NREL/PO-510-31792
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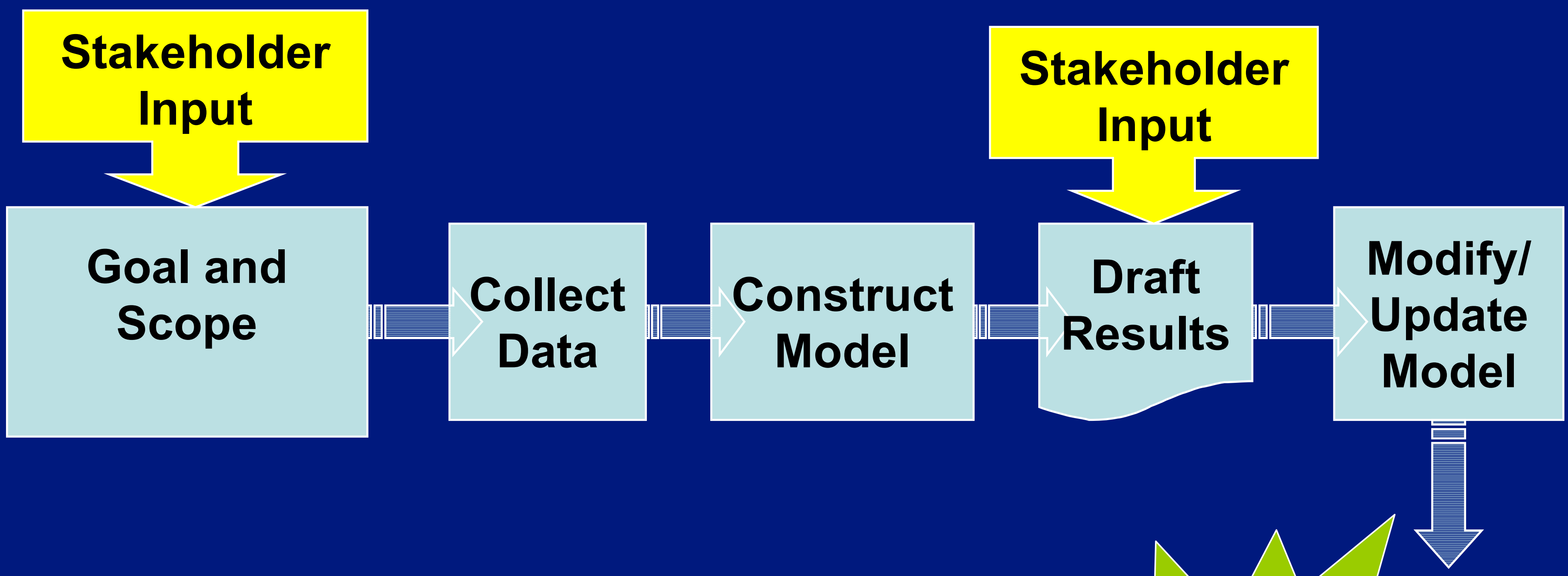
What is a life cycle assessment?

- A “comprehensive” accounting of a product’s flows to and from the environment
  - Air, water and solid waste emissions
  - Energy resources
  - Other primary resources extracted from the environment
- “Cradle to grave”
- Always a comparison of options

