Looking Beyond GHG, Land Use, Energy, and Biodiversity – Other Environmental, Health, and Safety Considerations

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Characterizing Environmental, Human Health, & Safety Impacts

- **What environmental, human health, and safety benefits and impacts can we expect to see with increased biofuels use?**
- **How will we identify the significant implications? (positive or negative) Which ones do we already know about?**
- **Where along the biofuels supply chain will these concerns exist?**
- **Will there be indirect effects on human health due to changes in land, water, and ecosystems?**
- **Will existing regulatory standards be adequate to protect environment, human health and safety?**
- **How can we design the biofuels supply chain to minimize potential adverse environmental, human health, and safety effects?**

Environmental Challenges / Benefits Will Depend on:

- Type of Fuel
- Type of Feedstock
- Type of Conversion Technology
- Geographic Location of Operations
- Characteristics and Status of Natural Resources and Environment

- Need tools to compare pathway choices and weigh tradeoffs
  - Local, regional, national, global
  - Energy security, rural development, environmental improvement, GHG reductions
  - But also health and safety

Some Questions to Think About

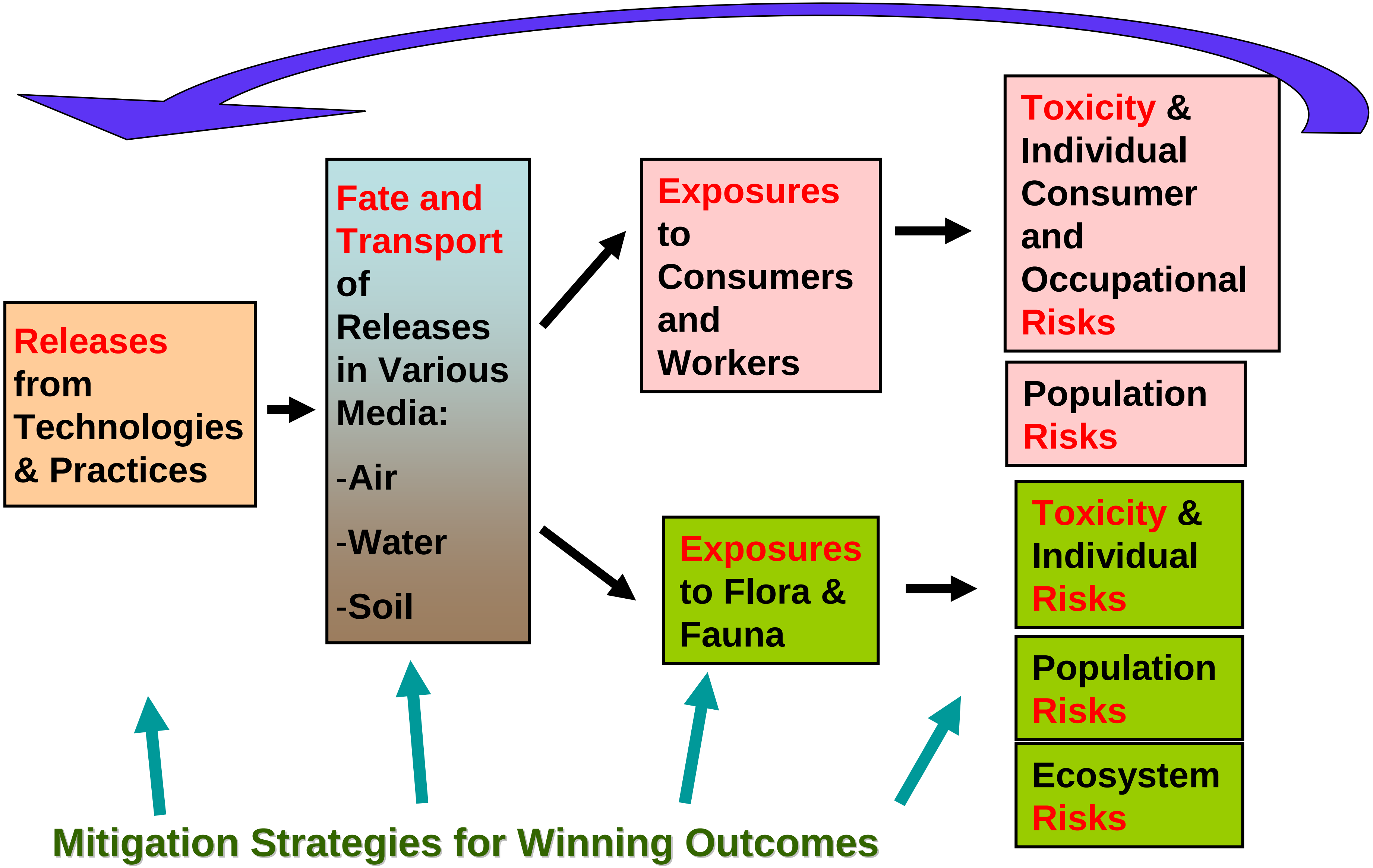
Have we adequately identified all the targets of relying on biomass?

