Lifecycle Environmental Impacts Associated with Biofuels

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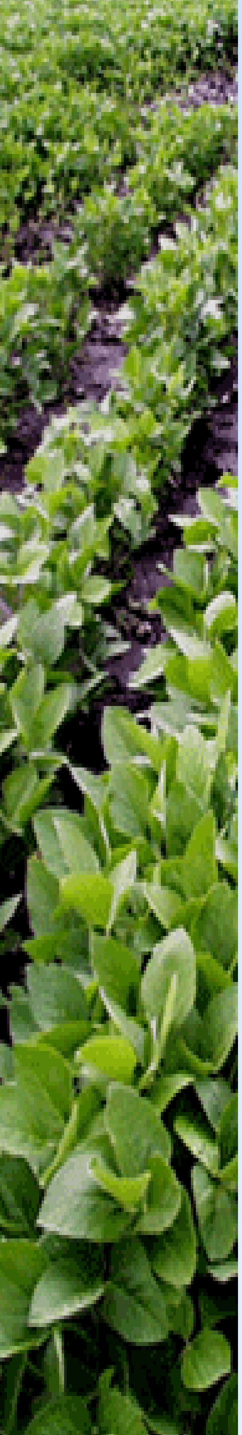
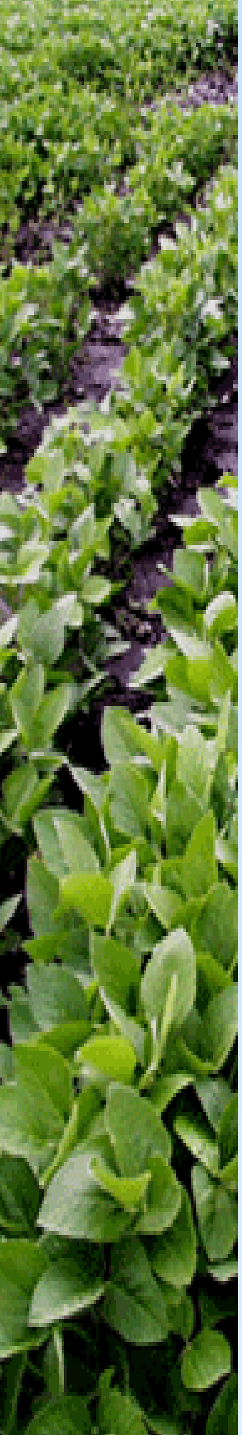


Biofuels from Corn-Soybean Rotations

- Soybean → Biodiesel
- Corn → Ethanol
- Corn Stover → Ethanol
  - Considered an agricultural waste
  - Critical for soil health (soil carbon, erosion control)
  - Can be harvested and baled like hay

A Lifecycle Perspective



Ethanol

Soy meal

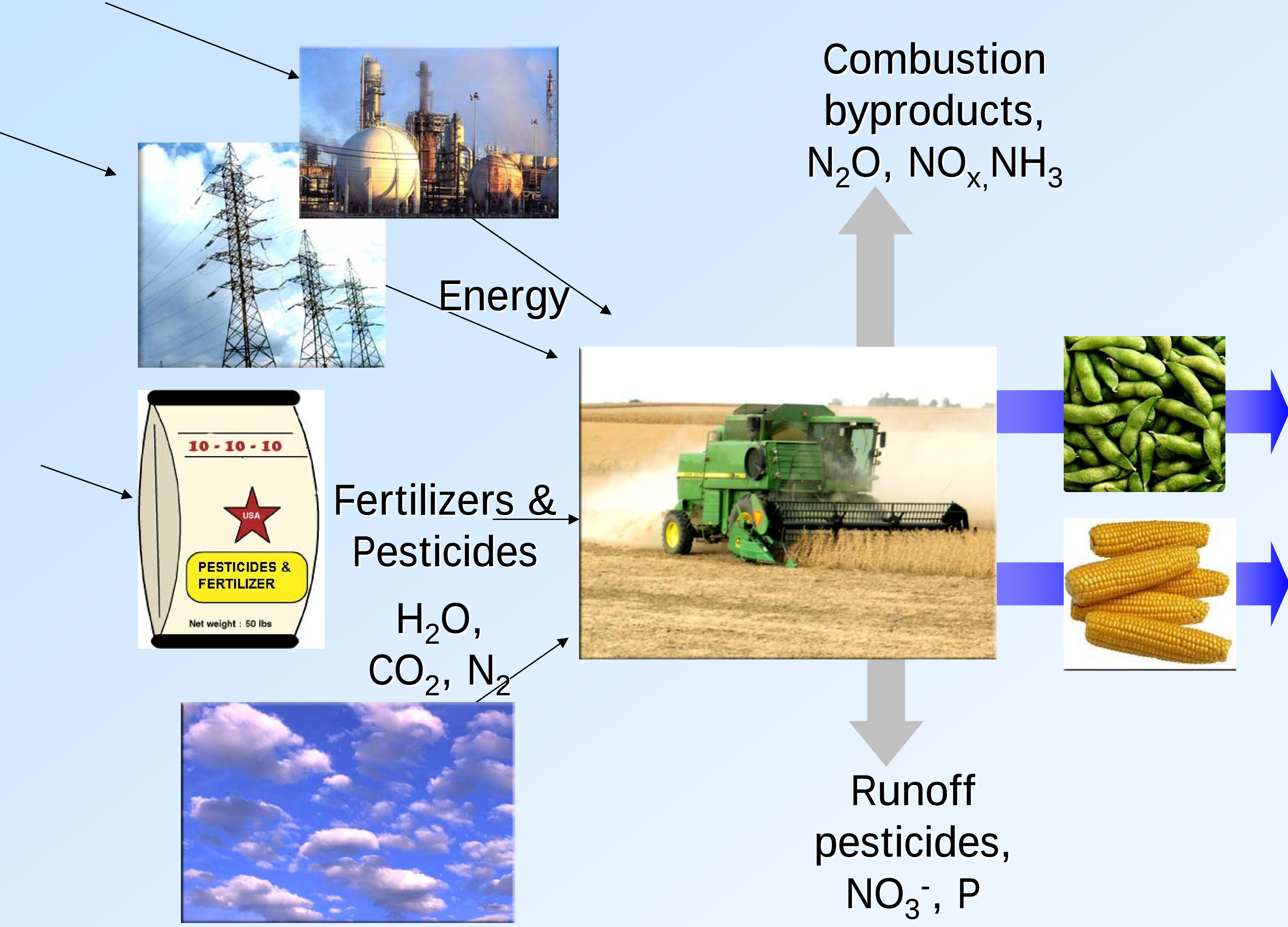
Dried distillers grains

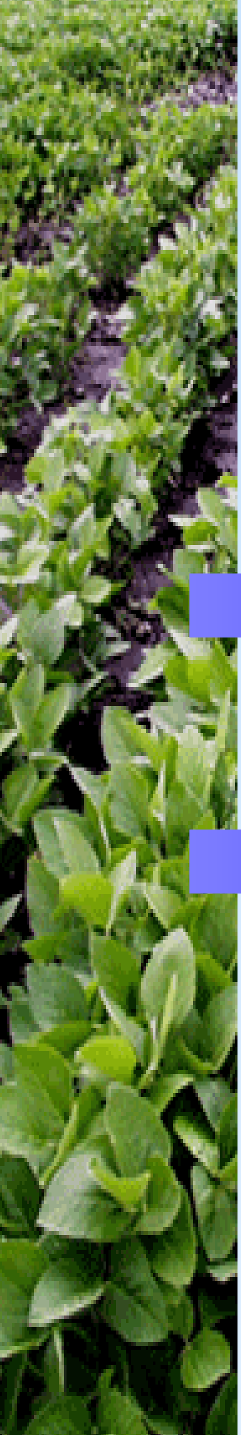
Other by-products

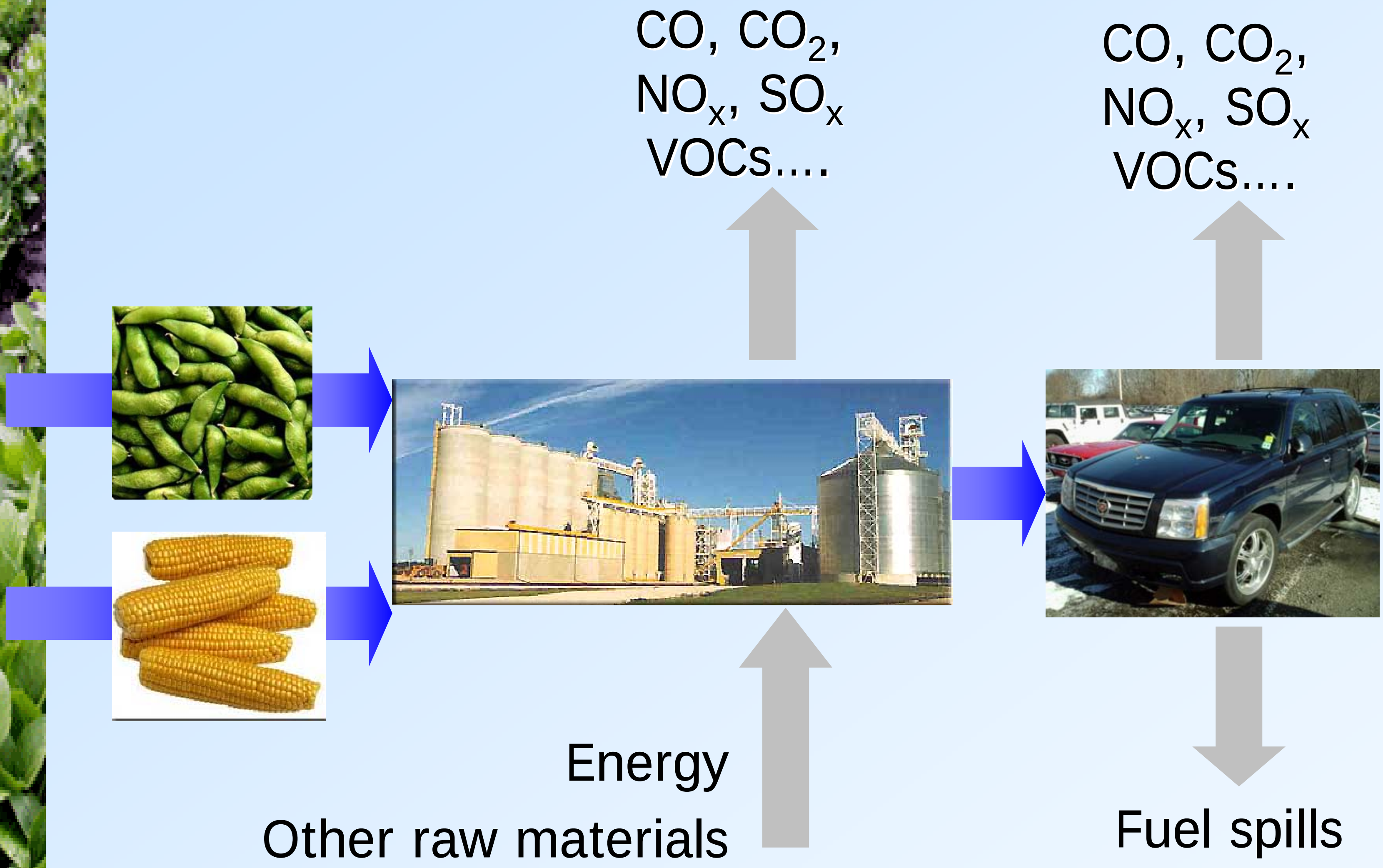
Biodiesel

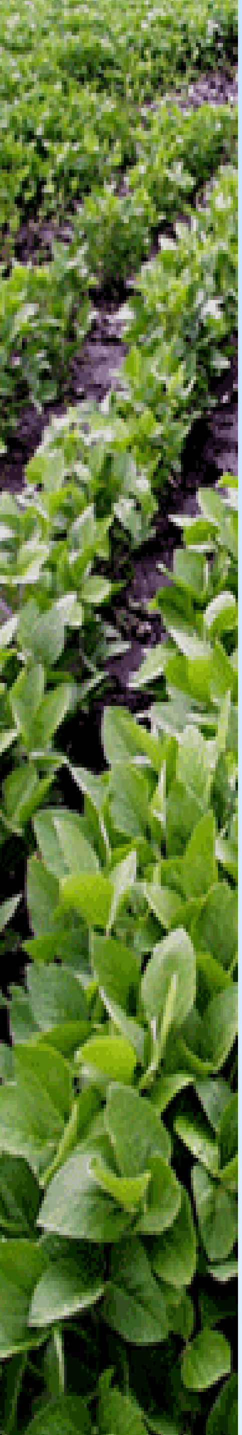
Ethanol

Environmental impacts occur at all stages in the lifecycle


Combustion byproducts,
N_2O, NO_x, NH_3
Energy
10 - 10 - 10
USA
PESTICIDES & FERTILIZER
Net weight : 50 lbs
Fertilizers & Pesticides
H_2O,
CO_2, N_2
Runoff pesticides,
NO_3^-, P

