Energy and Greenhouse Gas Emissions Effects of Fuel Ethanol

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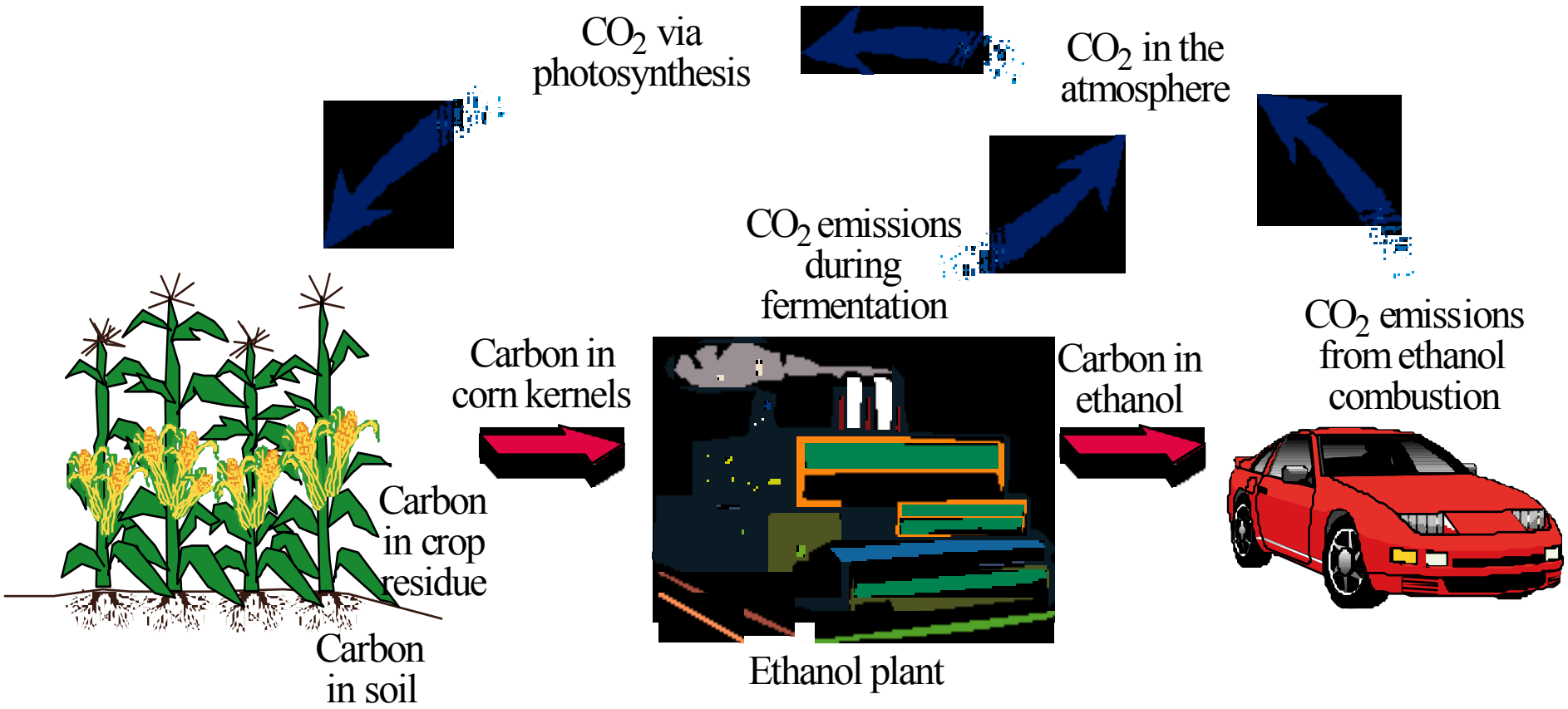
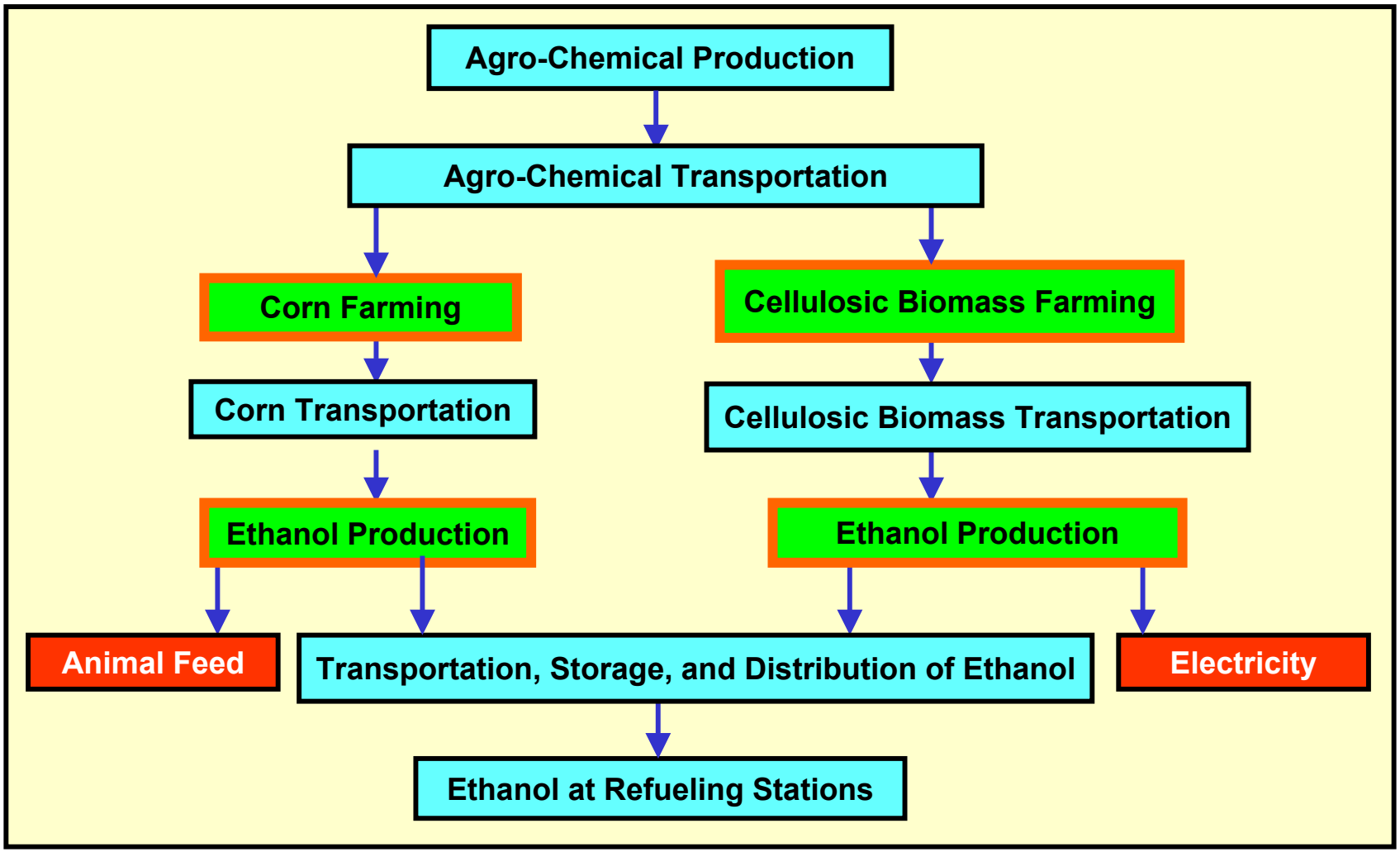