- GHG reductions
- Energy independence and affordability
- Energy Efficiency
- Economic Development
- Water Quality and Availability
- Land Conservation, Value, and Ecosystem Services
- **Public Health**

Some Questions to Think About

- Have we compared all the benefits/impacts of using biomass for fuel vs. power and other uses?
- Compared current & future feedstocks with each other and with other potential feedstocks? Considered same resource demands by other industrial and economic systems. For local, regional, national, and global implications?
- Compared benefits/impacts of
  - different kinds of conversion technologies?
  - different fuels?
- Examined the impact of the geospatial relationship of Feedstock production, conversion, and use?

The Risk Paradigm Applied to Biofuel Practices & Technologies



Practices & Technologies of the Biofuels Supply Chain

Feedstock Production → **Feedstock Logistics** → **Biofuels Production** → **Biofuels Distribution** → **Biofuels End Use**

Feedstock Production

Practices:

Trends in land use & land use shifts

Trends in Crop rotation shifts & new crops

Trends in GMO use

Trends in irrigation, nutrient & pesticide applications

Feedstock Logistics

Practice:

Trends in harvesting & storing agricultural residuals

Transportation of feedstock

Biofuels Production

Practice:

Integration of conversion technologies: thermochemical, biochemical, biological, chemical

Trends in GMO use

Production of fuels, power, heat, & chemicals for manufacturing

Land & infrastructure needs

Production of co-products (e.g., DDGs & glycerol) & waste

Biofuels Distribution

Practice:

Transport: Use existing pipeline, barge, truck

Storage: tank infrastructure & prevention of material incompatibility

Building new infrastructure

Biofuels End Use

Practice:

Varying concentrations of Ethanol, Biodiesel, & other fuels

Varying adoption rates & geographical distributions

Potential Releases Across the Supply Chain Beyond GHG

Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use




Feedstock Production

- Invasive or noxious plants
- Allele drift
- Nutrients & pesticides

Feedstock Logistics

- Soil erosion
- Particulates from harvesting / processing feedstocks
- Emissions from transport of feedstocks

Biofuels Production

- Air emissions
- Water emissions
- Wastes
- Co-Products
- GMO alleles in co-products

Biofuels Distribution

- EtOH / BTEX releases to water and soil
- Chemical anti-corrosive additives
- New fire retardants
- Emissions from transport and storage

Biofuels End Use

- Vehicle emissions from combustion of various blends
- Atmospheric chemical reactions

Feedstock, Process, and Fuel Type Combinations Matter

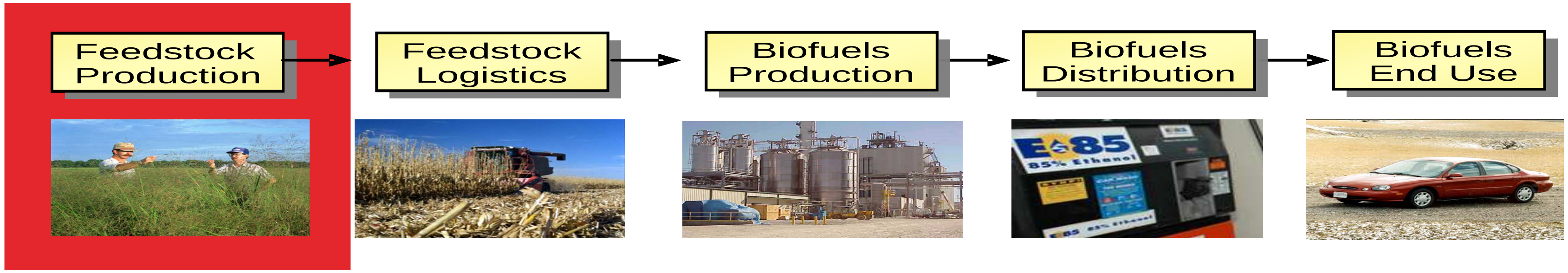
Feedstock	Conversion Technology	Products and Uses
Agricultural Crops Agricultural Residues Animal Residues Food Processing Waste Woody Biomass MSW and C&D Wastes	**Thermo-chemical:** - Gasification - Pyrolysis - Hydrothermal Depolymerization - Combustion - Fuel Synthesis **Biochemcal:** - Acid Hydrolysis - Pretreatment & Enzymatic Hydrolysis - Fermentation - Anaerobic Digestion **Chemical:** - Transesterification	**Fuel Types:** - Ethanol - Biobutanol - Mixed Alcohols - Biodiesel - Green Diesel - Renewable Diesel - FT Diesel & Gasoline - Dimethyl Ether - Synthesis Gas, Biogases, & H_2 - Hydrogen **Other Products:** - CHP (steam & electricity) - Chemical Feedstock