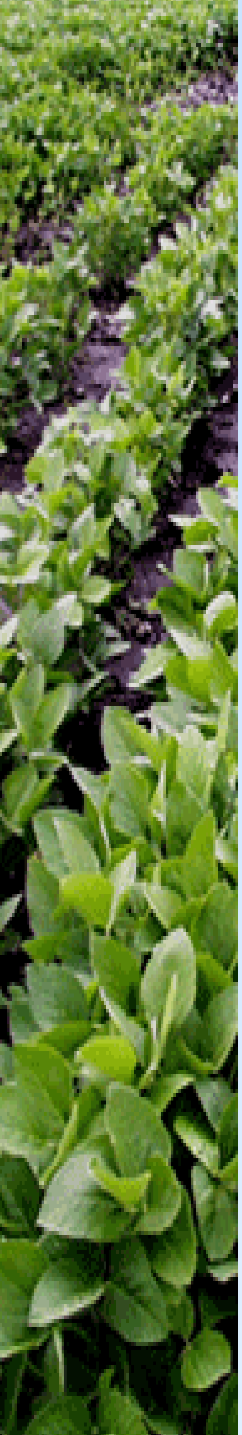



CO, CO_2, NO_x, SO_x VOCs....
CO, CO_2, NO_x, SO_x VOCs....
Energy
Other raw materials
Fuel spills



Life Cycle Assessment (LCA)

- Documents material and energy flows throughout a product's life (***inventory***)
  - Raw material (including energy) production
  - Farming
  - Biofuel Processing
  - Biofuel use
- Examines environmental ***impacts*** of all stages in the product's relevant lifetime
- Identifies possible problems or ***opportunities***
- Quantitative basis for decision-making

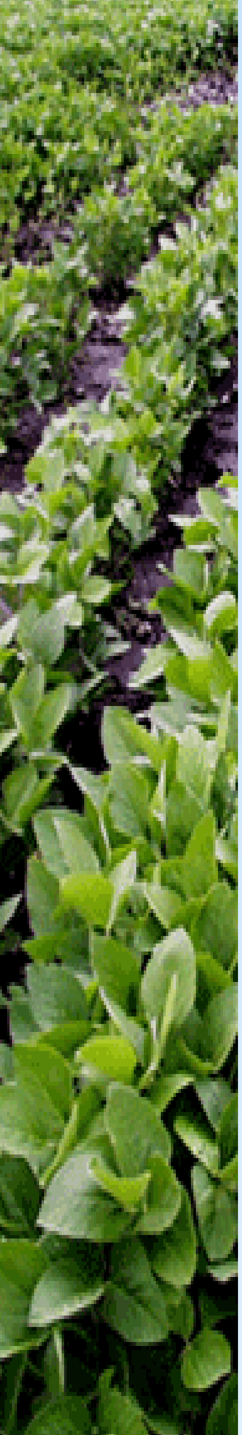


Focus today: Energy / Environmental Issues

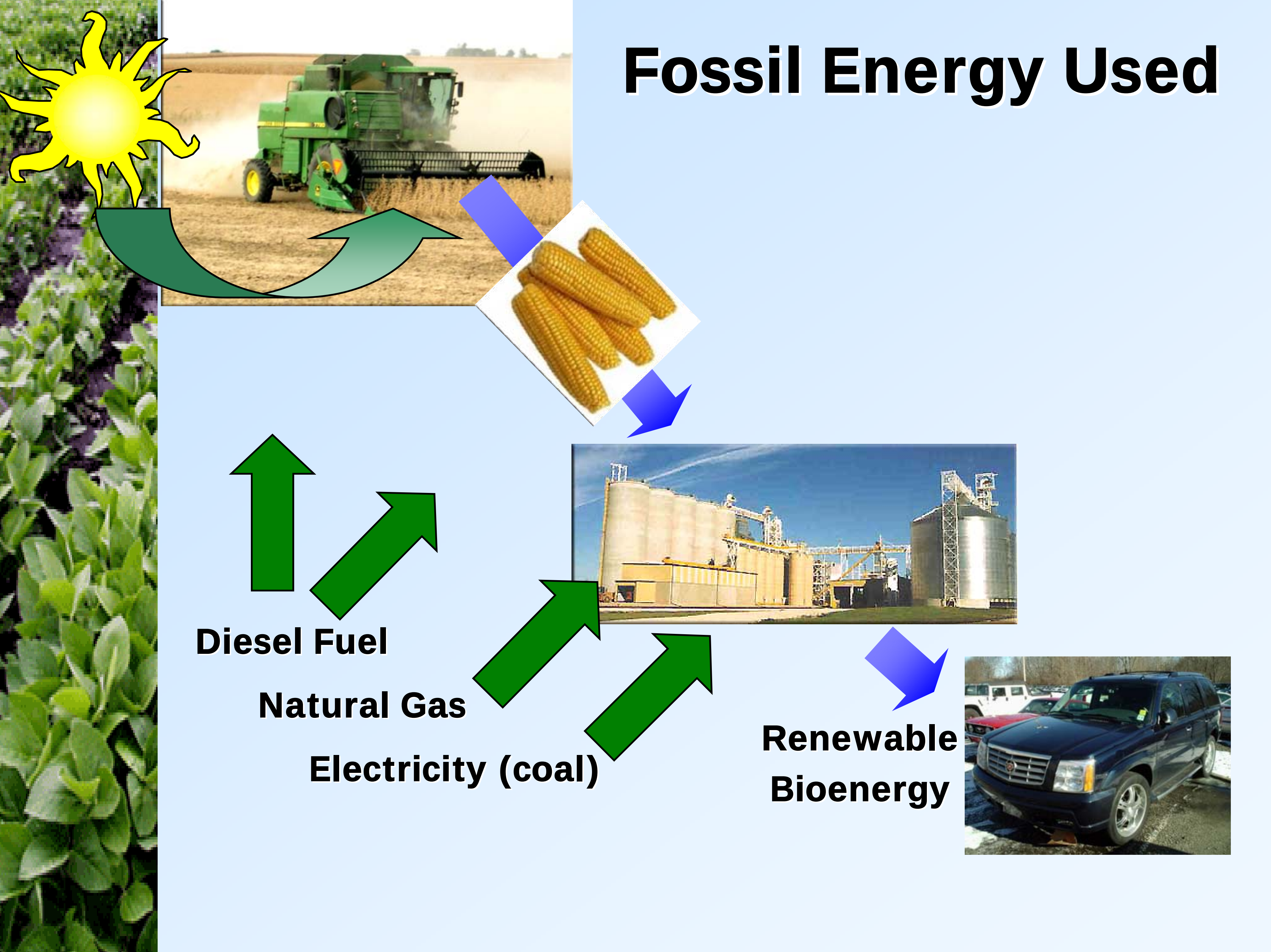
- Energy Security / Conservation[1]
  - How much domestic / renewable energy is consumed to generate the biofuel?
- Environmental quality[2]
  - Are there any detriments from agricultural activities required for biomass → biofuel systems?
    - Nitrogen cycling
    - Carbon cycling

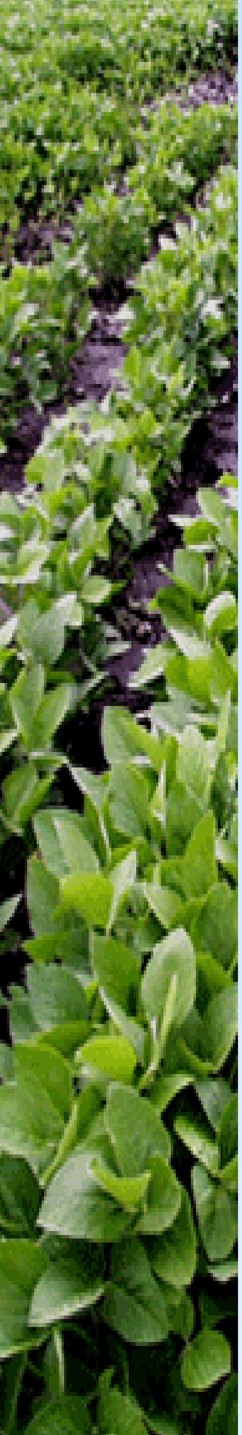
1 PhD research of Amanda Lavigne

2 Sabbatical research – NREL 2004



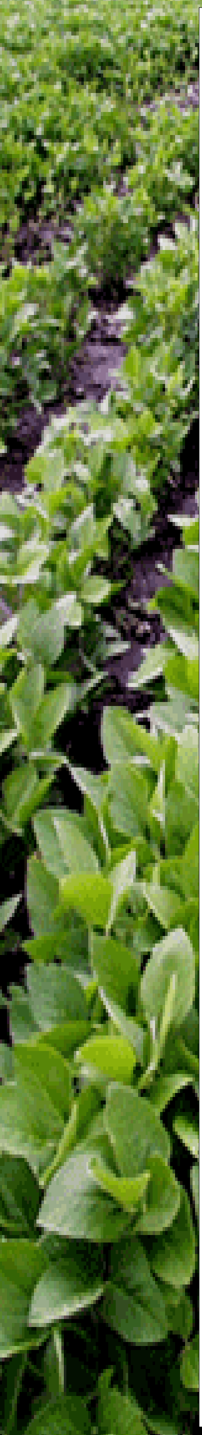
Energy Security and Resource Conservation