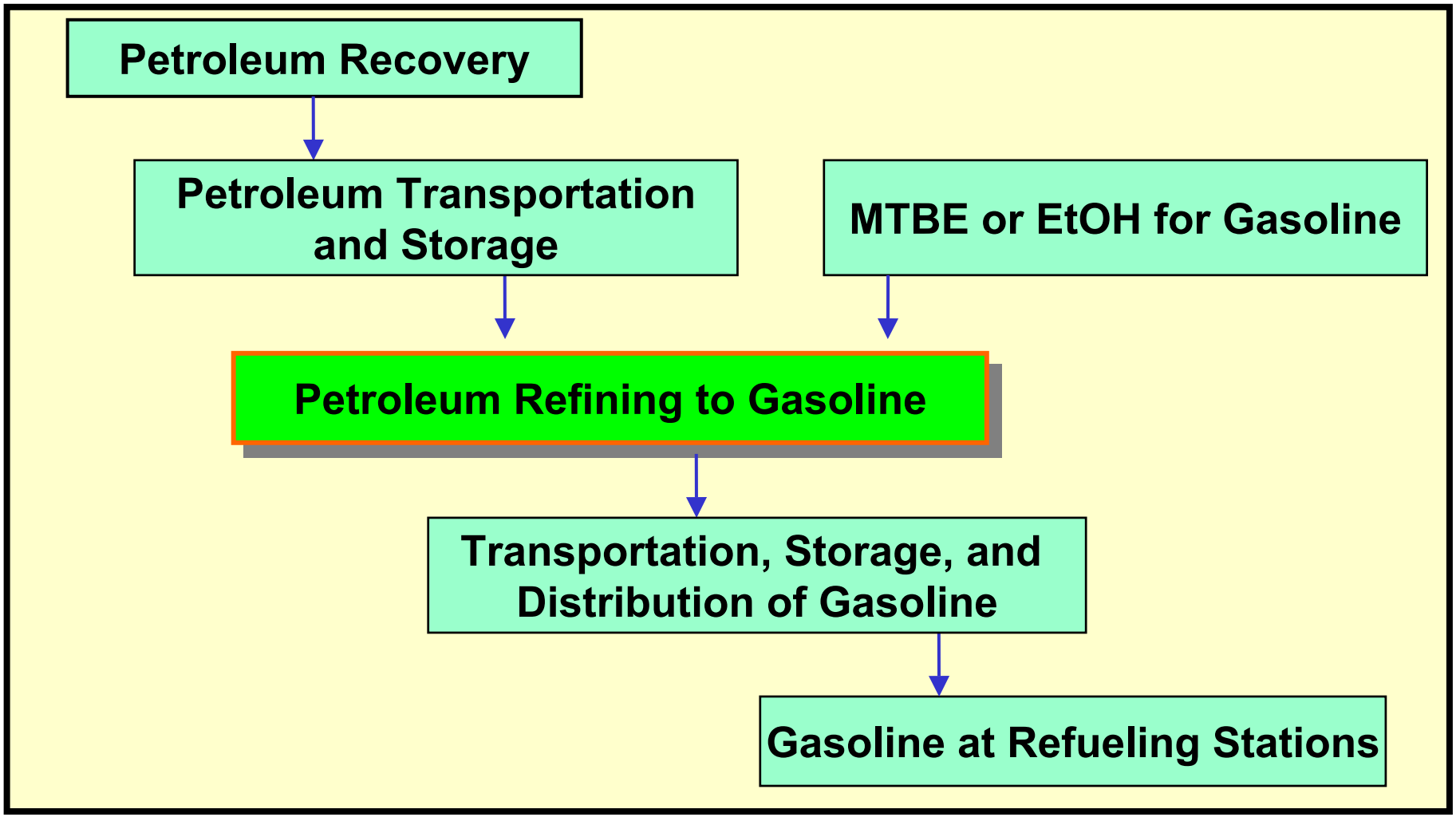
Recycling of Carbon by Fuel Ethanol Results in Net CO_2 Benefits



