Sustainable biomass: a systems view

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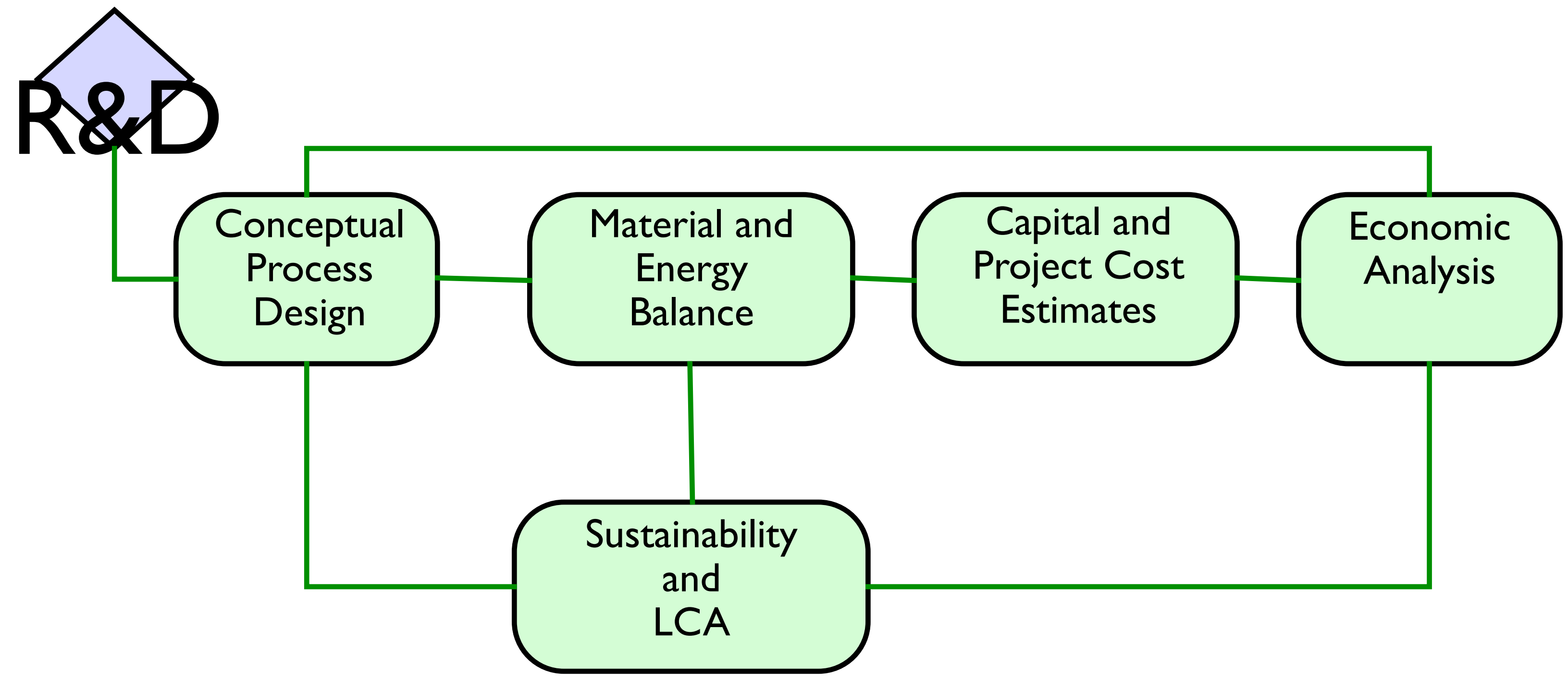
August 3-4, 2004
USDOE/NASULGC
Biomass and Solar Energy Workshops

Overview

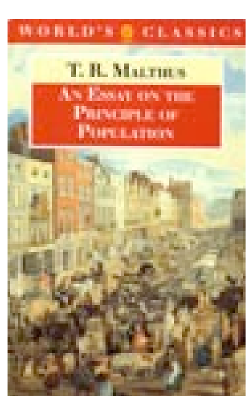
- Analysis driven R&D
- The conundrum of sustainability
- An economic perspective
- A life cycle perspective
- A plea for transparency, education and dialogue

Analysis driven R&D



The conundrum of sustainability: Malthus...

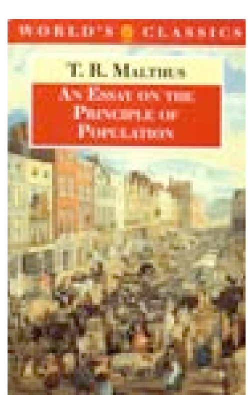
"...the question is...whether man shall henceforth start forwards with accelerated velocity towards illimitable and hitherto unconceived improvement; or be condemned to a perpetual oscillation between happiness and misery...."



Thomas Malthus, *An Essay on the Principle of Population* (1798)

The conundrum of sustainability: ...Scrooge

"...the question is...whether man shall henceforth start forwards with accelerated velocity towards illimitable and hitherto unconceived improvement; or be condemned to a perpetual oscillation between happiness and misery...."



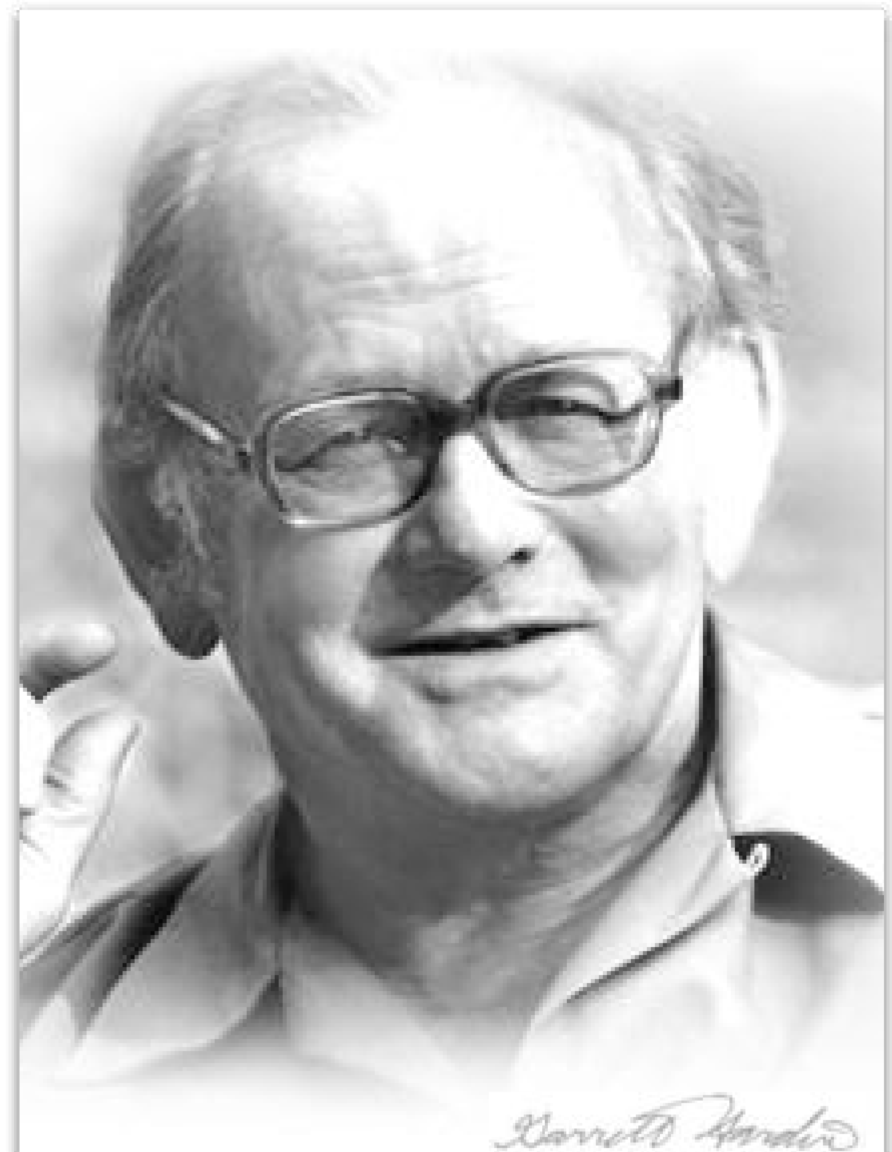
Thomas Malthus, *An Essay on the Principle of Population* (1798)




The conundrum of sustainability: Hardin

"Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

Garrett Hardin, "The Tragedy of the Commons" *Science* (1968)



The conundrum of sustainability: Hardin

"The class of 'No technical solution problems' has members. My thesis is that the 'population problem'...is a member of this class."


The Tragedy of the Commons

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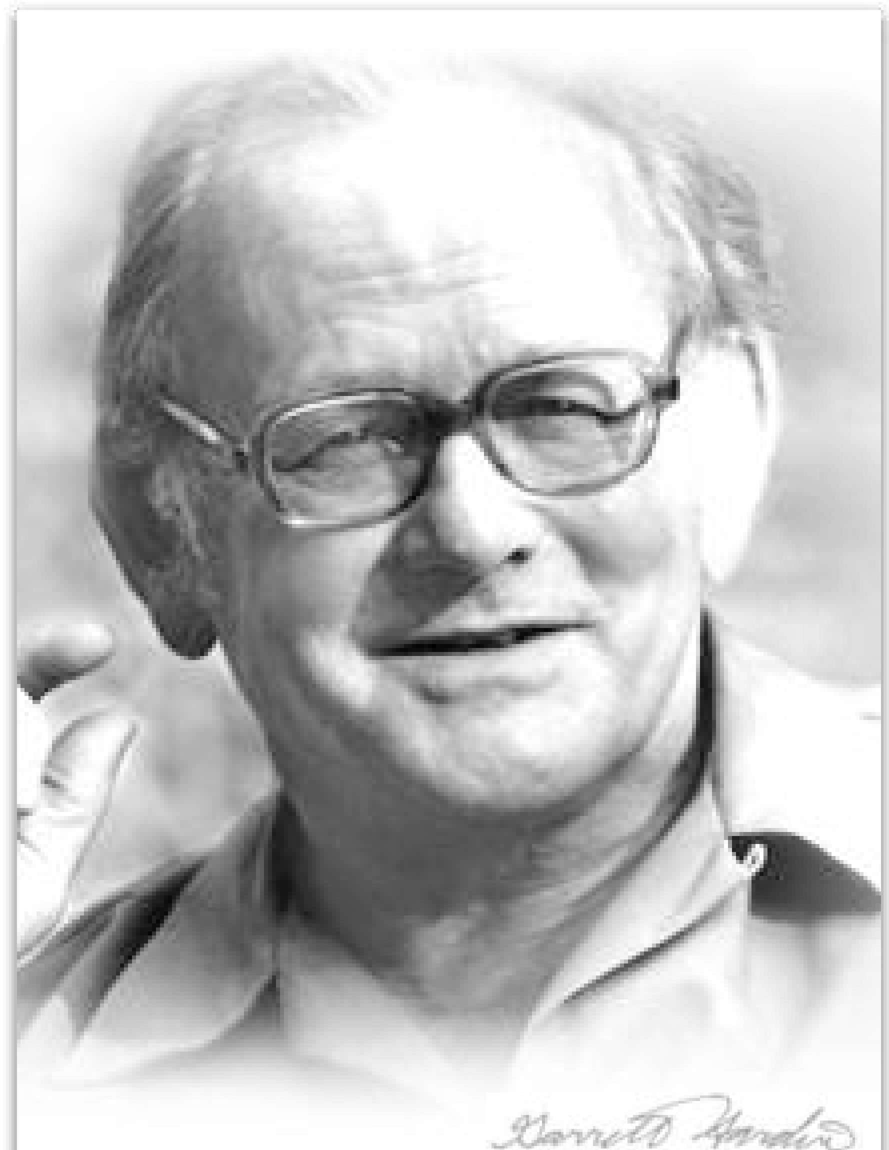

The conundrum of sustainability: Hardin

"The class of 'No technical solution problems' has members. My thesis is that the 'sustainability problem'...is a member of this class."

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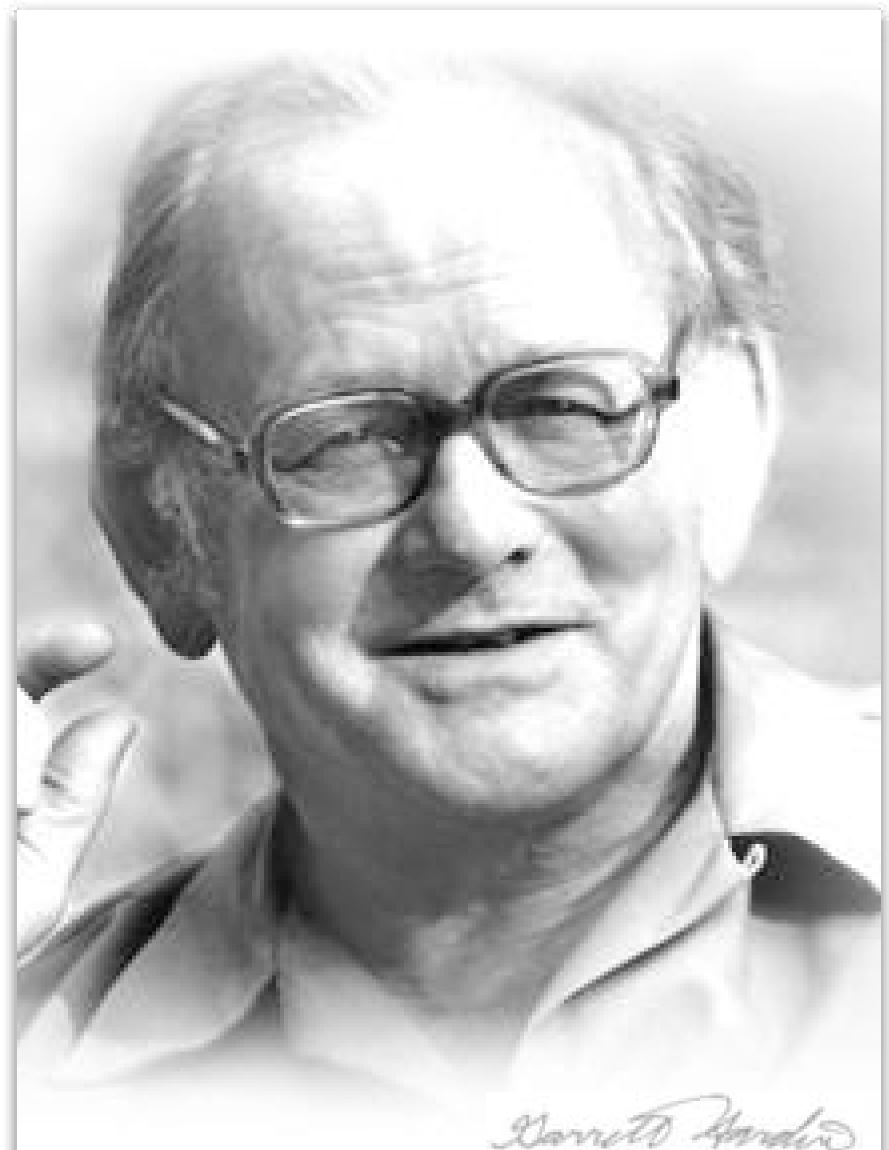
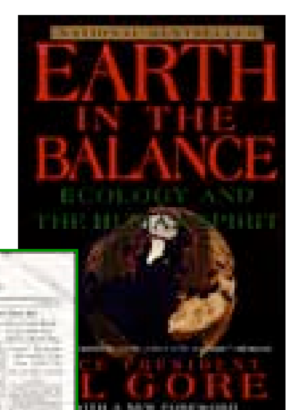





The conundrum of sustainability: Politics

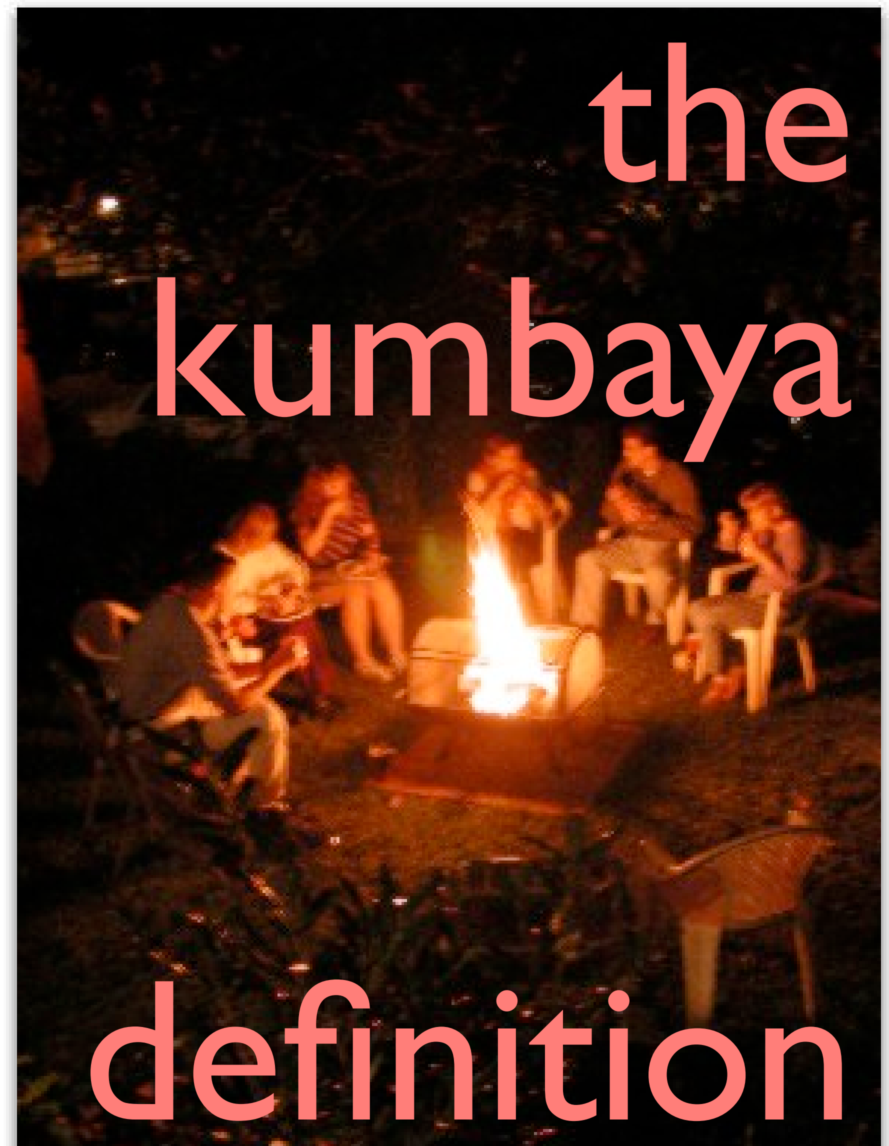
Senator "Malthus"



The conundrum of sustainability:

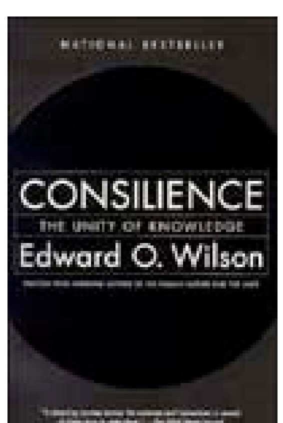
"[S]ustainable development meets the needs of the present without compromising the needs of the future generations"

Our Common Future. United Nations' World Commission on Environment and Development (1987)



