Chem/ESPM/PH 234 Class 7

Transportation Fuel Impact Assessment & Valuation

T.E. McKone

- How does LCA go from emissions to damage to valuation of damages?
- Macro-scale metrics of damage and monetization, implicitly utilitarian, commonly used and accepted in LCA decisions about fuel choices
- Challenges for LCA in addressing impacts, valuation of impacts, and informing decisions
- Exercise

Some Numbers to Ponder

- **5,000 and 160 billion**
- **10,000 to 20,000**
- **100,000 to 200,000**
- **30 million**
- **$60 billion to $120 billion**
- **$0.56**

What is the answer to the ultimate question of life, the universe and everything?

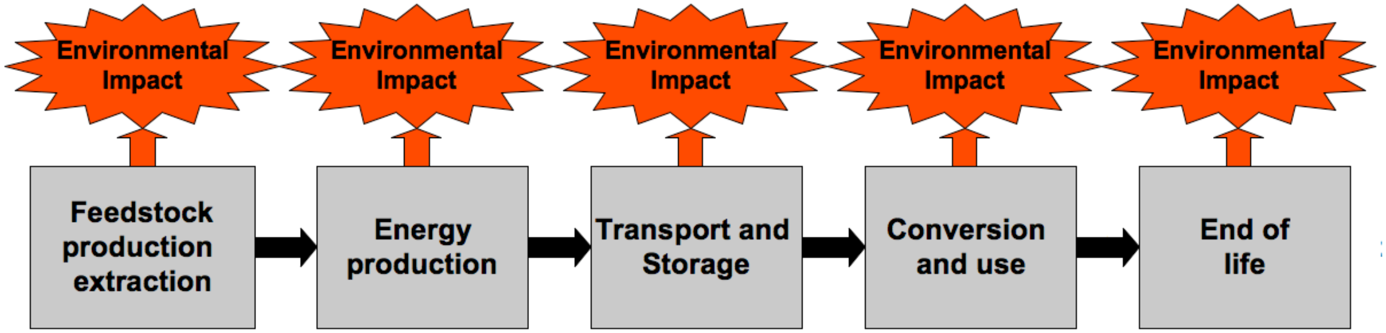
42

- Douglas Adams, *Hitchhiker's Guide To The Galaxy* (1979)

