Chapter 5: Energy Use in Agriculture

5.1 Sources of Greenhouse Gas Emissions from Energy Use on Agricultural Operations

Agriculture operations, such as crop and livestock farms, dairies, nurseries and greenhouses, use energy from a variety of sources. Energy use depends in part on the size and sort of agricultural operation and trends in fuel costs. While energy use in agriculture causes CO_2 emissions, this source is small relative to the total U.S. emissions of CO_2 from energy.

Energy is used directly in agriculture for a range of purposes, including operating vehicles and irrigation pumps, and controlling indoor temperatures of greenhouses, barns, and other farm buildings. Crop production requires a large amount of liquid fuel for field operations. Most large farms use diesel-fueled vehicles for tilling, planting, cultivating, disking, harvesting, and applying chemicals. Gasoline is used for small trucks and older harvesting equipment primarily. Smaller farms are more likely to use gasoline-powered equipment, but as farms get larger they tend to use more diesel fuel. In addition, energy is used in some operations to dry crops such as grain, tobacco, and peanuts; and livestock operations use energy to operate various types of equipment. Indirectly, GHG emissions result from energy consumption and other processes in manufacturing of agricultural inputs such as fertilizer, lime, and other soil amendments. These indirect emissions are not detailed in this inventory. The U.S. GHG Inventory addresses energy and non-energy processes in industry and manufacturing by general end-use sectors rather than specific end uses such as agriculture.

While many irrigation systems in the United States are gravity flow systems that require little or no energy for water distribution, irrigation systems that use pumps to distribute water use energy. Based on the most recent USDA Farm and Ranch Irrigation Survey, in 1998 about 38 million acres of U.S. farmland were irrigated with pumps powered by liquid fuels, natural gas, and electricity, costing a total of $1.2 billion ($32 per irrigated acre) (USDA NASS 1999b). Electricity was the main power source for these pumps, costing $801 million for 20 million acres. Diesel fuel was used to power pumps on about 10 million acres and natural gas was used on about 6 million acres.

The area of land irrigated can vary substantially from year to year, depending on environmental conditions. For example, in 1998, 50 million acres of farmland in the United States were irrigated (including gravity flow irrigation), about 4 million acres more than were irrigated in 1994 (USDA NASS 1999b). Corn for grain or seed, alfalfa hay, cotton, soybeans, and orchard land (e.g., fruit trees, vineyards, and nut trees) required the most water in 1998, accounting for 57% of all irrigated land. California irrigated the most land, covering about 8.1 million acres of farmland in 1998. Other leading irrigation States include Nebraska, Texas, and Arkansas.

The amount and type of energy used in agriculture operations affect CO_2 emissions. Generally CO_2 levels increase with higher energy use. Some fuels have higher carbon content than others, resulting in higher CO_2 emissions per Btu burned (Table 5-1). However, some fuel/engine applications are more energy efficient than others and require less fuel to perform similar operations. For example, diesel fuel has a higher Btu content than natural gas on a volumetric basis and diesel engines have a higher performance rating compared to engines designed to run on natural gas. Therefore, even though diesel fuel has higher carbon content per Btu compared to natural gas, using diesel engines to perform some farm operations may result in lower CO_2 emissions.

Table 5-1 Energy use and carbon dioxide emissions by fuel source on U.S. farms, 2001

Fuels	Energy con-sumed		Carbon content	Fraction oxidized	CO_2 emissions
	Trillion Btu	*Qbtu*	*Tg C/ Qbtu*		*Tg CO_2 eq.*
Diesel	484	0.484	19.95	0.99	35.04
Gasoline	144	0.144	19.34	0.99	10.11
LP gas	66	0.066	16.99	0.99	4.07
Natural gas	58	0.058	14.47	0.995	3.06
Electric-ity	370	0.37	**	**	58.81
Total	1,122	1.122			111.09

