Chapter 5

Small Farm Systems

Contents

List of Tables

List of Figures

CHAPTER 5
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Introduction

The last chapter dealt with solar greenhouse technology as an alternative for family and community food production. This chapter and the next will deal with small-scale alternatives to large-scale, energy-intensive agricultural technologies—this chapter with systems by which the small farmer can reduce his energy costs and increase the self-sufficiency of his food-producing operations, and chapter 6 with the local farmers' market as a way for the small farmer to increase his profits by selling directly to the consumer.

Few trends since World War II have been more thoroughly documented—or more generally lamented—than the decline of the small family farm. A number of economic factors have contributed to this trend. The rapidly increasing cost of farmland (amortization and interest) has been the most important of these factors, because it makes farming more capital intensive and thereby encourages large-scale ownership. Rising energy costs and general inflation over the last decade have also made small-scale farming increasingly precarious. The three major costs (other than land) associated with farming are feed for livestock, fertilizer for the soil, and energy to run farm machinery and heat buildings. Rising petroleum prices affect the first factor indirectly and the last two directly; the combination has had a drastic impact on the economic viability of the small farm. Some larger farmers, with more assets to borrow against, have been in a better position to ride out the current cost-price squeeze; corporate growers in some cases have been able to balance increased costs with increased profits from other sectors of the food industry, such as processing, packaging, and distribution.

Small farmers have not had these options, and many of them, especially on the fringes of expanding urban centers, have felt compelled to sell their land to developers. According to the Soil Conservation Service of the U.S. Department of Agriculture (USDA), about 24 million acres of rural land were converted to housing developments, reservoirs, or highways between 1967 and 1975—an area about the size of the State of Indiana.[1] About half of this land was either active cropland or high-quality rural land that could have been turned into productive cropland with a relatively small investment. Recent figures suggest that rural land continues to be converted to these same uses at a rate of about 1 million acres per year.[2] No figures are available on how much of this acreage has come from small-scale farms, but the small farmer, who generally has been most vulnerable, has had the greatest economic incentive to give up his land.

Two ways to improve the viability of the small family farm would be to develop local markets where the small farmer can get a higher return on his produce (see ch. 6) and to develop local, low-cost sources of energy, fertilizer, and livestock feed. This chapter discusses two such attempts to reduce energy costs and increase the self-sufficiency of the small farm. The first is the New Life Farm, a research and educational center in the Ozark Mountains near Drury, Me., which is developing alternative energy sources and energy-conserving farming techniques. The second is the Small Farm Energy Project in Cedar County, Nebr., a 3-year research and demonstration program that is intended to show the impact of proven alternative energy technologies and conservation techniques upon the energy consumption and production costs of small-scale, low-income farmers.

[1]Jefferey Zinn, "Farmland Protection Legislation," Library of Congress issue brief No. IB7801, May 29, 1980, p. 1.

[2]Julian L. Simon, "Resources, Population, Environment: An Oversupply of Bad News," *Science*, vol. 208, No. 4451, June 27, 1980, p. 1435.

Alternative Energy Technologies (I)– Energy From Biomass

A recent OTA report on the energy potential of biomass concluded that:

> Energy from the conversion of wood and other plant matter represents an important underexploited resource in the United States. As renewable, abundant, and domestic resources, these and other sources of biomass can help the United States reduce its dependence on imported oil. The amount of energy supplied by biomass, now relatively small, could expand rapidly in the next two decades–a period when the Nation's energy problems will be particularly acute.[3]

Biomass currently produces about 1.5 Quads[4] per year, or about 2 percent of the U.S. 1979 energy consumption of 79.7 Quads/yr, primarily from the direct combustion of wood in the forest products industry and, to a lesser degree, in home heating.

By the year *2000,* between 6 and 17 Quads/yr could be produced from biomass sources, depending on a number of factors including how much cropland is used for food productions This represents between 8 and 22 percent of current domestic consumption, by comparison, imported oil and natural gas supplied about 23 percent of U.S. energy consumption in 1979. Assuming that U.S. consumption rises to 100 Quads/yr by 2000, energy from biomass could make a significant contribution to the administration's goal of 20 percent solar and renewable sources for that year.

Figure 15 shows the six major sources of biomass energy and their relative contributions to the high and low estimates of potential bioenergy supplies. (Energy from municipal solid waste, another potentially significant source, is discussed in ch. 7.) The three major processes for converting these sources into usable forms of energy are: 1) direct combustion and gasification; 2) distillation into alcohol; and 3) anaerobic digestion to produce biogas.

Direct combustion of wood is the most widespread application of bioenergy today, with between 1.2 and 1.3 Quads/yr used for process energy in the forest products industry and another 0.2 to 0.4 Quad/yr used in home heating and fireplaces. These uses are likely to expand considerably in response to rising energy prices, even without new Government incentives. *Gasification* of wood and herbage (i.e., grass and crop residues) could be more practical than direct combustion for supplying process heat, particularly in industrial applications. The widespread adoption of this technology could depend on the development of reliable, mass-produced gasifiers that could be attached to gas- or oil-fired boilers. Both gasification and direct combustion could compete with other uses of forest products, however, and would compete with coal in many industrial applications.

Alcohol *fuels* can be produced from a wide variety of biomass feedstocks, and they are the only renewable source of liquid fuels for transportation that uses available technology.[6] *Ethanol* (grain alcohol) is already being produced from grains and sugar crops as an octane-boosting additive to gasoline. About 50 million gal of fuel ethanol were distilled in 1979, and installed capacity may be as high as 200 million gal by the end of 1980; but with domestic gasoline consumption at 110 billion gal/yr, ethanol is a small addition to current U.S. fuel needs.[7] Production could reach 10 billion gal/yr (enough to blend 100 billion gal of gasohol) by 2000, but production of more than 1 billion or 2 billion gal/yr could put ethanol in competition with other uses of grain and have serious inflationary impacts on the price of food and animal feed.[8] *Methanol* (wood alcohol) can be produced from grasses and crop residues as well as from wood; no large-scale production facilities currently

[3] *Energy From Biological Processes* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, July 1980), OTA-E-125, p. 3.

[4] A Quad equals 1 quadrillion (10^{15}) Btu. This is approximately equal to the energy of 10 million bbl of crude oil, 50 million tons of coal, or the typical annual output of eighteen 1,000-MW electrical powerplants.

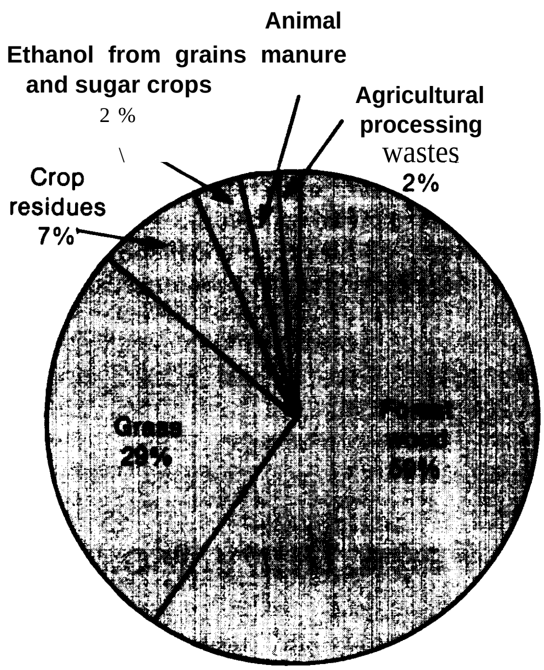
[5] *Energy From Biological Processes,* op. cit., PP. 23-24.

[6] Ibid., p. 6; see also OTA's technical memorandum, *Gasohol* (Washington, D.C.: Office of Technology Assessment, U.S. Congress, September 1979), OTA-TM-E-1.

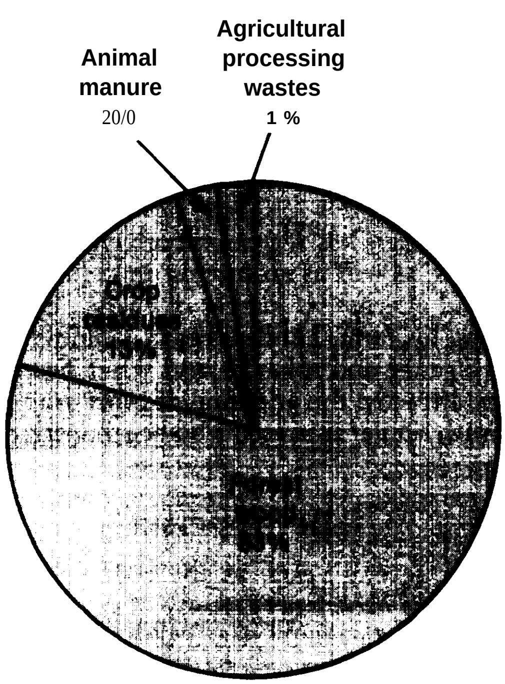
[7] *Energy From* Biological Processes, p. 87.

[8] Ibid., p. 100.

Figure 15.—Potential Bioenergy Supplies (not including speculative sources or municipal wastes)



High total = 17 Quads/yr



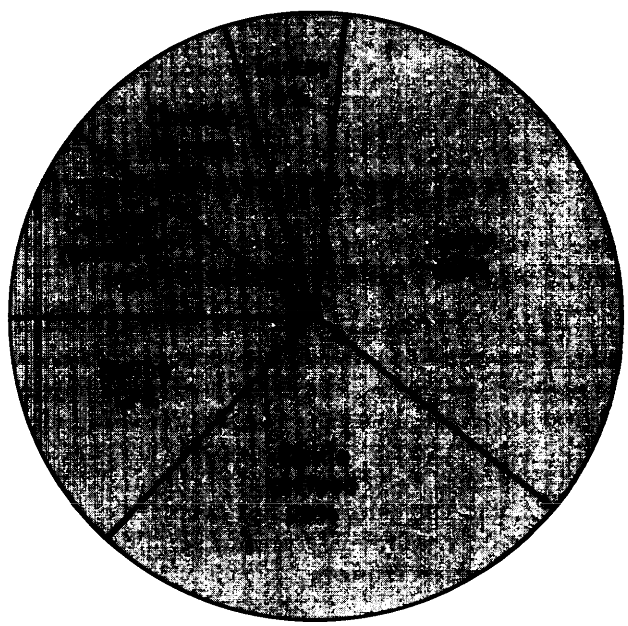
Low total = 6 Quads/yr

SOURCE: Office of Technology Assessment.

exist, however, and it is also estimated that methanol can be produced from coal at about half the cost of biomass conversion.[9]

Anaerobic *digestion* of biomass produces biogas, a burnable mixture of about 60 percent methane and 40 percent carbon dioxide. Potential feedstocks include municipal sewage and solid organic wastes, certain grasses and aquatic plants, and animal manure. OTA estimates the energy potential of manure alone at 0.2 to 0.3 Quad/yr (see figure 16).[10] Anaerobic digestion of manure is also

Figure 16.—Types of Animal Manure From Confined Animal Operation



Total energy potential = 0.2 -0.3 Quad/yr

SOURCE: Office of Technology Assessment from K. Smith, et al., "Animal Wastes," contractor report to OTA, March 1979.

an efficient waste treatment process whose byproducts can be used as a soil conditioner or dewatered for use as animal bedding, and may have potential as a high-protein feed supplement. In addition, the manure/biogas fuel cycle does not compete with the production of other commodities; instead, it makes use of an existing, underexploited resource without destroying its value for other uses.[11]

[9]Ibid., p. 103, table 9.
[10]Ibid., p. 123.
[11]Ibid., p. 12.

This biomass fuel cycle is best suited to small-scale exploitation because of the dispersed nature of the resource base:

> About 75 percent of the manure resource is on animal operations of 1,000 head of cattle or less (or the equivalent for other animals such as swine, turkeys, chickens, and dairy cows), and 50 percent is on operations one-tenth this size or smaller. Only 15 percent of the manure resource occurs on large feedlots of the equivalent of more than 10,000 head of cattle. Because manure cannot be economically transported for long distances, exploiting the manure resource will require digester designs suitable for relatively small animal operations. Important features of these digesters will be automatic operation and low installation cost.[12]

In short, anaerobic digestion of animal wastes is a technology whose resource base makes it particularly appropriate for small-scale onfarm applications. There is still a need to develop and demonstrate a variety of digester designs in order to improve their flexibility and reliability, reduce their capital costs, determine the biogas yield and effluent characteristics of different feedstocks, and explore alternative applications for both biogas and byproducts. The following case study examines the efforts of one group of Missouri farmers to develop digesters suitable to their needs.

[12]Ibid., p. 127.

A Case Study of the New Life Farm, Drury, Mo.[13]

The Community Setting

The Ozark region of southwestern Missouri is sparsely populated and affords a poor living for most of its residents. The hills have been heavily logged or cleared for fields and pastures, and much of the land is badly eroded, leaving few acres of good farmland. A large portion of the land is used for hog- and cattle-raising, but even these operations are only marginally profitable. Overgrazing has led to further erosion.

