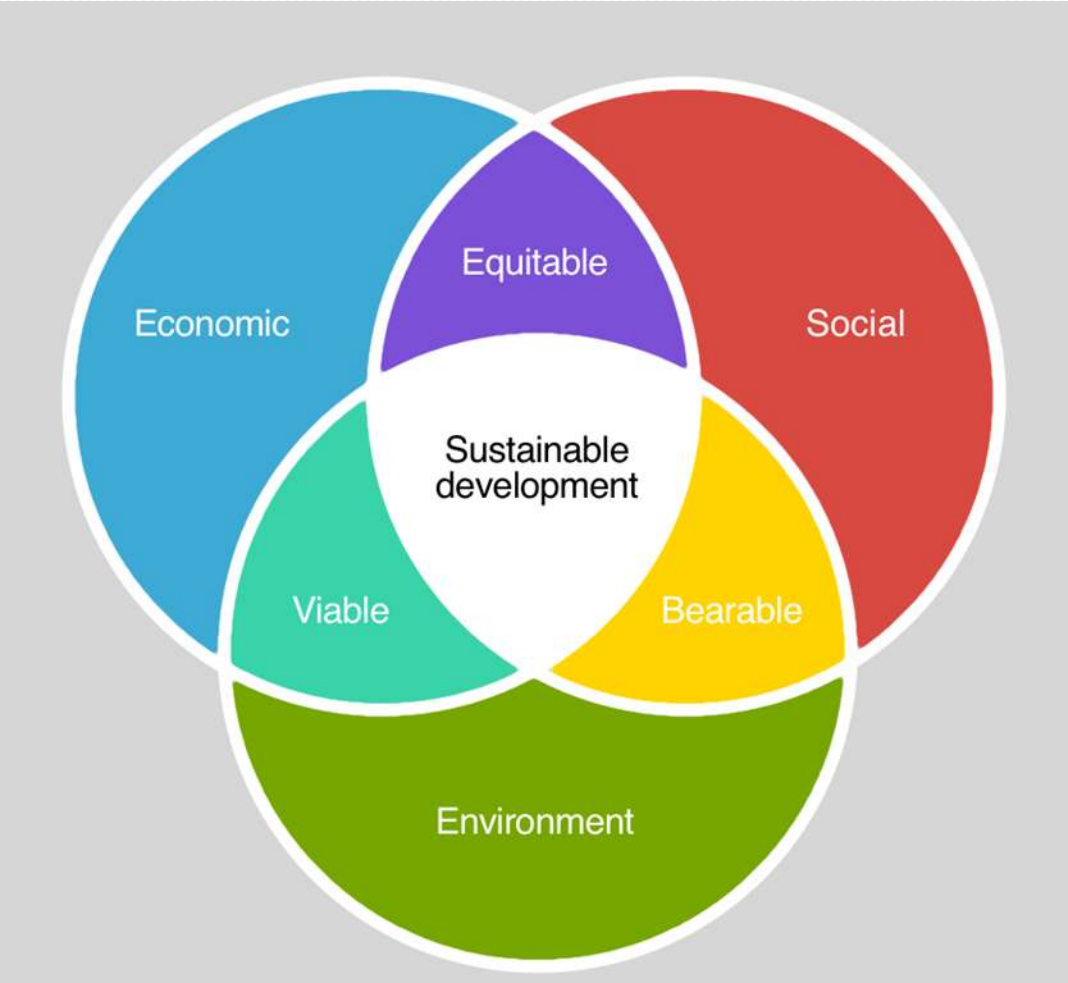
- "A society grows great when old men plant trees in whose shade they know they will not sit."
  - Ancient Greeks

http://treestewards.org/2011/10/10/selfish-people-and-selfish-trees/

Sustainable Development

- "Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs."
  - *Our Common Future*, 1987

