THE 2001 NET ENERGY BALANCE OF CORN ETHANOL

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INTRODUCTION

- In the United States and many countries in the world, ethanol is used as a gasoline additive, not as a fuel. The only exception is Brazil.
- Prices of ethanol, crude oil, and petroleum refined products such as gasoline and methyl tertiary butyl ether (MTBE) are subsidized.
- Gasoline and MTBE prices do not reflect the external costs of burning fuel such as health and environmental effects.

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Why Ethanol

- Ethanol is mostly produced in countries that have surplus of agricultural commodities, excess natural resources, high greenhouse gas emissions (GHG), and high dependency to imported oil
- Examples are grains and oilseeds in the United States; sugarcane and oilseeds in Brazil; grains, oilseeds, sugar beets, and wine in European Unions; sugar cane in India; and grains in China

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OVERVIEW

- The Net Energy Balance of Corn Ethanol:
  - Energy used in production of corn
  - Energy used to transport corn to ethanol plant
  - Energy used to convert corn to ethanol and byproducts
  - Energy used in ethanol distribution

Sources of Data

- USDA/ Economic Research Service (ERS), 2001 Agricultural Resources Management Survey (ARMS)
- USDA/ National Agricultural Statistics Service (NASS), 2001 Agricultural Chemical Usage and 2001 Crop Production
- Stokes Engineering Company, energy used in production of fertilizers

Sources of Data--Continued

- Greenhouse Gas Regulated Emissions and Energy Use in Transportation (GREET) model, energy used in production of chemicals
- 2001 survey of ethanol plants, BBI International, thermal and electrical energy used in ethanol plant
- ASPEN Plus, a process simulation program, to allocate energy used in ethanol plant to ethanol and byproducts

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Exclusion

- Energy used in production of farm machinery and equipment
- Energy used by farm labor (food, clothing)
- Energy used in production of cement, steel and stainless steel

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The Corn Producing States

- States included in the study: IA, IL, IN, MI, MN, NE,OH, SD, and WI.
- The above states account for 79% and 92% of U.S. corn and ethanol production capacity
- Farm input use for each state is used to estimate the 9-State weighted average of input levels for corn production

Energy Used in Corn Production

- Direct energy:

  Gasoline, diesel fuel, LPG, natural gas, and electricity
- Indirect energy:

  Fertilizers (nitrogen, phosphate, potash, and lime) and pesticides (herbicides and insecticides)
- Others:

  Seed, purchased water, custom work, grain dying, and inputs hauling

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Energy-Related Inputs Used to Grow Corn, 9-State Weighted Average

Item	Unit	9-State Weighted
Seed	**Kernels/acre**	28,739
Fertilizer:		
Nitrogen	**Pounds/acre**	133.5
Potash	**Pounds/acre**	88.2
Phosphate	**Pounds/acre**	56.8
Lime	**Pounds/acre**	15.7
Energy:		
Diesel	**Gallons/acre**	6.9
Gasoline	**Gallons/acre**	3.4
LPG	**Gallons/acre**	3.4
Electricity	**Kwh/acre**	33.6
Natural gas	**Cubic ft/acre**	246
Custom work	**Dollars/acre**	10.1
Chemicals	**Pounds/acre**	2.66
Purch. Water	**Dollas/acre**	0.2
Average yield	**Bushels/acre**	139.3

Fertilizers and Chemicals

- New estimates of energy used for production and delivery of nutrients to farm:
  - Nitrogen 24,500 Btu per pound of N
  - Phosphate 4,000 Btu per pound of P_2O_5
  - Potash 3,000 Btu per pound of K_2O
- Energy used in production of pesticides:
  - Herbicides 153,000 Btu per pound
  - Insecticides 158,000 Btu per pound

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Fuels and Electricity

- Btu content (LHV):
  - Diesel fuel 128,450 per gallon
  - Gasoline 116, 090 per gallon
  - LPG 84,950 per gallon
  - Natural gas 983 per cubic ft.
  - Electricity 3,412 per kwh
  - Coal 9,773 per pound
  - Ethanol 76,330 per gallon

