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Biofuel Life-Cycle Results And Issues

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Several Life-Cycle Analysis (LCA) Models Are Available to Examine Vehicle/Fuel Systems

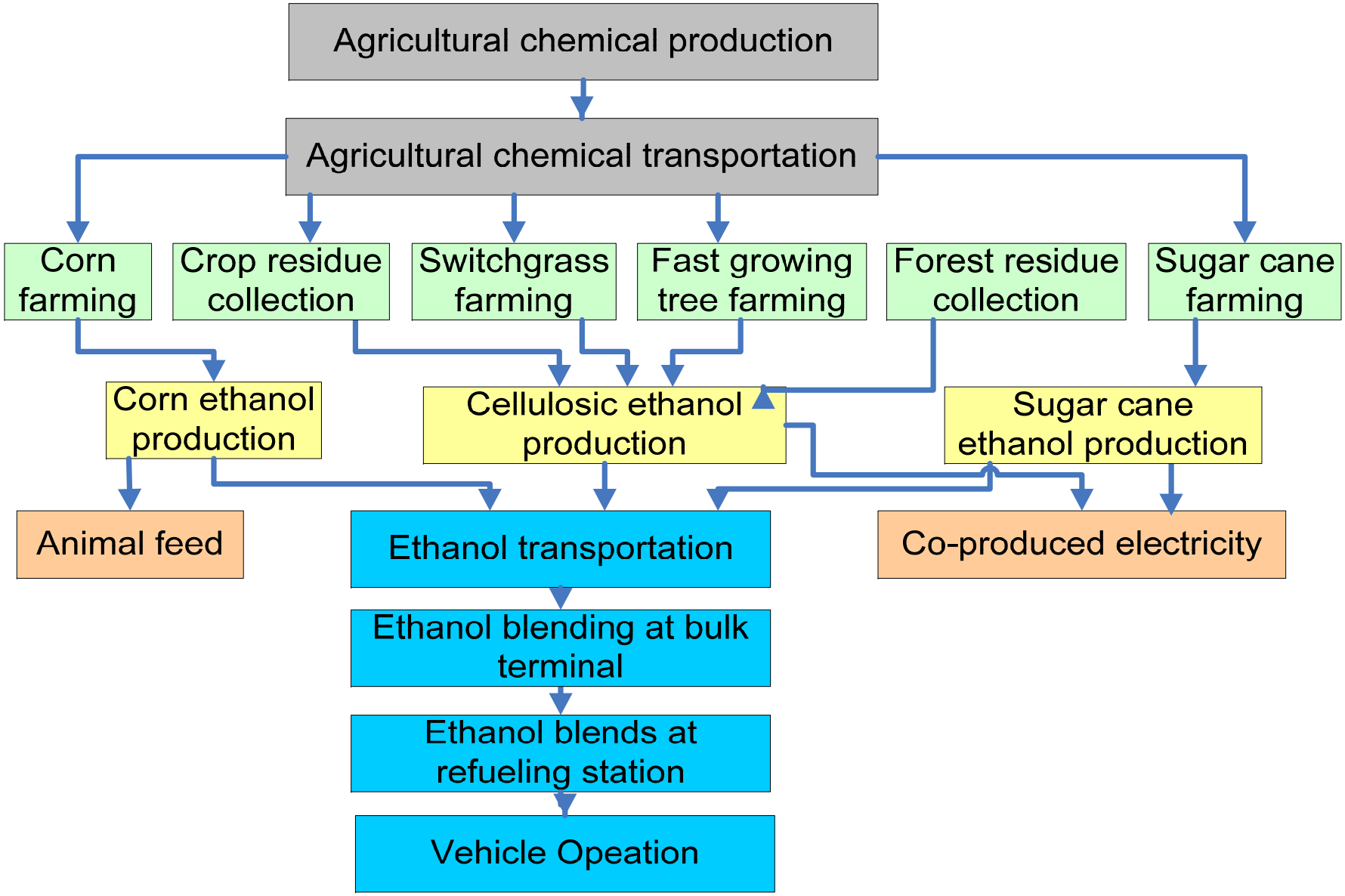
- The lifecycle emission model (LEM) at University of California at Davis
- The GREET model at Argonne National Laboratory
- Canadian GHGenius model (a derivative of the LEM)
- LBST's E3 database in Europe
- The Ecobalance model by PriceWaterhouseCooper in Europe
- Other generic LCA models that can be applied to examine transportation fuels and vehicle technologies