** Varies depending on fuel used to generate electricity and heat rate of the power generating facility.

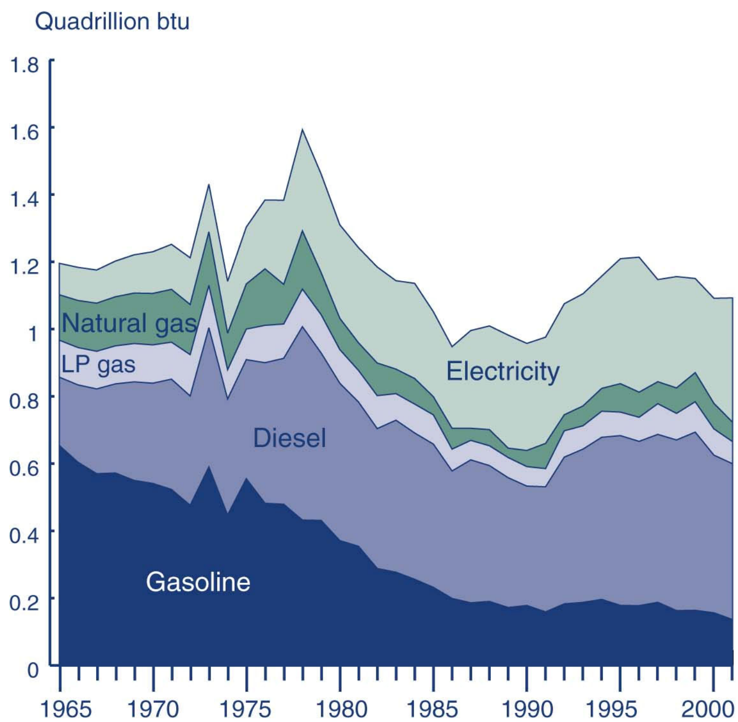
Electricity is generated from multiple fuels, the proportions of which may vary from year to year, affecting overall emissions. It is assumed that electricity used on agricultural operations is generated from coal, natural gas, or petroleum. Emission factors are higher for fuels when they are used to generate electricity because there is a heat loss associated with various power generating facilities.

5.2 Summary of Greenhouse Gas Emissions from Energy Use in Agriculture

Over 1 Qbtu of energy was used directly in agriculture in 2001, resulting in about 111 Tg CO_2 emissions (Table 5-1). The same year, total energy consumption for all sectors in the United States, including agriculture, was 82 Qbtu, resulting in emissions of 5,597 Tg CO_2. Agriculture's contribution to this total was very small at about 2 percent. Within agriculture, electricity accounted for about 53 percent and diesel fuel for about 31 percent of CO_2 emissions from energy use (Table 5-1). Gasoline consumption accounted for about 9 percent of CO_2 emissions, while liquefied petroleum (LP) gas and natural gas accounted for about 4 percent, and 3 percent respectively.

Emissions from fuel consumption vary regionally across the United States. The highest emissions are in the Northern Plains and Corn Belt States (Table 5-2). Intermediate emissions occur in the Pacific, Southern Plains, Mountain, and Lake States. Relatively small emissions are estimated for the Southeast, Northeast, Delta, and Appalachian States. There is a strong correlation between production and energy use/emissions. The States with the most agricultural production use the most energy.

Figure 5-1
Energy use in agriculture by source, 1965-2001



5.3 Long-term Trends in Greenhouse Gas Emissions from Energy Use in Agriculture

Agricultural energy use and resulting CO_2 emissions grew throughout the 1960s and 1970s, peaking in the late 1970s (Figure 5-1). High prices, stemming from the oil crisis of the late 1970s and early 1980s, led farmers to be more energy-efficient, driving a decline in energy use and CO_2 emissions throughout most of the 1980s. This decline is attributed to switching from gasoline-powered to more fuel-efficient diesel-powered engines, adopting energy-conserving tillage practices, shifting to larger multifunction machines, and adopting energy-saving methods of crop drying and irrigation (Uri and Day 1991; USDA ERS 1994). Farm energy use leveled off in the late 1980s as energy prices subsided (Figure 5-1). Since 1990 there has been a small upward trend in energy use; however, farm energy used today is still well below the peak levels of the 1970s. Moreover, energy productivity, i.e., output per unit of energy input, has increased significantly.

One of the most notable changes in farm energy consumption over the past 30 years is the substitution of diesel fuel for gasoline (Figure 5-2). Gasoline use dropped from 41 percent of total energy used on farms in 1965 to only 8 percent in 2001, while diesel's share of total energy rose from 13 to 28 percent. Producers switched to diesel fuel equipment as farms grew in size—average farm size in 1965 was 340 acres compared to 434 acres in 2000 (USDA NASS 2002). As farmers scaled up their operations they began to purchase large-scale equipment with more horsepower. Heavy-duty vehicles generally are powered by diesel engines because they are more energy efficient than gasoline engines (Uri and Day 1991). Diesel-powered equipment has become the standard on U.S. farms.