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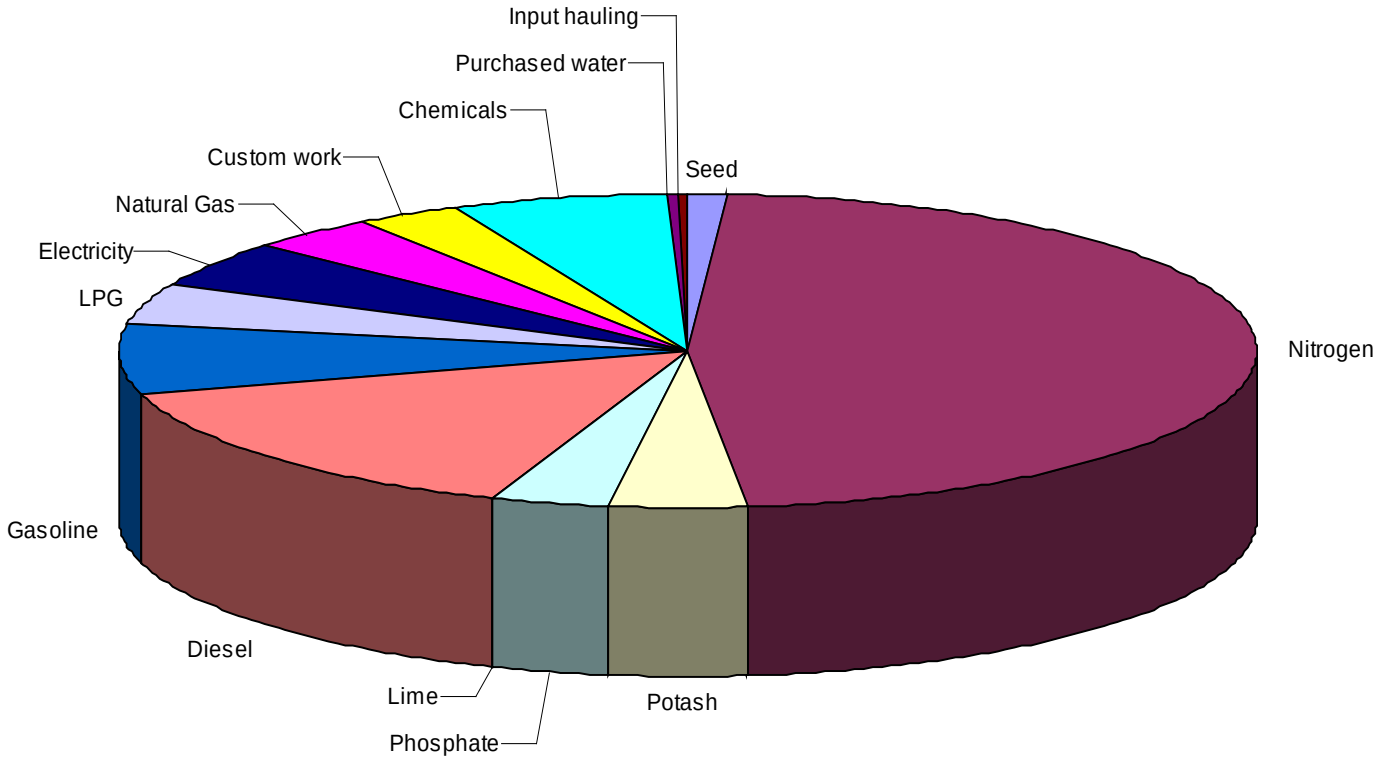
Total Energy Requirement of Farm Inputs, 9-State Weighted Average, Btu per Bushel of Corn, 2001



Transporting Corn to Ethanol Plant

- Energy used:
  - 5,636 Btu per bushel
  - 2,120 Btu per gallon

Energy Used in Conversion

- 2001 survey of ethanol plants, BBI international:
  - Dry mill, 34,700 Btu of thermal energy and 1.09 kwh of electricity per gallon of ethanol
  - Wet mill, 47,116 Btu of energy per gallon of ethanol