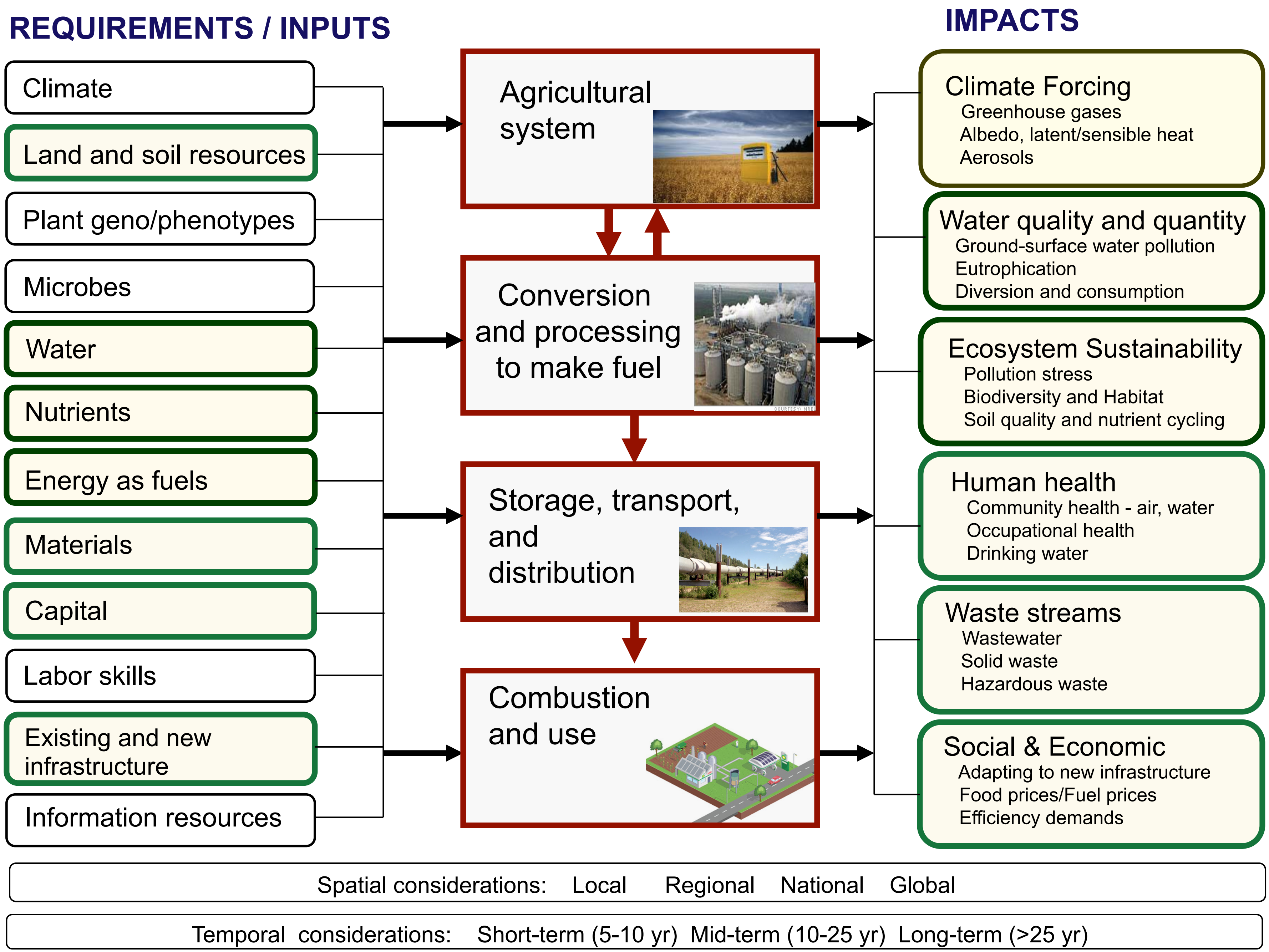
The Life-Cycle Approach

A life-cycle approach is used to evaluate:

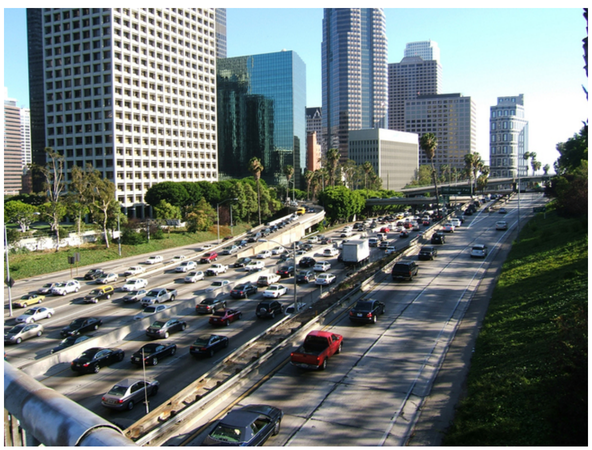
- net energy service provided by energy or transportation technology
- net global warming potential
- human health and ecological damage
- security