The traditional small farmers in the area are conservative and tend to distrust outsiders. They feel cut off from their fellow Missourians to the north, who tend to own larger and more productive dairy and hog farms, and often joke about seceding from Missouri and joining Arkansas. They are particularly distrustful of State and Federal officials and feel that they are being shortchanged by the various farm assistance programs in the area.

The New Life Farmers, by contrast, are by and large young and college-educated. Many are from urban backgrounds and came to the Ozarks as part of the "back to the land" movement in the late 1960's. Few of them joined communes, however; for the most part, they came alone or with their families to set up farms. They were interested in self-reliance and living in harmony with nature, but many had little experience with rural living or farming techniques.

One of these young farmers was Ted Landers, who purchased a 240-acre farm near Drury in 1972. Landers has degrees in both engineering and business, as well as an interest in organic gardening and alternative sources of energy. Soon after buying his farm, Landers began building a methane digester and solar air and water heaters. His work attracted the attention of other young farmers with similar interests, who began working with him.

Development

After several years, as the young farmers became more experienced, many of them wanted to share what they had learned with others who had similar interests. Some of them also wanted a chance to use their skills in research and community organizing without having to take conventional, full-time jobs. They set about organizing

[13]Much of the material in this case study is based on a working paper, "New Life Farm, Drury, Missouri," prepared by Michael Fischer and Michael Swack for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

Photo credit: New Life Farm

New Life Farm, Drury, Mo.

New Life Farm (NLF) as a community institution with a number of goals:

- pursuing R&D techniques that could be used by local farmers to improve the productivity of their land while maintaining the natural balance of the ecosystem;
- acting as an educational center for training in these technologies and assistance in implementing them;
- providing periodic employment for laborers, researchers, and managers from the community; and
- serving as a focal point for community services like day-care and for activities such as theater groups and crafts collectives.

NLF was incorporated in the spring of 1978 as a tax-exempt, nonprofit educational and research organization. Its bylaws require members to contribute 6 days of work on the farm each quarter, and those who have done so for three of the last four quarters may run for the board of directors and vote on project decisions and changes in the bylaws. There were 40 members in November 1979, and members have served on the county Soil and Water Board and local University Extension Service advisory panel. One member teaches at the local university, and another has run for public office at the State level.

NLF has four major projects currently underway, two of which involve the development of methane or biogas digesters.[14] These devices consist of sealed tanks which are loaded with manure, grass, or other crop wastes; the organic material decomposes into a high-quality liquid fertilizer and a burnable gas that can be used in place of propane or natural gas for heating and cooking. The "Rural Gasification Project," funded bya$155,000 grant from the Community Services Administration (CSA), will design and build 20 such digesters, 4 in each of five regions across the country, for low-income farmers who will pay 10 percent of the cost. NLF is also involved in a joint research effort with University of Missouri faculty at Rolla to test and evaluate the performance of a large batch-loaded phytomass (or plant material) digester under a variety of circumstances. This project, funded by a 3-year, $230,000 grant from the Department of Energy (DOE), will try to determine what type of crops produce what types of gas and

14 Descriptions of these projects are based on various New Life Farm brochures and discussions with members.

fertilizer, as well as how the application of the fertilizer affects crop productivity over the long term.

Another project is the "Why Flush? Water Quality Conservation Project," which is funded primarily by the Rockefeller Foundation.[15] It is designed to educate the public on alternatives to current methods of handling sewage, with particular attention to onsite treatment systems such as comporting toilets. NLF's fourth project is "Solar Heating Made Easy," a joint effort with Southwest Missouri State University, which is funded by the U.S. Office of Education's Community Service and Continuing Education program. The project runs 2-day workshops throughout the State, during which a class of about 10 trainees is shown by NLF members how to install a simple, low-cost solar space or water heater in the home. (See chs. 3 and 4 for discussions of the workshop approach.)

The New Life Farm Systems of Technologies[16]

One of the unique features of the NLF approach is the way in which the technologies will be integrated into larger systems. Each technology becomes a component in a cyclic process whereby the byproducts of one stage (energy and/or materials) become the inputs for the next stage. Although some waste is inevitable, a well-designed cycle needs very few inputs of energy or materials from outside the system and produces very little waste that is not reclaimed. Conventional technologies, by contrast, can consume many external inputs and discard large volumes of wastes as solids, sewage, or air pollution. The NLF approach is intended to be less costly and gentler on the environment.

The NLF biogas project, which was selected for study in this report, illustrates how technologies can be integrated into a cyclical system. It combines alternative farming methods, fertilizer production, waste disposal, and energy production into a unified system designed not only for the needs of the small farmer but also for the ecology of the region.

The geology of the Ozarks, with a thin topsoil over a porous limestone base makes surface waste disposal difficult and possibly hazardous to health. Manure and sewage, which may still contain pathogens (disease-causing micro-organisms), and chemical fertilizers can pass quickly through the limestone without adequate elimination of pollutants, making groundwater pollution a potentially serious problem. The thin topsoil produces poor pasturage, and over the years the steady clearing and overgrazing of the hilly land has led to massive erosion. Soil quality has been further impaired because many farmers do not fertilize their fields due to the high cost of fertilizers. Finally, the region lacks indigenous fossil fuel resources, and the cost of importing energy (mostly propane and electricity) is very high, as a result, energy costs have become an increasingly significant percentage of the farmer's budget.

The biogas system addresses all of these problems simultaneously. The system begins with tree cropping. NLF grows a variety of honey locust trees, whose pods are high in protein and carbohydrates and can be used as animal feed. The trees produce four times the nutrients per acre that would be produced by oats, and their roots help to anchor the topsoil and prevent erosion. The grass growing beneath the locusts is no longer overgrazed and can be gathered in controlled harvests and fed into the digester, along with animal manure.

These organic materials are mixed with water in the digester to form a slurry that is about 10 percent wastes by weight. The slurry can be fed to the digester either continuously (adding a little fresh material each day) or in batches (reloading with a fresh slurry every 30 to 60 days), depending on the type of materials and the convenience to the farmer. The slurry is pumped into a sealed tank where it decomposes through the action of anaerobic microbes—bacteria and fungi that feed and reproduce rapidly in the absence of oxygen. One byproduct of this anaerobic decomposition is biogas, which is composed of about 60 percent methane

[15] The project has received a $3,750 grant from the Rockefeller Foundation and $500 from the National Demonstration Water Project.

[16] Information on these technologies was supplied by Ted Landers of New Life Farm, but performance projections are based on limited data. For example, the quality and quantity of gas and sludge produced from different materials under different conditions is the subject of considerable debate. Landers claims that his estimates are conservative and is trying to confirm them through controlled experiments, but a great deal of research remains to be done.

(the main component of conventional natural gas) and 40 percent carbon dioxide, with traces of hydrogen, hydrogen sulfide, and nitrogen. The other byproduct is a sludge that is high in carbon and nitrogen compounds and makes an excellent substitute for conventional chemical fertilizers. Using this sludge, the topsoil can be enriched and built up over time with less danger of ground water pollution than is posed by either manure or chemical fertilizers.

Some controversy exists as to whether or not anaerobically digested nutrients exist in compounds that are more likely to remain in the topsoil than the compounds in chemical fertilizers. However, it does seem clear that anaerobic digestion (which takes place at temperatures of 950 F over a period of up to 60 days) succeeds in killing most of the pathogens present in manure. Thus, to the extent that sludge instead of raw manure is applied to the soil, some improvement in ground water quality should result.

One of the main goals of NLF research on biogas digesters is to gain a more precise understanding of the nutrient content of sludge, how it varies with the mix of materials being digested, and how these nutrients are made available to plants. The goal of NLF's development efforts is to build and demonstrate digesters that can be built easily by farmers, perhaps with some hired labor for specialized tasks, in a reasonably short time and at a low cost. These goals are combined in NLF's two biogas digester projects: the Rural Gasification Project (RGP), which is developing manure digesters; and the joint phytomass project, which is developing digesters for crop residues and other plant wastes.

NLF Methane Digester Design and Performance

NLF has built five small-scale, continuous-loading hog manure digesters for RGP and is designing a sixth. These digesters represent three prototype configurations, with slight variations in size and input mix, but are based on a common design (see figure 17). The digester is an insulated tank divided into upper and lower sections connected by a surge tube. A submersible sump pump in the loading pit moves slurry into the bottom or "active" section. The amount of slurry in the lower section, called the "active volume," is the usual measure of a digester's capacity; NLF's manure digesters ranged from 300 to 500 cubic feet (ft^3). The slurry is heated to optimal temperature by a hot water pipe or a coil gas heater like that in a hot water heater. As decomposition begins and biogas pressure increases in the active section, some of the slurry is forced into the upper or "surge" section. Biogas collects at the top of the active section and can be drawn off through a gas line to the household appliances or other uses (see below). Sludge is removed periodically through a discharge tube in the bottom of the active section and replaced with fresh slurry to maintain a fairly stable level of decomposition and biogas output.

Most biomass will produce 1 ft^3 of biogas per day for each cubic foot active volume of slurry, although some manure slurries will produce twice this yield. NLF feels that the latter estimate is true for hog manure, and the yield from their RGP-3 digester compares favorably with yields reported by other experimenters, shown in table 11. A 300-ft^3 digester like the RGP-3 would require input manure of approximately 180 1b/day, the daily wastes of about 120 hogs.[17] Table 12 itemizes the costs and potential energy savings of three RGP manure digesters. A digester of this size could easily supply all of the gas needed for cooking, water heating, and maintaining digester temperature on a small farm.

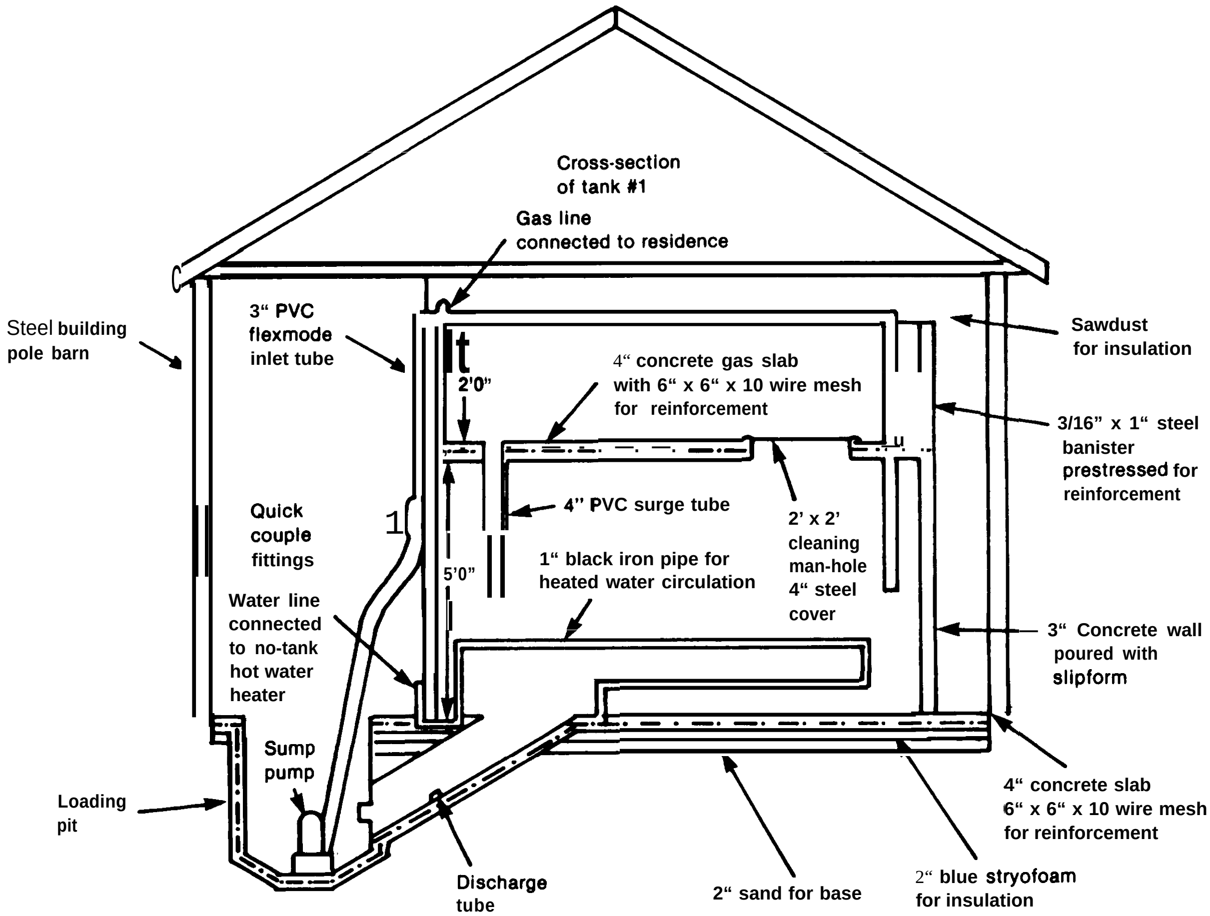
The NLF phytomass digester consists of four batch-loading reactors of 4,000-gal capacity each, which can be operated either in parallel or in series; this modular design gives the digester more flexibility in operation. The four reactors have a total active volume of 2,000 ft^3, which could yield 2,000 ft^3 of biogas per day. These units have not been operated extensively enough to provide reliable data, however, and the proposal submitted to DOE indicated that the facility would operate at a combined rate of only 1,210 ft^3/day.[18]

Initial test results with orchard grass cuttings show that a 5-percent slurry has an average daily biogas output of 200 ft^3 per reactor over the first 30

[17] Richard Merrill, "Methane Generation," in Energy Primer, ed. the Portola Institute (Palo Alto, Calif.: New Alchemy West, 1974), p. 143; the figure for steers seems rather low.

