



# **An Update of Energy and Greenhouse Emission Impacts of Fuel Ethanol**

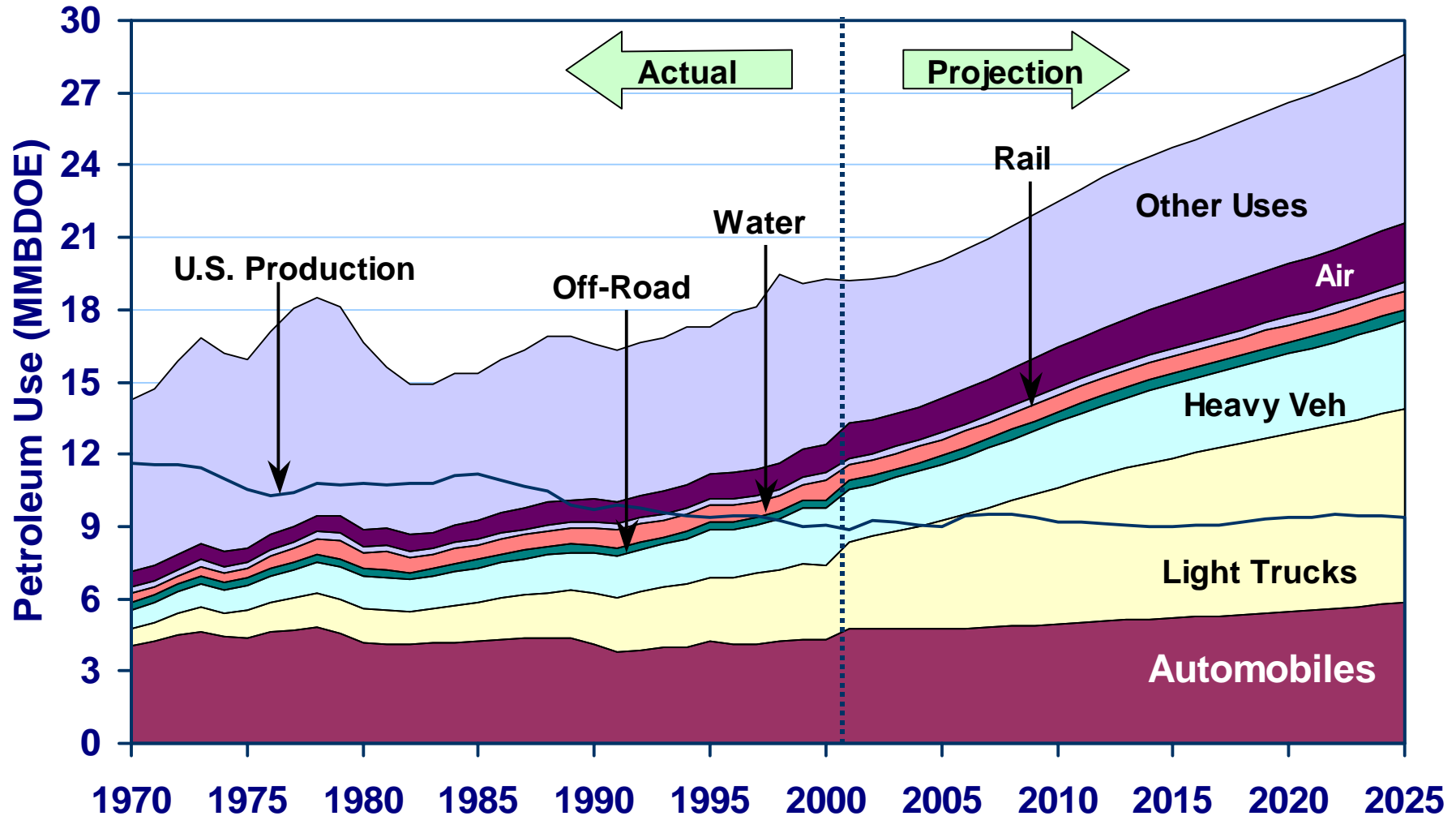
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**Center for Transportation Research**  
**Argonne National Laboratory**

**The 10<sup>th</sup> Annual National Ethanol Conference**  
**Scottsdale, AZ, Feb. 8, 2005**

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# U.S. Now Consumes about 19 Million B/D of Oil, Transportation Accounts for ~75%

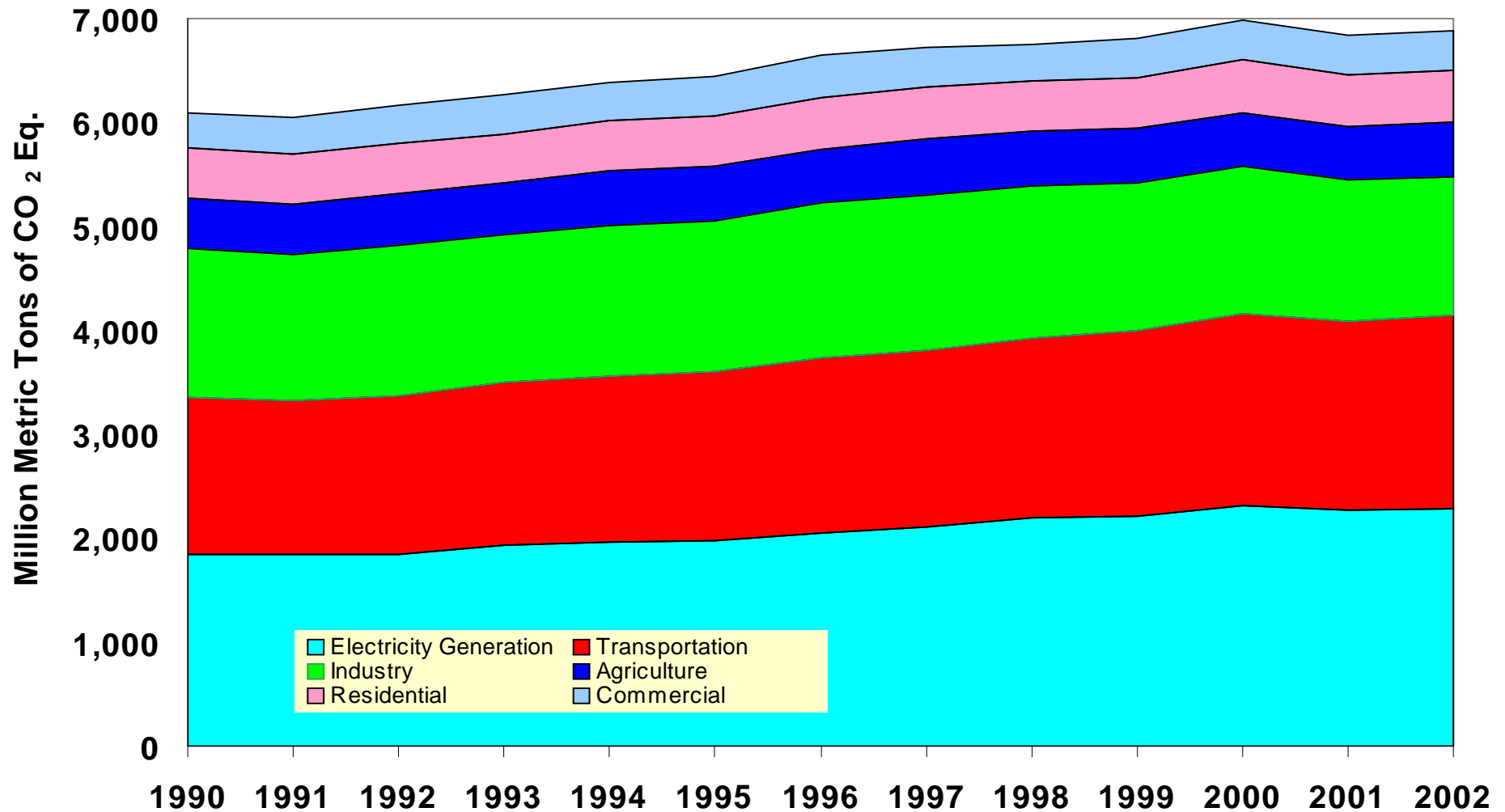


Data sources: ORNL (2003), the Transportation Energy Databook; EIA (2003), Annual Energy Outlook; Annual Energy Review