Triple-Bottom Line



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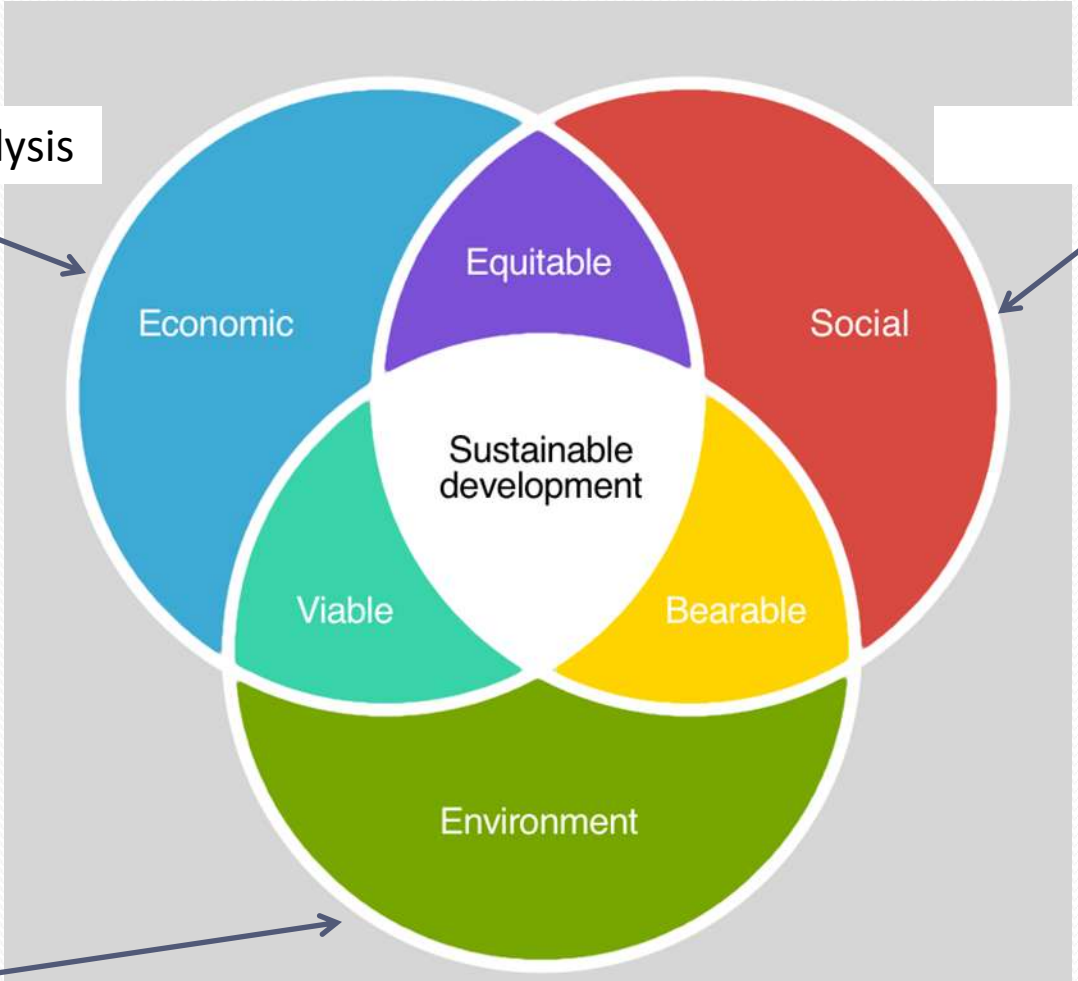
Triple-Bottom Line

Economic	Social	Environmental
Affordability	Equity	Pollution Prevention
Resource Efficiency	Human health	Climate Protection
Cost internalization	Education	Biodiversity
Trade and business activity	Community	Precautionary action
Employment	Quality of life	Avoidance of irreversibility
Productivity	Public participation	Habitat preservation
Tax burden	Safety	Aesthetics

Quantifying Sustainability

Life-Cycle Cost Analysis

?????



Life Cycle Assessment

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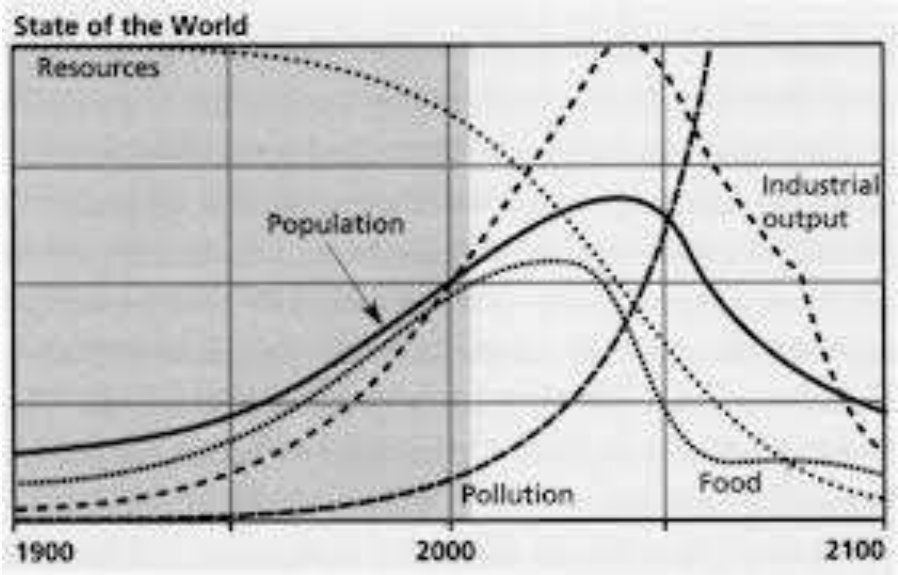
Life-Cycle Assessment

