3.3 Energy

Agriculture uses energy directly for operating machinery and equipment on the farm and indirectly in fertilizers and pesticides produced off the farm. Since a 1978 peak, total energy use in agriculture (excluding electricity) fell by 25 percent to 1.6 quadrillion British thermal units (Btu) in 1993, due to improved energy efficiency. An additional 1 quadrillion Btu of energy is used by the food processing industry. Agriculture also supplies renewable energy in the form of biomass for electricity generation and as feedstocks, mostly corn, for production of alternative fuels such as ethanol.

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Different types of energy are often required for different activities in food production. Energy used to produce food is classified as either direct or indirect. Direct energy, mostly refined petroleum products, is used on farms for planting and harvesting, fertilizer and pesticide application, and transportation, while electricity is used for irrigation and other purposes. Dairies require a major input of electricity for cooling milk, operating milking systems, and supplying hot water for sanitation. Indirect energy, on the other hand, is consumed off the farm for manufacturing fertilizers and pesticides. In addition, substantial amounts of energy, including natural gas, oil, electricity, and coal, are used in manufacturing or processing of food after it leaves the farm. Most food processing firms use energy to provide steam, hot water, and process heating.

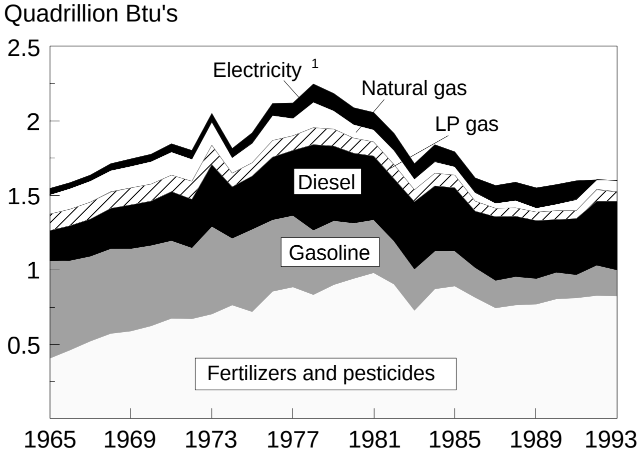
The agricultural sector also supplies energy. The Clean Air Act Amendment of 1990 (CAA) has increased the demand for ethanol—already used as a fuel extender and octane enhancer—by requiring oxygenates in about 35 percent of the Nation's gasoline. Ethanol primarily uses corn as a feedstock, but can use other biomass as well. On a larger scale, biomass from agricultural and forestry sources is used directly as fuel for electricity generation.

Energy Use in Agricultural Production

Agricultural energy use peaked at 2.2 quadrillion Btu in 1978. However, oil price shocks during the late 1970's and early 1980's forced farmers to become more energy-efficient. Many farmers have switched from gasoline-powered to fuel-efficient diesel-powered engines, adopted energy-conserving tillage practices, shifted to larger multifunction machines, and adopted energy-saving methods of crop drying and irrigation. Between 1978 and 1993, energy (excluding electricity) used by agriculture declined 25 percent, primarily due to a reduction in the direct use of energy (gasoline, diesel, liquefied petroleum or LP gas, and natural gas); energy used to produce fertilizers and pesticides declined only slightly. (Separate electricity expenditures in agriculture have not been available since 1991.)

In addition, the composition of energy use has changed significantly. Gasoline use has dropped from 42 percent of total energy use in 1965 to only 11 percent in 1993, while diesel's share of diesel fuel has risen from 13 percent to 29 percent (fig 3.3.1). This

Figure 3.3.1--Composition of energy use in agriculture, 1965-93



[1] No data on electricity use since 1991.

Source: USDA, ERS.

change reflects the shift away from gasoline-powered machinery toward more efficient, diesel-powered machinery.

While farm energy use declined by 25 percent between 1978 and 1993, agricultural output increased by almost 47 percent (in 1987 dollars, Economic Report of the President, 1995). As a result, the ratio of energy use to agricultural output fell by 50 percent between 1978 and 1993.