Optimizing Multiple Outcomes

Local, Regional, National Results

Scenario / Pathway	FS- A CT-W Fuel	FS- B CT-X Fuel	FS-C CT-Y Fuel	FS-D CT-Z Fuel
GHG emissions	↓	X		X
H_2O demand				
H_2O quality				
PM				
CO				
NOx	↑	↓	↑	
VOCs				
Ethanol emissions				
Biodiversity & land use				

Environmental & Health Questions: Feedstock Production Practices and Technologies



Practices:

- land use shifts
- crop rotation shifts
- new crops and invasive or noxious plants
- irrigation
- nutrient & pesticide applications
- Genetic Engineering

Environmental Questions:

Do these practices effect:

-NPS run-off of N, P, and pesticides?

- soil erosion and quality?

-water availability, acreage & function of waters?

- water quality, hypoxia, pathogen levels in waters?

-Biodiversity?

Applicable Regulations:

- FIFRA
- TSCA

How Does Genetic Engineering Impact Environmental and Health Outcomes?

Engineered Traits:

- Stress Tolerance (drought, cold, heat, salt, heavy metals, floods)
- Resistance to pests (insects, viruses, fungi, bacteria)
- Tolerance to herbicides
- Improved water, nutrient, light, CO2 utilization
- Rapid growth / increased yields

Environmental Outcomes:

- Climate Change/Carbon Storage/Soil Quality
- Land Use
- Invasiveness
- Hydrology & Water Quality
- Biodiversity & Gene Flow

How does GE Influence land use change and other agricultural practice?

How does GE Influence allergenicity and other public health issues?

How does GE Influence carbon storage?

How does GE influence biodiversity?

The environmental performance of Ethanol varies greatly depending on production processes

ETBE may present environmental problems that are similar to those that arose from MTBE.

The major contributors to life cycle greenhouse gas emissions are agricultural practices and petroleum inputs

MSW ethanol use in vehicles reduces net greenhouse gas emission by 65 percent compared to gasoline and by 58% when compared to corn ethanol.

However, landfilling with landfill gas recovery either for flaring or for electricity production, results in greater reductions in GHG emissions compared to MSW to ethanol conversion.

Non-Agricultural Crop & Residue Feedstocks

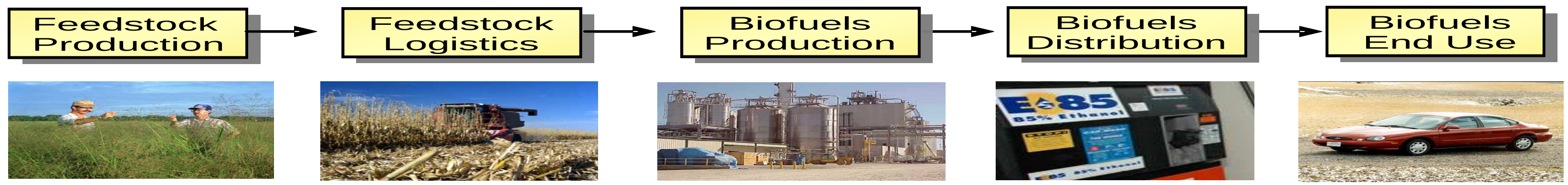
Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels End Use

<u>WASTES:</u>

- **-Manures**
- **-Animal Rendering**
- **-Fats & Greases**
- **-MSW**
- **-Sewage Sludge**
- **-Construction & Demolition Debris**
- **-Urban Wood Waste**
- **-Food Processing Waste**
- **-Tires**

Are we OPTIMIZING USE of <u>ALL</u> feedstock for LARGE SCALE SUSTAINABLE PRODUCTION OF FEEDSTOCKS?