Another major change in farm energy consumption began around 1979 when automobile manufacturers began producing more fuel-efficient vehicles. Laws such as the Energy Policy and Conservation Act of 1975 increased average fuel economy standards and both gasoline- and

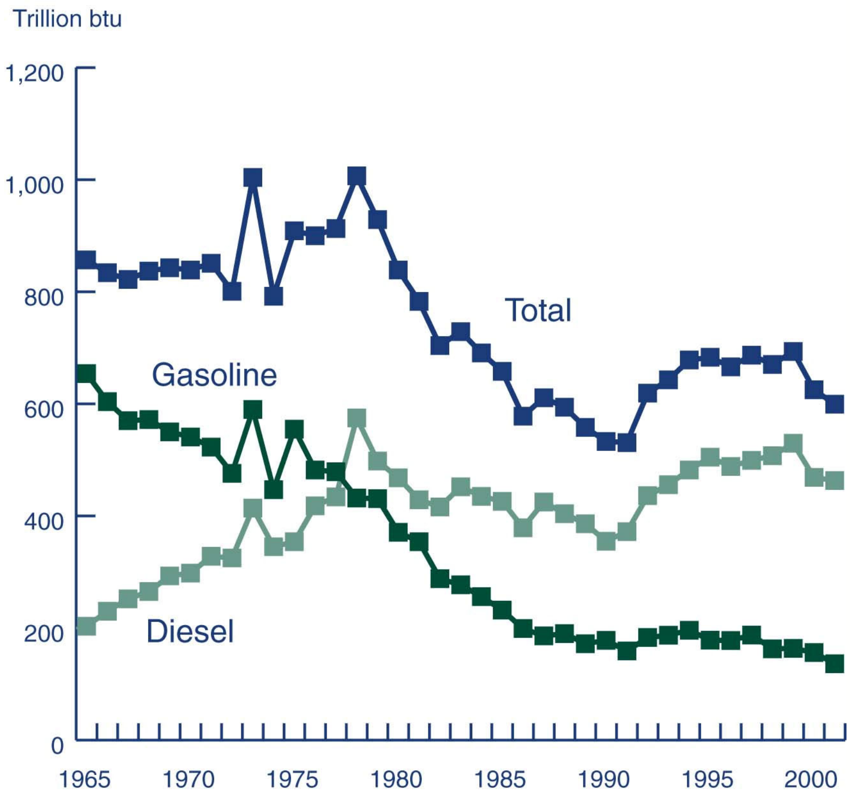
Table 5-2 CO_2 emissions from energy use in agriculture, by region, 2001

Region	States	Energy Emissions
		Tg CO_2 eq.
Northeast	Maine	5.4
	New Hampshire	
	Vermont	
	Massachusetts	
	Rhode Island	
	Connecticut	
	New York	
	New Jersey	
	Pennsylvania	
	Delaware	
	Maryland	
	District of Columbia	
Lake States	Michigan	12.9
	Wisconsin	
	Minnesota	
Corn Belt	Ohio	18.5
	Indiana	
	Illinois	
	Iowa	
	Missouri	
Northern Plains	North Dakota	17.6
	South Dakota	
	Nebraska	
	Kansas	
Appalachian	Virginia	8.2
	West Virginia	
	North Carolina	
	Kentucky	
	Tennessee	

Region	States	Energy Emissions
		Tg CO_2 eq.
Southeast	South Carolina	6.2
	Georgia	
	Florida	
	Alabama	
Delta States	Mississippi	6.3
	Arkansas	
	Louisiana	
Southern Plains	Oklahoma	12.2
	Texas	
Mountain	Montana	11.6
	Idaho	
	Wyoming	
	Colorado	
	New Mexico	
	Arizona	
	Utah	
	Nevada	
Pacific	Washington	12.3
	Oregon	
	California	

Note: Does not include Alaska and Hawaii.

Figure 5-2
Gasoline and diesel fuel used on farms, 1965-2001



diesel-powered equipment became increasingly energy efficient throughout the 1980s and 1990s. This is reflected in Figure 5-2, which shows total fuel consumption peaking in 1978 at about 1 Qbtu and falling to a low of 531 trillion btu in 1991.