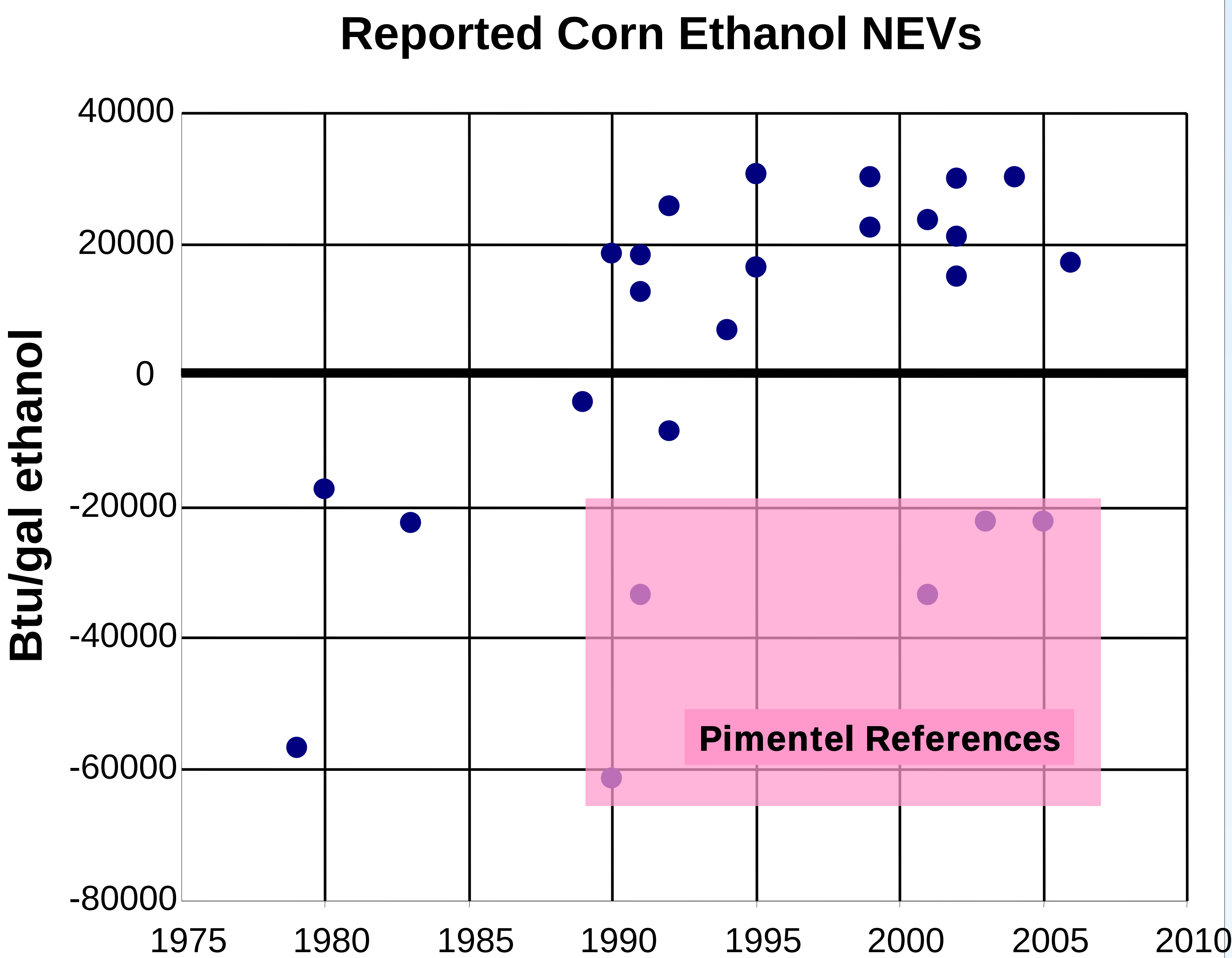

Fossil Energy Used
Diesel Fuel
Natural Gas
Electricity (coal)
Renewable
Bioenergy

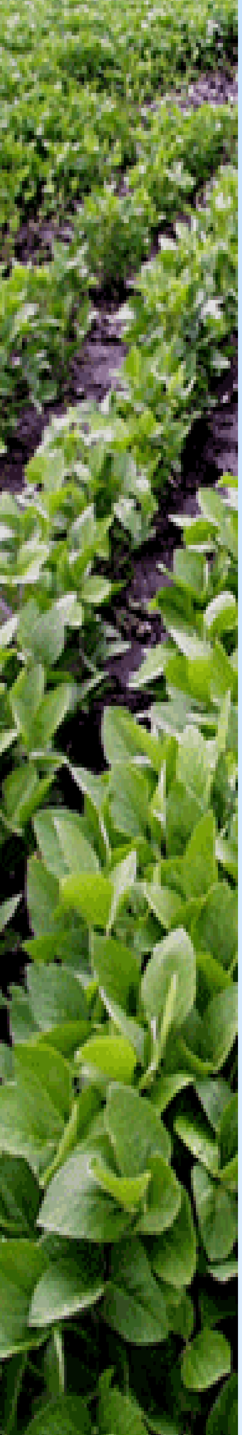


Metrics – Energy Issues

- Current – Net energy value
  - NEV = Energy out – “consumer” energy in
- Alternatives – National Energy Policies
  - Energy Security
    - % energy inputs that are imported
  - Energy Resource Conservation
    - % energy inputs that are renewable
  - Global warming
    - % energy inputs from fossil fuels
- All quantified over lifecycle



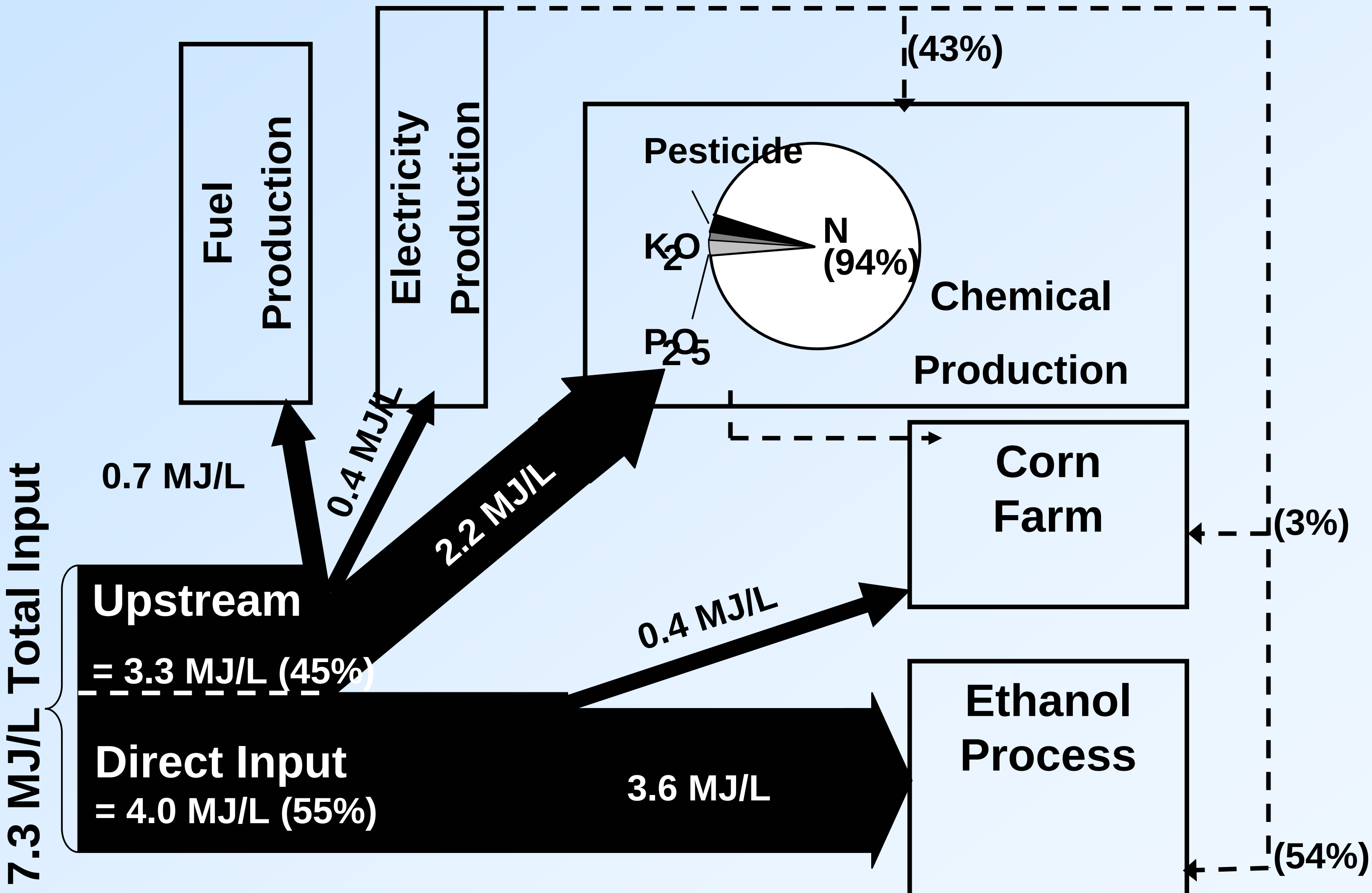

Reported Corn Ethanol NEVs
Btu/gal ethanol
40000
20000
0
-20000
-40000
-60000
-80000
1975
1980
1985
1990
1995
2000
2005
2010
Pimentel References

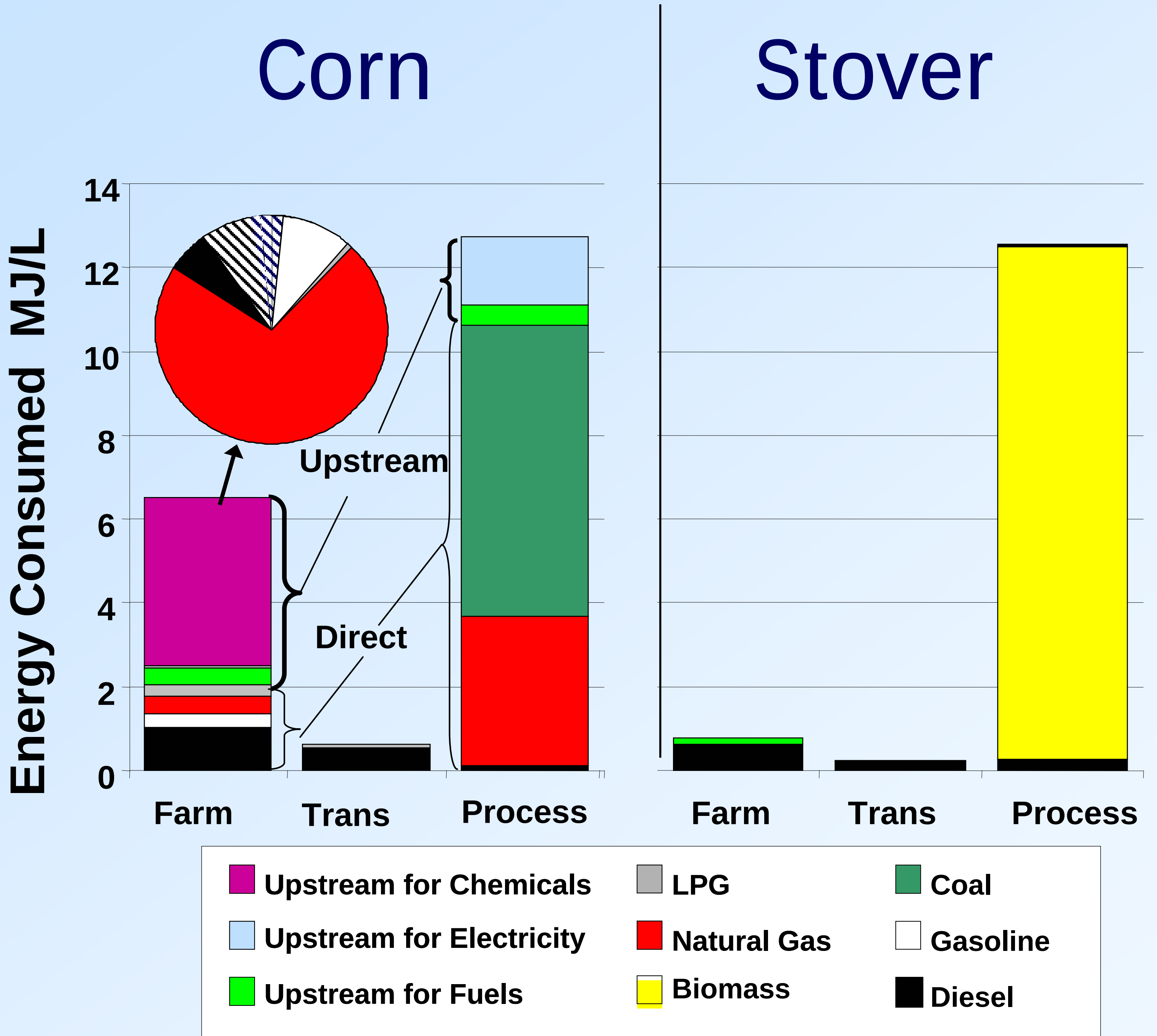


Corn vs. Stover

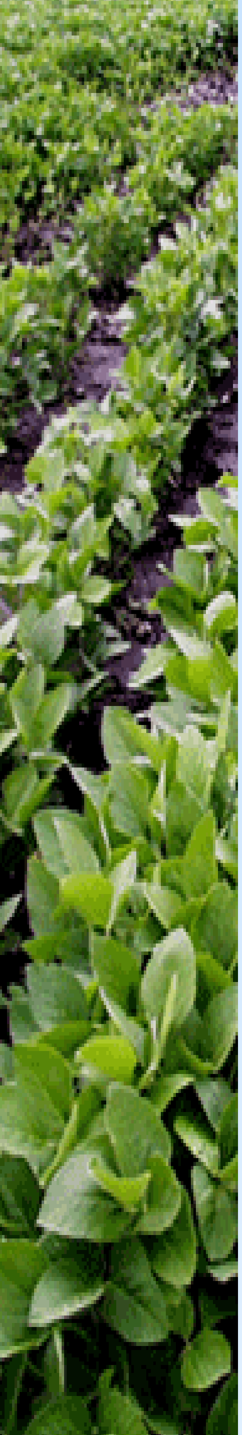
- Net Energy Value
  - Corn: 6.6 MJ/L
  - Stover: 10.1 MJ/L

