Energy and American Agriculture

By Marvin Duncan and Kerry Webb

American farmers have long prided themselves on their ability to produce abundant supplies of food and fiber. To accomplish this feat — and to do it profitably — American farmers have increasingly relied upon agricultural production practices that are both capital intensive and energy intensive. Their success has been premised on the ready availability of inexpensive energy. Agricultural producers, as well as those who supply inputs and market the products, must now consider their roles in an environment in which energy is no longer inexpensive and in which its ready availability is becoming questionable.

In the most basic sense, agricultural producers are in the energy conversion business: Producers grow plants to convert sunlight into an energy source useful to human beings as a foodstuff-either directly as a food or indirectly as an input into livestock production. Other inputs, including fossil fuels, are used to augment this energy conversion process. The increasing scarcity and cost of fossil energy will require greater attention in the future to the efficiency of energy use — both in terms of economic efficiency and of engineering efficiency.

This article examines the issue of energy use in U.S. agriculture. The energy efficiency of U.S. agriculture is compared to that of under-developed economies. Energy use trends and energy sources used in agriculture are discussed. Finally, the questions of economic and engineering efficiency in energy use are examined along with probable future directions in energy use trends.

.ENERGY USE IN PERSPECTIVE

The U.S. population consumes energy far in excess of its proportion to the world population. As recently as 1975, the energy used by the U.S. economy was an estimated 71.7 quadrillion British thermal units (Btu's).[1] The United States, with 5 per cent of the world's population, accounted for about 29 per cent of world energy consumption in that year. At the same time, the entire Sino-Soviet block — with about 28 per cent of the world's population — accounted for only about one-fourth of the world's energy consumption. Moreover, by some estimates, U.S. energy consumption is expected to more than double by the year 2000.

Though large in absolute terms,. the proportion of U.S. energy consumed in the food and fiber sector is relatively small. The sector requires only about 13 per cent of total energy consumed domestically each year in the

[1] A Btu is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near its maximum density.

Table 1
BTU'S USED IN U.S. FOOD AND FIBER SECTOR BY MAJOR TYPES OF INDUSTRIES

Item	1970* Trillion Btu's	1970* Per Cent	1980 Trillion Btu's	1980 Per Cent	Change in Per Cent
Type of industry use:					
Farm production	1,051.4	22.5	1,095.3	21.1	+ 4.2
Farm family living	554.6	11.9	499.2	9.6	−10.0
Food and kindred product processing	1,302.9	27.9	1,548.3	39.8	+ 19.8
Marketing and distribution	832.7	17.9	988.9	19.0	+ 18.8
Input manufacturingt	925.3	19.8	1,063.8	20.5	+ 15.0
Total	4,666.9	100.0	5,195.5	100.0	+ 11.3

'For some industries data are for 1971, 1972, or 1973.
†Includes estimates for six selected industries.
SOURCE: Committee on Agriculture and Forestry, United States Senate, **The U.S. Food end Fiber Sector: Energy Use end Outlook,** September 20, 1974.

United States. (Table 1 contains data on energy use by the U.S. food and fiber sector by type of industry for 1970 with estimates for 1980.) Energy use in the food and fiber sector has increased rapidly, however—about three times between 1940 and 1970, while farm output almost doubled over roughly the same period.'

Farm energy use accounts for only 3 per cent of the total U.S. energy consumed.[3] Further, farm production uses only slightly more than one-fifth (line 1 of Table 1) of the energy used in the U.S. food and fiber sector. That expenditure of energy and its efficient use have resulted in a number of benefits to U.S. consumers. There has been an abundant and dependable supply of high-quality food for consumers. At the same time, the increasing productivity of U.S. agriculture—largely the result of replacing labor with machinery and fossil energy—has released large numbers of people for employment in other sectors of the economy. Food prices are substantially lower than they would be without mechanization and the productivity gains that come with energy intensive farming. Finally, U.S. agricultural production is so abundant that the products from nearly one-third of the country's harvested acres are exported; and the foreign exchange earnings of these exports ($24 billion in fiscal 1977) have paid for a large part of this country's energy imports in recent years.