# The Transportation Sector is the Second Largest U.S. GHG Emitting Source



EPA (2004), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002

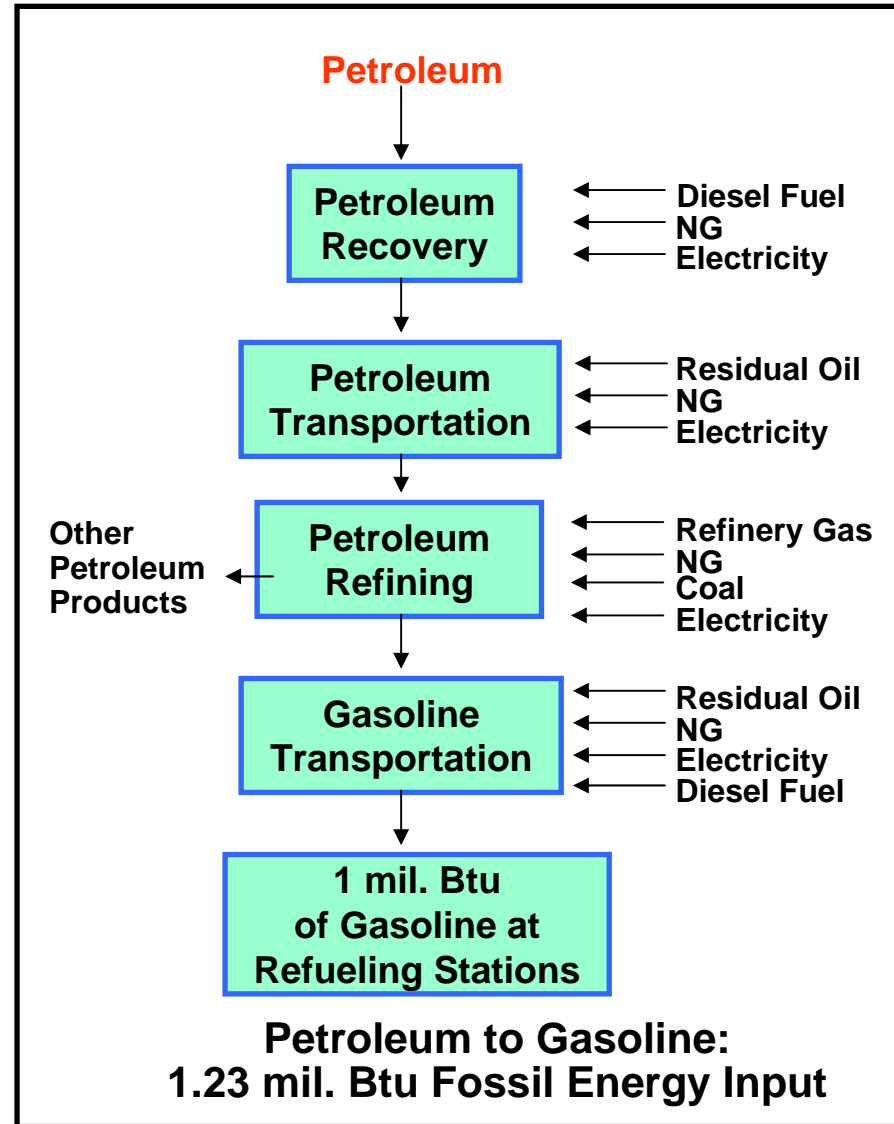
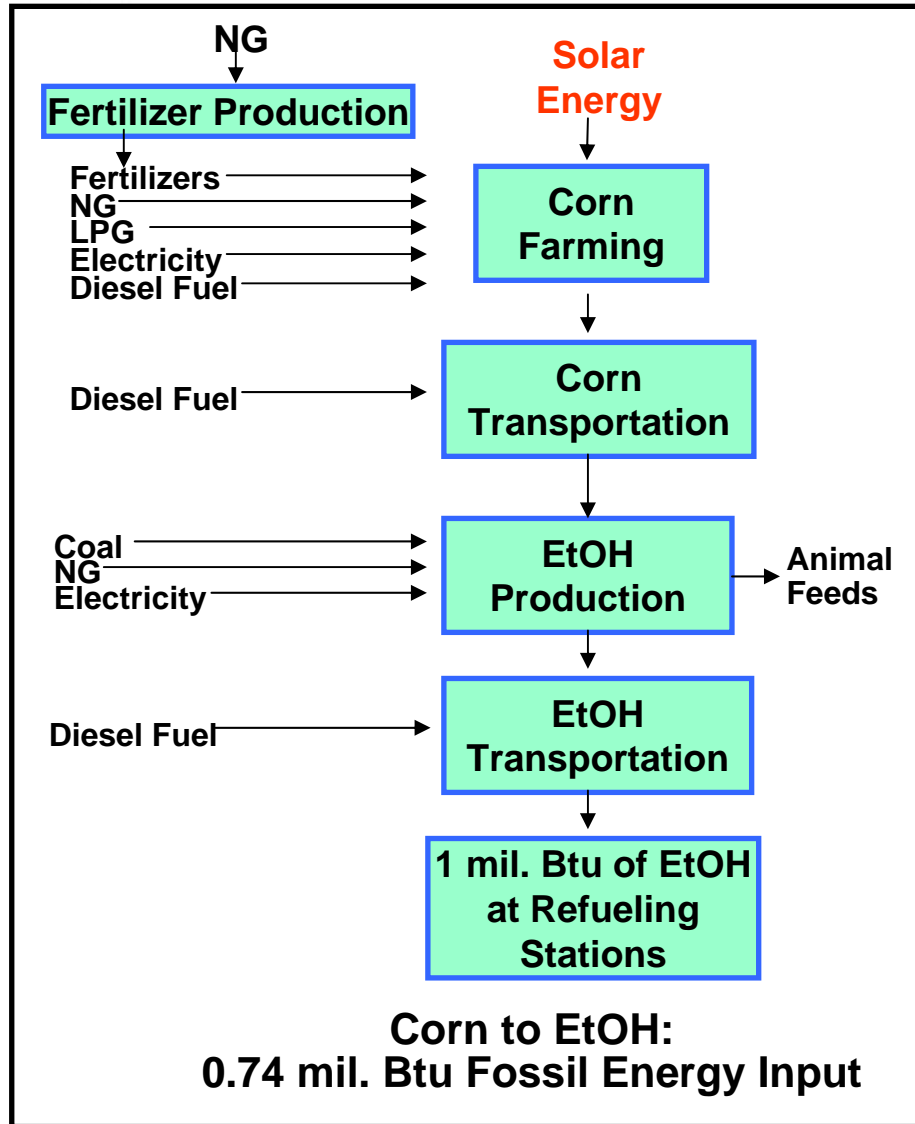




# Energy Effects of Fuel Ethanol Have Been Subject to Debate

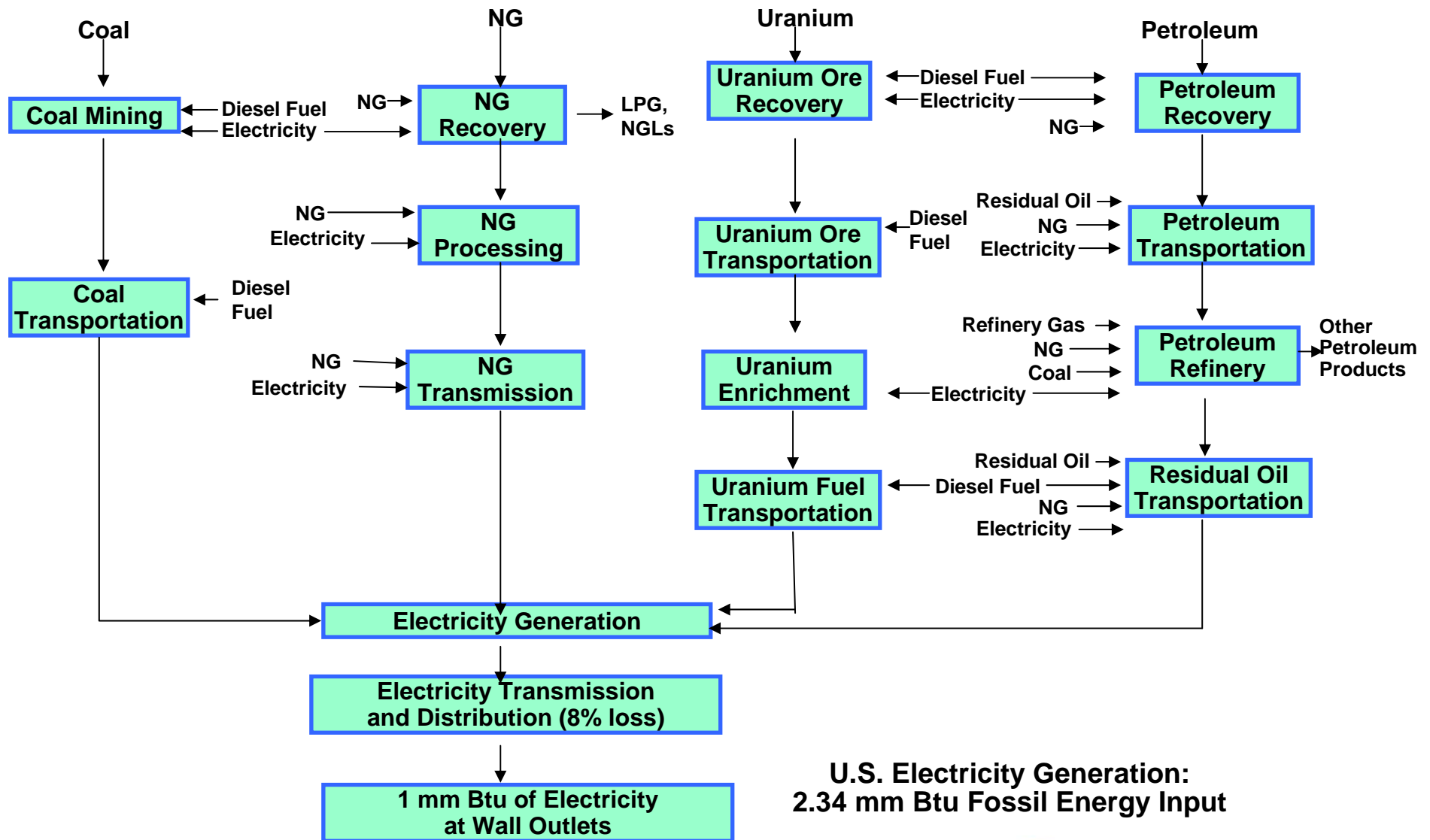
- ❑ Many studies basically examined energy use of producing ethanol
- ❑ Though self evaluation of ethanol's energy balance is easy to understand, it may not be useful to fully understand true energy benefits of fuel ethanol
- ❑ A more complete way is to compare fuel ethanol with the fuels to be displaced by ethanol (i.e., gasoline)
- ❑ GHG emissions were simply ignored in some debatable studies
- ❑ Argonne has been conducting WTW comparative analyses of transportation fuels with the GREET model
- ❑ This presentation covers comparative results between ethanol and gasoline