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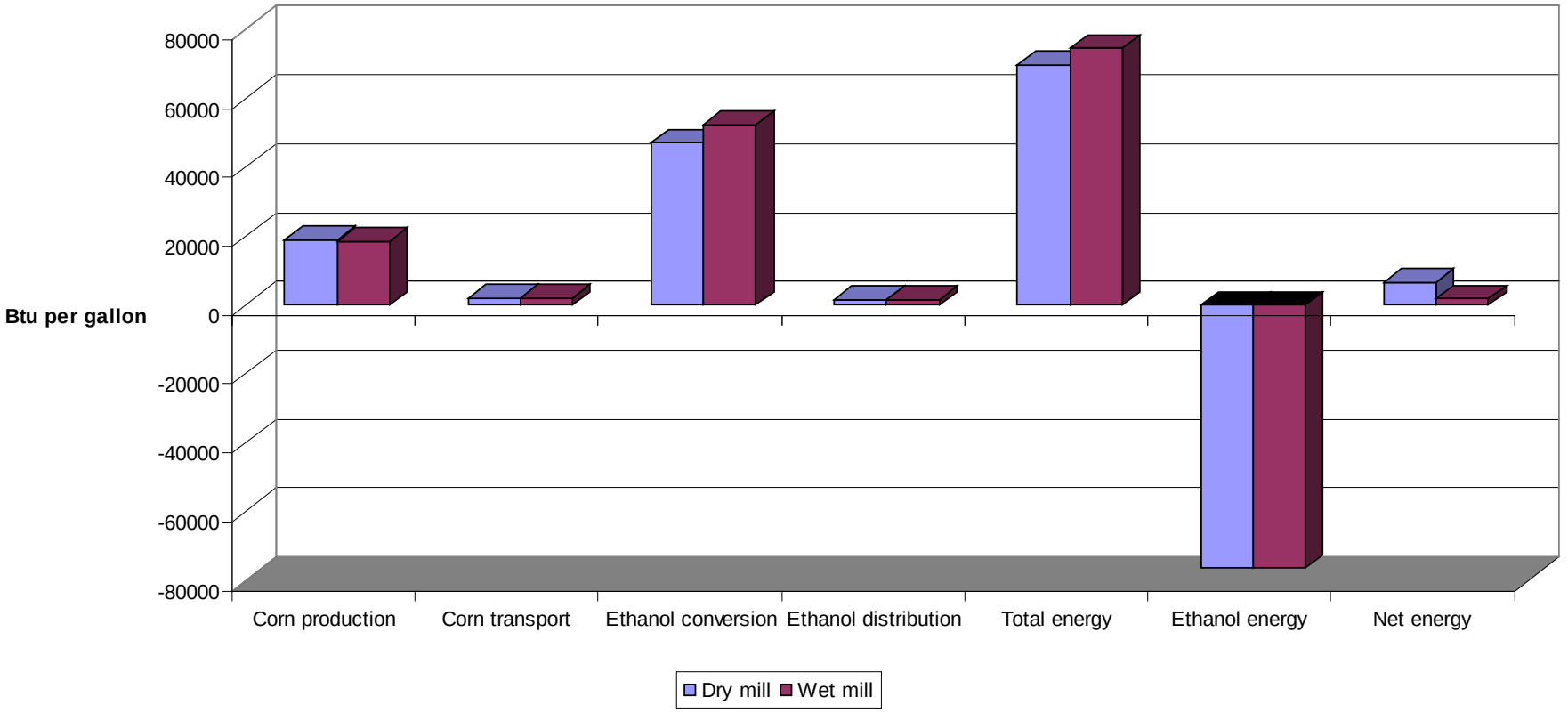
Net Energy Value of Corn-Ethanol Without Byproduct Credits, 2001



Ethanol Plant Outputs

- Wet mill:

  Corn-ethanol, corn gluten meal, corn gluten feed, corn oil, CO_2 , and other products

- Dry mill

  Corn-ethanol, distillers dried grains with soluble, modified distillers grains, wet distillers grains, condensed distillers Soluble, and CO_2

How to Allocate Total Energy to Ethanol and Byproducts

- Methodology:
  - Energy content
  - Market value
  - Output weight basis
  - Replacement value
  - Process energy for energy used in plant and % weight of starch and non-starch for energy used to grow corn and transport corn to ethanol plant

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Allocation Rules

- Energy used in corn production:
  - 66% to ethanol and 34% to byproducts
- Energy used in transporting corn to ethanol plant:
  - 66% to ethanol and 34% to byproducts
- Energy used in conversion of corn to ethanol and byproducts, ASPEN Plus:
  - Wet mill, 64% to ethanol and 36% to byproducts
  - Dry mill, 59% to ethanol and 41% to byproducts