Life Cycle Analysis—A Tool for Dialogue

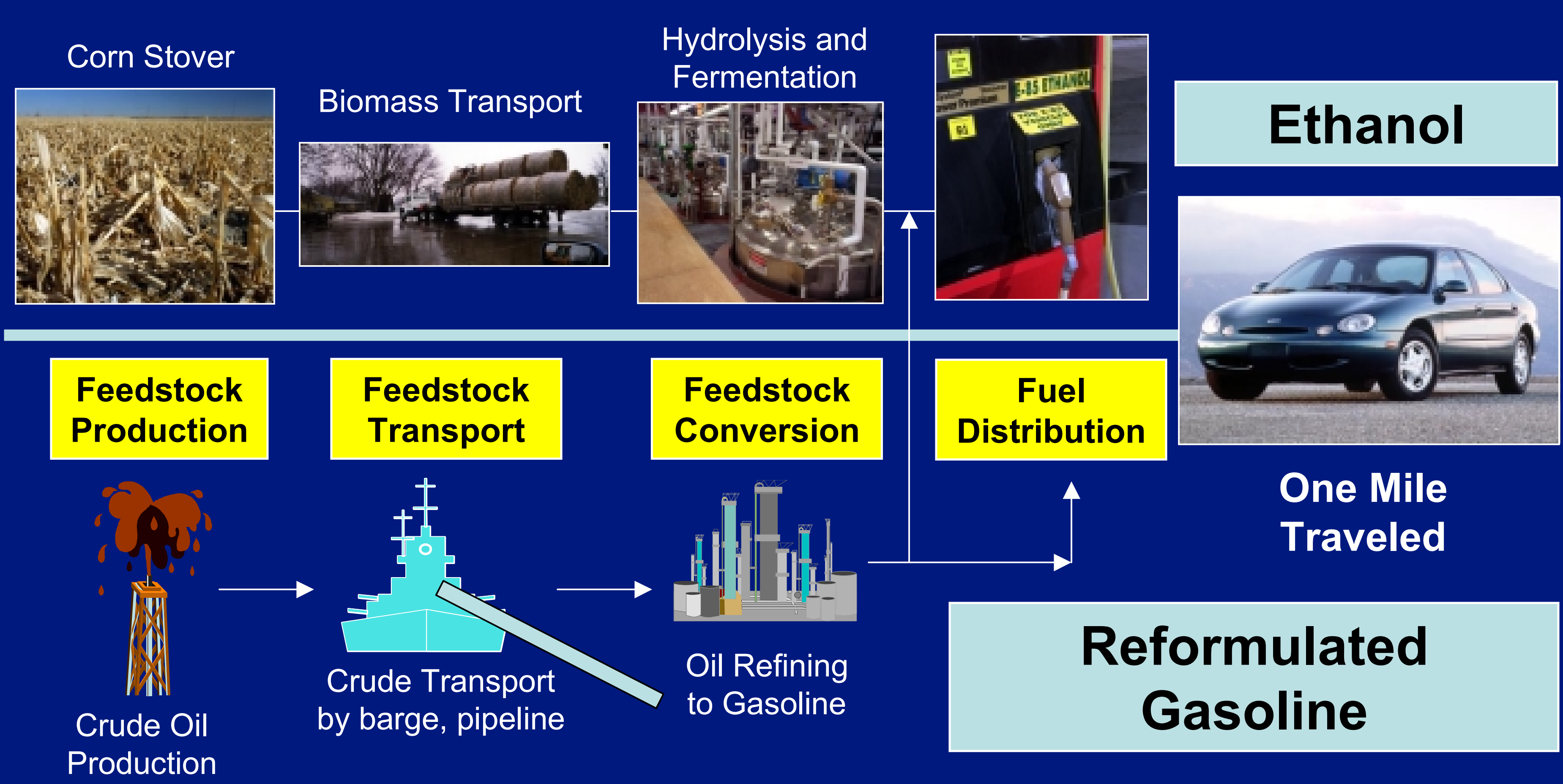


Involving stakeholders in such studies helps to sort out the uncertainties of the science from the uncertainties of the moral and ethical choices we need to make.