How do Other Feedstocks Compare?



<u>Inputs</u>

- Land Use
- Energy Inputs
- Water Inputs
- Chemical Inputs
- Nutrients
- GMOs

<u>Outputs</u>

- GHG and other air emissions
- Nutrients
- Wastes
- Water contamination
- Tons/acre biomass
- Allele drift

Waste As a Feedstock Has Environmental and Material Value

- Manures – reduce nutrient loadings
- Food Processing wastes – reduce waste management needs
- Greases – reduce waste water treatment fouling
- Woody Biomass – reduce wildfires; increase landfill diversion
- Construction and Demolition – increase landfill diversion
- MSW – increase landfill diversion; may also increase recycling rates, based on location & material
- Disaster Debris – landfill diversion; risk management

Environmental & Health Questions Associated with Practices & Technologies of Feedstock Logistics

Feedstock Production → **Feedstock Logistics** → Biofuels Production → Biofuels Distribution → Biofuels End Use

Practice:

Harvest of agricultural residuals

Transportation of feedstock

Applicable Regulations:

- **TSCA**
- **FIFRA**

Environmental Questions:

Do these practices effect:

- net energy use?

- transportation infrastructure needs?

- land use change?

-Soil erosion?

-soil productivity?

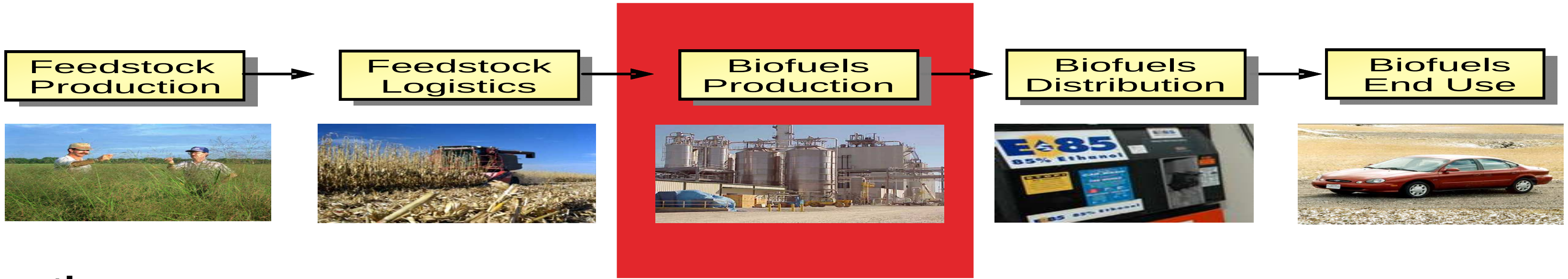
- water quality?

Health Questions:

Occupational exposures

Increased transportation emissions

Environment & Health Questions Associated with Conversion Technologies



Practices:

Integrated conversion technologies with water, energy and other demands

Production of fuels, power, heat, and chemicals for manufacturing

Land & infrastructure needs

Large volume production of co-products (e.g., DDGs and glycerol)

Do these practices effect:

- Air quality?
- Water quality and quantity?
- What wastes are generated? Management options?
- Microbial protein contamination of co-products
- Are there opportunities for sustainable use of co-products?
- Can designs optimize environmental outcomes? (e.g., CHP, DfE, Green Chemistry)
- Potential for Human Exposure

Applicable Regulations:

NEPA

EPCRA

CAA

RCRA

TSCA

CWA

SDWA

PPA

Research Issues Specific to TSCA 101 Chemicals & Biofuels

General exposure

- How much used enzyme will be distributed in different media?
- Do thermostable enzymes differ in environmental fate from those produced by normal flora in soil/water?
- How active will the used residue be?
- What are the consequences for humans? Other organisms?