U.S. agriculture, however, is sometimes accused of being energy inefficient when compared to agricultural production in other countries. Indeed, it has frequently been suggested that energy scarcities and resultant higher energy costs will ultimately cause U.S. agriculture to adopt the more labor intensive practices of the third world countries. But when data on energy efficiency are examined, the

2 Harold O. Carter and James G. Youde, "Some Impacts of the Changing Energy Situation on U.S. Agriculture," *American Journal of Agricultural Economics.* Volume *56,* Number 5, December 1974, p. 881.

3 *Energy Use in Agriculture: Now and for the Future,* Council for Agricultural Science and Technology, Report Number 68, August 1977, Ames, Iowa, pp. 1-3.

Table 2
ENERGY USE PER HECTARE IN RICE PRODUCTION IN VARIOUS COUNTRIES'

Country	Installed Horse-power Per Hectare Farm Machines and Draft Animals Only	Energy For Farm Operations Million Btu's Per Hectaret	Energy For Irrigation and Nitrogen Fertilizers Manufacture Million Btu's Per Hectare	Total Energy Input Per Hectare Million Btu's	Rice Yield Kilograms/ Hectare	Energy Intensity Million Btu's Per Ton of Rice
India	0.7	20	6.5	26.5	1,400	19
China	0.7	20	12	32	3,000	10.7
Taiwan	0.5	10	22	32	4,000	8
Japan	1.6	10	25	35	5,600	6.2
U.S.A.	1.5	7	25	32	5,100	6.3

'Total grain production depends not only on seed variety, soil quality, etc., but also on the mix of grains grown. Therefore, comparing a single grain gives a better comparison of the energy intensity of various farming methods.
†Energy used to perform various tillage, planting, and harvesting activities.
SOURCE: Arjun Makhijani, **Energy and Agriculture in the Third World, Ballinger** Publishing Company, Cambridge, Mass., **1975,** p. **17.**

popular notion—that subsistence farming uses less energy per unit of production than American agriculture—is not supported.

Table 2 contains data pertaining to the relative energy efficiency of various countries in the case of rice production. Although it is true that developed countries such as Japan and the United States use substantially greater amounts of installed horsepower, fertilizer, and irrigation energy per hectare in rice production than the developing countries, when noncommercial energy sources are taken into account, there is a surprisingly small difference in the total energy input per hectare among the five countries.[4] Japan and the United States have substituted machine power with vastly superior productivity for labor and animal power. Japanese and U.S. rice yields, as a result of superior production techniques and seedstocks, are markedly higher than in India or China. Moreover, when the Btu's required to produce a ton of rice are calculated, it is clear that the energy efficiency of the more mechanized rice production is superior to that of the labor and animal intensive agriculture. Thus, while U.S. farmers use more fossil energy per hectare than the farmers of most other countries, the energy use per unit of product is much lower for U.S. farmers than for their counterparts in underdeveloped countries.

The common belief that energy use in agriculture in underdeveloped countries is far less than in developed countries is based on the comparative use of fossil fuels, nuclear energy, and hydroelectric power. The energy sources common to poor people—wood, crop residues, animal manure, and human and animal labor—are not usually taken into account. When these noncommercial energy sources are included, the total energy use in agriculture per hectare in underdeveloped countries often exceeds that in industrialized countries. Noncommercial energy sources make an important contribution to the total energy

[4] One hectare is equal to 2.47 acres.

supply of underdeveloped countries as well. In fact, on a per capita basis, they may provide up to 70 per cent of the total energy requirements of many underdeveloped countries.[5] The principal difference in energy use between developed and underdeveloped countries is not that substantially less energy is used in the latter countries, but rather how little useful work is obtained from the energy used there as compared to developed countries.

ENERGY USE PATTERNS

Because energy used in U.S. agricultural production amounts to about only 3 per cent of total U.S. energy consumption, conservation measures directed at farming alone would have a limited effect in alleviating a national energy crisis. However, as fuel costs increase, there is a great incentive for farmers to use energy efficiently and conservatively. By knowing just how energy is being used in agriculture, it can be determined where it might be conserved.