[18] James E. Gaddy, "Energy From Farm Crops," research proposal submitted to DOE, 1977; the author is a professor at Missouri State University, Rolla, and principal investigator in the NLF phytomass digester project.

Figure 17.—New Life Farm/RGP Biogas Plant #1



SOURCE: New Life Farm.

Table 11.—Daily Yields From Several Biogas Digester Designs (ft^3 biogas per ft^3 active volume per day)

Builder/designer	Waste type[a]	Daily yield[b]
Chinese peasants	Unknown	0.67-0.83
Indian peasants	Unknown	1.25
Dr. William Jewell of Cornell University for DOE	Cow manure	2.50
Ken Smith of the Ecotope Group for DOE and State of Washington	Cow manure	1.67-6.67
Energy Harvest, Inc.	Cow manure	4.17
New Life Farm:		
RGP #3	Hog manure	0.60-2.40
Phytomass	Orchard grass	0.80 (estimate)

aAssumes 10-percent slurry by weight.
bAssumes biogas at 60 percent methane.

SOURCES: Ted Landers of New Life Farm and Lee Johnson, "Neighborhood Energy: Designing Democracy in the 1980' s," *Stepping Stones: Appropriate Technology and Beyond,* Lane de Moll and Gig Coe (eds.), (New York: Schocken, 1978), p. 183, table 5.

days. It is assumed that increasing the slurry to 10 percent phytomass would double the output to 400 ft^3/day per reactor. This yield of 0.8 ft^3/ft^3/day is about half the yield of manure digesters (see table 11). The four reactors, loaded in sequence at the optimal interval, should produce a reliable 1,000 ft^3/day of biogas. Figure 18 shows three measures of the phytomass digester's performance.

It is estimated that full-scale operation of the NLF phytomass facility would require inputs of 44 tons of dried plant wastes annually. This would amount to 17 acres of cornstalks or pasture grasses, or a little less than 33 acres of weeds or uncultivated grasses.[19] The same initial tests with orchard grass shows that the sludge from the digester

[19]Ibid.; and L. John Fry, "Practical Building of Methane Power Plants."

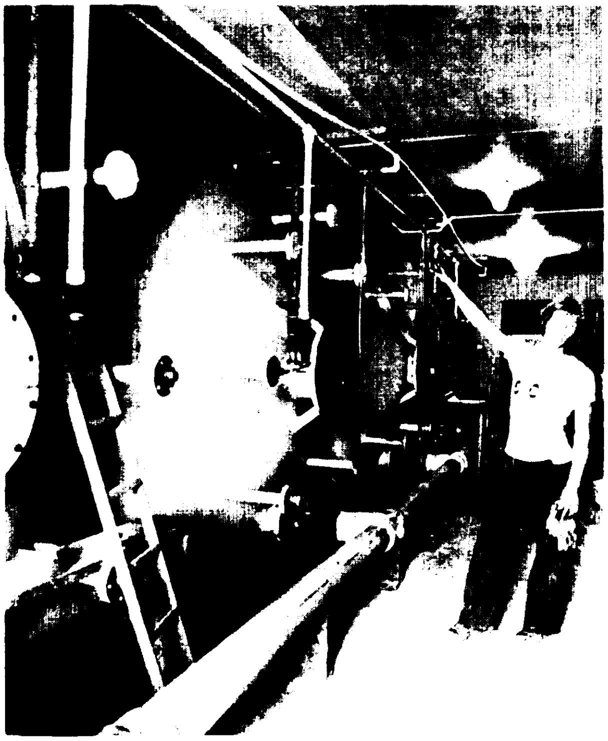


Photo credit: *New Life Farm*

Methane digester tanks

would return significant amounts of nutrients to the soil. Table 13 presents the nutrient content of the sludge and the annual production of each nutrient by the NLF phytomass digester. Tables 14 and 15 present a cost/benefit analysis of the phytomass system, based on the present size and on double that capacity; note that the process shows some economies of scale.

Biogas Applications and Economics

The energy uses to which biogas might be applied vary considerably from season to season, while biogas production would be relatively constant year-round. Consequently, biogas must either be used to meet those energy loads which are more or less stable or somehow be stored for use in times of excess demand. Otherwise, the surplus energy of the gas would be wasted instead of used to offset the cost of the system. This is an important consideration in determining the most economical scale for a given farm: digesters large enough to supply winter space-heating needs (about 380 ft^3/day output) would produce a large amount of surplus gas in the summer, whereas the applications that are constant from day to day, such as hot water heating and cooking, demand relatively small amounts of gas (about 100 ft^3/day).[20]

As it turns out, however, this innovative technology shows conventional economies of scale: large volumes of gas can be produced more cheaply than smaller volumes. Larger digesters would thus provide greater energy savings, and a better return on investment, if they could be applied to larger loads or their output somehow stored for later use.

[20]Consumption figures from Dawson, 1975.

Table 12.—Technical and Economic Data for Three RGP Digesters

Item	Digester #1	Digester #4	Digester #5
Active volume	**300 ft^3**	**400 ft^3**	**500 ft^3**
Tank construction	**Slip form concrete**	**Plastic**	**Plastic**
Materials cost	**$1,885**	**$2,000**	**$1,500**
Labor cost	**$1,885**	**$1,000**	$1,000
Levelized capital costs[a]	$480	$382	$318
Annual yield (50% utilization)	31.04 MMBtu	41.39 MMBtu	51.74 MMBtu
Levelized energy savings[a]	$604	$815	$1,015
Net savings	$124	$433	$697
Cost/MMBtu	$15.46	$9.23	$6.15
Cost/MMBtu (100% utilization)	$7.73	$4.61	$3.08
1980 cost of LPG/MMBtu	$6.49	$6.49	$6.49

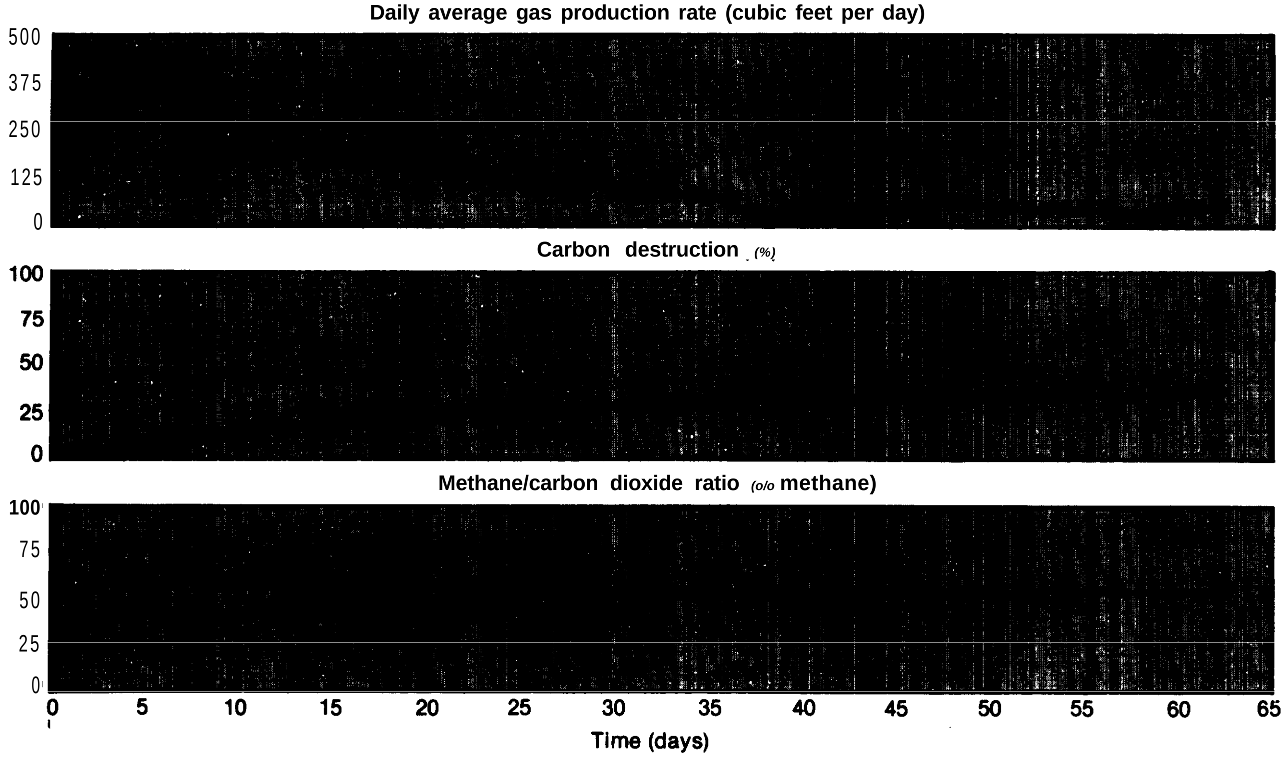
aUses lifecycle costing methods presented in OTA's *Application Of solar Technology to Today's Energy Needs,* vol. II. Tax deductions, O&M expenditures, biomass costs, and replacement costs have been omitted. The following assumptions were applied:
Capital charges on a 10-year loan= 15%
Consumer discount rate =6% (current savings interest)
Life of system= 20 years
Initial cost of LPG = 60¢/gal
Inflation = 6%
Fuel escalation (above inflation) = 5%

SOURCE: New Life Farm.

Figure 18.—NLF Phytomass Digester Reactor Operating Performance

Reactor 4
Agricultural residue—orchard grass
Startup date Nov. 21,1979

Batch size–3,600 (gallons)
Percent Residue 5.5(%)
Culture/residue ratio 4:1



SOURCE: New Life Farm.

Table 13.—Nutrlent Content and Output of NLF Phytomass Digester

Nutrient	Percent of sludge	Annual yield (lb)[a]
Nitrogen.	3.3	825
Phosphorus.	1.2	300
Potassium	0.7	175
Sulfur	0.6	150
Sodium.	0.3	75
Magnesium	0.5	125
Calcium	13.2	3,300
Manganese	0.06	15
Zinc.	0.06	15
Iron	0.6	150

aTotal sludge = 25,000 lb/yr.

SOURCE: Office of Technology Assessment.

The conventional method for storing gas is to compress it and keep large volumes in a small space under high pressure. The NLF designers, however, generally oppose this approach: it would require a significant amount of gasoline or electricity to run the compressors, and the pressurized gas itself is highly explosive. Instead of storing the gas, they intend to use it to produce other forms of energy (such as electricity or alcohol) that can be stored more easily or for which there is a stable year-round demand.

Surplus gas from the 2,000-ft^3 NLF phytomass digester, for example, could be used as feed gas for

Table 14.—Capital Costs for Two Farm Digester Systems"

	NLF Phytomass (4 modules; 2,000 ft³)	Projected (8modules; 4,000 ft³)
Steel tanks, 4,000 gal minimum .	$2,660	$4,080
6-kW generators with engine, 120 VAC, 60 herz.	1,250	1,250
Gas storage tank with concrete pit.	700	900
Forage chopper with blower. . . .	1,000	1,000
Building materials	1,460	2,080
Heater.	300	400
Sludge pump, 10 gal/min.	200	200
Piping, agitators, valves, miscellaneous	1,000	1,300
Labor[b]	500	700
Totals	$9,070	$11,910

aEstimates are presented for two digester sizes in order to demonstrate economies of scale. Modular reactors are batch-loaded in sequence in order to maintain relatively constant total yield. Note that these figures include costs for electric generators. Prices are in 1978 dollars.
bDoes not include cost of farmers' labor, only that of specialized help such as welders.

SOURCE: New Life Farm.

Table 15.—Energy Cost From Farm Digester

Size (ft³ active volume).	730	1,460
Yield (MMBtu/yr).	267	534
Capital cost.	$9,070	$11,910
Annual operating costs		
Biomass.	$150	$300
Maintenance, 2%	180	240
Capital charges, 8%	720	
Total.	$1,050	$1,490
Energy cost		
As methane (per MMBtu).	$4.10	$2.80
As electricity (per kWh at 20% efficiency).	$0.055	$0.038
Price of liquid propane (1978)		$4.60/MMBtu
Marginal cost of electricity (1979).		$0.060/kWh

SOURCES: New Life Farm and Rural Electrification Administration, USDA.

a 15-horsepower engine turning a 7.5-kW electrical generator. At 20-percent thermal efficiency, this system could produce 3,500 kWh/month, compared to average farmhouse loads of 900 kWh/month.[21] NLF might be able to sell its surplus electrical power to the rural electric cooperative or use it to supply another system in their farm operation. In addition, about 10,000 Btu/hr in waste heat is available in the exhaust gas and radiation from the engine, which could be used to heat the building that houses the digester.

