ENERGY CONSERVATION SERIES:

Agricultural Energy Consumption In the United States

NRCS Natural Resources Conservation Service

New Jersey

In the United States, agricultural operations are highly dependent on machinery, chemicals, and other inputs which reduce labor costs and enable higher yields. Energy use is closely tied to the efficiency of these operations. A comprehensive analysis of the particular ways in which energy is used in agriculture, and an equally comprehensive analysis of the relative efficiencies of these various uses, is therefore warranted for the benefit of farmers and the consumers of their products.

Filling tractor fuel tank
PHOTO: NINA McKITTRICK

The U.S. food system accounted for 15.7 percent of total U.S. energy consumption in 2007, up from 14.4 percent in 2002 (10). On-farm production amounts to approximately 20% of the total system energy, while 40% of agricultural energy use goes into the manufacture of chemical fertilizers and pesticides (9). However, agriculture consumes more petroleum products than any other single industry in the food system (10).

Energy Use by Commodity

The share of total US energy consumption by agricultural operations was approximately 2.73% in 2008 (3), making energy use by agriculture fairly insignificant in terms of reducing total consumption of energy by the nation.

Table 1 represents energy-intensive inputs for selected field crops commonly grown in the United States. The first column represents total gallons of fuel used in the field, while the second represents total equivalent amounts of energy consumed in the manufacture and application of fertilizers and pesticides used. This data reflects use levels found with conventional management techniques in 1976, as no newer information is available.

It is evident that the cultivation of different crops results in significantly different energy expenditures. Fruits and vegetables may require high levels of fungicide and insecticide use, often along with high levels of fertilizer use. Soybeans, oats and wheat, on the other hand, show a low level of fuel use since they require fewer field operations and less fertilizer. All these crops can vary considerably in energy use based on their management and place in the overall cropping system.

Energy use in greenhouse operations is quite different from field crops. In New Jersey, winter heating may use 1 gallon equivalent of fuel oil per square foot, plus or minus 0.5 gallons depending on location and type of structure, among other factors.

Nursery production in the state is a significant enterprise, however, energy use data has not been calculated. Such energy use could be high in farm operations where there is high production intensity.

Energy Use in Food Production

In 1996, United States production of animal proteins for food use consumed approximately 76,367 kilocalories (kcal) per kilogram of protein produced (2). Of all types of US protein products, the production of chicken is the most

Table 1- Inputs to Field Operations
Source: Federal Energy Administration (8)

Crop	US Gallons/ Acre Fuel Inputs	US Gallons/ Acre Chemical Inputs
Corn	26.6	28.1
Soybeans	13.8	03.1
Winter Wheat	11.7	09.9
Alfalfa	30.0	10.7
Fresh Vegetables	62.5	43.9
Potatoes	59.8	94.3
Sugar Beets	48.9	39.7
Oats	07.8	05.0
Grapes	58.1	30.5
Dry Edible Beans	33.1	14.3

efficient in terms of the fossil energy input required, closely followed by dairy products and eggs (2). Other types of animal protein production, by product, are significantly less efficient in their use of fossil energy inputs, however, the maximization of use of biomass inputs greatly reduces the necessity of fossil energy inputs. As an example, the production of grain-fed beef uses 35 kcal of fossil energy per kcal of protein production, whereas production of beef by grazed cattle uses 10 kcal of fossil energy per kcal (2).

Comparing plant protein production and energy use, quite a different picture is presented, even with intensively produced fruits and vegetables. In the eastern US, for example, apple production was estimated to use 0.91 kcal of inputs per kcal of product. Direct inputs to production of 1 kcal of apples required inputs of 0.62 kcal of petroleum, accompanied by indirect inputs of 0.15 kcal of herbicides, insecticides, and fungicides combined (pesticides); and 0.l0 kcal of soil fertility additives such as lime, and nitrogen fertilizers (1).