# Comparative Results Between Ethanol and Gasoline Are More Relevant to Policy Debate





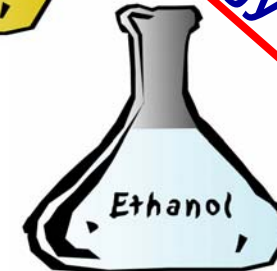
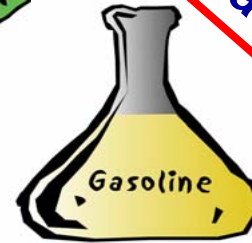
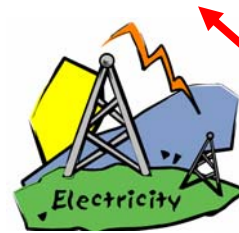
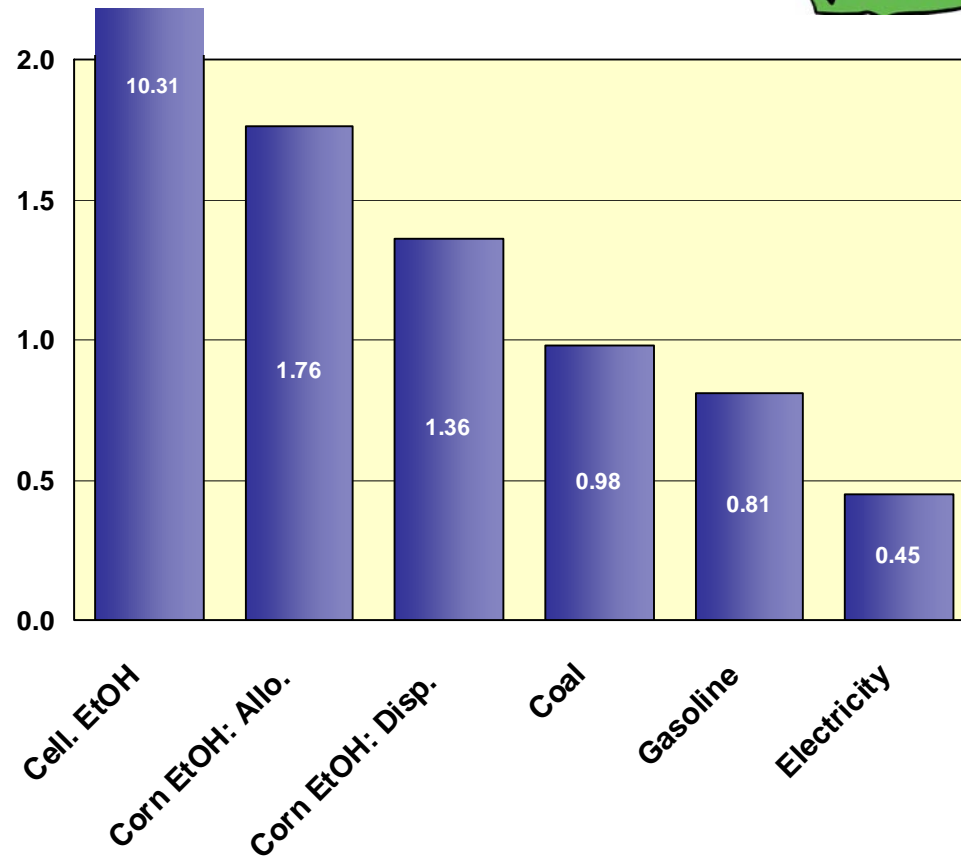
# Though Electricity Requires a Large Amount of Fossil Energy Input, There Is No Substitute



U.S. Electricity Generation:  
2.34 mm Btu Fossil Energy Input

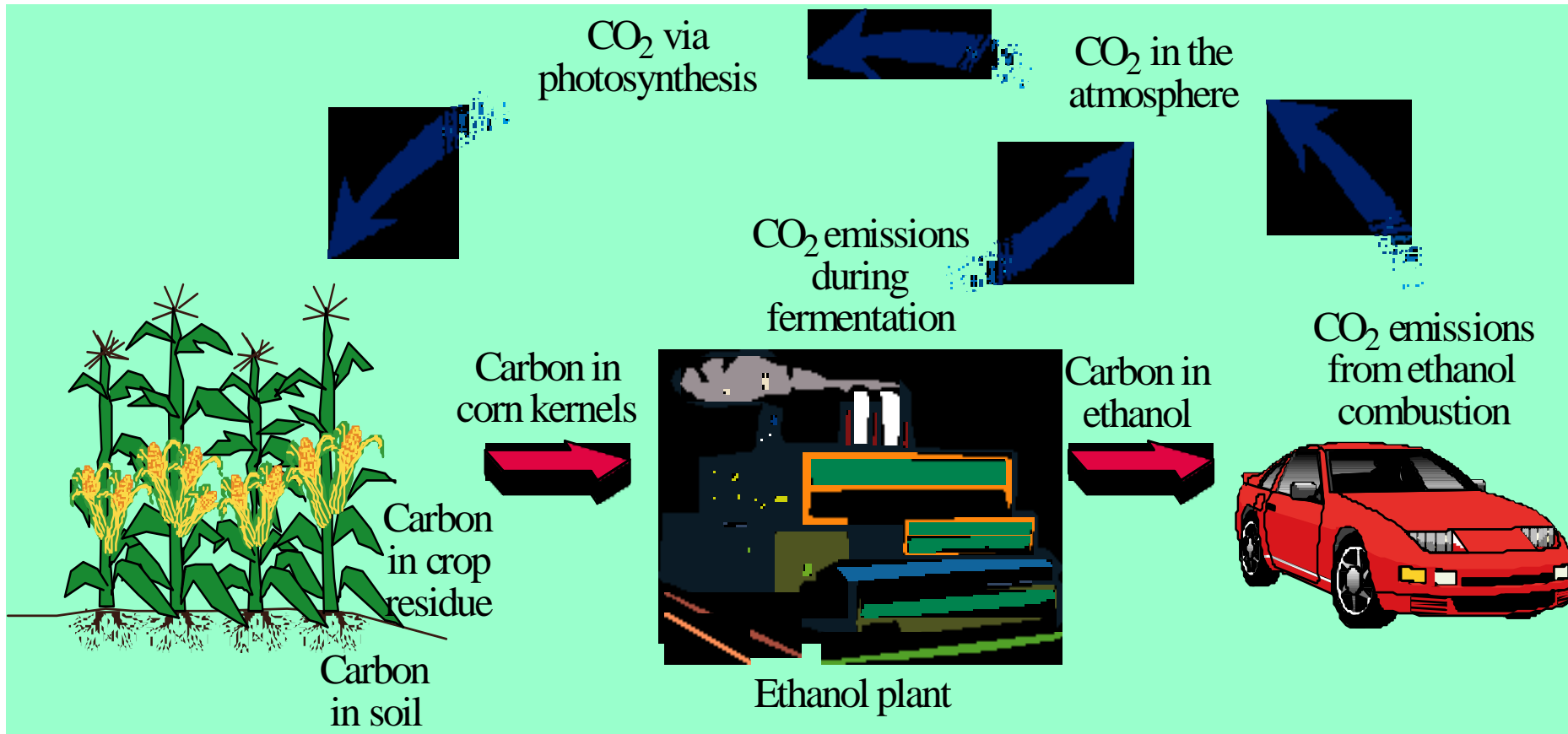
# Energy in Different Fuels Can Have Very Different Qualities

**Fossil Energy Ratio (FER) =**  
energy in fuel/fossil energy input



Increase in Energy Quality

# Recycling of Carbon by Ethanol Results in CO<sub>2</sub> Benefits for It



Carbon capture in ethanol plants for beverage use is not considered in ANL analysis. Additional GHG benefits could be achieved by considering carbon capture.