Demand for refined petroleum products such as diesel fuel, gasoline, and LP gas in agricultural production is determined mainly by the number of acres planted and harvested, price of energy, and weather. Farm fuel use in 1994 was greater than in 1993. Diesel fuel use, at 3.5 billion gallons, was up 6 percent from 1993 while LP gas, at 0.9 billion gallons, increased 3 percent (table 3.3.1). This increase was due principally to lower fuel prices and a slight increase in the number of acres planted and harvested. Gasoline consumption, at 1.4 billion gallons, was unchanged from the 1993 level.

Farm fuel prices in the United States are heavily influenced by international market conditions, particularly crude oil supplies by the Organization of Petroleum Exporting Countries (OPEC). Historically, each 1-percent increase in the U.S. price of imported crude oil has translated into a 0.7-percent rise in the farm price of gasoline and diesel fuel. Following the Arab Oil Embargo of 1973-74, world oil prices rose rapidly. They escalated again due to the Iranian crisis in 1979, peaked in 1981, then fell

Table 3.3.1—Fuel purchased for farm use, 1974-94[1]

Year	Gasoline	Diesel	LP gas
		Billion gallons	
1974	3.7	2.6	1.4
1975	4.5	2.4	1.0
1976	3.9	2.8	1.2
1977	3.8	2.9	1.1
1978	3.6	3.2	1.3
1979	3.4	3.2	1.1
1980	3.0	3.2	1.1
1981	2.7	3.1	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	3.0	0.6
1988	1.6	2.8	0.6
1989	1.3	2.5	0.7
1990	1.5	2.7	0.6
1991	1.4	2.8	0.6
1992	1.6	3.1	0.9
1993	1.4	3.3	0.7
1994	1.4	3.5	0.9

[1] Excludes Alaska, Hawaii, and fuels used for household and personal business.

Source: USDA, ERS, based on NASS, Farm Production Expenditures Summaries, and unpublished data.

steadily until 1985, and fell sharply in 1986 due to a glut of oil in the world market. Oil prices rose sharply again in 1990 and 1991 following the Persian Gulf war and have since been falling gradually. Farm gasoline prices mirrored world oil prices, rising, for example, from 47 cents per gallon in 1974 to $1.29 in 1981. Between 1992 and 1994, gasoline prices fell steadily, then rose slightly in 1995 (table 3.3.2). During the first half of 1996, gasoline prices were on the rise due to increased seasonal demand.

Farm fuel expenditures represented 3.5 percent of total farm production expenses in 1994, down from 3.6 percent in 1993 (table 3.3.3). In 1994, farm fuel expenditures totaled $5.55 billion, an increase of less than 1 percent from 1993. An increase in the number of acres planted and harvested in 1994, even with lower energy prices, accounted for this slight increase in total expenditures. The Corn Belt, at $1.02 billion, was the farm production region with the highest total energy expenditures, followed by the Northern Plains at $704 million (fig. 3.3.2). Farm expenditures for

Table 3.3.2—Average U.S. farm fuel prices, 1974-95[1]

Year	Gasoline[2,3]	Diesel[3,4]	LP gas[3]
		$/gallon[5]	
1974	0.47	0.37	0.30
1975	0.50	0.39	0.30
1976	0.53	0.41	0.33
1977	0.57	0.45	0.39
1978	0.60	0.46	0.40
1979	0.80	0.68	0.44
1980	1.15	0.99	0.62
1981	1.29	1.16	0.70
1982	1.23	1.11	0.71
1983	1.18	1.00	0.77
1984	1.16	1.00	0.76
1985	1.15	0.97	0.73
1986	0.74	0.58	0.55
1987	0.92	0.71	0.59
1988	0.93	0.73	0.59
1989	1.05	0.76	0.58
1990	1.17	0.95	0.83
1991	1.19	0.87	0.75
1992	1.15	0.82	0.72
1993	1.14	0.82	0.78
1994	1.08	0.77	0.72
1995[6]	1.11	0.77	0.73