Environment, Health,& Safety Questions Related to Distribution Infrastructures

Feedstock Production → Feedstock Logistics → Biofuels Production → **Biofuels Distribution** → Biofuels End Use

Practices:

Distribution of ethanol varying blends of EtOH (E-10 to E-85)

Use existing pipeline, barge, truck, and tank infrastructure

Build new distribution infrastructures (e.g., pipelines)

Health Questions:

- Are there significant health impacts associated with biofuels distribution infrastructure?
  - Could leaks during biofuels distribution affect human health?
  - Are there concerns with flammability, volatilization, and associated exposures for human health?

Environmental Questions:

What is potential for leaks from material incompatibility of blends?

Do detection methods work?

How dol blends impact plume migration and remediation?

Regulations:

NEPA

CAA

RCRA

CERCLA

EPCRA

CWA

SDWA

Safety - flammability, volatilization, and exposure

Environment, Health, & Safety Questions Related to End Use of Biofuels

Health Questions:

- How could end use of biofuels affect human health?
- Are there differences in exposure rates to emissions?
- If fuel blends result in different emissions of NOx, VOC, PM, Ozone would there be new or different health consequences?

Practices:

Varying blends of Ethanol, Biodiesel, and other fuels

Varying adoption rates and geographical distribution

Environmental Questions:

Air quality (ozone, PM, air toxics, secondary PM from PM) and impact non-attainment?

Do different fuel blends impact air emissions (e.g., NOx, VOC, PM, Ozone) differently?

-What are the human health and ecological exposure rates and risks?

Regulations:

CAA

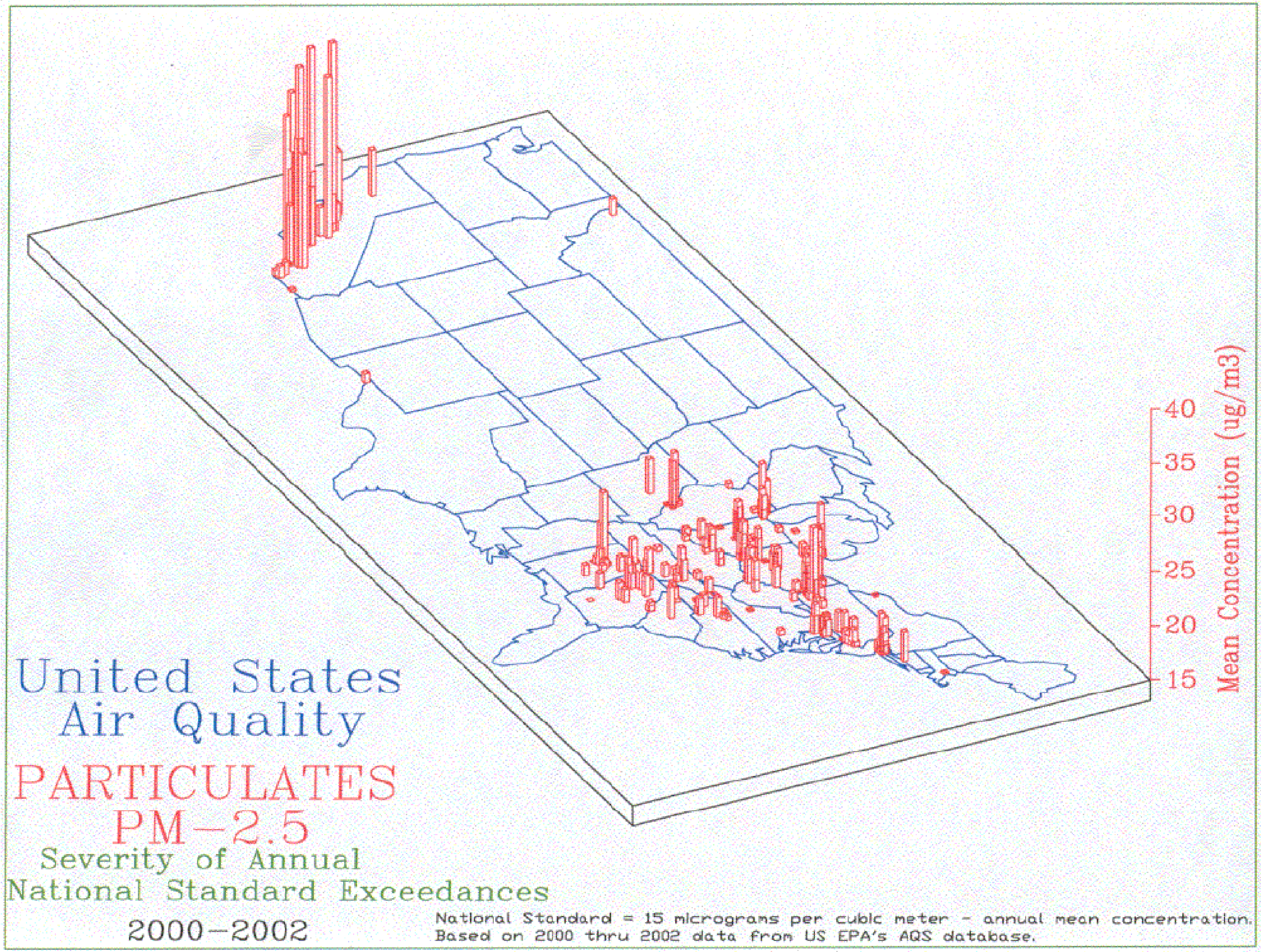
RCRA

CERCLA

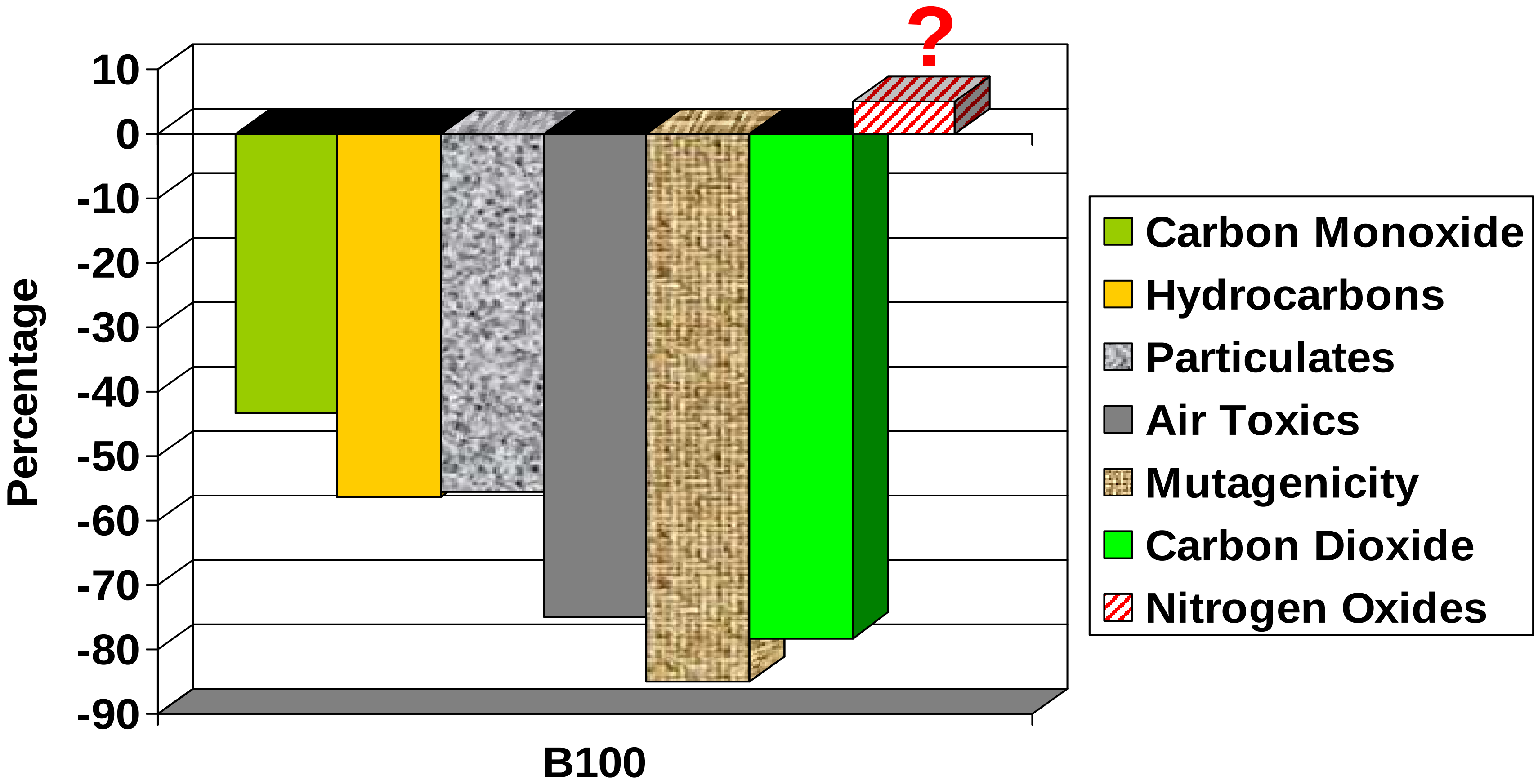
CWA

Safety

- flammability, volatilization, and exposure to consumers and first responders


United States
Air Quality
PARTICULATES
PM-2.5
Severity of Annual
National Standard Exceedances
2000-2002
National Standard = 15 micrograms per cubic meter - annual mean concentration.
Based on 2000 thru 2002 data from US EPA's AQS database.
Mean Concentration (ug/m3)
40
35
30
25
20
15

Emission Difference between Biodiesel and Petrodiesel



Source: Draft EPA Report *EPA420-P-02-001*

Air Emission Effects for Ethanol

- Most studies show slight increase in Nitrogen Oxides
- Most studies show decrease in CO and PM
- Increase in ethanol, formaldehyde, and acetaldehyde emissions, particularly in cold climates
- In urban areas for each of the biofuel production options examined, one study showed net reductions for almost all criteria pollutants, with the exception of carbon monoxide (unchanged) and VOCs, which may increase in certain processes.
- Conventional and hybrid electric vehicles, when fueled with E85, could reduce total sulfur oxide (SO_x) emissions to 39-43% of those generated by vehicles fueled with gasoline.

E85 Effects on Cancer & Mortality

- E85 (85% ethanol fuel, 15% gasoline) may increase ozone-related mortality, hospitalization, and asthma by about 9% in Los Angeles and 4% in the United States as a whole relative to 100% gasoline usage.
- Ozone increases in Los Angeles and the Northeast United States are partially offset by decreases in the Southeast United States.
- E85 also increased peroxyacetyl nitrate (PAN) in the U.S. but was estimated to cause little change in cancer risk.
- Due to its ozone effects, future E85 may be a greater overall public health risk than gasoline.
- Unburned ethanol emissions from E85 may result in a global-scale source of acetaldehyde larger than that of direct emissions.

