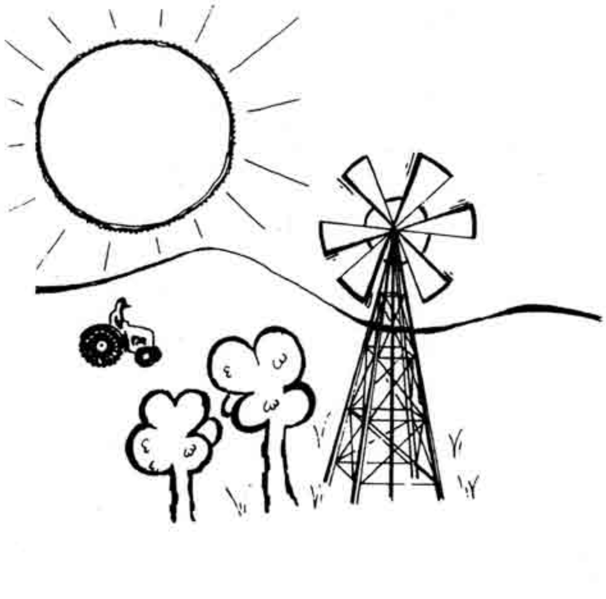

SMALL FARM ENERGY PRIMER

An Energy Saving Tool To Assist Small Farmers In Lowering the High Costs of Energy Inputs on Their Farms

Published by the Small Farm Energy Project of the Center for Rural Affairs July, 1980

INTRODUCTION

The "Small Farm Energy Primer", published in July, 1980, is a collection of reports on energy alternatives and conservation techniques to help lower the high costs of energy inputs on small farms. The reports, entitled, "Project Focus", include innovations built by northeast Nebraska farmers who participated in the Small Farm Energy Project, a special 3-year research effort based in Hartington, Nebr. The Energy Project was initiated in Cedar Co., Nebr. in the fall of 1976 and was concluded in early 1980. The aim of the "Energy Primer" is to help farmers discover and develop viable alternatives for their own farms.

The Center for Rural Affairs is a private, non-profit organization located in Walthill, Nebr. It seeks to promote rural development by providing information to Nebraskans about the trends and implications of changes in government, agriculture and private industry. The Center welcomes the reprinting and quoting of this report. Acknowledgement of authorship is appreciated.

The Energy Project publishes a bi-monthly newsletter for $5/year. A slide presentation and other publications are also available.

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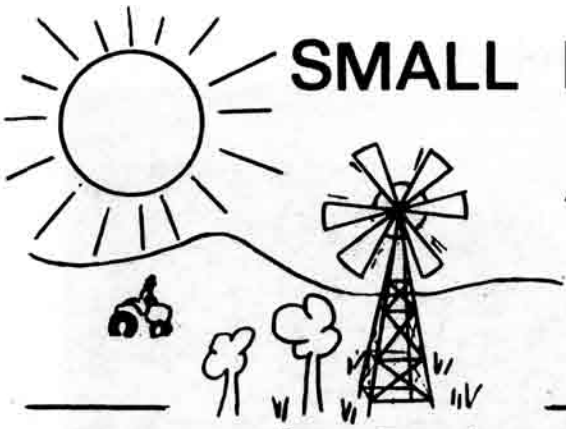
Additional copies of this publication are available for $3 from:

Small Farm Energy Project
P.O. Box 736
Hartington, NE 68739



SMALL FARM ENERGY PROJECT

A Final Report Summary

"With the goal of 'energy self-sufficient farms' as the future of agriculture."

A Project of the Center for Rural Affairs

Research Project Assists Low-Income Farmers

In October, 1976, the **Center for Rural Affairs** of Walthill, Nebraska started the Small Farm Energy Project **as a three year research and demonstration project** funded by the Community Services Administration. The Project, now completed, was conducted on **48 cooperating, low-income farms in Cedar County, Nebraska.** The Center developed the Energy Project to demonstrate that the adoption of alternative energy technologies by small family farms can make positive contributions to their incomes.

Premise of the Energy Project

Use of energy in agriculture has become increasingly controversial. Our **farms and our food supply are increasingly dependent on purchased energy inputs,** vulnerable to changes in both the price and availability of fossil fuels. In the past three decades, the emphasis in American agriculture has been placed on **farm expansion with the adoption of mechanization.** The gasoline and diesel fuels necessary to operate these machines account for 70% of agricultural energy use in the Northern Plains and Corn Belt. With this dependence on fossil fuels, it is alarming to realize farm **energy costs have nearly doubled in the 1975 to 1979 period.**

At the same time, the expansion of farms by use of energy and energy-intensive technologies has dramatically altered the economic structure of American agriculture, **resulting in diminished economic opportunity for rural people.** The small farmer has been sold out to the large and expanding operator making use of energy-intensive technolgies. The complexity and expense of energy-intensive farming make intimidating barriers to young couples trying to get a start in farming. **Thus small family farmers are directly threatened by large-scale mechanization developed in an era of cheap energy.**

Implicit in these conditions is an irony: **the energy crisis is an economic opportunity for America's small family farmers.** Where creative minds are applied to the development of low-cost alternative energy systems for use on farms with limited resources, small family farmers can reduce costs of production and increase net incomes. In response to the energy crisis, the small family farmer can make use of renewable energy resources, demonstrating that skills and resourcefulness, the human factor, is once again at a premium in agriculture.