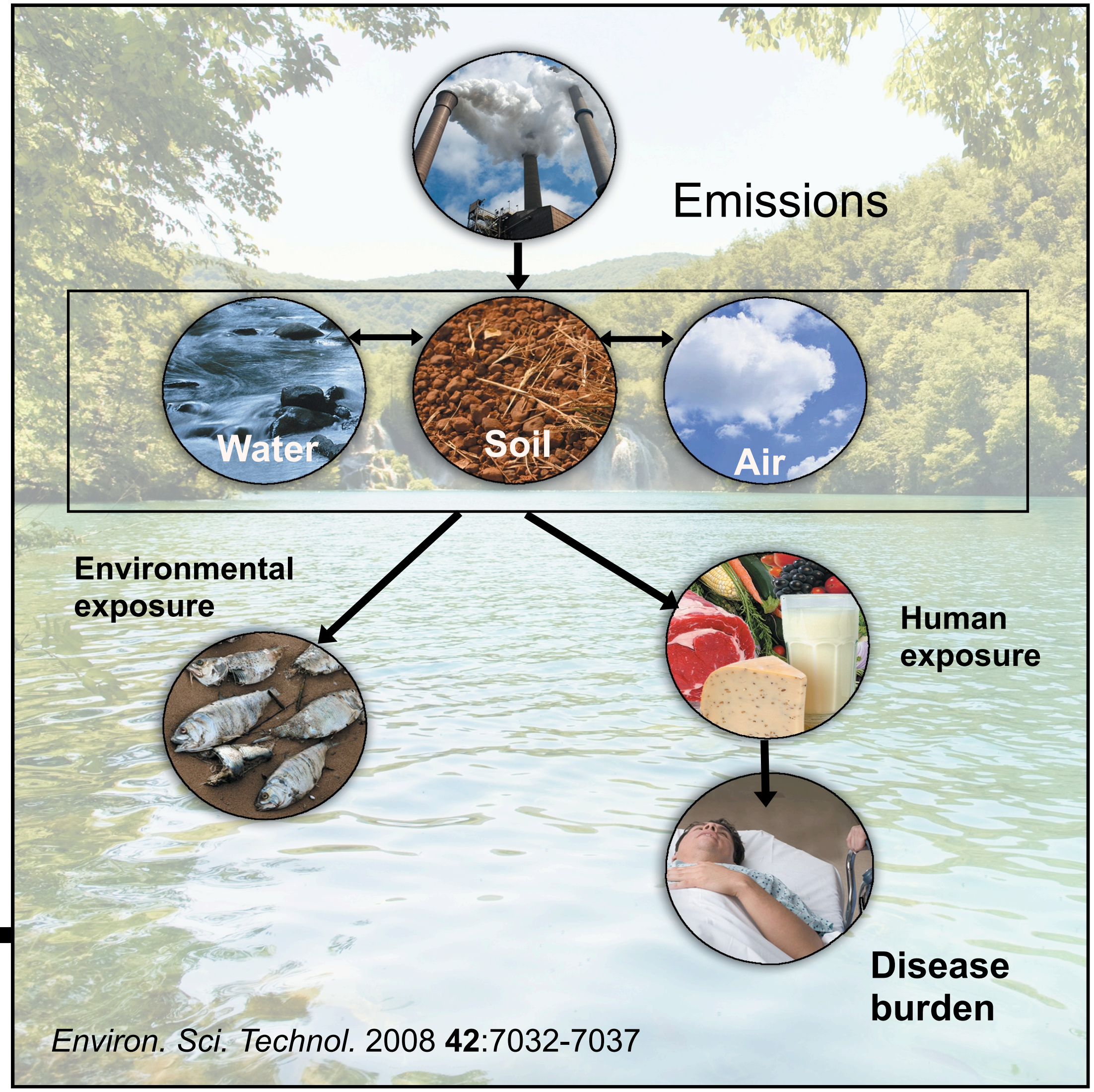


Biofuel
Life Cycle Assessment


REQUIREMENTS / INPUTS
Climate
Land and soil resources
Plant geno/phenotypes
Microbes
Water
Nutrients
Energy as fuels
Materials
Capital
Labor skills
Existing and new infrastructure
Information resources
Agricultural system
Conversion and processing to make fuel
Storage, transport, and distribution
Combustion and use
IMPACTS
Climate Forcing
Greenhouse gases
Albedo, latent/sensible heat
Aerosols
Water quality and quantity
Ground-surface water pollution
Eutrophication
Diversion and consumption
Ecosystem Sustainability
Pollution stress
Biodiversity and Habitat
Soil quality and nutrient cycling
Human health
Community health - air, water
Occupational health
Drinking water
Waste streams
Wastewater
Solid waste
Hazardous waste
Social & Economic
Adapting to new infrastructure
Food prices/Fuel prices
Efficiency demands
Spatial considerations: Local Regional National Global
Temporal considerations: Short-term (5-10 yr) Mid-term (10-25 yr) Long-term (>25 yr)

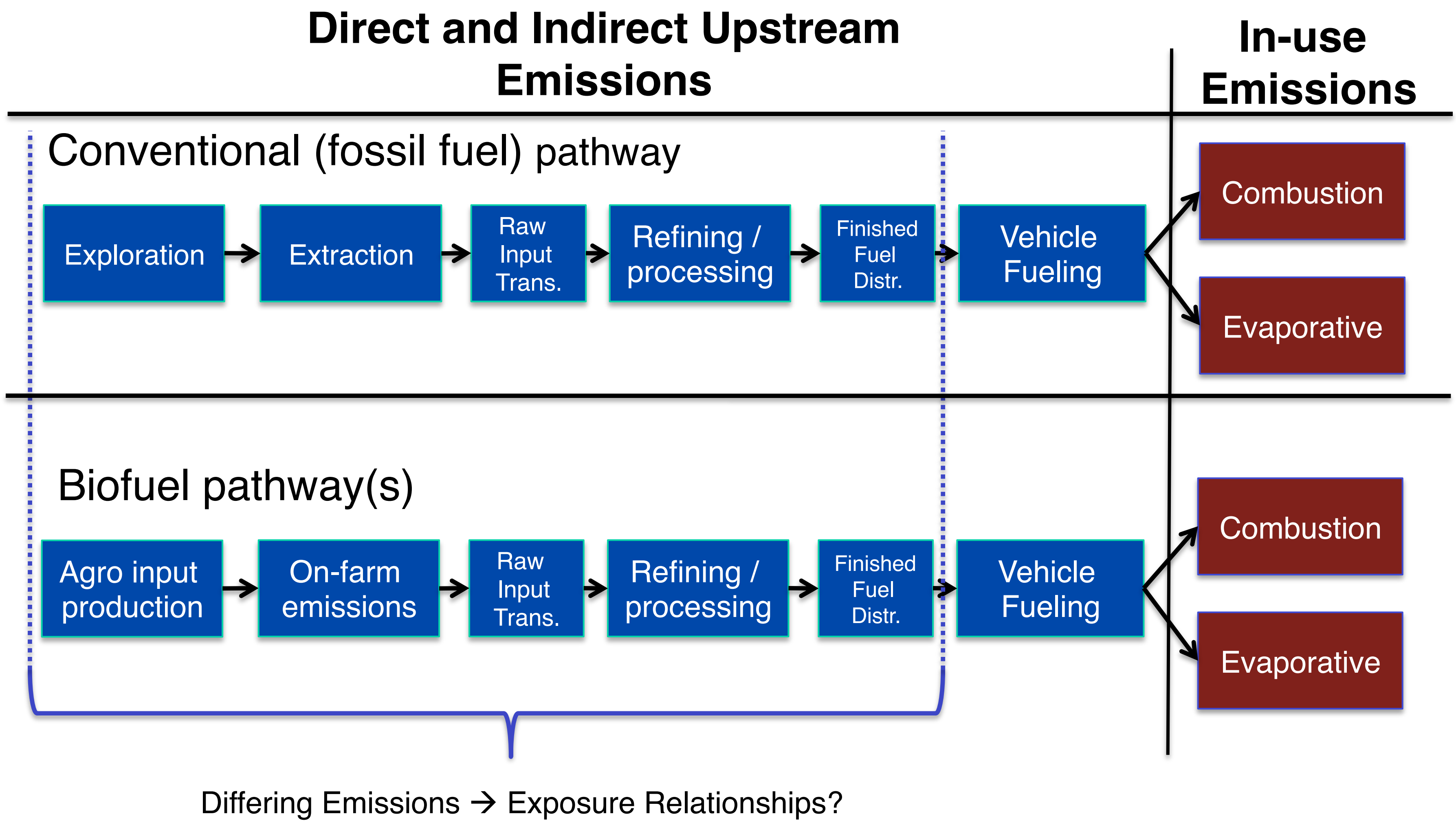
Approach for Human Health and Ecosystem Impact