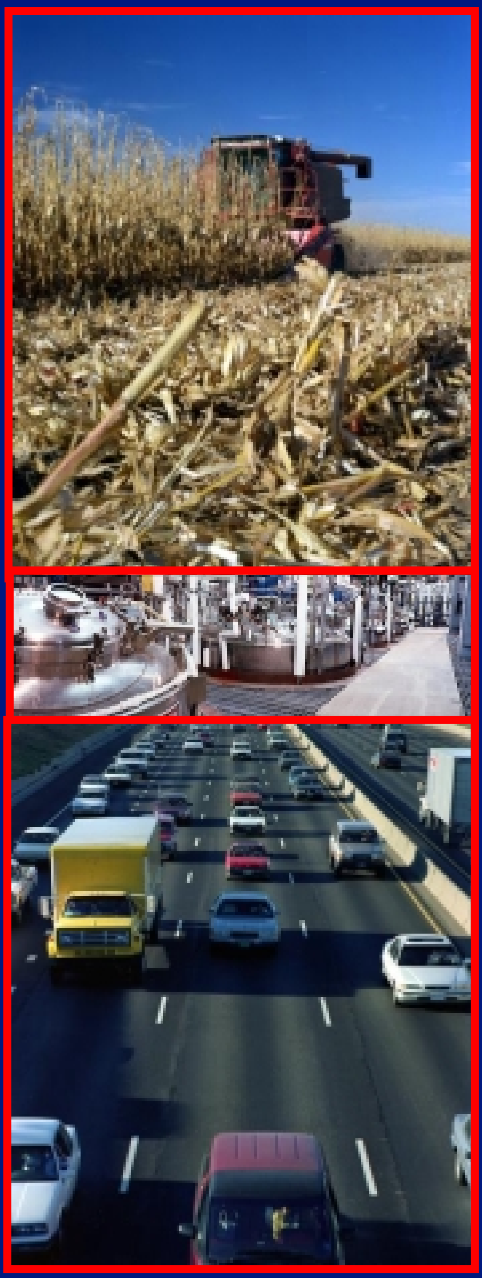
Turning Corn Stover to Ethanol

- 85% of the residue left after grain harvest (stover) rots on the ground, releasing CO_2
- The other 15% is incorporated in soil as organic matter
- DOE posits that a certain amount of residue can be collected and used for ethanol production
- Our life cycle study asks if the benefits of carbon recycling and fossil energy avoidance can be properly balanced against the lost opportunity for sequestering carbon in soil and improving soil health