- International Organization for Standardization (ISO 2006)
  - “addresses the environmental aspects and potential environmental impacts (e.g., use of resources and the environmental consequences of releases) throughout a product’s life cycle from raw material acquisition, through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle to grave).”

LCA History

- 1960's – Energy and raw material concerns
- Harold Smith (1963): calculate cumulative energy requirements for production of chemical intermediates
- *The Limits of Growth* and *A Blueprint for Survival*
- Dozen studies to look at costs and environmental impacts
- Who laid the groundwork?



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Life-Cycle Assessment History

- The Coca-Cola Company (1969) developed methods and groundwork for LCA of today
  - Compared different beverage containers to determine environmental releases and required raw materials
- Other companies followed suit

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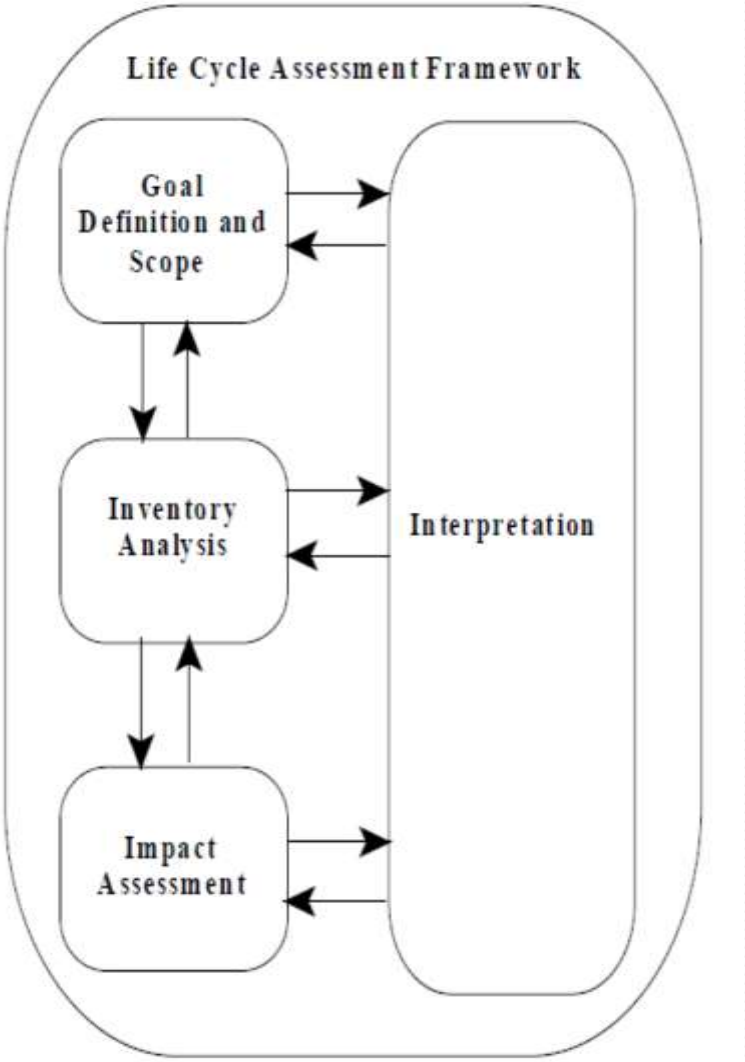
Life-Cycle Assessment Framework