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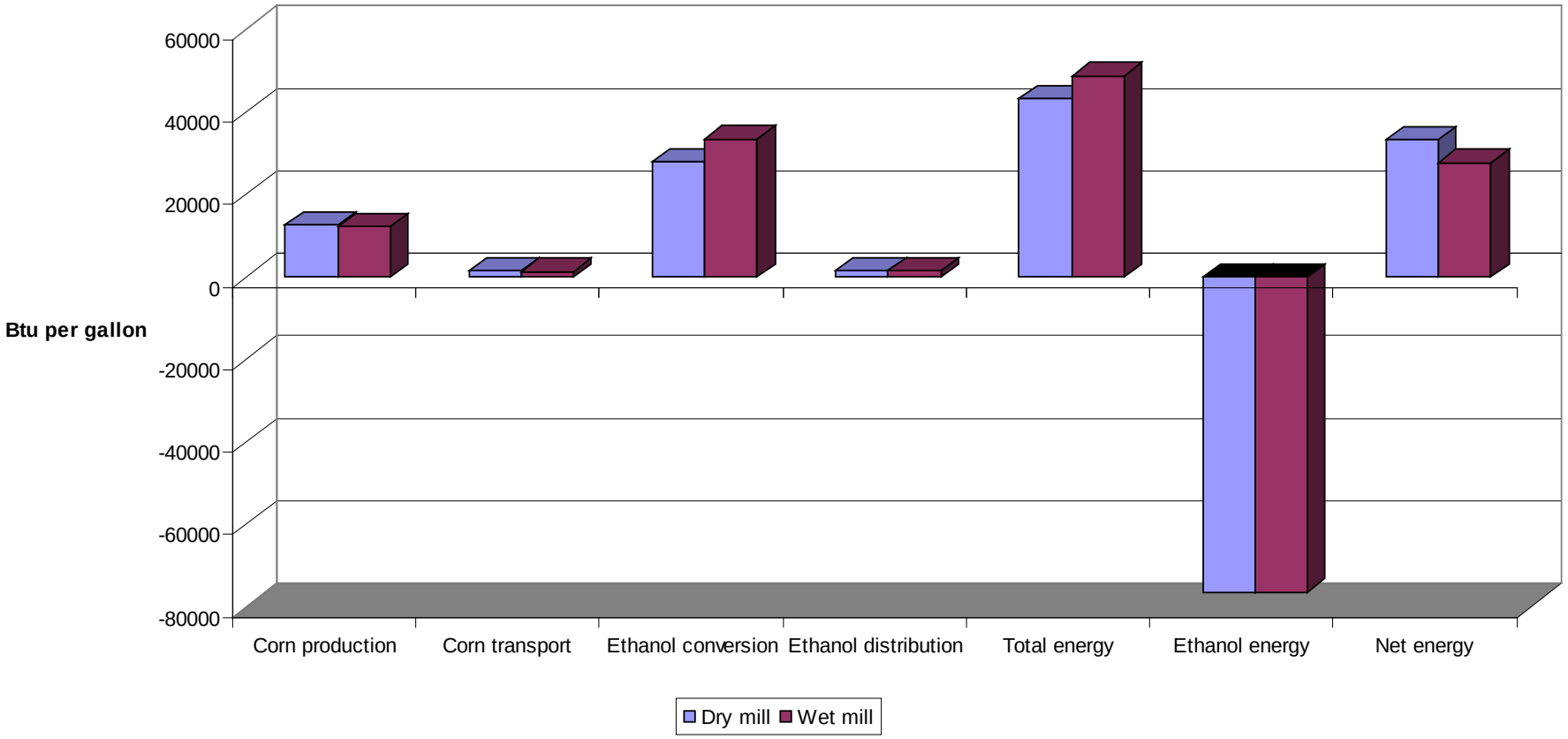
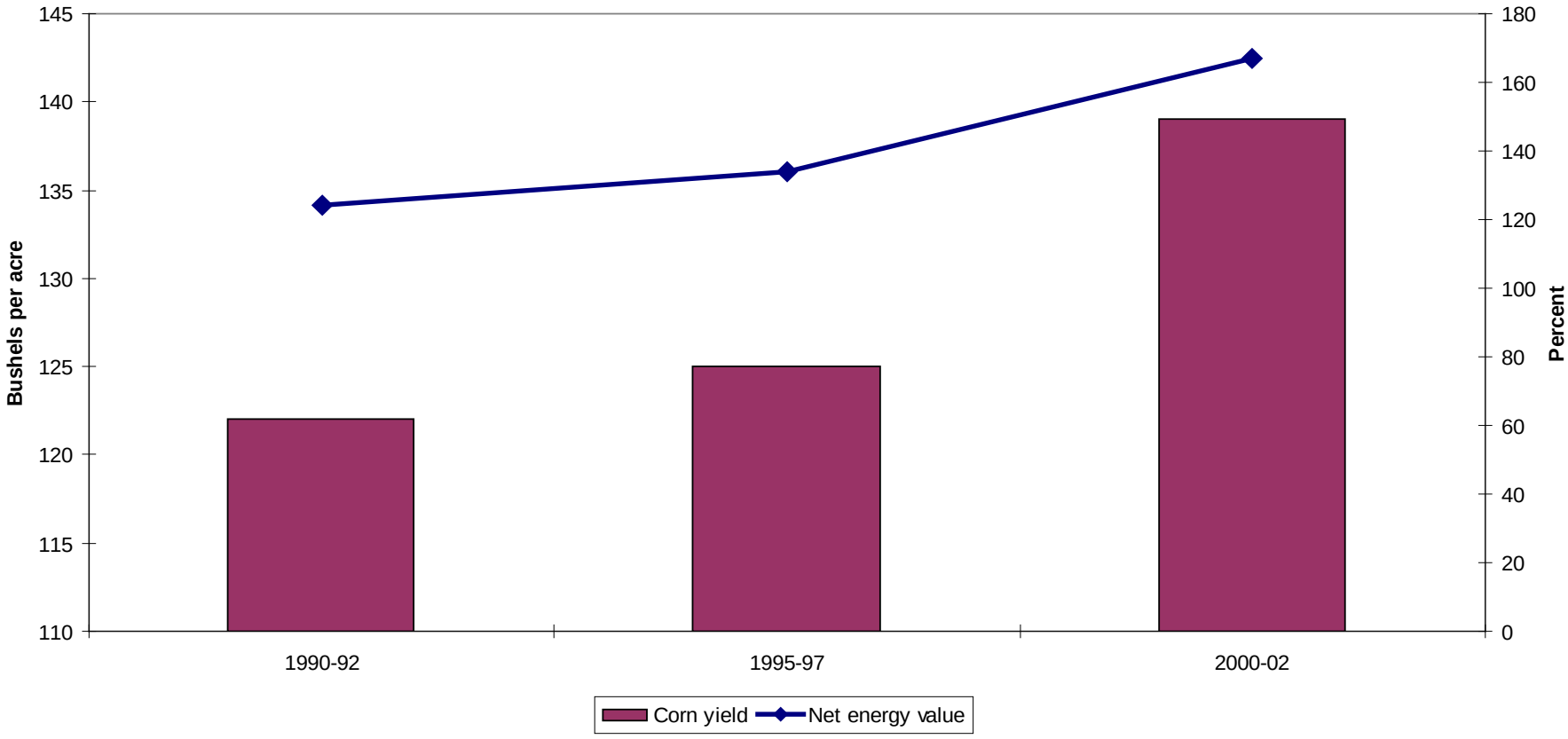