GREET Includes Some of the Potential Biofuel Production Pathways

- Sugar Crops for EtOH
  - **Sugar cane**
  - Sugar beet
  - Sweet sorghum
- Starch Crops for EtOH
  - **Corn**
  - Wheat
  - Cassava
  - Sweet potato
- Butanol Production
  - **Corn**
  - Sugar beet
- Cellulosic Biomass via Gasification
  - **Fitscher-Tropsch diesel**
  - **Hydrogen**
  - Methanol
- Oils for Biodiesel/Renewable Diesel
  - **Soybeans**
  - Rapeseed
  - Palm oil
  - Jatropha
  - Waste cooking oil
  - Animal fat
- Cellulosic Biomass for EtOH
  - **Corn stover**, rice straw, wheat straw
  - **Forest wood residue**
  - Municipal solid waste
  - **Energy crops**
  - Black liquor

The feedstocks that are underlined are already included in the GREET model.

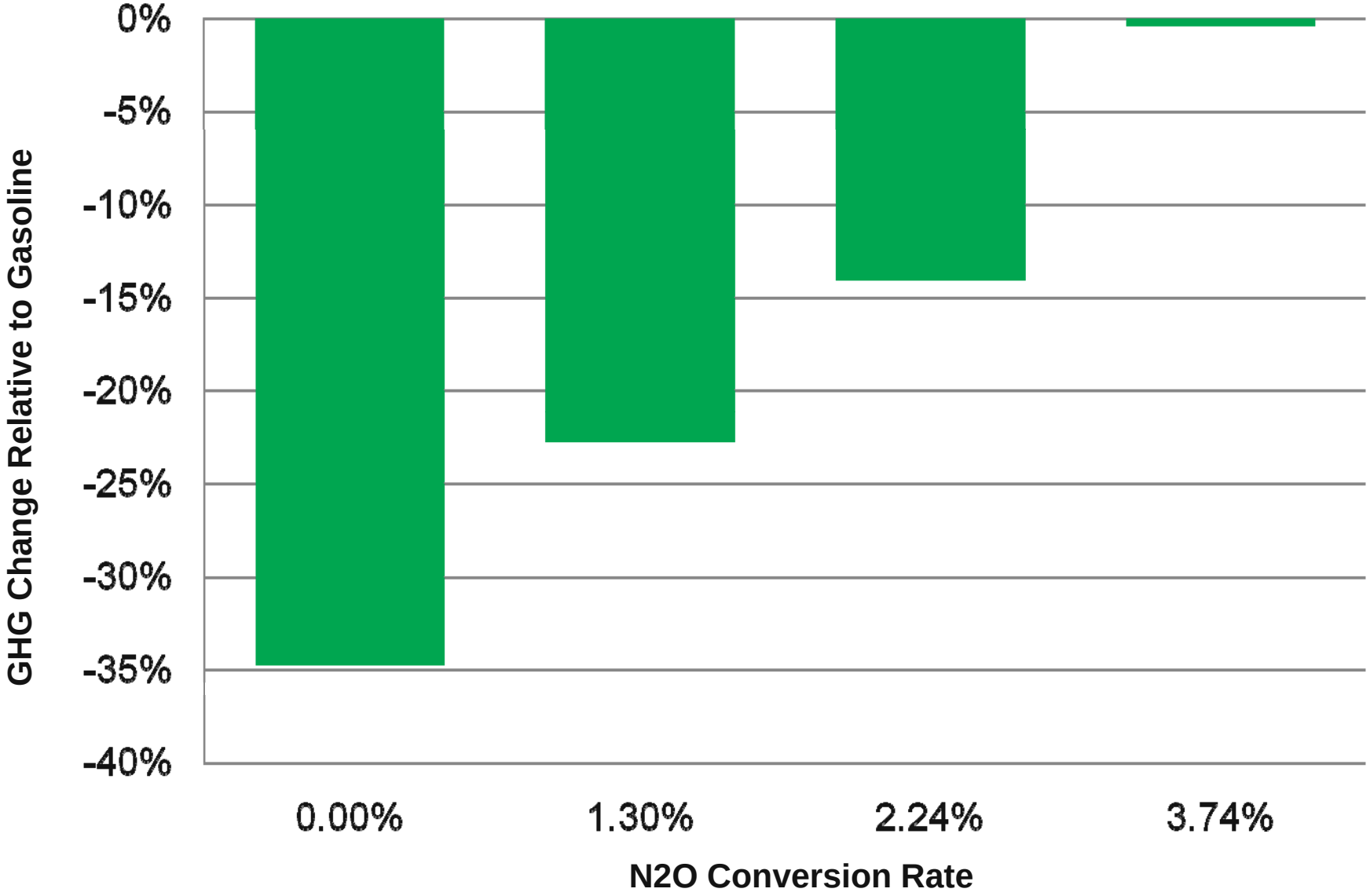
GREET Ethanol Life-Cycle Analysis Includes Activities from Fertilizer to Ethanol at Refueling Stations



