Consewation and Alternative Energy Sources: The Answer to Agriculture's Energy Problems?

By Kerry Webb and Marvin Duncan

Increased energy consumption through the use of chemicals and machinery during this century has resulted in extensive gains in farm output and productivity. As a result, millions of people have been released for employment in other sectors, and food prices have been maintained at substantially lower levels than without energy-intensive farming. Moreover, investment in farm energy has brought such production abundance that about one-third of U.S. agricultural output can be exported to help purchase oil imports. However, with rising farm energy prices and the threat of fuel shortages, the necessity for conservation and supply alternatives becomes apparent. This article, therefore, examines conservation methods which farmers can presently apply to save both energy and money. The potential for using sunshine and wind as farm energy sources is also discussed. Finally, the development and economic feasibility of biomass energy supplies, *i.e..* gasohol and methane gas, are examined.

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ENERGY CONSERVATION

There are currently numerous ways farmers can reduce their energy use. Most of the methods require little more than better management techniques or some small additional investments. Not only will these procedures save energy and reduce costs, but many of them may even improve the quantity or quality of the output.

Minimum Tillage

Minimum tillage involves leaving crop residues on the soil surface and minimizing plowing, disking, or harrowing. Generally, only the soil right around the plant is prepared and maintained during planting and cultivating seasons. The U.S. Department of Agriculture (USDA) estimates that some 40 million U.S. acres are presently being farmed using minimum tillage practices and that this figure has climbed substantially in the last 10 years. In addition to saving energy through less use of vehicles in the field, conservation tillage benefits may also include reduced soil erosion, improved weed control, increased soil moisture storage, and better double cropping opportunities. The use of energy in the form of pesticides will increase under minimum tillage because of fewer pest-destroying tillage operations, but the net energy saving is still substantial. Although minimum tillage practices cannot be universally adopted due to soil differences, evidence suggests that some form of minimum tillage can be practiced in part of every state.

Efficient Fertilizer Use

Fertilizer, which requires enormous energy for its production, is the largest energy input in producing field crops. About 35 per cent of the energy used in growing crops is required to produce fertilizer. Thus, efforts to use fertilizer more efficiently by soil testing will save both energy and money. Soil tests reveal the nutrient content of the soil and provide information about the type and quantity of fertilizer needed for a specific crop. Research has shown that as much as $43 per acre and 1,800 Btu's per bushel annually can be saved by applying the correct amount of fertilizer to grain sorghum in Missouri.[1] Similar savings can be accomplished throughout most of the nation and particularly in areas growing corn and wheat. Returning animal manure and crop residues to the soil when appropriate, and using nitrogen-fixing legume/grass combinations rather than applying commercial nitrogen, can also lead to more efficient fertilizer use.

Irrigation

Farmers using pump irrigation could save both energy and water by operating their pumping stations more efficiently. About half of the nation's irrigation pumps are estimated to be operating at 75 per cent or less pumping efficiency.[2] In addition, most operators could reduce the amount of irrigation water applied without materially reducing crop production. For example, on a 130-acre field, the use of automated gated pipe (a system which delivers water directly to the furrows in amounts dictated by soil conditions) with water reuse facilities can save more than $1,000 per year in energy costs, or up to twice the annual costs of depreciation, interest, and maintenance.

Other Conservation Practices

Many other practices currently available to farmers will result in significant farm energy conservation, e.g., using the right vehicle for a specific job, using lights only when necessary, insulating livestock shelters, and maintaining farm vehicles properly. However, adoption of these practices will have only a limited effect in alleviating a national energy shortage because agriculture accounts for only 3 per cent of U.S. energy consumption.[3] Although these practices may each save only a few dollars per year in energy costs, an organized conservation program could add up to substantial savings for individual farmers. Table 1 outlines some major areas for energy conservation and the annual dollar savings farmers may obtain as a result.

SOLAR ENERGY

The concept of using solar energy as an alternative to fossil fuels is rapidly gaining acceptance. It has been estimated that the potential energy output from solar power could supply up to 20 per cent of the national energy

1 U.S. Department of Agriculture, A *Guide to Energy Savings for the Field Crop Producer* (Washington, D.C.: Government Printing Office, June 1977), p. 6.

2 *Ibid.*, p. 21.

