Energy From Agriculture:

New Technologies, Innovative Programs & Success Stories

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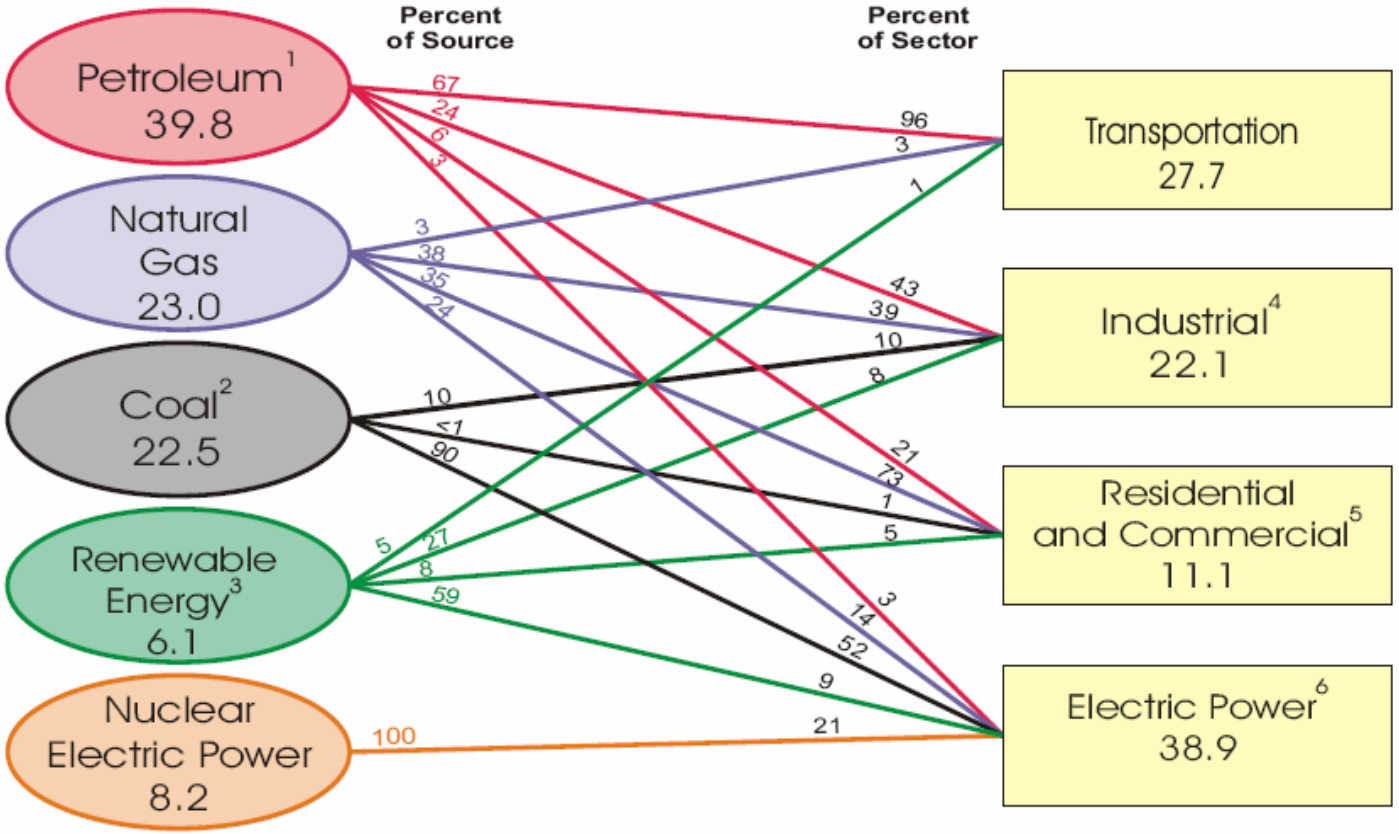
Rural Development

This paper:

- documents the current contribution agricultural renewables are making to the nation's energy supply,
- discusses the economics of energy production from agricultural renewables, and
- summarizes several recent studies that estimate the amount of renewable energy agriculture can produce.

U.S. Primary Energy Consumption by Source and Sector, 2004



Source: DOE. Annual Energy Review 2004.

[1]Excludes 0.3 quadrillion Btu of ethanol, which is included in "Renewable Energy."
[2]Includes coal coke net imports.
[3]Conventional hydroelectric power, wood, waste, alcohol, geothermal, solar, and wind.
[4]Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[5]Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[6]Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Note: Sum of components may not equal 100 percent due to independent rounding.
Source: Energy Information Administration, *Annual Energy Review 2004*, Tables 1.3 and 2.1b-2.1f.