Key Issues Affecting Biofuel WTW Results

- Nitrogen fertilizer plants
  - Energy use
  - Natural gas vs. coal as feedstock
- Farming
  - Crop and biomass yields
  - Energy and chemical inputs
- Energy use in biofuel plants
  - The amount of process fuels
  - The type of process fuels
- Credits of co-products of biofuels
  - Distillers grains and solubles for corn ethanol: 0-50%
  - Electricity for cellulosic and sugarcane ethanol
  - Soy meals and glycerin for biodiesel
  - Acetone for butanol
- N2O conversion factors of nitrogen fertilizer
  - IPCC: 1.325% (GREET adopts it; equivalent to 1.77% of Crutzen factor)
  - Crutzen et al.: 3-5% (equivalent to 2.24-3.74% of IPCC factor)
  - Background vs. N fertilizer-induced N2O emissions in fields
- Land use changes and resulted CO2 and CH4 emissions
- Some of the issues are affected heavily by the scale of biofuel production

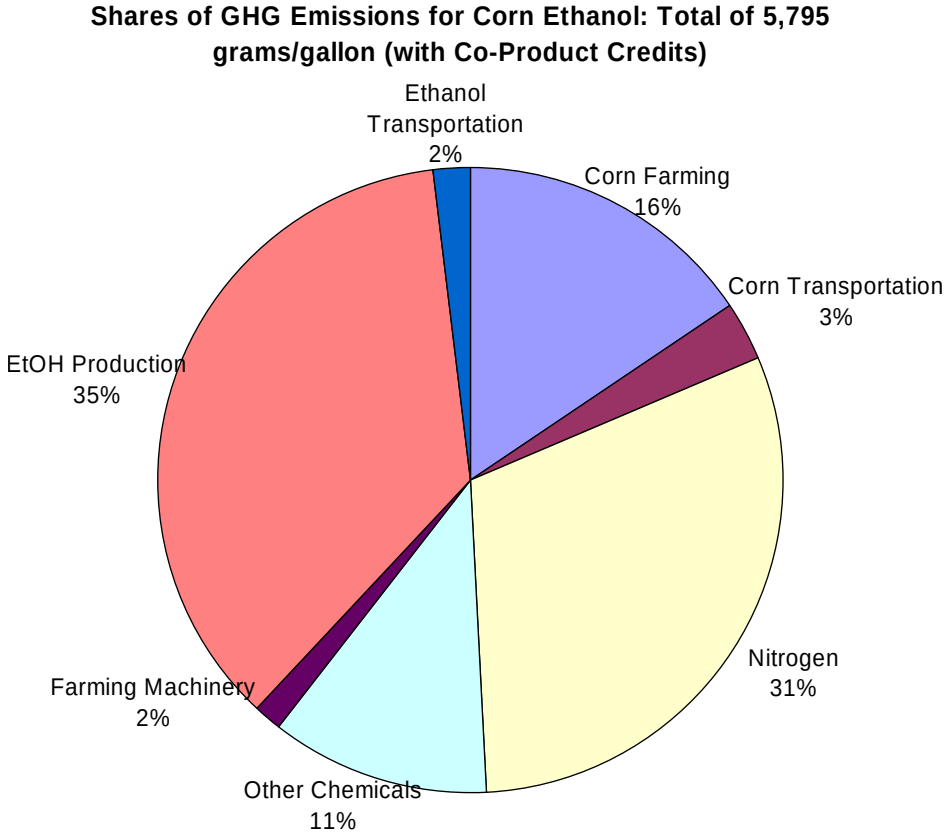
N2O Conversion Factors Can Affect Corn-Based Ethanol GHG Changes Significantly