A second potential use for excess biogas is to heat an alcohol still. Recent increases in the price of gasoline have helped make the production of alcohol fuels on the farm a more attractive option. Although operating an alcohol still consumes more than 50 percent of the energy in biogas that it produces in distilling alcohol, the alcohol can be stored much more easily. This arrangement would provide a constant, high-volume demand for biogas and allow the farmer to produce fuel for his machinery at a lower unit cost. Either system—biogas/electricity or biogas/alcohol–would increase the cost effectiveness of both technologies by reducing or removing the need for fuels or energy from off-farm sources.

The NLF biogas system responds to the local needs and condition of farmers in the Ozarks. In the case study that follows, a group of low-income farmers in Cedar County, Nebr., has addressed a somewhat different set of needs and conditions through the application of solar technologies.

[21]Consumption figure from Federal Power Commission.

Alternative Energy Technologies (II)–Onfarm Solar Applications

The energy needs of the small-scale farmer can give rise to a wide variety of innovative solutions. As in the case of the NLF system of technologies, they may involve the integration of alternative farming techniques with small-scale applications *of* alternative technologies. The techniques and technologies may be familiar; what is new is their integrated application to the particular needs of the small farmer, an application that responds to local needs and conditions by developing the means to make better use of local resources.

The NLF system is based on anaerobic digestion, a fuel cycle that produces energy from biomass. It evolved in response to the needs of hog farmers in the Ozarks, but many of its developers were from urban backgrounds and had engineering or management skills that might not be available in other communities. By contrast, the case study that follows examines a project that is designed to show how far a group of low-income farmers without special skills can progress toward energy self-sufficiency when provided with technical and cost-sharing support.[22] Its participants are established, full-time farmers who are developing their own applications of alternative technologies, most of them based on solar energy, to the resources and needs of small farming and livestock operations in northeastern Nebraska.

The principles of passive and active solar power have already been touched on in chapters 3 and 4, and the onfarm applications of these principles will be examined in some detail in the case history. For a more thorough examination of this subject, the reader should consult an earlier OTA report, *Application of Solar Technology to Today's Energy Needs.*[23]

[22] Rural Development, Inc., "Evaluation of the Small Farm Energy Project at the Center for Rural Affairs," contractor report to Community Services Administration, contract No. P-78-30, Dec. 1, 1979, p. 1.

[23] *Application of Solar Energy to Today's Energy Needs* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, June 1978), vol. 1, OTA-E-66; and vol. II, OTA-E-77, April 1979.

A Case Study of the Small Farm Energy Project, Cedar County, Nebr.[24]

The Community Setting

Cedar County is a small rural county in northeastern Nebraska which has experienced a slow but steady decline in population during the past several decades—a pattern not unusual for poor rural counties in the Midwest.[25] In 1970 over 45 percent of the work force was engaged directly in agriculture and much of the remainder in the sales and service occupations that support it. Many of the residents are decedents of German, Czech, and Swedish settlers, and the county has a well-integrated community life common to an earlier period of U.S. history. This is illustrated by the extremely low crime rate in the county: 454 crimes reported per 100,000 population, compared to a rate of 3,619 per year for Nebraska as a whole.

In 1974 there were 1,258 farms in Cedar County, with an average size of 354 acres.[26] This indicates a pattern of small-scale agriculture that is unusual in Nebraska (average farm size 683 acres) and in most of the Midwest. The topography partially explains the persistence of small-scale farming. The area is characterized by rolling hills and numerous creeks and marshy valleys that impede the movement of large farm machinery across the fields. The hilly terrain and frequent dry spells pose a danger of wind and water erosion. Consequently, the local farmers often employ more traditional, labor-intensive methods of farming, including small fields, contour plowing, windbreaks, and terraced hillsides.[27]

Local farm operations are generally more diversified than in other areas of Nebraska, where farmers often rely entirely on grain for their cash crop. Cedar County farmers grow a number of crops, including alfalfa and soybeans as well as corn and oats. Local farmers use some chemical fertilizers, but they depend largely on crop rotation to main-

[24] Much of the following discussion is drawn from Rural Development, Inc., op. cit.

[25] Ibid., p. 19.

[26] U.S. Census Bureau, 1974 *Census of Agriculture*.

[27] Rural Development, Inc., op. cit., pp. 19-21.

tain soil fertility. The farms are mechanized, often with three or more tractors each, but they still require the work of the entire family.

Hog breeding and dairy operations are more common in Cedar County than in the rest of the State, and they are well-suited to intensive use of the available land. General livestock farms seem to be less vulnerable to energy price increases and supply disruptions than specialized operations of the same size. The major variable is electricity demand: dairy farms have a fairly substantial load for hot water and milkers year-round; and hog farms have a heavy load for space- and floor-heating during winter farrowing; but general livestock farms, which farrow less often in winter and milk fewer dairy cows, have a lower and more stable demand for electricity y.

Table 16 presents a social, economic, and agricultural profile of Cedar County and the State of Nebraska. Both median family income and per capita income are lower than the averages for Nebraska and the Nation as a whole. In 1970 the county ranked 2,684 out of the 3,067 U.S. counties in median family income. Farm production costs consume a greater percentage of gross farm income than in the rest of the State, and energy costs often represent 20 percent of the operating expenses for some of the smaller operations. Projections based on figures supplied by DOE indicate that energy costs on these small farms will double by 1984. Small farmers with low net incomes will be most vulnerable to energy shortages and price increases, which might in some cases make the smallest agricultural and livestock operations economically untenable.

Development

The Small Farm Energy Project (SFEP) is an attempt to address these local needs and conditions. The project is sponsored by the Center for Rural Affairs (CRA), a nonprofit corporation in Walthill, Nebr., as part of an advocacy program for small farmers and other low-income rural residents. CRA's interests include a wide range of agricultural methods and appropriate technologies, but because the cost of electricity was rising faster than other farm expenses, their particular focus in this project was on technologies that would conserve or produce energy.

CRA submitted its proposal to CSA, which approved it on October 1, 1976, as a "national research and demonstration project" and funded it for an initial 15-month period. A second CSA grant approved a year later provided the funding necessary to complete the 39 months of work outlined in the CRA proposal.

The objectives of the project are:

- to determine the energy price vulnerability of small farmers;
- to produce working models of technologies that save or produce energy;
- to calculate what impact these innovations

Table 16.—Socioeconomic and Agricultural Profile of Nebraska, Cedar County, and the Small Farm Energy Project

			Small Farm Energy Project	
Measure	Nebraska	Cedar County	All innovators	Major participants
Population change, 1960-70	+ 5.2%	– 8.8%	NA	NA
Per capita income, 1974	$4,508	$2,660	NA	NA
Mean years of education, 1970	12.2	12.1	12.0[a]	12.9a
Average family size, 1970	3.5	3.5	5.8[b]	6.2[b]
Average farm size (acres), 1974	683	354	357[c]	381[d]
Percentage of farms with more than 20 milk cows, 1974	4.O%	16.6%	62.5%[b]	66.7%[b]
Average gross farm income, 1974	$55,224	$40,047	$34,735[d]	$40,633[d]
Average net farm income, 1974	$13,057	$8,368	$2,919[d]	$5,066[d]
Profitability (net •/• gross), 1974	23.6%	20.90/o	8.40/o	12.5%

NA = not applicable.
[a]Average 1977 figures.
[b]1975 figures.
[c]1977 figures.
‘1976 figures.

SOURCES: U.S. Census Bureau, 1970 Census of Population and 1974 Census *of Agriculture;* and Small Farm Energy Project.

have on farm energy usage, in terms of both Btu and dollars;

- to develop and implement an educational program; and
- to develop an energy and income recordkeeping system for small farmers.

The stated *research* objective of the project is to determine the impact of proven alternative energy technology and conservation techniques on the energy use, cost of production, and net incomes of low-income farmers. For this reason the project includes a control group of farmers keeping energy records. The stated *demonstration* objective of the project is to show how far a group of 24 low-income farm families can progress toward energy self-sufficiency when provided with technical assistance and cost-sharing over a 3-year period.

Fifty full-time, low-income farmers from Cedar County were selected as SFEP participants (see table 16 for a profile of this group). Twenty-five were in the innovating group, which received technical and cost-sharing assistance to help them construct alternative energy devices on their farms. The other 25 were in the control group, whose only involvement was to maintain detailed energy and income records for 3 years. In addition, a board of directors composed of local residents—two farmers, a lawyer, and a banker—was established, not only to help establish the project's credibility with the local farmers but also to serve as a channel for disseminating information about SFEP and gathering community opinion for management decisions. The project works out of a storefront office in Hartington, the county seat.

The SFEP Innovation Strategy

The project is designed to be a controlled experiment in innovation. The three major elements in its innovation strategy are:

Education.–First the farmers learned what technologies were available and how to make use of them. The project staff arranged a series of lectures and discussions by engineers, agricultural specialists, and farmers from other communities who had undertaken similar projects on their farms. They also held hands-on workshops with the innovating group, and individual staffers held one-on-one sessions with the "innovators" during farm visits. The Hartington project office set up a resource library and started mailing out an innovator newsletter.

Self-Selection and Installation.–Next each farmer chose a technology that he thought he could apply to his own farm. This self-selection by the innovators was the cornerstone of SFEP's approach to technology transfer. The project staff helped in preparing designs and cost estimates so the farmers could base their decisions on the probable construction time, payback period, and amount of cost sharing from project funds. The farmers built and installed most of their innovations, with technical support from the SFEP staff and sometimes with "barn raising" construction help from the staff and other farmers in the innovating group.

Data Gathering.—The innovating farmers have monitored the technical performance of most of their installations. The primary focus of SFEP recordkeeping, however, for both the innovators and the control group, was on energy: what kinds of energy were used, how much of each source, and how much they paid for it. Both groups of farmers submitted quarterly and annual records, which have been analyzed in the projects' annual progress reports, The results[28] are open to question because the sample is small and because the energy-awareness caused by recordkeeping also influenced the energy use of the control group. Nevertheless, the figures give a rough indication of the conservation effect of the innovating group's projects:

- innovators used an average of 37 million Btu less in 1978 than in 1977, while the control group used an average of 29 million Btu more;
- because of price increases, innovators still had an energy cost increase of 1.8 percent, but the increase was 9.8 percent for the control group; and
- for the first 2 years of the project, increases in energy expenditures averaged 12.4 percent for the innovating farmers and 22.7 percent for the control group.

**center for Rural Affairs, "Preliminary Report, January 1977 through December 1978, for the Impacts of Various Energy Innovations on Consumption and Net Incomes for 43 Small Farms," prepared for Community Services Administration, July 1979.

SFEP Innovator Energy Projects

Table 17 lists the types and numbers of energy projects undertaken by the farmers in the innovating group. Individual participants initiated as few as two projects or as many as nine, and most of them completed at least one project without technical or cost-sharing support. Almost 75 percent of the projects begun in the first 2 years were carried through and actually utilized, including most of the major ones.

Table 17.—Types of Projects Adopted by Innovating Farmers Under the Small Farm Energy Project, 1977-79

Conservation	
Insulation, storm windows, and doors	30[a]
Flue dampers	3
Energy-efficient waterers	2
Small conservation projects	21[b]
Subtotal	56
Alternative sources of energy	
Solar space heating	6
Other solar projects	14
Wood heat	9
Wind electrical generator	1
Subtotal	30
Agriculture	
Soil testing	14
Comporting and limited tillage	5
Subtotal	19
Total number of projects	105

aSome farmers insulated both their water heater and their walls, or both their farmhouse and their barn.
bExcludes 23 "projects" that consisted of adopting pressurized gas caps to prevent fuel loss by evaporation.

SOURCE: Rural Development, Inc., for Community Services Administration.

About half of the SFEP projects involved conservation measures, including improved insulation for the farmhouse, barn, and other buildings; installing energy-efficient watering and milking equipment; and doing tune-ups on farm machinery. A number of them involved changes or improvements in farming methods, such as soil testing, increased comporting, limited cultivation where possible, improving terraces to reduce fertilizer needs, and changing to a shorter season corn to reduce drying costs. Over a third of the projects, however, involved applications of renewable energy sources, including conversion to wood stoves for the farmhouse or workshop, a wind generator, and 20 applications of active or passive solar devices.