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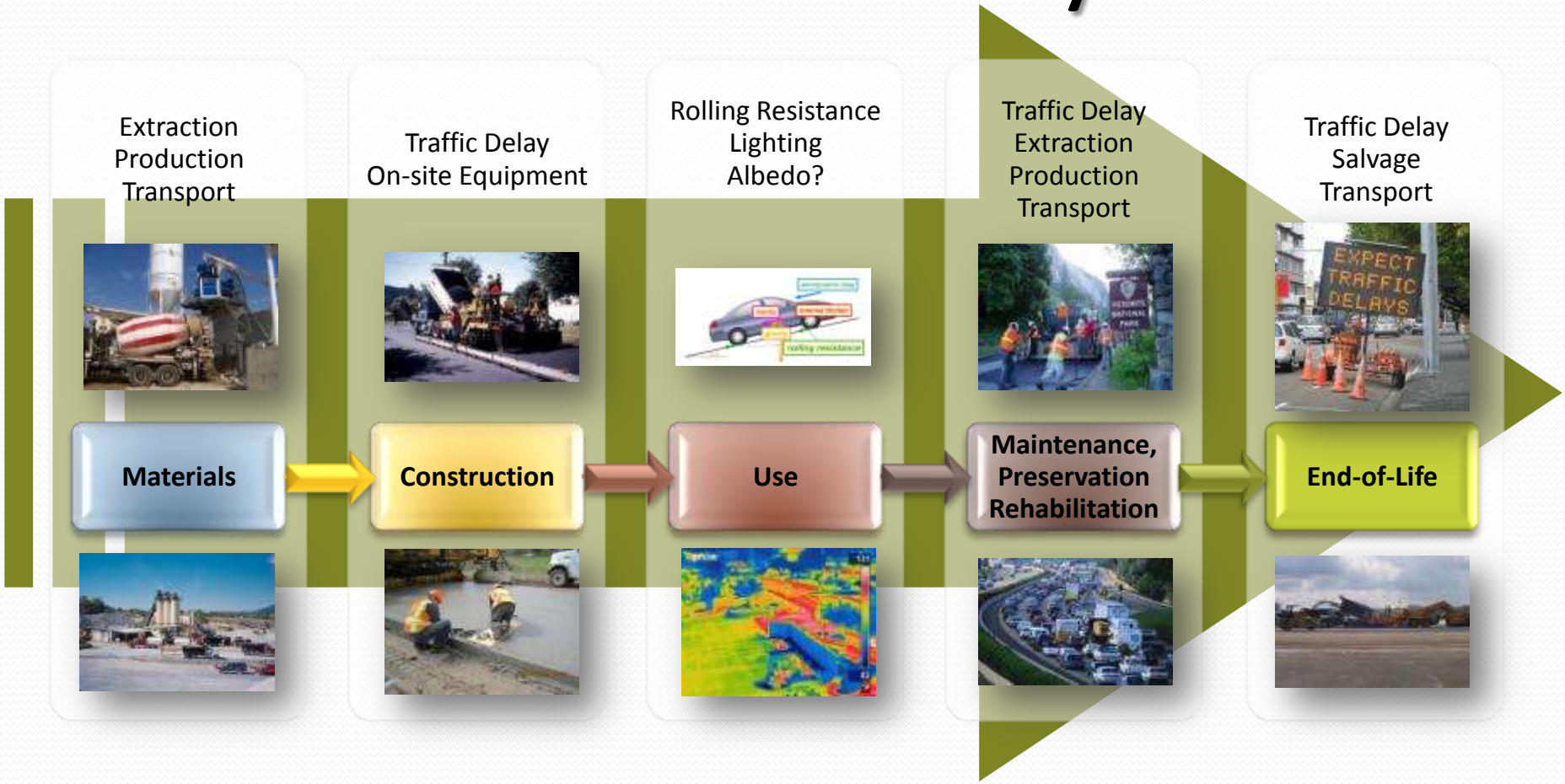
LCA Phases

- Goal and scope definition
  - Determine depth and breadth of LCA
  - System boundaries (i.e., what stages and processes will be included)
- Inventory analysis
  - Accounting phase
  - Inputs (materials, energy, and resources)
  - Outputs (waste, pollution, and co-products)

LCA Phases

- Impact assessment
  - Understand environmental significance
  - Translate environmental flows to impact categories
    - Energy use
    - Resource Use
    - Emissions
    - Toxicity
    - Water
    - Waste
  - Interpretation

Pavement Life-Cycle



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Pavement LCAs

- Process based
  - Data collected for every process
  - Specific, regionalized, and data intensive
  - Like LCCA, requires some assumptions in terms of material usage, transportation, and ultimately performance/maintenance

Materials

- LCCA
  - How much does it cost to buy the asphalt and the aggregate and produce a mixture?
- LCA
  - How much energy is required to extract, process, and transport aggregate and asphalt?
  - How much $C0_{2e}$ is produced during this process?
  - How much energy is used and $C0_{2e}$ is produced at the plant?