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

Table 1
SAVINGS FROM ENERGY-CONSERVING PRODUCTION PRACTICES'

Production Practices	Range of Potential Annual Savings from Reduced Energy Use
I. Conservation Tillage Practices	
(savings per acre)	$ 0.45– 1.25
2. Efficient Fertilizer Use	
(savings per acre–field crops)	$ 33.00– 43.00
(savings per acre–vegetables)	$ 6.00– 40.00
(savings per acre–orchards)	$ 6.00– 12.00
3. Better Irrigation Management	
(savings per acre)	$ 1.75– I 1.00
4. Grain Drying Techniques	
(savings per bushel)	$ 0.03– 0.07
5. Better Management of Range and Herd	
(savings per 300-head herd)	$20I.00–$I,650.00
6. Proper Insulation and Ventilation of Livestock and Poultry Buildings	$800.00–$1,500.00

'For the calculations and farm products involved, see the series: A Guide to Energy Savings for the Field Crop Producer; for the Livestock Producer; for the Poultry Producer; for the Dairy Farmer; for the Orchard Grower; for the Vegetable Producer, U.S. Department of Agriculture, Washington, D.C., June **1977.**

consumption and 25 per cent of U.S. agricultural energy needs by the year 2000.[4] The belief that solar energy is an environmentally clean and renewable source of energy has led to the 1980 Federal budget proposal that outlays for solar research and development be increased 40 per cent over 1979.[5] In addition, large amounts of money are also being spent in the private sector for solar energy development.

Direct applications of solar energy use in agriculture date back many years. But, until recently, the costs associated with its widespread use have been prohibitive. Today, although most applications are still in the experimental stage and quite costly, the uses of solar energy range from providing heat for livestock shelters, greenhouses, and water systems to the direct conversion of sunshine into electricity for farm uses such as irrigation pumping. However, the most promising area of

[4] See the Bureau of National Affairs, Inc., *Energy* Users Report. No. 279, December 14, 1978, p. 8, and Roland Kessler, Wind and Solar Potential for Power *Generation—1985-1990,* Proceedings, National Symposium on Electrical Energy for the Food Chain, Fwd and Energy Council (Columbia, Mo.: 1976), p. 88.

[5] U.S. President, Office of Management and Budget, *The* Budget of the United States Government, 1980 (Washington, D.C.: U.S. Government Printing Office, January 1979).

use is in harnessing the sun's heat to dry grain. Over 1 billion gallons of LP gas equivalent are used annually to dry the nation's crops and feeds. With proper solar equipment, it is estimated that up to half of the necessary energy could be derived from the sun.

Crop Drying

The most economical applications of solar grain drying are in low-temperature, in-storage systems. These systems collect solar energy to augment the heat that naturally occurs in the air, and speed the drying of grain stored in bins or other shelters. Although there are many different designs of solar grain-drying equipment, in the basic process sunshine passes through a clear glass or plastic plate which traps the resulting heat. Fans then pull the heated air into the storage bins where the grain is dried.

The use of solar energy equipment on farms will be primarily determined by its cost relative to the costs of other energy forms. Recent research at eight Midwestern locations, experimenting with solar grain-drying systems, suggests that increasing fossil fuel prices have almost made solar grain-drying feasible.[6] This research showed that, depending upon the equipment design, 1976 corn-drying costs ranged from 10 to 30 cents per bushel using the solar equipment. However, about 70 to 80 per cent of this was in fixed costs associated with depreciation, interest, insurance, and taxes. Variable costs ranged from 1.5 to 8.4 cents per bushel. Costs for conventional corn-drying—using LP gas, natural gas, or electricity—averaged about 15 to 24 cents per bushel, with about 30 to 40 per cent of the total in fixed costs, and variable costs of 9.0 to 16.8 cents per bushel.

Although the use of solar power for drying grain may be near to being economically feasible, there are some drawbacks. First, because solar energy is available only during clear, daylight hours, some type of conventional backup system or heat-storing device may be required. Such a system may be quite expensive and could significantly reduce the economic attractiveness of the solar energy equipment. Second, present technology has not yet determined the type and size of the optimal solar energy systems for different regions of the country. Location, humidity, amounts and types of grains to be dried, the amount of moisture to be removed, and additional factors make the determination of the "right" system for an individual farmer extremely difficult. As a result, there may not be much incentive now for large-scale substitution of solar for conventional systems. However, for those farmers considering replacing worn-out or obsolete systems or adding to current capacity, solar systems may be very attractive.