Since the turn of the century, energy use in agriculture has changed dramatically. Since 1910, the amount of land harvested in the United States has remained relatively constant. However, the average index of crop production in the country nearly doubled between the 1911-20 decade and the decade of 1967-76.[6] The bulk of this increase can be accounted for by energy intensive technology. While the average index of farm labor fell 74 per cent, the average indices for machinery and agricultural chemicals rose 382 and 2,312 per cent, respectively, between the two periods. Research suggests that about half of the increase in energy inputs has gone to improve productivity (with such inputs as fertilizers and chemicals), while half has been used to replace labor (with such inputs as larger machinery).

Complete data on energy consumption in agriculture are not available for all recent years. However, the U.S. Department of Agriculture (USDA) has made an intensive effort to calculate farm production energy use for 1974.[7] Chart 1 summarizes energy use in U.S. agricultural production. According to the USDA, over 1.3 quadrillion Btu's of direct energy input went into agricultural production that year. An additional 700 trillion Btu's of indirect energy went into production of fertilizer, pesticides, and other agricultural chemicals. Crop producing activities used 89 per cent of the total consumption, while livestock production used only 11 per cent. The production of corn, soybeans, winter wheat, and grain sorghum consumed half the energy used in crop production nationally. More energy is used in corn production than any other crop; however, the production of tobacco and citrus fruits is far more energy intensive on a per acre basis.

About one-fifth of the 1974 total consumption of energy in U.S. farming was accounted for by agriculture in Tenth Federal Reserve District states.[8] Within these states, planting, cultivating, and harvesting used 20 per cent of the crop producing energy. Indirect energy in fertilizer and pesticides accounted for another 37 per cent of the District's energy use in crop production. The increasing use of irrigation within the District resulted in one-fourth of the total crop energy being used for

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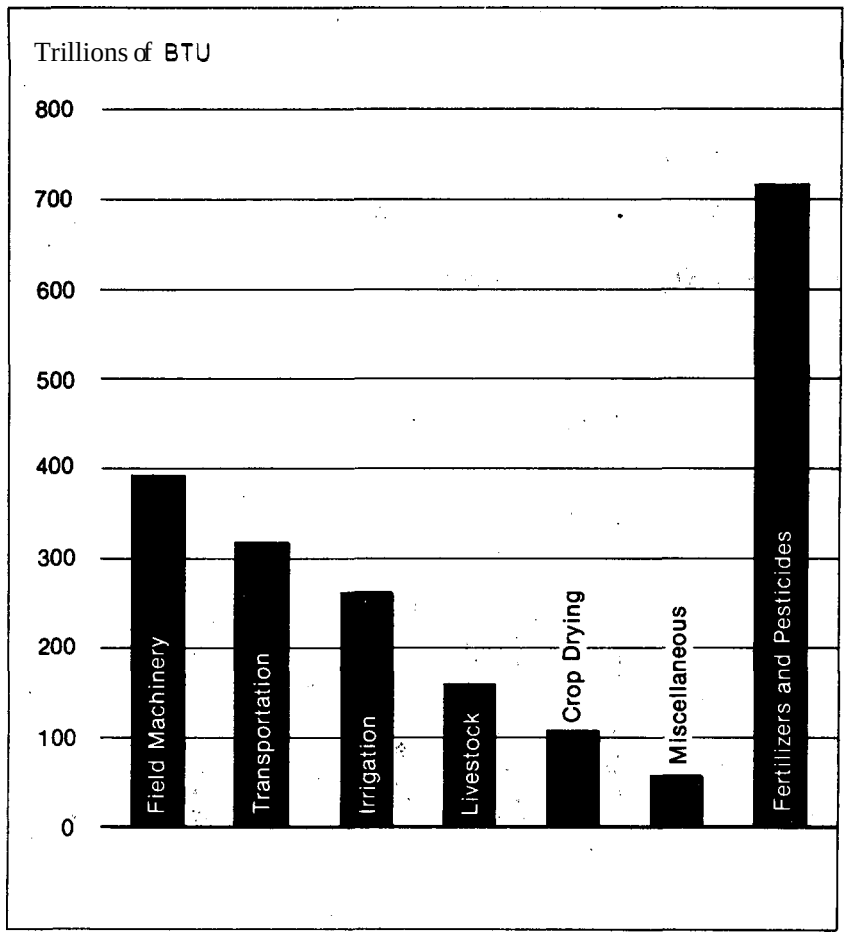
5 Arjun Makhijani, ***Energy and Agriculture in the Third World.*** Ballinger Publishing Company, Cambridge, Massachusetts. 1975. pp. 15-20.