The adoption of energy-conservation tillage practices has contributed to decreasing fuel use on farms in the United States. Conservation tillage leaves roughly 30 percent of plant residues on the soil surface after planting. It requires far less energy than conventional-till, which involves extensive field preparation prior to planting, and removes 70 percent or more of the plant residue from the soil (Lin et al. 1995). In the most extreme case, using a moldboard plow for conventional-till, almost 100 percent of the plant residue is removed. Adoption of conservation-till on major field crops, such as corn and soybeans, began to increase significantly in the 1980s. For example, on corn acreage between 1987 and 1992, the use of the moldboard plow declined from 21 to 12 percent and conventional tillage without the moldboard plow dropped from 60 to 49 percent (Lin et al. 1995). Conservation tillage methods, such as mulch-till, increased from 14 to 25 percent, and no-ridge-till rose from 5 to 14 percent.

5.4 Methods for Estimating CO_2 Emissions from Energy Use in Agriculture

CO_2 emission estimates for energy use are constructed from fuel consumption data using standardized methods published in the U.S. GHG Inventory (EPA 2003a). Emission estimates from fuel use in agriculture are not explicitly published in the U.S. GHG Inventory; however, they are contained in the estimates of fuel consumption and emissions by sectors. The emissions estimates presented in this chapter were prepared separately from the U.S. GHG Inventory.

Estimates of CO_2 emissions from agricultural operations are based on energy data from the Agricultural Resource Management Survey (ARMS) conducted by the National Agricultural Statistics Service (NASS) of the USDA. The ARMS collects information on farm production expenditures including expenditures on diesel fuel, gasoline, LP gas, natural gas, and electricity (USDA NASS, 2001b). NASS also collects data on prices paid by farmers for gasoline, diesel, and LP gas (USDA NASS 2001b). Energy expenditures and fuel prices are used to approximate consumption by dividing expenditures by purchase prices. NASS aggregates individual State data into 10 production regions, allowing for fuel consumption to be estimated at the national and regional levels. Electricity and natural gas prices, which are not collected by NASS, are from the Energy Information Administration (DOE EIA) of the Department of Energy that reports average electricity and natural gas prices by State (DOE EIA 2001). State-level price data were aggregated by NASS region to produce estimates of regional prices.

Table 5-3 Average emission factors for 1998-2000 by utility and non-utility generators by USDA NASS regions

Region	tons CO_2/MWh
Appalachian	0.767
Corn Belt	0.843
Delta States	0.616
Lake States	0.792
Mountain	0.781
Northeast	0.534
Northern Plains	0.843
Pacific	0.224
Southeast	0.636
Southern Plains	0.749

Following the method outlined in Annex A of the U.S. GHG Inventory (EPA 2003a), consumption of diesel fuel, gasoline, LP gas, and natural gas was converted to CO_2 emissions using coefficients for carbon content of fuels and fraction of carbon oxidized during combustion, both of which are published in Annex A of EPA (2003a) and provided in Table 5-1. These carbon content coefficients were derived by EIA and are similar to those published by the Intergovernmental Panel on Climate Change (IPCC). For each fuel type, fuel consumption in units of Qbtu was multiplied by the carbon content coefficient (Tg C/Qbtu) to estimate Tg of carbon contained in the fuel consumed. This value is sometimes referred to as "potential emissions" because it represents the maximum amount of carbon that could be released to the atmosphere if all carbon were oxidized (EPA 2003a). However, only a portion of the carbon is actually oxidized during combustion. Table A-15 in Annex A of the U.S. GHG Inventory provides coefficients for the fraction of carbon oxidized during combustion by fuel type (EPA 2003a). These coefficients are also shown in Table 5-1 of this report. It is assumed that 100 percent of the carbon oxidized is emitted to the atmosphere as CO_2. CO_2 emissions are estimated by multiplying potential emissions by the fraction of carbon oxidized for each fuel type.

A different approach was used to estimate emissions from electricity, since a number of fuel sources can be used to generate electricity. Also, fuel sources vary significantly by region; for example, some regions of the country rely more on coal for electricity generation, while other regions use more natural gas to generate electricity. The mix of fuel sources used in a region can change from year to year. To address this variation, CO_2 emissions from electricity generation were derived from adjusted emission factors obtained from EIA. EIA typically reports CO_2 emissions from electricity generation by State and U.S. Census Region (DOE EIA 2002). In response to a special request from USDA, EIA aggregated their State emission factors into the NASS production regions. The regional-level electricity emission factors represent average CO_2 emissions generated by utility and non-utility electric generators for the 1998-2000 time period (Table 5-3). These regional emission factors were multiplied by estimated electricity use in each NASS farm production region to calculate CO_2 emissions.