Energy Saving Demonstrations

The Project's basic objective was to demonstrate the impact of proven energy-saving innovations and conservation techniques on the energy use, cost of production, and net incomes of small, low-income farmers. It measured the energy consumption and net farm income of two comparable groups that do and do not adopt energy-producing and energy-saving practices. **Twenty-four cooperating farmers agreed to innovate with alternative energy projects on their farms.** The remaining record-keeping farmers made a pledge not to. Both groups kept detailed records. The results hold promise that **farmers can respond to the energy crisis by making more efficient use of the energy they purchase and by producing their own energy.**

The Project involves only "appropriate-use" alternative energy innovations. Such innovations are:

—**low-cost** using locally available materials
—**home-built** making use of common farm skills
—**easy to manage and maintain**
—**meeting constraints existing on the farm**.
—**cost-effective.**

By combining the common sense of the farmer with the experience of the professional, practical innovations meeting the needs of the farm are developed. Important agrarian values are supported by **this process which empowers small farmers in their community.**

Key Project Findings

Farmers participating in the Energy Project kept detailed records on farm inputs, production, and sales. Record books also provided information on field and livestock operations. The records show that there is considerable variance in the way these diversified farms operate. In 1976, at the beginning of the Energy Project, farms in the "innovative cooperator group" and in the "record keeping group" had similar energy use.

Key findings of the Project were the following:

—**Liquid fuels represent 46% of energy use on the small western corn belt farm; electricity another 27%; heating fuels about 14%; and fertilizers about 13%.**

—**Energy consumption has increased 24.5% in the 1976-1979 period; energy expenditures increased 62.6%.**

—**Energy use for farm production comprises 60% of the small farm's energy consumption;** 40% is for domestic use in space heating, electricity and non-farm transportation.

—**The general trend among farmers toward larger horsepower diesel tractors,** which compete with residential demand for heating fuels and which are less amenable to ethanol fuels, is apparent among small farmers in this study.

—**A trend toward specialized farm operations was evident among participating farmers** though such energy-intensive practices were shown to have **heightened dependance on energy** and vulnerability to energy price increases.

—**Cost-effective solar energy innovations** that farmers build themselves using locally available materials can be low-cost, easy to maintain and may be applied to a variety of farm energy needs.

—**In 1979, an average of $1138 in energy expenses per farm was saved by innovating farmers,** compared to their counterparts—a reduction of 17% in three years. **Nearly 70%** resulted from the adoption of energy-efficient farm practices using conventional farm technology, indicating the importance of **energy conserving attitudes and farm practices,** such as making better plans for trips to town, re-evaluating fertilizer purchases, and more frugal use of machinery.

—**Various forms of alternative energy are not always appropriate for each small farm.** Cost effectiveness is site or farm "specific".

An Alternative Research Project

On-Farm Research Conducted

The Energy Project has differed from most attempts at agricultural research because its purpose was not to develop sophisticated technology to enhance specialized farm output per unit of labor —the conventional approach which breeds antagonism among farmers as they race to keep up with technological change. Instead, **this Project has worked to adapt proven alternative energy technologies to the existing farm operation,** making the farmer an active participant in practical research. In this community-based approach to agricultural research, the products were not so much devices for the farm as skills for the farmer. **Actively involving the farmer in much of the research** has provided a real life situation rather than the artificial atmosphere of a laboratory farm.

This research approach **joined the practicality of the farmer with the alternative energy technologies available to him. The farmer determined whether or not the technology was appropriate for his farm.** Small farmers have traditionally been innovative and as a result the farmer is best able to deal with his problems if he is provided with some technical assistance.

The **self-selection strategy** was utilized throughout the cooperating farmer's process of undertaking an alternative energy innovation and **included the following steps:**

—Consideration of potential innovations at workshops and field-days

—Selection of an innovation suited to the farmer's needs

—Construction of the project with technical support provided

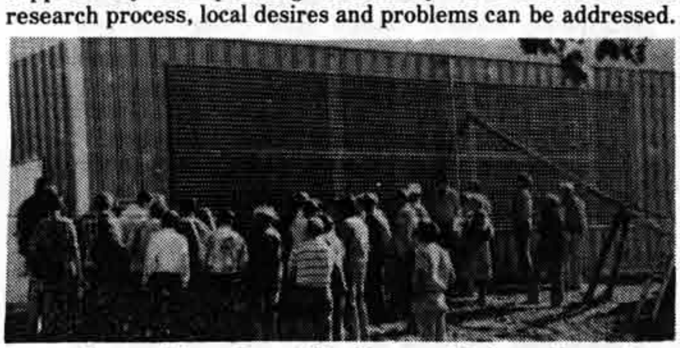
—Monitoring of the innovation's performance

—Sharing with others the experience of implementing the project

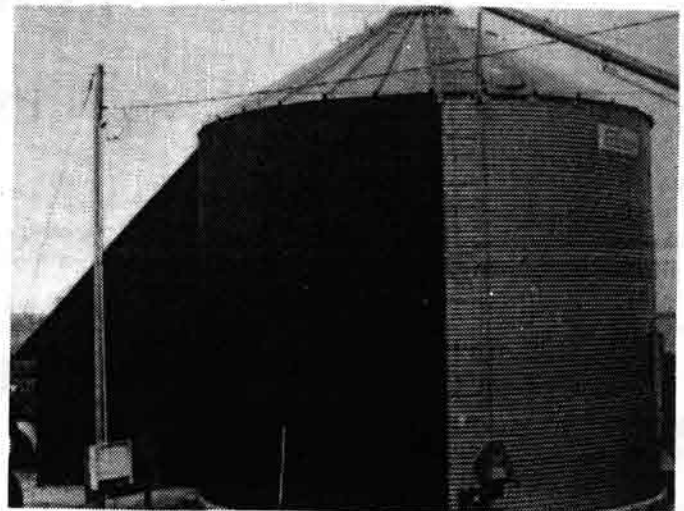
The farmer was responsible for taking the initiative during each of the stages of the process. He also had the opportunity to reject the project as inappropriate for his farm. As a result, **the group of farmers serve as a "technology review panel."** The availability of time for the busy small farmer is also an important aspect that is a consideration prior to selecting an innovation. It was nearly one year after the Project began before the first major innovation was constructed.

The innovations farmers have chosen would indicate that the **self-selection strategy has worked very well.** Monitoring of the output of the projects by the farmers themselves substantiate that **farmers are good judges of what is practical. The most popular projects have proven to be the most cost-effective.**

Another important feature of this community based research effort has been an **advisory committee** of prominent Cedar County citizens, who helped to provide local community support. By incorporating community involvement in the research process, local desires and problems can be addressed.



