Chapter 5: Energy Use in Agriculture

5.1 Summary of Greenhouse Gas Emissions from Energy Use in Agriculture

Almost one quadrillion btu of direct energy was used for agriculture in 2005, resulting in about 69 Tg of CO_2 emissions (Table 5-1). The same year, total energy consumption for all sectors in the U.S., including agriculture, was approximately 96 quadrillion btu, resulting in 5943Tg of CO_2 emissions (EPA 2007). Production agriculture's contribution to this total was very small at a little more than 1%. Within agriculture, diesel fuel accounted for about 43% and electricity for about 33% of CO_2 emissions from energy use. Gasoline consumption accounted for about 13% of CO_2 emissions, while LP gas and natural gas accounted for about 7% and 4%, respectively.

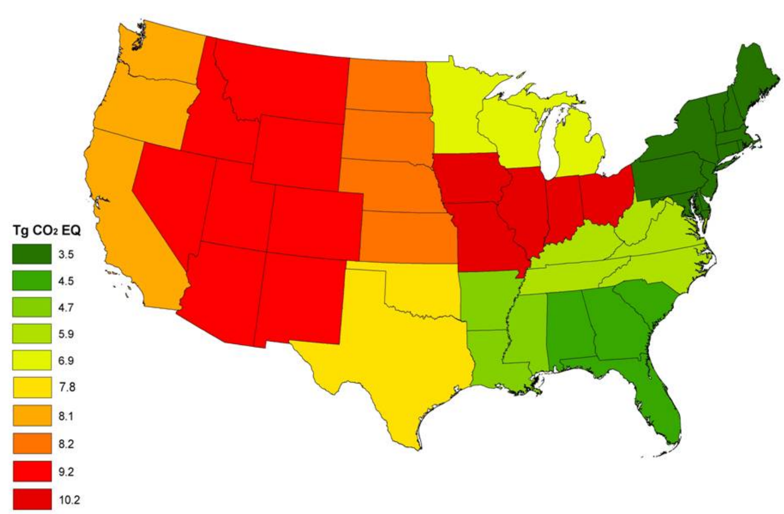
5.2 Spatial and Temporal Trends in Greenhouse Gas Emissions from Energy Use in Agriculture

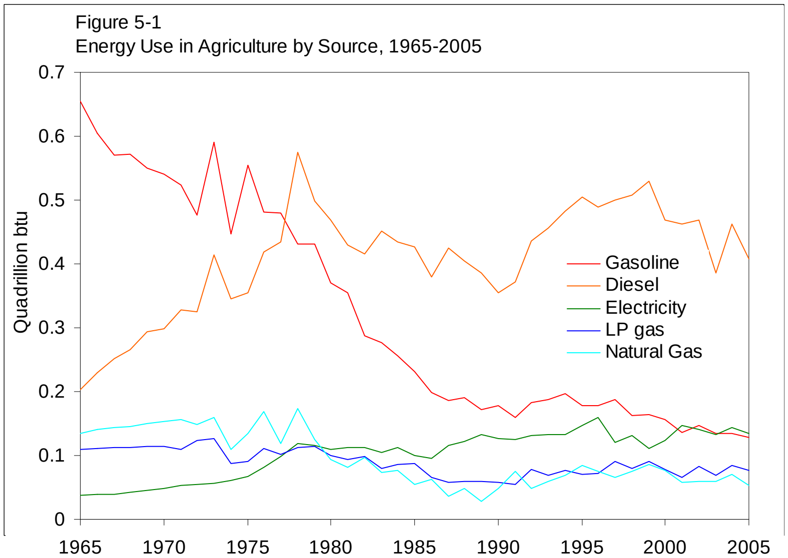
The highest emissions in 2005 were in the Corn Belt and Mountain States (Map 5-1). Intermediate emissions occurred in the Pacific, Northern Plains, Southern Plains, and Lake States. Relatively small emissions were estimated for the Southeast, Northeast, Delta, and Appalachian States. There is a strong correlation between production and energy use/emissions. Generally, the States with the most agricultural production use the most energy and therefore have the highest CO_2 emissions. However, emissions also vary by the types of energy used for farm production in each region. For example, even though the Pacific region had the overall highest energy use in 2005, it ranked only fourth in CO_2 emissions, because much of the energy used for agricultural production in the Pacific region comes from hydroelectric power.