Define energy flows - NG

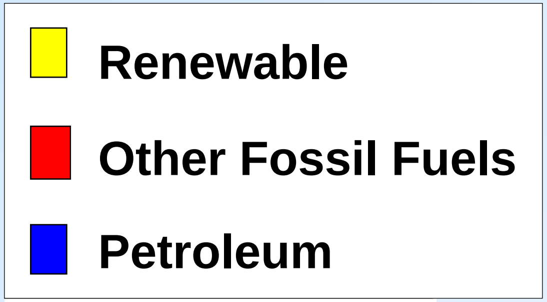


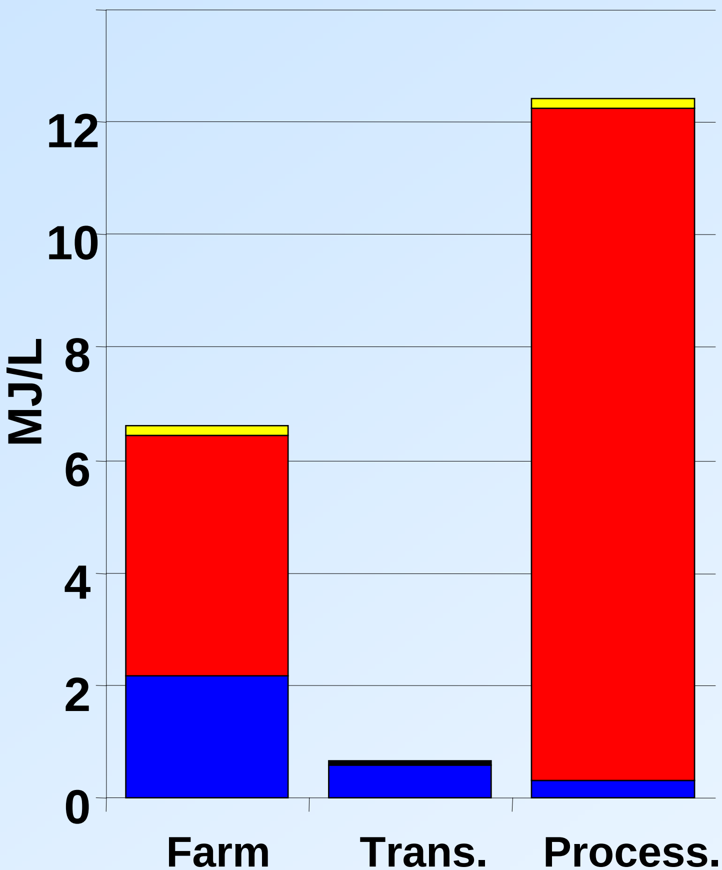


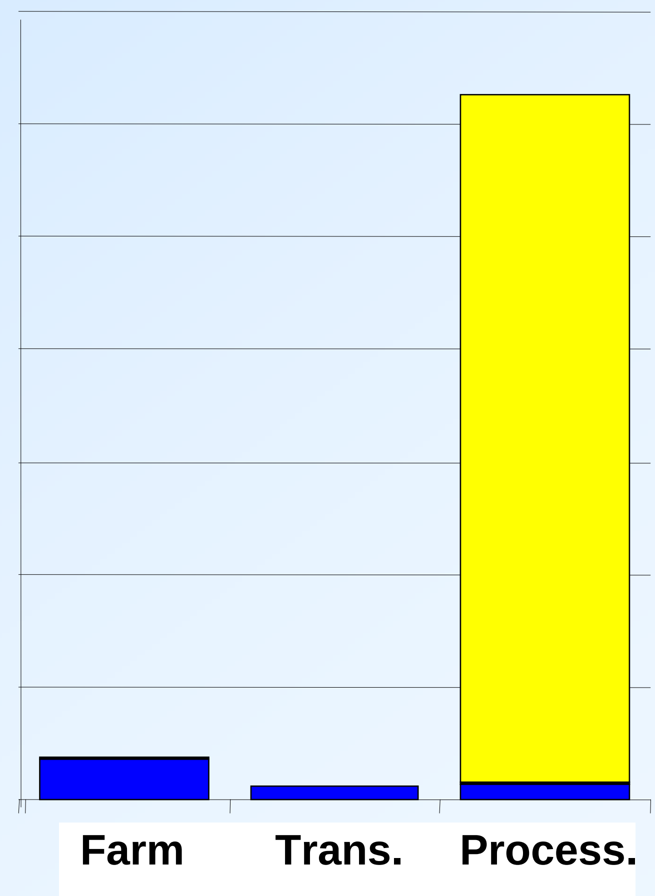
Corn
Stover
Energy Consumed MJ/L
14
12
10
8
6
4
2
0
Upstream
Direct
Farm
Trans
Process
Farm
Trans
Process
Upstream for Chemicals
Upstream for Electricity
Upstream for Fuels
LPG
Natural Gas
Biomass
Coal
Gasoline
Diesel

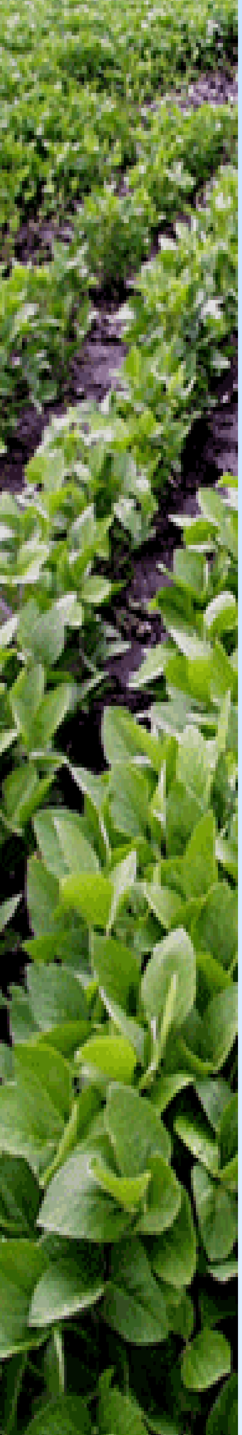


Categorize


Renewable
Other Fossil Fuels
Petroleum

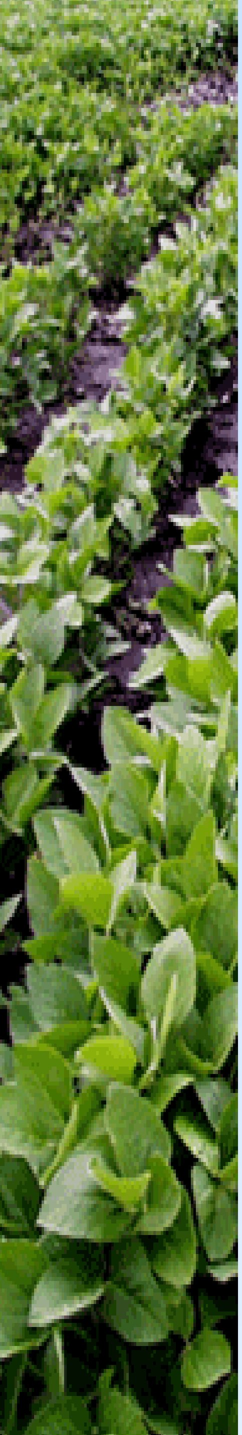

MJ/L
0
2
4
6
8
10
12
Farm
Trans.
Process.


Farm
Trans.
Process.



Summary Energy Issues

- Stover superior for all energy related metrics
  - Lower NEV
  - Much more renewable resources
  - Much less imported oil

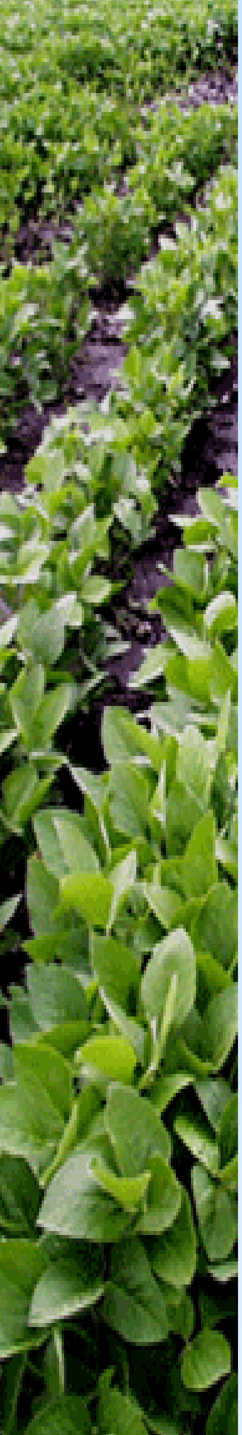


Environmental Impacts:
Nitrogen and Carbon Cycling

Goal: Quantify environmental impacts associated with agricultural activities for corn and corn stover harvest

→Greenhouse gas emissions

→Eutrophication



The Nitrogen Cycle

- Necessary for all living things
- Natural cycles affected with conversion of N_2 to NH_3, NO_3^-
- Greatly increases agricultural yields
- Excess reactive nitrogen responsible for many environmental problems