Source: Jacobson, Mark Z.. 2007. Effects of ethanol (E85) versus gasoline vehicles on cancer and mortality in the United States. *Environmental Science Technology.* 41 (11): 4150-4157

Air Quality and GHG Emissions Associated with Using Ethanol in Gasoline Blends

Pollutant	*Conventional Gasoline*	*Reformulated Gasoline*
Acetaldehyde	**Increase**	**Increase**
Benzene	**Decrease**	**Decrease**
1.3-butadiene	**Decrease**	**Decrease**
Formaldehyde	**Increase**	**Decrease**
CO	**Decrease**	**Decrease**
NO_x	**Increase**	**No change**
Tailpipe VOC	**Decrease**	**No change**
Evaporative VOC	**Increase**	**No change**
Total VOC	**Increase**	**No change**
Particulate matter	**Decrease**	**Decrease**
(Peroxyacetyl Nitrate) PAN	**Increase**	**Increase**
Isobutene	**Decrease**	**Decrease**
Toluene	**Decrease**	**Decrease**
Xylene	**Decrease**	**Decrease**

OUNL, BATELLE, DOE

What's Needed?

- Apply the risk framework to Biofuels to identify EHS issues / benefits
- Integrate this information with other outcomes
- Compare different biofuels pathways to optimize outcomes

Research & Data Needs

Expand from existing efforts to understand media specific and life cycle impacts on a local, regional, national, global scale

- Improve our understanding of the baseline state of the environment (monitoring)
- Characterize existing and emerging practices and technologies associated with biofuels production for targeted performance goals
- Inventory and assess <u>real</u> releases from practices & technologies (monitoring)
- Assess fate and transport of chemicals (monitoring & modeling)

Research and Data Needs

- Assess exposures and risk to human health and the environment
- Impacts on ecosystem services on local, regional, national, global scale
- Sensitivity analyses on what the greatest stressors are and under which circumstances
- Development and implementation of mitigation options
- Continuous monitoring of improvements or decline