—A recent farm tour at the Gary and Delores Young farm provided visitors the opportunity of studying the vertical wall collector for heating the dairy barn. The dairy facility also utilizes a heat exchanger which uses heat from the milk cooling system for heating water, thereby saving energy.



—The solar grain dryer on a 6000 bu. bin at the Earl Fish farm, Belden, Nebr. Fish, a cooperator of the Energy Project, has successfully dried grain using the solar system for three years. The collector saves over $100 per year in drying costs during his corn harvest.

Project Participants

The participants in the Project were typical operators of the smaller, well-kept farms in the rolling hills of Cedar County that maintain livestock as the final product for market. **Hogs and dairy cattle are the mainstay of these family farms.**

The Project's target group was low-income farmers with net incomes within 125 percent of the poverty level established by the federal government. Average gross farm income in 1977 for Project participants was $36,000. **Net income in 1977 averaged $3,700 per farm, although energy costs, including fertilizer costs, exceeded $4,000, mostly for motor fuels and space heating.**

Farmers who participated in the Project grow corn, oats, alfalfa, and some soybeans on an average of 240 acres of cropland. Including land in pasture and the farmstead, the average **total farm size was 357 acres.** Farmers depend largely on crop rotations to maintain soil fertility though some commercial fertilizer is applied. The farms provide most of the family income and take the labor of the whole family (average size of five) even though they are fully mechanized (an average of 3.4 tractors per farm).

The difference between the small diversified farm and the large specialized farm, centers on the conflict between traditional agrarianism and modern industrial values. The following comments of Project participants describe much better than any summary their **attitudes toward farming, farm size and mechanization.**

"When you are farming a limited acreage you can't have a big investment in machinery. No matter how much money you are handling you can't live beyond your means. Now young farmers want to start on the same level their folks are at today, not realizing that it took them 30 years to get to that point."

"I think there is **a place for the small operator** because he can take care of his operation and do it right while a big operator can't. For example, a small farmer can utilize terraces and compost his manure to obtain additional production without deteriorating his basic resources, his land and water."

Cooperating farmers have spoken freely about their concepts of small farms and related issues after being associated with the Energy Project, although their concepts are not supported elsewhere within the agri-business structure. However, **with the support of a community based organization** such as the Energy Project, farmers are more open to speak out on such aspects.

Project Innovations & Energy Savings

Energy Saving Devices Constructed

Cooperating farmers invested $29,699 in 148 innovations during the three-year project. The technical characteristics of the energy innovations emphasized projects which were simple, home-built, low-cost, acceptable by the local community, matched to the farm, and cost effective. When these concepts were emphasized, the innovations supported traditional agrarian values like independence, self-sufficiency, thrift, common sense, harmony with nature, and seeing the fruits of your own labor.

Various Technologies Utilized

The technologies used can be categorized into three broad groups:

—Production of flow energy such as innovations that utilize biomass, and wind.

—Utilization of recyclable resources,i.e. the production of methane and compost from livestock manure and from municipal, feedlot, and commercial wastes.

—Conservation of fossil fuel as with insulation and weatherization, engine maintenance, minimum tillage, conservation farming practices, and farming without chemicals.

Twenty-four of the cooperators, the "innovative" group, have a variety of alternative energy innovations and energy conservation practices which they have implemented, by self-selection. In keeping with the traditional self-reliant spirit of most farmers, cooperating farmers were required to be actively involved with decision making, research, construction, and maintenance of the innovation. **The Energy Project provided technical assistance to cooperators. It also provided some cost-share assistance**, based on recommendations of the local advisory committee, as an incentive for the farmer to implement innovative projects.

Major Energy Innovations

Major innovations implemented included:

—Vertical wall solar collectors for the home
—Solar grain drying
—Solar hot water heaters for dairies
—A solar heated farrowing barn
—A wind electric generator
—Composting of manure to lower fertilized purchases
—An attached solar greenhouse
—Portable solar collector for space heating &grain drying

The most popular major innovations, the solar grain dryer and the vertical wall solar collector, have also been the most cost effective of innovations built by cooperating farmers. Both projects require basic carpentry skills, common to most farmers.

Because wind electric generators are quite complicated to build, a **cooperator's wind electric system is the Project's only major innovation that is not home-built.** The wind system has proven to be a very complex system and has often developed malfunctions which the farmer could not repair. **The wind generator has less economical feasibility than the solar collectors**, but it is probable that such systems will become more feasible in the future as energy prices continue to rise. The innovation was important to the Energy Project, providing indications that wind and electrical demand of the farm are closely matched. In addition, the wind project has involved changes in the institutional barriers affecting the connection of wind systems to utility grids.

An analysis of the potential of methane production was conducted on one of the cooperating farms. **A proposed methane plant was cancelled due to escalation of capital investment and low return on investment.** The results of the study indicated that methane production is not feasible for the average small farm of theEnergy Project. Results of the study also indicated that the **appropriate use of alternative energy technologies must take into consideration the aspects of each farm.** Application of the technology is "site specific" and is not always cost effective for all farms.

Other Innovations

Minor innovations included:

—Window box solar collectors
—Solar food dryers
—Wood stoves
—Recycling of compressor heat in dairies
—Minimum tillage
—Wind water pumping
—Use of heat exchangers in livestock buildings.

In addition to these innovations, all of the homes and many of the farm buildings were insulated and weatherized. Soil testing, installation of pressure vacuum filler caps on fuel tanks, and other conservation items were also utilized. **Cooperators were most willing to adapt conservation devices compared to other innovations.**

Energy Savings

Vertical wall collectors range in size up to 300 sq. ft. costing approximately $3 per sq. ft. **The vertical wall collector,** used primarily for space heating in the home, **has the potential to save a farmer over $100 per year over a 10-year period.** The first **solar grain dryer** built by a cooperator **cost under $500 and appears to have the potential of saving $260 a year over 10 years** when used as a substitute for more energy-intensive batch drying.