Nutrients in water

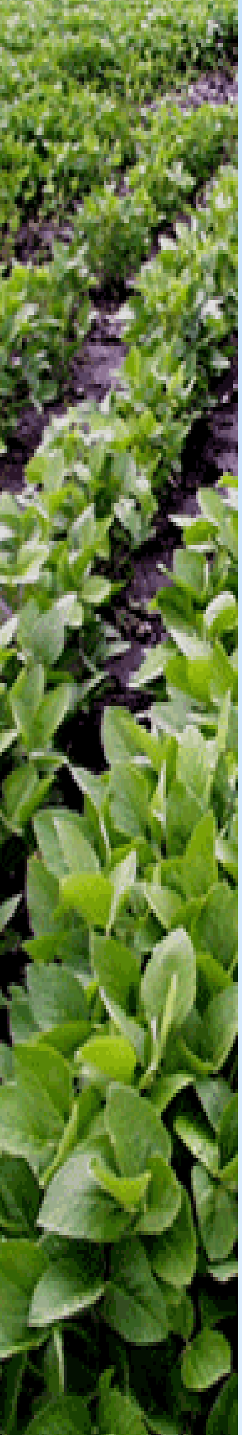
Excess nutrients discharged to water

- **Algal Blooms**
- **Excess aquatic plant growth**

→ Eutrophication

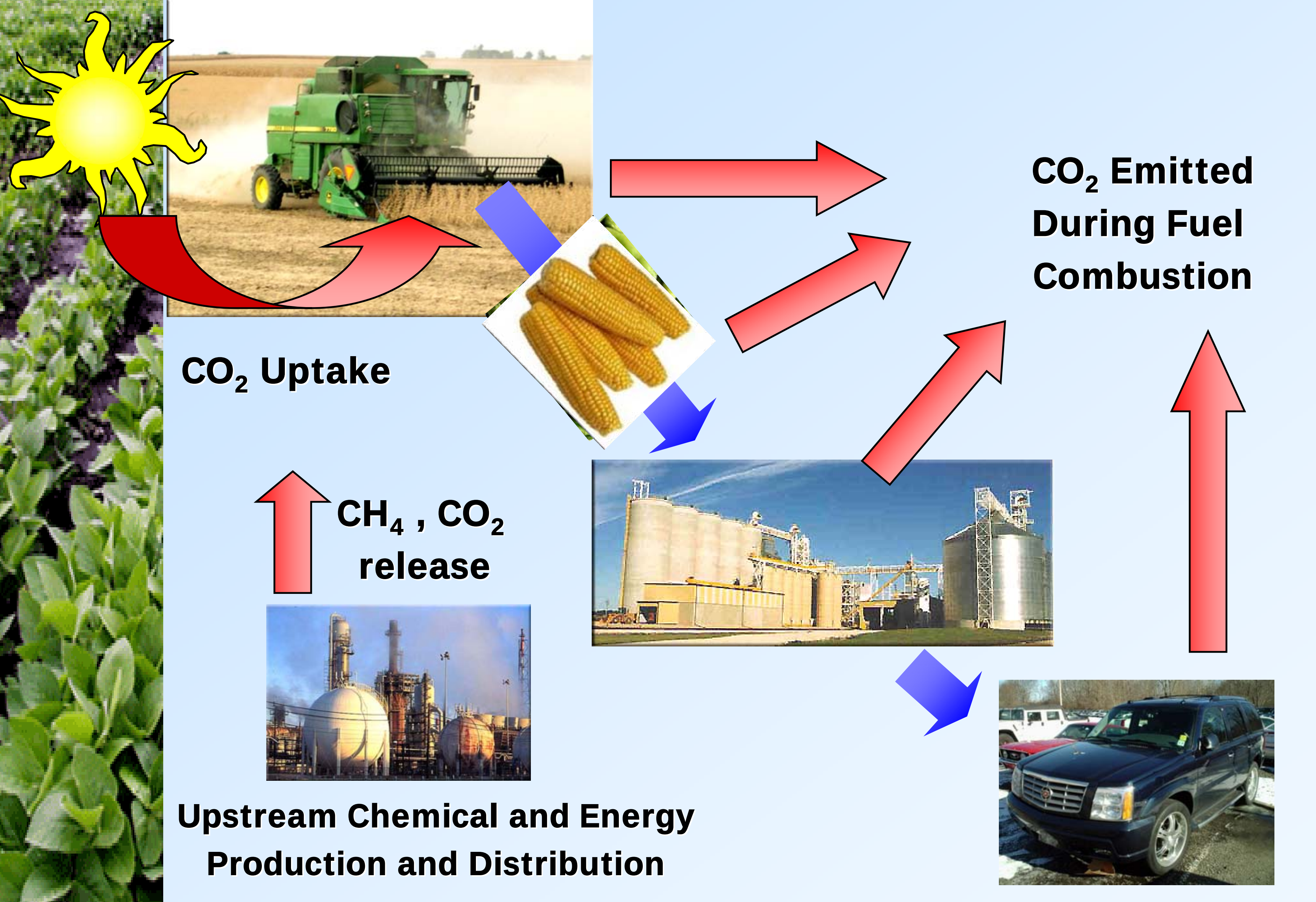
Mutation in frogs from excess N and P in aquatic systems

http://www.nrel.gov/biomass/photos.html

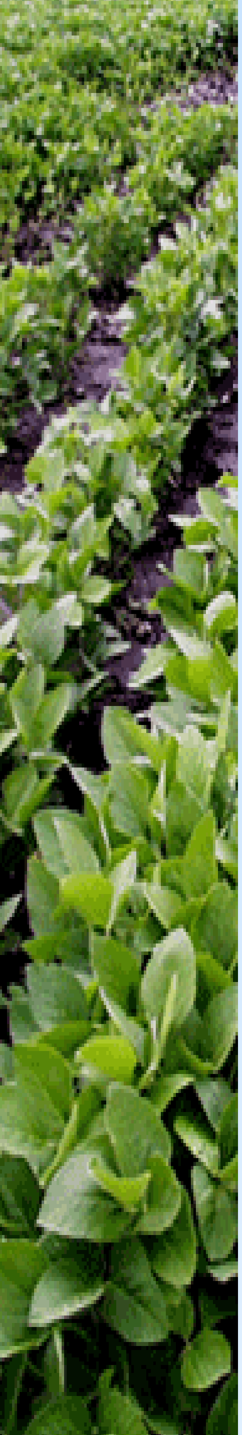


National Scale Issues - Hypoxia

- Too many nutrients - extreme eutrophication
- Oxygen consumption reduced $\rightarrow$ lethal
- Gulf of Mexico along Louisiana coast
  - D.O. < ~2-3 mg/L
  - First observed in mid-1980s
  - ~15,000 km^2 (~50 x 300 km)
    (~ size of Massachusetts)
- Detrimental to ecosystem and economy



Carbon Cycling



Environmental Impacts

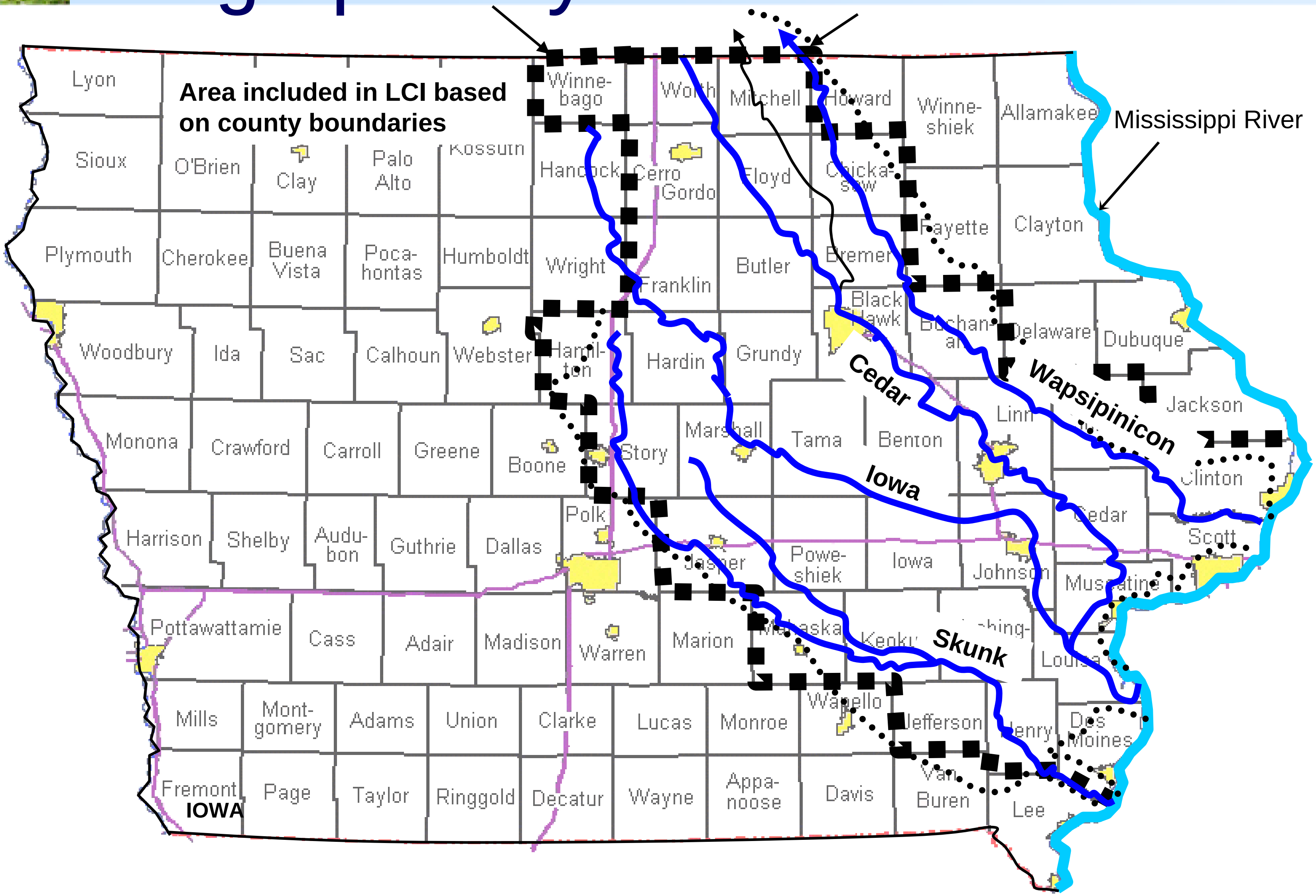
- **Carbon Related**
  - **Greenhouse gases**
  - **Fossil fuel depletion**
  - Organic carbon content in soil
- Nitrogen Related
  - Nutrients in water
  - Acidification
  - Greenhouse gases

Environmental Benefits: Carbon Cycle

VS.

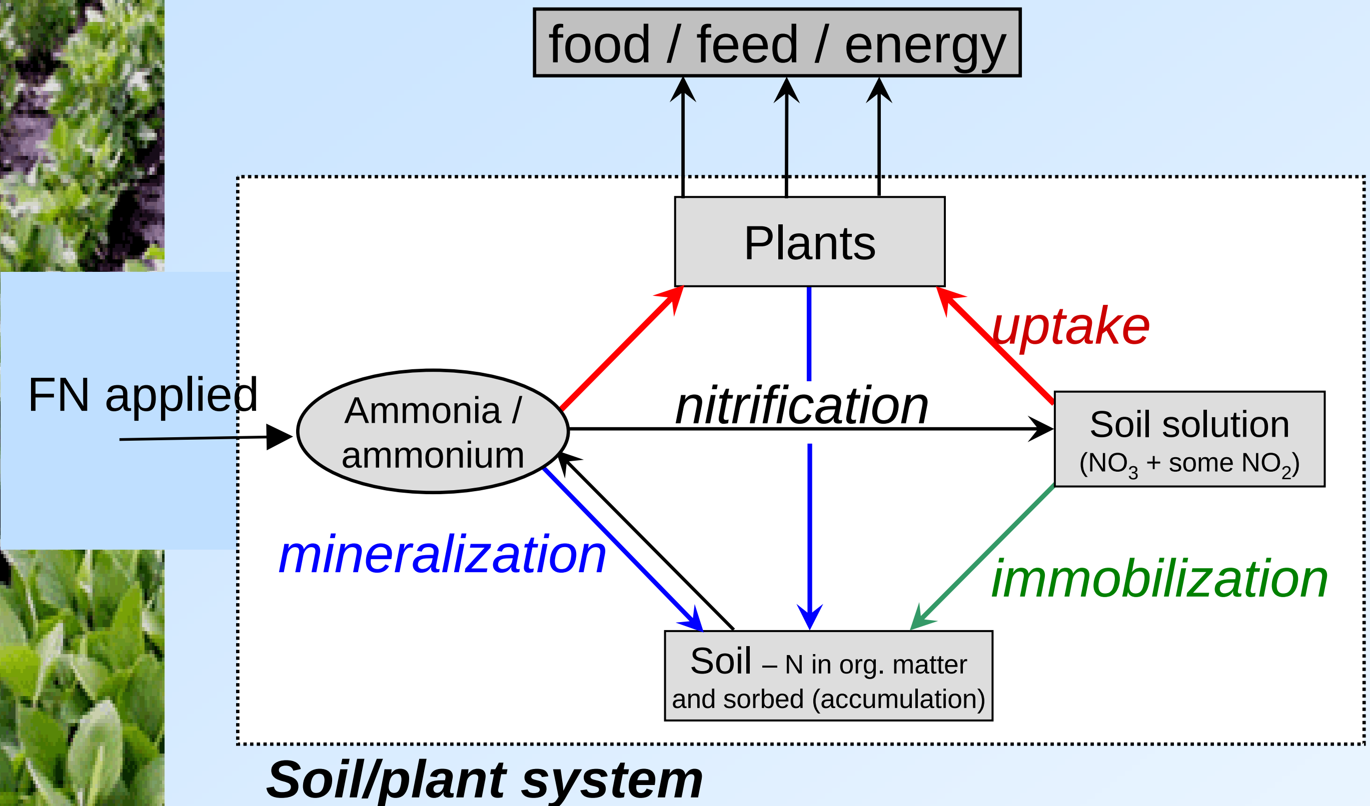
Environmental Degradation: Nitrogen Cycle