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 1970s and early 1980s, drove farmers to be more energy-efficient, driving a decline in energy use and CO_2 emissions throughout most of the 1980s (Miranowski 2005). 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 Day 1991, USDA ERS 1994, Lin et al. 1995). Another major change in farm energy consumption began around 1979 when automobile manufacturers began to produce more fuel-efficient vehicles. Laws, such as the Energy Policy and Conservation Act of 1975, increased average fuel economy standards and both gasoline- and diesel-powered equipment became increasingly energy efficient

Map 5-1

Farm Energy Use by Region in 2005





throughout the 1980s and 1990s.

Farm energy use leveled off in the late 1980s as energy prices subsided (Figure 5-1). Since 1990 there has been an upward movement in energy use; however, farm energy used today is still well below the peak levels that occurred in the 1970s. Moreover, energy production, energy output per unit of energy input, has increased significantly.

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

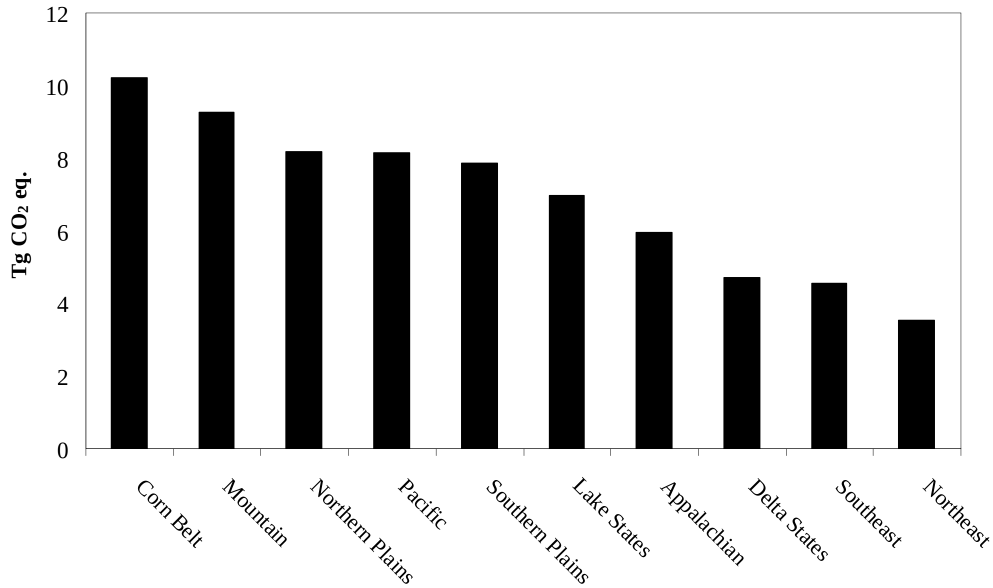
Agricultural operations, including crop and livestock farms, dairies, nurseries and greenhouses, require a variety of energy sources. Energy use in agriculture varies across agricultural operations by crop or livestock type, size of operation, and geographic region (Figure 5-2, Table 5-1). Energy use also varies over time depending on weather conditions, changes in energy prices, and changes in total annual crop and livestock production. While energy use in agriculture causes CO_2 emissions, this source is small relative to the total U.S. CO_2 emissions from energy.

Different forms of energy are used for different purposes in U.S. agriculture. Energy used on farms is typically categorized as direct and indirect energy (Maranowski 2005). Direct energy is used on the farm for various operations, whereas indirect energy is the energy used to produce energy-intensive farm inputs, such as commercial fertilizers. Liquid fuel is the most versatile form of direct energy used on farms. Crop production uses large amounts of diesel fuel, gasoline, and liquefied petroleum (LP) gas for field operations. Most large farms use diesel-fueled vehicles for tilling, planting, cultivating, disking, harvesting, and applying fertilizers and pesticides. Gasoline is used for small trucks and older harvesting equipment. Smaller farms are more likely to use gasoline-powered equipment, but as farms get larger they tend to use more diesel fuel.

Farmers use a significant amount of energy to dry crops, such as grain, tobacco, and peanuts. Several types of energy can be used for crop drying, including LP gas, electricity, diesel fuel and natural gas. Annual rainfall can have a significant effect on the amount of energy used to dry crops from year to year. For example, above-average rainfall, especially just prior to harvest time, can increase the moisture level of grain. In order to meet quality standards it may require more energy to dry the grain. Weather can also affect the energy used in livestock facilities and other farm buildings that use various forms of energy for heating, cooling, and air circulation. Natural gas is commonly used to control greenhouse temperatures and dairies rely heavily on electricity to power milking machines and other equipment.