Life Cycle Analysis— Corn Stover vs Petroleum in Iowa



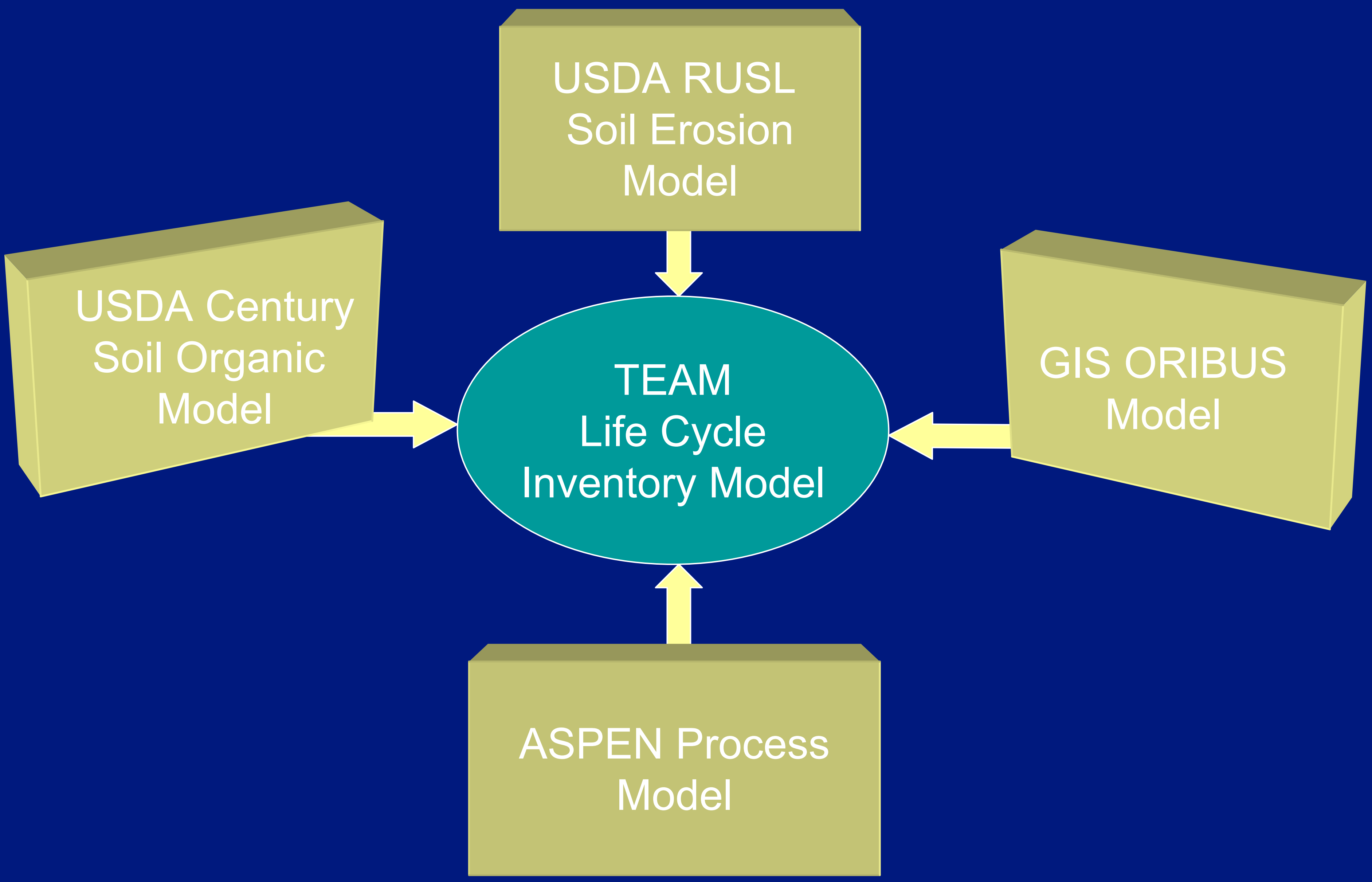
Assembling the Experts



This is the first study to holistically assess the farm, the soil, the conversion technology, and the vehicle technology

- Soil Scientists
  - Keith Paustian, Ken Killian at the Natural Resources Ecology Lab (CSU)
  - Dave Lightle, John Brenner at USDA's Natural Resources Conservation Service
- Agronomics
  - Marie Walsh at Oak Ridge National Laboratory
  - Richard Nelson at Kansas State University
- Process Engineering
  - Andy Aden

Life Cycle Analysis Requires Integration of Specialized Models



Involving Stakeholders

Private Sector
- Environmental groups
- Farmers
- Automakers
- Ethanol Producers
- Chemical Producers