Most of the projects were fairly simple, home-built, low-cost devices constructed from locally available materials. Generally the farmer adapted the technology in a design suited to the needs of his particular farm operations. The following discussions of six of these installations include a brief description of the technology and an account of its design, operation, and benefits. In keeping with the spirit of the SFEP approach to technology transfer, the first two accounts are in the words of the farmers themselves unless indicated by brackets. The third and fourth are taken from reports submitted by a study team composed of Cedar County residents, and the last two accounts are based on SFEP's second-year report.[29]

Portable Solar Collector (figure 19).–This is an adaptation of an active solar hot-air system also referred to as the vertical-wall or "North collector," after the Colorado rancher who originally developed it. It can be built directly onto the south wall of the structure to be heated, or it can be constructed in the workshop and mounted later or, as in this design, moved from building to building. The collector plate is painted black and covered with a Filon fiberglass glazing, cool air from the structure is drawn first behind the collector (for preheating) and then through the air gap in front of the collector plate, where it picks up the solar heat and delivers it into the building. Like the south roof of a solar greenhouse (see ch. 4), the slope of the collector should be perpendicular to the Sun's rays in winter. Innovator Gary Young's account:

> A portable solar collector is moveable. I put it on an old grain trailer that I was going to junk. I made it portable so I could heat the house or dry grain. Construction on it is really a lot more simple than you would think. The most complicated part is figuring out the air gapping. The frame is made of lumber from an old hoghouse. When we heat the house it takes cold air off the floor. The one-inch air gap has air baffles in it to turbulate the air so that it will take all the heat possible off this black aluminum. Then I just nailed the Filon on. You don't want any outside air getting into the collec-

[29]See the working Paper, "Report From Community Study Team: Small Farm Energy Project."

Figure 19.—Portable Solar Collector

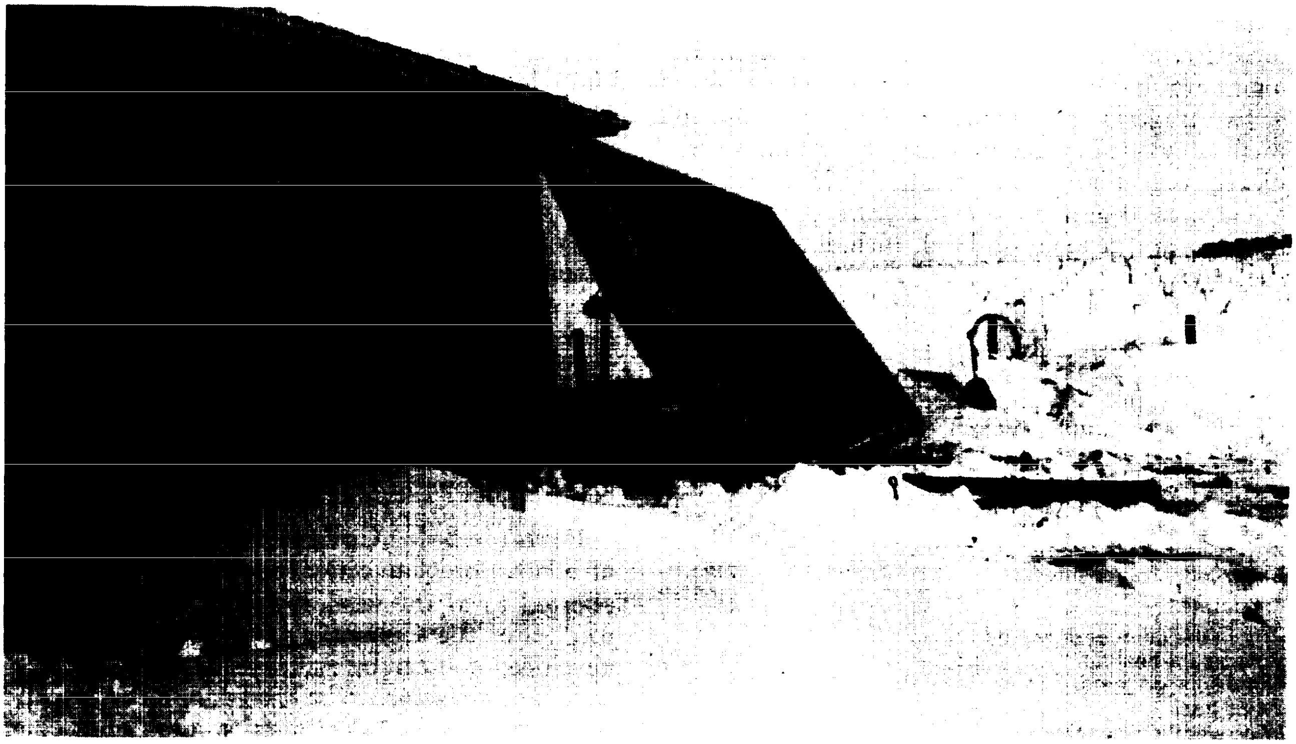


Photo credit: Office of Technology Assessment

tor in the wintertime, so you use a lot of caulk to seal everything. Sun shines through the Filon and heat gets absorbed by the aluminum; heat is transferred to the air in the one-inch air gap, and this air enters the house.

The SFEP people wanted me to build one a couple of years ago, but Delores [his wife] didn't want a collector sitting by the house or hanging on the house, because it would detract from the beauty of it. And then, when I [said] I wanted to make a portable collector, Delores said "yes" if it could be moved from the house in the summertime so she could raise her flowers. So we had to develop a way to attach it to the house and grain bin, so it could be moved from one place to the other.

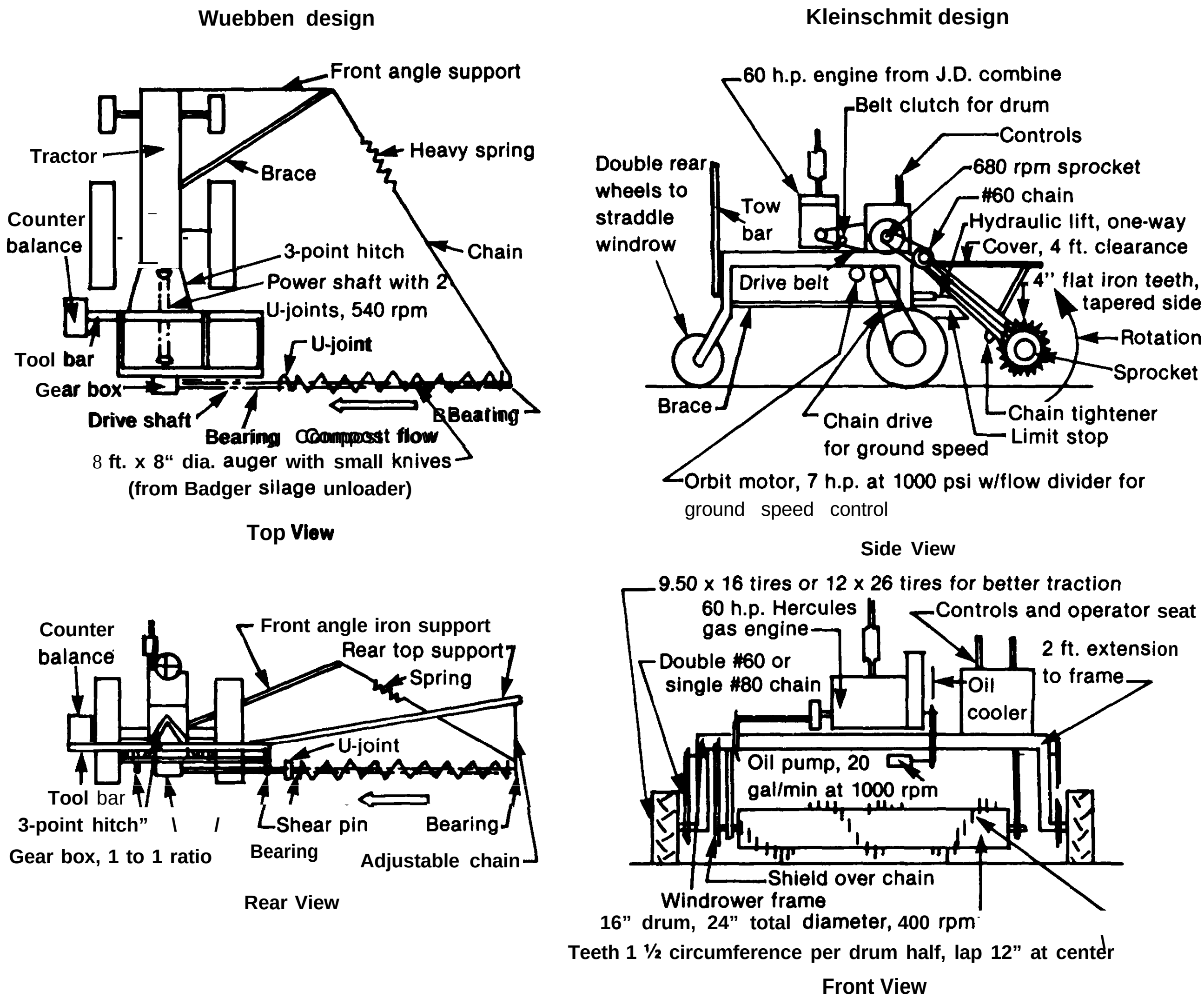
To hook up the collector, you use these innertubes with these adapter plates. One hooks onto the back side of the collector, and the other one hooks onto a plate just like this on the barn [or on] the house. I just bolt them together and seal them up. I think a portable one like this will have it over the permanent one, because farmers may have a bin at this place and another bin at another place a few miles down the road.

Another advantage of this design is that the tilt of the bed is adjustable so we can get maximum absorption of the sun. For the grain drying season, the sun was still quite a bit higher than it is in the wintertime, so we made it adjustable so that we can get more sun in the early fall. We get full absorption of the sun, and in the wintertime we can tilt it up some more and get maximum heat from the sun in the dead of winter.

The thing was pretty cheap, too. Not counting the time and my old lumber, I spent $1,300 to build it. That includes fan, motors, controls and everything. This one surely heats the house nicely. The furnace never runs except for an hour or two early in the morning. I'm sure our fuel bill will be far less than half what it was. Before, we filled the tank every 2 weeks—we have a 500-gallon tank—where we now fill it about every 6 to 8 weeks. On our house-our house has 1,200 square feet–we might recover the cost of this in 4 to 6 years. That's just on the house alone. It doesn't include grain drying.

Home-Built Compost Turners (figure 20).–Comporting is based on the aerobic decomposition of animal and vegetable wastes, a process that

Figure 20.—Home-Built Compost Turners



is described in chapter **7.** To aerate the wastes and keep them from overheating (which would destroy their nitrogen content), the compost pile must be turned periodically. Turning compost by hand, especially if large piles are involved, can be extremely time-consuming. An alternative is to lay it out in windrows (long piles similar to the rows into which grain or hay is raked for drying before it is stored or baled) and turn it with a machine designed for that purpose. Commercial compost turners are available in sizes ranging from the self-propelled, $52,000 Scarab used by the Bronx Frontier Development Corp. in their 365,000-ton/yr composting operation in the South Bronx (see ch. **7)** to the tractor-pulled, $5,000 Easy-Over composter that can turn 500 tons of compost in an hour.[30] Because 500 tons is about the *annual* volume of a 25-cow dairy operation,[31] it would clearly be an advantage to the small farmer if he could rent the machine out or share its capital costs with his neighbors. Two SFEP participants built their own compost turners at a much lower

[30]"Percy Knauth, "An Iowa Farmer Rediscovers Nature's Way," Quest, May 1980, p. **74,** Knauth's source, farmer Richard Thompson, estimates that it would take five men 20 hours to turn this much compost.

[31]Volume figures based on OTA, *Energy From Biological Processes*, op. cit., p. 130; and Richard Merrill, op. cit., p. 143.

cost with salvaged parts. Bill Kleinschmit developed a machine for turning windrows of compost. His account:

There are a few basic reasons why comporting is a good idea. The nitrogen in the manure will stabilize, and it isn't going to be leached down by the rain. You save a lot of it, and it really nourishes the plants. Another benefit is that with compost you get rid of the threat of disease from having the manure around. A man from Iowa spoke at a seminar. He had a terrible colon infection in his hogs [and cattle] prior to starting comporting. Since he started comporting, he has had only minimal problems with infection. It helped get rid of the bugs, provided fertilizer for the ground, and produced better, healthier grain.

My project with the Small Farm Energy people was building this compost turner. I started with a windrower that was no longer good for windrowing. It was completely shot. But the parts I wanted weren't. The engine and the drive mechanisms, chains, and the big pulley came from a big John Deere 55 combine that we used to have. I had to have something that was slow, so I took an oil pump, orbit motor, and a flow control valve and with this I could achieve as little as maybe 6 inches a minute or less, and then I could still go up to 10 feet a minute with no problem. And the drum was just a 16-inch drum and I had just taken some 4-inch scrap iron and made the angle for the teeth of the drum. That's pretty well what it's been made of—what one person might call a lot of junk.

The windrow that my comporting machine is set up for is about 8 feet wide and 4 feet high. You can make the windrow whatever length you want it. I think the one I have now is well over 100 feet long.

The thing was cheap to build. I paid $150 for the windrower, and the guy was happy to get rid of it because it had been sitting there for 5 or 6 years. I don't have over $1,000 in it right now. The engine may need an overhaul and I may stick a different engine on it that would take less fuel, but other than that, I don't feel there's too much that I would have to put into it.