Example Materials Inputs for LCA

Material	Percentage by Layer by Total Mixture Weight			Total	Haul Distance (miles)	Weighted Haul for Structure (miles)
	Surface	Binder	Base			
Virgin Binder (PG 67-22)	4.3	2.7	3.1	3.2	100	100
Granite	87.1	--	--	--	28	--
Limestone	--	48.6	42.6	--	5	--
Virgin Agg	87.1	48.6	--	54.7	--	7.5
Sand	--	19.5	20.4	15.6	41	41
RAP	--	24.3	33.9	22.7	5	5
RAS	4.8	4.9	--	3.0	--	--
Fly Ash	3.8	--	--	0.8	130	130

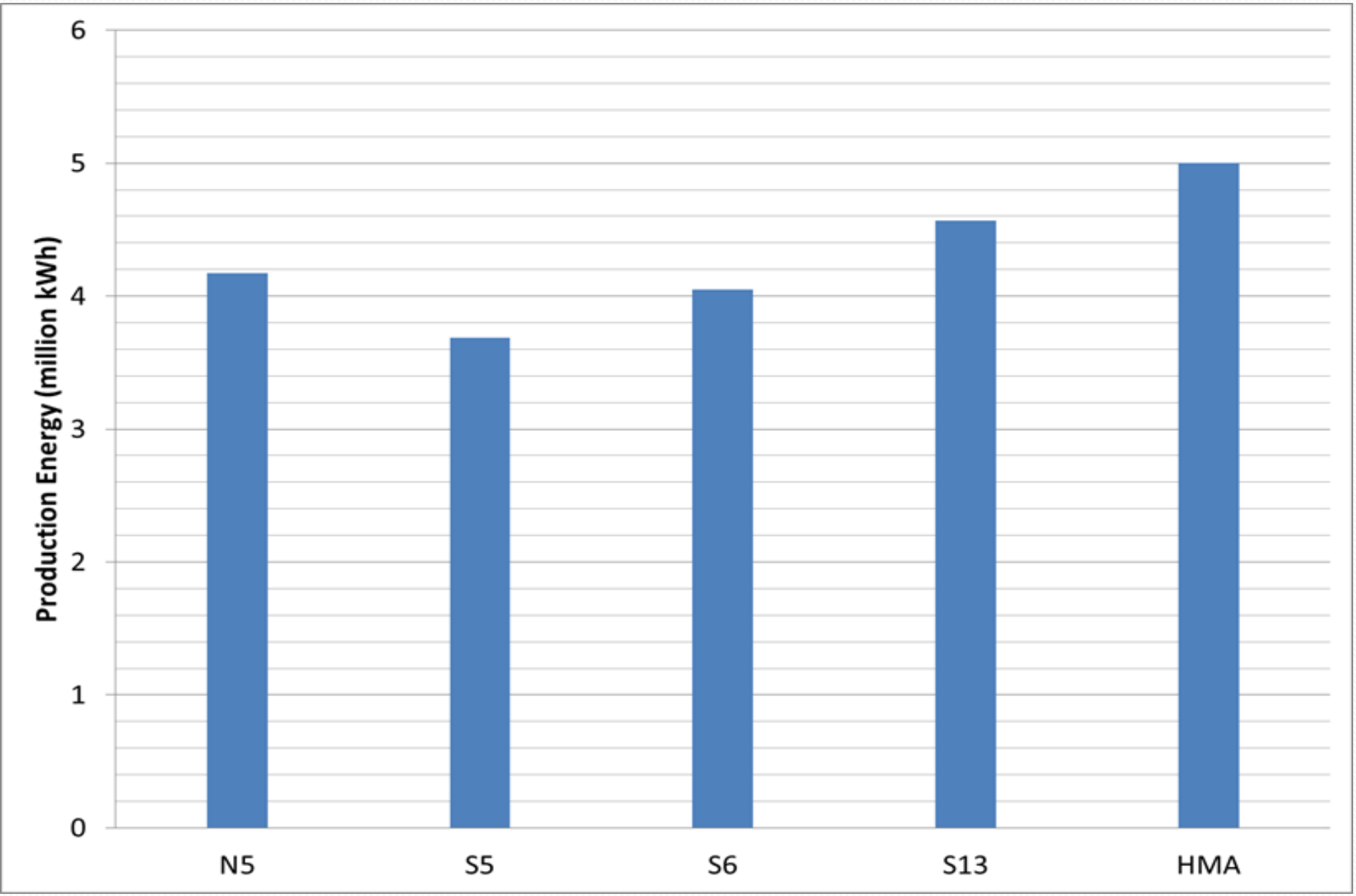
Construction

- LCCA
  - How much does it cost to construct the mixture through manpower, fuel usage, and machine time?
  - User-delay costs?
- LCA
  - How much CO_{2e} is produced and how much energy is used to place the mixtures?
  - How much CO_{2e} is produced from traffic congestion?

Construction/Production Inputs

- Paver – Working time, efficiency, rate (ft/min)
- Rollers – Working time, efficiency, rate
- MTV – Working time
- Plant – Production rate, temperature, plant type
- WMA – some programs use an assumed drop in energy

Production Energy for Extracting/ Processing Raw Materials



Use Phase

- LCCA
  - Not commonly considered
- LCA
  - How much energy is spent lighting the pavement?
  - How much fuel is used driving on the road?

Maintenance and Rehabilitation

- LCCA
  - What is the rehab schedule for pavements?
  - What are economic effects of user-delay?
    - Lost time
    - Fuel costs
- LCA
  - What is the rehab schedule for pavements?
  - What are environmental effects of user-delay?
    - Fuel usage
    - Greenhouse gases

End-of-Life

- LCCA
  - Is there any salvage value to the material?
- LCCA
  - Is the material recycled?
  - Do I have to transport it somewhere?
    - Fuel usage
    - Greenhouse gases

LCA Tools Available

- Highway Impact Estimator - Athena
- AsPECT - TRL
- PaLATE – UC Berkeley (no longer maintained)
- Project Emissions Estimator (PE-2) – Michigan Tech
- RoadPrint – Pavia Systems
- GreenDOT – AASHTO
  - Estimates CO_2 from construction, operations and maintenance

Tools must fit Framework

- ISO 14044 defines general requirements and guidelines
  - LCA for all products
  - Not specific enough for pavements
  - Basic framework started in 2010 at UC Davis
  - European framework developed and will be public by 2016