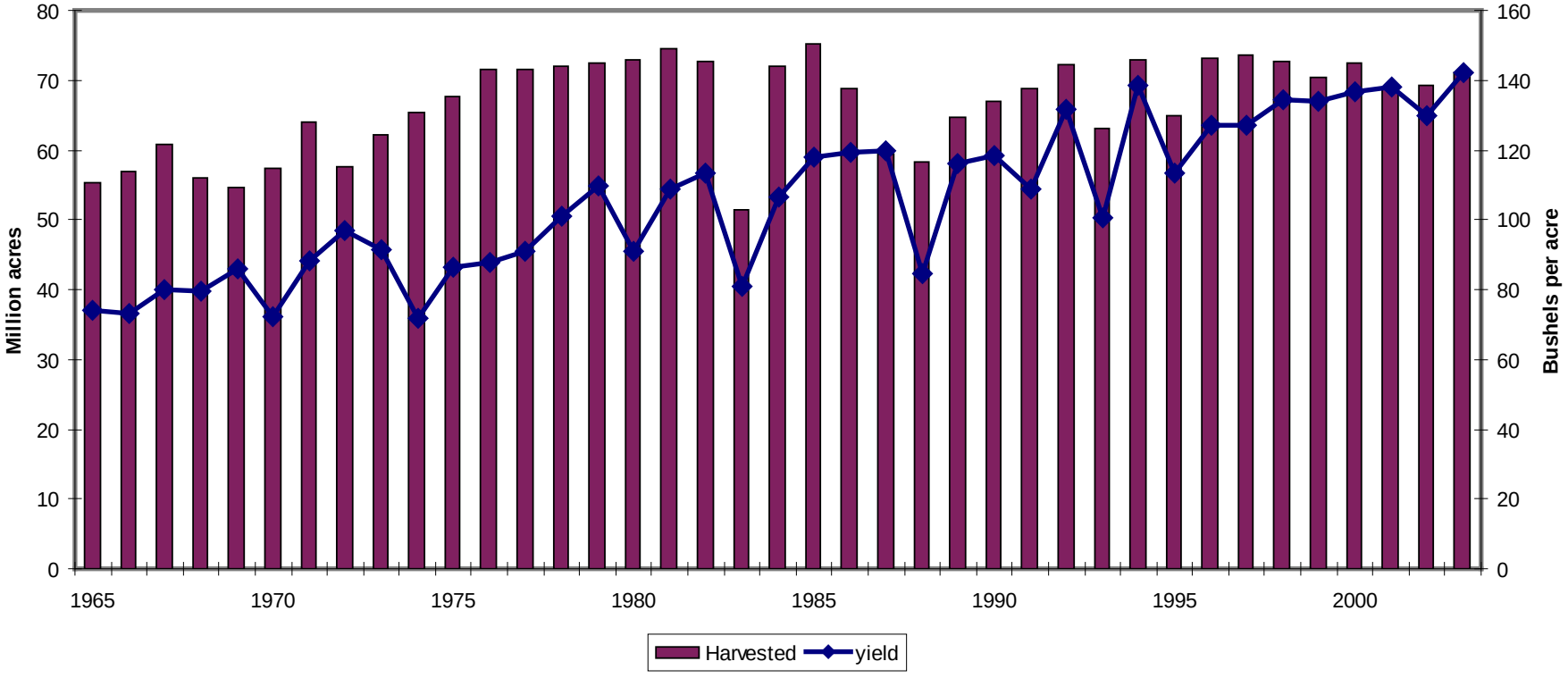
Energy Use and Net Energy Value of Corn-Ethanol with Byproduct Credits, 2001