As far as the benefits, well, the first year I did this with just a manure spreader and a manure loader. I put about 10 loads of raw manure on one area, 10 loads of compost on another, and then the rest of the field had nothing on it. I had fairly good oats where I had put raw manure. Where I put the compost, I used half as much manure by volume, and I would say I had about half again more results. The other area I don't care to talk about—that didn't have anything.[32]

Solar Grain Dryer (figure 21).–Traditionally, corn was picked in the ear and stored in slatted cribs, where air flow removed the moisture. The advent of the combine (which picks and shells the corn in the field) led to the circular steel storage bin, in which the corn is dried with heat produced from propane or electricity. The energy used for this conventional method of drying corn often exceeds the total amount required for plowing, planting, cultivating, and harvesting the crop.[33] Four SFEP farmers chose to address this energy cost by installing solar grain dryers based on a simple design developed by Dr. William Patterson of South Dakota State University. In each case, a collector made of corrugated metal is attached to the southern two-thirds of the storage bin, with an air space between the collector and the wall of the bin. Solar heat transferred to the air as it passes behind the collector raises its temperature by 50 to 10° F and lowers its relative humidity. The warm, dry air then flows through the grain to remove its moisture. In the Wuebben dryer the air rises from the bottom of the collector, enters the storage bin through vents at the top, and is drawn down through the grain by an exhaust fan located at ground level. In the Fish dryer the air is drawn through vertical openings on the north side of the bin to a fan on the south side, which then forces the warm air up through the grain. Unlike Gary Young's portable collector, these permanent installations can only be used during the fall harvest, but they can still reduce the small farmer's energy needs. None of the four SFEP solar grain dryers is exactly alike, but all are home-built with materials that can be salvaged or obtained from the local lumber yard. The community study team's report:

Solar drying is a form of low temperature drying. Along with saving propane and electricity, the method is believed by some farmers to result in a superior quality of dried grain. To construct a solar grain dryer a sheet of corrugated metal is painted black and wrapped around the south facing curve of the bin. The metal is open at one end and connects with an airtight shed at the other end. The

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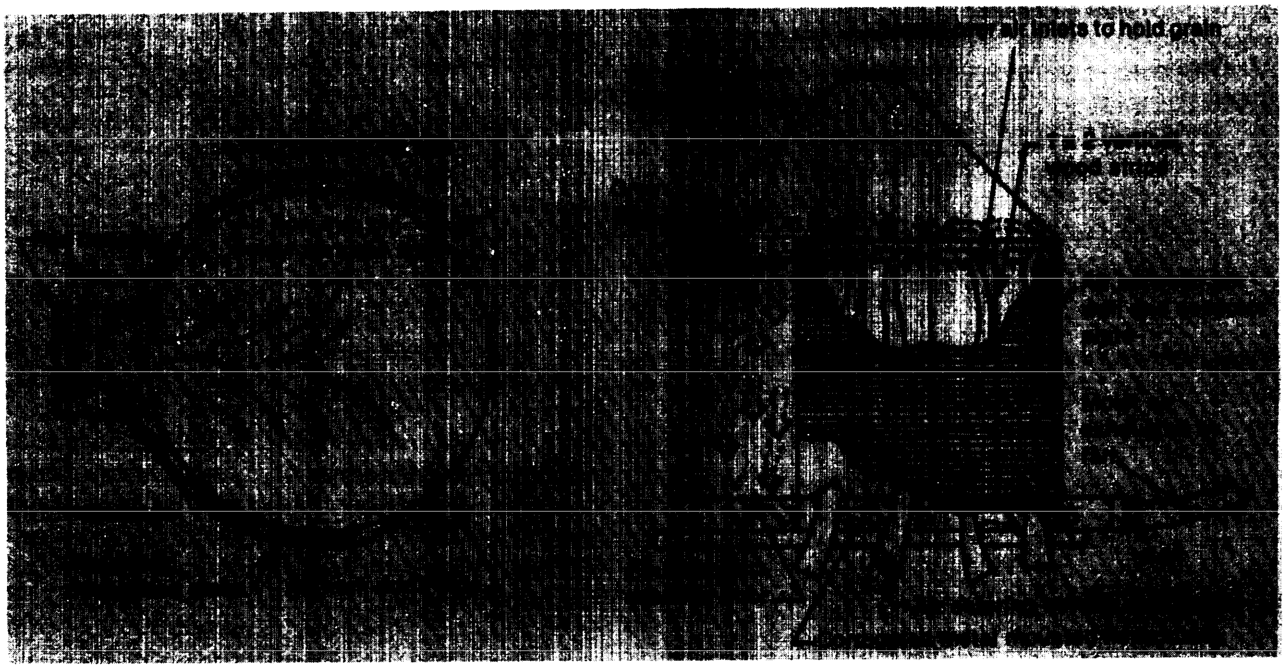
[32] Many small farmers in Cedar County apparently do not fertilize some of their fields, or do so only with raw manure.
[33] Rural Development, Inc., op. cit., p. 5.

Figure 21.—Top View of Fish Solar Grain Dryer and Wuebben Solar Dryer, West View



SOURCE: Small Farm Energy Project.

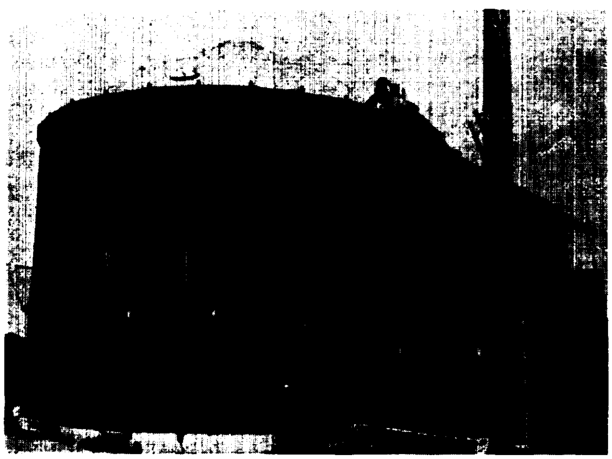


Photo credit: Office of Technology Assessment

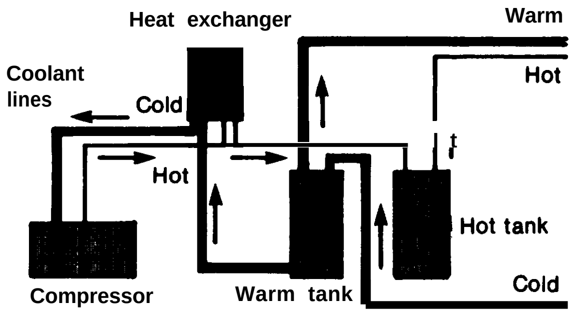
Solar grain dryer

shed contains a big fan that sucks outside air past the blackened metal, which heats it, and forces it into the bin. The Trubys have incorporated a fiberglass cover over the corrugated black metal collector plate in their bin. The bin holds 6,000 bushels and requires a 7-to 9-horsepower fan. The average solar grain dryer costs about $600, and it will achieve an annual savings of about $319.[34]

Solar Dairy Water Heater (figure 22).–Modern dairy farmers use automatic milking machines powered by electricity, which makes them highly dependent on this form of energy. However, they also use a significant amount of electricity to heat water for cleaning the machines and washing the cows for milking. Two of the SFEP innovators chose to apply an active solar energy system to their water heating needs: solar energy is transferred to water circulating through copper tubing attached to a 64-ft^2 collector plate on the south roof. The major problem with such a system in a cold climate is that it may freeze up. One solution is to use a mixture of water and antifreeze in the collector system and then use it to heat potable water. The SFEP design, in which the potable water itself circulates through the collector, is

[34] Six thousand bushels represents the corn harvest of 555 acres at average 1979 yields. The cost savings would be over a 10-year period, assuming 10-percent inflation and annual price increases of 2 percent for electricity and 5.7 percent for propane.

Figure 22.—Dairy Water Heat Exchanger



SOURCE: Small Farm Energy Project.

more efficient but more complicated, since it must be drained when there is a danger of freezing. The two SFEP installations incorporate a drain-down system designed by the Domestic Technology Institute at Lakewood, Colo., involving solenoid valves, a pump, differential thermostats, a freestat, and some rather complicated wiring. This complexity prevents the farmer from building the whole system himself and substantially increases the cost; it may be desirable to develop or select a simpler design such as the thermosiphon.[35] Edgar Wuebben, a dairy farmer who also built a compost turner (see above), has installed a drain-down, potable-water solar heater. The community study team's report:

> One of the energy-saving devices on the Wuebben farm is a solar water heater for the grade-A dairy barn. Water is pumped through the rooftop collector and then drains down into a hot water heater, where it can be warmed further with conventional power. In the winter, when there is danger that freezing might burst the pipes, solenoid valves open and drain the water out of the collector when a temperature drop tells [the switching mechanism] the sun has gone down.
>
> The Wuebbens use a 120-gallon storage tank. They could have used some type of antifreeze in the system, but the lower danger of contamination and the efficiency of the drain-down system seemed more appropriate.[36] The dairy operation required 50 to 80 gallons of water per day. Without the solar collector, heating the water required about 20 kWh per day; with the collector, the electricity used is reduced to 5 kWh per day. The Wuebbens expect to recover the cost of the system in about 6 years. However, [the SFEP] staff estimate the average cost of this type of heater at about $1,597 and the annual savings at about $175. This would mean a 9-year payback period instead of 6 years.[37]

Solar-Heated Farrowing Barn (figure 23).–Hogs are one of the major sources of income for farmers in Cedar County, and heated farrowing barns have become a popular means of increasing production by allowing sows to farrow year-round. These barns are usually heated with propane, kerosene, or electricity. With technical assistance from Professor Peterson of South Dakota State University (who also developed the basic solar grain dryer design, above), Rick Pinkleman converted an old dairy barn into a solar-heated farrowing barn.

Figure 23.—Solar-Heated Farrowing Barn

Photo credit: Office of Technology Assessment

The first step was to weatherize and insulate the barn. The south roof, which measured 17 by 50 ft and had a slope of 70° from the horizontal, proved to be an excellent location for the collector. He painted the corrugated metal roof black and covered it with clear corrugated fiberglass to trap the

[35] Rural Development, Inc., op. cit., p. 8.

[36] If antifreeze were pumped through the collector, heat would have to be transferred to the potable water in some way. Some designs call for the antifreeze to be piped through a heat-exchanger coil immersed in the hot water tank. Many local building codes forbid this practice, however, because any leaks that develop in the heat-exchanger coil will contaminate the potable water with antifreeze.

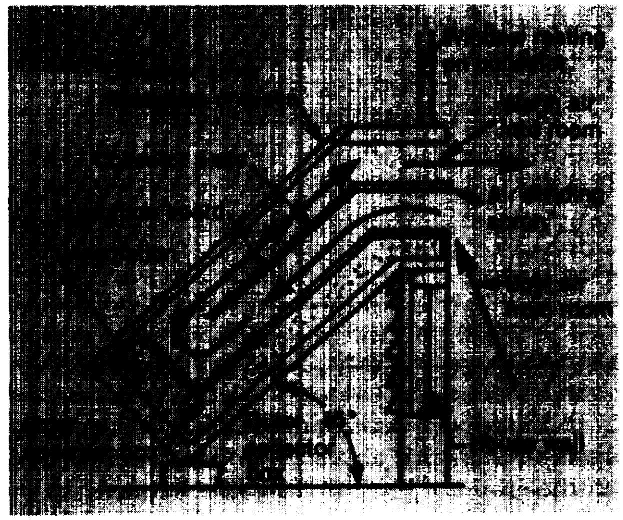
[37] Again, cost savings are over a 10-year period, assuming 10 percent inflation and annual price increases of 2 percent for electricity and 5.7 percent for propane.

solar heat. A fan pulls air from the attic through the collector and into a heat storage area containing 850 plastic, l-gal milk jugs filled with a mixture of water and methanol. A second fan pulls the preheated air through a ventilator duct into the barn itself. At night the heat stored in the water jugs is transferred to the air, thus helping to keep the barn warm. This system has too little heat storage to work without backup heat, but it should make a significant difference is space-heating costs for the farrowing barn.

Other SFEP Innovations.–Home space-heating costs can be reduced more effectively through conservation measures than through passive solar additions,[38] and most of the farmers in the innovating group added insulation to their farmhouse walls and ceilings, installed storm windows and doors, insulated their water heaters, and purchased pressurized gas caps to reduce the loss of fuel through evaporation. Nevertheless, one family built a solar greenhouse on an old porch (see chs. 3 and 4), another farmer built a small solar "window box" collector (figure 24), and several others installed fixed vertical-wall collectors similar to Gary Young's portable design (see figure 19). Another family's solar hot-air application was the solar food dryer (figure 25). In a slightly different kind of project, the Kaiser family bought a commercial wind generator and set it up on their farm. It produced electricity in winds over 8 miles per hour and had an average output of 200 kWh/month; this saved the family about 20 percent on its electric bill.