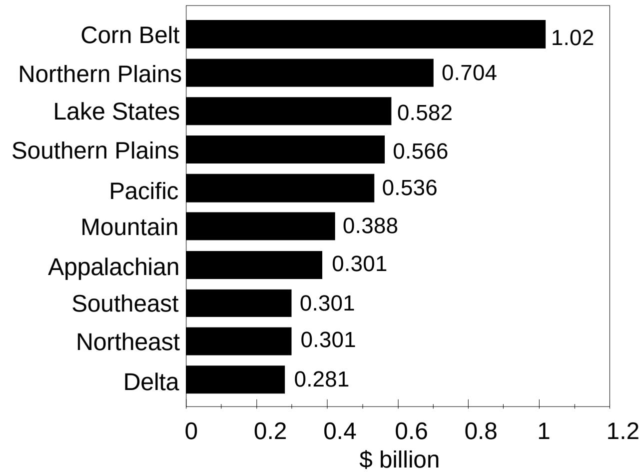
[1] Based on surveys of farm supply dealers conducted by the National Agricultural Statistics Service (NASS), USDA.
[2] Leaded regular gasoline survey item discontinued after 1992, and unleaded gasoline survey item added January, 1993.
[3] Includes Federal, State, and local per gallon taxes.
[4] Excludes Federal excise tax.
[5] Bulk delivery.
[6] Prices based on April 1995 survey of farm supply dealers conducted by NASS, USDA.
Source: USDA, ERS.

electricity were an additional $2.33 billion in 1991, the last year separate data were gathered. If a similar expenditure for electricity occurred in 1994, total farm energy expenditures would be $7.9 billion or 4.9 percent of total farm production expenses.

Energy Use in Food Processing

Energy is an important input to manufacturing and processing food after it leaves the farmgate. Food and kindred products, SIC (Standard Industrial Classification) 20, is the Nation's largest manufacturing sector with the value of its shipment as high as $404 billion in 1993. The sector's firms process foods and beverages largely for human consumption, as well as related products such as animal feed. Food manufacturing and processing firms use power-driven machines and material-handling equipment and, in 1991, consumed 4.7 percent (1 quadrillion Btu) of total energy.

Figure 3.3.2--Farm sector fuel expenditures, by region, 1994



Source: USDA, ERS, based on NASS, Farm Production Expenditures, 1994 Summary.

Industries within the food and kindred products sector use different types of energy and at various intensities. Eight industries of the sector's 49 accounted for nearly half of the total energy consumed (table 3.3.4). The most common energy sources are natural gas, electricity, coal, LP gas, and residual and distillate fuel oil. Beet sugar is the most energy-intensive industry at 28,300 Btu per dollar of shipments, compared with meat packing at 1,000 Btu.

The sector's output rose 25 percent between 1977 and 1991, while its energy use fell 2 percent, mainly due to improvements in efficiency such as waste heat recovery and the substitution of membrane separation for thermal separation.

Energy from Agricultural Biomass

Biomass (plant and animal matter) includes a broad range of biological materials—such as agricultural and forestry products and wastes including animal manure—that can be used to produce energy. These feedstocks may be used for direct combustion, gasified, and/or processed into biofuels such as ethanol, methanol, ethyl or methyl esters, methane, and biocrude. Biomass could provide clean energy and thereby reduce the emissions of greenhouse gases and other pollutants.

Table 3.3.3—Farm energy expenditures, 1980-94

Year	Gasoline	Diesel	LP gas	Other	Total fuel	Fuel share of farm production expense	Electricity: Non-irrigation	Electricity: Irrigation	Total energy
			$billion			*Percent*		*$billion*	
1980	3.31	3.12	0.67	0.82	7.92	5.9	1.22	0.54	9.68
1981	3.36	3.35	0.70	0.81	8.22	6.2	1.32	0.66	10.20
1982	2.87	3.25	0.76	0.85	7.73	5.9	1.42	0.69	9.83
1983	2.64	3.15	0.66	0.89	7.34	5.6	1.62	0.59	9.55
1984	2.40	3.06	0.72	0.82	7.00	5.4	1.64	0.59	9.23
1985	2.16	2.92	0.69	0.68	6.45	5.1	1.56	0.65	8.68
1986	1.51	2.04	0.49	0.65	4.33	4.1	1.42	0.58	6.69
1987	1.37	2.13	0.38	0.47	4.35	3.9	2.03	0.43	6.81
1988	1.42	2.12	0.38	0.53	4.45	3.8	2.17	0.48	7.10
1989	1.44	2.12	0.38	0.51	4.45	3.6	1.69	0.64	6.78
1990	1.65	2.42	0.53	0.57	5.14	3.9	1.65	0.65	7.47
1991	1.50	2.34	0.44	0.65	4.93	3.8	1.57	0.76	7.25
1992	1.72	2.65	0.65	0.63	5.65	3.9	na	na	na
1993	1.58	2.69	0.58	0.67	5.52	3.6	na	na	na
1994	1.50	2.70	0.62	0.73	5.55	3.5	na	na	na

na = not available.