Sustainability: an ethic and a direction

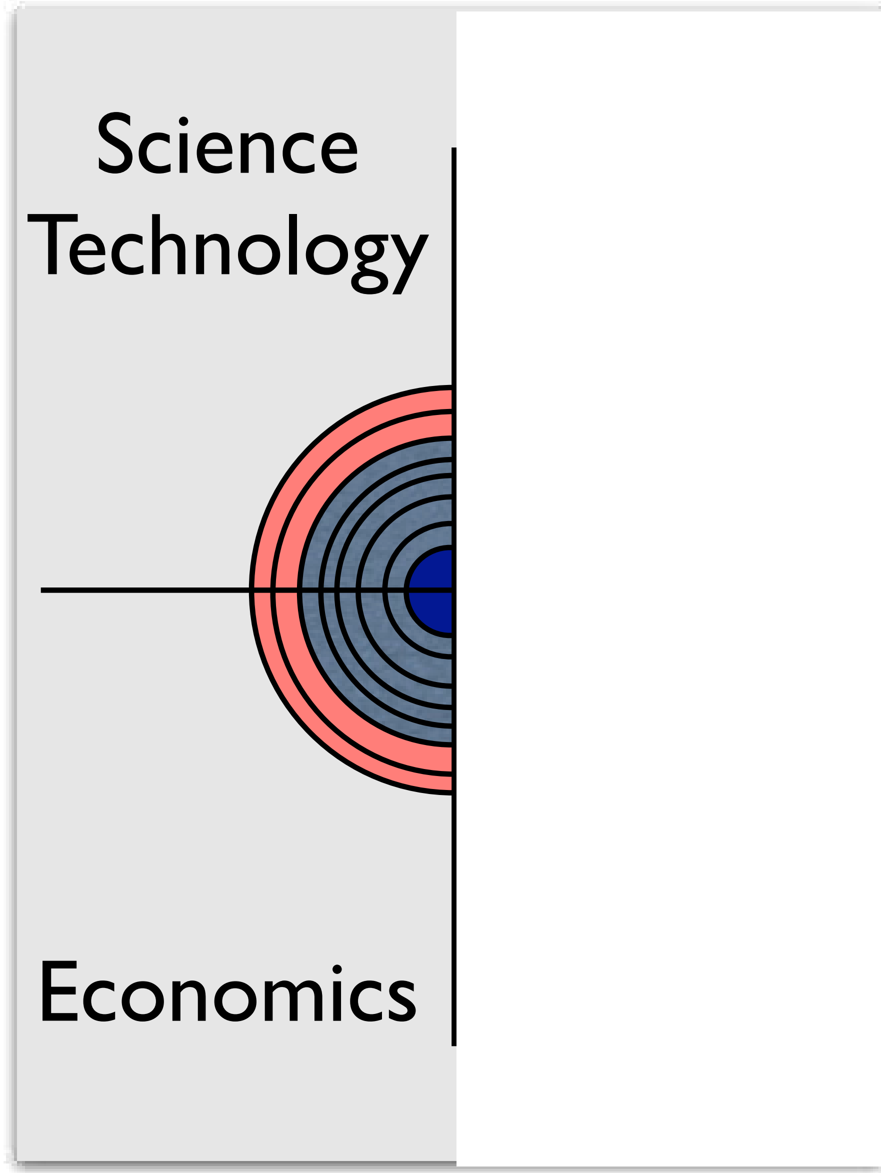
"The common aim must be to expand resources and improve quality of life for as many people as heedless population growth forces upon Earth, and do it with minimal prosthetic dependence. That, in essence is the ethic of sustainable development."-



E.O. Wilson, *Consilience: the Unity of Knowledge*

Sustainability

The intersection of science and ethic and the ultimate example of E. O. Wilson's "Consilience"



Assessing sustainability

Sustainability	Measure/Approach
Expanding Resources	Renewable vs nonrenewable resources
Quality of life	Economics Values
Earth	Environmental impacts Systems perspective
Prosthetic dependence	Technology Systems perspective
Ethic	Dialogue Systems perspective

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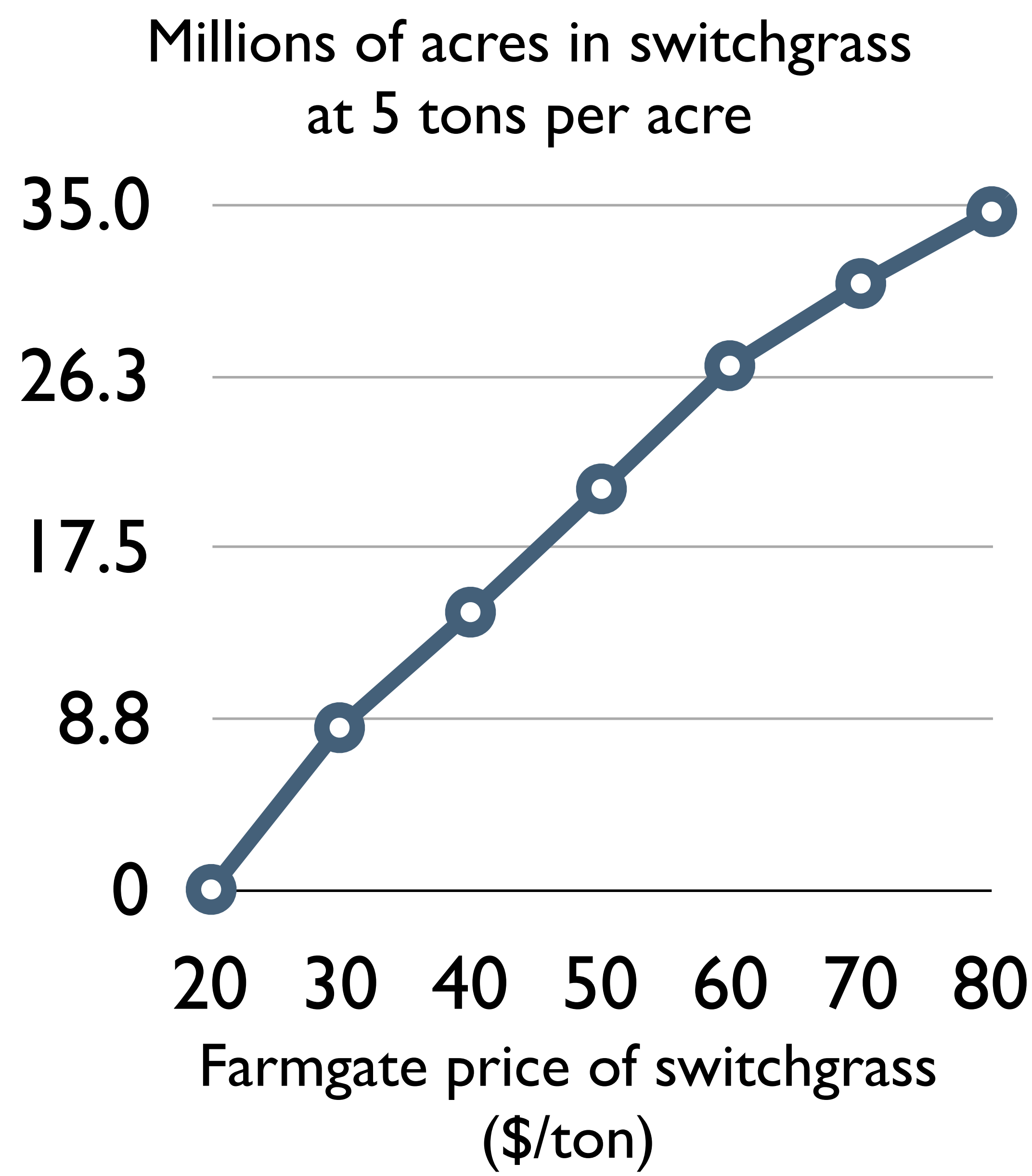
Technoeconomic analysis: feedstock

- Biomass production economics
- POLYSYS cropland competition model
- BIOCOST model for estimating the cost of producing and harvesting biomass

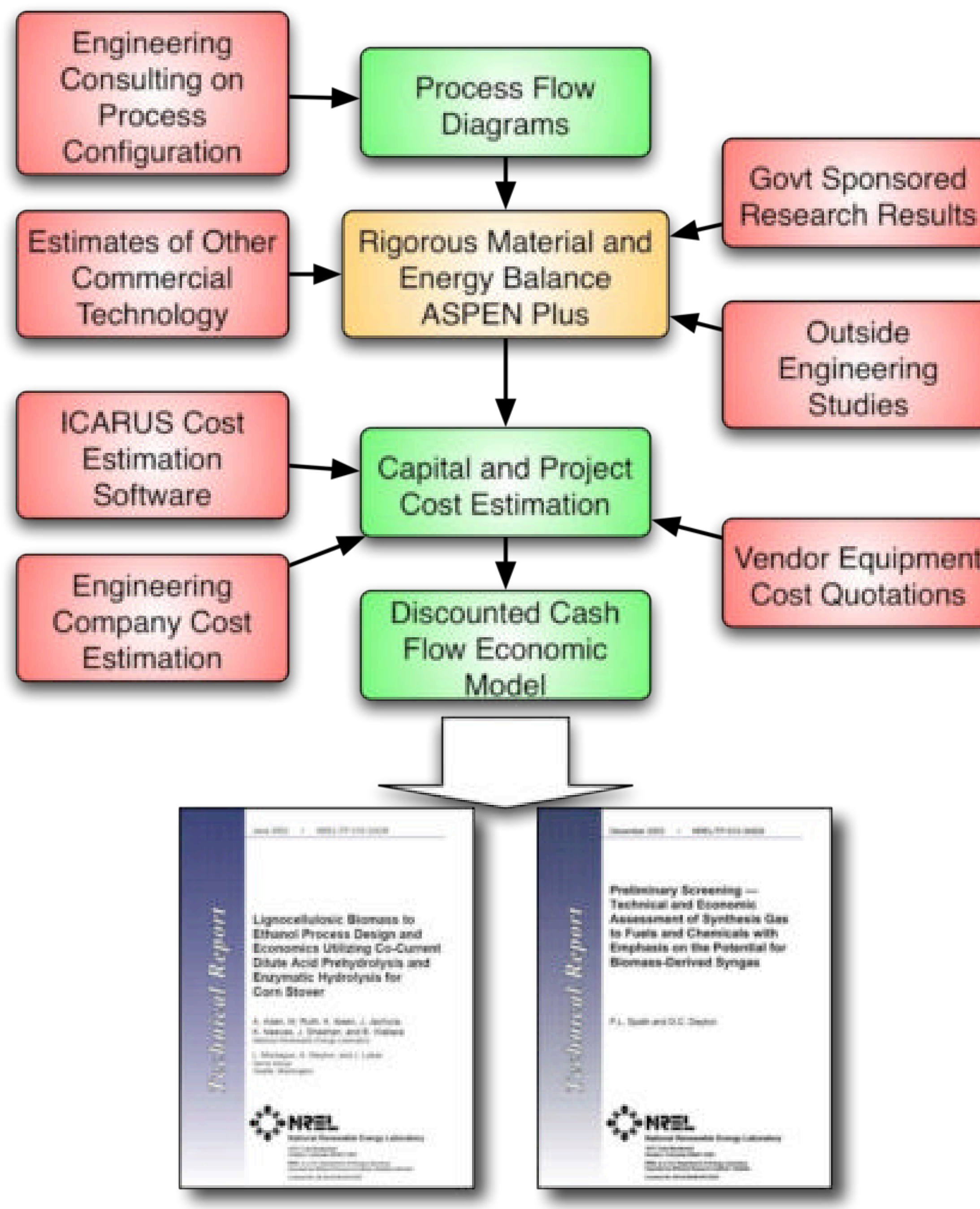


Technoeconomic analysis: conversion

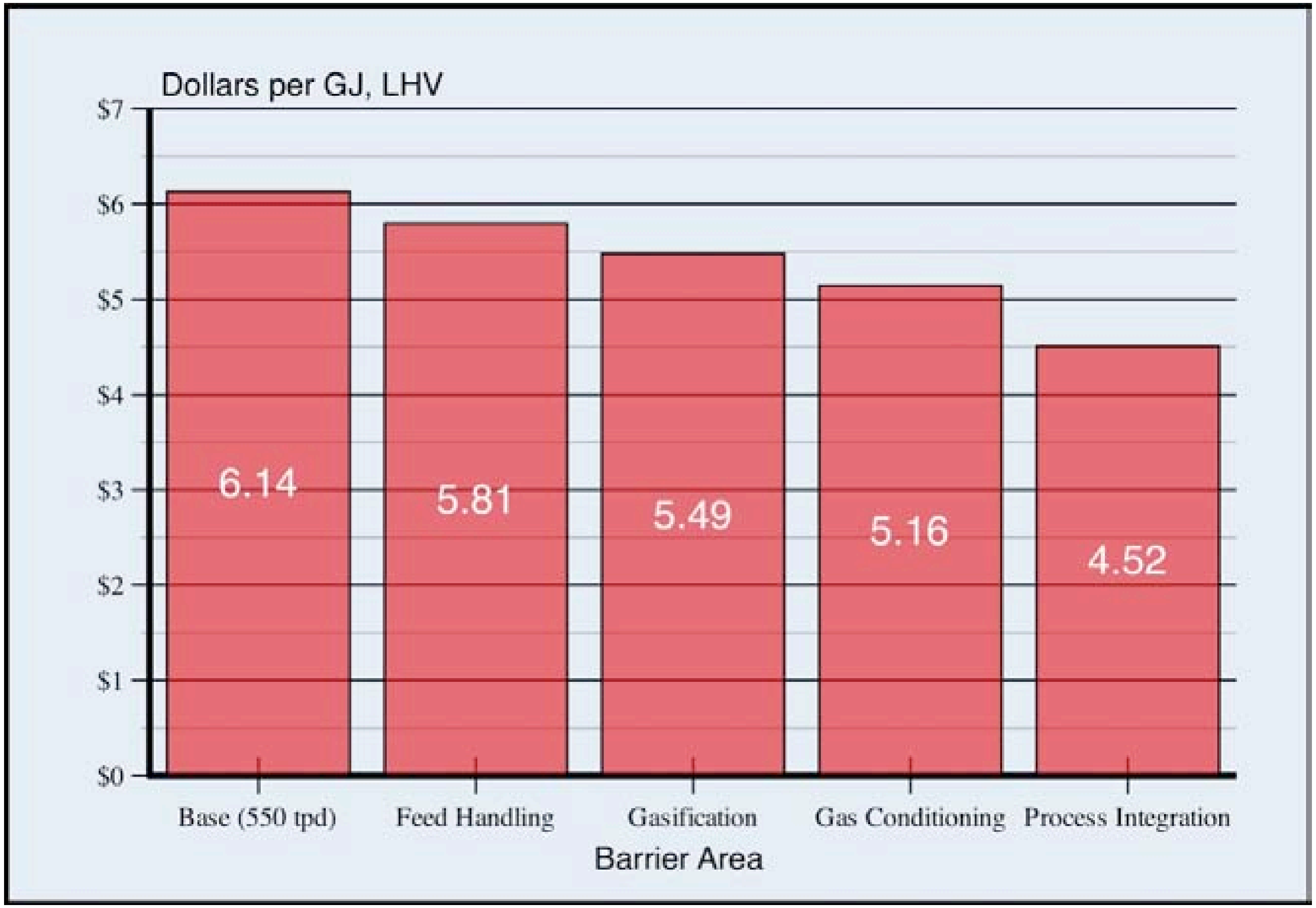
- Process models of varying degrees of complexity depending on the level of R&D effort supported

- Industrially valid tools like ASPEN

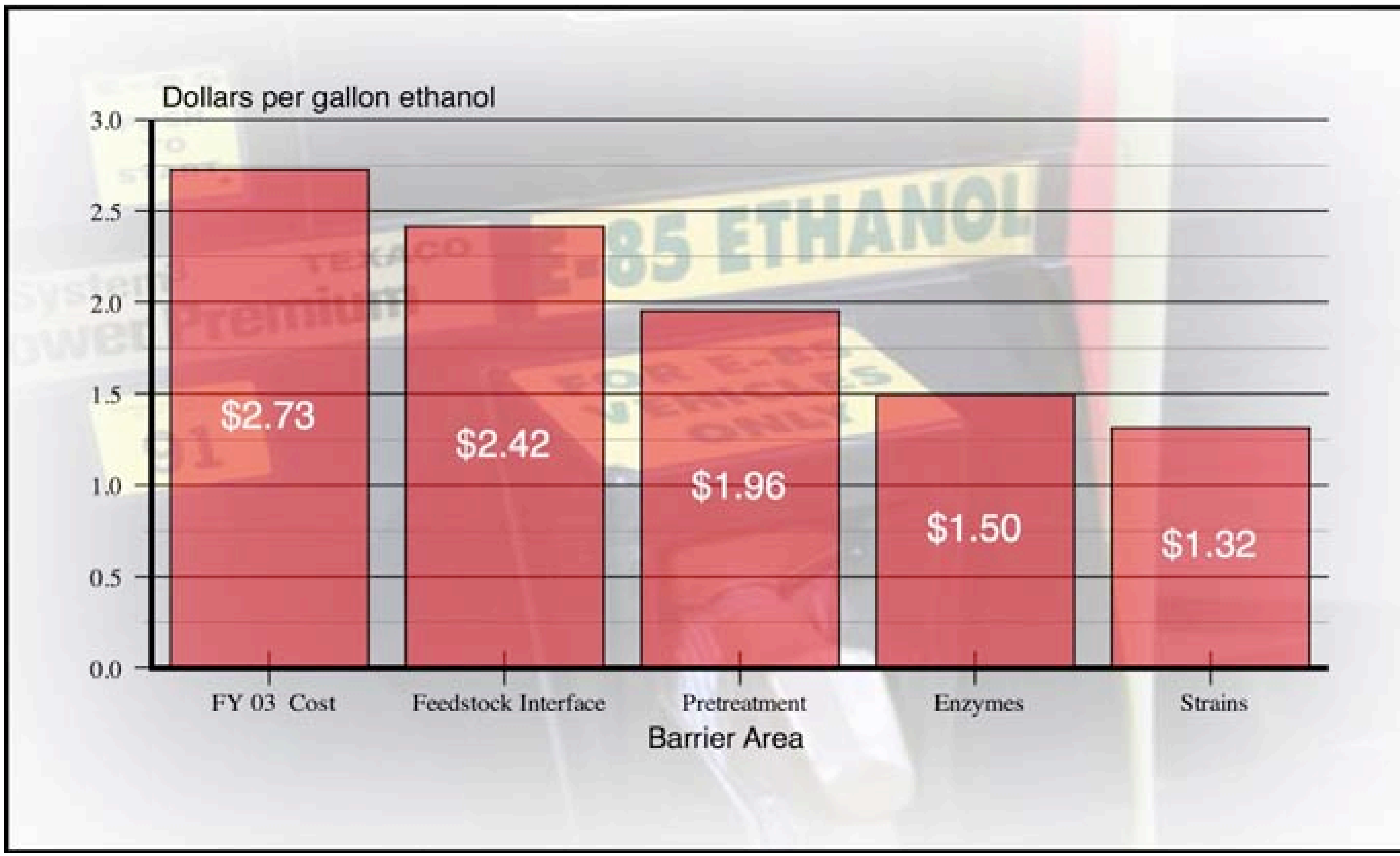
- Economic analysis of varying degrees of complexity