Impact Characterization

Lifecycle Phases for Air Emissions



Key Pollutants for Human Health Impacts

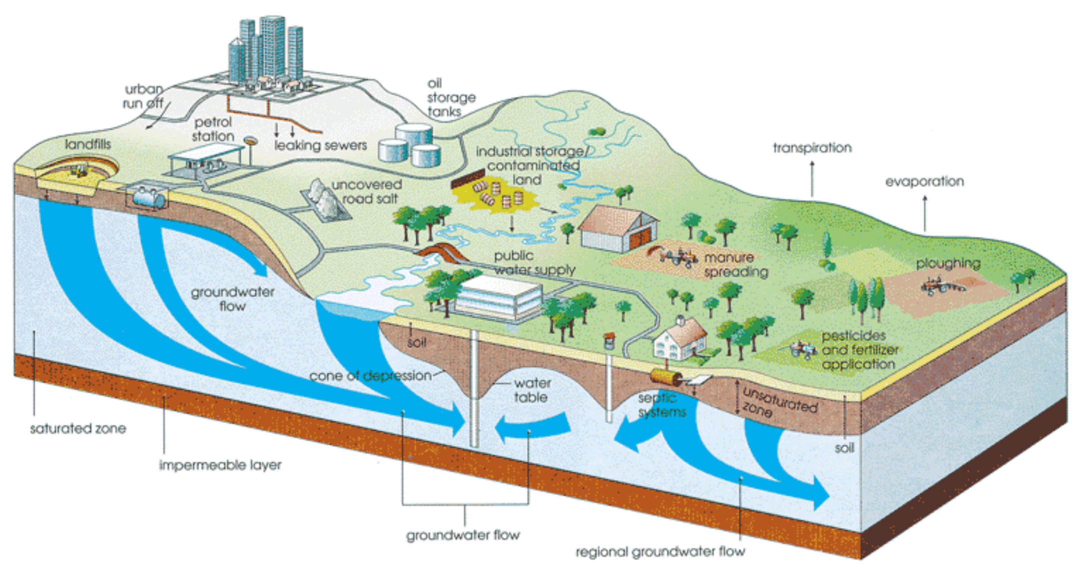
Pollutants of concern

- Primary *and* secondary PM2.5
- Ozone and nitrogen oxides
- Hazardous air pollutants (benzene, butadiene, acetaldehyde, formaldehyde)
- Other toxic multimedia pollutants (toluene)

Novel chemicals used as fuels and in fuel processing

Biofuels and Water Quality

- **Impacts on surface water quality**
  - Treated discharges from refineries
  - Untreated discharges from refineries and agricultural operations
  - Non-point runoff from agricultural lands
  - Accidental discharges to water (pipe/tank leaks)
- **Impacts on ground water quality**
  - Leaking underground tanks
  - Waste-water injection wells
  - Percolation pits at refineries
  - Leaching from farm fields and farm operations
- **Soil, surface water and ground water connections**



Health Impact Assessment Model

Emission | **Fate** | **Exposure** | **Effects** | **Damage**

Emission flow $[kg\text{-}emitted / y]$

Mass in environment $[kg]$

Intake flow $[kg\text{-}intake / y]$

Incidence $[cases / y]$

Damage [value / y]

$\overline{FF}$ $[y]$

$\overline{XF}$ $[1/y]$

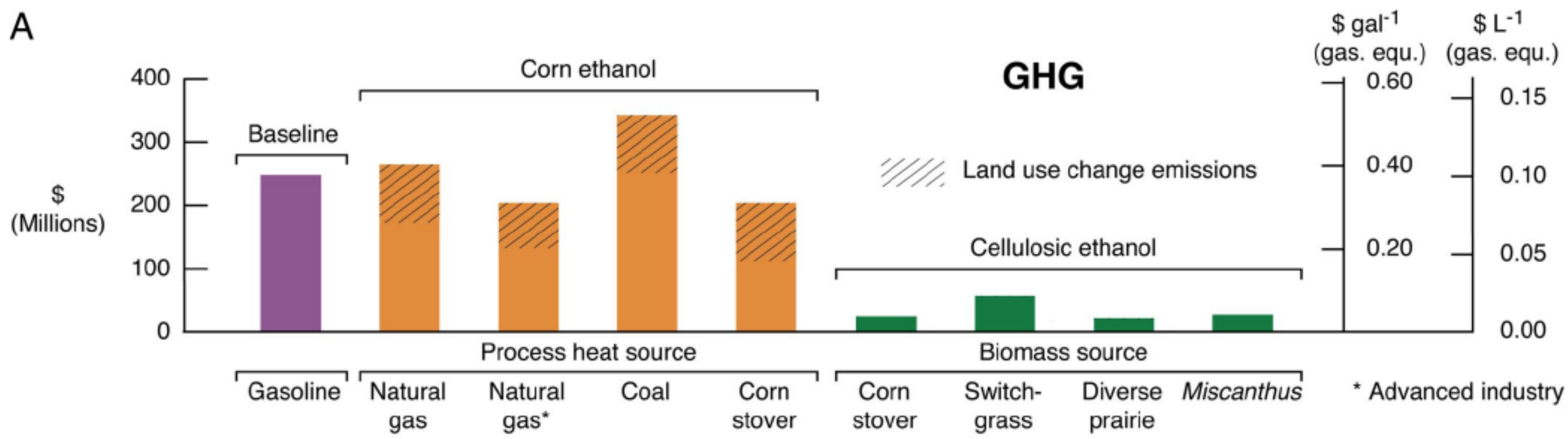
$\overline{EF}$ $[cases/kg\text{-}intake]$