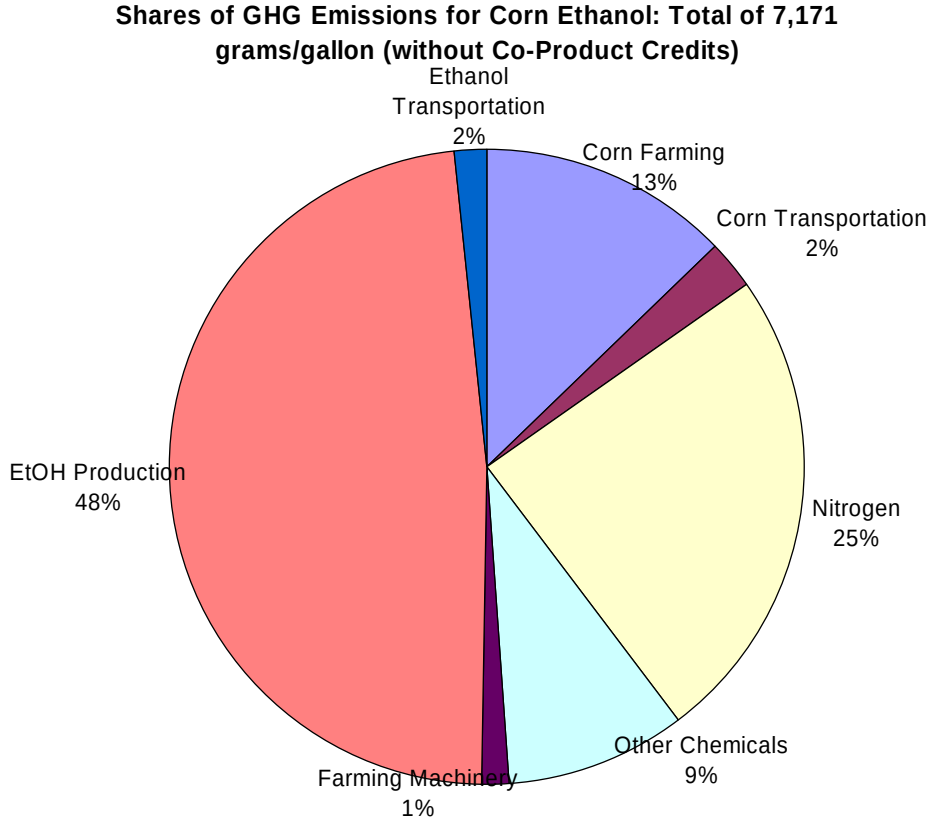


GHG Emission Implications of Potential Land Use Change by Large-Scale Biofuel Production Needs to Be Examined