Syngas from biomass



Ethanol from biomass



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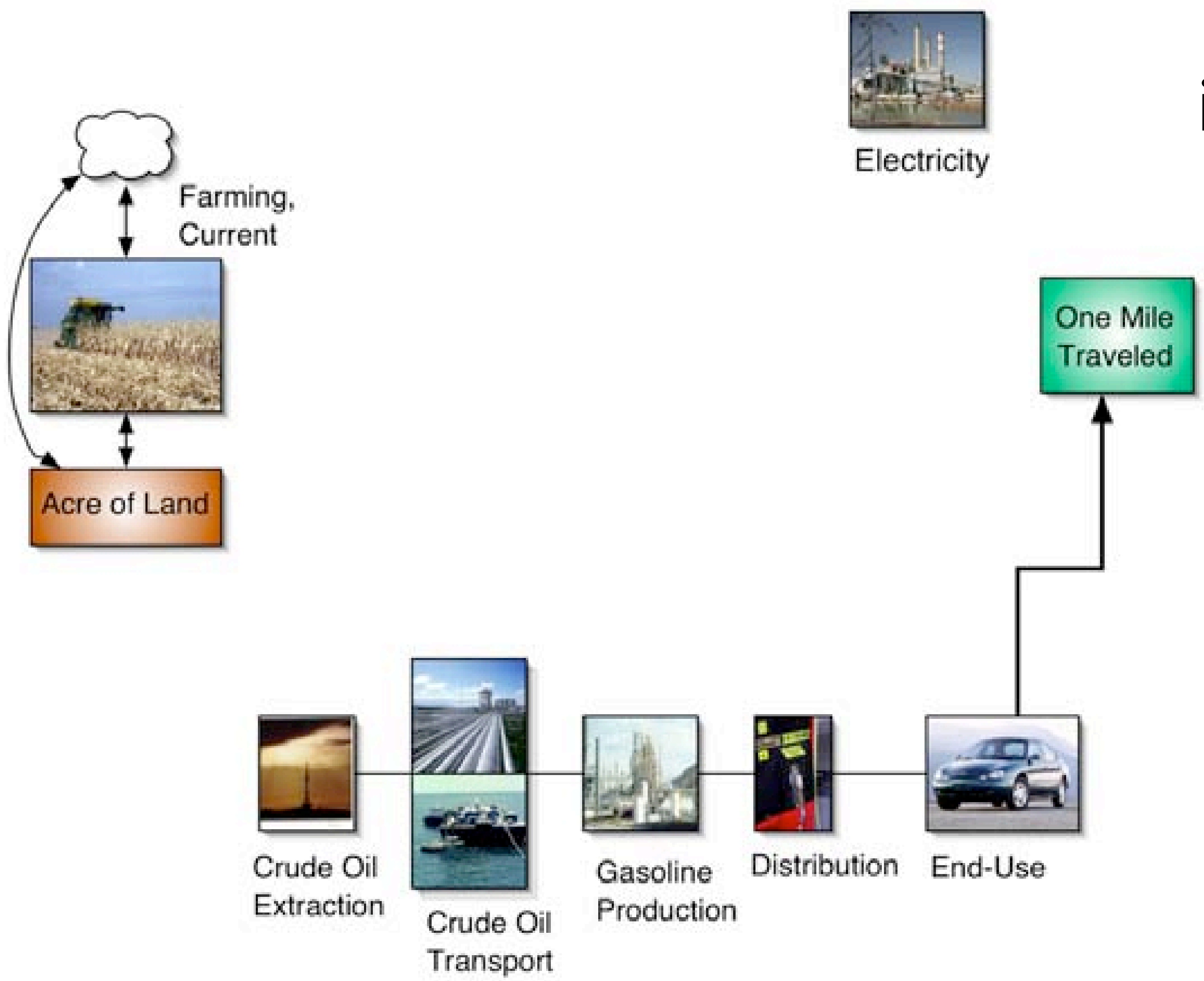
Life cycle assessment and the systems perspective

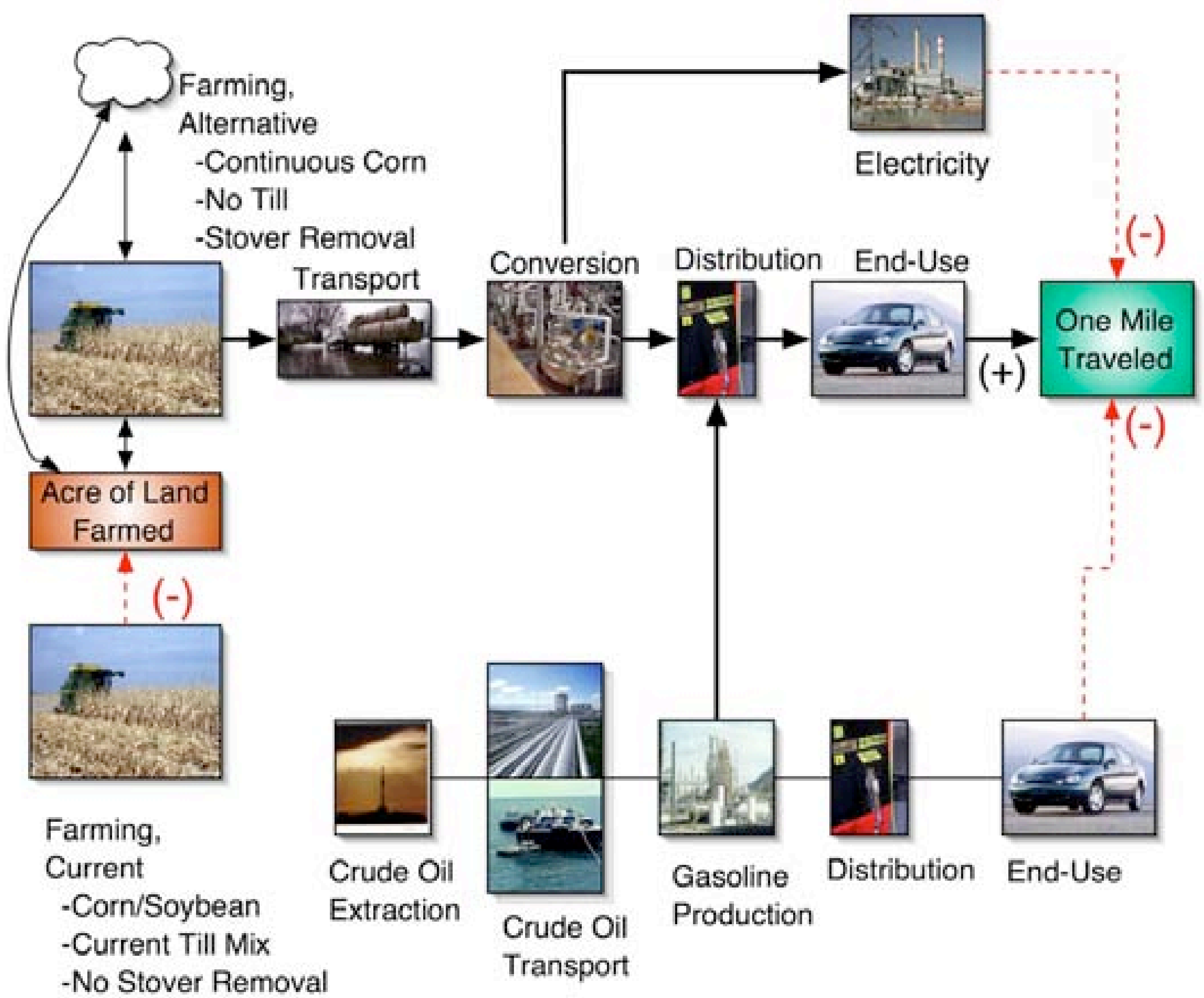
- Cradle to grave (Cradle to cradle)
- Ultimate system is the world
- Normalized comparisons of technology changes or alternative technologies
- Natural resource flows (renewable and non-renewable)
- Environmental flows (air, water, land)

Life cycle assessment and the systems perspective



System before introduction of stover to ethanol production

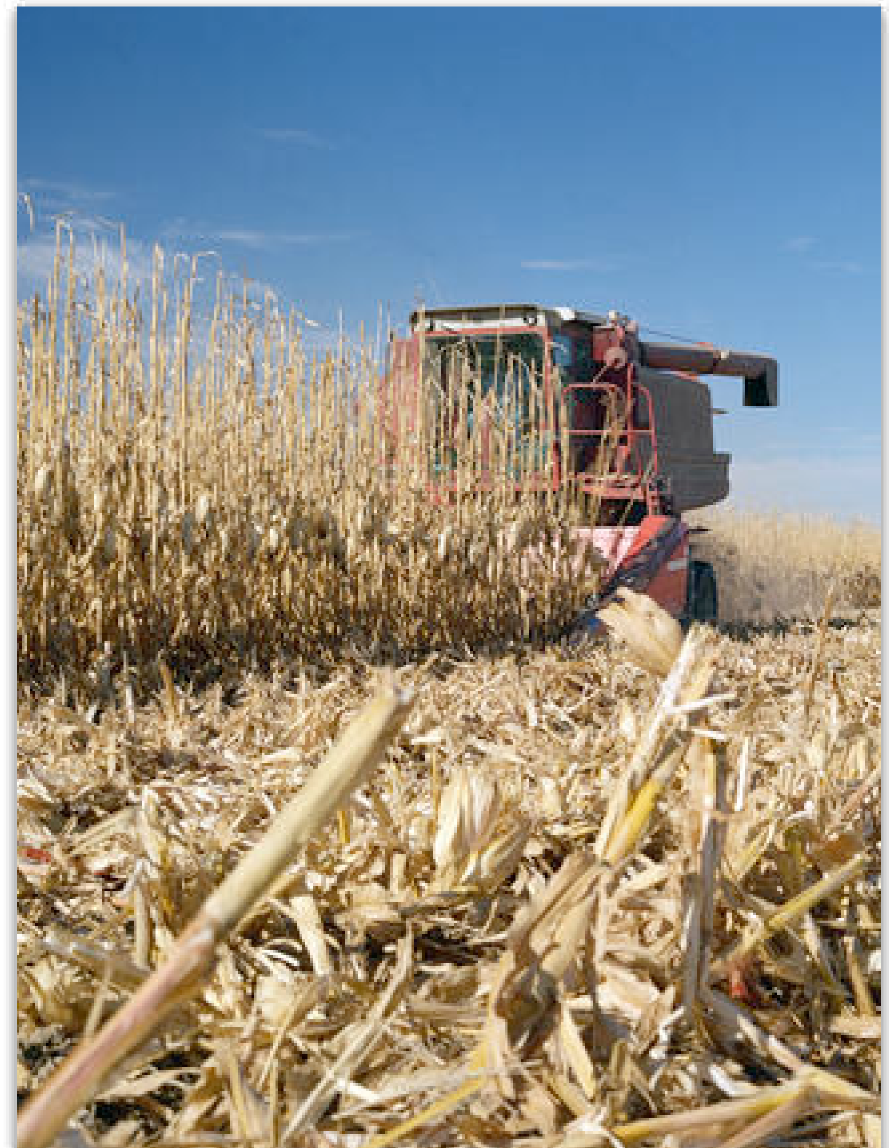
Life cycle assessment and the systems perspective



System after introduction of stover to ethanol production

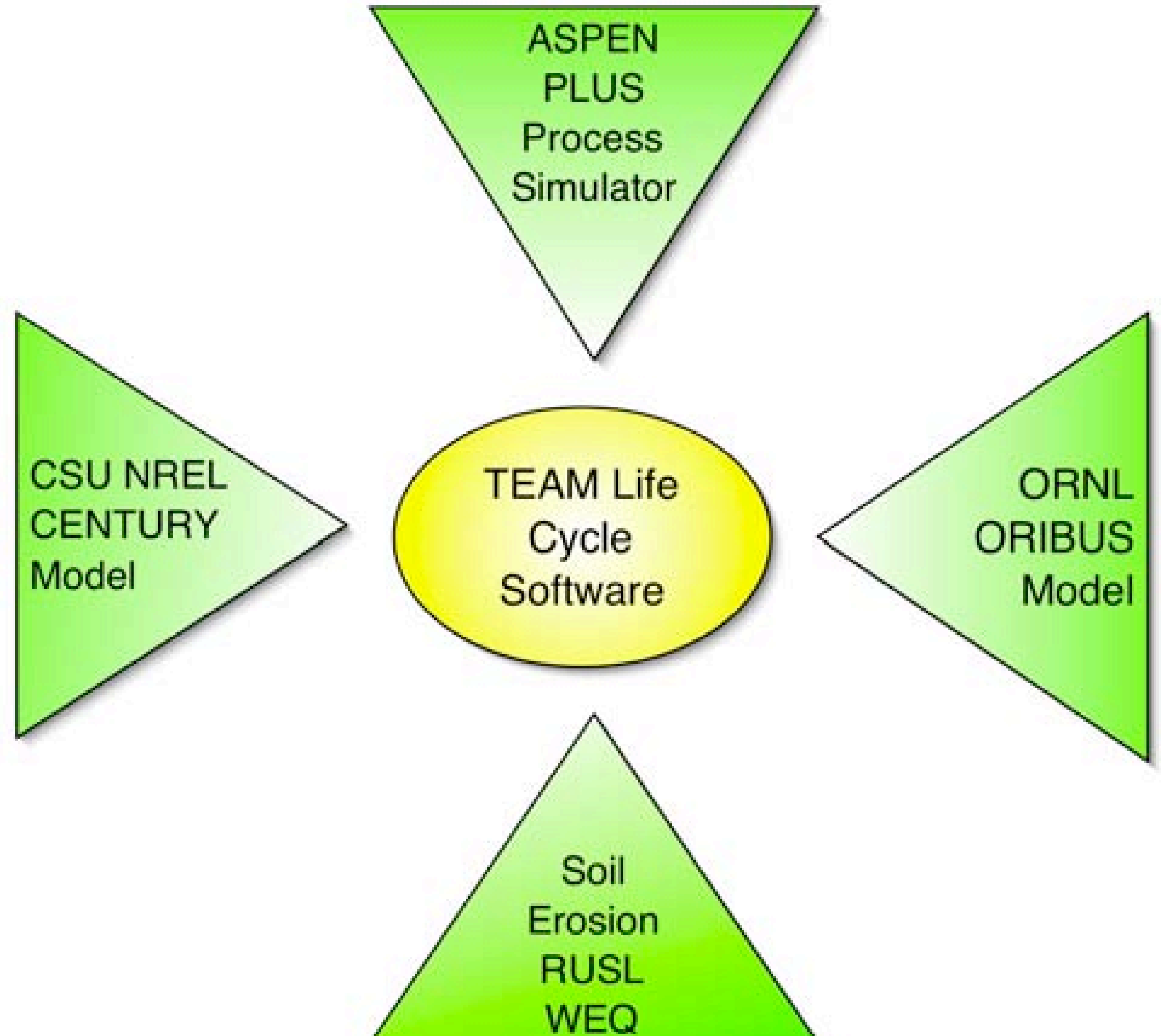



Ethanol from Agricultural Residues



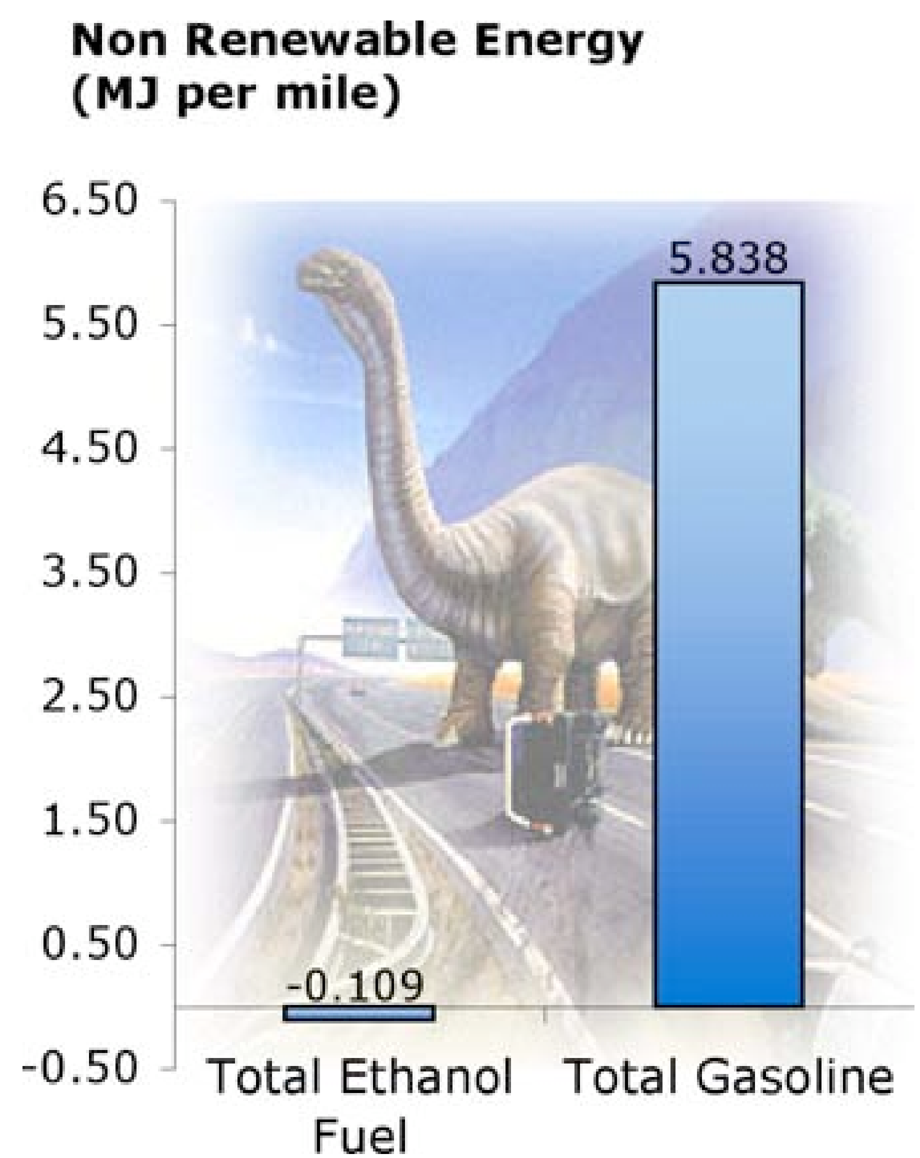
Bringing together experts

- Soil carbon model
- Soil erosion model
- Agronomic model for collection and transport logistics
- Process simulator for ethanol conversion