6 U.S. Department of Agriculture, ***Changes*** in ***Farm Production and Efficiency.*** 1977, Statistical Bulletin Number 581, Washington, D.C., November 1977, pp. 6-7.

7 U.S. Department of Agriculture, ***Energy and U.S. Agriculture: 1974 Data Base,*** Volume 1, (Washington. D.C., Government Printing Office, September 1976).

8 The Tenth District includes Colorado, Kansas, Nebraska. Wyoming, most of New Mexico and Oklahoma, and 43 counties in western Missouri.

Chart 1
ENERGY USE IN U.S. AGRICULTURAL-PRODUCTION

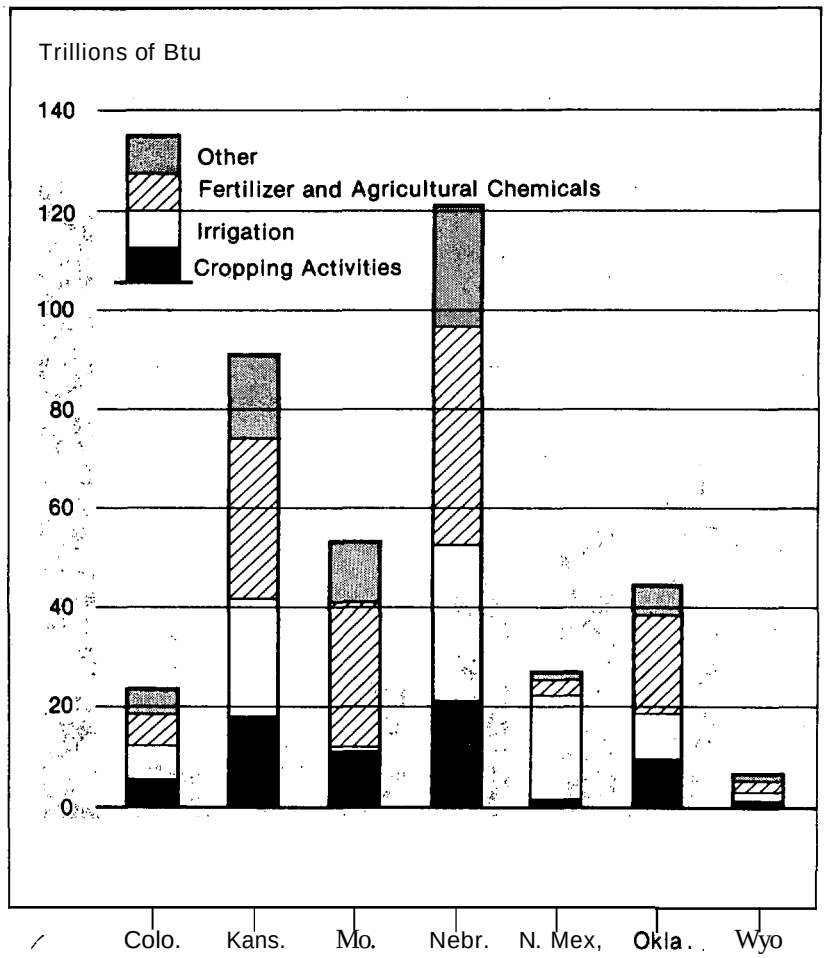


SOURCE: **Energy and** U.S. **Agriculture: 1974 Data Base.**

that purpose. This figure is substantially higher than for the nation as a whole, where only **15** per cent of the crop energy was used for irrigation. Crop drying and farm vehicle use made up the remainder of the energy consumption.