WIND ENERGY

The wind has been considered as a source of energy for centuries. Farmers have long used wind power to pump water, to turn grain mills, and to generate electricity. Although the use of wind-propelled machines has gradually declined during the last 40 to 50 years, increased energy prices have resulted in extensive wind research and development projects. Because the most important factors are wind speed and conversion efficiency, the state of present technology and relatively low alternative energy prices generally suggest that water pumping or electricity generation is economically feasible only in the relatively high-wind areas of the Central and Southern Plains. The equipment

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6 U.S. Department of Agriculture, *The Performance and Economic Feasibility of Solar Grain Drying Systems*, by Walter G. Heid, Jr., Agricultural Economic Report No. 396, ESCS (Washington, D.C.: Government Printing Office, February 1978).

needed to harness the wind's energy is presently much more expensive than conventional energy sources, particularly if some type of backup system is installed.

In generating electricity, it is estimated that only 10 to 30 per cent of the wind energy can be converted to electrical energy.[7] Although peak power output is obtained at wind speeds of 25 miles per hour, average annual wind speed for most of the major agricultural states outside the Central and Southern Plains is only 10 to 11 miles per hour. In addition, most wind generators will not operate until speeds of at least 7 miles per hour are attained. Research has found that a large windmill with a 15- to 20-foot propeller can generate about 250 kilowatt hours of electricity per month—assuming an average wind speed of 10 miles per hour. This amounts to about $120 to $150 of electricity per year. However, such a unit would cost about $7,500 to construct, while annual maintenance costs would probably be more than the $150 saved in electricity. Because the costs farmers presently pay for conventional sources of electricity range from 4 to 6 cents per kilowatt hour, it is unlikely that large-scale applications of wind power will be developed until the cost of electricity increases markedly above present levels.

ENERGY PRODUCTION FROM BIOMASS

There has recently been a strong revival of interest in biofuels, *i.e.*, fuels produced directly or indirectly from organic material or biomass, with much of the interest stemming from the sharply higher energy prices since 1974. A great deal of scientific study and applied feasibility analysis have been directed toward such alternative energy sources—including both those commonly used during an earlier era and those dependent upon the refuse of an affluent, throw-away society.

Another spur to the development and use of biomass has been a return of relatively low prices for some farm products--such as corn, wheat, sugar cane, and sugar beets. Farmers producing these products have once again turned their attention to popularizing the production of ethanol from farm products as a fuel source, in an attempt to address simultaneously the problems of energy shortages and low farm prices.

Although industrial use of biomass fuel in the United States is only about 1 per cent of all U.S. fuel consumption, it is conceivable that farmers in the future may devote substantial acreage to the production of crops for energy production. Under "energy farming," it is likely that all the plant material would be used in energy production. The crops most likely to be produced on an energy farm would not necessarily be familiar to present-day farmers. Rapidly growing woody plants appear to be feasible for energy production. Some less common types of plants--such as giant reed, cattails, weeds, and desert plants (guayule, for example)—are also thought to be desirable. Certain aquatic plants are also possibilities. Corn, sorghum, and sugar cane could also find some use in energy production. Nonetheless, despite considerable research, energy farming—in the sense of producing plant products for direct use as a fuel source or as feed stocks for conversion processes—does not appear to be *economically* feasible now, nor in the immediate future.

Plant and animal wastes and residues presently provide the largest sources of biomass for fuel production. It is estimated that over 10 quadrillion Btu's per year of energy could be produced from biomass sources. These sources include municipal waste, animal wastes,

[7] Thomas G. Carpenter, Cooperative Extension Service Report, Ohio State University, Columbus, Ohio, May 1977 (Columbus, Ohio: Ohio State University, May 1977).

lumber and pulp mill wastes, forest residues, and agricultural residues. The paper and pulp industry presently derives close to 40 per cent of its total energy consumed from wood wastes.[8] The sugar cane industry uses large amounts of its wastes (pressed cane residue, or bagasse) as a source of energy, as well. Thus far, however, economics have worked against widespread use of residues and wastes for energy production.