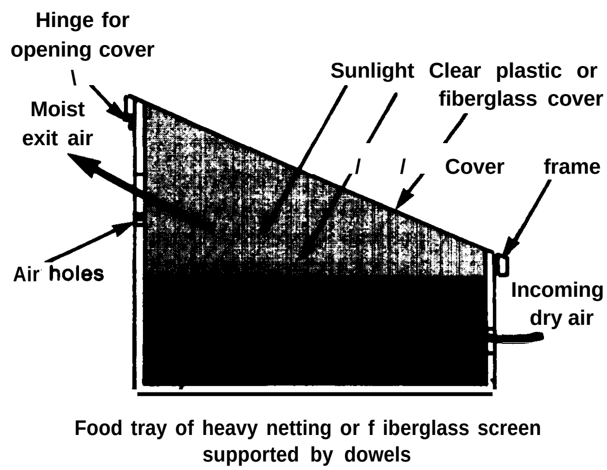
38 See *Residential Energy Conservation* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, July 1979), OTA-E-92, vol. I.

Figure 24.—Solar Window Box Collector (cross-section view)



SOURCE: Small Farm Energy Project

Figure 25.—Solar Food Dryer (cross-section view)



SOURCE: Small Farm Energy Project.

Critical Factors

Public Perception and Participation

The two small farm projects examined in this chapter illustrate the manner in which public participation can affect public perceptions of local development projects. The settings were not especially conducive to public interest or involvement: small farm communities tend to be conservative and to distrust outsiders. SFEP and NLF used different techniques for gaining public approval and participation.

SFEP made citizen involvement a feature of its project design from the very outset. The staff of CRA are all midwesterners, but they realized they still might be viewed as outsiders in Cedar County. Early in the planning phase, therefore, a board of directors was established to oversee the project and represent it in the community. The four directors were all native Nebraskans and influential, active community members whose participation helped to establish the project's credibility with local farmers. The CRA staff also surveyed county residents and institutions while the proposal was being developed to determine what activities would be most appropriate for the county's needs.

Planning and decisionmaking at the New Life Farm in Missouri, on the other hand, was limited to the group of original New Life Farmers, all of whom were outsiders. These people seem to have accurately identified the needs of small farmers in the region and are very open to public participation, but few natives of the community were involved in the organization's early stages or in its ongoing operations. NLF members have tried to establish personal relationships with local farmers, and several jobs at the farm have been filled by local residents, but the broader community still knows little about the project or its aims. NLF has recently stepped up their outreach efforts, in part to attract more private donations, but unlike the Cedar County project it has not come to be seen as a creation of the local community.

SFEP's greater success as a demonstration project results in large part from its stress on self-selection, which makes use of existing patterns of technology transfer. Traditionally, information and new farming techniques have been passed on from neighbor to neighbor and generation to generation. Recognizing this, SFEP's technical assistance focuses on one-to-one relationships and individual innovation, allowing local people to demonstrate technologies that can be useful in the kind of farm operations actually found in the area. This makes the farmers themselves active agents in technology transfer, and it also allows them to become active participants in the project without joining a formal organization. By contrast, NLF's organizational style seems to be more akin to an urban cooperative model than to traditional rural practice. This may actually work against public participation, because local farmers who want to learn about new farming techniques at NLF may feel that an active commitment to the organization would be required.

While it is difficult to determine from available data how well NLF has been accepted by the Ozark farmers, data on the SFEP outreach programs indicates widespread support in Cedar County. Over half of the local residents surveyed by the community study team knew about SFEP and its activities, and a number of nonparticipants had planned or begun building their own energy projects. So had 25 percent of the control group, which was subject to the same outside influences—i.e., SFEP's educational component as well as the general increase in energy consciousness throughout the Nation.

The lack of a true control group is one of several flaws in the project's quasi-scientific design; another is small size of the sample, but perhaps the most serious flaw is the lack of randomness in selecting the participants. Most of the SFEP innovators were self-motivated to participate, and they were apparently hand-picked by the staff and local advisory board. In addition, 9 of the 24 innovators undertook a disproportionate share of the projects, including the largest installations, and the data presented in table 16 suggest that these major participants were better educated and had more profitable farms.

Essential Resources

Most of the projects at NLF and SFEP can be built by the farmers themselves at low cost and with locally available materials. NLF's small manure digesters, which could supply the cooking and water heating needs of an average farm, can be built for between $2,500 and $3,500, although the designers think the price could be reduced in time (see table 12). Most of the SFEP projects have even lower costs, and many of them make use of salvaged materials. Most small farmers possess the carpentry and plumbing skills necessary for their construction, although they may need to hire local labor for some of the construction work on the larger installations. The most complicated materials, and the only ones not locally available, were the drain-down switches for the solar dairy hot water systems.

The costs of raw materials depends on the type of system and the type of crop used. Solar energy, of course, is free; but the amount of solar energy available will vary with location and season. Manure for comporting or for digesters is readily available and frequently underutilized by current farming methods. Plant wastes for the phytomass digester are also available at low cost: wild grasses and weeds can be collected for about $0.25 bale, or $264/yr; cornstalks can be gathered for $4.73 per 1,600-lb bale, or $150/yr.[39] Since the sludge from the digesters can still be used for compost or feed, this technology makes more efficient use of an available resource without destroying its value for other uses.

One traditional rural resource has not been exploited, however: the communal or shared labor of local farmers. The rural "barn raising" tradition may still exist in these communities, but it was not reported to have emerged among the innovating farmers in Cedar County,[40] not all of whom were close neighbors, or between NLF and the native farmers in the Ozarks.

Technical Information and Expertise

The literature on solar and biomass technologies is growing rapidly, but much of the early research was done under less than optimal conditions, and many promising areas have barely been touched. Part of the problem has been that very little money has been available for conducting formal scientific experiments, and even in areas where preliminary research has been done, there is considerable debate about whether these technologies are appropriate to real-life, onfarm applications. Both NLF and SFEP have tried to fill these information gaps.

NLF's experiments with biogas digesters are adding to the sometimes sketchy information generated by a handful of experimenters around the world over the last 20 years. There is a fairly good understanding of which parameters (feedstock, carbon-to-nitrogen ratio, temperature, etc.) affect gas yield, but as yet there is no precise understanding of what impact these factors have individually or in combination. Similarly, little research has been done on the nutrient value of biomass sludge, the availability of the nutrients to plants, or on the long-term impacts of applying sludge as a fertilizer and soil conditioner. NLF's research efforts address these questions, although the results are not yet widely available.

SFEP, despite its project design, is less a rigorous research program than a well-designed and highly successful education and demonstration program. Its workshop approach was particularly useful in disseminating information: agronomists and farmers came to speak to the Cedar County group, and consultants were hired to work with both participants and staff. The results clearly demonstrated the potential of farmer-built, self-selected technologies on these Nebraska farms, but there was very little new technological innovation in any of these applications.[41] Furthermore, because of the inevitable roughness of the onfarm data gathering and because of the number of uncontrolled variables and outside influences in the Cedar County "experiment ," it would be difficult to establish conclusively that the economic viability and energy vulnerability of these farms have been significantly affected, let alone that the results can be applied to small farms in other regions of the United States.[42]

If the NLF and SFEP installations are to be replicated on a widespread basis, more detailed information will be needed on the design, costs, and performance of these and other small-farm energy systems. A preliminary evaluation of the SFEP project suggested several methodological changes that might improve the usefulness of information generated by this program and similar efforts elsewhere:

- collect better baseline data on the farmers' attitudes toward change, in order to evaluate the project's impact in this area;
- include a larger number of farmers, in order to offset random effects and make valid conclusions;
- adopt a case study approach, in order to collect and analyze data on a technology-by-technology and farm-by-farm basis, rather than in the aggregate;

[39] Fischer and Swack, op. cit., p. 69.
[40] Rural Development, Inc., op. cit., pp. 53-54.

[41] Ibid., pp. 71-72.
[42] Ibid., pp. 40-41, 59, 71.

- concentrate on the technologies that have the greatest potential energy-saving impacts;
- develop a model farm, with the active participation of the farmer, by installing a number of technologies to demonstrate the potential benefits of an integrated small-farm energy system; and
- utilize comprehensive cost-benefit analysis at all stages of the project .43

The NLF system of technologies is an example of the sort of model farm that might be developed, although the model should include solar as well as biomass applications. SFEP has indicated that it will undertake case studies of individual installations, but no studies are available as yet.

Financing

Both of these small projects have been financed primarily by grants. The NLF case study, like several others in other chapters, demonstrates that trying to survive exclusively by grants can cause an organization a number of problems.

NLF generally develops a prototype before it seeks finding for a project, which both reduces the risks involved and encourages grantors to take the project seriously; but dependence on Government and foundation grants has led to restrictions on its use of funds. The large DOE "Energy From Farm Crops" grant, for instance, is earmarked for specific research on the phytomass digester, and thus works against the type of integration that NLF would like to achieve. In addition, Government grants may not be forthcoming unless a project is in line with the current objectives and priorities of the granting agency. NLF has a friendly relationship with the local bank and can borrow against its savings account, but a conventional loan is highly unlikely at the present time. An alternative would be to pursue a broader mix of finding sources, like the "consortium funding" of the Bronx Frontier project (see ch. 7), but for this approach NLF might need the help of an experienced grants manager. Another alternative, since there seems to be commercial potential for the manufacture and sale of digesters, would be for NLF to investigate the possibility of selling its services as a design consultant.[44]

SFEP has avoided some of the restrictions imposed by the grants economy. Its project design stressed the installation of devices based on proven technologies and design concepts, which serves to reduce risks; but it also stressed self-selection by the innovating farmers, which led to a greater variety of applications. Cost-sharing, which has been used in a number of agriculture programs, appears to have been useful both because it is accepted by the farmers and because it reinforces the innovator's sense of ownership. However, while the cost share was found to be important in initiating innovations in the early stages of the project, it was not always needed to sustain the innovation process. Many of the SFEP farmers undertook projects without cost-sharing, and only 52 percent of the money allocated for this purpose was actually spent. The average cost share was 43 percent of the project cost; the staff and advisory board felt that a 100-percent share would be seen as a giveaway program and that more than a 50-percent share would be useful only for "high risk" or "first time" innovations.[45] The proposed model farm, however, may require a larger share because of the number of installations involved.

Institutional Factors

The full development and widespread dissemination of these small-farm technologies would require the active cooperation and backing of the land-grant colleges and the Agricultural Extension Service (AES). NLF has thus far enjoyed a cordial relationship with the local state university through joint research on the phytomass digester, and there seems to be a great deal of interest in the project from government officials at the Federal, State, and local levels. Similarly, SFEP has tried to establish friendly relations with the University of Nebraska Cooperative Extension Service, which has moved one of its energy specialists to nearby Concord. Institutional change has been slow, however, and a number of barriers remain.

AES operates with relative success throughout the United States, partly because its over 100 years of activity has given it legitimacy and credibility. However, its responsiveness to the problems of the small farmer varies greatly from one region to

[43]Ibid., pp. 17, 29, 39,64,66.
44 Fischer and Swack, op. cit., p. 79.

[45]Rural Development, Inc., op. cit., pp. 43-44.

another, according to a SFEP consultant. Extension programs are jointly funded by Federal, State, and county governments, but they are managed at the State level. This should allow them to respond to local agricultural needs, but some State-controlled programs tend to focus on the problems of large-scale farming groups, whom they perceive to be their primary clientele. According to information gathered by Rural Development, Inc., for CSA, nothing similar to SFEP had been undertaken by AES anywhere in the Nation.[46] This created an opportunity for SFEP, which employs a number of the educational and outreach techniques developed and used by AES, to supplement the activities of the existing extension programs. There is evidence, however, that the State AES agency opposed the establishment of SFEP.

To be eligible to receive its CSA grant, the SFEP proposal had to be approved by the Governor of Nebraska and the State Tax Commissioner (in his capacity as head of the State's Energy Office). During the review period, the Governor received a letter from the University of Nebraska opposing the project: the University, with the backing of Nebraskans for Progressive Agriculture (a group of large farmers with ties to the University), claimed that the SFEP staff was unqualified to undertake the project and that it would duplicate efforts already underway at the University through AES. SFEP was able to refute these arguments, but the incident apparently served to politicize the project. Three years later, in the spring of 1979, Rural Development, Inc., reports that:

> . . . during a conversation the evaluators had with the Director of the [University ofl Nebraska Cooperative Extension Service, it was clear that he was not open to cooperation with persons working on agriculturally-related problems who were not associated with land-grant or traditionally agricultural-mandated institutions . . . . The SFEP project had not significantly affected the University of Nebraska [Cooperative] Extension Service, although the project staff, advisory board and cooperators prefer that it would.[47]

NLF, too, has experienced opposition to its efforts to involve local high school students in its workshops.

The Missouri and Nebraska projects may, to some extent, find themselves working in competition with AES and local extension services. By addressing a new clientele (the farmers at the lower end of the income and acreage ranges in their areas) and by encouraging alternative agricultural techniques, they might unintentionally challenge the conventional methods advocated by the established institutions and threaten to usurp their local role. Joint grants and joint research, such as NLF has undertaken with the State University of Missouri at Rolla, may help to overcome these barriers, but institutional change is likely to remain a slow and incremental process.