Life Cycle Study

Public Sector
- U.S. DOE
- U.S.D.A.
- U.S. EPA
- State/local govt

Sustainable Decisions

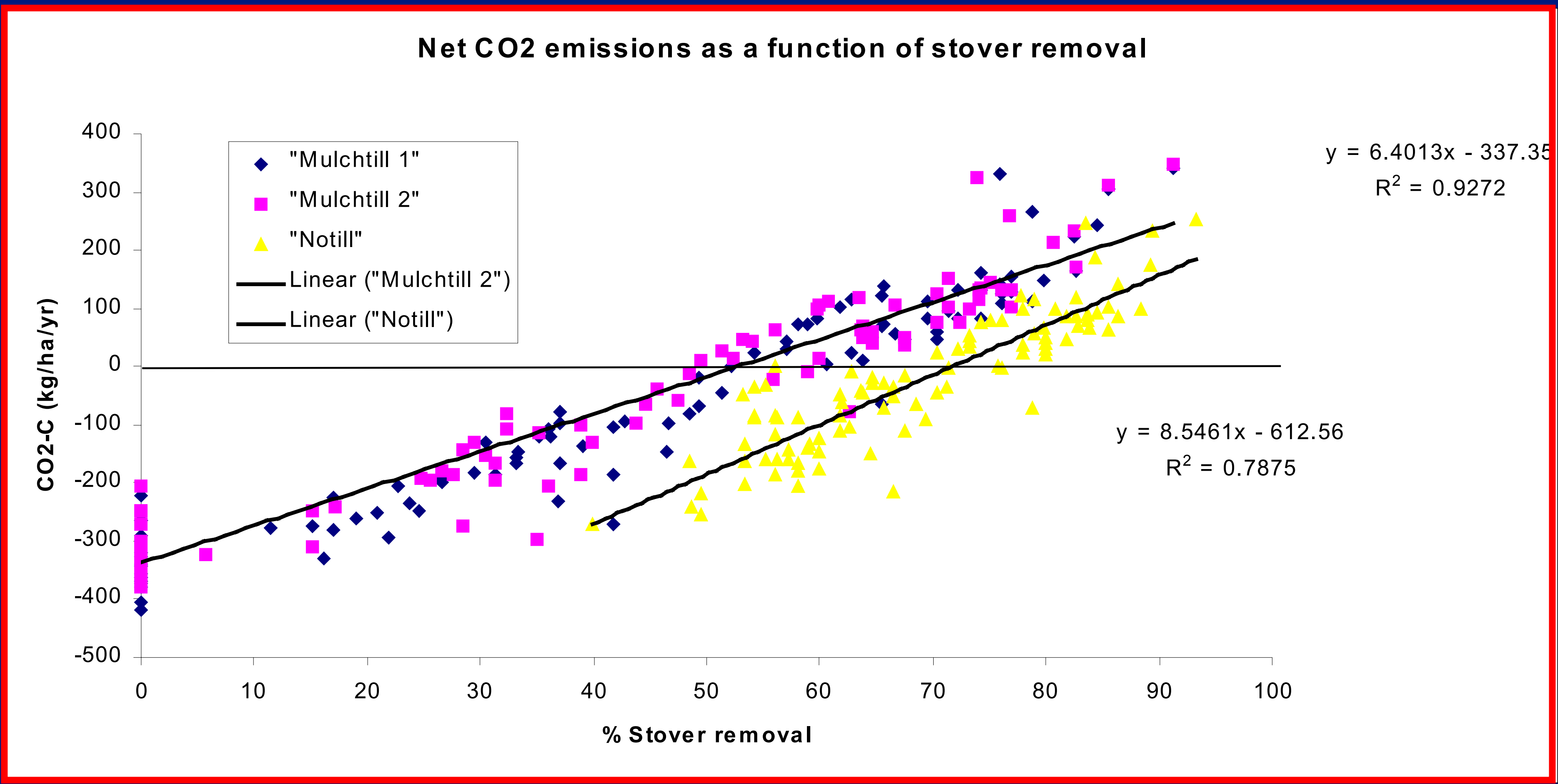
Stakeholder Input on Metrics for Sustainability

- Fossil energy avoidance
- Land use and biodiversity
- Greenhouse gas
- Soil sustainability
- Urban air emissions
- Air and water toxics
- Solid waste
- Eutrophication
- Acidification
- Community—rural jobs, local economy

Soil Carbon Effects

- USDA's Century model allows us to consider the effects of different tilling practices and crop rotations in combination with different levels of stover collection on soil carbon sequestration
- Maximizing sequestration offers transient benefits in terms of greenhouse gas reductions
- In order to prevent release of soil carbon, farmers can collect no more than 40 to 50% of the stover left after harvest
- "No till" practices allow more stover removal
- Soil responses are highly variable from county to county