Source: USDA, ERS, based on NASS, Farm Production Expenditures, 1980-1994 Summaries. Data for 1992-94 are from the NASS, unpublished data.

Table 3.3.4—Consumption of energy by industry group, 1991

Standard Industrial Classification	Industry group[1]	Total	Net electricity[2]	Residual fuel oil	Distillate fuel oil[3]	Natural gas[4]	LP gas	Coal
					Trillion Btu			
20	Food and kindred products	956	169	27	17	W	5	154
2011	Meatpacking plant	49	12	1	1	32	1	1
2033	Canning fruits & vegetables	44	5	2	1	36	*	Q
2037	Frozen fruits & vegetables	40	10	2	*	26	*	0
2046	Wet-corn milling	140	14	*	*	52	*	68
2051	Bread, cake, & related prod.	32	8	*	1	23	*	0
2063	Beet sugar	67	1	W	*	19	*	43
2075	Soybean oil	51	6	*	*	25	*	13
2082	Malt beverage	50	8	3	*	23	*	16

[1] Only the eight largest subcategories of food and kindred products are shown.

[2] "Net electricity" is the sum of purchases in and generation from noncombustible renewable resources, minus quantities sold and transferred out.

[3] Includes Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.

[4] Includes natural gas obtained from utilities, transmission pipe lines, and any other supplier(s) such as brokers and producers.

* Estimate less than 0.5.

Q = Withheld because of relative standard error greater than 50 percent.

W = Withheld to avoid disclosing data for individual establishments.

Source: USDA, ERS, based on U.S. Department of Energy/Energy Information Administration, 1994.

With the improvement in technologies, many agricultural products are now used for producing electricity and liquid fuel for transportation. In 1993, over three quadrillion Btu of biomass energy were consumed in the United States, representing about 3.7 percent of total U.S. energy consumption. Energy from wood accounted for 87 percent of total biomass energy consumption, while energy from solid waste and corn-ethanol made up 10 and 3 percent. Wood was consumed in the United States for industrial and utility (two-thirds) as well as residential use (one-third). Wood energy use in the commercial sector was estimated to be over 20 billion Btu in 1986, the last year of available data.

Consumption of wood in the residential sector has been declining, due to people moving from rural to urban areas; the scarcity of inexpensive fuel wood; environmental restrictions on the burning of wood, especially in populated areas; and the emergence of clean-burning and more efficient gas fireplaces.

Biomass Electricity

During the 1980's national interest grew in wood-burning electric-generating plants as a result of the National Energy Policy Act and state utility regulatory actions. More than 5,800 megawatts of power from wood-fueled electricity were added to the 200 existing in 1979. Of nearly a thousand wood-fired plants ranging from 1 to over 100 megawatts, only a third offer electricity for sale. The rest are owned and operated by paper and wood production industries for their own use.

Biomass-based electricity is most economical in those regions where electricity is relatively expensive and wood is cheap.

Despite rapid growth in the 1980s, the biomass power industry is now in a low-growth phase because of low fossil fuel prices, excess capacity, competitive bidding for power sales, and costly permitting procedures. Competition from efficient natural gas-turbine generators has also dampened the market for biomass projects. Natural gas has benefited from its low investment cost per kilowatt hour (Kwh), affordability and abundance due to new drilling technology, and ability to burn cleaner than coal, wood, and oil.

Energy crops (wood and grass) could become important feedstocks for the production of liquid fuels, electricity, chemicals, and other industrial products. With increases in yield and competitive conversion technologies, biomass crops such as herbaceous plants and wood might compete with fossil fuels for a broad range of uses. A biomass industry could also provide new income for farmers, jobs in rural areas, and markets for agricultural residues. Key to this scenario are increases in fossil fuel prices; more rapid advances in biomass gasification, gas clean-up, and gas-turbine power generation; and market development for biomass coproducts such as pulp wood chemicals. Policies that restrict greenhouse gas emissions or promote biomass production on idled land could also help.