Energy Conservation Important

Although solar devices received the most publicity, it was **simple energy conservation devices and practices that resulted in most of the energy savings by cooperating farmers.** The cooperating group used approximately the same amount of energy as the record-keepers at the beginning of the Project. However, **after three years the cooperators spent $1138 dollars per year less on energy.**

—The chart to the right indicates the various energy expenditures of two groups of farms. Total energy expenditures were nearly the same at the beginning of the research efforts of the Energy Project. However, after three years, the cooperating farms spent $1138 less in energy expenditures than their counterparts in the record-keeping group. Most of the savings were due to energy conservation techniques.

Average Farm Energy Expenses

	Cooperating Farms				Record-keeping Farms			
	1976	1977	1978	1979	1976	1977	1978	1979
Electricity	$ 944	$ 992	$1,083	$1,157	$ 788	$ 830	$1,027	$1,175
Fuel Oil	209	262	231	343	191	178	189	322
Propane	265	197	201	200	336	249	357	439
Diesel	353	489	558	804	318	421	515	893
Tractor-gas	617	789	807	928	792	903	1,057	1,316
Car-gas	587	792	720	1,035	592	903	789	1,069
Fertilizer	1,011	1,045	882	1,283	1,220	1,252	1,272	1,674
Total	$3,986	$4,566	$4,482	$5,750	$4,237	$4,736	$5,200	$6,888

Diversified Livestock Farms

Lower Energy Inputs

A comparison of average energy consumption and expenditures by type of operation suggests that **diversified, general livestock farms are less vulnerable to energy price increases than dairy or hog farms of comparable size.** According to the three-year analysis of farms cooperating in the Project, **farms with dairy, beef and hogs gave consistently higher net profit per dollar spent on energy as comparably-sized dairy and hog farms.** Although the results of the analysis are preliminary, they **seem to indicate that the diversified farm was in a better position to handle energy price increases and fluctuating market conditions.** □

Continuing Activities of the Energy Project

Although the initial research and demonstration phase of the Energy Project has been completed, **several new efforts are underway to assist farmers in reducing energy costs.** Several of these efforts of the Energy Project are described in the following paragraphs.

Farm Energy Training Program

Based on Farm Experience

Organizations and agencies wanting to develop farm energy programs can now take advantage of the new **Training Institute established by the Small Farm Energy Project.** The institute offers seminars, hands-on workshops, and one-to-one consultation with program staff of client organizations. Each program is **individually tailored to meet the needs of the particular client group.**

The Training Institute's services are being **provided by the staff and cooperating farmers** of the recently completed three-year research effort **of the Small Farm Energy Project.**

Included in the Institute's curriculum are:

—Sizing up the farm for alternative energy possibilities
—conservation on the farm
—principles of retrofitting energy-saving devices
—determining cost-effectiveness before making a commitment
—rules of thumb in solar construction
—how to find the best "hardware"
—financing alternative energy devices
—monitoring and evaluating projects
—working with small farmers on various issues
—organizing community based energy projects

The Institute is **designed to serve organizations with farm memberships** or with programs serving farmers, but **can be adopted to the needs of other rural organizations** as well. The Institute is also available to assist organizations with other small farm issues besides energy conservation. The Institute is non-profit but will be supported by client fees. Fees are arranged based on the cost of providing the service required and the ability of the organization to pay.

Project Begins New Outreach

Three State Project to Use Local Volunteers

The Energy Project has entered a new phase of its efforts to assist small farmers in energy alternatives. Emphasis on **demonstration work is being conducted in a three state area** surrounding Cedar Co., **utilizing community paraprofessionals and volunteers** working with low-income farmers. The new effort, called the **Small Farms Project,** has been launched with the financial support of ACTION, a federal agency.

In conjunction with the new outreach effort, the Energy Project is teaming up with the Small Farm Advocacy Project, also sponsored by the Center for Rural Affairs. The Advocacy Project has found that providing information, technical assistance and demonstration of cost effective technologies is not always enough to initiate widespread use of the technologies. The Farmers Home Administration, for example, has denied requests for loans to finance solar innovations and it has been found that **small farmers are often discriminated against in the administration of various federal farm programs. The Small Farm Advocacy Project has been designed to reform such practices** of discrimination, particularly in the area of farm credit. Volunteers of the Small Farms Project are therefore conducting both small farm energy and advocacy work. The Project has implemented local activities "involving small farmers in energy saving, income enhancing innovations and strengthening the participation of small farmers in federal farm programs intended to benefit them." Several multi-county areas are the focal points of the outreach work in the states of **Nebraska, Minnesota and So. Dakota.**

Other Outreach Efforts

Another example of an outreach effort of the Energy Project is the "Rural Ministries Project", funded by various church denominations. This effort is similar to other outreach efforts of the Energy Project, but focusing on specific involvement of both lay and professional church people at the local and regional level. Persons interested in details of this project can contact the Energy Project for more information.

Alcohol Fuel Project Underway

Energy Project Conducts Two-Year Study

In the fall of 1979, the Small Farm Energy Project and its sponsor, the Center for Rural Affairs, were awarded a **$43,000** grant for **developing experimental farm alcohol fuel systems** in Cedar County, Nebr. The funding is being provided for a proposal submitted to the Dept. of Energy's Appropriate Technology Small Grants Program. The proposal includes provisions for a **permanent on-farm alcohol system and also a portable distillation system.**

Initially the alcohol project is **conducting experimental work with small scale equipment, and later will utilize scaled-up versions for actual farm use.**

A major element of the study is the **development of low-energy designs to improve the net energy results of on-farm alcohol production. At the same time the effort is concentrating on low-cost plant designs that are simple to operate and maintain.** Initial results of the study indicate that the farmer has much to learn before implementing an effective alcohol plant.