Direct energy used in livestock production is small (Chart 1) compared to that used in producing crops. In 1974, cow-calf operations used the greatest amount of such energy, although milk cows were the most energy intensive on a per head basis among various livestock. In Tenth District states, feed handling consumed the most energy, using up 41 per cent of the livestock energy budget. Lighting, heating, ventilation, and water supply consumed **12** per cent, while farm vehicles used 33 per cent of the livestock energy. Charts **2** and 3 show the proportion of energy consumed by various operations in District states.

Chart 2
ENERGY USED TO GROW CROPS



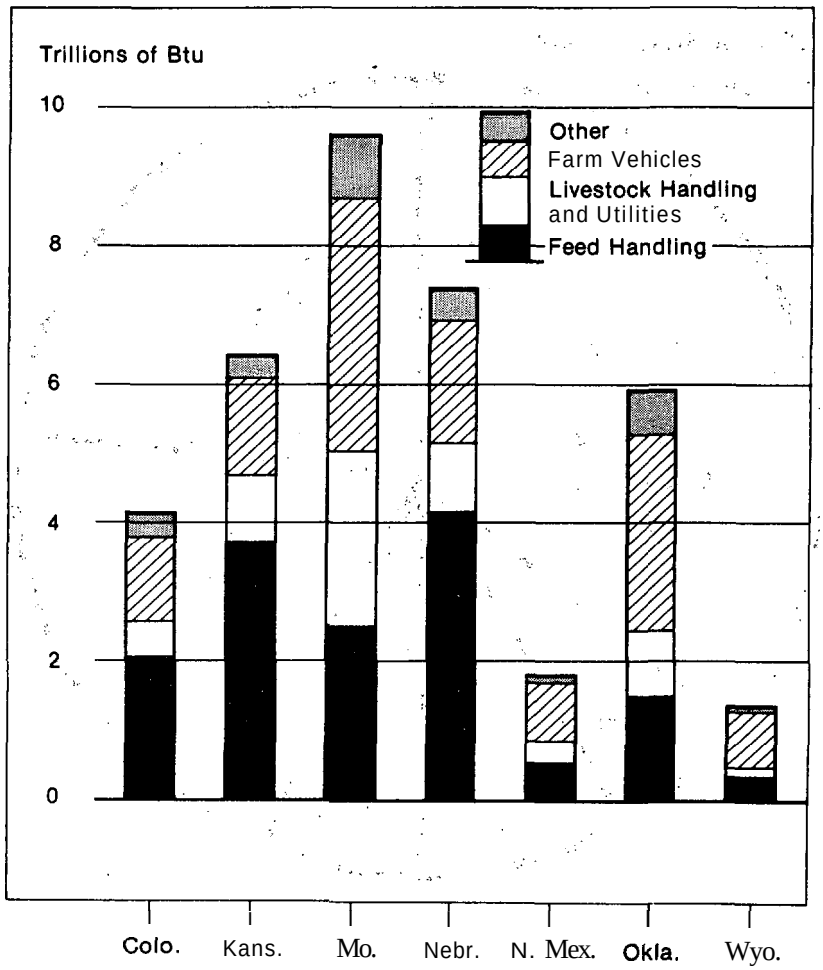
SOURCE: **Energy and** U.S. **Agriculture: 1974 Data Base.**

Energy Sources

Knowing how energy is used on the farm is only part of the information needed to understand agriculture's energy problems. The sources of energy also need to be identified so that their importance and substitutability can be analyzed. It should be noted that energy sources or fuels are generally not substitutable on a one-for-one basis. Moreover, even when converted to equivalent energy units, various fuels are not at all equivalent in terms of cost. Thus, energy use decisions must be tempered by technological and economic considerations, in addition to availability constraints.

Direct farm energy in 1974 was derived from six main sources: gasoline, diesel fuel, fuel oil, LP gas, natural gas, and electricity (Chart 4).