Applicator for fertilizers and pesticides
PHOTO: TEXAS A&M UNIVERSITY

Energy efficiency of the production of feedstuffs used in animal protein production tends to be lower than that of the production of vegetable products consumed directly by humans. Production of alfalfa in Ohio, as an example, was estimated to use 0.16 kcal of inputs in the production of 1 kcal of alfalfa, with 0.084 kcal of that used as petroleum, 0.025 used as soil fertility additives, and 0.0035 used as pesticides (6). However, as noted previously, even with the efficient production of feed grains, the production of meat is not as energy-efficient as for fruits and vegetables. It should be emphasized that if grains are consumed directly by humans, energy inputs into production are relatively low compared to calories produced in the grain unless significant processing takes place.

Comparing Direct and Indirect Energy Use

In examining energy use by the agricultural industry, consumption of energy must be broadly categorized as either "direct" or "indirect". Direct consumption is expenditure of energy on the farm. Direct consumption encompasses uses such as the powering farm machinery, heating and ventilation of production facilities, lighting, and transportation of labor to and around the farm. Direct uses accounted for approximately 1.1% of total US energy use in 2008 (7). Indirect consumption, by contrast, is consumption of energy in the production of the non-energy inputs to agriculture, such as fertilizers and pesticides. It accounted for approximately 1.63% of total US energy consumption in 2002 (7).

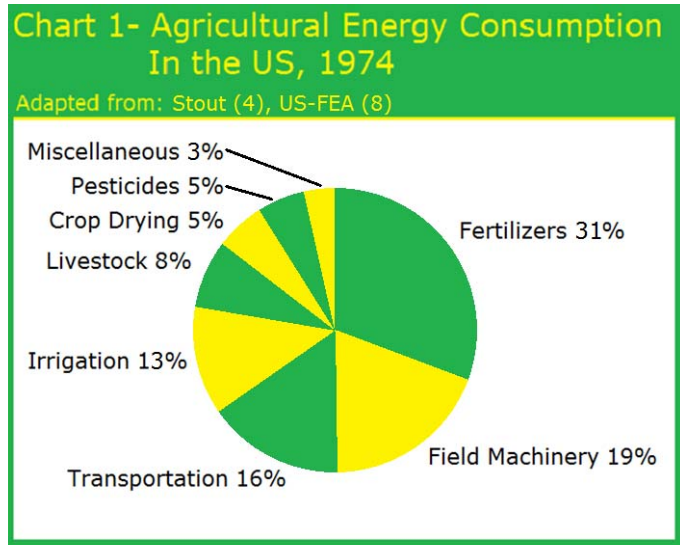


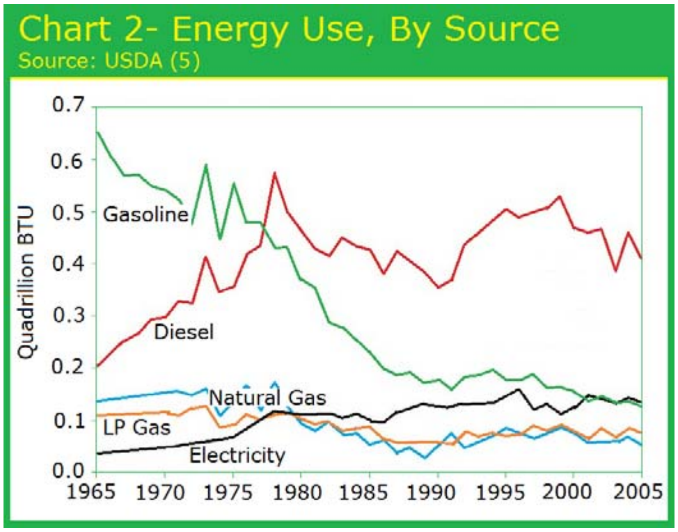
Chart 1 provides a breakdown of the various direct and indirect energy uses in US agriculture. Energy invested in fertilizers far exceeds any other inputs. More than two-thirds of the energy invested in fertilizers, is used in the production of nitrogen fertilizers (4). Conversely, while energy invested in pesticide manufacture is higher than any other input on a per unit basis, overall energy use in operations is low because only a few pounds or gallons are used per acre.