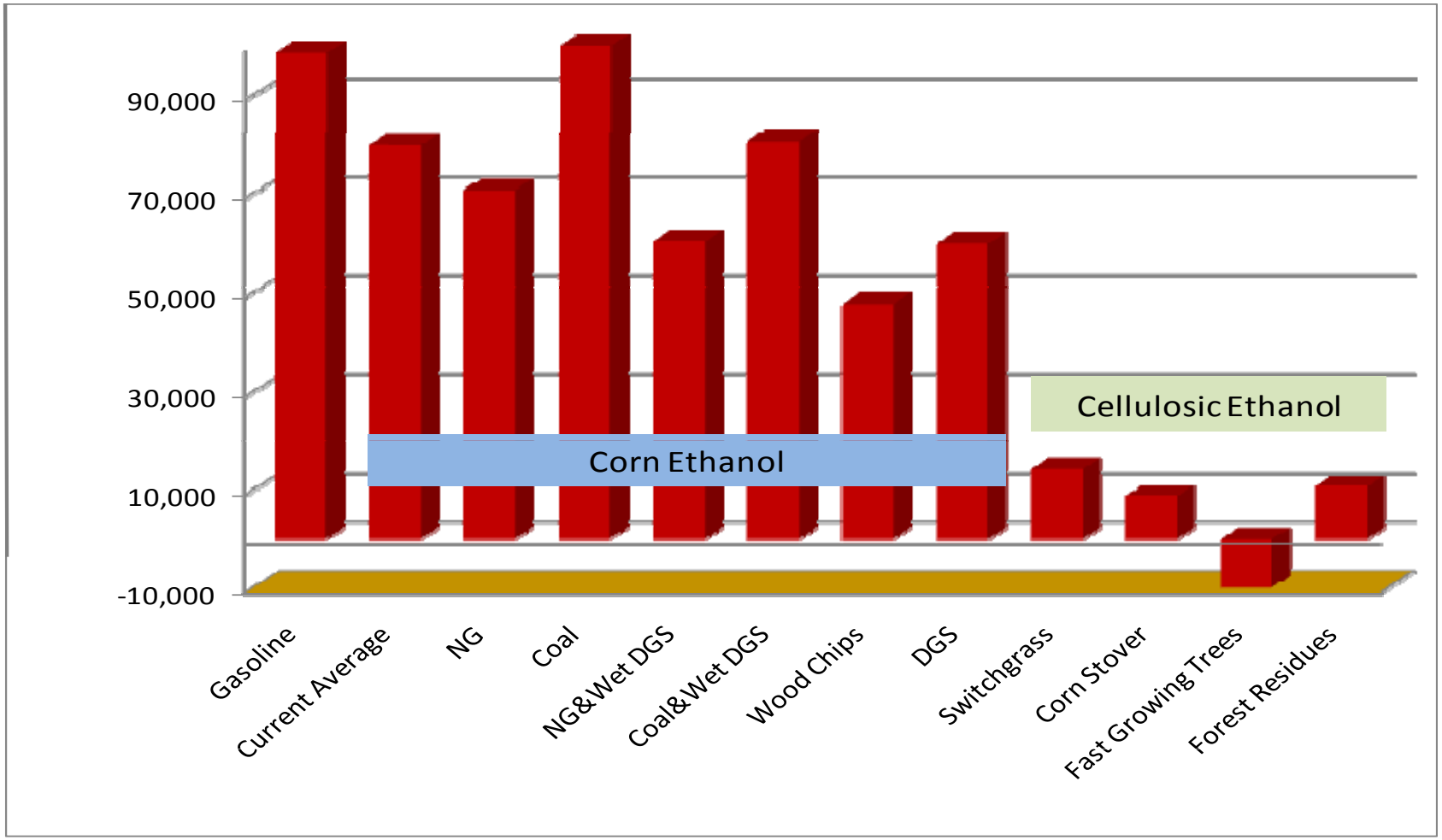
- Potential land use changes
  - Direct land use change: regional or national scale
  - Indirect land use change: global scale
  - Both can be simulated with global general equilibrium models
  - How fine is the resolution of global GE models?
- Carbon profiles of major land types
  - Models in the U.S. and Europe are available
  - Carbon profiles of land types in other parts of the world (South America, Asia, Africa) are less understood
- Time horizon of biofuel programs; “for ever biofuels” can mathematically result in zero GHG emission changes from land use changes
- There are no reliable simulation results; some new efforts in this area started only very recently