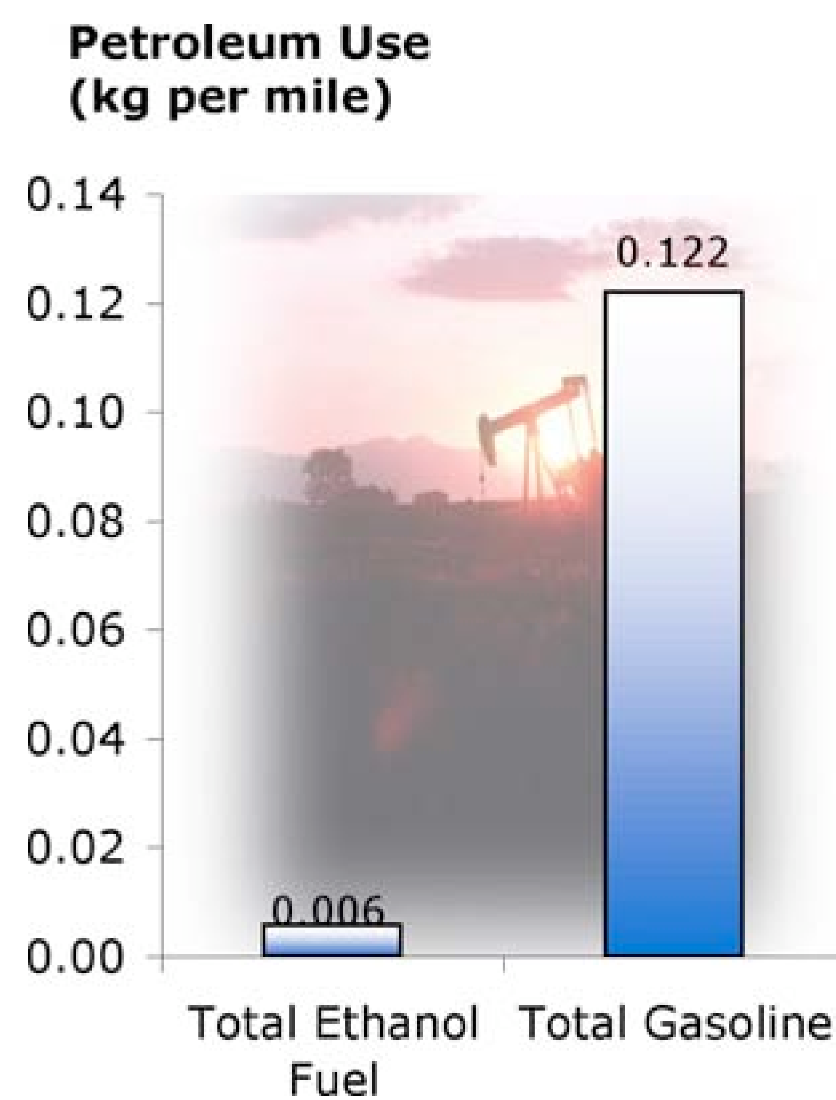
Findings: fossil energy

Switching to bioethanol made from corn stover reduces fossil energy use by 102%



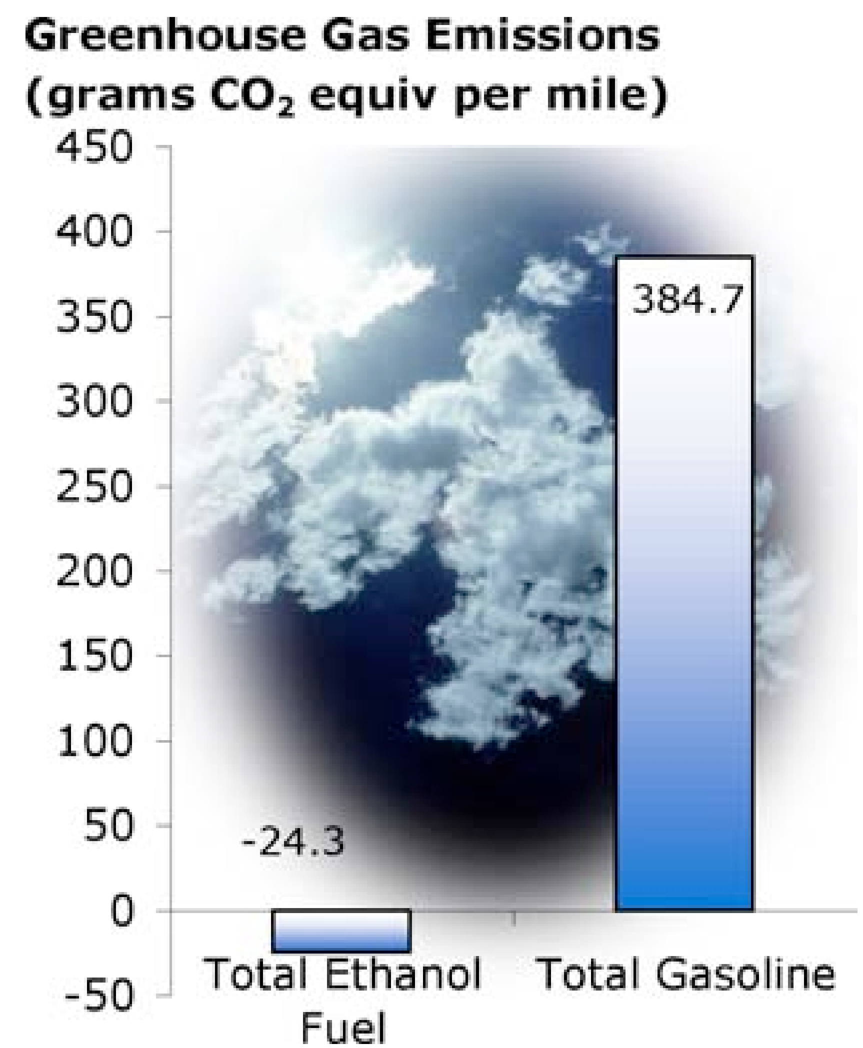
Findings: petroleum

Switching to bioethanol made from corn stover reduces fossil energy use by 95%



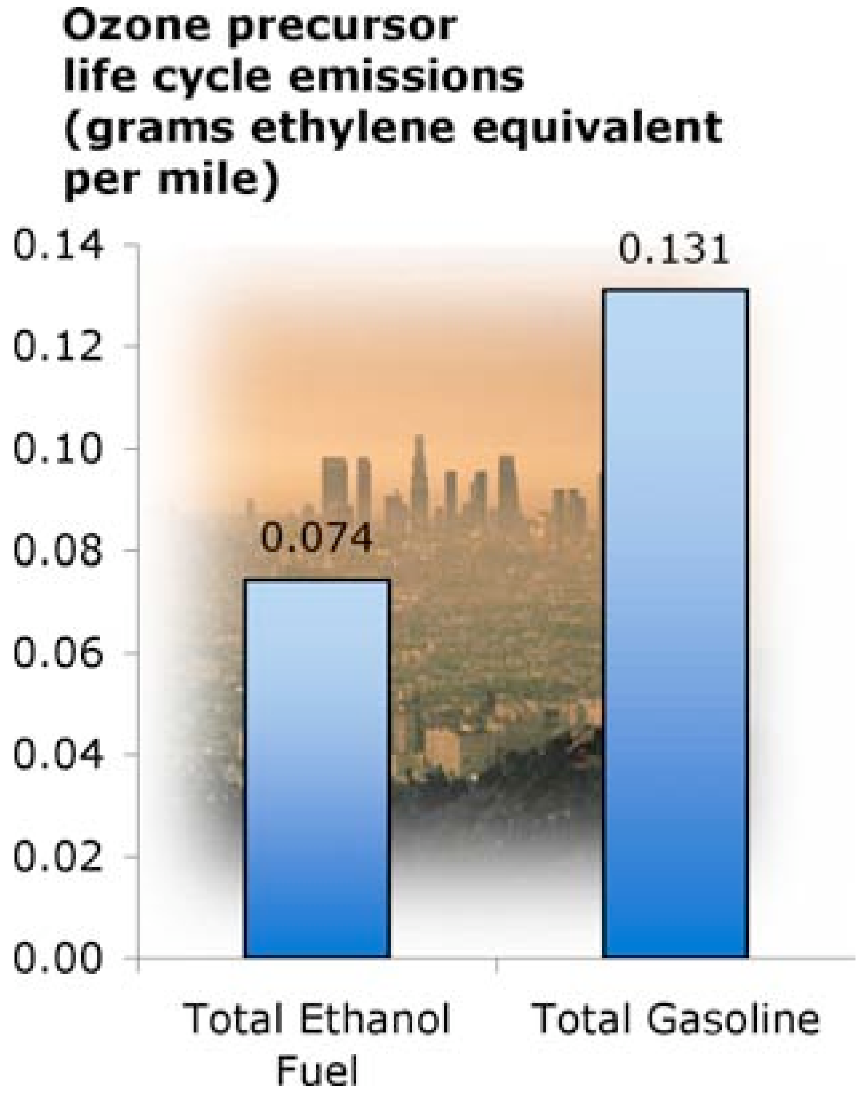
Findings: Greenhouse gases

Switching to ethanol made from corn stover reduces greenhouse gas emissions by 106%



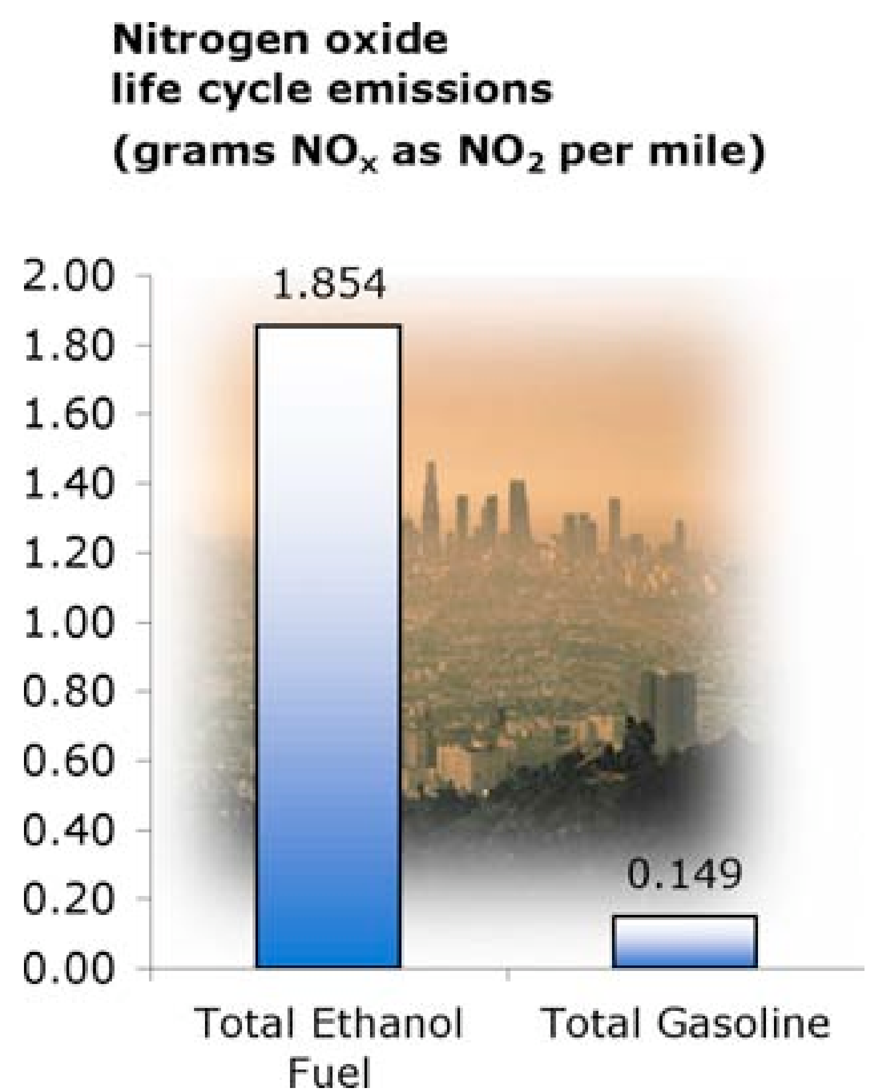
Findings: air quality

Switching to ethanol made from corn stover reduces hydrocarbons that lead to ozone formation by 44%



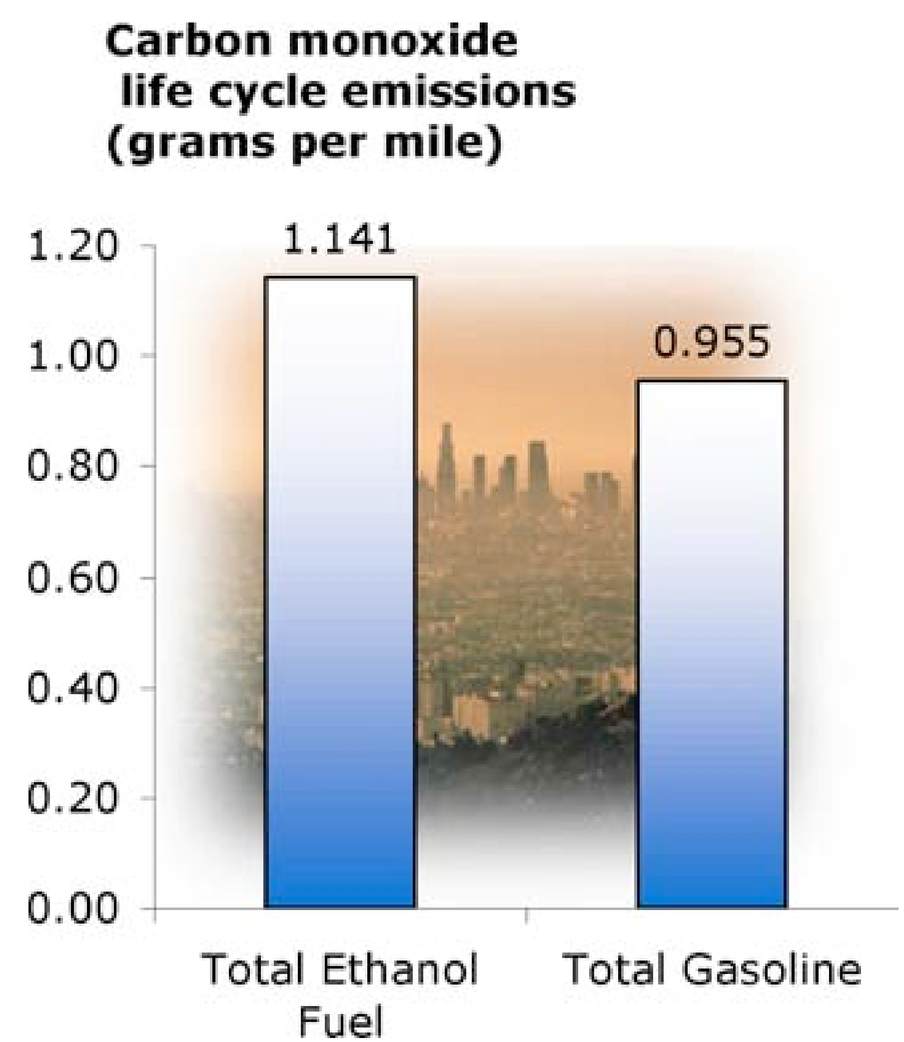
Findings: air quality

Switching to ethanol made from corn stover increases emissions of NOx 12-fold

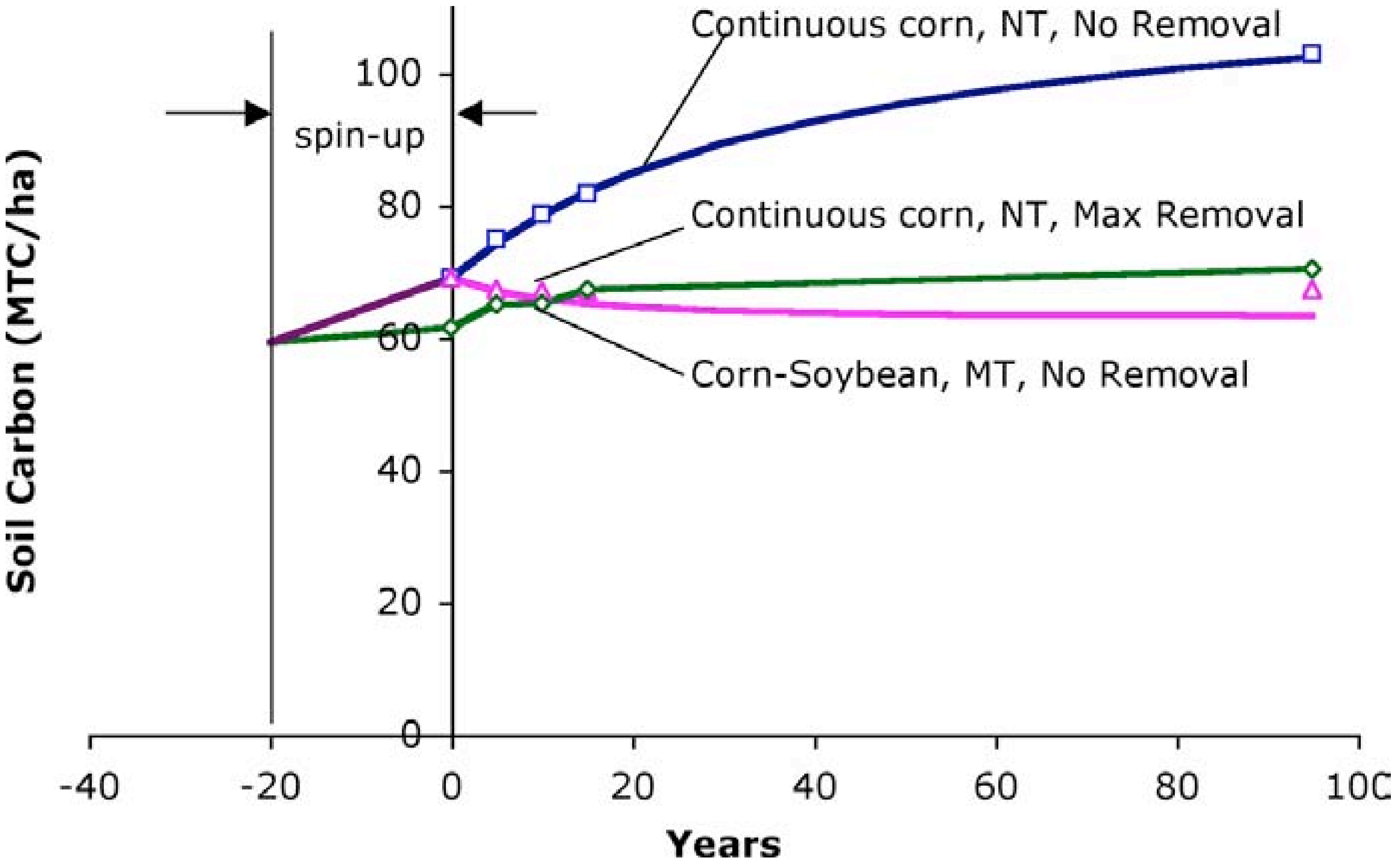


Findings: air quality

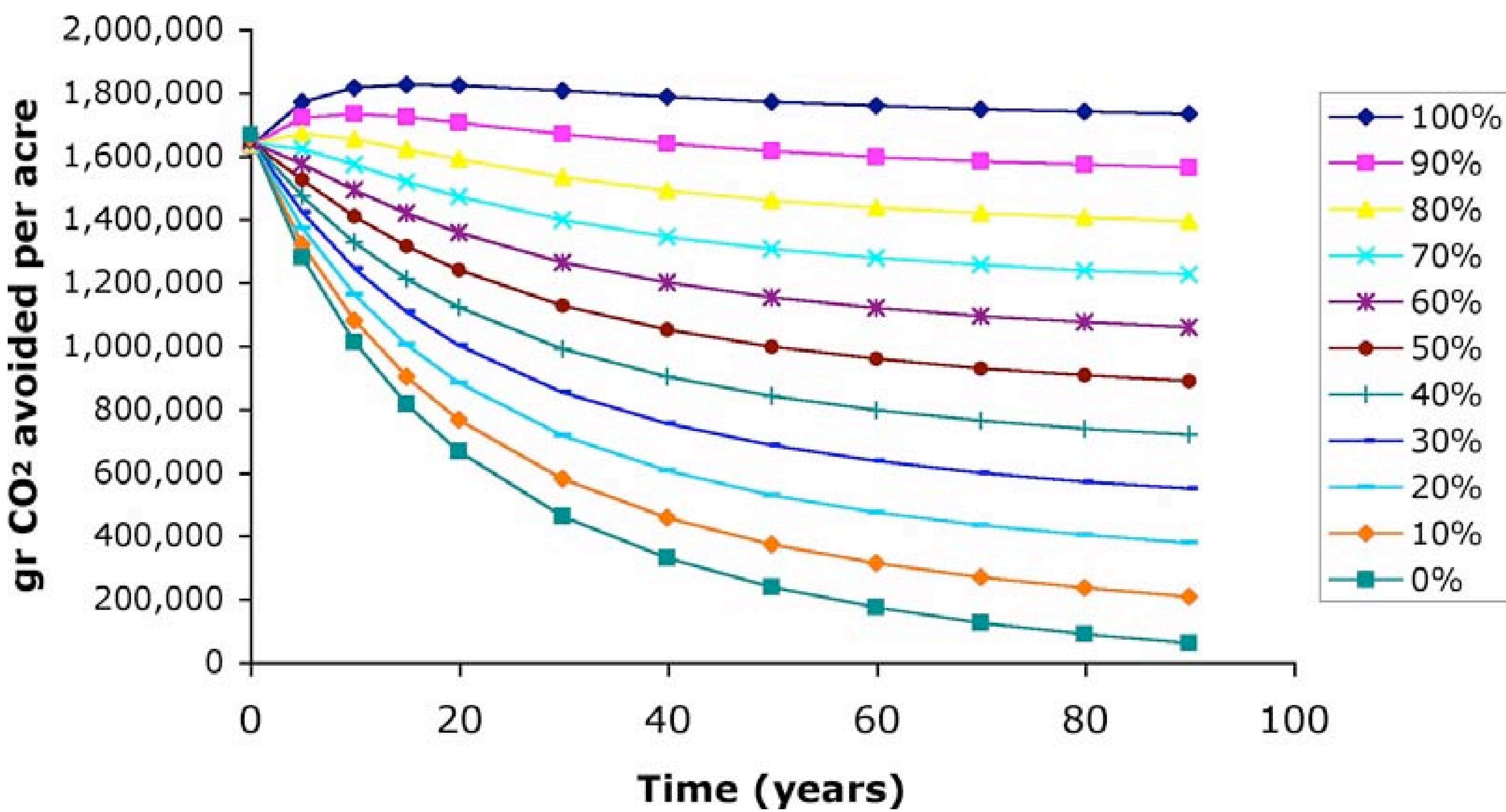
Switching to ethanol made from corn stover increases emissions of CO by 20%