Net Energy Value of Corn-Ethanol and 9-State Average Corn Yield per Acre



Corn: Harvested Area and Yield per Acre, 1965-03



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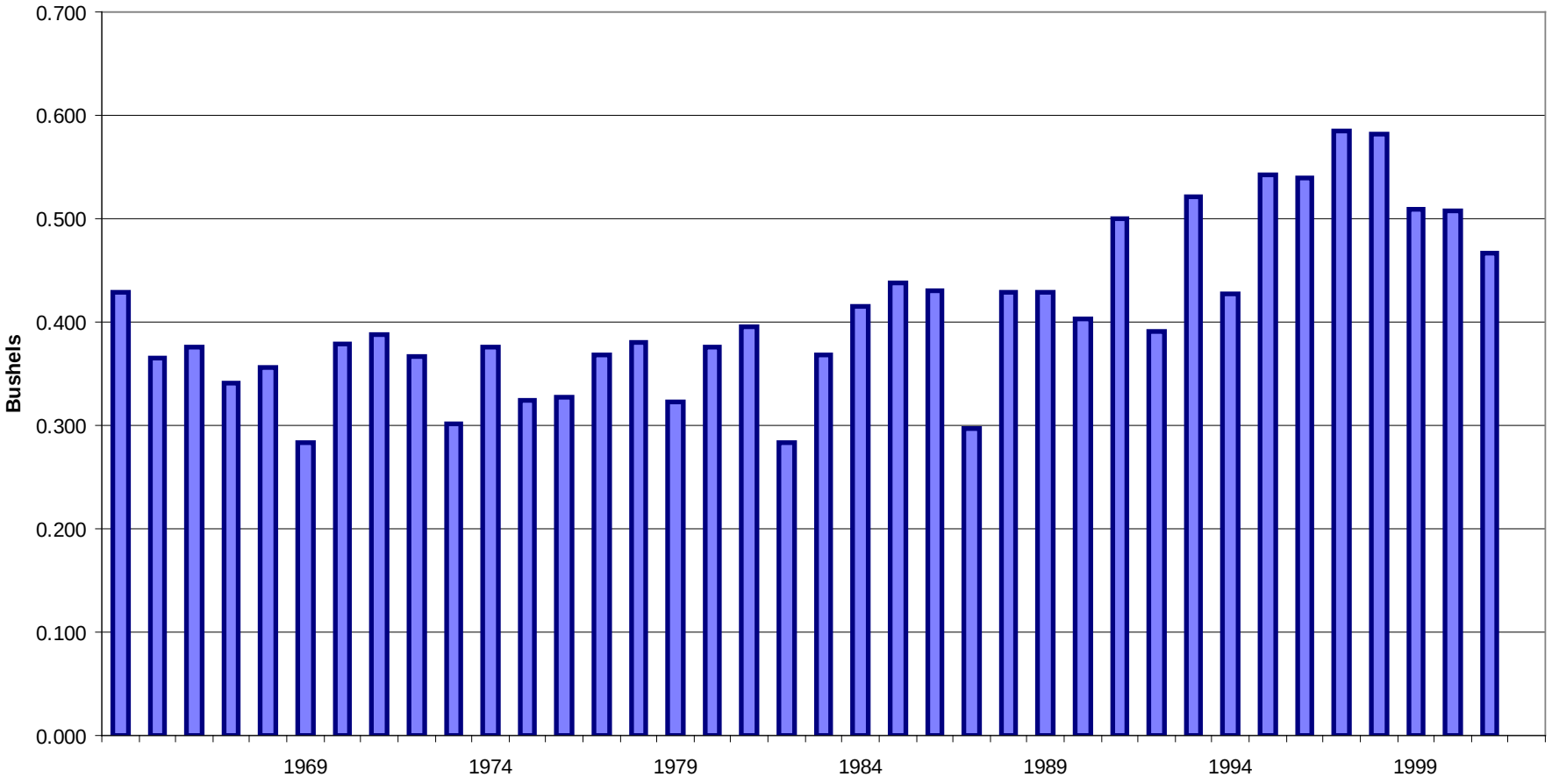
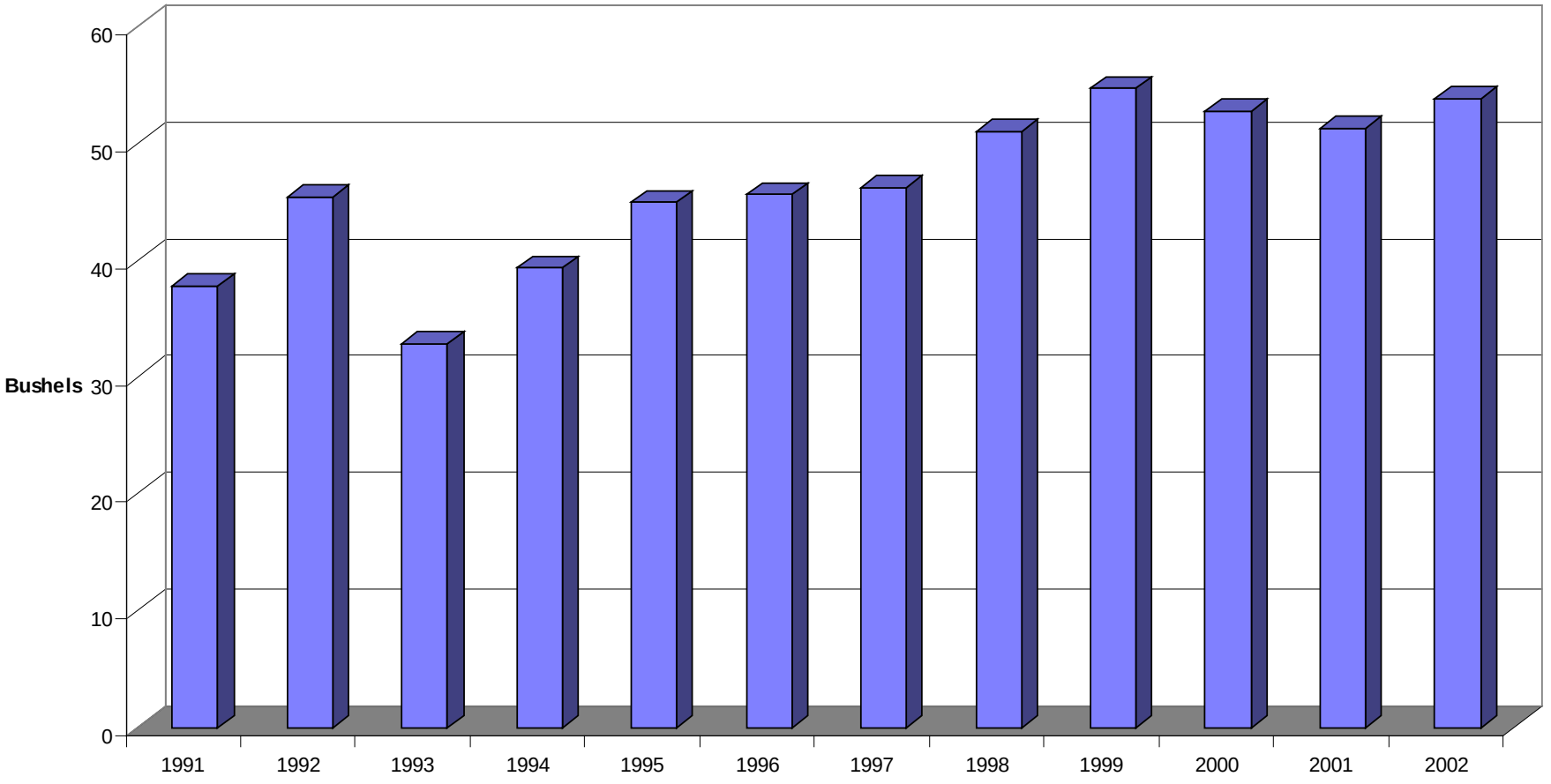
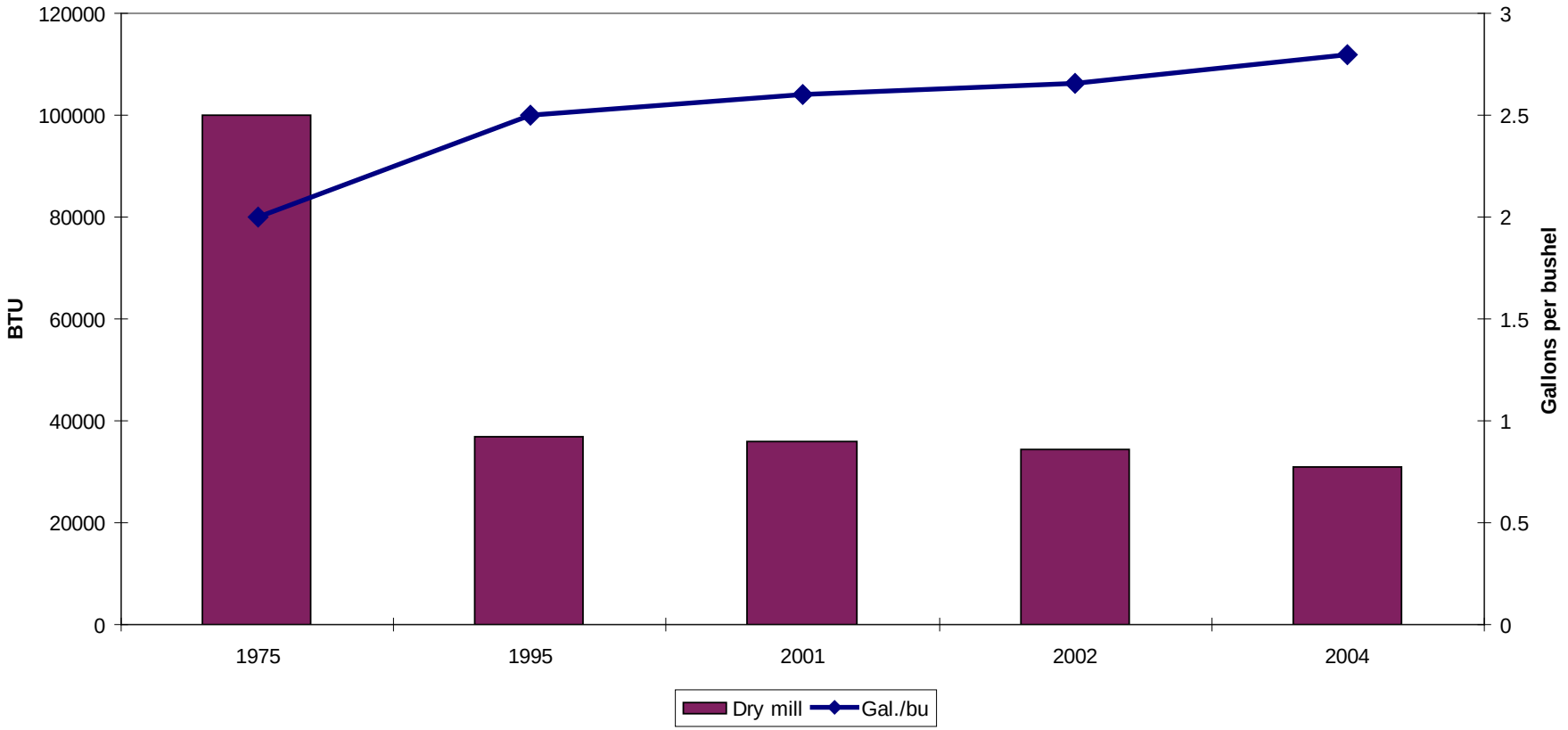
Bushels of Corn per Pound of Fertilizer, 1966-02



Bushels of Corn per Pound of Pesticides, 1991-02



Dry-Mill: Thermal Energy Use per Gallon of Ethanol and Ethanol Yield per Bushel



Conclusions

- Corn yield per acre will continue to increase
- Fertilizer industry has become more energy efficient
- Energy used to produce a bushel of corn will continue to decline
- Ethanol yield per bushel of corn will increase to its theoretical limit
- Ethanol plants will become more energy efficient
- Net energy value of corn-ethanol will continue to improve

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