Geographic System Considered



Proposed Study area in Iowa – Based on NAWQA Data for Eastern Iowa Watersheds
(Skunk, Cedar, Iowa and Wapsipinicon River systems)
Allows calibration between measured agrichemical fluxes and those estimated for LCI

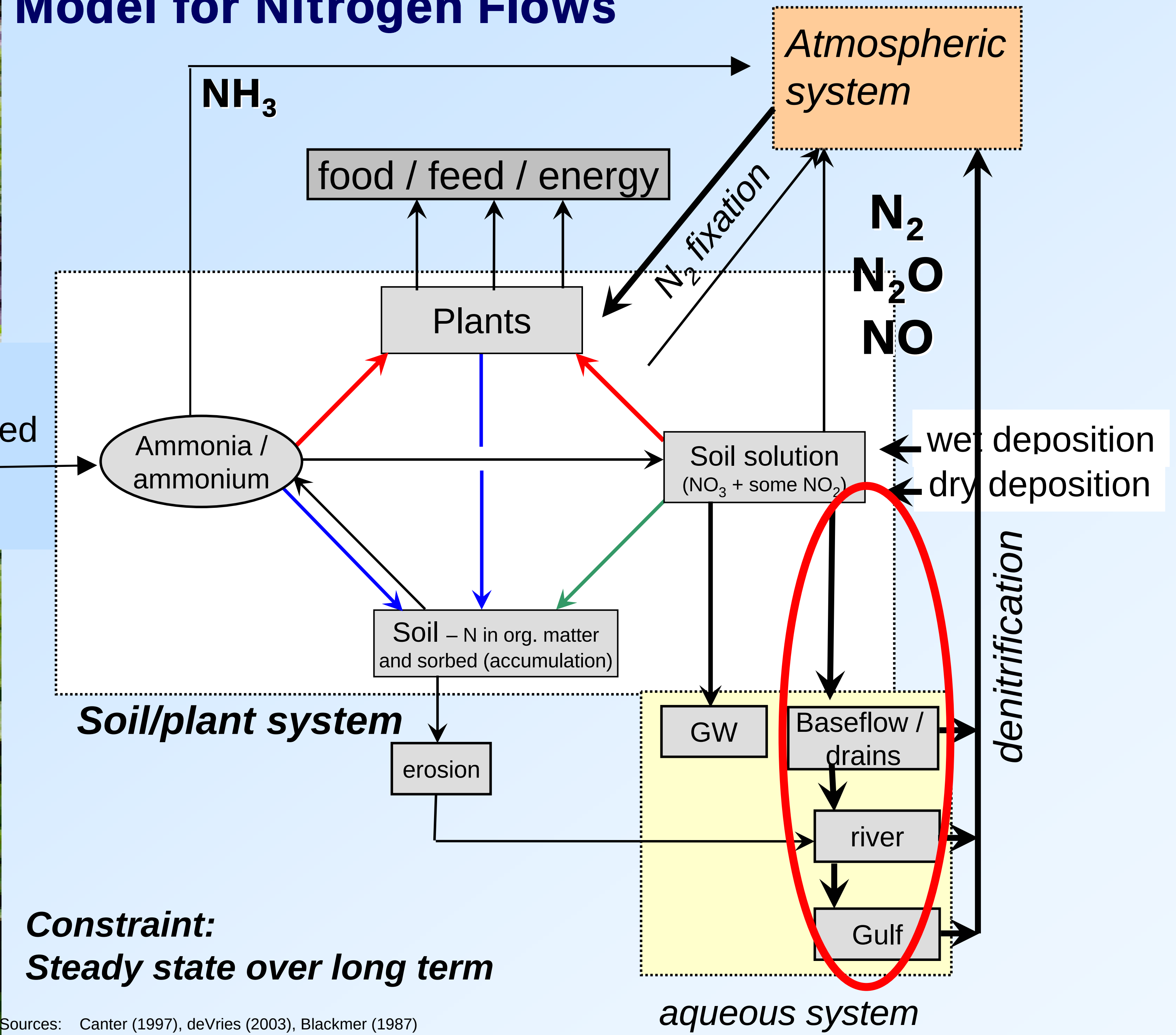
LCA Inventory
→ Generate Model for Nitrogen Flows



Constraint:
Steady state over long term

Sources: Canter (1997), deVries (2003), Blackmer (1987)

Model for Nitrogen Flows



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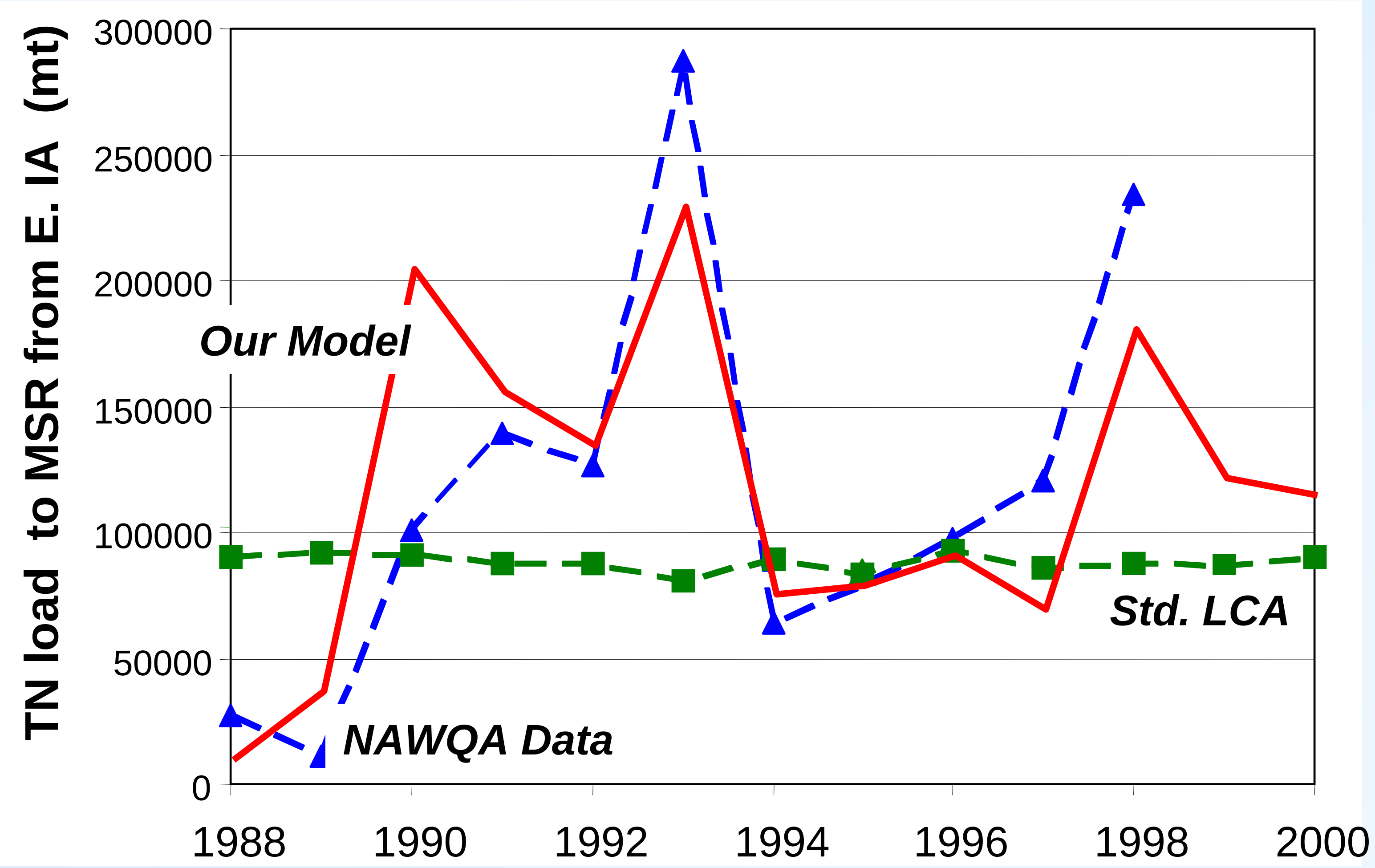
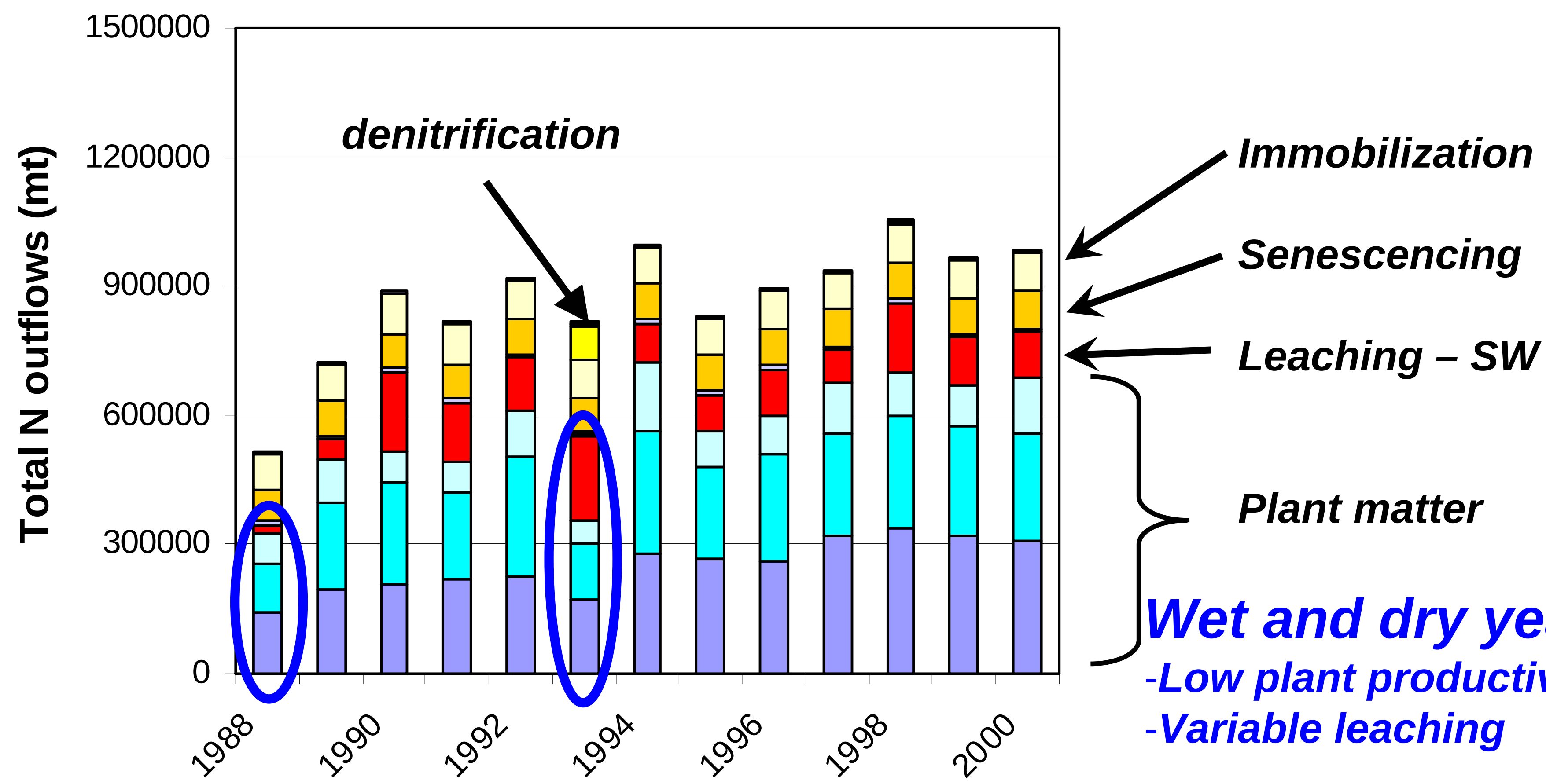
Variable Nutrient Leaching