Surveying the present status of biomass as a fuel source of future importance to U.S. agriculture leads to the conclusion that two sources merit further discussion — methane production from animal wastes and ethanol production from grain crops. These are important for two reasons. First, the necessary technology is presently available. Second, considerable public interest surrounds proposed and presently operating pilot projects. If biomass is to be a significant factor in energy production for U.S. agriculture or for the U.S. economy within the next decade, it will likely be due principally to either or both of these processes.

Methane From Organic Wastes

The process for producing methane gas from organic wastes is not new. Indeed, it was widely used by European farmers during World War II to supplement other scarce energy sources. Small-scale anaerobic digester units for producing methane are used in such developing countries as India, Korea, and Taiwan. The process occurs naturally as well—in the form of swamp gas resulting from bacterial decay of organic matter. In brief, the process entails the anaerobic (without air) digestion of plant or animal residues by bacteria to produce methane gas (see Figure 1).

The process of anaerobic digestion is receiving attention in the United States for at least two reasons in addition to the obvious need for new energy sources. First, the process is technically suited for use on an individual farm or feedlot. Second, it offers the possibility of recycling organic waste, thus avoiding disposal problems and producing usable products such as an animal feed and fertilizer along with methane gas. The anaerobic process can be expected to produce a biogas that is 50 to 70 per cent methane. The product could be burned on farms as a fuel for heating buildings or water. It can also be cleaned to remove impurities such as carbon dioxide and trace amounts of hydrogen sulfide. Once cleaned, it can be substituted for natural gas.

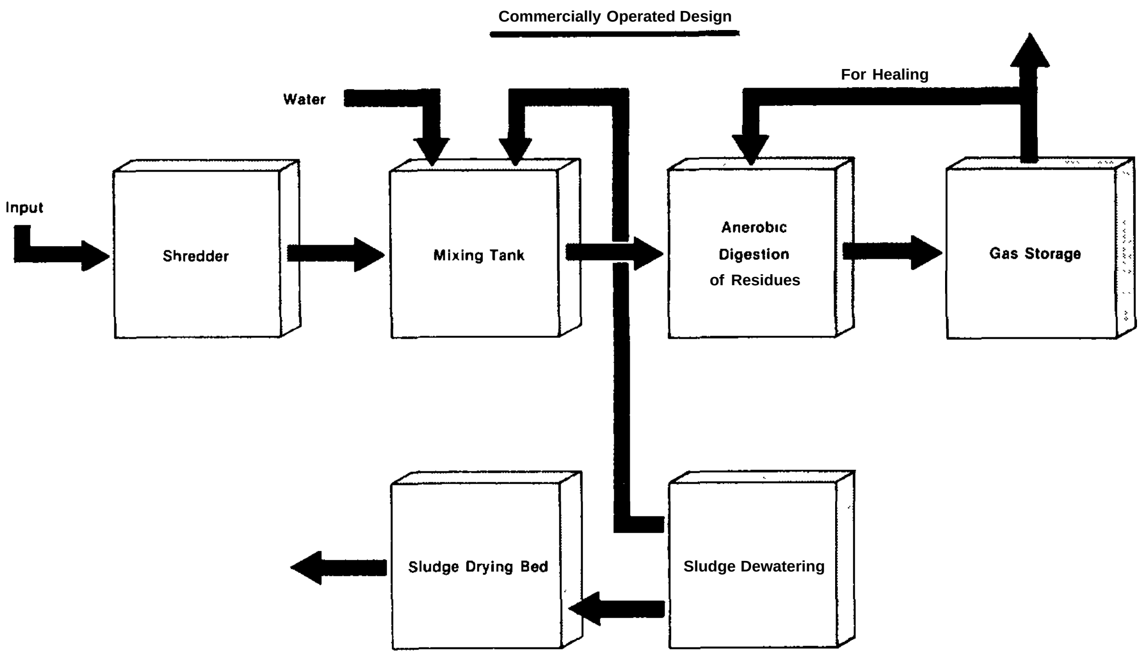
The present economics of producing biogas from animal and plant processing waste suggest that production plants will need to be very large to capture the necessary scale economies to produce gas at near competitive prices. A recent USDA study suggests that a plant utilizing the manure from a 150,000-head feedlot could theoretically produce gas costing $1.99 per 1000 cubic feet.[9] This compares to an average U.S. wellhead price for natural gas in 1977 of 77.9 cents per 1000 cubic feet. Farm size systems would have gas costs substantially in excess of alternative commercial energy substitutes.