Chart 3
ENERGY USED TO RAISE LIVESTOCK



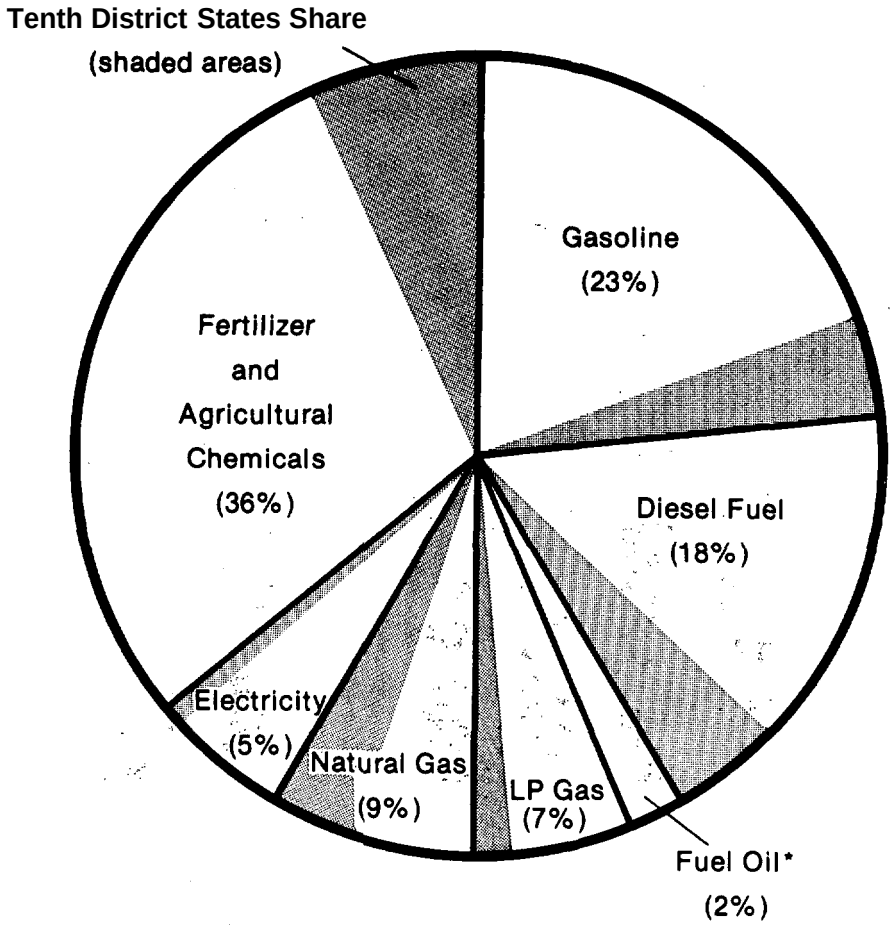
SOURCE: **Energy and** U.S. **Agriculture: 1974 Data Base.**

Indirect energy consumption used in the production of fertilizers and agricultural chemicals is also shown in the chart.

Gasoline and diesel fuel are used in growing most crops and also serve as the fuel sources for two-thirds of the energy required for livestock production. Fuel oil is mainly used to protect citrus fruit'from frost and also in drying crops. Next to gasoline and diesel fuel, LP gas is the most versatile energy source and serves as a major input in many field operations, crop drying, and brooding. The energy from natural gas and electricity is used to fuel the bulk of the nation's pumped irrigation.

Tenth District states account for 30 per cent of the total pump-irrigated acreage in the United States. Thus, rising fuel costs will become extremely important to farmers in this

Chart 4
AGRICULTURAL ENERGY USE BY VARIOUS FUELS
U.S. AND TENTH DISTRICT STATES



'Less than one per cent of the fuel oil is used by Tenth District states.
SOURCE: Energy and U.S. Agriculture: 1974 Data Base.

region as profit margins come under increased pressure, For example, at present, pumped irrigation depends almost entirely on natural gas and electricity. Because irrigated farms produce a relatively small proportion of the total crop output, it is very difficult for rising energy costs to be passed on to the consumer. Substitution of other fuels or other inputs (for example, more fertilizer and less water) may be possible to a limited extent. However, switch-over costs and the availability of other fuels and inputs make it doubtful that farmers could reduce their costs very much—at least in the near future. Although some conservation measures (for example, minimum tillage practices) may help, the dependence on energy

for irrigation leaves producers with few alternatives, other than to absorb the increased production costs.