A Full Understanding of Ethanol's Energy and GHG Emissions Accounts for All Production Steps



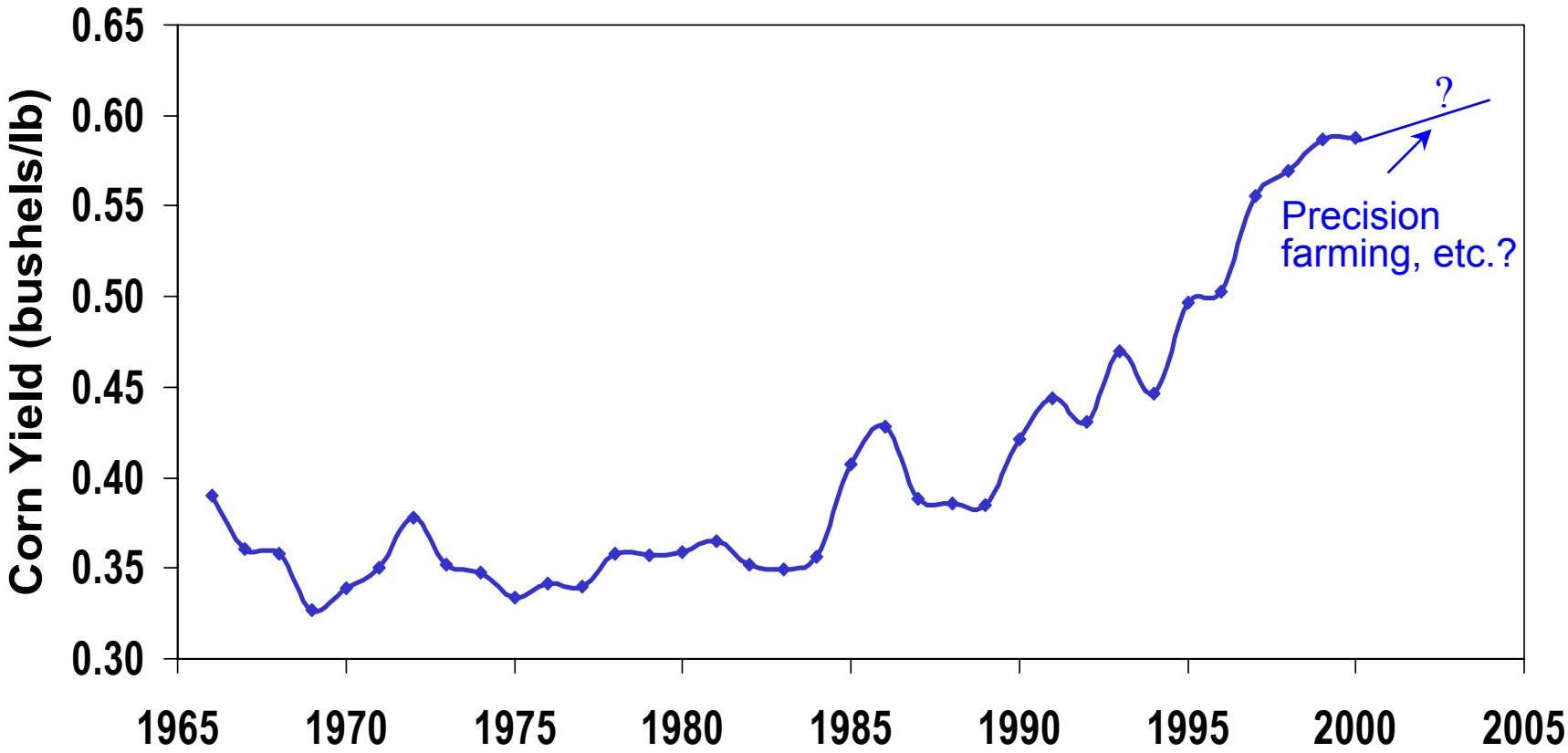
Petroleum Refining Is the Key Energy Conversion Step for Gasoline Cycle