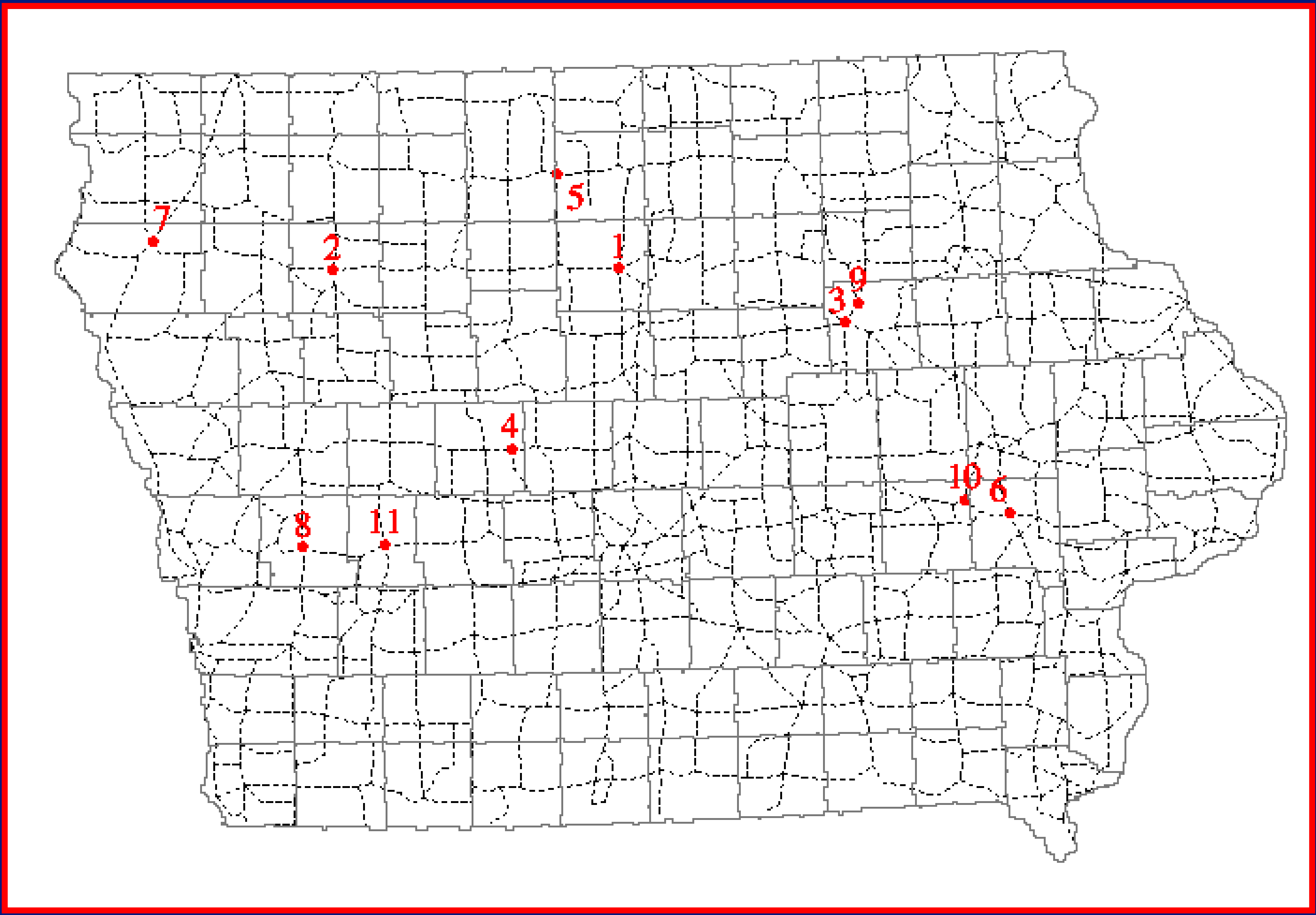
Effect of Stover Removal on Soil Carbon Emissions for All Counties in Iowa