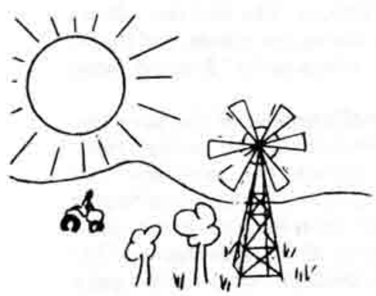
The new alcohol project funded by DOE represents the first venture by the Energy Project into farm alcohol production research. **The project differs from previous work of the Energy Project, since it involves development work where previous projects mainly emphasized demonstration.** □

People Involved in the Project

—**48 cooperating farms** in Cedar Co., Nebr.
—**Co-directors** are Dennis Demmel and Ron Krupicka
—**Research director** is Rob Aiken
—**Office Manager** is Janet Hamilton
—**Outreach volunteers** located in Minnesota, So. Dakota, and Nebraska

Cedar Co. Advisory Committee includes Allen Heine, Jerome Noecker, Pat Rogers, and V.E. Rossiter, Sr.

—**Sponsoring Agency** is the Center for Rural Affairs, P.O. Box 405, Walthill, NE 68067, phone 402-846-5428.



PROJECT FOCUS # 1

Small Farm Energy Project

The Kaiser Wind Electric System

JUNE, 1980
[Revised Edition]

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

The use of wind generators was wide spread prior to rural electrification. The state of the art of wind generation of electricity hasn't changed much since that time because cheap electricity has stalled the development of wind systems.

Although the Energy Project has tended to emphasize home-built energy innovations, the sophistication of wind generating equipment usually requires commercially built systems. The strong interest in exploring the potential of wind energy led to the installation of a commercial wind system by Benny and Shirley Kaiser on their farm in 1978. The wind system has been one of the most expensive energy innovations used by Energy Project cooperators, and it has given a low return on investment. Despite various difficulties with the system, the experience has provided useful information. Wind energy promises to be an increasingly important energy source as wind systems become more refined and as the cost of electricity continues to rise.

—Benny Kaiser describes his farm's wind electric system to a tour group visiting his farm. The wind system has been of interest to many persons in the area, but has been troubled with a series of technical malfunctions. Kaiser and his family have assisted the Energy Project by maintaining records of the performance of the wind system.

Policy Issues

Electric Utilities

The installation of a wind electric system by the Kaiser family represented an opportunity for the Energy Project to demonstrate and study some important concepts in the debate of decentralized versus centralized power in rural areas. It was felt that wind energy is of considerable potential in rural areas, and monitoring equipment was installed to help determine the feasibility of the energy source.

In order to realize the full potential of wind energy, however, it was clear that **various institutional barriers had to be removed or changed.** The newest wind technologies involve connection to existing power lines; most Rural Electric Cooperatives (REC's) and utilities are oriented to centralized power, so their willingness to allow these systems to be connected to their lines is often less than enthusiastic.

Insurance Companies

In addition, the Kaisers encountered **difficulties in dealing with their insurance company.** The wind turbine was damaged at one time by high winds. The Farmers Mutual Insurance Company paid the claim but cancelled coverage of the wind system. The local agent looked over the repaired system, but failed to provide a new policy. The dealer for the wind system identified other insurance companies who would insure the system as part of a whole farm policy, and the Kaisers have considered changing policies.

—Installation of the wind electric generator is shown on the left . A crane was used to place the generator, manufactured in So. Dakota, onto the top of the 54 ft. single pole tower. A later model of the generator was installed using a "gin pole". The steel tower was a contribution of Valmont Industries. The local REC has cooperated in allowing connection of the wind system to REC lines. The wind system was one of the most expensive innovations installed by Energy Project cooperators, and has provided a low return on investment. However, wind systems may play an important role in the future of supplying electricity to farms, especially as electric prices continue to rise.

Wind Equipment & Costs

The Kaiser wind system consists of a direct drive, DC generator; a Gemini synchronous invertor, which allows utilization of local REC power lines for "storage"; and a tower made of a single steel pole without guy wires.

The Generator

The wind generator is a version of the old Jacobs Wind Electric System, now being manufactured by Dakota Wind and Sun Ltd. in Aberdeen, S.D. **The generator has** been modified to increase its output capacity to 4 kilowatts (kw), which is reached in winds at or above 25 mph. The original Kaiser generator was not designed for use with the 4 kw Gemini Invertor, and, in addition, **the brush holders failed shortly after the wind system was installed.** As a result, the generator was subsequently replaced with an appropriate generator.

Three blades made from Sitka Spruce provide a rotor diameter of 14 feet . The rotor utili zes a blade actuated centrifugal governor so that when the wind increases, the centrifugal force causes each propeller blade to turn such that the force of the wind upon the blade is reduced. This feathering mechanism is designed to prevent damage during high winds. The tail vane of the wind system is connected by a cable to the base of the tower. Normally the tail is held in the off position by this cable, and must be cranked into the wind in order to activate the system. This is an important safety feature; if the cable breaks, the wind generator will return to its normal off position instead of remaining in its power position, unable to be stopped.

Soon after the system was installed, **a tornado-like wind** clocked at over 100 mph apparently succeeded in moving the tail from its normally "off" position and slamming it into the blades, **bending the tail and breaking one blade.** The manufacturers described it as a freak incident, and the system was eventually repaired. The Kaisers have also experienced difficulties with the cable controlling the tail mechanism.