A commercial biogas installation has been constructed in Oklahoma that utilizes 500 to 600 tons of manure daily from adjacent cattle feedlots—the production from approximately 100,000 cattle. The installation is capable of producing up to 1.6 million cubic feet of gas daily. This compares to a daily marketed production of natural gas for the United States

[8] **Electric Power Research Institute, *Biofuels: A Survey* (Palo Alto, Calif., 1978), p. S-4.**

[9] **U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service, *An Assessment of Anaerobic Digestion in U.S. Agriculture, by* Ted Thornton (Washington, D.C.: Government Printing Office, 1978), pp. 14-21.**

Figure 1
ANAEROBIC DIGESTION SYSTEM PROPOSED BY BAILIE



SOURCE: Ted Thornton, **An Assessment of Anaerobic Digestion in U.S. Agriculture,** ESCS-06, U.S. Department of Agriculture, March 1978.

during 1976 of 54,664 million cubic feet. In addition to the gas, two feed products are also produced for sale to the livestock industry. Other such installations are being planned for construction in the near future.[10]

It seems reasonable to expect that future anaerobic digestion systems will tend to be built at, or in conjunction with, large feedlots or plants processing large volumes of agricultural products in order to assure an adequate and constant supply of raw material. Indeed, a constant supply seems to be a very important consideration. It is unlikely that the small, labor-intensive anaerobic digestors successfully used in developing countries will find wide use in this country. U.S. labor costs are simply too high and less expensive alternative energy sources are still readily available.

On balance, as natural gas becomes more expensive, production of biogas will be economically feasible in a wider range of locations. However, the limited numbers of sites capable of continuously supplying the raw materials required by plants large enough to be economically viable suggest it is unlikely that anaerobic digestion will ever supply more than a relatively small percentage of U.S. energy needs. Because methane produced for on-farm use will—in most cases—be more expensive than alternative energy sources, it is not expected to have a measurable impact on U.S. farm energy use in the foreseeable future.

10 "Oklahoma Feedlot Pumps Energy Into Chicago," *Successful Farming,* January 1979, pp. 24-25.

Ethanol From Grains

Farmer interest in gasohol—a mixture of gasoline and ethanol—is not of recent origin. Early in this century, the USDA investigated the use of alcohol as a farm fuel. Interest in gasohol ran high during the years of low farm income between the two World Wars. A commercial blend of gasoline and ethanol was sold at gas pumps from time to time during that period but was not commercially viable. From time to time since then, there has been passing interest in gasohol.

A lively debate is currently underway in farm, political, and research circles over the merits of gasohol. Researchers have conducted numerous studies to determine the relative performance of internal combustion engines fueled by gasoline and by gasohol. Small performance advantages for gasohol along with the concept of using a domestically produced energy source have been pointed to as proof that gasohol is worthwhile, and that Federal and state subsidies in the form of tax forgiveness and guaranteed loans for plant construction are in the public interest. For example, Rep. Paul Findley said in a December 12, 1977, statement to the Subcommittee on Agricultural Research and General Legislation of the Senate Agriculture Committee:

> I believe strongly, therefore, that using alcohol gasoline blend motor fuel is practical and beneficial not only for individual motorists and consumers but also for our nation, and is worthy of every application. It is for this reason that I have expressed my hope and that of my constituents that a pilot alcohol production plant will be built soon, hopefully in Illinois.

A gasoline-alcohol mix bums well in internal combustion engines, and may also increase performance. The important and difficult questions, however, are whether the production process is energy-efficient and whether the product is economically feasible.

A recent report prepared for the Task Force on Physical Resources of the Committee of the Budget of the U.S. House of Representatives addresses the questions of energy efficiency and economic feasibility. The answers given there are generally consistent with other reputable studies and reports on the subject.[11] The study assumed a national program requiring the production of 10 billion gallons of ethanol to mix with 90 billion gallons of gasoline annually. The ethanol would be produced in plants large enough to capture most of the economies of scale in production. State-of-the-art technology would be used. Briefly, the process (see Figure 2) entails fermentation of feedstocks such as sugar or grain to produce the ethanol and water. The ethanol-water mixture is then heated in a distillation process to produce anhydrous ethanol (200 proof). The anhydrous ethanol is used in a gasoline-ethanol mixture as a motor fuel.