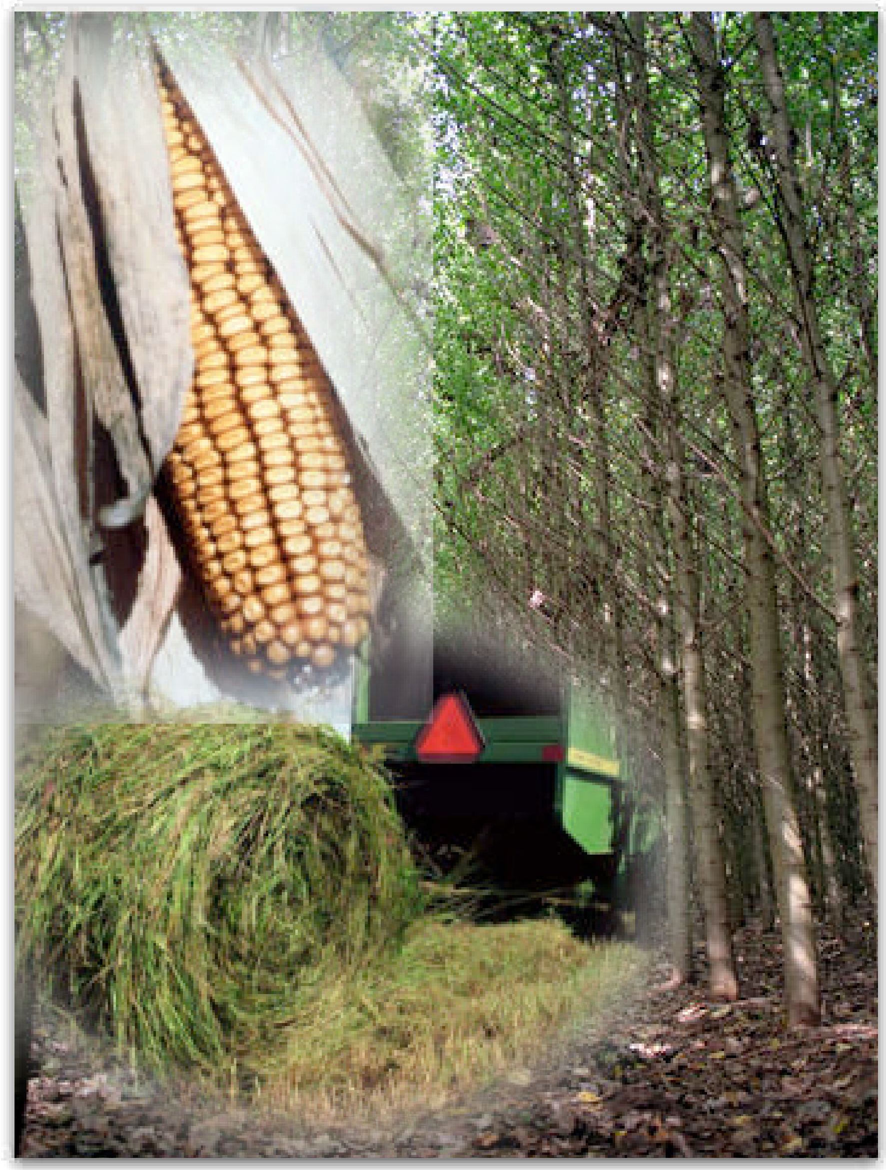
Findings: soil effects



Findings: Net GHG v time

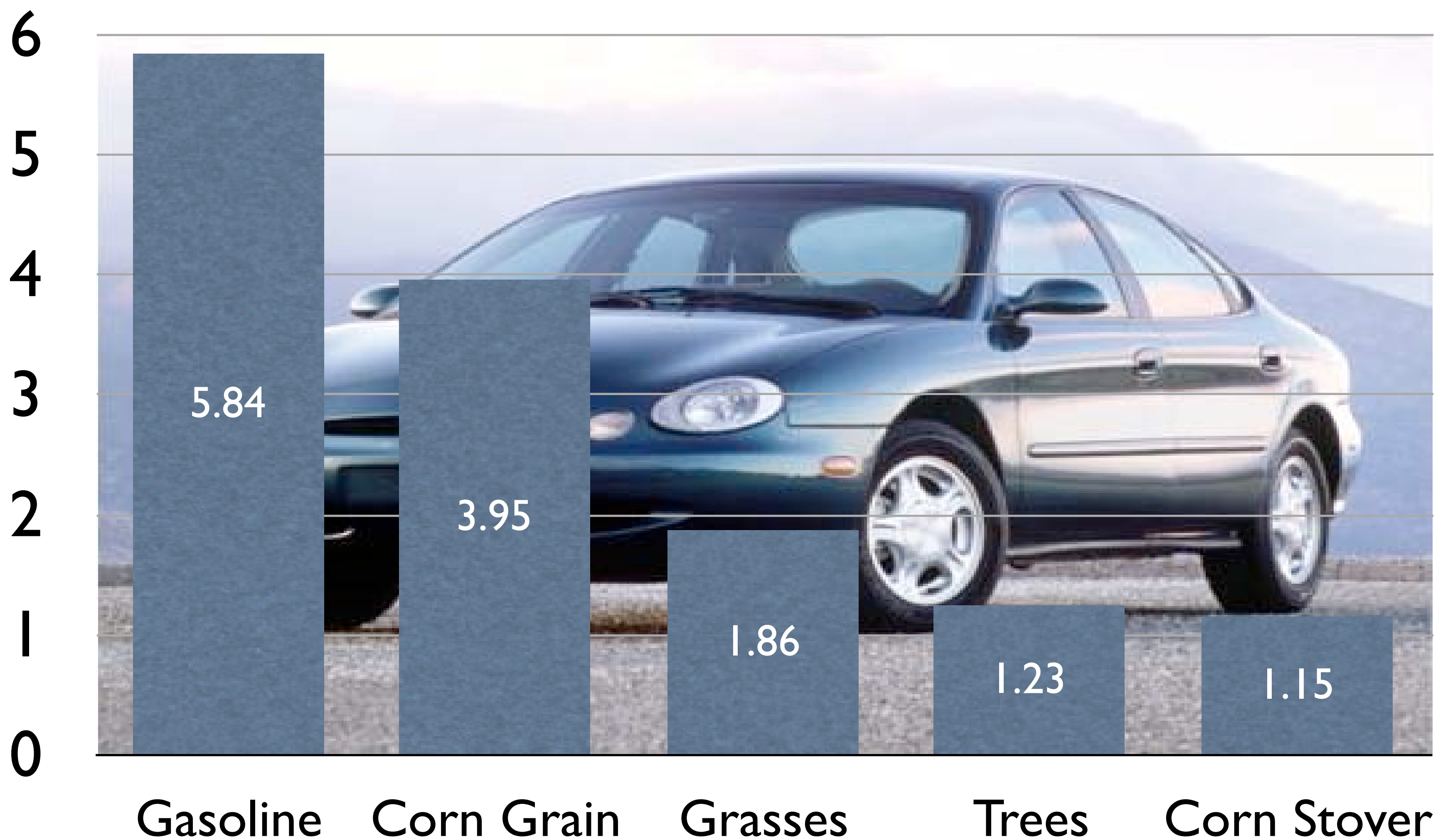


Ethanol from other biomass sources



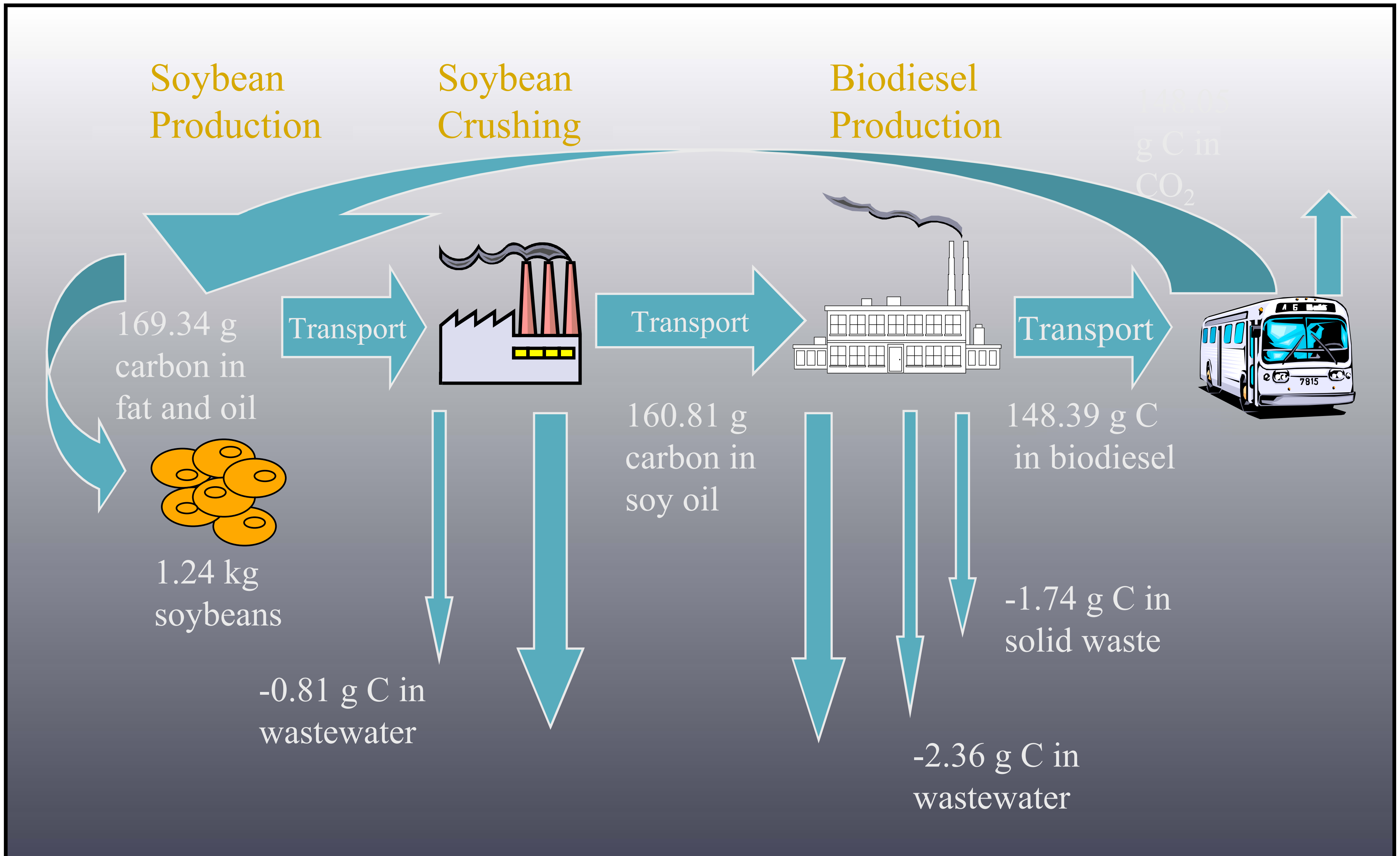
Fossil energy use for E85 (MJ per mile)

The choice of biomass makes a difference



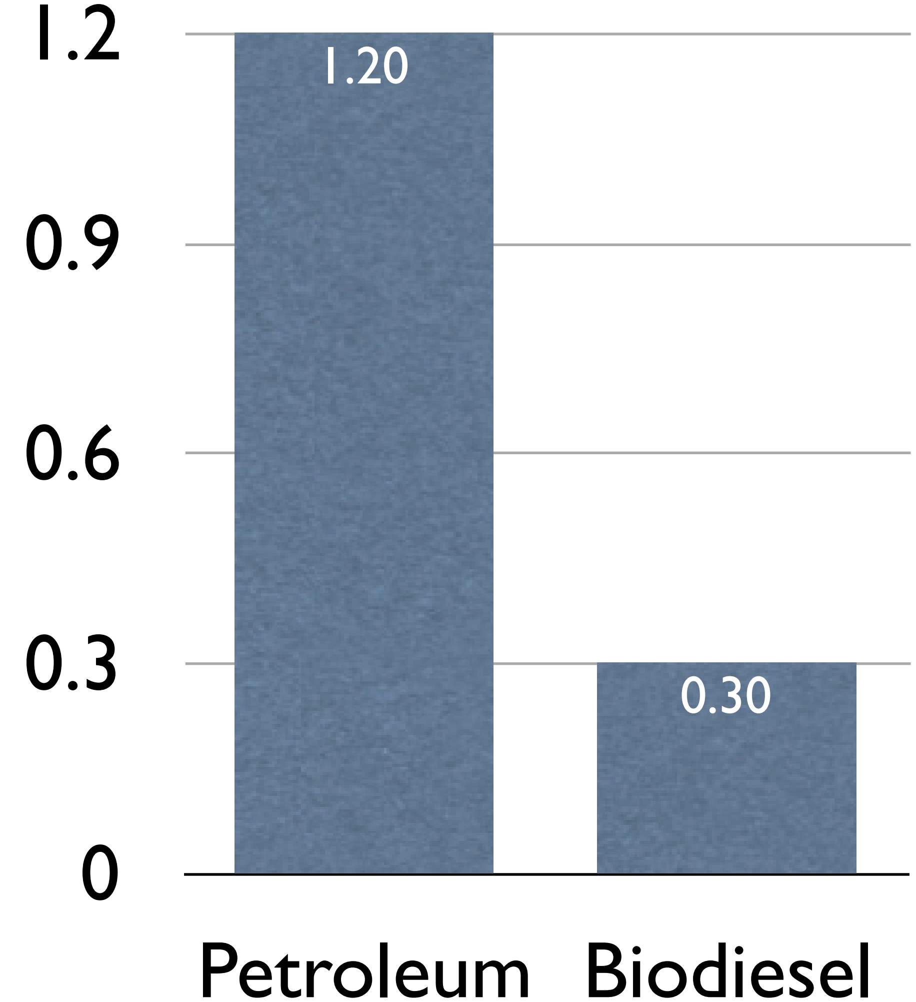
Biodiesel from soybeans

System for soy biodiesel



Findings: fossil energy use (MJ per MJ)

Biodiesel uses only 1/4 of the fossil energy used to make petroleum diesel



Other findings

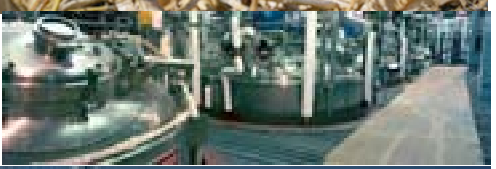
- Biodiesel from soybeans
  - reduces petroleum use by 95%
  - reduces CO_2 emissions by 78%

Other findings

- Biodiesel from soybeans
  - reduces particulate matter 32%
  - reduces carbon monoxide emissions by 35%

Other findings

- Biodiesel from soybeans
  - increases NOx emissions by 13%
  - increases hydrocarbon emissions by 35%

Biomass co-firing with coal

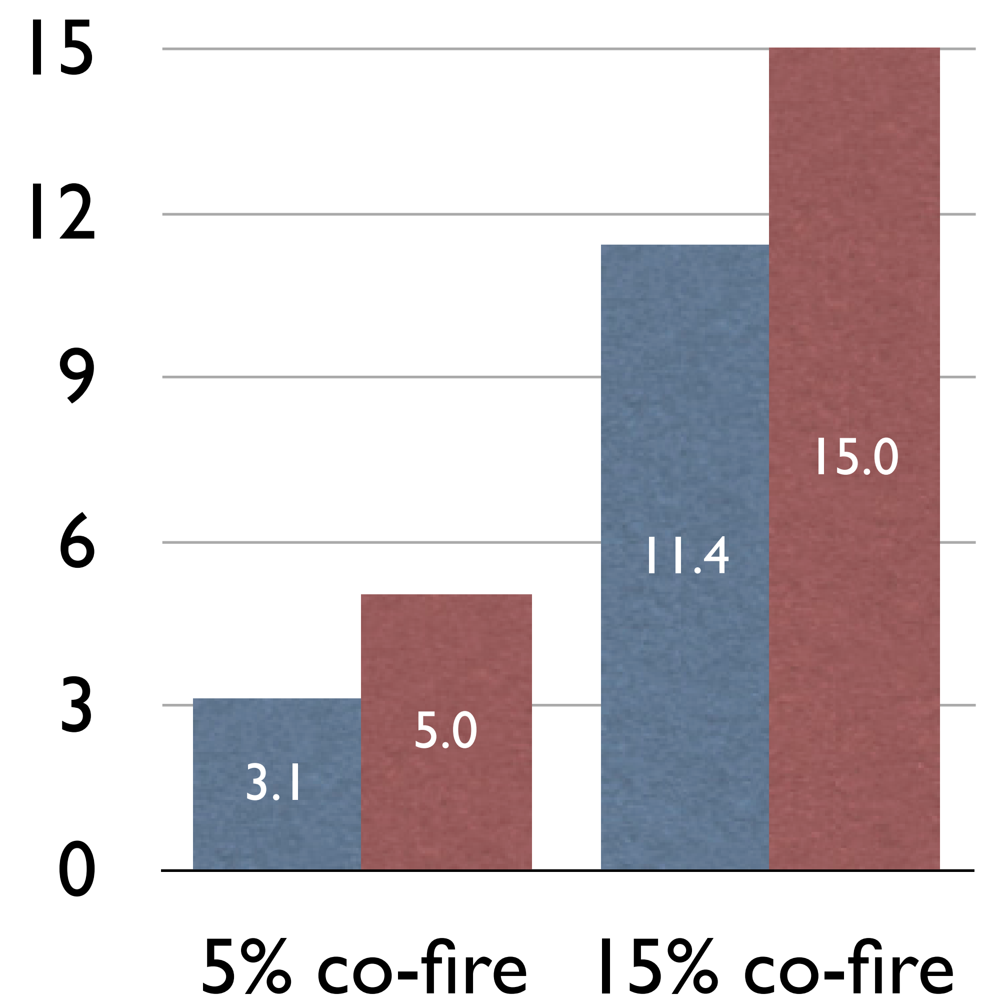
Life cycle assessments conducted by Pamela Spath and Maggie Mann