- FHWA Sustainable Pavements TWG – Fall 2014 Meeting

Environmental Impact Reporting: A need for brevity and consistency

Nutrition Facts

Serving Size 1 ounce Servings in bag 4

Amount Per Serving

Calories 155	Calories from Fat 93
	% Daily Value*
Total Fat 11g	16%
Saturated Fat 3g	15%
Trans Fat	
Cholesterol 0mg	0%
Sodium 148mg	6%
Total Carbohydrate 14g	5%
Dietary Fiber 1g	5%
Sugars 1g	
Protein 2g	

Vitamin A	0%	• Vitamin C	9%
Calcium	1%	• Iron	3%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Relationships
PCRs, LCAs, and EPDs

- Product Category Rule (PCR): The Framework
  - "Set of specific rules, requirements, and guidelines for developing Type III environmental product declarations for one or more product categories" (ISO 14025)
- Life-cycle Assessment (LCA): The Process
  - "Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle" (ISO 14040)
- Environmental Product Declaration (EPD): The Declaration
  - "Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information" (ISO 14025)

Product Category Rules

- PCR – defines the rules for a product LCA and is industry accepted and defines the environmental product declaration (EPD) format
- NAPA has begun the process of developing PCR(s) for asphalt mixtures
  - Heather Dylla, Richard Willis, Amlan Mukherjee, Dan Staebell are leading the Technical Working Group

Environmental Product Declaration

- EPD – declared LCA for a product and is a form of certification
  - Can be specific (producer) or general (industry)
- EPDs follow the framework developed in the PCR
  - NRMCA has already developed PCR using Carbon Leadership Forum and ASTM
- EPDs may be required soon for construction projects which produce specific amounts of CO_2

How do we educate/facilitate this technology transfer?

Extraction
Production
Transport

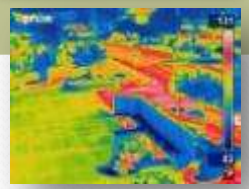
Materials

Traffic Delay
On-site Equipment

Construction

Rolling Resistance
Lighting
Albedo?

Use



Traffic Delay
Extraction
Production
Transport

Maintenance, Preservation Rehabilitation

Traffic Delay
Salvage
Transport

End-of-Life

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Thank you!

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