Forms of Energy used in Agriculture

The specific forms taken by the energy used directly in United States agriculture (see Chart 2), No. 2 petroleum distillate (also known as "diesel fuel", "home heating oil", and "fuel oil"), used as both fuel for internal combustion engines and as a heating fuel, accounts for the greatest share by energy content (5). In 2005, approximately 0.45 quadrillion British Thermal Units (BTU) of No. 2 distillate were used in US agriculture (5). Gasoline, classified as a light petroleum distillate and used nearly exclusively as a fuel for internal combustion engines, and electricity supplied by local utilities, were both used in a quantity of approximately 0.14 quadrillion BTU (5). LP and natural gas, both fossil gases used primarily as heating fuels and occasionally to power machinery used indoors, were used in quantities of approximately 0.05 quadrillion BTU (5).

From 1995 to 2005, use of gasoline in agriculture has steadily declined at a rate of approximately 0.005 quadrillion BTU annually (5). This can be explained by: 1) the sensitivity of agricultural operators to the rising price per BTU of gasoline, 2) the fact that there is no way to use it with more than about 40% efficiency, and 3) the retirement of large gasoline-fueled equipment, which largely ceased to be manufactured after 1970 (4).

Use of LP gas, and "natural" gas, in agriculture, has remained at roughly the same levels from 1990 to 2005, but trends in the use of each gas tend to move in proportion to the price of the other gas. This can be explained by the fact that almost all equipment powered by either of these gases can easily be retrofitted to use the other gas at very little cost.



Saving Energy in Agriculture

The ways in which energy use must be examined in agriculture is unique to each segment of the agricultural industry, and is differentiated primarily by crop type and secondarily by geographic location. Energy use tends to be more intensive in the production of perishable products intended for sale as food, such as vegetables, as a high value is given for the timely production of these products and a consequentially high investment can be made in producing them under conditions less than ideal in a given time and place. Significant energy savings can be realized by producing seasonal crops during their natural season. Crops which can be stored for a long period of time or easily transported over a long distance, such as grains or fiber products, tend to require lower energy inputs as time can be taken to grow them in places where the sun will do the work of the energy inputs for an agricultural operation.

Direct comparisons of the relative energy efficiency of various segments of the agricultural industry are difficult as the outputs of these segments differ in their nutritional value, dollar value per pound, overall usefulness to society per dollar produced, and other measures. However, comparisons can be made between similar agricultural operations conducted in different regions of the United States. Such operations tend to use more energy as suitability of the region for that operation declines. For example, the production of cereal grains in the Southwest tends to require a relatively high consumption of electricity and No. 2 distillate, to power irrigation equipment, and returns on all energy inputs are decreased somewhat due to reduced yields caused by the unsuitable growing conditions of the area.

Location of agricultural operations to maximize the efficiency of delivering the products of the operations, often can affect the relative value of the particular forms of energy used in the operations. Locations which have easy access to market, almost as a rule, have higher real-estate values and significantly more legal restrictions which are a hindrance to efficient agricultural operations. In these locations, opportunities to produce energy on the farm are reduced due to the scarcity of the space needed. Additionally, as distance to food markets decreases, municipal zoning ordinances which preclude certain energy-saving practices, such as anaerobic manure digestion, tend to become more common and restrictive.

An effective way to simultaneously bring the benefits of reduced energy use to multiple segments of the agricultural industry is to utilize the synergies between differing types of crop cultivation. Avoidance of monocultures can often allow the farmer to use the by-products of one crop as inputs for the next. For example, reductions in the large portion of inputs in the form of soil fertility additives (see Chart 1) can be realized through maximizing the use of nitrogen-fixing cover or primary crops on cultivated land.. In most areas nitrogen availability is the largest limiting factor to plant growth, so the energy-efficiency of methods used to increase it account for a large proportion of an operation's overall energy efficiency. Use of nitrogen-fixing rotations or manure application can be of great benefit to the efficiency of nitrogen management.

Alfalfa, a source of nitrogen in crop rotations
PHOTO: OREGON STATE UNIVERSITY

In addition, total energy flow through agricultural operations can be ultimately reduced through the use of biomass energy sources. Use of cover crops and reduced-tillage cultivation practices may reduce the need for irrigation, and further reduce the need for the use of fossil fuels in tillage of land.