Biomass co-firing

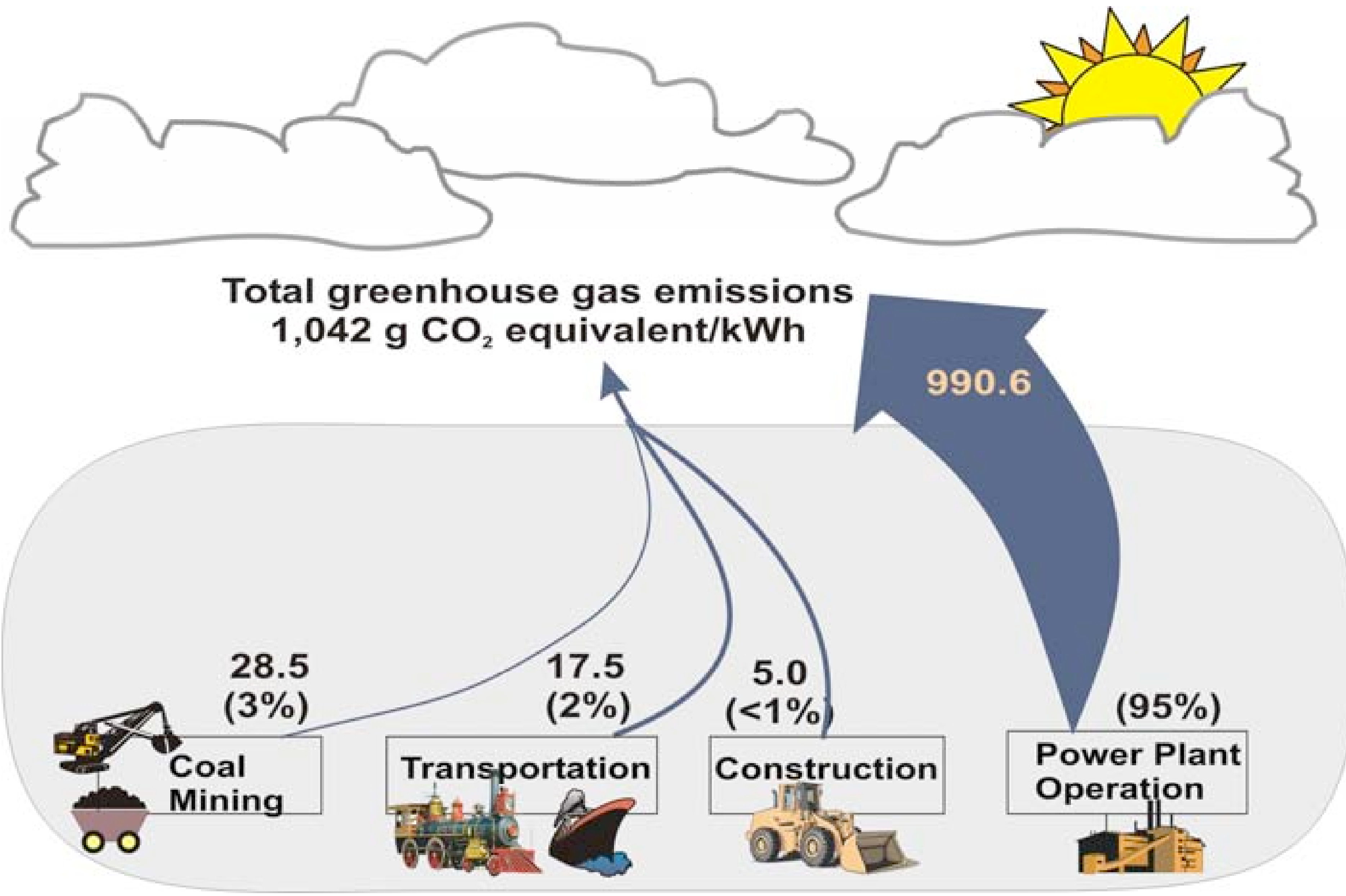
- Coal fired power plants generate >50% of U.S. electricity
- 5% to 15% co-firing (heat input basis)
- Pulverized coal boiler representing average U.S. plant
- Modifications for biomass handling
- Credit for avoided operations

Biomass co-firing Fossil energy savings

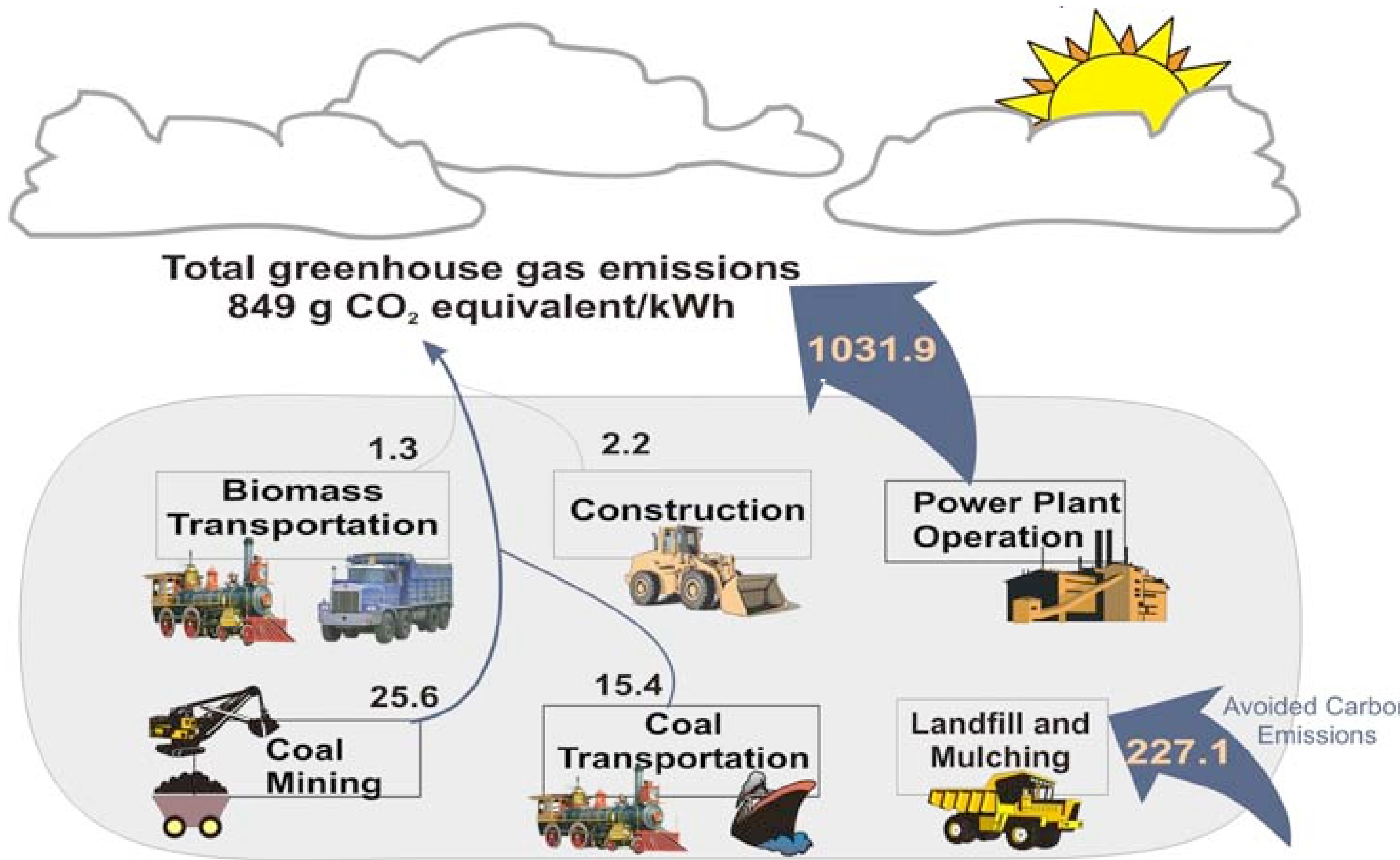
- Reduction in fossil energy consumption is 60 to 76% of potential reduction associated with displaced energy value of the biomass



Greenhouse gases
No co-fire



Greenhouse gases 15% co-fire



Greenhouse gas emissions reduced by 18%

Biomass co-fire
Other air emissions

Air pollutant	Reduction in emissions	
	5% co-fire	15% co-fire
Sulfur oxides and particulates	3%	12%
Nitrogen oxides	2%	8%
Methane	101%	105%

Biomass co-firing Summary

- In most cases, rate of reduction is less than rate of co-firing because of lower power plant efficiency and emissions and energy consumption associated with the biomass
- Methane emission reductions exceed 100% because of avoided methane generation in landfill operations
- Rate of reduction in greenhouse gas emissions is actually higher than rate of co-firing because of avoided landfill emissions




Biomass gasification for power production

Life cycle assessments conducted by Pamela Spath and Maggie Mann

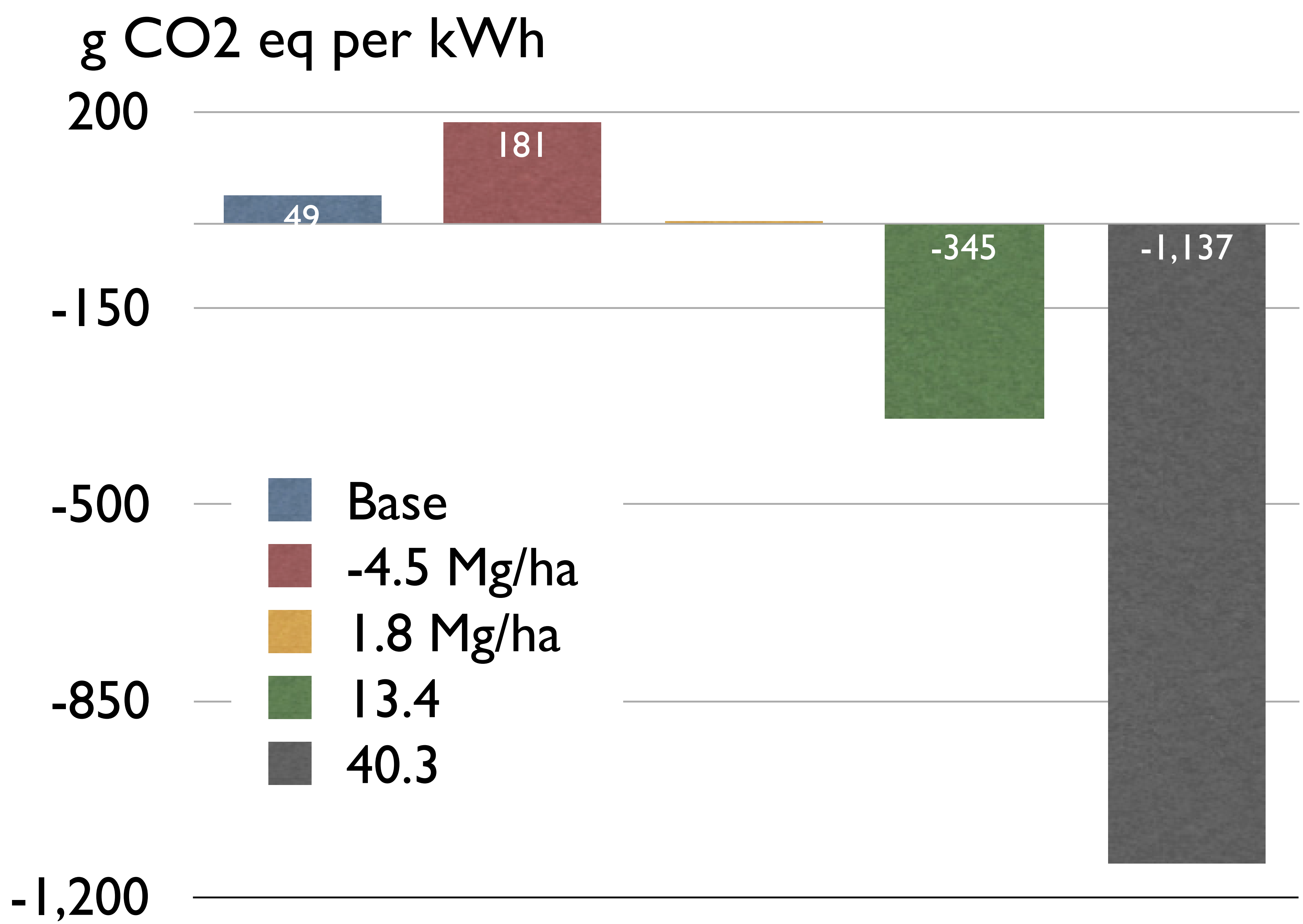
Biomass gasification for power production

- Biomass Integrated Gasification and Combined Cycle Power Production
- Indirectly heated gasification
- Use of hybrid poplar (fast growing trees) as dedicated energy crop feedstock
- Various assumptions for soil carbon sequestration due to trees

Biomass gasification
Soil carbon effect

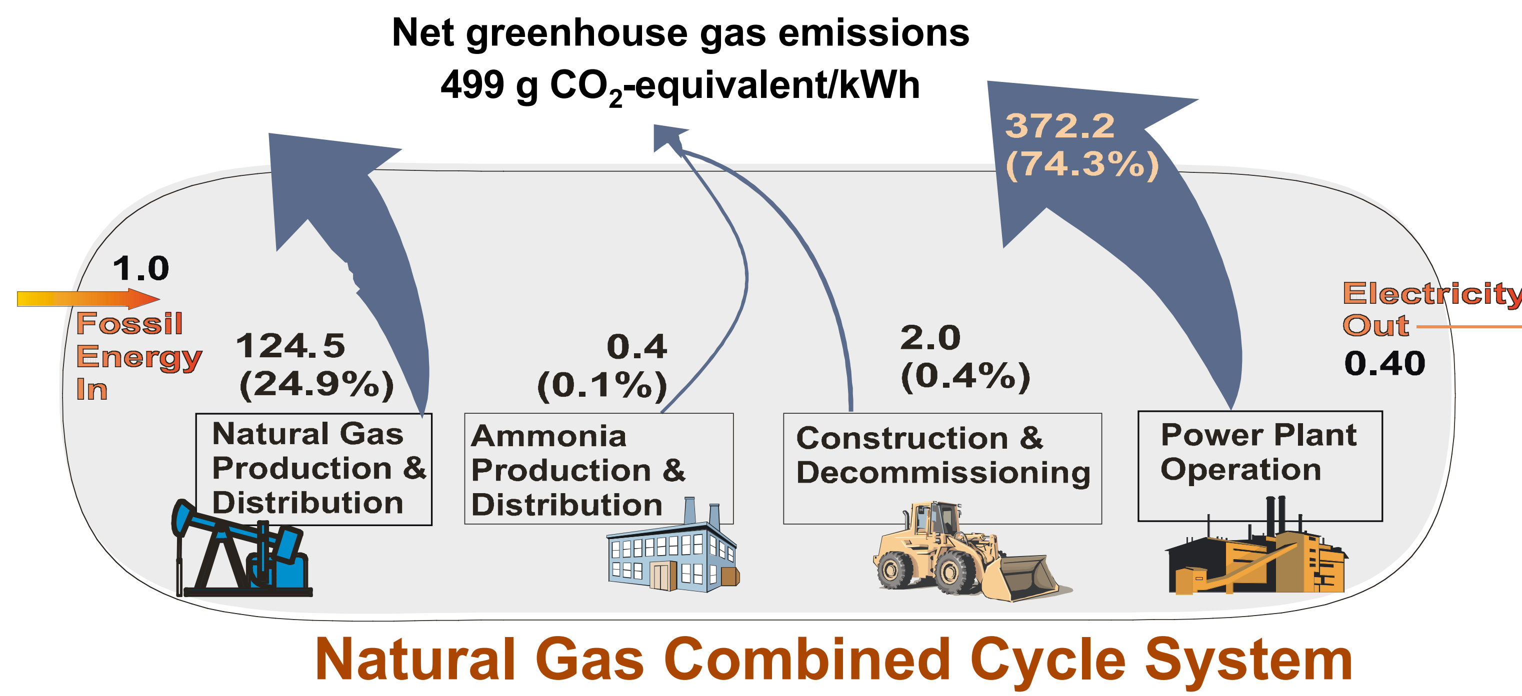
Hanson 1993	-4.5 to 40.3 Mg/ha over 7 yrs
Perlak et al 1992	13.4 to 17.9 Mg/ha over 7 yrs
Marland and Schlamadinger 1996	40.3 Mg/ha over 7 yrs
Ranney and Mann 1994	30-40 Mg/ha over 20-50 yrs, then equilibrium
Recent field trials	Suggest a loss of soil carbon

Biomass gasification
Soil carbon effects

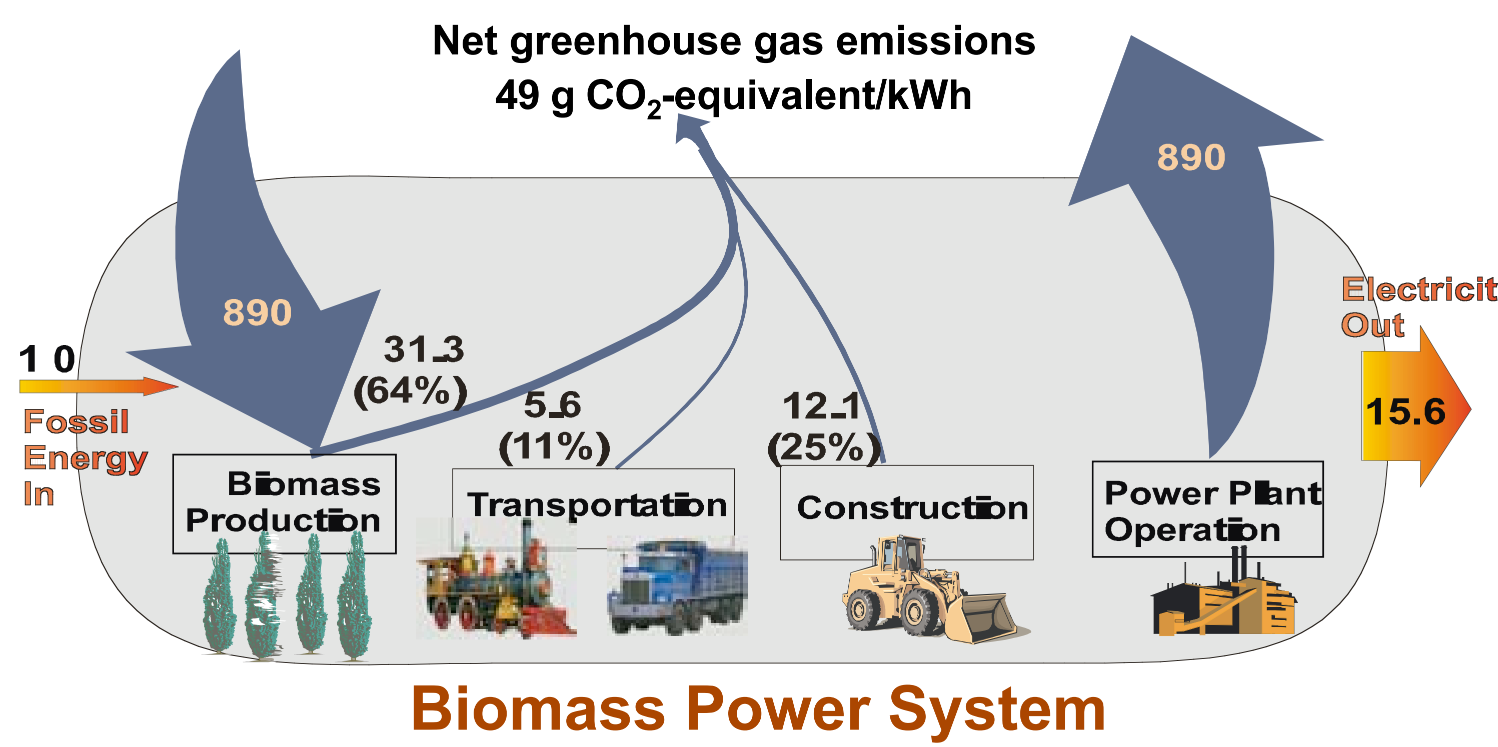


Biomass gasification Greenhouse gases

Natural gas
499 g CO_2/kWh



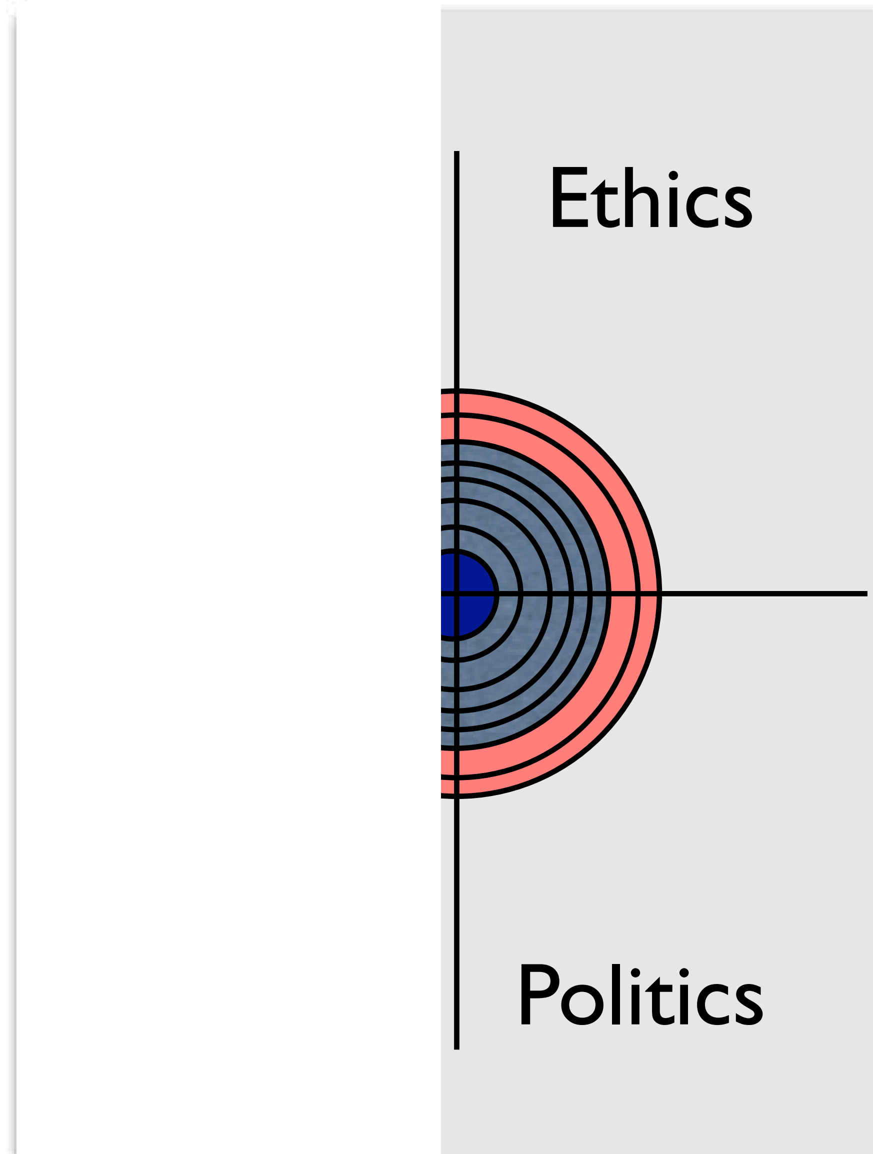
Biomass
499 g CO_2/kWh



Life cycle assessment allows us to quantify the benefits of bioenergy in terms of its ability to significantly reduce fossil energy, petroleum and greenhouse gas emissions along with identification of trade offs