Fuel-Cycle GHG Emission Shares for Corn-Based Ethanol



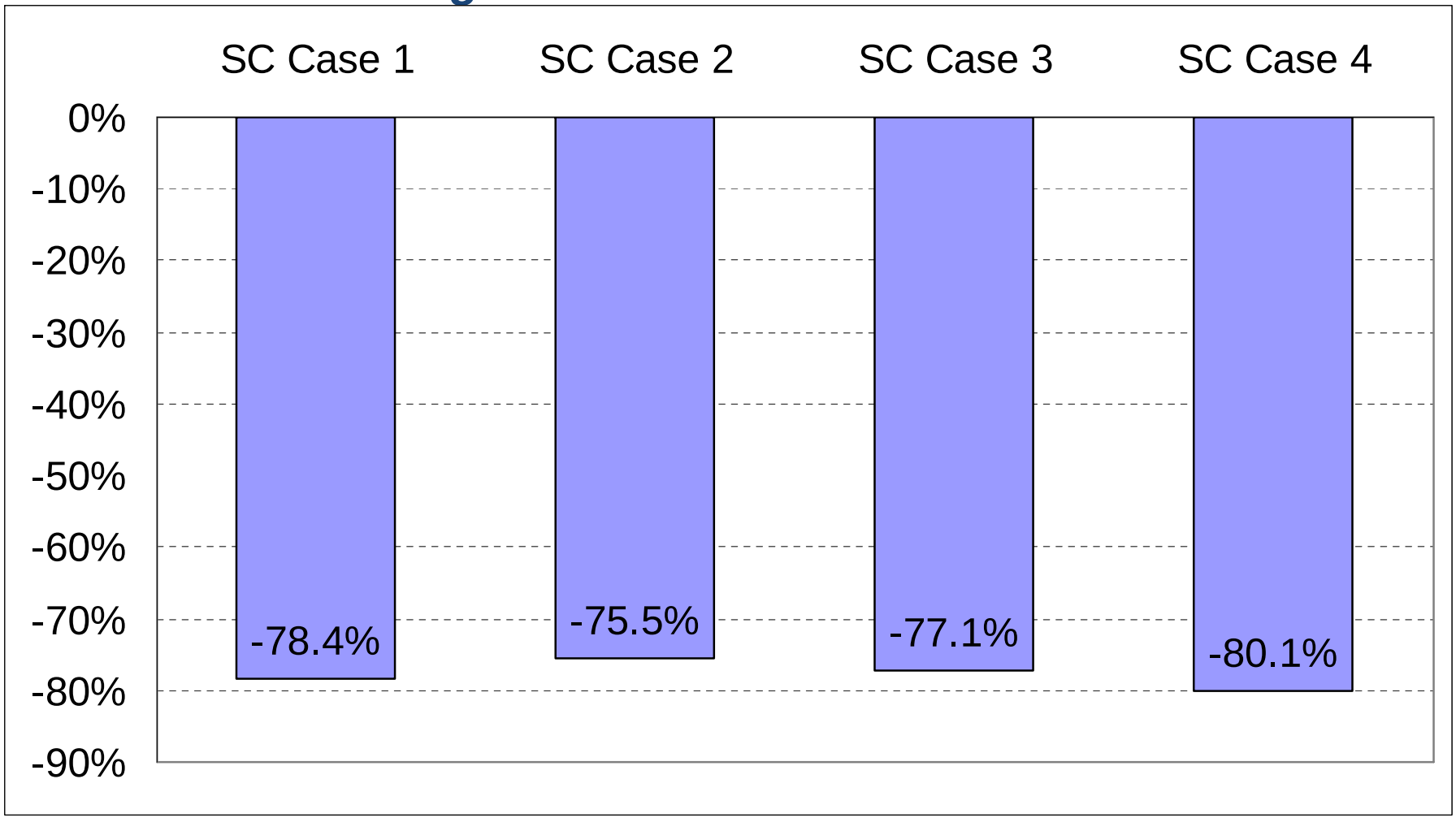


GHG Emissions of Corn Ethanol Vary Considerably Among Process Fuels in Plants



The dimension of different corn farming practices is another aspect that we have not examined