The goal of the audit is to identify opportunities to change production practices so that energy efficiency is optimized. Farm audits identify the energy efficiencies of agricultural operations by quantifying the various forms of energy inputs used in a particular operation. Many opportunities to use biomass as an energy input are particularly beneficial to conservation of energy. Audits can focus on resources available for the creation of biomass resources, such as seasonally vacant land, timber resources, and opportunities to use by-products of the operation in a way beneficial to the generation of usable biomass resources. Identification of opportunities to use wind or solar energy may also be of benefit to reducing the farm's energy inflow.

Audits must also seek to minimize traditional energy inputs. For example, the cost of overhauling ventilation fans can be compared to the cost of the energy wasted by worn bearings in these fans. The audit can then identify changes that can be made to an operation's capital expenditure structure, so as to optimize the maintenance of equipment for energy efficiency.

Through these processes, the audit will identify any changes that can be made in a particular operation to maximize energy efficiency and reduce overall energy use. The audit will first determine the maximum efficiency of each possible input. The audit will then compare these different energy input scenarios and recommend the optimum relative balance of all possible energy inputs to an operation.

REFERENCES

1. Funt, R. C. "Energy Use in Low-, Medium-, and High-Density Apple Orchards—Eastern US". Pimentel, D.: Handbook of Energy Utilization in Agriculture. Boca Raton, Florida: CRC Press, 1980.
2. Pimentel, David; Pimentel, Marcia. Food, Energy, and Society (*revised edition*). Niwot, Colorado: University Press of Colorado, 1996.
3. Pirog, Richard, et al. "Food, Fuel, and Freeways: An Iowa Perspective on How Far Food Travels, Fuel Usage, and Greenhouse Gas Emissions". Leopold Center for Sustainable Agriculture, Iowa State University, June 2001.
4. Stout, B. A. ed. Energy Use and Management in Agriculture. Belmont, CA: Breton Publishers, 1984.
5. United States Department of Agriculture. "Agriculture and Forestry Greenhouse Gas Inventory, 1990-2008. Office of the Chief Economist, June 2011.
6. United States Department of Agriculture. *Firm Enterprise Data System.* Stillwater, Oklahoma: USDA-ERS, and Oklahoma State University Dept. of Ag. Economics, 1977.
7. United States Department of Energy. Annual Energy Outlook 2008. Energy Information Administration, April 2008.
8. United States Federal Energy Administration. "Energy and US Agriculture". Volume 1, No. 459. US Government Printing Office, 1976.
9. Heller, Keoleian (2000) Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System, The University of Michigan - Center for Sustainable Systems, Ann Arbor, MI, 1-60, CSS00-04.
10. Buffington, John and Jerrod Zar (1977) "Realistic and Unrealistic Energy Conservation Potential in Agriculture" Agriculture and Energy, ed. by William Lockeretz. New York: Academic Press.

FURTHER READING

1. Canning, Patrick, et al. "Energy Use in the U.S. Food System". USDA Economic Research Service Economic Research Report, No. 94, March 2010.
2. McLaughlin, M. B. et al. "Comparison of Energy Inputs for Inorganic Fertilizer and Manure-Based Corn Production". Canadian Agricultural Engineering, Vol. 42, No. 1, 2000.
3. Miranowski, John. "Energy Consumption in US Agriculture". University of Iowa Staff General Research Papers, 2004.
4. Reitz, H. J. "Energy Use In U.S. Citrus Production and Harvesting". Pimentel, D.: Handbook of Energy Utilization in Agriculture. Boca Raton, Florida: CRC Press, 1980.
5. United States Census Bureau. "2006 Manufacturing Energy Consumption Survey". 2006.
6. United States Department of Agriculture. Agricultural Resources and Environmental Indicators, 1996-97. July 1997.
7. United States Department of Energy. Energy Outlook 2011. Energy Information Administration, April 2011.

RUTGERS
New Jersey Agricultural Experiment Station

This publication was developed by Rutgers Cooperative Extension, for USDA Natural Resources Conservation Service in support of Agreement No. 68-2B29-11-150.

Cooperating Agencies: Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer.

1_F9.9 040212 1338

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

www.nj.nrcs.usda.gov