# Key Parameters for Ethanol's Energy and Emission Effects

## □ Energy use for chemicals production

- Fertilizers (N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O)
- Herbicides
- Insecticides

## □ Farming

- Corn and biomass yield
- Chemicals use intensity
- Energy use intensity
- Soil N<sub>2</sub>O and NO<sub>x</sub> emissions
- Soil CO<sub>2</sub> emissions or sequestration

## □ Ethanol production

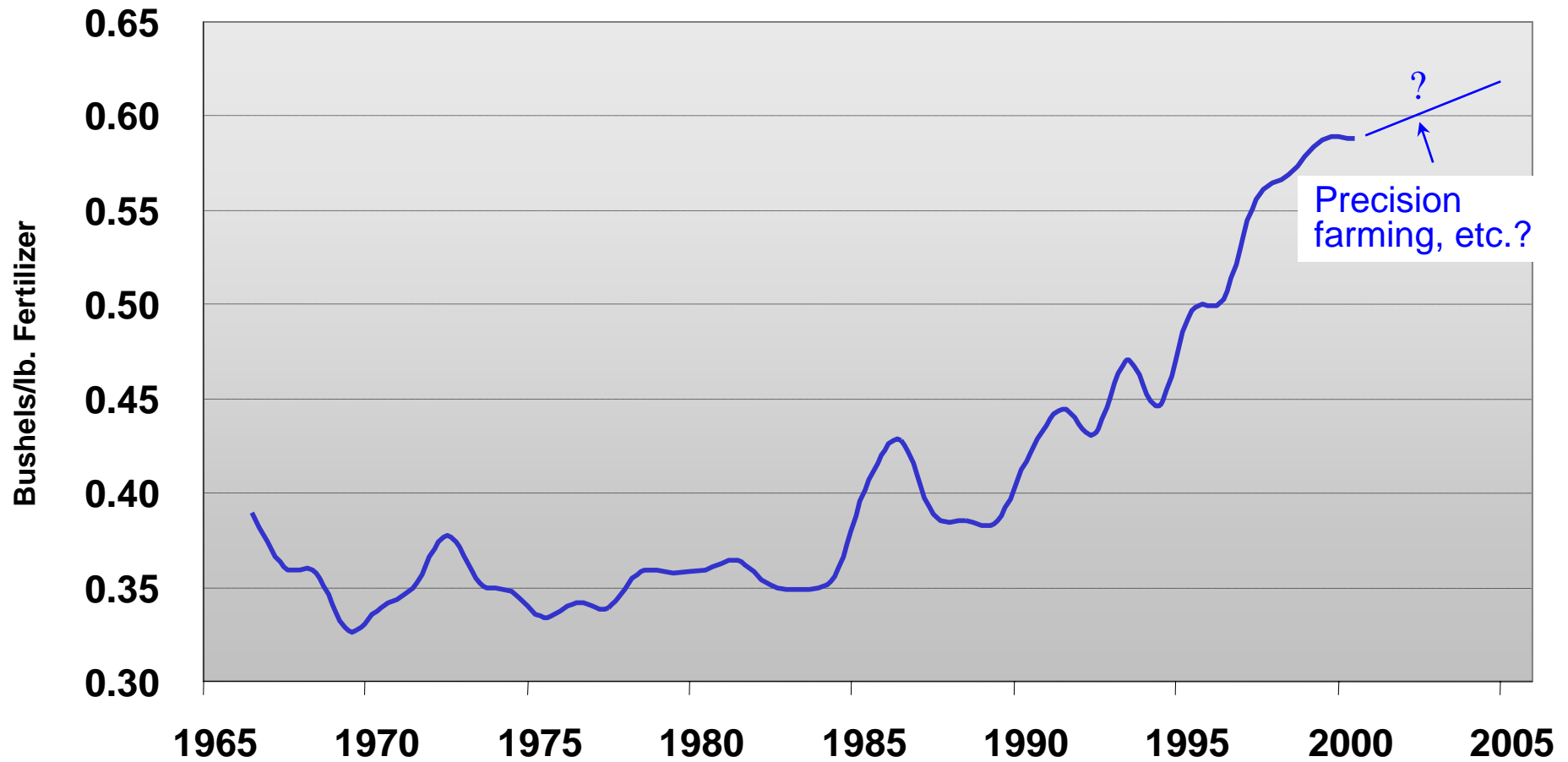
- Corn ethanol: wet vs. dry milling
- Ethanol yield
- Energy use intensity
- Co-product types and yields

## □ Vehicle fuel economy

- Gasoline vehicles with E10
- Flexible-fuel vehicles with E85



# U.S. Corn Output Per Pound of Fertilizer Used Has Risen (3-yr Moving Average)



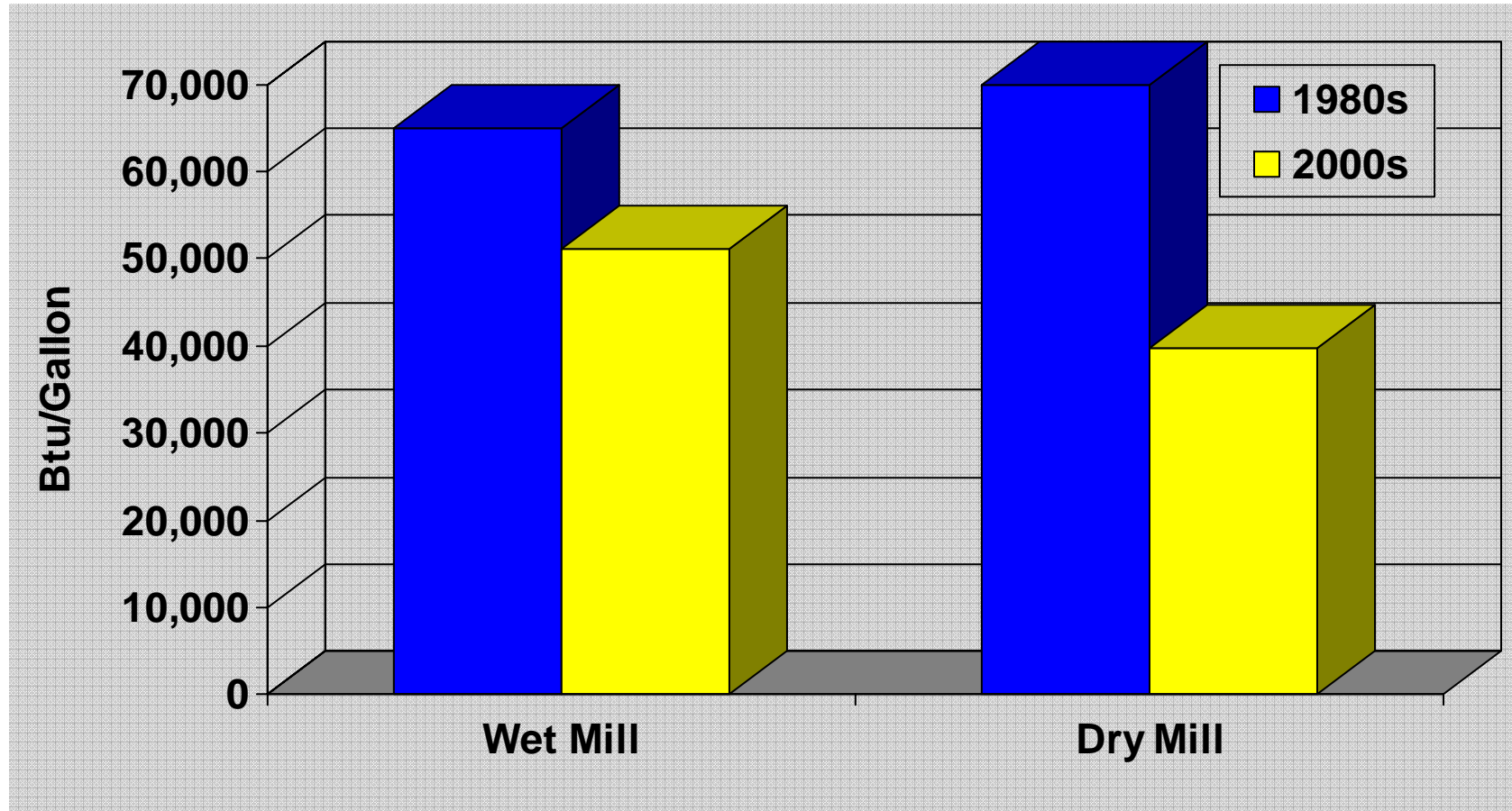
Source: from USDA data.



## N<sub>2</sub>O and NO<sub>x</sub> Emissions from Nitrogen Fertilizer Are a Major Emission Source

- ❑ Argonne's analysis shows that depending on soil type and condition, 1-3% of N in nitrogen fertilizer is converted into N in N<sub>2</sub>O
- ❑ On the well-to-wheels basis, N<sub>2</sub>O emissions from that conversion could account for up to 25% of total GHG emissions from corn ethanol
- ❑ For economic reasons, N fertilizer use per bushel of corn has reduced in the U.S.; this has positive side effects on reducing environmental pollution and GHG emissions

# Technology Has Reduced Energy Use Intensity of Ethanol Plants



Source: from Argonne's discussions with ethanol plant designers and recent USDA data.