U.S. Energy Production from Renewable Sources, 2004

Renewables	Quads	Percent
Hydroelectric	2.275	44
Wood	1.989	33
Waste	0.560	10
Alcohol	0.296	5
Geothermal	0.340	5
Wind	0.143	2
Solar	0.063	1
Total	6.116	100
Source:DOE. Annual Energy Review 2004 Tables 10.2a and 10.2b		

Electricity, Gasoline and Diesel Use During 2004 and the Proportion from Renewables

	2004 Consumption	Amount from Renewables	% from Renewables
Gasoline (Bill Gal.)	136.008	3.4	2.5
Diesel (Bill. Gal.)	42.525	0.025	0.06
Electricity (Bill. Kwh)	3,953	358.8	9.08
Hydroelectric		269.6	6.82
Wood		37.3	0.94
Waste		22.7	0.57
Geothermal		14.4	0.36
Wind		14.2	0.36
Solar		0.6	0.02

Source: DOE. *Annual Energy Outlook 2005. Tables 5.13c and 8.2a*

Production Technologies: Current Structure and Challenges

- Ethanol from Grain
- Ethanol from Lignocellulosic Biomass
- Biodiesel
- Electricity from Wind Power
- Electricity From Anaerobic Digestion

Agriculture's Role in Energy Production: Current Levels and Future Prospects

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Ethanol From Grain

- Industry is growing very rapidly. It produced 3.41 billion gallons in 2004 and is expected to produce 4.0 billion in 2005 and 5.0 in 2006.
- A shift to larger plants is occurring.
- Each dollar increase in natural gas price increases the cost per gallon about $0.034
- Ethanol demand has been dominated by mandated markets. The Energy Policy Act of 2005 provides flexibility in the way oil companies use ethanol.
  - RFS minimum use is less than expected production capacity for 2006 and 2007.
  - Demand for ethanol to produce reformulated gasoline and for use as an octane enhancer should be strong.
  - Ethanol market may experience some abrupt swings as it goes through this transition.

Ethanol from Lignocellulosic Biomass

- Analysis based on Aden, *et.al. Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis for Corn Stover. NREL/TP-510-32438. 2002.*

- Plant designed to process 2,205 tons per day (2000 metric tons).

- Estimated costs are for the nth plant.
  - start up after 2010
  - Project investment of $197,400,000 and operating capital of $9.9 million.
  - Operating costs of $73,800,000 including buying biomass at $30 per ton.
- Production
  - Initial conversion rate of 67.8 gallons per ton
  - Later conversion rate of 89.7 gallons per ton
  - Also produce 3.7 kWh per gallon of anhydrous ethanol, use 1.42 in the plant and sell 2.28 @ $.041

Estimated Production Cost per Gallon of Denatured Ethanol Produced From Lignocellulosic Biomass, based on Aden,et.al.

Conver-sion Rate	Cost of	Enzyme	Plant Output Million Gallons / Year			Investment
Gallons/ Ton	Feedstock $ / Ton	Cost Per Gal	Anhydrous	Denatured	Cost/Gal. Denatured	Cost/Gal. Denatured
Base Case						
67.8	30	0.10	52.3	53.4	1.39	3.70
		0.20			1.49	
	50	0.10			1.68	
		0.20			1.78	
Future Case 89.7	30	0.10	69.3	70.7	1.05	2.79
		0.20			1.15	
	50	0.10			1.27	
		0.20			1.37	

Biodiesel

- Production is increasing rapidly from 0.5 million gallons to 25 million gallons in 2004. Production is expected to approach 75 million gallons in 2005.

- Econonics of biodiesel plants based on Haas, et.al. “A Process Model to to Estimate Biodiesel Production Costs. *Bioresource Technology.* Elsevier. 2005.

  - 10 million gallon annual capacity

  - continuous-process vegetable oil transesterification plant w/ester and glycerol recovery.

  - Investment cost of $11.5 million

  - Operating and capital costs of $0.5005 per gallon
  - Glycerol credit of $0.128 per gallon

Biodiesel Costs for a 10-Million Gallon per Year Plant

Biodiesel From Soybean Oil Cost Per Gallon			Biodiesel From Yellow Grease Cost Per Gallon		
Degummed Soybean Oil $/lb.	w/o Tax Credit	w/$1.00/Gal. tax Credit	Yellow Grease $/lb.	w/o Tax Credit	w/$0.50/ Gal. Tax Credit
$0.15	$1.48	$0.48	$0.074	$0.94	$0.44
0.20	1.85	0.85	0.098	1.12	0.62
0.25	2.22	1.22	0.122	1.31	0.81
0.30	2.60	1.60	0.147	1.50	1.00
0.35	2.96	1.96	0.168	1.68	1.18

Biodiesel Demand

- Many niche markets including 400 fleets of vehicles associated with school districts, city and state governments, and federal agencies will grow to 6.5 million/year by 2010.
- State mandates – MN for 17 million/year.
- Potential demand as a lubricity agent for ultra-low sulfur diesel fuel.- 1% would require 470 million/year by 2010.