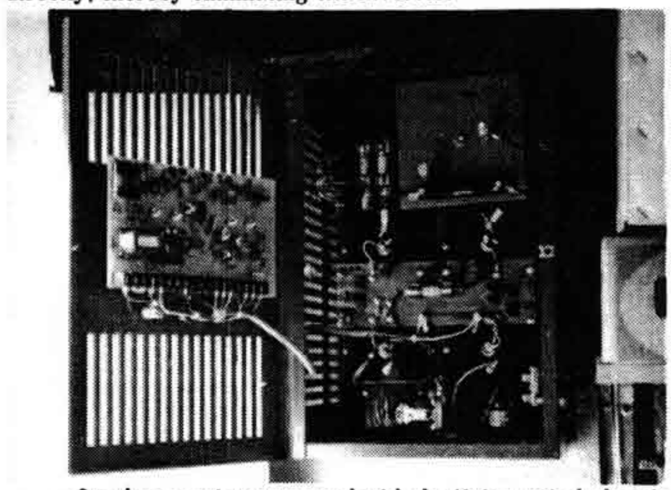
—The wind electric generator at the Benny Kaiser farm is a 4 kw generator using a three-bladed turbine. It was manufactured in So. Dakota. This photo shows the tail folded in the "off" position for severe weather protection. The generator pivots on the stub tower, which is bolted to the single pole, steel tower.

The Synchronous Invertor

In the past, batteries had to be utilized for storage with wind systems to assure a constant and regular flow of electricity, since wind power is irregular due to fluctuations in wind speeds. **The synchronous invertor takes the variable voltage DC current produced by the wind generator and converts it to AC current** matched to the voltages and frequencies of the AC power in REC lines. This eliminates the cost, maintenance, and electrical compatibility problems associated with battery storage systems. **The invertor allows power to be drawn from REC lines during low winds, and it also allows for excess power from high winds to be "dumped" onto the lines.**

There have been **numerous malfunctions of the invertor,** often interrupting electrical production for some time. According to the dealer for the system, the generator and invertor are not fully compatible equipment. There has been a **history of difficulties with similar invertors** on other wind systems elsewhere, and the **efficiency of the conversion** of DC power to AC current is highly **questionable** and could be quite low.

The Kaisers are seriously considering the purchase of an Enertech **induction generator,** which would produce AC power directly, thereby eliminating the invertor.



—Synchronous invertor used with the Kaiser wind electric system. The invertor converts DC current from the generator to AC power for use on the farm. It also allows the farm to use power from the REC, in addition to wind power, during low wind periods.

The Wind Tower

The steel pole and its base bolts, used by the Kaiser system, were contributed by Valmont Industries in Valley, Nebraska. The base of the pole has a mounting plate that is used to bolt the 12" diameter base of the pole to four 1¾"x7' steel bolts embedded in concrete. The pole consists of a 38' tower with a 12' extension and topped with a 4', four-legged generator mount giving a **total height of 54 feet.** The tower has removable step pegs to allow climbing the tower for maintenance.

The manufacturer of the generator has suggested that guy wires be used with the tower to help stabilize it, and perhaps avoid future repeated damage to the tail assembly and rotor.

Initial System Cost

Tower Base, concrete	$90.82
Tower & Base Bolts, contributed by Valmont Industries—no charge (estimated value, $750)	
Top Stub Tower, by dealer, Natural Power Systems—no charge (estimated value, $80)	
Tower Cap, Dakota Wind & Sun, Ltd.	95.00
Wind Turbine and Generator, Dakota Wind & Sun, Ltd.	2,690.00
Gemini Invertor, Windworks	734.00
Sales Tax on above	127.02
Miscellaneous Wire & Hardware	55.66
Labor for Trenching, Installation of Tower & Wiring	105.00
Total Equipment Expenditure	**$3,897.50**

(Note that the above prices are those at time of purchase, Fall, 1977, and subject to extensive price increases.)

Installation & Hook-up

Installation Steps

Site selection was the first important step for best wind reception. Prevailing winds in the area are northwest and southeast, so obstructions of trees or buildings were avoided in these directions from the wind tower location. At the selected site a concrete base for the pole was poured. The REC's boom truck was used to set the pole on the bolts of the concrete base. The wind generator was then placed on the pole by using a "gin pole". The wire from the generator to the synchronous invertor was run down the interior of the hollow pole and then underground to the invertor, which is located inside the house.

A lightning arrester has been installed to protect the system from lightning.

REC Hook-up Procedure

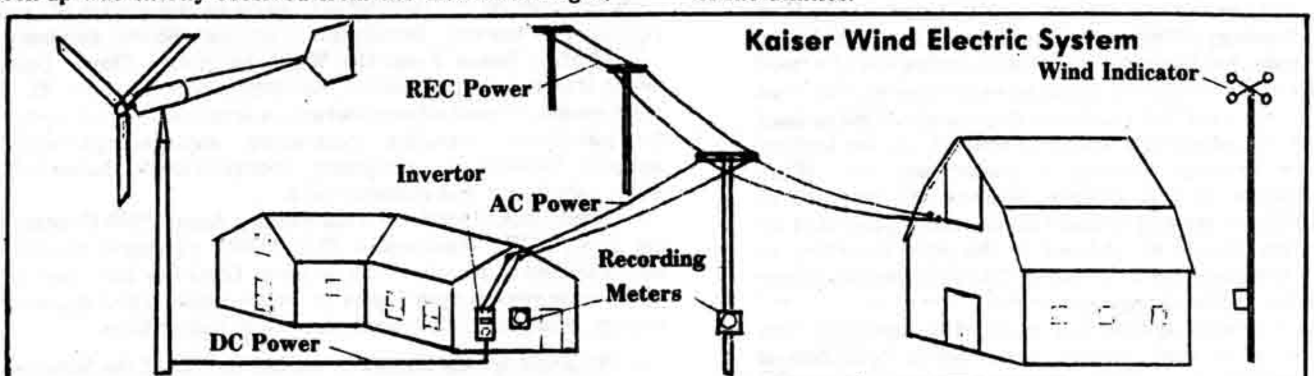
The local REC, Cedar-Knox Public Power District, has cooperated in allowing the wind system to be connected to the local power lines. The process of obtaining this arrangement started during the Spring of 1977 when a Project cooperator approached the manager of the REC to ask about the possibilities of connecting such a system to REC lines. The initial response was that the REC had a contract with the Nebraska Public Power District, which stipulated all REC power would be purchased from NPPD. However, NPPD officials later stated that they had no objections to wind systems as long as their customer, the local REC, agreed to the arrangement.