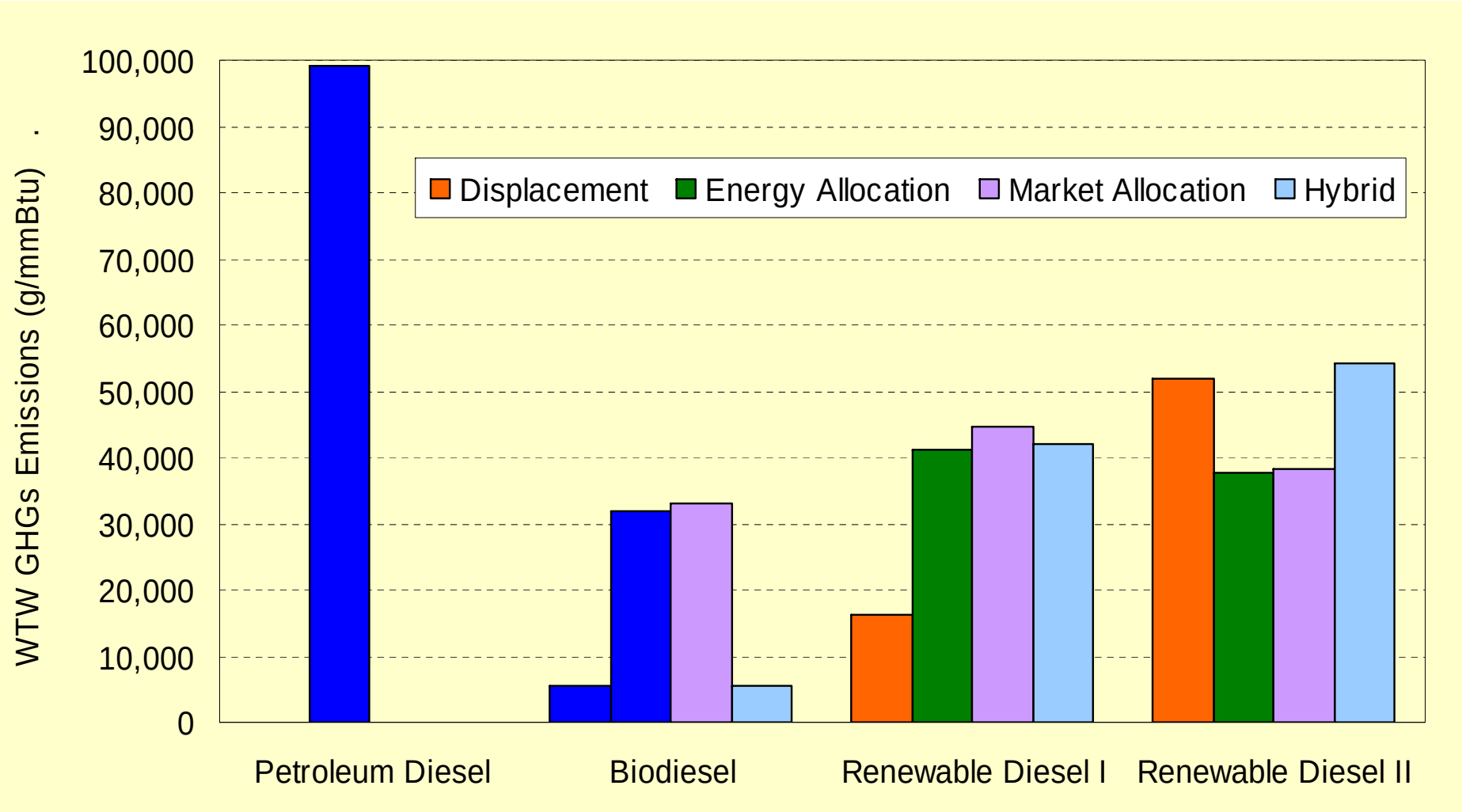
Sugarcane Ethanol Produced in Brazil and Used in the U.S. Results in Large GHG Reductions



Case 1: basecase; Case 2: energy embedded in farming equipment and ethanol plants included; Case 3: energy embedded in farming equipment included; Case 4: production and use in Brazil