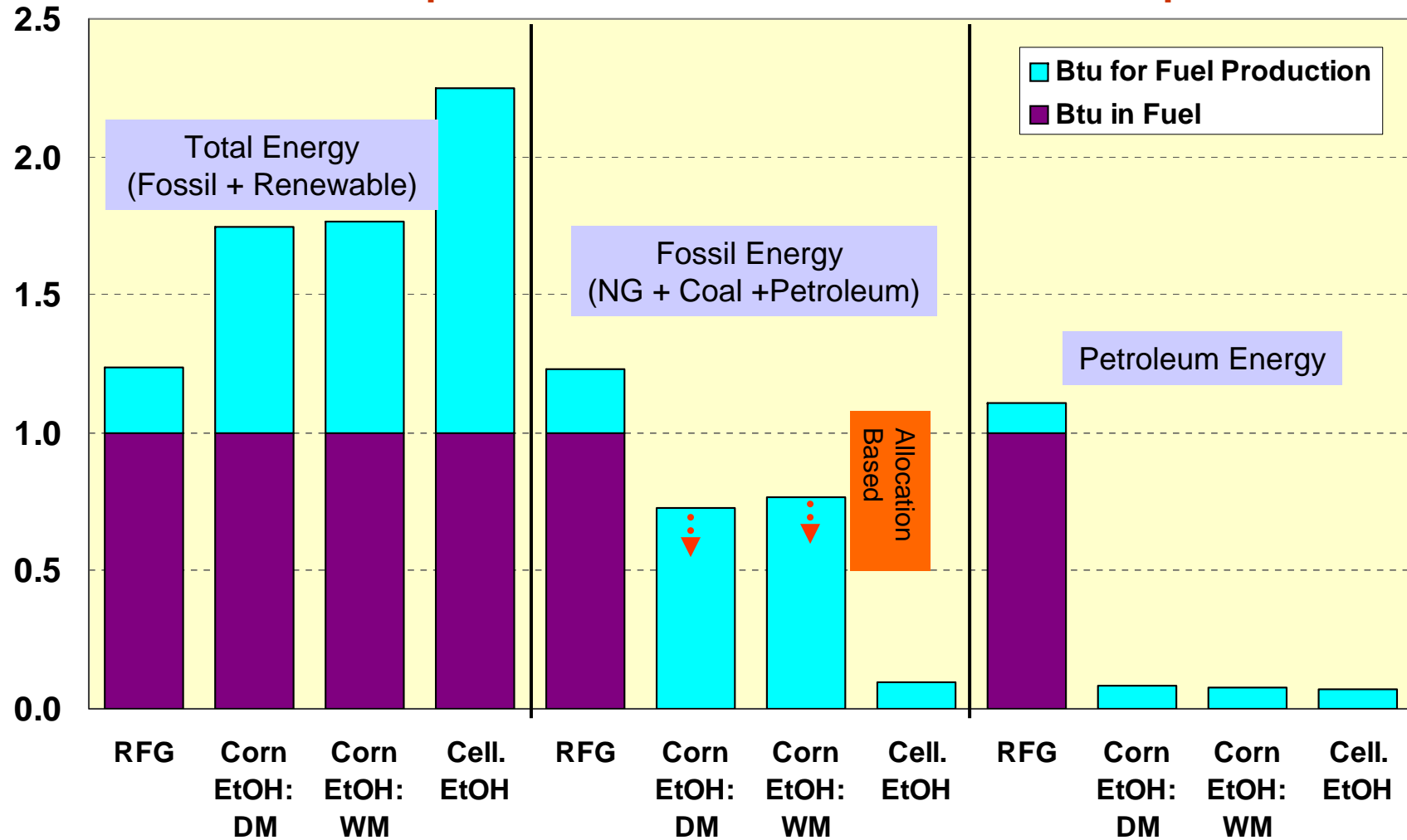
## Allocation Method of Co-Products Is a Critical Factor in Determining Ethanol's Energy and Emission Results

Allocation Method	Wet milling	Dry milling
Weight	52%	51%
Energy content	43%	39%
Process energy	36%	41%
Market value	30%	24%
Displacement	~16%	~20%

- Weight and energy methods no longer used
- Some studies did not consider co-products at all
- Process energy allocation values are from USDA 2004

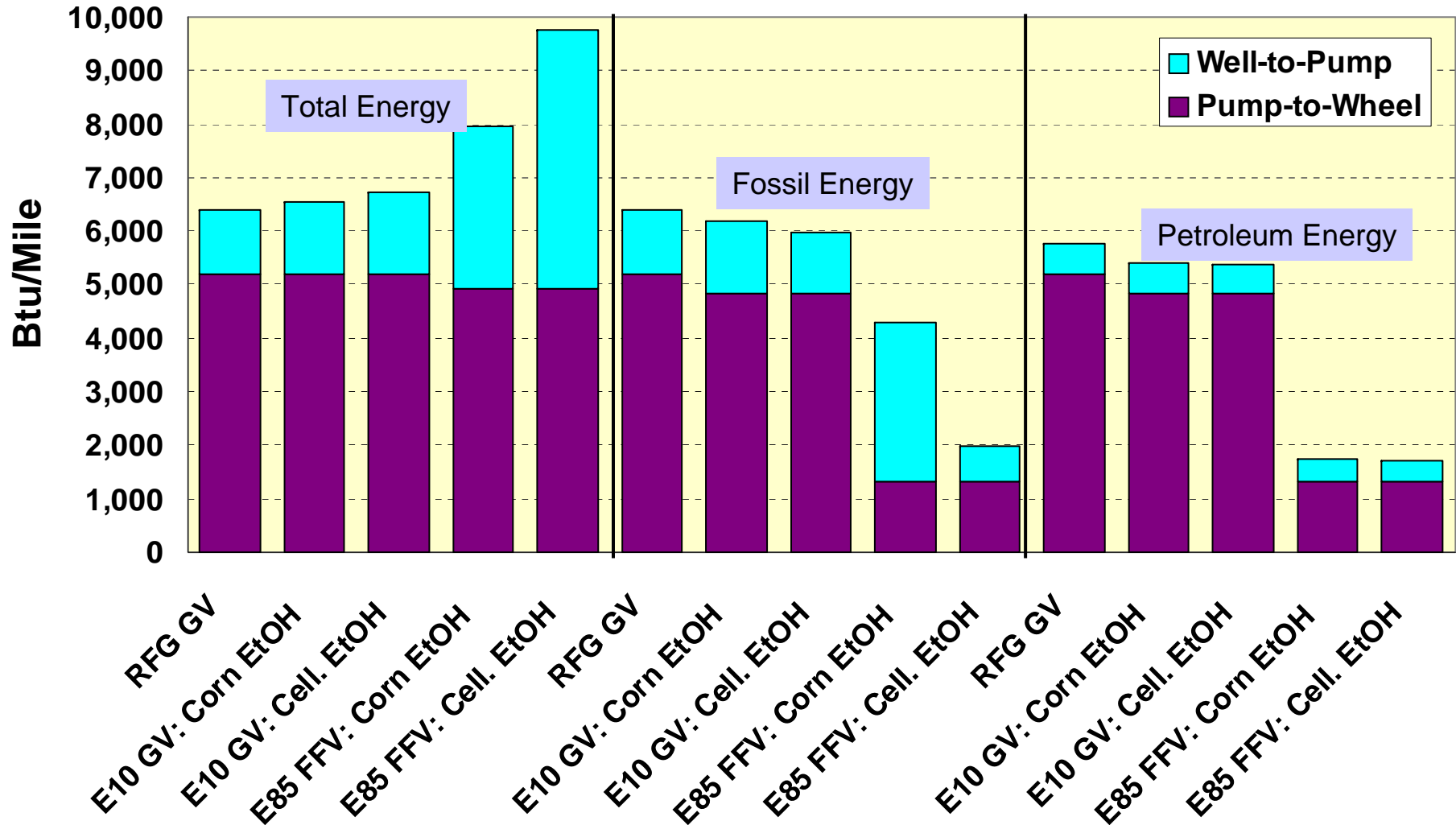
# Energy Benefits of Fuel Ethanol Lie in Reductions in Fossil Energy and Petroleum Use