The REC was then supplied with technical information on the Gemini Synchronous Invertor and several newspaper articles on similar efforts in other areas of the country. One article discussed the court battle in which a New York group won permission to connect a wind electric system to Consolidated Edison's power lines. Verbal approval for allowing the hook-up was shortly received from the district manager, who requested copies of other agreements so that a formal written agreement could be established. The Energy Project provided the manager with various copies of agreements used in other parts of the country.

After more communications with an REC representative on such points as a ratchet meter, a demand charge, and reluctance to credit the farmer for power placed onto the REC lines, the matter was presented to the Board of Directors of the Center for Rural Affairs, sponsoring agency of the Energy Project. They suggested that these issues should be discussed before the REC Board of Directors.

The Energy Project Advisory Committee then made a presentation to the REC Board with the cooperating farmer and Energy Project staff present to answer questions. The manager, who dominated the REC response, explained that **the district's main peak demand occurred during summer months when wind output is low,** and that high winds during the winter would not benefit the district either. The REC, however, agreed to use a Wisconsin **contract** as a model and **required that a demand charge be imposed if the farmer's REC electrical use dropped below a minimum amount.** The REC emphasized that metering equipment, used to determine what value such a wind system is to the REC, would be installed at the expense of the Small Farm Energy Project. The REC cooperated in the installation of the metering equipment.

There have been no technical problems with the interface of the wind system with the REC, according to a utility representative. It appears that electricity has been returned to the REC, though quite minimal. Although **the REC has not credited the Kaisers with electricity returned to the grid,** recent federal legislation obligates utilities to pay customers for power generated by small systems. However, such credits are likely to be priced at near wholesale rates, because of the cost of transmission lines and other equipment maintained at the cost of the utilities.



Monitoring and Electrical Output

Monitoring of the Wind System

On the Kaiser farm, **monitoring equipment was installed to measure the demand and flows of electricity when influenced by the wind generator.** Four factors were investigated: 1) wind velocity 2) AC electricity produced by wind energy 3) REC electricity supplied to the Kaiser farm 4) electricity produced by wind power and placed onto REC power lines. The recording chart meters used to graph electricity to and from REC lines were loaned from USDA through the assistance of Dr. Leo Soderholm of Iowa State U. The magnetic tape recording meter used to measure the production of AC electricity from the wind was rented from NPPD at the request of the local REC.

Electrical Output & Economics of Wind System

The output of the particular wind electric system installed on the Kaiser farm has been less than originally projected by the manufacturer and dealer. As an example, output ranged from 230 kwh in October to 145 kwh in November during 1978, with **an average of 181 kwh/month.** The dealer initially projected monthly output ranging from 300 kwh to 700 kwh with an average of 500 kwh per month. Late in 1978, the manufacturer notified the Energy Project that **300 kwh/month was the most energy to be expected** from the system during months with average wind speeds of 12 mph.

The electrical output by the wind system indicated that the system **will supply approximately 10% of the Kaiser farm's present electrical needs.** Cedar Co. farmers currently pay an average of approximately 4 cents/kwh for REC power. **It is evident that the wind system will require many years to pay for itself.**

Tax credits for the investment in solar and wind systems provide some financial assistance to the farmer wishing to establish such a system. The current credit allowed is 40% on the first 10,000 dollars invested, or a maximum credit of $4000.

Investment credit is also a potential incentive for the wind energy enthusiast where energy is used for a farm or business.

Other Considerations

Difficulties With Wind Power

It may be important for farmers hoping to meet their electrical needs with wind power to understand that many of the wind systems available today were designed to meet farm electric demands equivalent to those prior to rural electrification. Inexpensive REC electricity put a damper on people trying to develop better wind generators. Electric motors, heat lamps and automated pipeline dairies have eased a farmer's tasks, but dramatically increased the demand for electricity. **There has been a lag in the development of wind technology suited to the power demands of today's farms due to the low cost of electricity in the past.**

In contrast to other innovations utilized by Energy Project cooperators, the **wind system is a complex technology.** The Kaisers have not been able to overcome the technical problems by repairing and maintaining the system themselves. **"Getting someone to repair the machine is more of a problem than the wind system itself"**, says Benny Kaiser. Based on the Kaiser experience, other **farmers who are considering wind electric systems might be wise to plan on performing repairs themselves**, at least at the present time when the technology and service are not yet refined.

Future Prospects

The U.S. Department of Energy (DOE) is sponsoring **wind energy development programs** which may result in wind electric systems capable of meeting a larger portion of farm electric needs. At Rocky Flats nuclear processing facilities outside of Denver, Colo., two major wind projects are going on. Commercially available farm-scale wind generators are being tested. Also, wind machine specialists are continuing in the design of improved wind generators rated from 1 to 40 kw.

Although Congress has passed legislation which requires that utilities pay for power dumped onto their lines by other sources, the fact that the rate paid for such energy is left to their discretion perpetuates **interest in alternative methods of storing wind energy.** Windworks, an organization in Mukwanago , Wisconsin, has been looking at the possible use of a **"load dumping circuit."** When there would be excess power, the "load dumping circuit" would be activated, and instead of going back into the grid, the electricity would be utilized, i.e. for heating water, space heating, running a compressor, etc. Windworks' conclusion on this process involves the question of economics. Fifty to seventy percent of the power generated by a wind system should be utilized at the site, according to Windworks, and therefore only about 25% of the surplus power is utilized with a "load dumping circuit."

This type of wind system has no standby capability. One characteristic of a wind system that uses a synchronous invertor is that if for some reason there is no power on the REC lines, AC current is not generated. DC current could be generated for space or water heating. For lighting, however, the wind system no longer has the buffering effect of the power coming from the REC lines. This means there could be a fluctuation in the current received due to the variable nature of the wind. For only limited standby capability, such as for DC lighting, a storage battery could be used to furnish the buffering necessary when there is no power on the lines.