Figure 5-2

Carbon Dioxide Emissions from Energy Use in Agriculture by Region[1] in 2005



[1]Regions are defined in Appendix Table D-1.

While many irrigation systems in the U.S. 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 2003 USDA Farm and Ranch Irrigation Survey, about 43 million acres of U.S. farmland were irrigated with pumps powered by liquid fuels, natural gas and electricity, costing a total of $1.55 billion (USDA NASS 2004). Electricity was the principal power source for these pumps, costing $953 million to irrigate 24.1 million acres at an average cost of $39.50 per acre. Diesel fuel was used to power pumps on about 12 million acres and natural gas was used on about 5 million acres (USDA NASS 2004).

Table 5-1: Definition of Regions Used in Figure 5-2

Region	States of Region	Region	States of Region	Region	States of Region
Corn Belt	Illinois	**Pacific**	California	**Southeast**	Alabama
	Indiana		Oregon		Florida
	Iowa		Washington		Georgia
	Missouri	**Southern Plains**	Oklahoma		South Carolina
	Ohio		Texas	**Northeast**	Connecticut
Mountain	Arizona	**Lake States**	Michigan		Delaware
	Colorado		Minnesota		Maine
	Idaho		Wisconsin		Maryland
	Montana	**Appalachian**	Kentucky		Massachusetts
	Nevada		North Carolina		New Hampshire
	New Mexico		Tennessee		New Jersey
	Utah		Virginia		New York
	Wyoming		West Virginia		Pennsylvania
Northern Plains	Kansas	**Delta States**	Arkansas		Rhode Island
	Nebraska		Louisiana		Vermont
	North Dakota		Mississippi		
	South Dakota				

The area of land irrigated can vary substantially from year to year, depending on environmental conditions. For example, in 2003, 52.6 million acres of farmland in the U.S. were irrigated (including gravity flow irrigation), about 6 million acres more than were irrigated in 1994 (USDA NASS 1999d, 2004). 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 2003, accounting for 56% of all irrigated land. The leading States for irrigated land in 2003 are California with 16%, Nebraska with 14%, and Texas with 9%, out of the total U.S. irrigated farm land area.

A significant amount of indirect energy is used off the farm to manufacture farm inputs that are ultimately consumed on the farm. Some farm inputs such as fertilizers and pesticides are produced by energy-intensive industries. For example, commercial nitrogen fertilizer is made primarily from natural gas and synthetic pesticides are made from a variety of chemicals. Although GHG emissions result from the energy consumption used in manufacturing energy-intensive agricultural inputs, these indirect emissions are not detailed in this inventory. For information on the GHG emissions of manufacturing commercial fertilizers see EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks (EPA 2007).

The amount and type of energy used in agricultural operations affect overall CO_2 emissions and generally CO_2 levels increase with higher energy use in agriculture (Figure 5-3). Some fuels have higher carbon content than others, resulting in higher CO_2 emissions per btu used**.** 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 gasoline on a volumetric basis but diesel engines have a higher performance rating compared to gasoline engines. Therefore, even though diesel fuel has higher carbon content per btu than gasoline, using diesel engines to perform farm operations may result in lower CO_2 emissions.

5.4 Methods for Estimating Carbon Dioxide Emissions from Energy Use in Agriculture

Carbon dioxide emission estimates for energy use are constructed from fuel consumption data using standardized methods published in the U.G. GHG Inventory (EPA 2007). 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 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 2006). NASS also collects data on price per gallon paid by farmers for gasoline, diesel, and LP gas (USDA NASS 2005a). Energy expenditures are divided by fuel prices to approximate gallons of fuel consumed by farmers. Gallons of gasoline, diesel, and LP gas are then converted to btu based on the heating value of each of the fuels. The individual farm data is aggregated by State and the State data is divided into 10 production regions, allowing fuel consumption to be estimated at the national and regional levels. Farm consumption estimates for electricity and natural gas are also approximated by dividing prices into expenditures. Since electricity and natural gas prices are not collected by NASS, we use data from the Energy Information Administration (EIA), which reports average prices by State (EIA 2005a, 2005b). NASS regional prices were derived by aggregating the EIA State data into NASS production regions.

Following the method outlined in Annex 2 of the U.S. GHG Inventory (EPA 2007), consumption of diesel fuel, gasoline, LP gas and natural gas was converted to CO_2 emissions using the coefficients for carbon content of fuels and fraction of carbon oxidized during combustion, both of which are published in Annex 2 and provided in Table 5-1 of this report. 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 quadrillion btu was multiplied by the carbon content coefficient to estimate the 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 2007). However, only a portion of the carbon is actually oxidized during combustion. These coefficients are provided in Table 5-1 of this report. It is assumed that of the carbon that is oxidized, 100% is emitted to the atmosphere as CO_2.