## Total Btu Spent for One Btu Available at Fuel Pumps

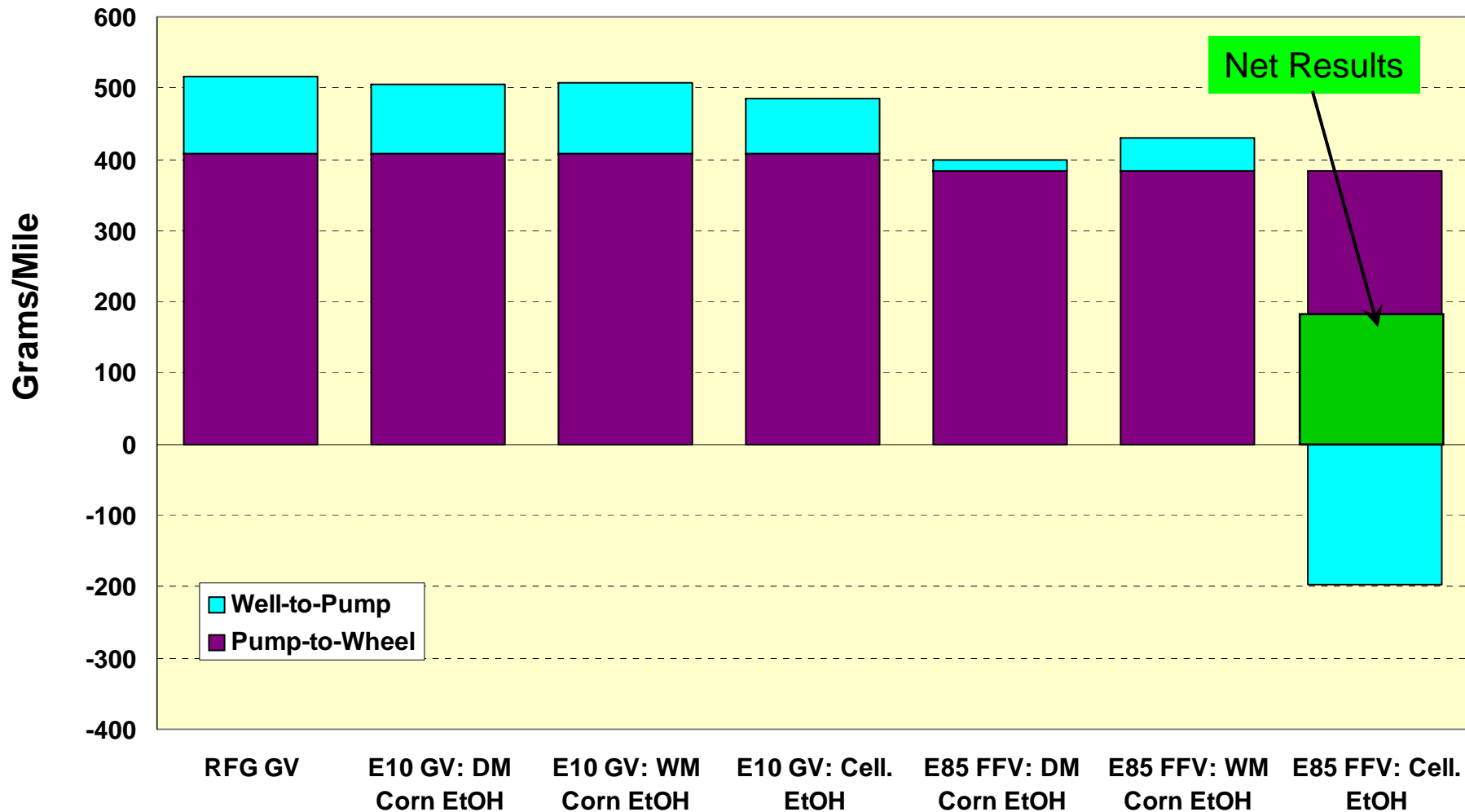




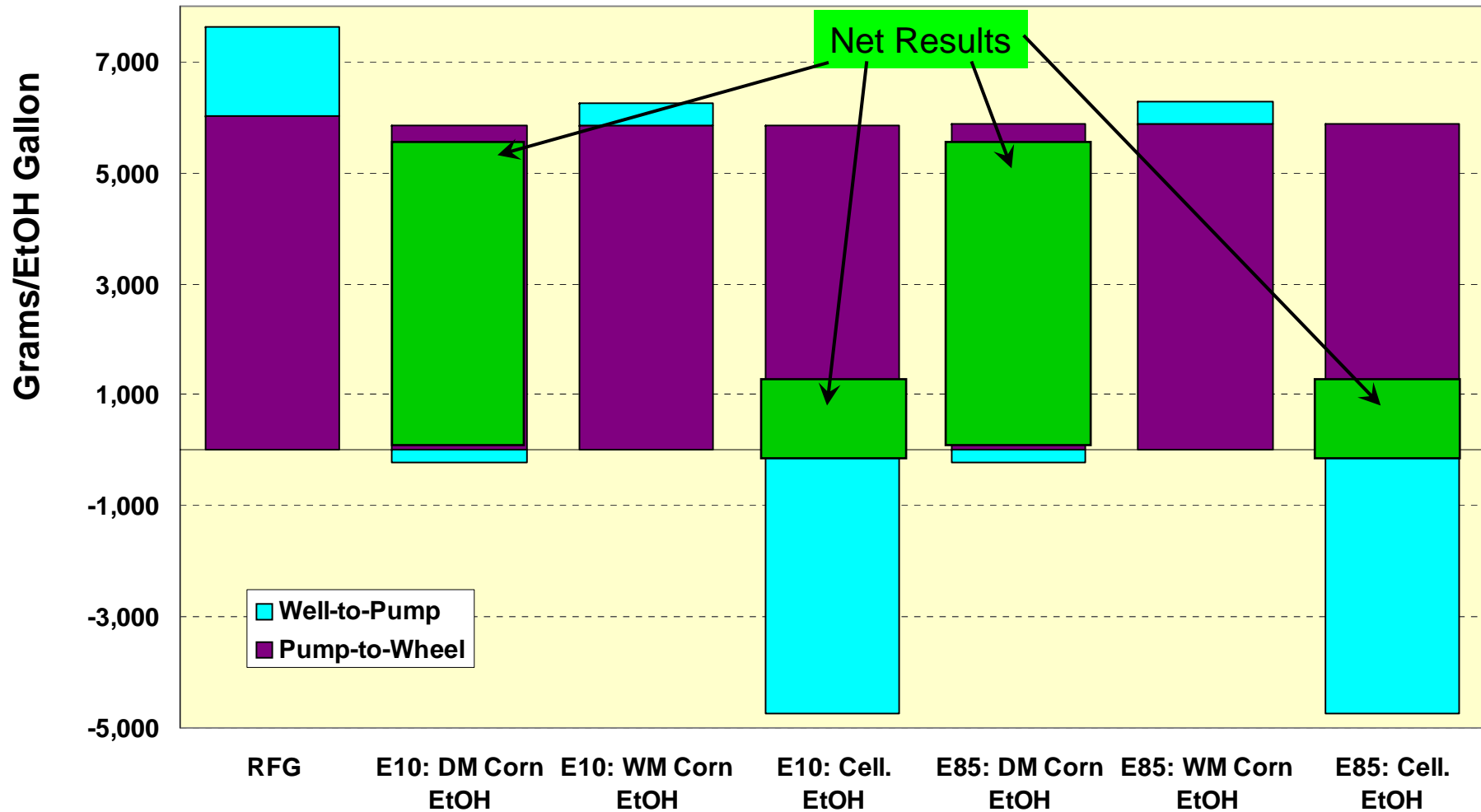
# Use of Ethanol to Replace Gasoline Results in WTW Energy Benefits