Stover Collection and Transport

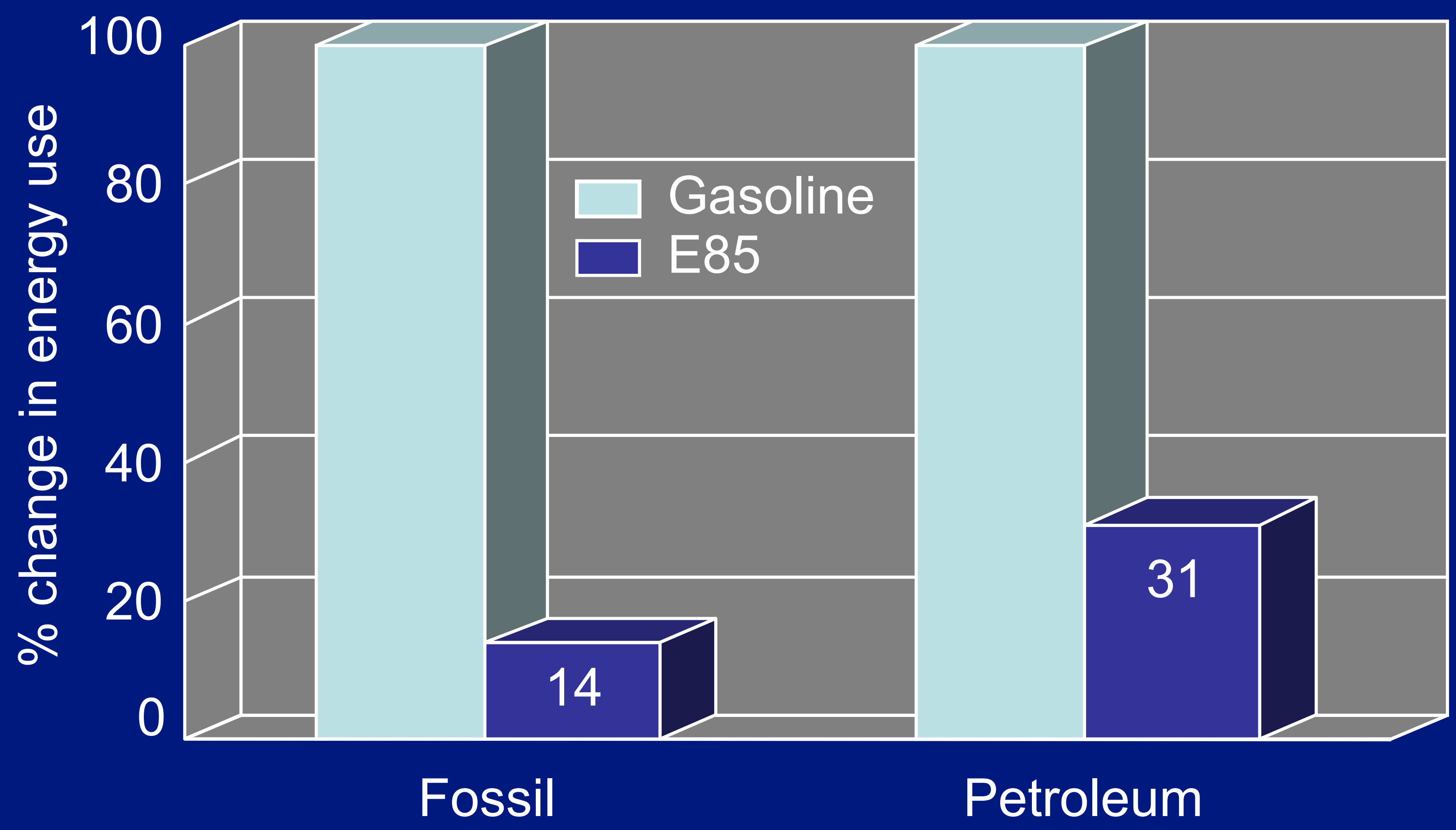
- We used a combination of GIS modeling and agro-economic modeling to assess the economic, energy and environmental impacts of stover baling, staging and transport
- We located ethanol plants from first to last on-line in Iowa based on optimal location and access to stover

Modeling an Evolving Industry



- In this scenario, corn stover was collected from existing farms where low or no till practices are in place.
- 11 plants producing approximately 60 MM gallons each could be supported.