Production Potential for Biodiesel

Oil Type	Million Pounds	Million Gallons*
Soybean Oil	18,309	2,378
Other Vegetable Oils	4,528	587
Total Vegetable Oils	22,837	2,965
Yellow Grease & Grease	2,656	345
Animal Fats	6,680	868
Total Other Oils	9,336	1,213
Total Supply	32,173	4,178

* Pounds are converted to gallons using a conversion ratio of 7.7 pounds/Gallon.

Electricity From Wind Power

- Production increased from 5.6 million megawatt-hours in 2000 to 142 million megawatt-hours in 2004.
  - Much of concentration in production is in the three west coast states and several midwestern states (MN, IA, CO, KS, NM, and TX).
  - Electricity from wind is noted as a clean resource, w/ no emissions of CO2, SO2, NOx.

- There is much potential for further development of wind power in central part of country, but development requires
  - transmission capacity
  - continuation of federal wind power tax credit

- DOE indicates wind is competitive with coal and gas combined cycle power generation.
  - Fuel price uncertainty is greater for coal and NG
  - Adding a carbon tax would probably tip the balance.

Electricity From Methane via Anaerobic Digestion

- Anaerobic digestion involves the controlled breakdown of organic waste by bacteria in the absence of oxygen. Major agricultural opportunities include food processing wastes and manure.

- In mid 2005, EPA AgStar listed 41 digesters on livestock operations.

- A list of benefits include
  - electricity sales and offsets of electricity purchases,
  - use of digested solids for fertilizer and bedding replacement, and
  - odor control.

- Profitability of digesters is not well documented. A MN study indicates an electricity price of $.08 per kilowatt-hour would be required to break even without subsidies.

Resource Base and Potential Production

- Preferred approach to estimate potential production is with a national supply and demand model that includes the major agricultural commodities.

- Available studies are for individual types of renewable energy that we have to put together.

Three Studies

- FAPRI. *Implications of Increased Ethanol Production for U.S. Agriculture.* FAPRI-UMC Report #10-05. University of Missouri, Columbia, August 22, 2005.

- De La Torre Ugarte, *et.al. The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture.* USDA/OEPNU, Washington, D.C., 2003.

- Gallagher, P., *et. al. Biomass From Crop residue: Cost and Supply Estimates. A.E. Report 819. USDA/OEPNU, Washington, D.C. 2003.*

Ethanol and Biodiesel from Grain

- Ethanol production increases from 4.2 billion gallons in 2006 to 7.0 billion in 2012
- Biodiesel production soybean oil increases to 450 million pounds, or 60.8 million gallons.
- Area planted to corn increases 3.65 million acres from 2006 to 2011, while soybean acreage decreases 0.87 million acres.

Bioenergy From Crop Production

- Production management scenario fixed ethanol from grain and introduced markets to purchase bioenergy crops .
- Model was solved for 2008.
- 41.87 million acres shifted to bioenergy crops. 23.37 is from cropland.
- Expected production is 188.1 million dry tons per year.

Biomass From Crop Residues

- Study estimates supply functions for each of five regions.
- Industry supply is gross production minus amount needed for conservation, erosion control, and livestock feed.
- Estimated industry supply is 145.0 million dry tons.
- Estimate 90% (130.5 million tons) could be harvested & transported for $35/ton or less.

Summary of Bioenergy Supplies From Agriculture

- FAPRI land use for corn and soybeans increases to 156.65 million acres, while De La Torre Ugarte et.al. reduce corn and soybean acres planted to 146.7 million.

- Given development of grain ethanol and biodiesel industries, I assume FAPRI acreages and reduce, switchgrass production. 188.1-57.7=130.4 tons

Summary of Bioenergy Supplies From Agriculture (cont.)

Source	Units	Production		
		No. Units	% 0f 2004 Use	Quads
Grain Ethanol	Bill. Gal.	7.0		
Lignocellulosic Ethanol	Bill. Gal.	23.9		
Total Ethanol	Bill. Gal.	30.9	22.7	2.35
Biodiesel	Mill. Gal.	260	0.6	0.03
Lignocellulosic Electricity	Mill. Megawatt Hrs.	53.4		
Wind Energy	Mill. Megawatt Hrs.	237.2		
Total Electricity	Mill. Megawatt Hrs.	290.6	7.35	2.96
Total Quads				5.34

Summary of Bioenergy Supplies From Agriculture (cont.)

- The total of 5.34 Quads

  - is based on yields through 2012, not further into the future.

  - Would require developing an industry to convert biomass into ethanol and electricity.

  - Requires a 17–fold increase in electricity from wind power.

- All lignocellulosic biomass could be used to produce electricity and no ethanol, producing 427.1million megawatt-hours. This would reduce ethanol to 5.2% and increase electricity to 16.8 % of 2004 U.S. consumption. This would produce 7.34 quads.