Fuel Ethanol Production Processes

Ethanol is produced from corn by two standard production processes: wet- and dry-milling. With the exception of the initial separation process, the two processes are very similar. In dry-milling, the first step consists of grinding the corn, which is then slurried with water to form the mash and cooked. Enzymes convert the starch in the mash to sugar and, in the next stage, yeast ferment the sugars to produce beer. In the dry-mill process, the beer, containing alcohol, water, and dissolved solids, is separated from solids. It is then distilled and dehydrated to create anhydrous ethanol. The solids are dried and sold as distillers' dried grain with solubles (DDGS), commonly used as an animal protein feed. Using current technology, a bushel of corn when processed will yield 2.6 gallons of fuel-grade ethanol and 16.5-17.5 lbs. of DDGS. Carbon dioxide may also be collected from a fermentation tank.

In wet-milling, the first step involves soaking the corn kernels in water and sulfur dioxide and separating the corn into its major components: the germ, fiber, gluten, and starch. All other components of the corn kernel are removed prior to fermentation of starch. These components are used to produce three coproducts: corn oil, corn gluten feed (CGF), and corn gluten meal (CGM). A bushel of corn, when processed by wet-milling, can produce 1.6 lbs. of corn oil, 12.5 lbs. of CGF, and 2.5 lbs. of CGM. The remaining starch is saccharified, fermented, and distilled as in the dry-milling production process.

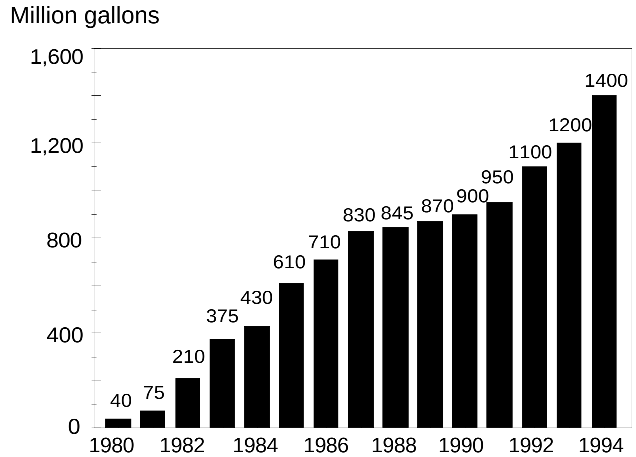
The Federal Government offers incentives for commercially competitive biomass energy, including unconventional fuel credits (99.3 cents per million Btu); power production tax credits (1.6 cents per kwh); alcohol fuel credits (60 cents per gallon of ethanol or methanol from biomass, in addition to 10 cents per gallon for “small” ethanol producers); accelerated depreciation (5 years versus 15-20 years) for certain biomass energy facilities; tax-exempt financing; cash subsidies (1.5 cents per kwh); and investment tax credits (6.5 percent) for growing energy crops exclusively for conversion of biomass to electricity (direct combustion and gasification) and liquid fuels. Given its uncertain competitiveness, biomass depends on projects that successfully demonstrate its utility for energy production in the United States. The U.S. Department of Energy (DOE) and the U.S. Department of Agriculture (USDA) are collaborating to develop technologies and to foster business arrangements that integrate electricity generation and rural development through biomass-based renewable energy (see chapter 5.1, *Agricultural Technology Development*). USDA will participate in these projects using existing authorities and programs, and DOE will share costs under authority of the Energy Policy Act of 1992 and the President’s Climate Change Action Plan.

Fuel Ethanol

The oil embargoes of 1973 and 1979 renewed interest in alcohol fuels, primarily fuel ethanol from grain. Energy security, new Federal gasoline standards, and government incentives have driven the grain-based fuel ethanol industry. When the energy crisis first exposed U.S. vulnerability to energy supply interruptions, fuel ethanol from agricultural resources was viewed only as a potential gasoline extender. In 1990, ethanol emerged as an octane enhancer after the Environmental Protection Agency (EPA) began to phase out lead in gasoline. More recently, ethanol production received a major boost with the passage of EPA’s Clean Air Act Amendments (CAA) of 1990 establishing the Oxygenated Fuels Program and Reformulated Gasoline (RFG) Program to control carbon monoxide (CO) and to mitigate ground-level ozone problems. Both programs require oxygen levels in gasoline of 2.7 percent (by weight) for oxygenated fuel and 2.0 percent for reformulated gasoline. The three leading oxygen additives are ethanol; ethyl tertiary butyl ether (ETBE), made from ethanol; and methyl tertiary butyl ether (MTBE) made from methanol, which is derived from natural gas.