# Per-Mile GHG Emission Results Show Larger Benefits of E85 and Cellulosic Ethanol

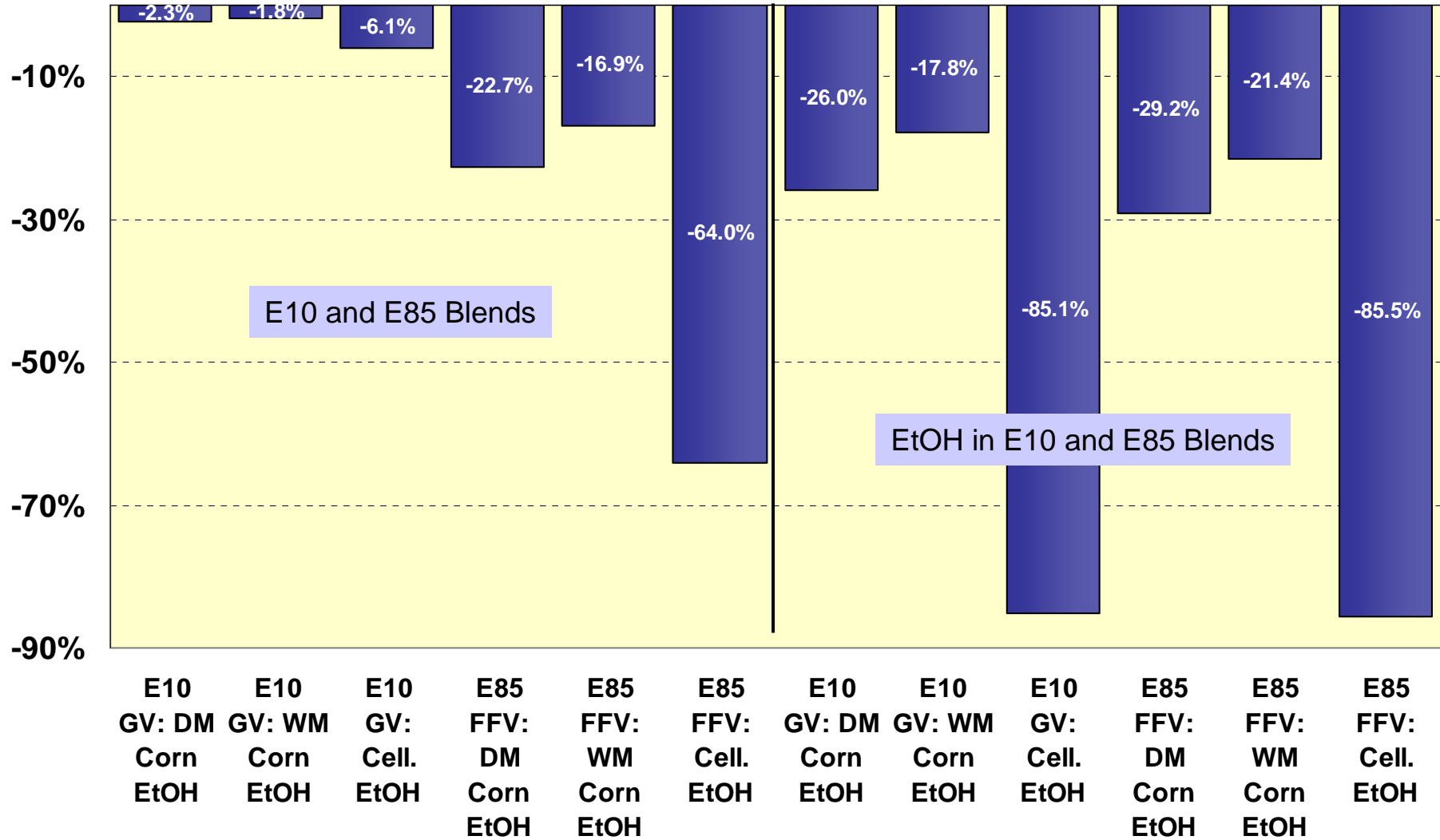


# Grams/EtOH Gal. GHG Emission Results Show E85 Achieves Incremental Benefits Over E10





# Corn EtOH Has 18-29% Reductions in GHGs and Cellulosic EtOH 85% Reductions



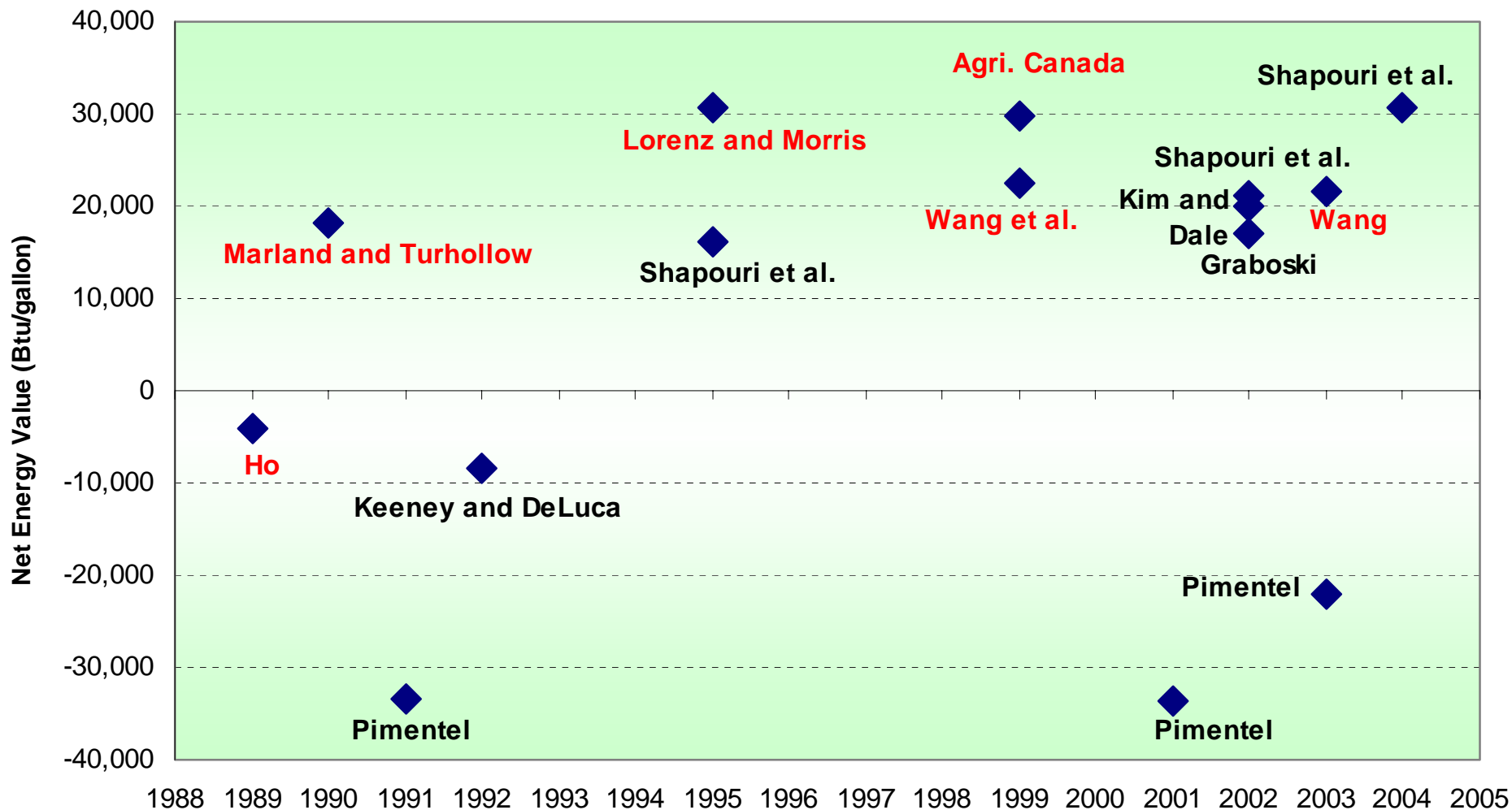


## Use of Process Energy Allocation Method Results in Increased GHG Emission Reductions by Corn Ethanol

- For ethanol-gasoline blends
  - E10 reduces per-mile GHG emissions by 3%
  - E85 reduces per-mile GHG emissions by 31%
- For ethanol in blends
  - Ethanol in E10 reduces GHG emissions by 38%
  - Ethanol in E85 reduces GHG emissions by 41%
- Method of dealing with co-products in corn ethanol plants is a key factor; what is the right method to use?
- From our research, Argonne concludes that the displacement method is the most defensible, appropriate method



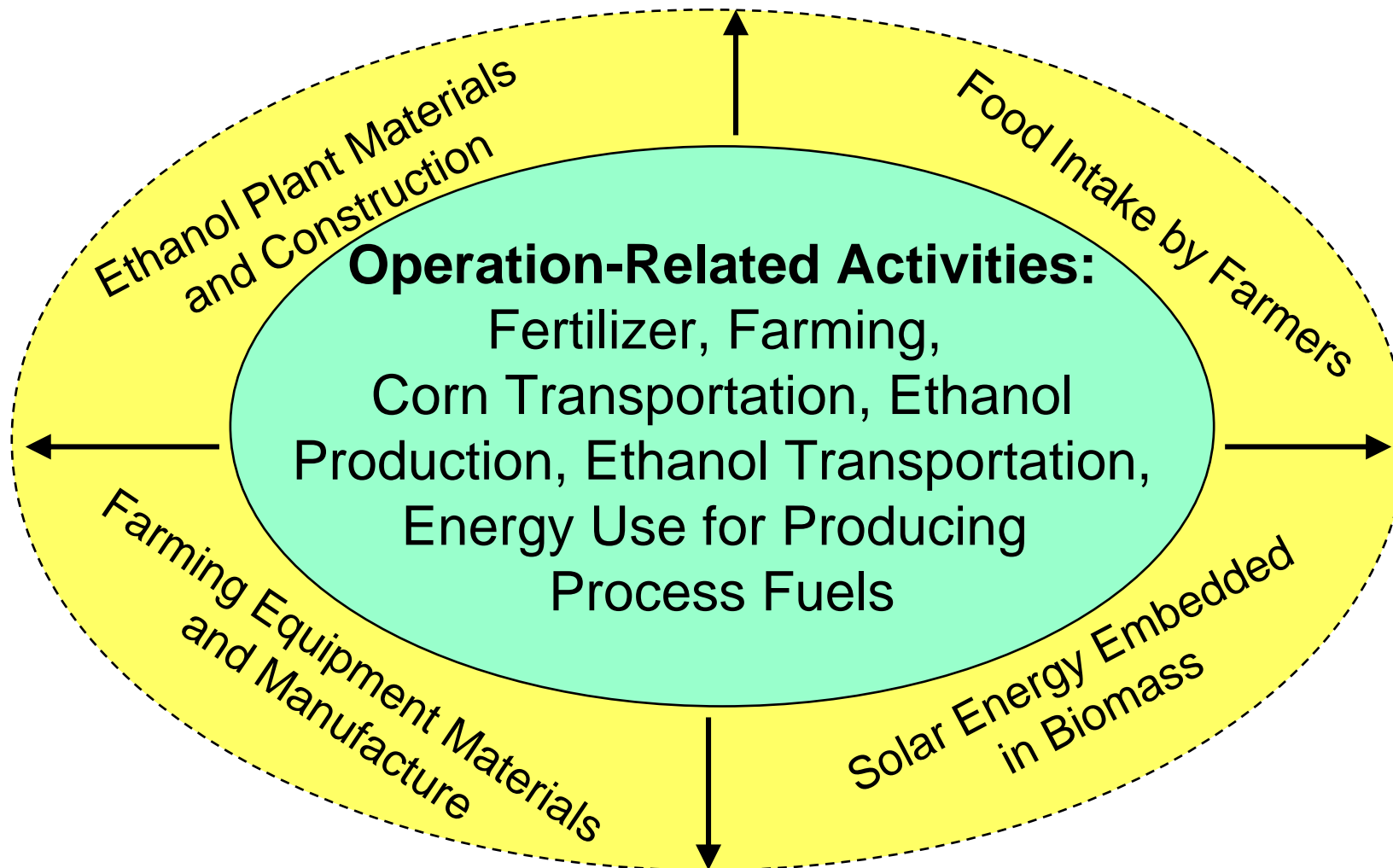
# Energy Balance of Corn Ethanol Results Among Studies (Based on Fossil Energy Use)



Studies highlighted in red have GHG emission results.