The distillation process alone requires substantial amounts of fossil energy under current technology. Coal, oil, or natural gas are assumed to be the energy sources used in

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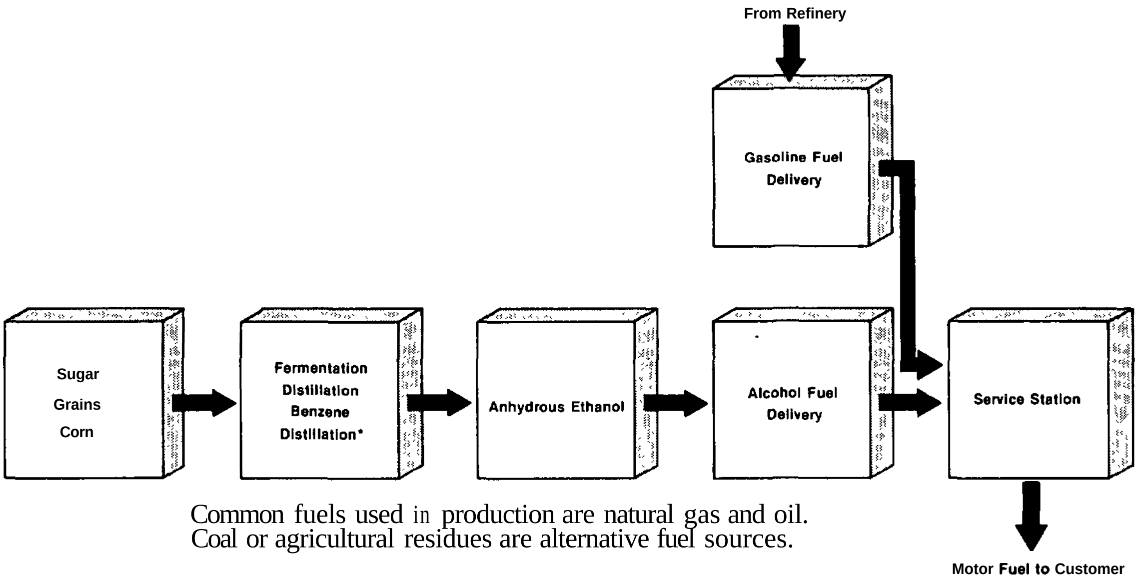
11 U.S. Congress, Senate, statements presented to the December 12, 1977, Hearing on Economic Feasibility of Gasohol before the Subcommittee on Agricultural Research and General Legislation of the Senate Agriculture Committee (Washington, D.C.: Government Printing Office, 1978); James G. Hendrick and Pamela J. Murray, *Grain Alcohol in Motor Fuels: An Evaluation,* Department of Agricultural Economics Report No. 81 (Lincoln: University of Nebraska, April 1978); Peter J. Reilly, *Economics and Energy Requirements of Ethanol Production,* Department of Chemical Engineering and Nuclear Engineering (Ames: Iowa State University, January 1978); and R.N. Wisner and J.O. Gidel, *Economic Aspects of Using Grain Alcohol as a Motor Fuel, With Emphasis on By-Product Feed Markets,* Economic Report Series No. 9, Department of Economics (Ames: Iowa State University, June 1977).

Figure 2
BIOMASS-ALCOHOL FUEL ROUTE



*To remove water from the ethanol produced.

SOURCE: W. Park, et al. Biomass-Based Alcohol Fuels, Metrek Division of the Mitre Corporation, Mitre Technical Report MTR-7866, McLean, Va., July 1978.

processing the grain to produce ethanol. As yet, no commercial process uses stover (stalks and leaves). While the net energy produced from such a process could be increased if stover were used for the process fuel, it is not clear that the economics would be enhanced. Collecting and transporting the stover would be costly, and energy-based chemical fertilizers would be needed to replace the nutrients in the stover that were previously returned to the soil. Additionally, increased soil erosion and loss of soil tilth might be expected if almost all of the stover was removed over a prolonged period.