Sustainability

The intersection of science and ethic and the ultimate example of E. O. Wilson's "Consilience"

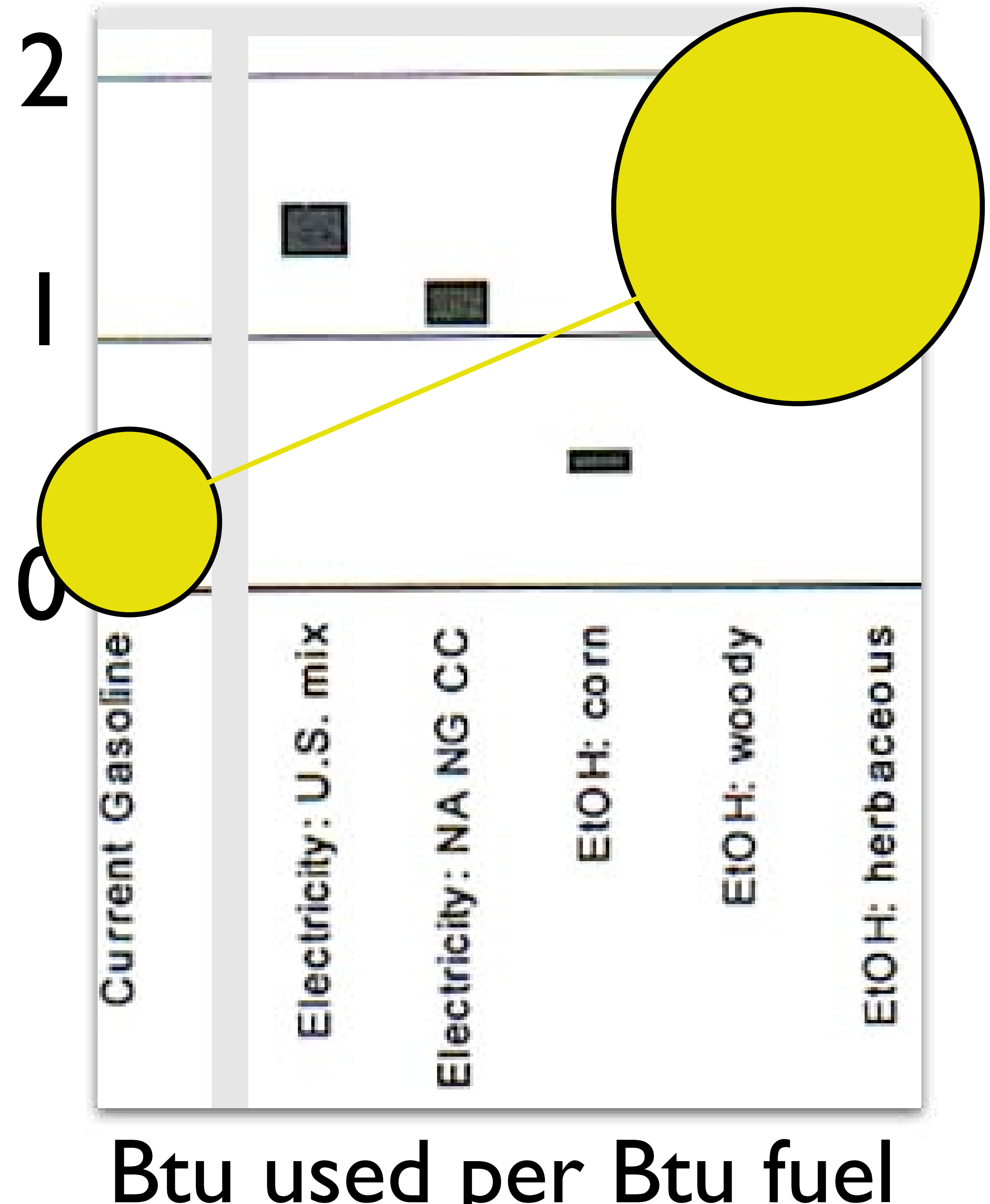


Techno-speak and policy geeks

- Examples of problems in dialogue with the public and policymakers
  - GM "Wells to Wheels" Study
  - David Pimentel

GM Wells-to-wheels

- Lignocellulosic ethanol seems to use 4 to 8x the energy required to deliver gasoline as an energy carrier

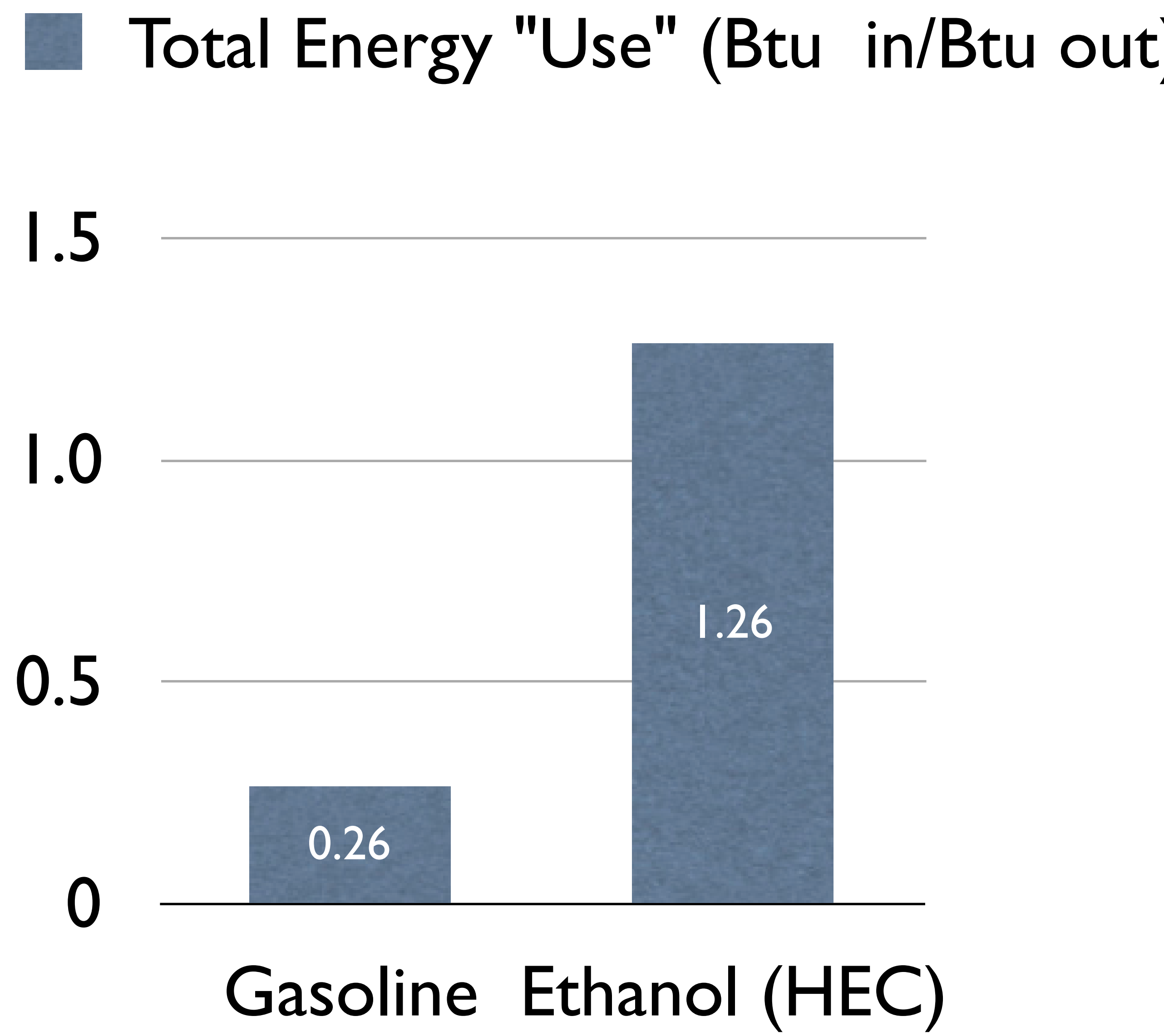


How policymakers saw it

- David Garman, AS for EERE, concluded that biomass makes no sense in the long run because it is so inefficient
- Is he right?

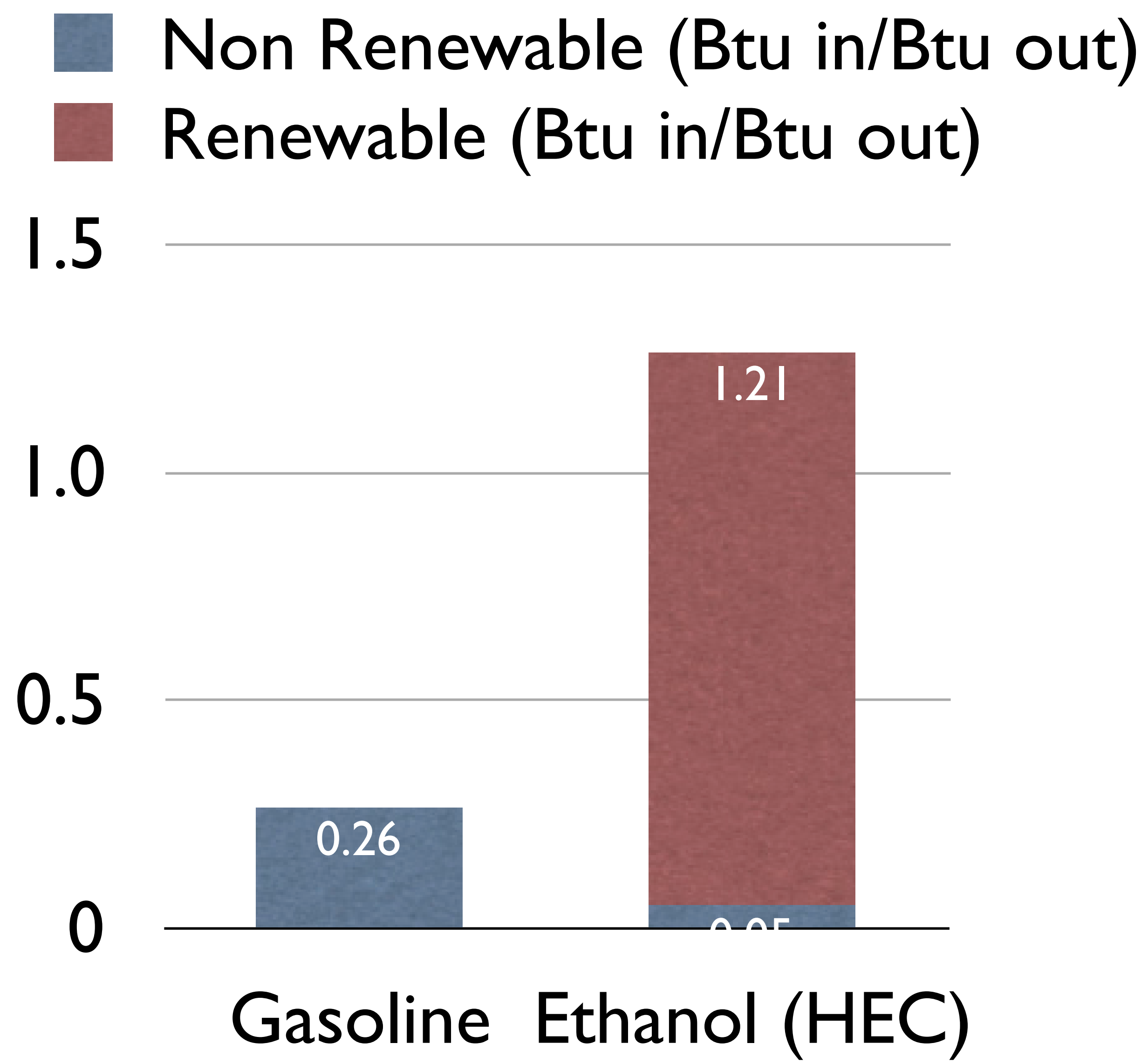
Getting to the right view of total energy

- The picture from the Wells to Wheel study
- Energy losses only



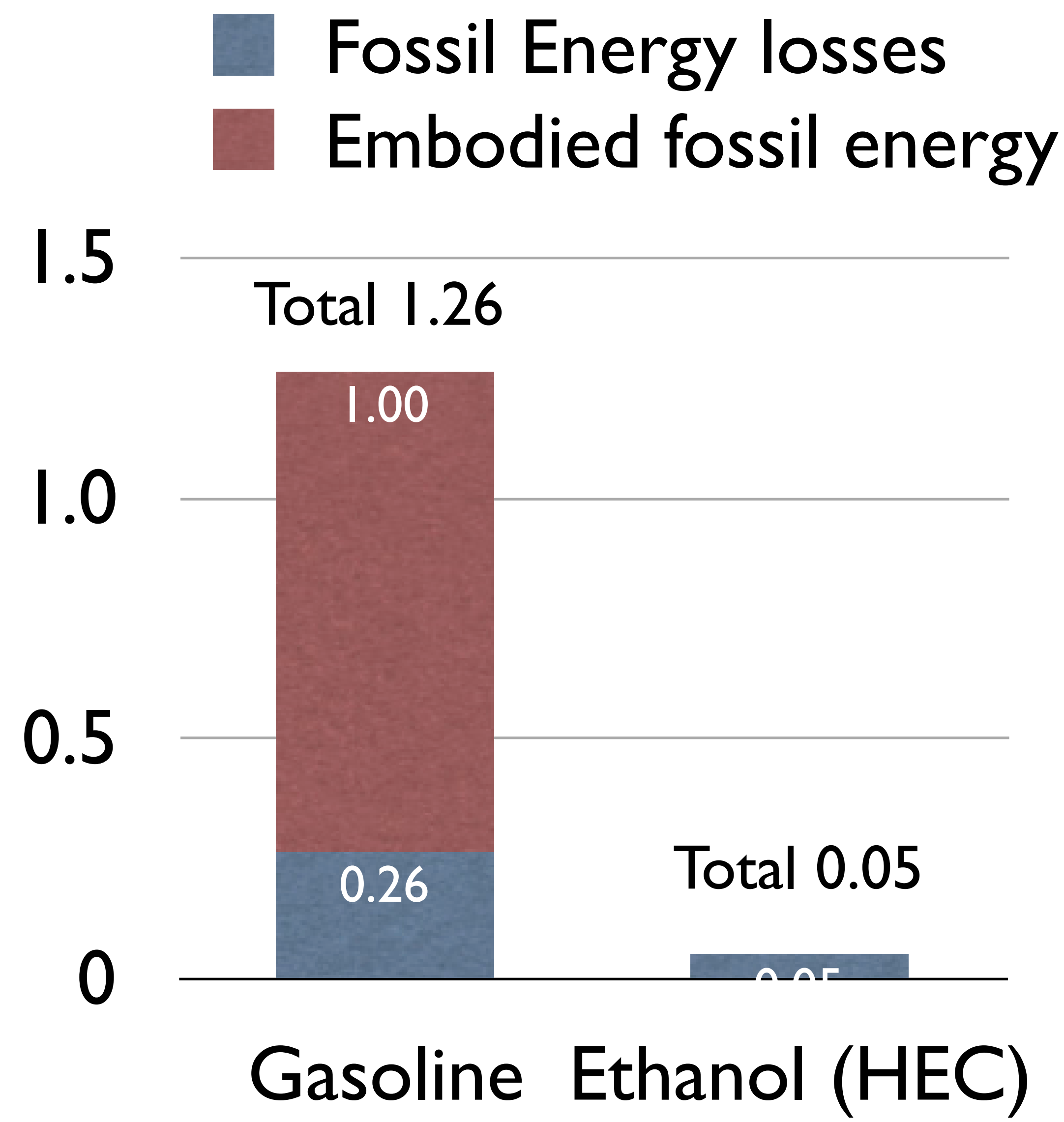
Deconstructing total energy

- Using the WtW study results only
- Fossil energy losses are 5x lower for ethanol
- But this is still not an apples-to-apples comparison