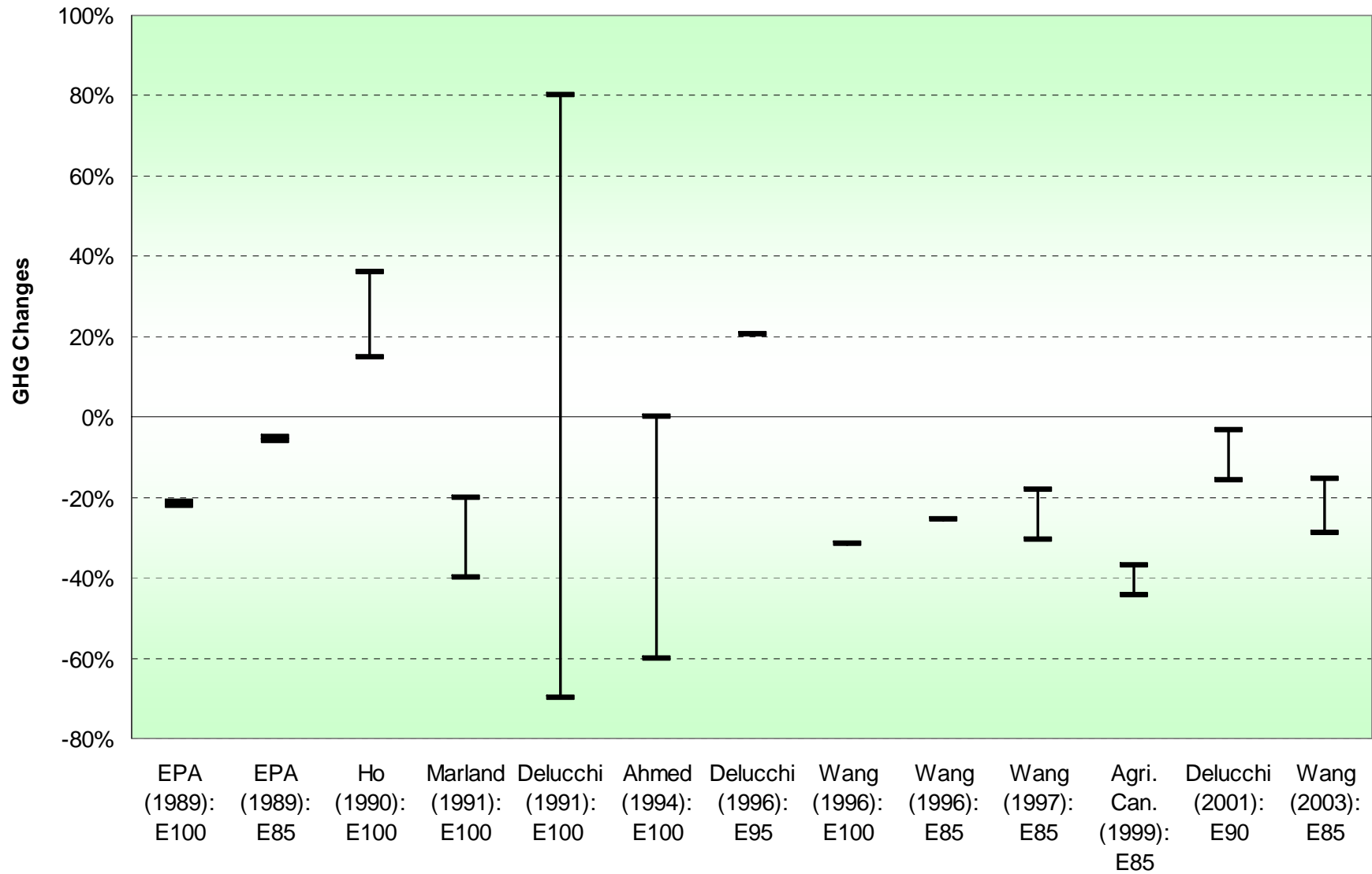


# Results of Ethanol Analysis Are Dependent on System Boundary Choices



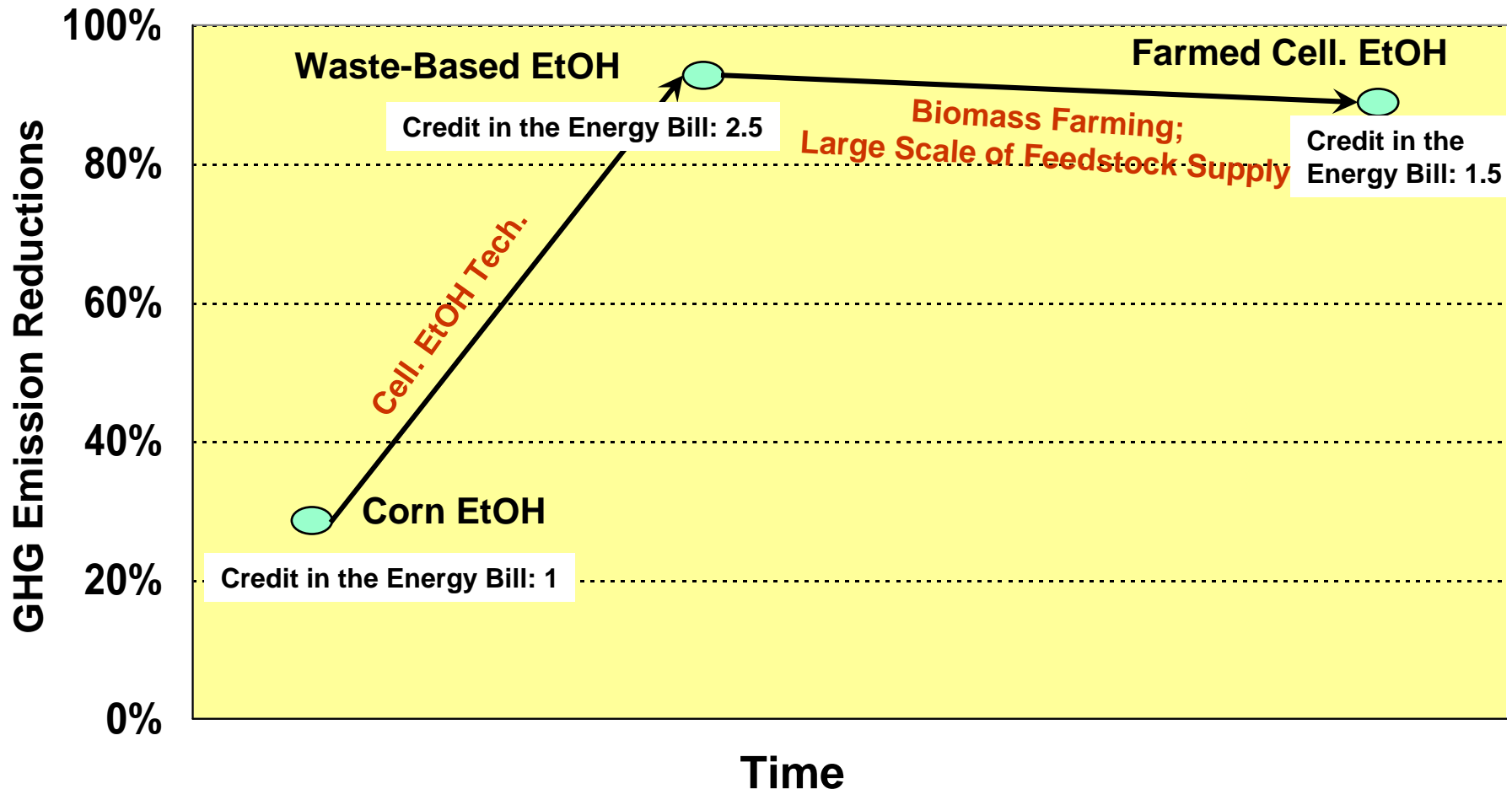


# Corn Ethanol GHG Emission Changes Among Studies





# Transition to More Sustainable, Larger Scale Fuel Ethanol Supply Is Reflected in the 2004 Energy Bill



3.41 billion gallons of corn ethanol was produced last year with 13% of US corn production; that is less than 2% of the U.S. gasoline market.



# Conclusions

- ❑ Any type of fuel ethanol helps substantially reduce transportation's fossil energy and petroleum use
- ❑ Energy balance value for a given energy product alone is not meaningful in evaluating its benefit
- ❑ Corn-based fuel ethanol achieves moderate reductions in GHG emissions
- ❑ Cellulosic ethanol can achieve much greater energy and GHG benefits
- ❑ Millions of FFVs already on road, if fueled with E85, can bring immediate, significant energy and GHG benefits