If ethanol plants could be located close to sources of essentially "free" energy, the adverse energy balance of the process could possibly be corrected. For example, an ethanol plant that had cost-free access to waste steam from another industrial process--such as in sugar cane processing--could use that steam in the distillation process. While it is unlikely that many opportunities for access to such free energy exist, some probably are available.

The technology used in ethanol production is well known and, despite substantial efforts to improve it, has remained basically unchanged for several decades. Consequently, it is unlikely that unanticipated economies of scale in production or more efficient production processes will be discovered in the foreseeable future. The successful application of solar energy technology to ethanol production could favorably change the energy balance of the process. Again, it is less clear that the economics would be improved, since solar energy applications are still very expensive.

The report of the Task Force on Physical Resources presented these conclusions:[12]

Automotive fuel can readily be produced from grain. One bushel of corn produces, through fermentation, 2.6 gallons of 200 proof (anhydrous) ethanol. This can readily be burned in automobile engines, in a 10 per cent blend with gasoline. A residue of this process is 17 pounds of distillers dried grains, a high protein feed.

This alcohol will not be price competitive with gasoline, however. A total annual subsidy of $10.4 billion or 10.4 cents per gallon of gasohol would be required.

Converting the energy in corn to ethanol results in a negative energy balance, since only 0.5 to 0.8 Btu (British thermal unit) of ethanol is derived from each Btu of energy used to grow and process the corn.

U.S. grain production would have to be materially increased to provide food and feed supplies as well as feedstocks for ethanol production. Wheat and soybean acreage would likely decrease.

An annual 10-billion-gallon (subsidized) ethanol market would result in a number of price changes. Food and feed grain prices would increase sharply, triggering increased total grain acreage. However, the 35 million tons of distillers dried grains produced as byproduct would depress soybean oil meal prices and probably result in lower soybean prices and production. Because of shifts in feedstuffs, livestock production would probably decline.

Net farm income would increase slightly--due to higher crop revenues. But, consumer food prices would also increase, principally due to higher livestock prices.

Any subsidy to ethanol production will have to be raised through increased taxation or deficit financing. Current Federal legislation provides forgiveness of the Federal highway tax on gasohol for a specified number of years as an inducement to gasohol producers. Several states have similar legislation to partially or completely eliminate highway taxes on gasohol. Since these tax revenues finance road construction and maintenance, an alternative funding source will now be necessary to offset losses to highway trust funds.

Thus, based on the studies cited in this article, a number of general statements about ethanol production from grain crops for use in a gasohol mix appear to be warranted.

1. Gasohol production, using present technology, wastes scarce energy resources rather than augmenting them.

2. Very large subsidies would be required to make gasohol competitive with gasoline. Revenues lost to highway funds through tax

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[12] U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service, Gasohol from Grain—The Economic Issues, ECCS No. 11 (Washington, D.C.: Government Printing Office, January 19, 1978).

forgiveness on gasohol would have to be raised elsewhere by taxes if highways are to be maintained.

3. Increases in net farm income would likely be disappointingly modest.

4. To the extent that gasohol subsidies were diverted from basic agricultural research and from market development efforts, the long-run potential farm income could be lower than in the absence of a gasohol program.

5. Widespread diversion of food and feedgrains for energy production could be disruptive to **U.S.** livestock production. Furthermore, **U.S.** dependence on food and feedgrains for energy production would limit the capacity of this country to offset, with exports, shortfalls in grain production elsewhere in the world.

Despite the apparent problems with gasohol that stem from an adverse energy balance and a break-even price substantially exceeding that of gasoline, some development of this alternative fuel is **occuring.** The various Federal and state subsidies to gasohol production may reduce the gap between gasohol and gasoline prices to a level that will encourage its use. In the desire to reduce its dependence on imported oil, the **U.S.** may simply choose to ignore the **energy-**wasting aspect of present gasohol production.

CONCLUSION

Rising costs and the possibility of supply interruptions will shape future decisions about energy use by **U.S.** farmers. Conservation promises to be an effective means of reducing both energy requirements and per unit production costs. Alternative energy sources hold substantial promise for the distant future. But a number of perplexing problems will limit the use of these energy sources in the near **future—high** initial investment costs, low or negative energy efficiency, and limited economic feasibility. On balance, alternative energy supplies are not likely to play a significant role in **U.S.** agriculture for some time. Conversely, over the next two decades energy conservation will be of major importance.