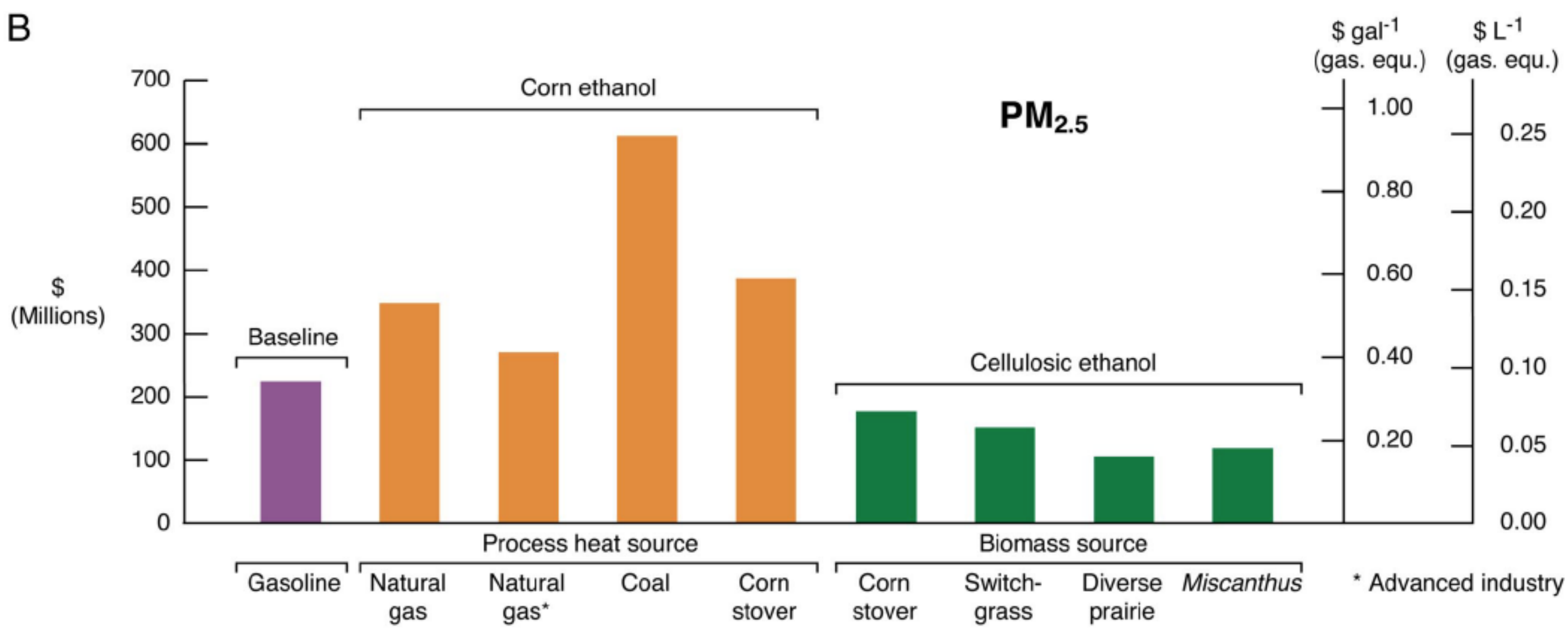
$\overline{DF}$ $[damage/case]$

$$\overline{iF_{xr}} = \overline{XF} \cdot \overline{FF}$$

$[kg\text{-}intake\ /kg\text{-}emitted]$

Hill et al. Monetized Damage





Approach for Non-Climate Damages

- Damage Function Approach:

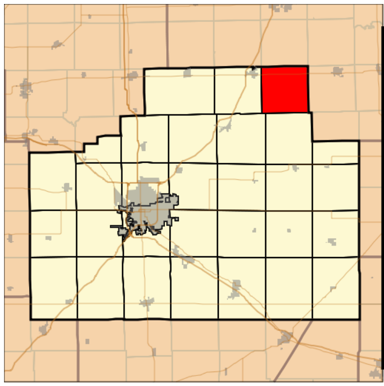
  Emissions → Ambient Concentration → Exposure → Effect → Damages

- Effects of air pollution on human health, grain crops and timber yields, building materials, recreation, and visibility of outdoor vistas

- Modeling used to estimate damages
  based primarily on SO_2, NO_x, and PM emissions across the 48 contiguous states.