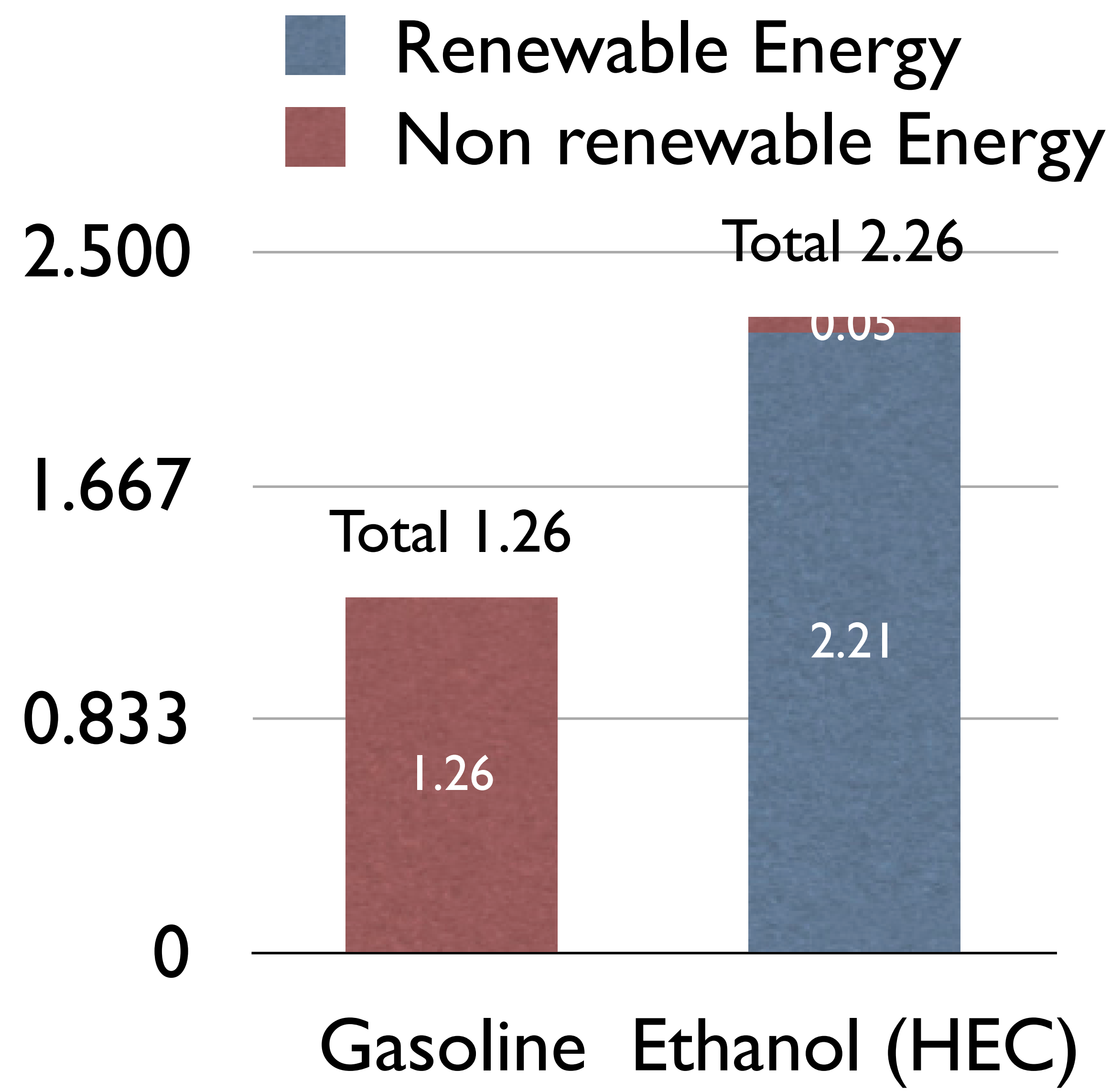
The complete fossil fuel perspective

- Adding back in the fossil energy in petroleum
- 25x lower fossil energy losses



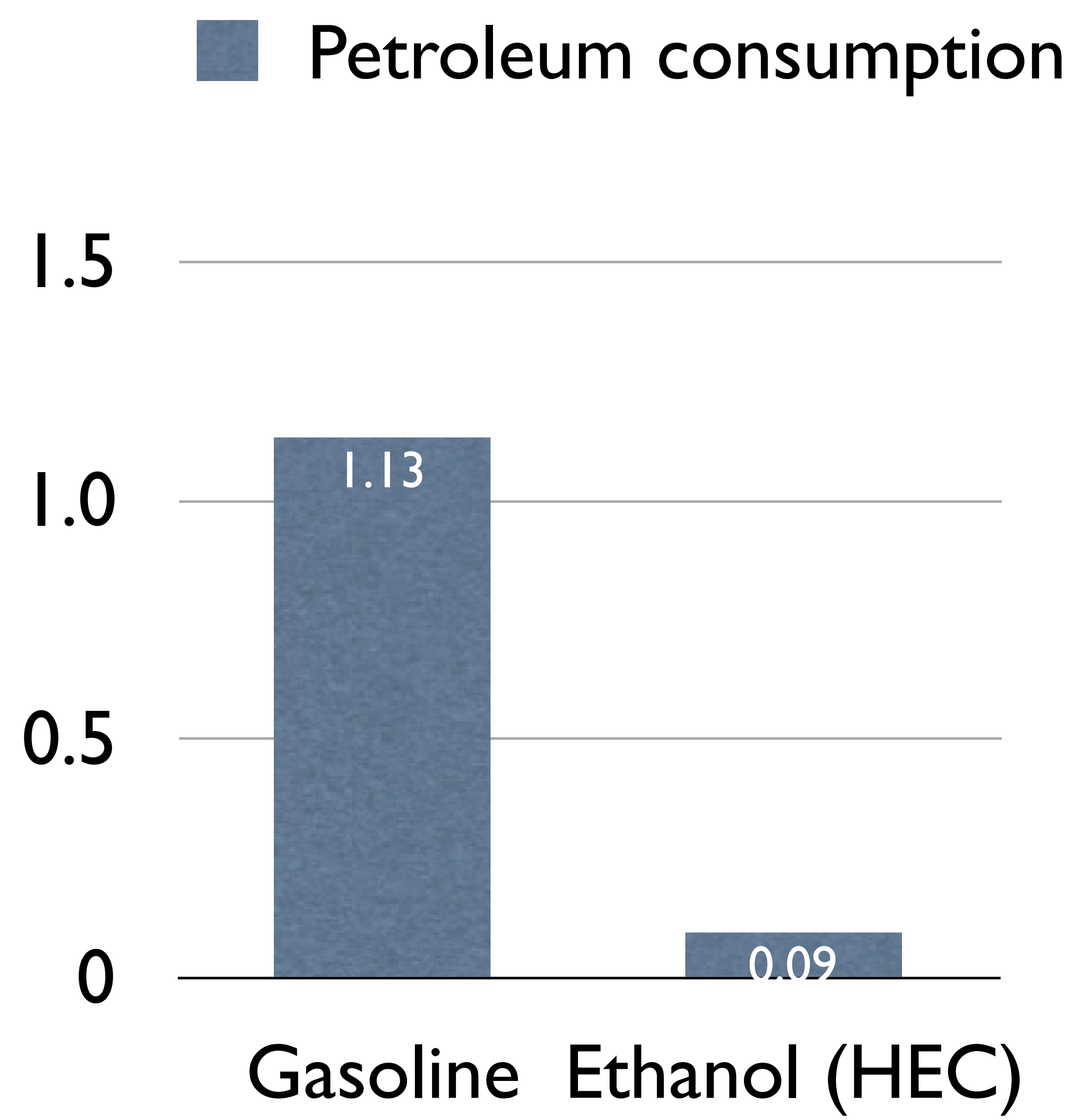
...and, finally, true total energy use

- The report's original conclusion is indeed correct
- But the difference in efficiency is vastly different than the results implied in the report's summary

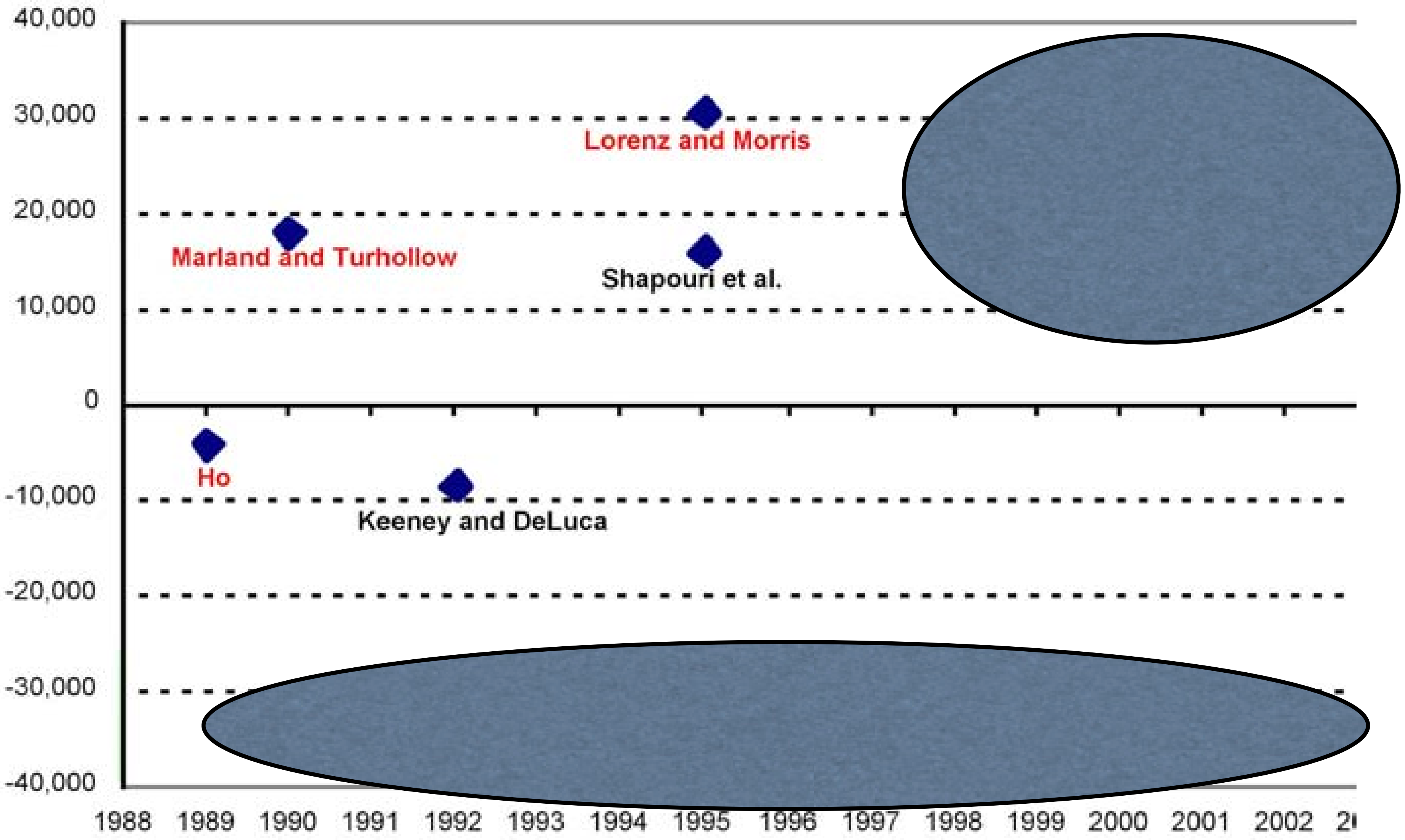


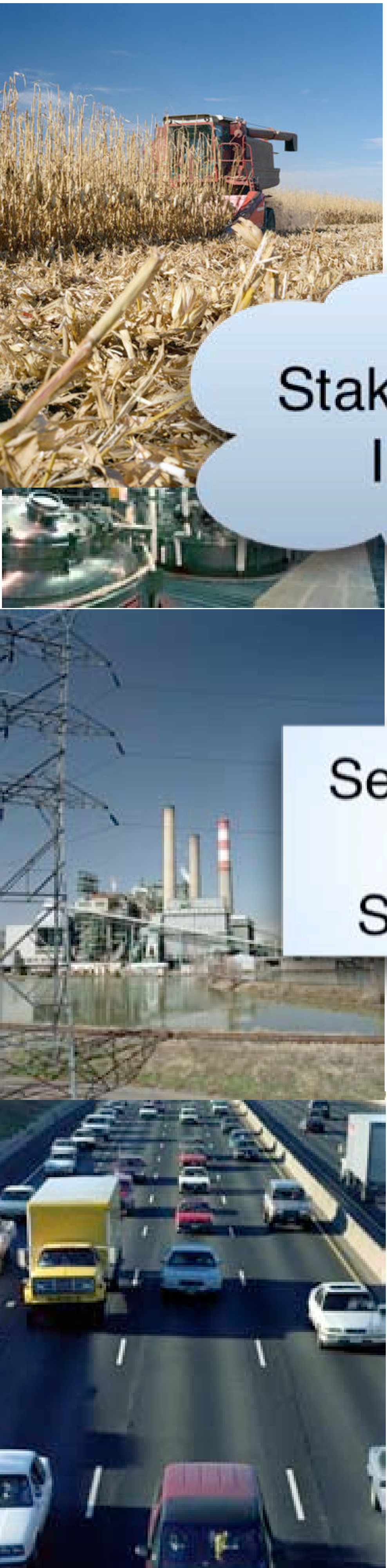
The petroleum use perspective

- Again, based on WtW study results
- 13x reduction in petroleum consumption for ethanol
- Petroleum use is higher than net fossil

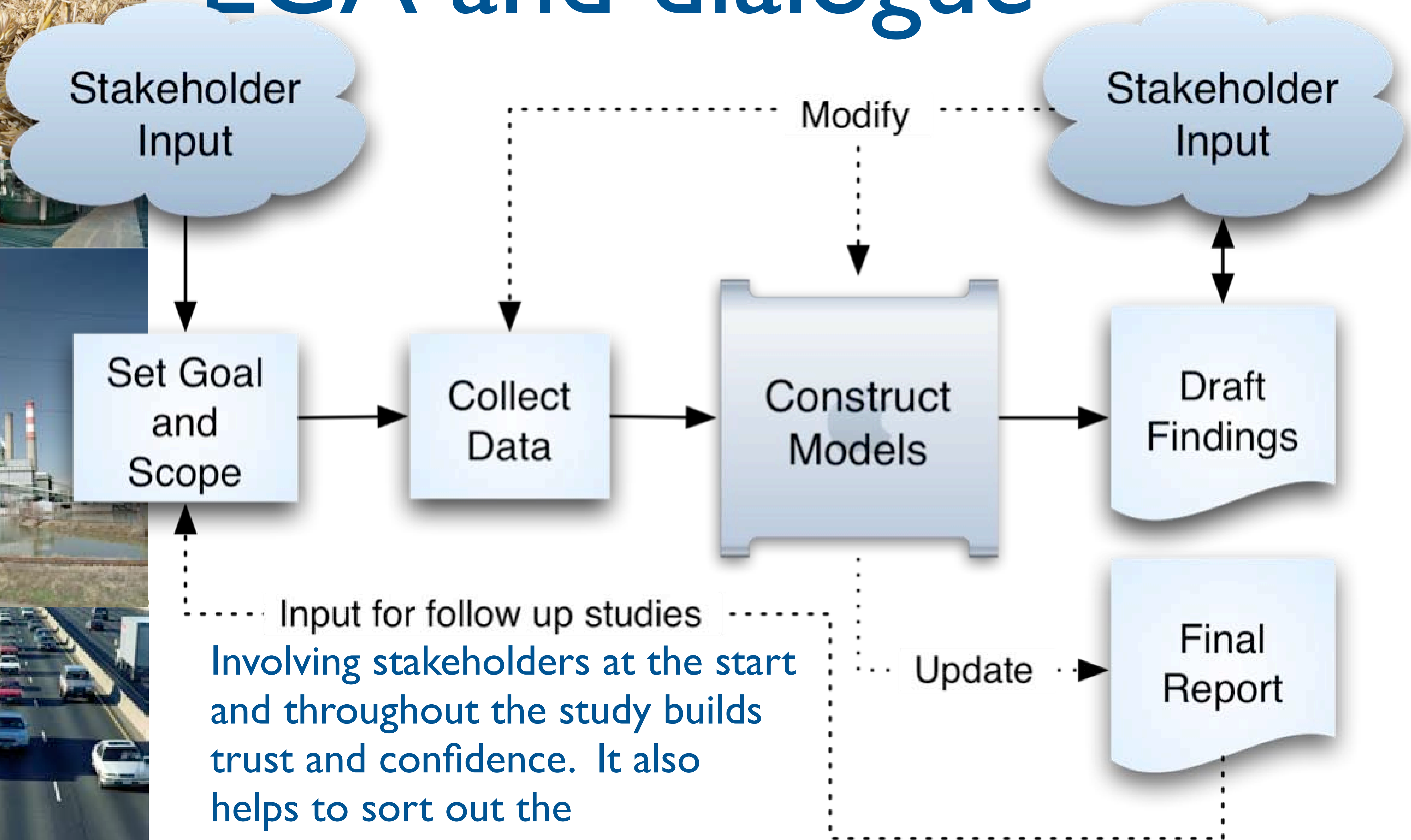


The corn ethanol debate: Pimentel





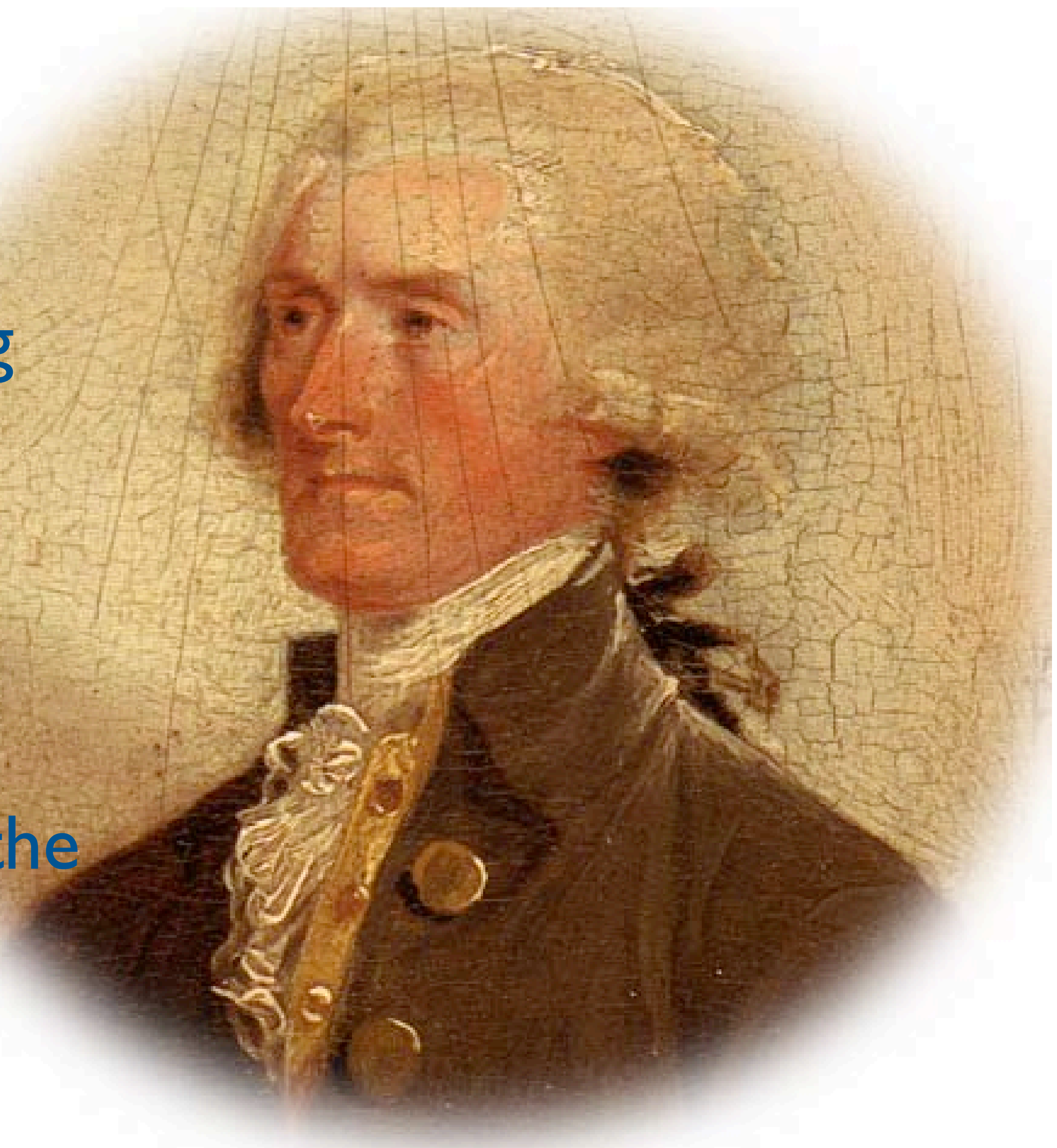
LCA and dialogue



Involving stakeholders at the start and throughout the study builds trust and confidence. It also helps to sort out the uncertainties of the moral and ethical choices we need to make

“Holistic dialogue”

- Distinguish the ethical and political from the technical
- Ethics involves defining Jefferson’s pursuit of happiness
- Life cycle assessment can promote this distinction by putting the disagreements of one along side the uncertainties of the other



“Holistic dialogue”

- “Let us engage in the serious business of conducting our discussion rationally and logically, to discover the truth about points on which we differ.”
  - Mortimer Adler

“Holistic dialogue”

- “...western civilization is the civilization of the Logos. Liberal education, up to the end of the twentieth century, carried forward the Great Conversation.”

“Holistic dialogue”

- As long as technical experts to contiue to offer expert opinions, the public will continue to scratch their heads in wonder
- We need to educate and engage our public in both the ethical and technical questions that surround sustainable energy