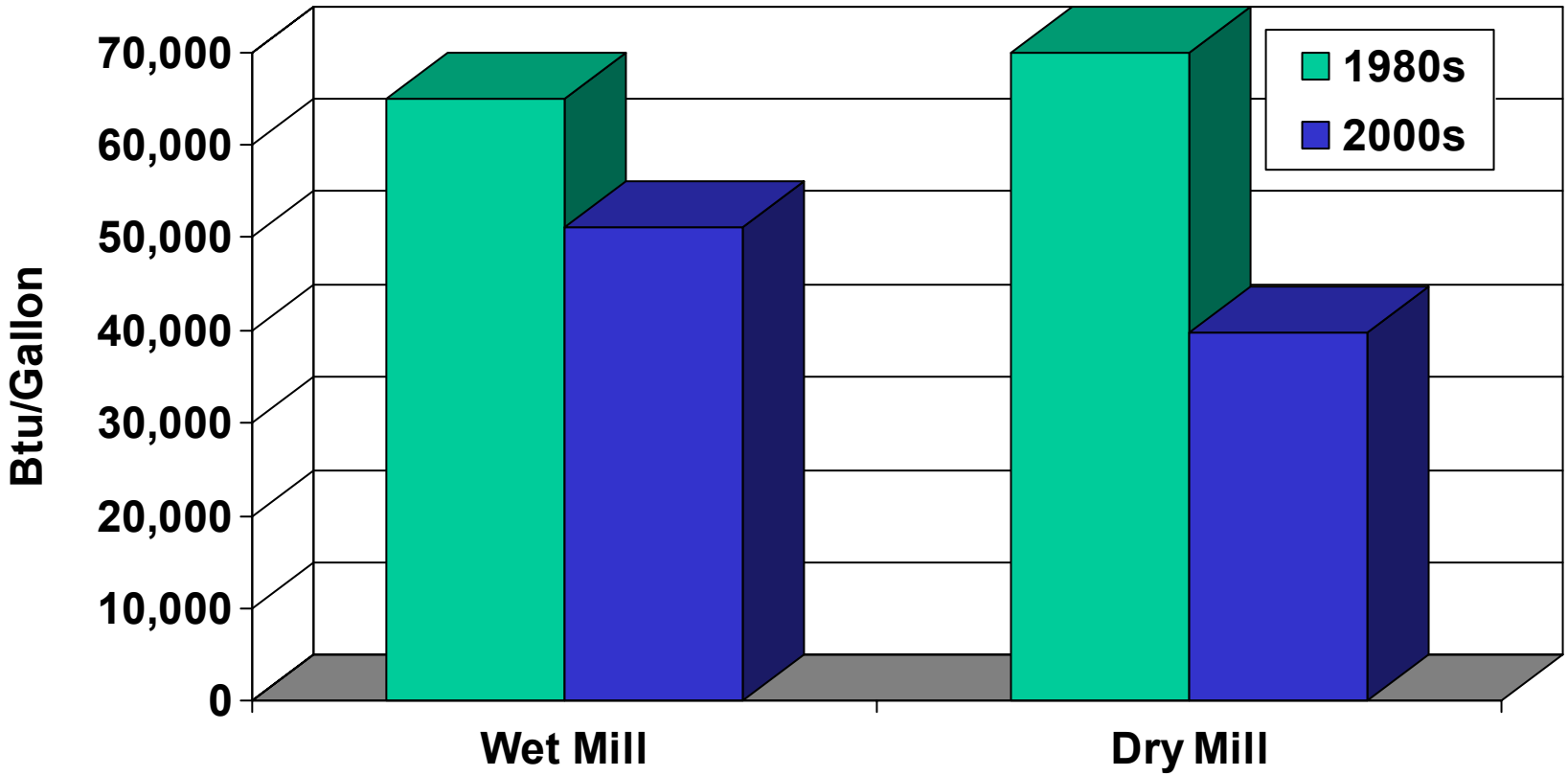
Key Parameters for Fuel Ethanol Fuel-Cycle Analysis

- **Chemicals Production**
  - Energy use for producing:
    - Fertilizers (N, P_2O_5, K_2O)
    - Herbicides
    - Insecticides
- **Farming**
  - Yield per acre: corn and biomass
  - Chemicals use intensity
  - Soil N_2O emissions
  - Energy use intensity
  - Soil CO_2 emissions
- **Ethanol Production**
  - Corn ethanol: wet vs. dry milling
  - Ethanol yield per unit of feed
  - Energy use intensity
  - Co-products
- **Vehicle Fuel Economy**
  - Gasoline vehicles for E10
  - Flexible-fuel vehicles for E85