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. Also, the mix of fuel sources used in a region can change over time. To account for these variables, the CO_2 emission estimates from electricity generation in this chapter are derived from the most current State data available from EIA. EIA typically reports CO_2 emissions from electricity generation by State and U.S. Census Regions (EIA 2001). In response to a special request from USDA, EIA tabulated State emission factors for 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. These regional emission factors were multiplied by estimated electricity use in each farm production region to calculate CO_2 emissions. As reported above, electricity

Table 5-2 Energy Use and Carbon Dioxide Emissions by Fuel Source on U.S. Farms, 2005

	Energy Consumed		**Carbon Content**	**Fraction Oxidized**	**CO_2 Emissions**
	Trillion Btu's	*Qbtu*	*Tg C/Qbtu*		*Tg CO_2 eq.*
Fuels					
Diesel	408.5	0.4085	19.95	0.99	29.58
Gasoline	128.5	0.1285	19.33	0.99	9.01
LP gas	76	0.076	17.2	0.99	4.74
Natural gas	53	0.053	14.47	0.995	2.80
Electricity	135	0.135	*	*	23.28
Total	**801**	**0.801**			**69.41**

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

Note: The BTUs for electricity consumed are based on 3,413 BTU per kWh, which is just the direct energy used on the farm. The emission coeficients from EIA include the energy source, e.g. the emissions from electricity produced from coal are calculated upstream at the coal-fired plant thus the estimated emissions for electricity are much greater than just the emissions from using electricity on the farm.

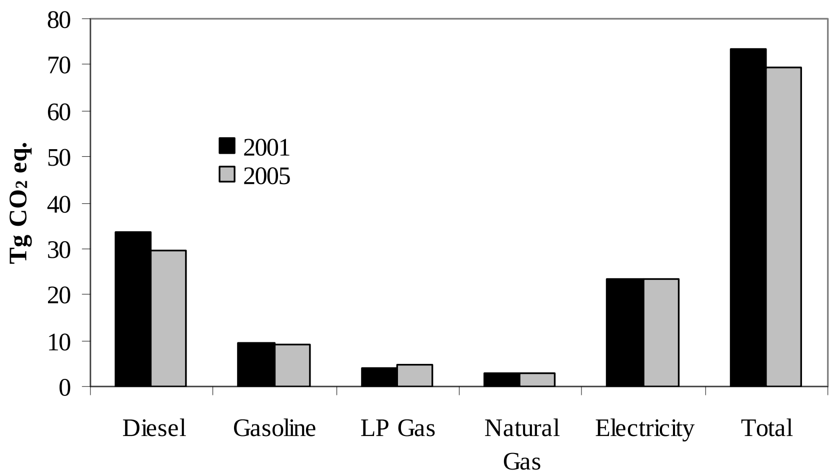
use is estimated from farm expenditure data collected by NASS. Price estimates for electricity published by EIA are divided into electricity expenditures to derive the kilowatt hours consumed by farmers. The kilowatt hours of electricity are converted to btu, based on a conversion rate of 3,413 btu per kilowatt hour.

5.5. Major Changes Compared to Previous Inventories

The first edition of the USDA GHG report (USDA 2004) included estimates of emissions from energy use for the year 2001. Annual GHG emissions are expected to vary with changes in crop and livestock production levels. In addition weather conditions can have a significant influence on energy use in agriculture, thereby affecting GHG emissions from year to year. Figure 5-3 shows that the results from the two study years are very similar. The total 2005 CO_2 emissions from energy production in agriculture are only about 4 Tg of CO_2 lower than the emissions estimated for 2001. The lower emissions in 2005 result primarily from farmers using less diesel fuel in 2005.

Figure 5-3

Carbon Dioxide Emissions from Energy Use in Agriculture by Fuel Source, 2001 & 2005



Note that the 2001 CO_2 emission estimates have been revised with updated data, so they are different than the estimates reported in the first edition of this report. As is often the case with survey data, the initial 2001 data used to derive the energy use estimates have been updated. With the exception of electricity, the revised 2001 CO_2 emissions estimates are very similar to the estimates originally reported. However, due to a calculation error, the 2001 figure reported for electricity in the original study was overestimated. Consequently, the revised CO_2 emission estimate for electricity is significantly lower than that reported previously.