Energy Costs

In **1974,** the cost for farm energy totaled over **$4.2** billion and amounted to almost **6** per cent of total production expenses. From **1973** through **1977,** direct agricultural energy costs have risen as follows: gasoline, **69** per cent; diesel fuel, **99** per cent; fuel oil, **109** per cent; LP gas, **130** per cent; natural gas, **220** per cent; and electricity, **59** per cent.[9] The proportion of total farming costs attributable to energy has risen sharply and can be expected to increase in the years ahead as fuel costs increase relative to the prices of other inputs.

Although farmers in Tenth District states used **20** per cent of the nation's agricultural energy, the District's energy bill **($704** million in **1974)** amounted to only **16** per cent of the total **U.S.** agricultural energy cost. When the various fuel costs are examined, expenditures for gasoline total **41** per cent of the Tenth District's energy budget, even though gasoline supplies only **29** per cent of the direct energy. On the other hand, natural gas expenditures amount to only **4** per cent of the energy bill yet provide one-fourth of the Tenth District's energy. These differences reflect the variations in market prices of the various fuels and also the different market situations through which each fuel is supplied. For example, the high gasoline and diesel fuel prices paid by the farmer are linked to the cost of imported oil. Likewise, interstate natural gas prices are artificially low due to government price regulations. Table **3** shows the proportionate consumption and the costs of fuels used in Tenth District agriculture. Cost differentials suggest to some observers that technological movements toward the use of more natural gas would be profitable. However, recent price increases and the prospect for further substantial increases if price deregulation occurs will likely limit increases in natural gas use.

[9] Direct agricultural energy costs do not include the cost of energy used in the production of fertilizer, chemicals, and machinery, or energy used in farm family living.

POLICY CONSIDERATIONS

Public policy questions regarding energy use in agriculture have recently been addressed from two quite different points of view. One point of view suggests that price signals in a market economy are sufficient to guarantee efficient use of energy. The other point of view suggests that it is necessary to examine the conversion ratios of energy in agriculture to establish efficient energy use. The former viewpoint examines economic efficiency while the latter is concerned with engineering efficiency.

Economic Efficiency

The economic efficiency viewpoint is intuitively attractive. In a market economy where relative prices guide resource use, those inputs with the greatest output efficiency relative to their respective costs are the ones used in production. If all input and product prices are established in the market place, if the prices established are true measures of the value society places on the goods, and if all prices are known to producers, then profit maximizing behavior by producers will at the same time result in the most efficient use of resources—including energy resources. Thus, when the **1976** average cost of employing a farm laborer for **10** hours is **$26.50,** but the physical work he performs can be purchased as electricity for only 3 cents, it is not surprising

Table 3
TENTH DISTRICT FUEL CONSUMPTION AND EXPENDITURES IN 1974

Energy Source	Per Cent of Tenth District Agricultural Energy Use	Per Cent of Tenth District Agricultural Energy Expenditure	1974 Average Tenth District Cost/1,000,000 Btu
Gasoline	29.4	41.1	$3.64
Diesel fuel	31.1	29.2	2.48
Fuel oil	0.1	0.1	2.50
LP gas	10.3	11.3	2.93
Natural gas	24.5	4.3	0.50
Electricity	4.6	14.0	8.04

SOURCE: Developed from USDA data.

that U.S. agricultural production is energy intensive.

However, not all the criteria outlined above are met.in the real world. Some problems exist. Various government price control mechanisms — such as regulating interstate natural gas prices while allowing intrastate natural gas prices to seek market -determined levels— distort relative resource price comparisons. Additionally, maintaining the price of domestic (U.S.) crude oil below the world crude oil price also distorts relative resource prices.

The further question of whether world market. prices accurately reflect the value society places on energy is an exceedingly difficult one. Do administered OPEC oil prices represent petroleum's true market value? Do present market prices for energy reflect all costs of production — including costs typically borne wholly or partially by society--such as those associated with water and air pollution or land reclamation? If petroleum supplies have finite limits, should petroleum be valued at today's world price or should a much higher value be placed on it to limit its current use and conserve the supply for future generations? These questions — for which there presently are no generally agreed upon answers — serve to warn policymakers that the present pricing structure for energy resources may not ,result in socially optimal energy' use patterns.