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



Technology Has Reduced Energy Use Intensity of Ethanol Plants



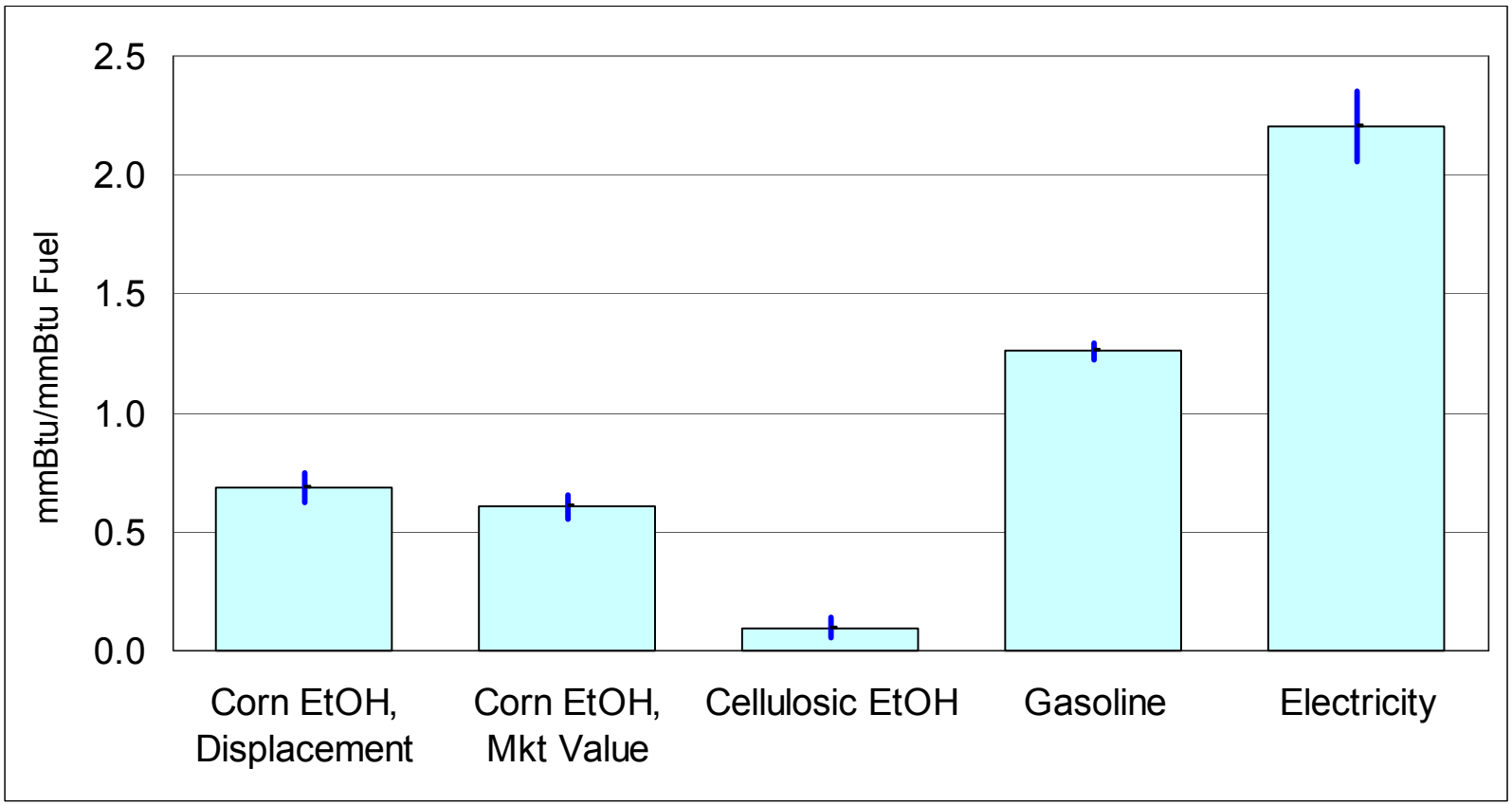
Source: from Argonne's discussions with ethanol plant designers and recent USDA data.

Energy and Emissions Allocated to Co-Products of Corn Ethanol Vary by Method

Allocation Method	Wet Milling	Dry Milling
Weight	52%	51%
Energy	43%	39%
Process energy	31%	34%
Market value	30%	24%
Displacement	~16%	~20%