Nitrogen outflows



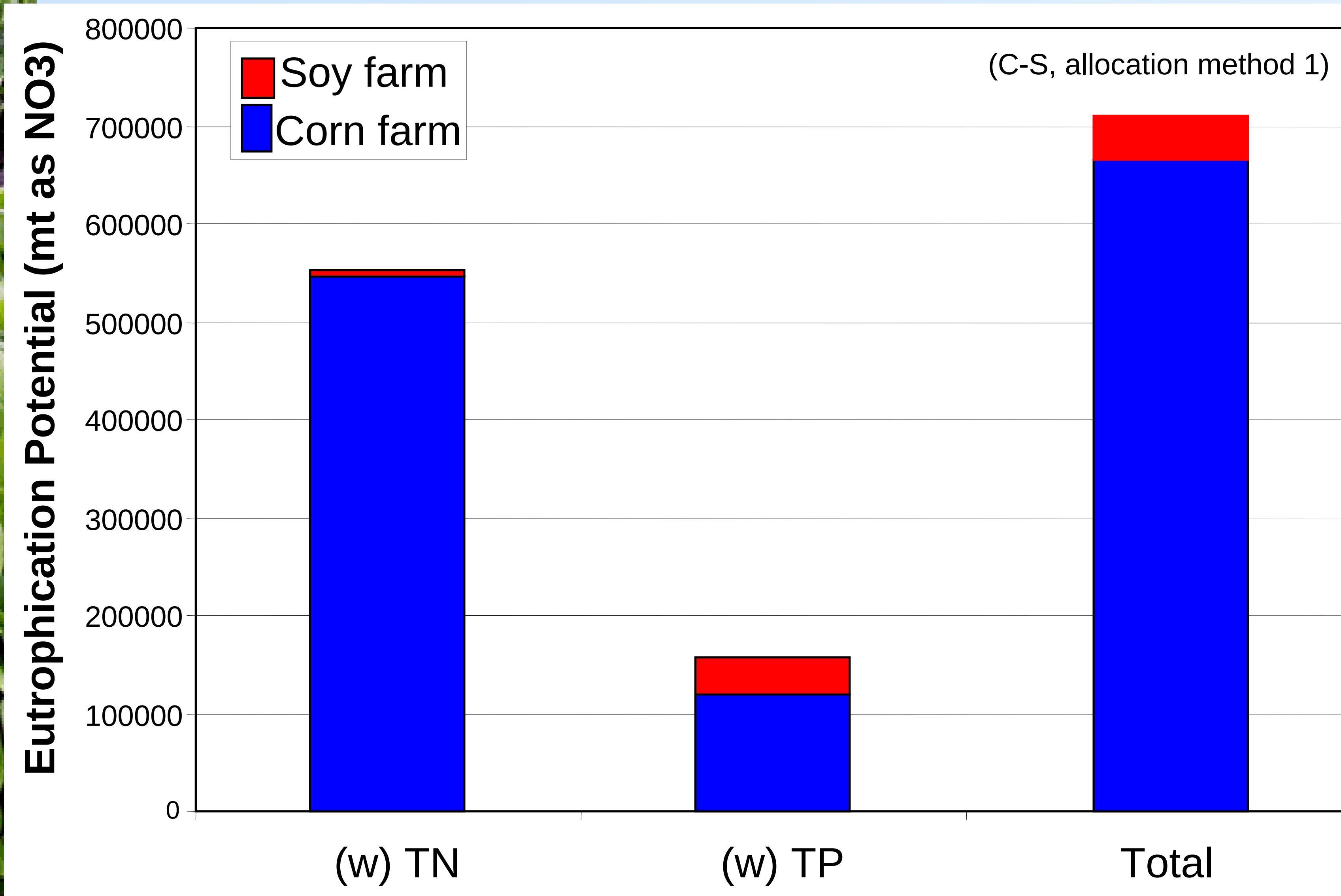
Wet and dry years

-Low plant productivity

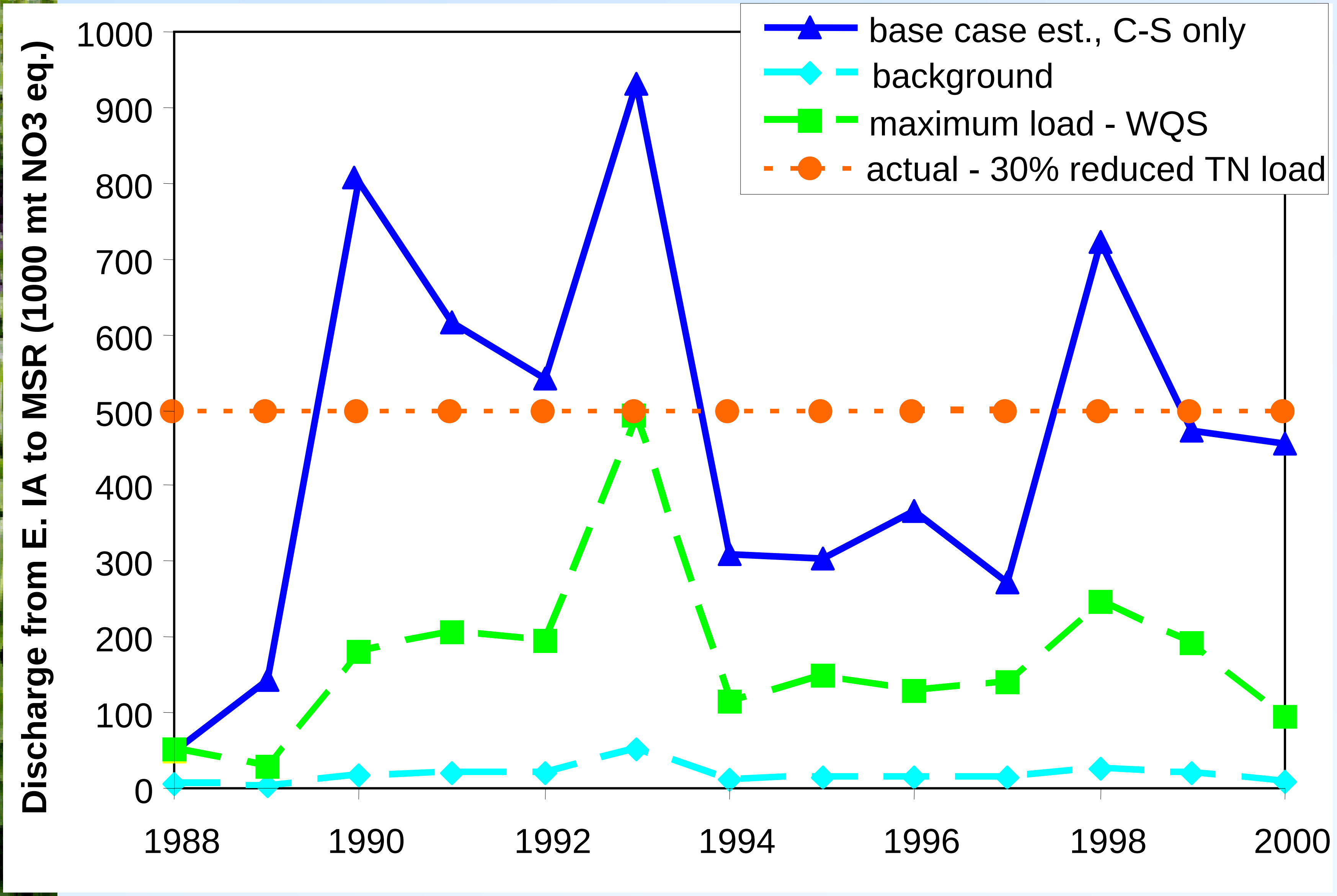
-Variable leaching

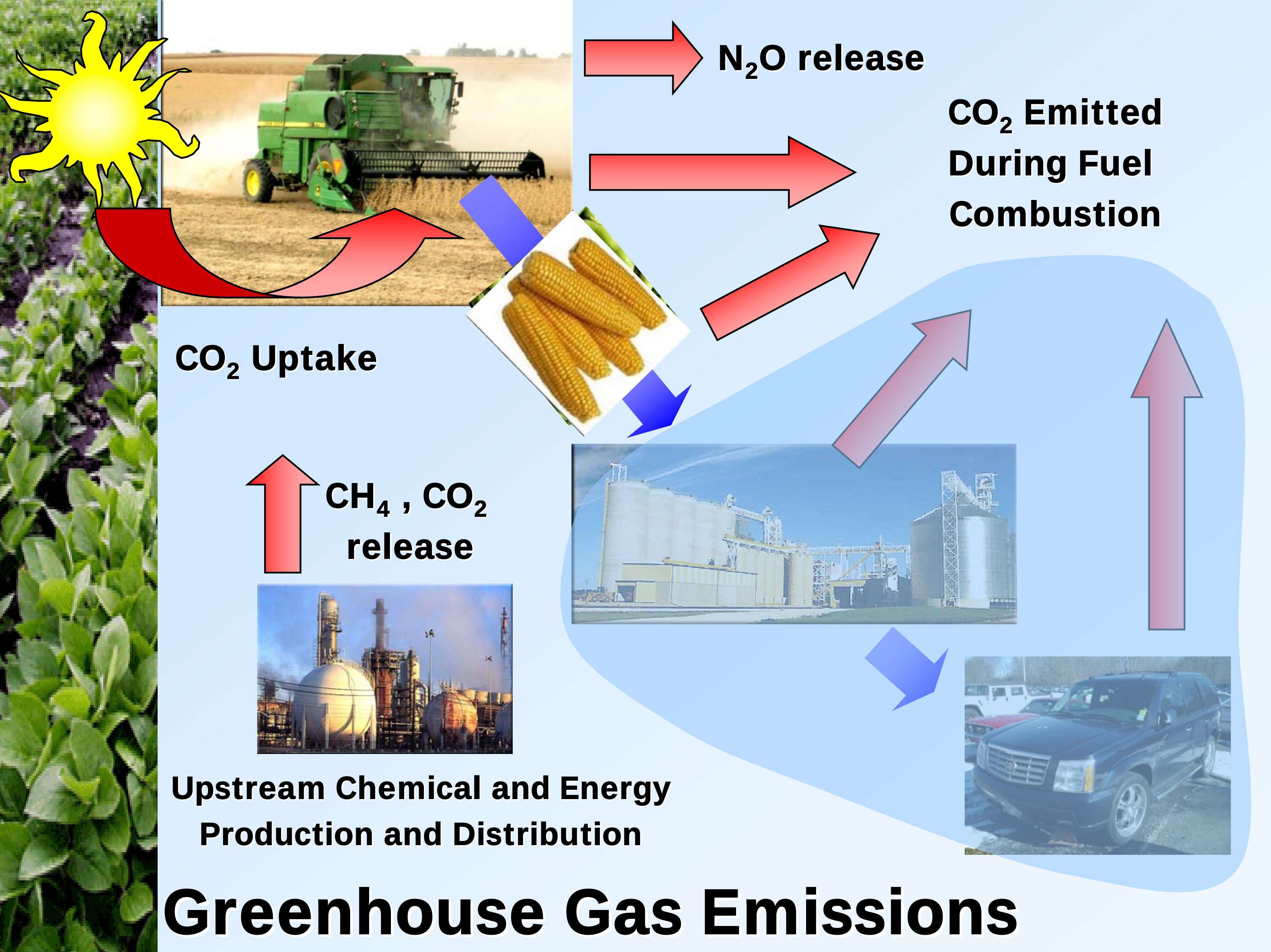
Scenario #1 – Base Case

Eutrophication Potential



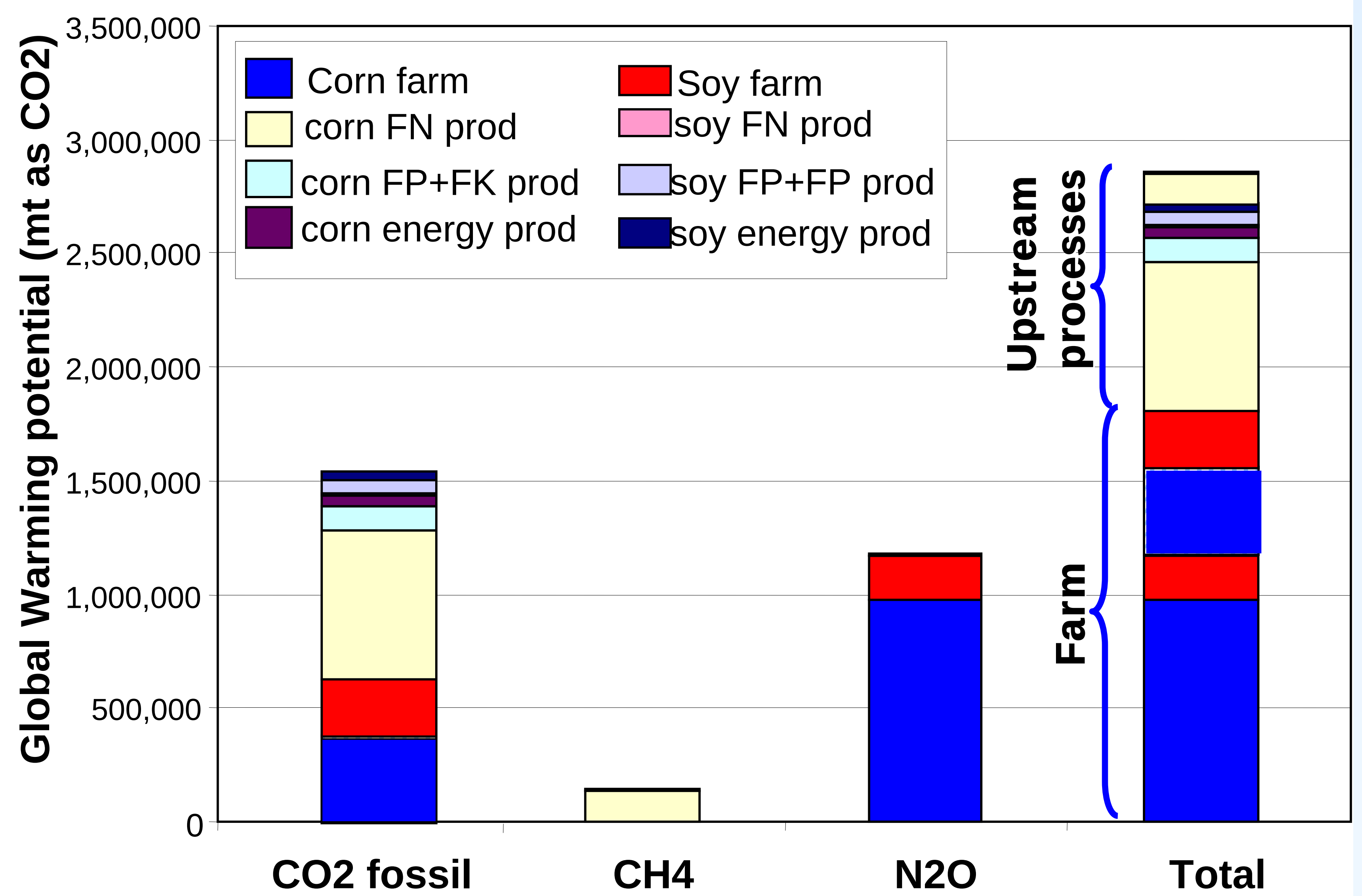
Significance - Eutrophication

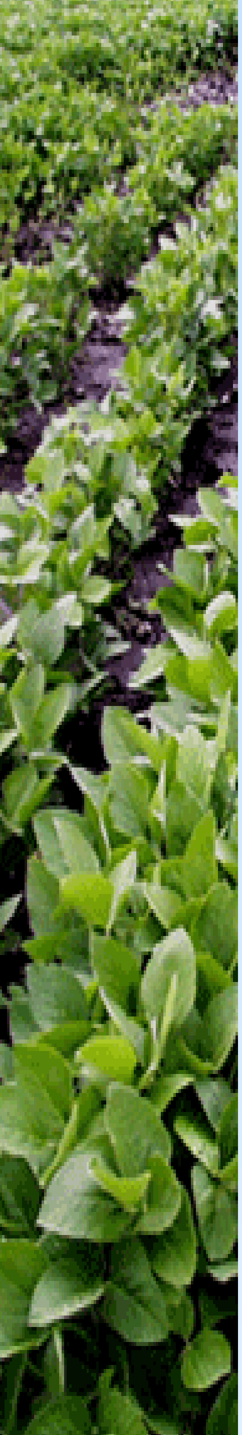



N$_2$O release
CO$_2$ Emitted During Fuel Combustion
CO$_2$ Uptake
CH$_4$, CO$_2$ release
Upstream Chemical and Energy Production and Distribution
Greenhouse Gas Emissions

* Cradle to Farm Gate only – does not account for changes in carbon sequestered

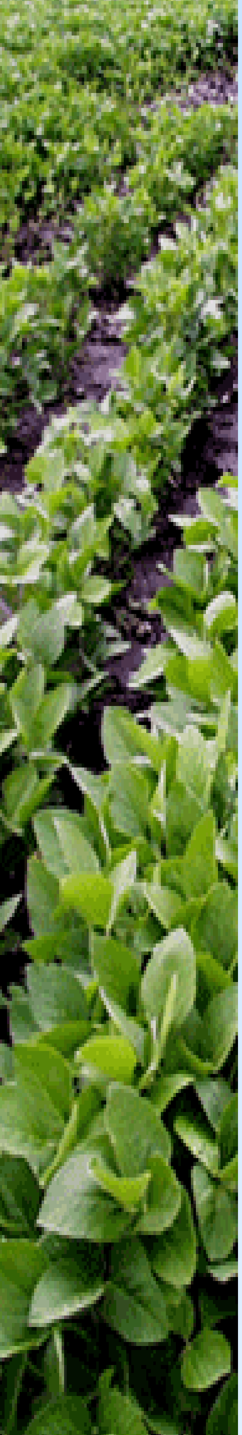
Global Warming Potential





Summary – Carbon vs. Nitrogen

- Benefits in Carbon related impacts