Adding ethanol, ETBE, or MTBE to gasoline to create "oxygenated" blends reduces the amount of CO released into the atmosphere. These three additives compete closely for markets. Methanol had been a cheaper oxygen additive than ethanol, but RFG programs and other chemical applications increased the demand for methanol, pushing methanol prices to $1.40 per gallon in 1994 from 35 cents in 1993. A temporary shutdown of a large methanol producing plant due to an explosion also caused methanol prices to rise. That gave ethanol, a substitute for methanol, a temporary boost. The methanol situation is expected to ease in 1997 as additional capacity comes on line. In addition, the Treasury Department announced in 1994 that the ethanol portion of ETBE was eligible for an exemption from the Federal excise tax of 18.4 cents per gallon, now available to ethanol. As gasoline blended with ETBE contains 5.6 percent ethanol, the tax break per gallon of ETBE amounts to 3 cents. For gasohol (gasoline containing 10 percent ethanol), the exemption is 4.5 cents. This ruling increased ETBE’s competitiveness with other qualifying alcohols in the RFG market. Ethanol’s competitiveness will also improve as producers adopt energy-efficient technologies and other cost-saving innovations.

Figure 3.3.3--U.S. ethanol production, 1980-94



Source: USDA, ERS, based on Renewable Fuels Association, 1994.

Fuel ethanol production in the United States has grown from just a few thousand gallons in the mid-1970’s to 1.4 billion gallons in 1994 (fig. 3.3.3). As of July 1995, U.S. fuel ethanol industry was comprised of 41 operational facilities in 15 States. Several large producers dominate the industry. Archer Daniels Midland alone had 59 percent of U.S. annual operational production capacity (1.7 billion gallons) in 1995. About 71 percent of fuel ethanol’s production capacity is in the Corn Belt region, followed by the Northern Plains with 14 percent. U.S. ethanol production capacity is nearly 2.2 billion gallons per year, including capacity under construction or in the engineering/financing stage and capacity which is shut down at present. The two main processes for producing ethanol from corn are wet-milling and dry-milling (see box, "Fuel Ethanol Production Processes," p. 139). Wet-milling accounts for about 60 percent of total ethanol production.

Ethanol production costs vary greatly, depending largely on net feedstock cost (grain cost minus value of byproducts). For 1981-91, net feedstock cost ranged from 10 to 67 cents per gallon of ethanol, due mainly to large swings in the price of corn ($1.58 to $3.16 per bushel). Changes in coproduct prices also contributed to this variation. Together, capital and operating costs for wet milling ranged from 78 cents to $1.07 per gallon, bringing the cost of ethanol to $0.88-1.74 per gallon. With an expected price of corn of about $3 per bushel in the 1995/96 marketing year, total cost of producing ethanol could rise 20 to 23 cents per gallon due to higher net corn cost, lowering its competitiveness with other fuels. Higher corn prices have reduced profits for fuel ethanol producers and, consequently, production has been cut. In May 1996, the market price of corn reached a record $4.98 per bushel and some large ethanol producers further cut back production.

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Recent ERS Reports on Energy Issues

Farm Energy, AREI Update, 1995 No. 16 (Mohinder Gill). Farm fuel prices are influenced by crude oil prices especially imported crude oil. In 1994, compared with 1993, farm fuel prices fell by 5 - 8 percent as the imported crude oil price fell by 4 percent. Farm energy expenditures, at $5.56 billion in 1994, were 1 percent less, compared with 1993 an estimated 5.8 billion gallons of fuel was consumed in 1994, 7 percent higher than 1993, because of increased planted acreage.

"The Agricultural Demand for Electricity in the United States," *International Journal of Energy Research*, 1995 Vol. 19 (Noel D. Uri and Mohinder Gill). The price of electricity is a factor impacting the quantity of electricity demanded by farmers for irrigation and nonirrigation uses, but there is no indication that other types of energy are substitutes for electricity. Number of acres irrigated and number of acres planted are important factors driving the demand for electricity for irrigation and nonirrigation uses.

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