Two regulatory issues have arisen from these projects: proprietary rights and patents, and digester safety. The SFEP participants view their small-farm technologies as examples of local innovation and adaptation which, as such, should be available for use by all farmers at the lowest possible cost. As a result, the staff has made no attempt to secure patents or copyrights, and some of the innovating farmers even suggested that a law should be passed so that some of the devices could not be patented. Biogas technology, on the other hand, raises a safety issue. The designers have sought to reduce the risks of oxygen contamination and explosion wherever possible, and the batch-loaded digesters are relatively safe because, once loaded, they remain sealed until digestion is completed. Nevertheless, NLF has installed a "gas sniffer" alarm in its digester building, and widespread adoption of biogas digesters may necessitate formal safety regulations, such as local building codes forbidding a digester from being attached to a livestock shelter.

46 Rural Development, Inc., op.cit., p. 5.

47 Ibid., pp. 55-56.

Federal Policy

Background

Unlike the cases studied in other chapters of this assessment, the two case studies in this chapter entail the development and adoption of a whole range of technologies, from new comporting techniques to solar and biomass energy systems. Consequently, they are related to and affected by a large number of Federal programs and policies. The development and diffusion of the small-scale farm technologies examined in these case studies, however, are most relevant to three broad, interrelated national issues:

- developing rural America;
- progressing toward greater energy self-sufficiency at all levels—national, regional, local, and individual; and
- retaining agricultural lands and preserving the structure of the farming sector.

The third issue, agricultural land retention, is discussed in chapter 6; the other two issues are discussed below.

Rural Development[48]

A 1970 congressional policy declaration stated that "the highest priority must be given to the revitalization and development of rural areas. " Defining the exact Federal role in these activities has been the focus of considerable debate ever since. Rural development has become a broad mission, involving initiatives by Federal, State, and local governments as well as the activities of the private sector. The coordination of these diverse efforts so that their results are mutually supportive has been a particular and continuing concern in the rural development initiatives of both Congress and the executive branch, several of which affect the development of alternative technologies for the small farmer.

The Rural Development Act of 1972.–This Act (Public Law 92-419) is the primary source of programs to promote economic and community development in rural areas, and most of the rural development activities of the legislative and executive branches have focused on the implementation of this legislation. The Act's stated purpose is "to provide for improving the economic and living conditions in rural America. " Of particular relevance is title V, "Rural Development and Small Farm Research and Education." Two of this title's goals are: 1) "to expand research on innovative approaches to small farm management and technology" and 2) "extend training and technical assistance to small farmers so that they may fully utilize the best available knowledge on sound economic approaches to small farm operations. " To this end the Act establishes the Small Farm Extension, Research, and Development Programs, which were to consist of:

> . . . extension and research programs with respect to new approaches for small farms in management, agricultural production techniques, farm machinery technology, new products, cooperative agricultural marketing, and distribution suitable to the economic development of family size farm operations. (sec. 502)

The Act designates USDA as the lead agency in Federal rural development efforts. USDA placed most of the operating programs under the Farmers Home Administration, while the responsibilities for lead-agency coordination were assigned to the Rural Development Service. A number of institutional changes have taken place since 1972, however, in part because of congressional criticism of the way in which the present and previous administrations have implemented the policymaking and coordinating mandate of the Act. These changes also reflect the findings of executive branch studies and reviews of rural development, the findings and changes which affect small farm technology are outlined below.

The earliest review was carried out in 1977 by a joint task force of officials from USDA and the Office of Management and Budget, under the direction of the Administrator of the Rural Development Service. The task force identified the following as one of the weaknesses in the current rural development efforts:

[48] Some of the material in this section is drawn from Sandra S. Osburn, "Rural Development: the Federal Role," Library of Congress, Congressional Research Service issue brief No. IB77113, June 23, 1980.

> Federal programs have concentrated heavily on public facilities investments which have improved the public infrastructure in many rural areas, but have not stimulated substantial private sector employment. Federal programs have also under-invested in human resource development and in technological innovation in rural areas .49

Their report also stressed the need to develop a national growth and development policy and to ensure that rural needs and interests would be included in any such policy.

A second review of Federal rural development policy took place as part of the White House Conference on Balanced National Growth and Economic Development, authorized under the Public Works and Economic Development Act of 1976, which took place from January 29 to February 2, 1978. On December 1, 1978, President Carter announced the findings of the conference's water and sewer task force; these proposals later led to an interagency Coordination and Service Delivery Agreement[50] that included a proposal to place more emphasis on alternative and innovative technologies for waste-management in rural areas.

The Secretary of Agriculture issued a memorandum on March 21, 1979, that set forth USDA's rural development policy and specified the following goals:

- improve rural income levels and increase rural employment opportunities;
- improve the access of rural residents to adequate housing and essential community facilities and services;
- provide a more equitable distribution of opportunities through targeting efforts on distressed areas, communities, and people;
- create and implement a process for involving the private sector and Federal, State, and local agencies in establishing policies and programs that affect rural areas; and
- strengthen the planning, management, and decisionmaking capacity of public and private institutions concerned with economic opportunity and quality of life in rural areas.

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[49] Ibid., p. 6.

[50] Other agencies involved in the agreement are the Departments of Housing and Urban Development, and Labor; Environmental Protection Agency; Economic Development Administration; Council on Environmental Quality; and Community Services Administration.

96th **Congress.—Continuing** congressional concern about the implementation of rural development policy was demonstrated by several pieces of legislation enacted or considered by the 96th Congress:

- *Rural Development Policy Act of* 1980 (Public Law 96-355).–This Act directs the Secretary of Agriculture to prepare a comprehensive Rural Development Strategy, based in part on the goals and recommendations of local communities and on the need to strengthen the family farm system, and to update this strategy annually in a report to the appropriate House and Senate committees. The Act also creates the position of Under Secretary of Agriculture for Small Community and Rural Development, to be appointed by the President with the advice and consent of the Senate. Significantly, the Act also extends for 2 years the authorization for title V of the Rural Development Act of 1972 (see above) and specifically authorizes the Secretary of Agriculture to promote R&D efforts related to appropriate technologies for small- and medium-sized farms.
- Other *legislation.—To* ensure that rural interests are considered in the design and implementation of national programs in other areas, bills were introduced that would establish an Office of Rural Health within the Department of Health and Human Services (H.R. 2886 and H.R. 3882) and a Rural Area Transportation Office within the Department of Transportation (S. 839). All three of these bills, however, died in subcommittee.

Energy Self-Sufficiency

Since the 1973 OPEC oil embargo, policies to promote energy self-sufficiency at all levels have become an integral part of other domestic policies, including agricultural and rural development policies. Major initiatives have been put forth since 1977, and many of the more recent initiatives contained provisions encouraging energy conservation or production. The most important of these are presented below.

The Food and Agriculture Act of 1977 (Public Law 95-1 13) contains in its title XIV (the National Agricultural Research, Extension, and Teaching

Policy Act of 1977) findings that bear directly on small farms and appropriate technologies, and call for new Federal initiatives in several areas, among which are:

- more intensive agricultural research and extension programs oriented to the needs of small farmers;
- development and implementation of energy-efficient and environmentally sound methods of utilizing nonfood agricultural products and waste products; and
- investigation of the effect of organic waste materials on soil tilth and fertility.

To that end, the Act amends section 502 of the Rural Development Act of 1972 to emphasize programs that will develop new approaches to small farm products, marketing techniques, and finance, it also adds to section 502 a new subsection (d) specifying that small farm extension programs "shall [use], to the maximum extent practicable, paraprofessional personnel to work with small farmers on an intensive basis."

Subtitle H of the Act encourages R&Don "uses of solar energy with respect to farm buildings, farm homes, and farm machinery," and promotes the establishment and operation of model solar energy demonstration farms in each State to determine "energy usage, income, costs, operating difficulties, and farmer interest with respect to these model farms."

The Energy Security Act of 1979 (Public Law 96-294) also contains numerous provisions relating to small farms, but the majority of them are contained in its title II, the Agricultural, Forestry, and Rural Energy Act of 1979. These provisions include the following:

- that the Secretary of Agriculture implement an Agriculture, Forestry, and Rural Energy Production, Use, and Conservation Program to enable the United States to achieve net energy independence in agricultural and forestry production by 2000;
- that the Secretary implement an applied research program to develop economical and energy-efficient fuels from biomass; techniques for using energy so derived in the production, processing, and marketing of agricultural commodities and forest products; and energy conservation systems and techniques for farmers;
- that the Secretary establish not less than four and not more than eight Agricultural Biomass Energy Centers, in different geographic regions of the United States to undertake research, development, and demonstration projects on promising new farm energy technologies; to develop a data base and perform energy need analyses for rural residents and communities; to disseminate information on new energy systems and provide technical assistance to farmers; and to support energy-efficient model farms; and
- that the Secretary establish an extension program to disseminate the results of farm energy research, to encourage the adoption of energy conservation and production technologies, to conduct workshops for interested farmers, and to provide technical and cost-sharing assistance for the installation of farm energy systems.

In addition, there are several provisions in title VII (the Omnibus Solar Commercialization Act of 1979) which direct the Secretary to support the dissemination of information on renewable resource research and to establish a National Solar Energy Information Center as part of a coordinated information and outreach program.

Other legislation relating to small farm energy policy included the bill to amend the Consolidated Farm and Rural Development Act (Public Law 96-438), which authorizes the Farmers Home Administration to make or insure loans for the development, construction, or modification of solar and other renewable energy systems on family farms.

Issues and Options

Existing and proposed legislation provides a broad range of technical and financial assistance for the diffusion of small-scale agricultural technologies. No major institutional changes appear to be needed at this time. The specific issues that emerge from the cases examined in this chapter fall into two interrelated areas: 1) R&D, and 2) education and outreach.

ISSUE 1: Research and Development.

These case studies include technologies at varying stages of development. For instance, knowledge of solar thermal phenomena is far more complete than knowledge of anaerobic decomposition.

As a result, solar thermal technologies like the vertical-wall collector and solar hot water system can already be demonstrated in onfarm applications. In fact, it is likely that further improvements in these systems might be discovered primarily through onfarm adaptation and everyday use.

However, some biomass systems like the biogas digester seem to be in two stages of development at once. Significant design improvements and cost reductions have been achieved through the experience gained in demonstrations, but much remains to be learned about both the basic biological processes involved in anaerobic digestion and about its operating parameters—the energy content of different feedstocks or feedstock mixes, their various biogas yields, and the nutrient value of the resulting sludge. Nutrient content and nutrient availability in digester sludge is the subject of particular debate.

In addition, little information has been generated thus far on the full potential of these solar and biomass installations as components in a larger, integrated system of farm technologies. The devices installed in the Small Farm Energy Project were not always those with the greatest energy-saving potential, and self-selection by the innovating farmers usually led to isolated, piece-by-piece installations. It would also be useful to gather more reliable data on the feasibility, costs, and benefits of an integrated farm energy system that combines a number of complementary energy technologies with a number of other conservation strategies, such as changing fuels in farm machinery, using low-tillage techniques, and incorporating some organic farming methods. Another focus for integrated R&D might be the investigation of alternative crop/livestock systems that make more efficient use of available resources and conditions as part of an integrated, sustainable, self-sufficient, and environmentally benign farming operation. New Life Farm, for example, modified the Ozark grass/hogs system by cropping a tree that had not previously been grown in the region, producing energy from hog manure, and returning sludge to the land to improve its fertility.

Option 1: Support increased R&D.–Congress may wish to accelerate the development and diffusion of alternative small-scale farm technologies by directing USDA and other Federal agencies to broaden and intensify their research efforts in the areas described above, as authorized by existing legislation. These efforts would generate more detailed and reliable information if individual projects were directed to give a high priority to information gathering; cost-benefit analysis would be especially desirable, and might be included in the technical assistance offered by the funding agency if local expertise is lacking.

ISSUE 2:
Education and Outreach.

The New Life Farm and the Small Farm Energy Project both had two functions: research and demonstration. NLF was perhaps more successful in its research component, but SFEP was particularly successful in its demonstration component. Self-selection by the innovating farmers simulates the manner in which such technologies might actually be disseminated on a local level, and the spread of conservation strategies among the nonparticipants in Cedar County illustrates how rapidly these technologies might be transferred in small farming communities.

Option 2: Support improved Demonstration and Extension Programs.—Legislation already passed by Congress (see above) calls for more intensive research and extension programs aimed at the energy needs of small farmers and authorizes the establishment of model farms in each State as well as a number of regional agricultural energy centers. Congress might wish to promote these initiatives by appropriating or earmarking additional funds to implement them. These model farms and regional centers might be located at AES or State extension research stations. An alternative would be to investigate ways to encourage regional "networking" among existing projects and community groups, particularly those with installations on working farms. It should be noted that NLF is incorporated as a research and educational organization, and that SFEP is funded by CSA as a "national research and demonstration project. " These and similar projects might serve as the nuclei for such regional networks. Finally, Congress might wish to promote the consideration and adoption of small-scale alternative agricultural technologies by directing Federal funding agencies to encourage project designs with a strong outreach component, and/or by directing the Secretary of Agriculture to disseminate the results of these projects to State agencies and county agents through AES.