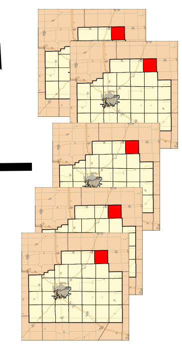
- Most of the damages are associated with human mortality

Defining and Allocating Impact



County-level economic activity
- Agriculture
- Fuel production
- Transport/storage
- Electricity production

Impact burden for this county
- Health damage
- Water
- Ecosystem damage
- Economic damage



Vehicle-miles in this county

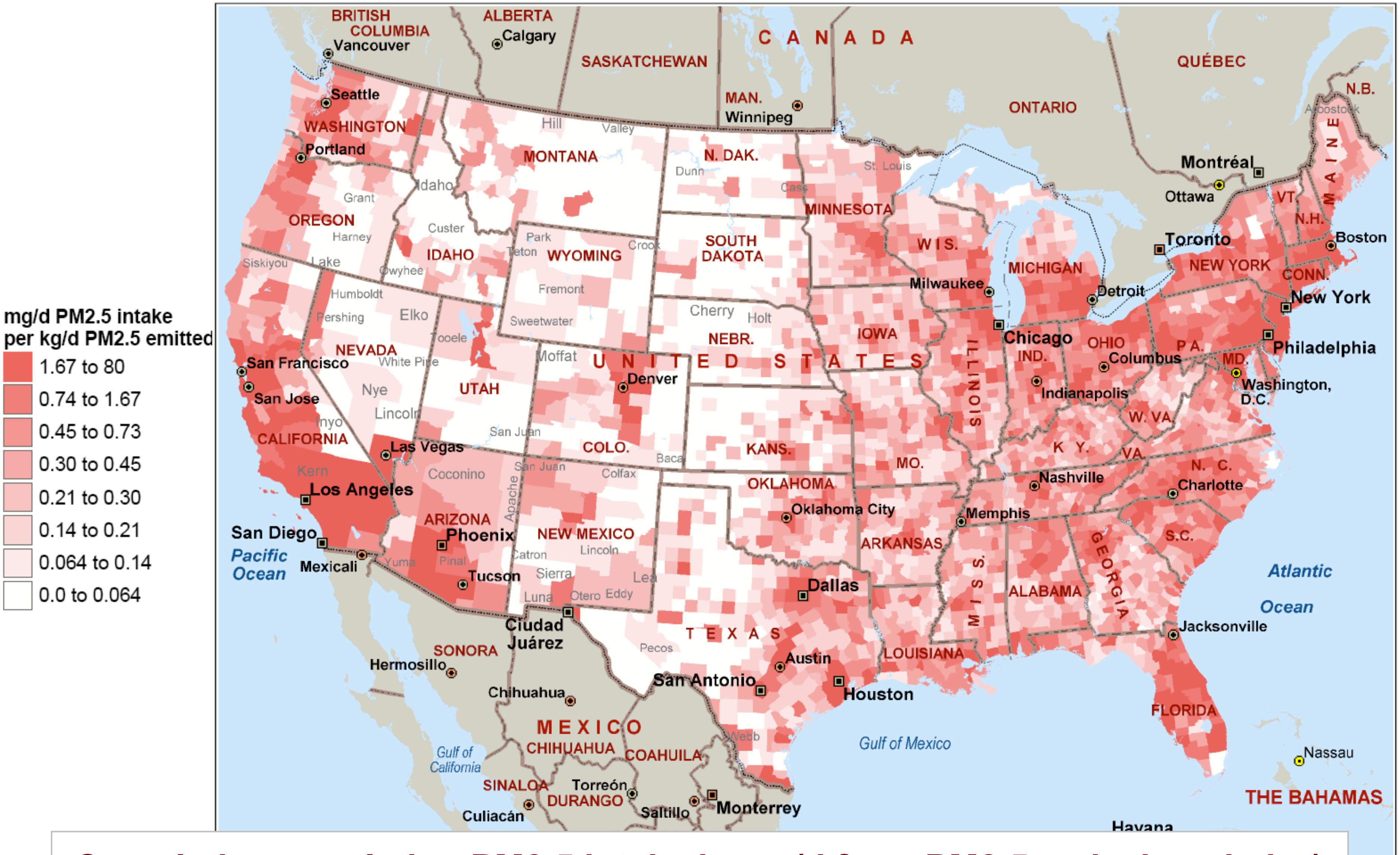
Local damage from vehicle miles traveled