  - Carbon uptake and sequestration
- Detriments in Nitrogen-related impacts
  - Eutrophication and hypoxia from excess nutrients significant water quality problem
  - N_2O – significant contributions to GWP
- Fundamental trade-off between global climate change and regional impacts of eutrophication



Summary – Corn vs. Soy

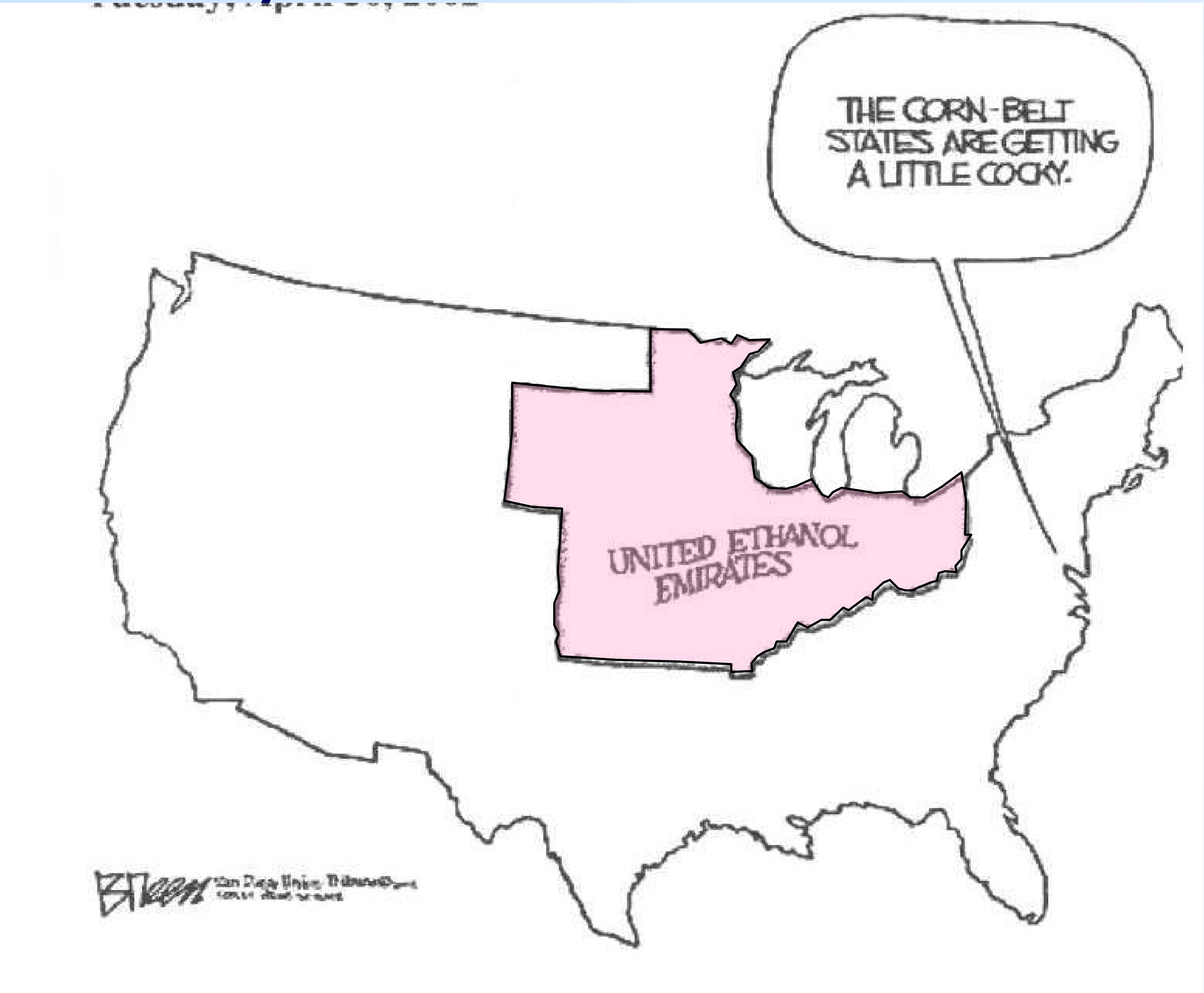
- High nitrogen fertilizer rates for corn
- Greater overall energy use
- Much greater impacts from corn than soy in cradle-to-farm gate LCA

Based on perspectives shown here,

Biofuels from soy or stover better for the environment than ethanol from corn

But… Many other issues to consider

Thank-you


THE CORN-BELT STATES ARE GETTING A LITTLE COCKY.
UNITED ETHANOL EMIRATES