Life Cycle Findings—Fossil Energy Avoidance

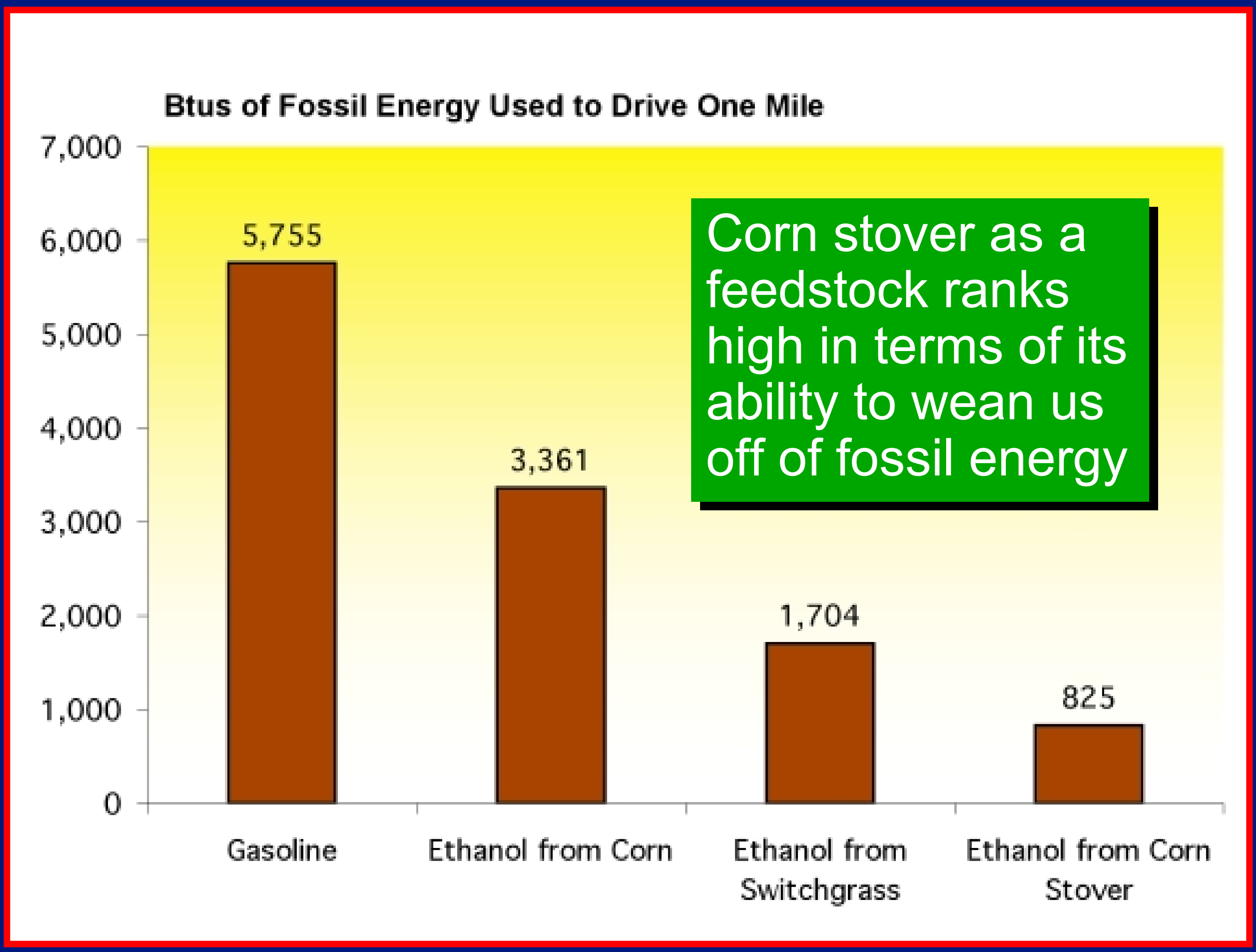


- Burning E85 in a flex fuel vehicle leads to:
  - 86% drop in fossil energy inputs relative to gasoline
  - 69% drop in petroleum use

Life Cycle Findings—CO_2 Reductions

- Given scenarios such as continuous production of corn and implementation of no till practices
  - Greenhouse gas emissions can be reduced by recycling biomass carbon from the field to the tailpipe and back again
  - Savings could be on the order of 80% reduction in CO_2 per mile driven on E85

Ethanol from Corn Stover is a "Renewable" Choice



Making Sustainable Choices

- Our latest life cycle study considered the effects of collecting corn stover on the long term health of soil
- Preliminary findings show that—***when done responsibly***—residue collection can offset petroleum fossil CO_2, reduce our dependence on petroleum and still allow carbon sequestration in soils