Engineering Efficiency

Engineering efficiency examines the ratio of energy output per unit of energy input. In a perfectly competitive market system such calculations would be considered little more than an academic exercise. However, in an environment in which constraints on market prices do exist, such calculations could be valuable in identifying those production processes which are the least energy efficient. The degree of engineering efficiency is primarily determined by the technology available for production and processing of inputs and outputs. This technology, in turn, reflects the current state of the art as well as tastes and preferences of people. High relative energy costs will likely stimulate new technology with greater energy efficiency. Likewise, changes in consumers tastes and preferences toward food products requiring less processing and transportation presumably could improve the food system's energy efficiency. For example, over 45 per cent of the energy expended in the food and fiber sector in 1970 went for food processing and marketing

which directly reflected consumer preference (Table 1).

Consideration of energy efficiency suggests energy policy alternatives. For example, Cornell University researchers have suggested that in corn production—which they assume typifies energy requirements in U.S. crop production—the energy resulting from an acre of harvested corn may be as much as 3.7 times as great as the on-farm energy expended in its production.[10] Considering these data in light of the need to supply food to an ever increasing world population, the potential increase in food production resulting from energy intensive agriculture is particularly appealing.

On the other hand, if energy used in the production of farm machinery and food processing were added to on-farm energy usage, research has shown that three times as much energy is required to produce the product as is consumed at the table.[11] These findings, coupled with calls for energy conservation and nonreliance on foreign energy sources, have led to suggestions for a more labor intensive agricultural production system along with reduced processing and transportation of foodstuffs.

On balance, energy efficiency must be viewed in both an economic sense and an engineering sense. Changes in energy prices relative to product prices and increased public recognition of the need for energy conservation can be expected to have an impact on agricultural production. In the future, farm equipment will be engineered for greater energy efficiency and will be more closely scaled to the demands for particular jobs. However, the capital stock for agriculture and for other basic industries was put in place under conditions of low energy prices. Consequently, more energy efficient machines will be incorporated into the capital stock only as rapidly as that stock becomes obsolete or worn out. Rapidly increasing energy prices will hasten such obsolescence, of course. Irrigation water will be used much more sparingly with little loss in productivity. New tillage practices will reduce energy consumption. Plant breeding advances will incorporate greater disease and pest resistance as well as greater resistance to adverse weather. Greater use of solar energy and biomass conversion will occur in those situations for which they are adapted—such as grain drying and heating or cooling brooder and farrowing houses.[12] Additionally, land tenure patterns adapted to fossil energy intensive agriculture are amenable to change only over a long period. On balance, then, the changes that occur are likely to be gradual but the cumulative impact could be substantial.

CONCLUSION

The productivity enjoyed by U.S. agriculture is largely based upon high levels of commercial energy (fossil fuel) consumption. This dependence frequently has led to suggestions that U.S. farmers return to a more labor intensive agriculture, in order to conserve increasingly scarce energy and to augment the energy supplies of developing nations. However, when the total energy use in food production is examined for the United States and for countries with labor intensive agricultural systems, the argument loses much

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10 David Pimental, *et al.* "Food Production and the Energy Crisis," *Science.* Volume 182, November 2, 1973, p. 445.

11 Michael J. Perelman, "Mechanization and the Division of Labor in Agriculture," *American Journal of Agricultural Economics.* Volume 55, Number 3, August 1973, p. 524.

12 Biomass conversion generally refers to the production of a gaseous or liquid energy source from plant or animal matter—usually from residues.

of its appeal. For what stands out in such a comparison is that the **U.S.** system produces far more food per unit of total energy used than the typical system of developing countries, with their intensive use of human and animal labor.

Nonetheless, **U.S.** farmers produce in a market economy. As energy prices climb relative to the cost of other inputs, farmers will shift toward more energy' efficient production techniques. These shifts will likely occur rather slowly—as equipment wears out or becomes obsolete as a result of new and more efficient technology—but the cumulative result will be quite significant. While **U.S.** farmers will probably continue to use energy intensive production techniques, there seems to be little doubt that as energy costs escalate, commercial energy sources will be used much more efficiently in the future.