Impact from all counties allocated to a vehicle mile traveled

Total impacts per vehicle-miles consumed in this county

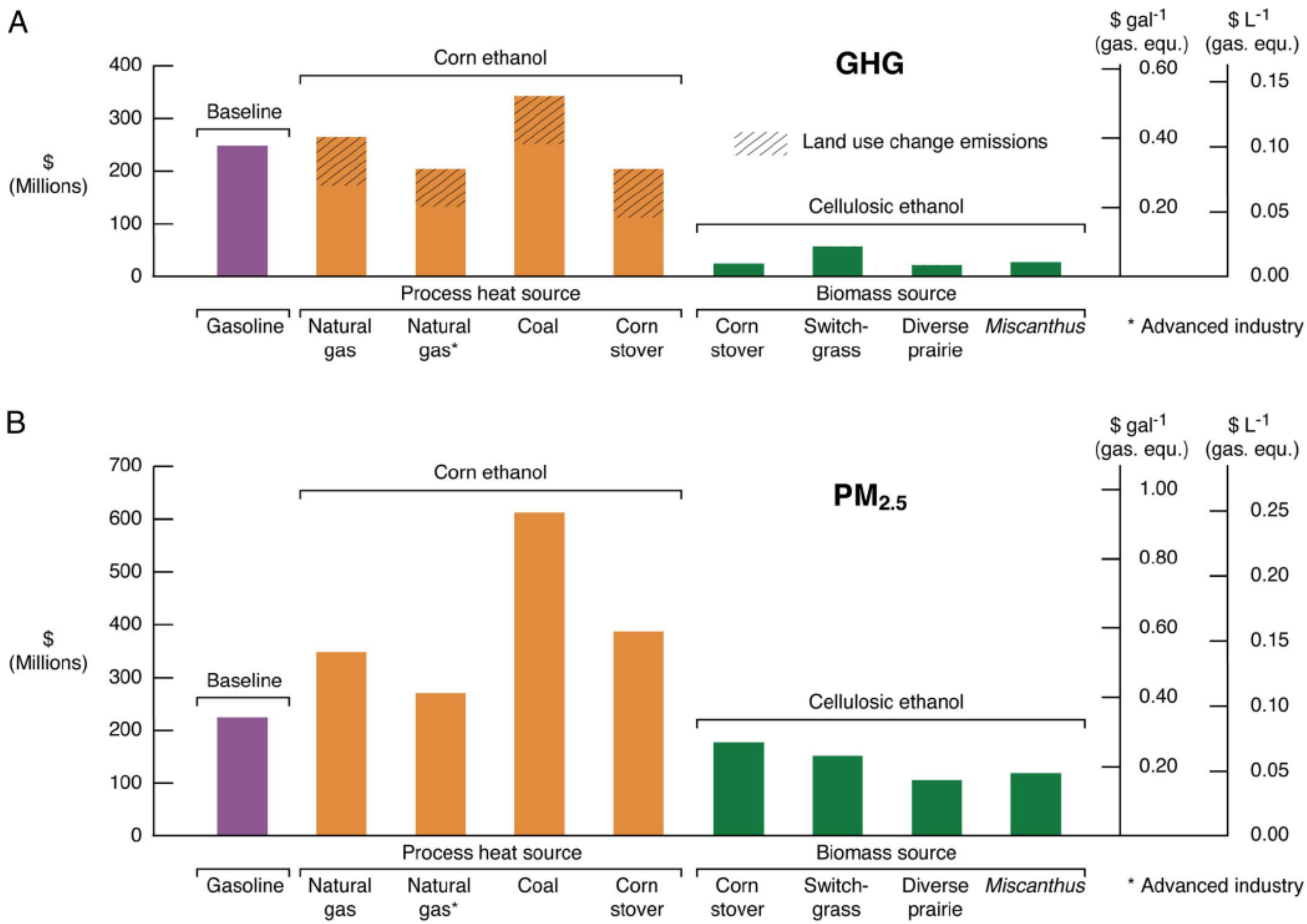
Contribution and Allocation

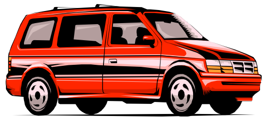
County-level resolution for emissions impacts



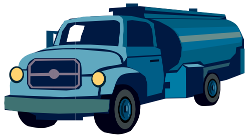
Cumulative population PM2.5 intake in mg/d from PM2.5 emissions in kg/d for each US County (expressed as intake fraction mg/kg)

Hill et al. Monetized Damage





Transportation Impacts (Non-Climate)



Aggregate non-climate damages: ≈ $ 56 billion (2005)