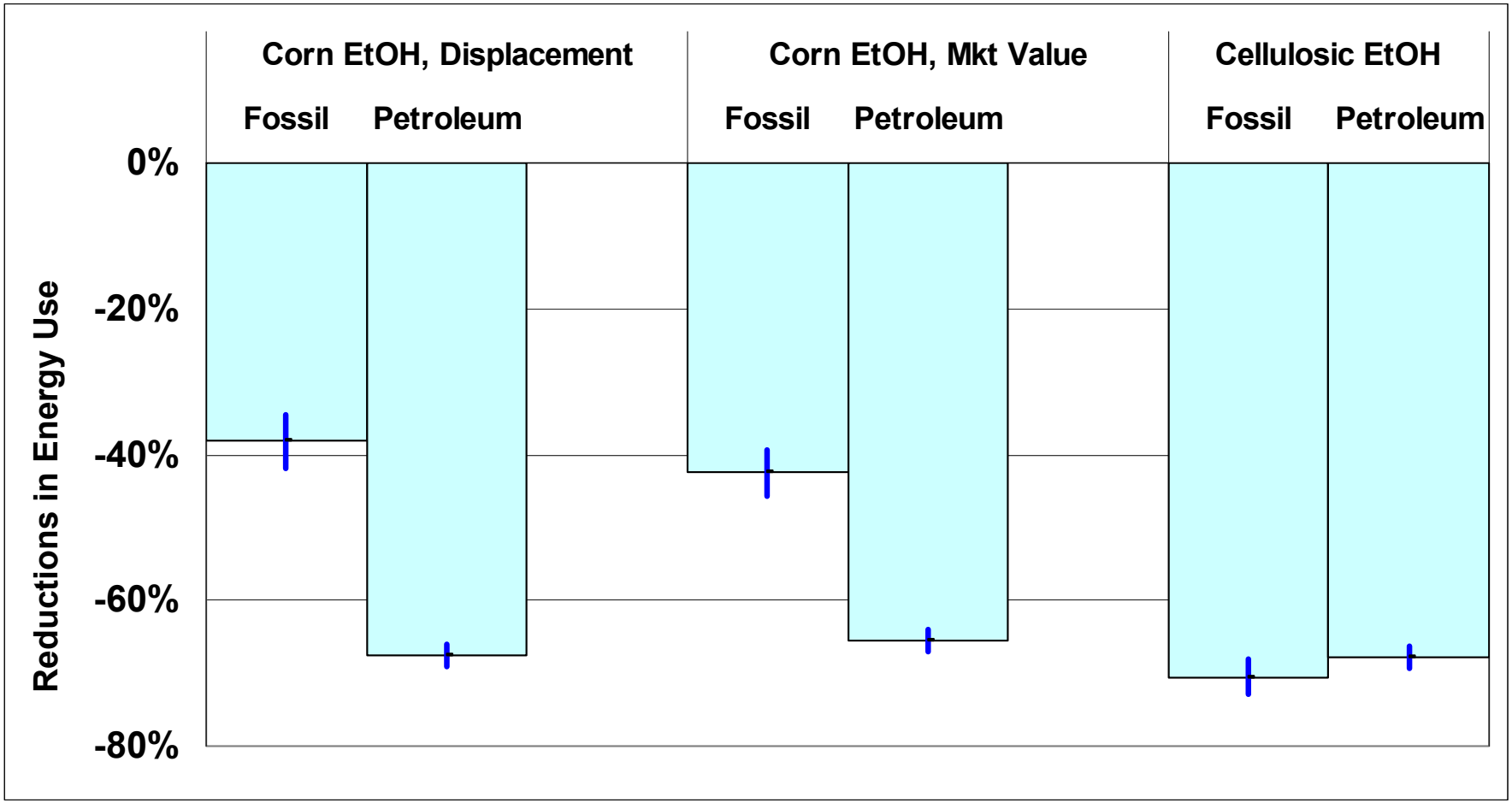
- Weight and energy methods no longer used.
- Some studies did not consider co-products at all.