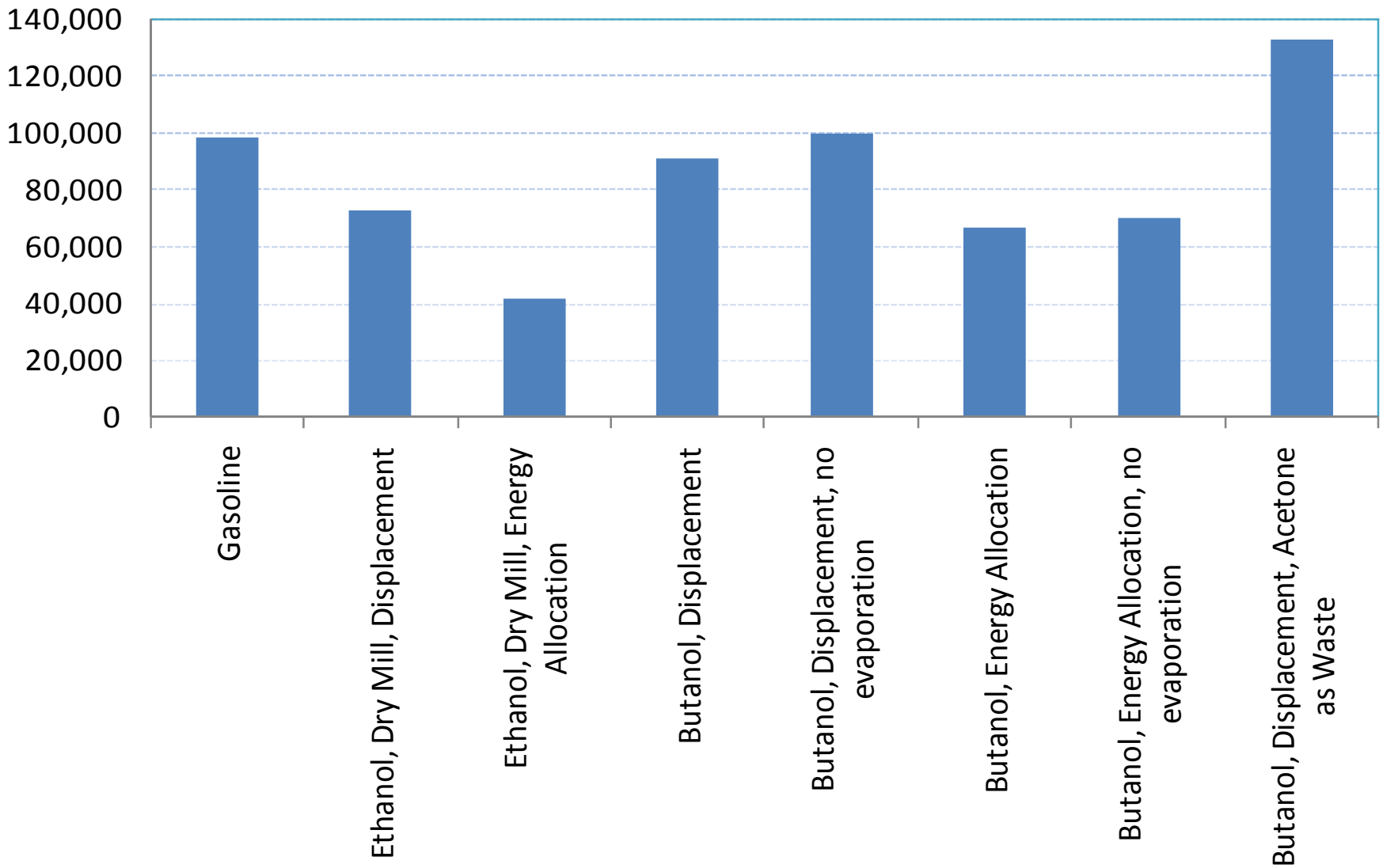
M. Wang, M. Wu, H. Huo, and J. Liu, 2008, Life-Cycle Energy Use and Greenhouse Gas Emission Implications of Brazilian Sugarcane Ethanol Simulated with the GREET Model, forthcoming in International Sugar Journal.

Ways of Dealing With Co-Products Affect GHG Results of Soybean-Based Biodiesel and Renewable Diesel



H. Huo, M. Wang, C. Bloyd, V. Putsche, 2007, Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels, Argonne National Laboratory (draft under peer review).

Corn-Based Butanol Results Show Importance of Methodologies for Co-Products: GHG Emissions in g/mmBtu



M. Wu, M. Wang, J. Liu and H. Huo, 2007, Life-Cycle Assessment of Corn-Based Butanol as a Potential Transportation Fuel, Argonne National Laboratory

Decisions Are Constantly Being Made in A World with Unknowns As Well As Knowns

"…as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - the ones we don't know we don't know."

Former U.S. Defense Secretary Donald Rumsfeld

- I have presented what we may understand as of now
- Mark Delucchi of University of California at Davis has been emphasizing the importance of the unknowns, especially regarding land use changes
- Life-Cycle Analysis could be more helpful the policy making process by separating issues into:
  - > Those which are inherent to given technologies
  - > Those which can be contained by policies

Other Aspects of Biofuels Related to Sustainability Debates

- Water issues of transportation fuel production
  - Consumptive water requirements: Argonne recently began to address these for biofuels and petroleum fuels
  - Waste water discharge and water quality issues
- Criteria air pollution problems
- Other ecological issues
  - Soil erosion and quality impacts
  - Biodiversity