Light-duty vehicles: $36 billion

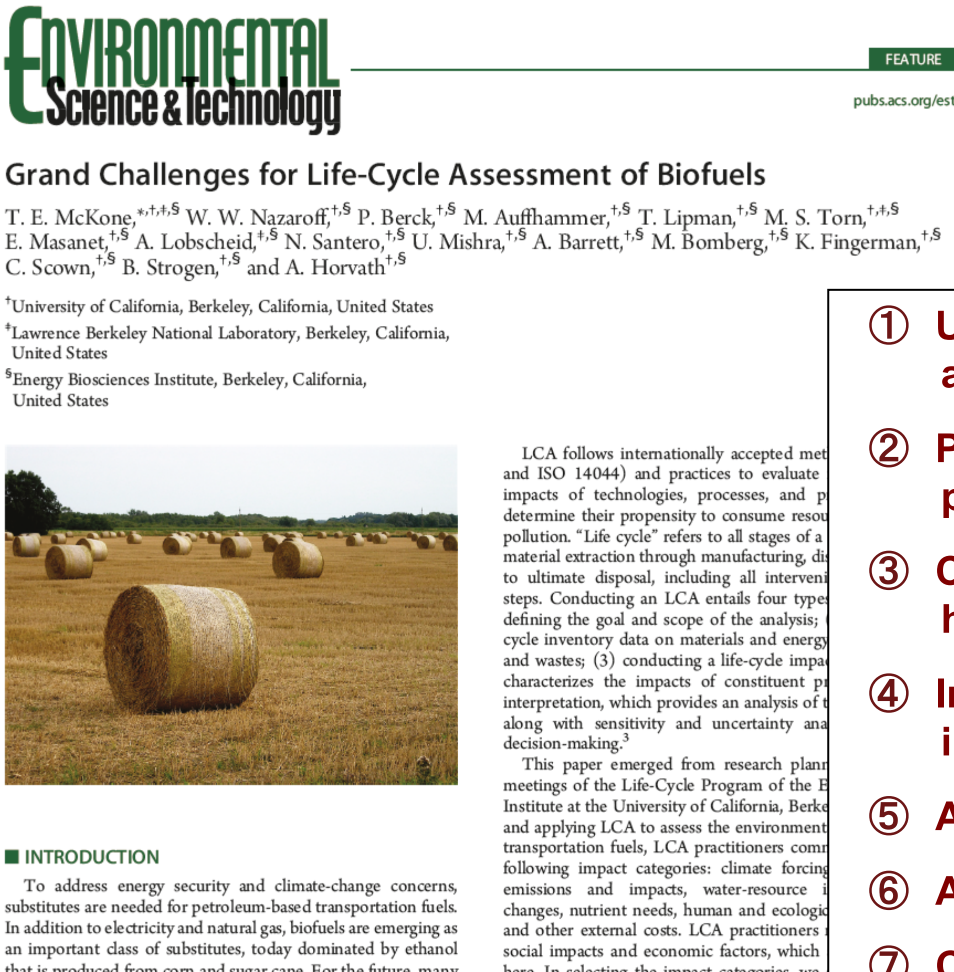
Heavy-duty vehicles: $20 billion

- Damages per vehicle-mile traveled (VMT) ranged from 1.2 cents to 1.7 cents.
  - 23-38 cents/ gasoline gallon equivalent
- Estimated damages did not vary significantly across fuels and technologies; caution is needed for interpreting small differences
  - Some (electric, corn ethanol) had higher lifecycle damages
  - Others (cellulosic ethanol, CNG) had lower lifecycle damages

Some Numbers to Ponder

- 5,000 gal/s and 160 billion gal/y gasoline (US)
- 10,000 to 20,000 early fatalities/y from gasoline production/combustion (US)
- 100,000 to 200,000 DALYs/y from gasoline (US)
- 30 million DALYs/y from all cause in the US
- $60 billion to $120 billion (monetized DALYs)
- $0.56 health cost per gallon

Grand Challenges for LCA of Biofuels
(3rd Most Downloaded ES&T Paper in early 2011)


Environmental Science & Technology

FEATURE

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Grand Challenges for Life-Cycle Assessment of Biofuels

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INTRODUCTION

To address energy security and climate-change concerns, substitutes are needed for petroleum-based transportation fuels. In addition to electricity and natural gas, biofuels are emerging as an important class of substitutes, today dominated by ethanol that is produced from corn and sugar cane. For the future, many

LCA follows internationally accepted met
and ISO 14044) and practices to evaluate
impacts of technologies, processes, and p
determine their propensity to consume resou
pollution. "Life cycle" refers to all stages of a
material extraction through manufacturing, di
to ultimate disposal, including all interveni
steps. Conducting an LCA entails four types
defining the goal and scope of the analysis; (
cycle inventory data on materials and energy
and wastes; (3) conducting a life-cycle impa
characterizes the impacts of constituent p
interpretation, which provides an analysis of t
along with sensitivity and uncertainty ana
decision-making.[3]
This paper emerged from research plann
meetings of the Life-Cycle Program of the E
Institute at the University of California, Berke
and applying LCA to assess the environment
transportation fuels, LCA practitioners comm
following impact categories: climate forcin
emissions and impacts, water-resource i
changes, nutrient needs, human and ecologic
and other external costs. LCA practitioners
social impacts and economic factors, which
here. In selecting the impact categories, we

① **Understanding farmers, feedstock options, and land use**

② **Predicting production technologies & practices**

③ **Characterizing tailpipe emissions and their health consequences**

④ **Incorporating spatial heterogeneity: inventories and impacts**

⑤ **Accounting for time in impact assessments**

⑥ **Assessing transitions as well as end states**

⑦ **Confronting uncertainty and variability**

Exercise

1) Is it ethical to put a value on life and disease in a policy making context?
2) Consider what value would you use for mortality gain/loss, for disease, and/or for statistical metrics of disease change (such as Disability Adjusted Life Years)
3) Review the Nuffield principles and consider how these would be used in making ethical choices in selecting and producing biofuels more generally - are these principles helpful?
4) Do we need multiple sources of data and input to reach a decision?
5) How are these processes complementary and what are the advantages and limitations of these alternative approaches to setting goals for biofuel production systems?