Energy Balance: Million Btu of Fossil Fuels Required to Make a Million Btu of Fuel Available at User Site



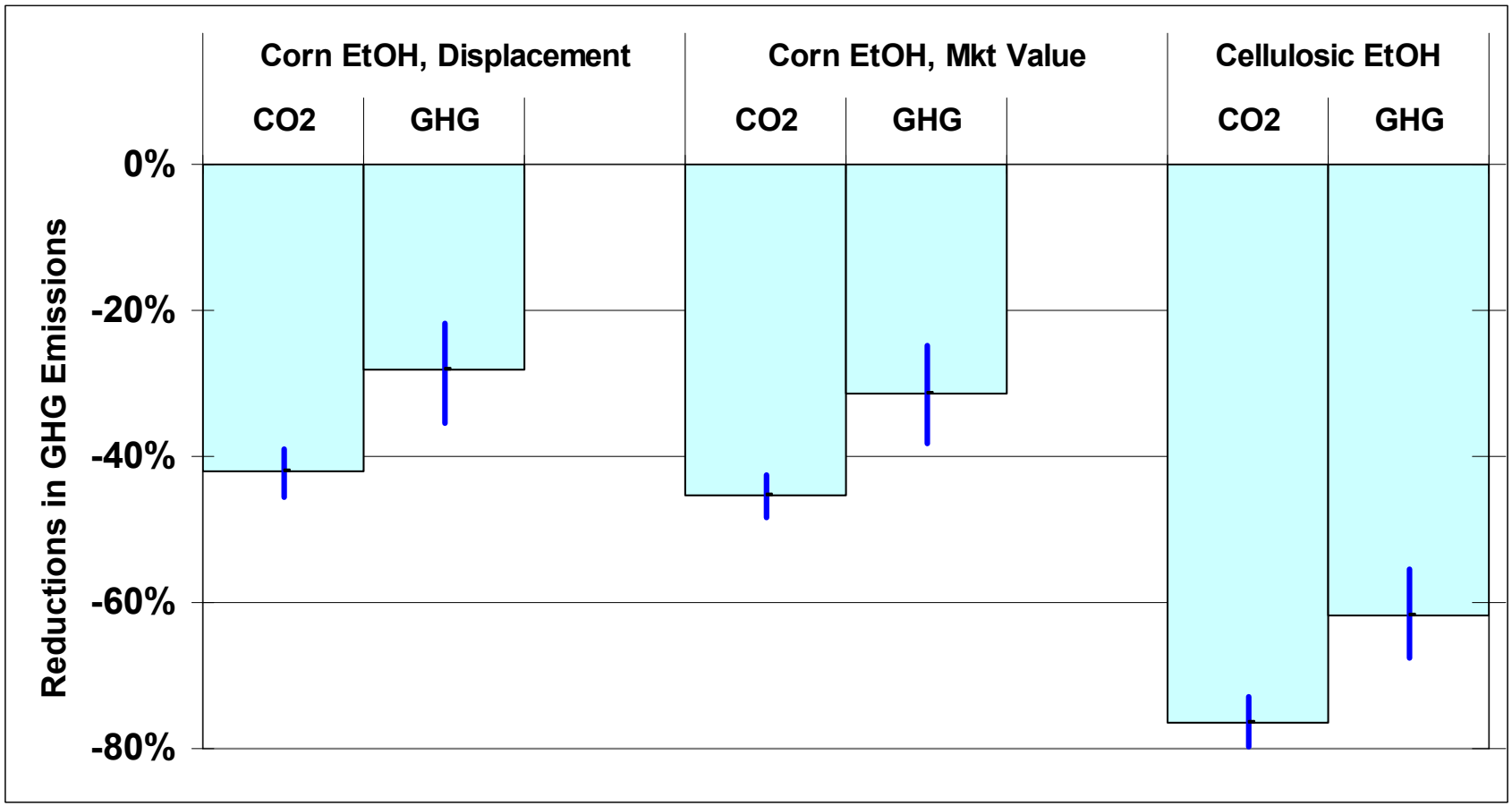
A problem with energy balance values is that the quality of a fuel is NOT taken into account!!!

E85 Reductions in Energy Use Relative to Gasoline



Note: Based on per-mile results of E85 use in FFVs. Fossil fuels here include petroleum, natural gas, and coal.

E85 Reductions in Greenhouse Gas Emissions Relative to Gasoline



Note: Based on per-mile results of E85 use in FFVs. GHG emissions are CO2-equivalent emissions of CO2, CH4, and N2O.

Summary: Effects of Ethanol Use

- Any type of fuel ethanol helps substantially reduce transportation's fossil energy and petroleum use.
- Corn-based fuel ethanol achieves moderate reductions in GHG emissions.
- Cellulosic ethanol will achieve much greater energy and GHG benefits.