Despite the many potential difficulties that can be encountered with wind electric systems, **it is apparent that wind can be a good source of energy.** This is particularly evident when considering the fact that **wind availability tends to be closely matched with farm demand,** as indicated by farm energy use records of the Energy Project. If, as is assumed, more practical and problem-free wind electric systems can be developed to meet the higher demands of modern farms, wind promises to be an important power source for rural areas. **Reduced demands by farms will also be beneficial to enhancing the potential of wind energy use. Conserving electricity, it should be noted, will still be cheaper than producing the electricity by wind or other methods.**

Other Uses of Wind Power

Many farmers are returning to the use of wind energy for **pumping water** on their farms. This usually requires rebuilding wind water pumps on the farm that have been idle for several decades when electricity was low-cost.

Some individuals have used simple **home-built wind machines like the Savonius rotor,** which is built from old 30 to 50 gallon drums cut in half. The half barrels are used as wind scoops on a vertical axis machine in several tiers. However, experience at the Energy Project indicates that such machines are perhaps over rated.

Wind electric generating equipment that produces a significant amount of electricity is quite sophisticated and, as a result, home-built systems are rare. Considerable knowledge of wind and its properties are required before an individual can build a system. In addition, maintenance of such systems is quite demanding and requires the best of mechanical and electrical talents. However, such systems have been built and utilized from time to time, but are usually not in operation due to technical malfunctions.

Wind Energy References

Wind Power Digest, Michael Evans, editor, 54468 CR 31, Bristol, IND 46507, quarterly, $8/yr. This excellent publication reviews equipment, books, bibliographies and discusses building, repair and maintenance of wind machines.

Energy From the Wind, by B. Burke and R. Meroney, Colorado State U., Fort Collins, CO 80521, 3800 references, $15. Annotated bibliography of journal articles, books, and reports.

The Homebuilt, Wind-generated Electricity Handbook, by Michael Hackleman, Earthmind, 5246 Boyer Rd., Mariposa, CA 95338, $8, 194 pages, 1975. This book was designed for small scale applications and includes discussion on restoration of used equipment, towers, installation, control boxes, and more.

Electric Power From the Wind, by Henry Clews, Solar Wind, P.O. Box 7, East Holden, ME 04429, 1973, 40 pages, $2. A brief review of most all considerations involved in wind energy for electricity, including generators, storage, conversion devices, installation, equipment manufacturers, home-built units, calculation and resource lists.

Windletter, American Wind Energy Assn., 1609 Connecticut Ave., N.W., Washington, D.C. 20009, published monthly and provided to members of the Assn. Dues are $25 per yr. Windletter covers such topics as policy issues affecting wind energy, equipment standards, financing, and utilities.

"Utilities Special Report", a special section of the Summer, 1979 **New Land Review** of the Center for Rural Affairs, P.O. Box 405, Walthill, NE 68067. Includes several articles on regulation of electrical rates, effects of utility policies upon rural customers, public power in Nebraska, and also an article on the Kaiser wind system and generation of electricity for utility lines. Write for a copy of this New Land Review. Contributions are welcome.

"Wind Energy Bibliography", Small Farm Energy Project, P.O. Box 736, Hartington, NE 68739, 3 pages, 25 cents. This is an annotated bibliography of various publications on generating electricity with wind, pumping water, home-built systems, policy issues, and more.

For More Information

"Project Focus" is published by the Small Farm Energy Project, a research and demonstration project sponsored by the Center for Rural Affairs and funded by the Community Services Administration. For more information, contact the Energy Project, P.O. Box 736, Hartington, Nebraska 68739, phone 402-254-6893.

PROJECT FOCUS #2

Small Farm Energy Project

The Fish Solar Grain Dryer

July, 1980
[Revised Edition]

Since the original publication of "Project Focus #2" in January, 1979, Earl Fish used his solar grain drying system in the fall of 1979. Due to the wet fall of that year, Fish filled his 6000 bu. bin with nearly 27% moisture corn, although moisture levels should be limited to about 22%. Warm winter weather conditions did cause some damage to the corn. In previous years, Fish had no difficulties with drying corn under 22%. Farmers should not exceed such moisture limitations for solar drying; results indicate that solar grain drying can be used successfully when used properly.

Many farmers in Northeast Nebraska are considering the possibility of Solar grain drying, thanks to the efforts of Earl Fish of Belden, who likes to tell everyone how well his solar dryer performs. Fish, who was skeptical of solar grain drying at first, began harnessing the sun's rays for his 6000 bu. grain drying bin in the fall of 1977. He was the first cooperator of the Small Farm Energy Project to install a major solar innovation. In his grain drying operation, Fish had used propane in prior years, but not from 1977-1979. He figures that the solar system, costing less than $500 to build has saved him over $100 per year in drying costs.

Two other cooperators of the Energy Project, LaVern Truby and Edgar Wuebben of Cedar County, followed the example of Fish by building their own versions of a solar collector for grain drying in 1978. They, too, have reported success.

The Fish Farm And Solar Dryer

Grain and Livestock Farm

Earl Fish is a jovial fellow who farms 380 acres in south central Cedar county. 250 acres are in grain crops. Beef and dairy cows are a part of the farm, and Fish feeds hogs and cattle. Corn is harvested using a combine.

Earl Fish and his wife, Dolores, have several sons who have moved off the farm. Bonnie and Brian are still at home and Brian is considering staying on the farm. **The solar grain dryer is just part of the energy saving program** of the Fish family. Dolores has talked Earl into building a **solar and wood heated greenhouse** attached to their home. The greenhouse was completed in the fall of 1978 and **provides supplemental heat to the home**, cutting down on propane use there, too.

The Grain Bin

The **6000 bu. bin** of the solar drying system is 24 ft. in diameter with 19 ft. sidewalls; it is equipped with a stirrator and conventional drying floor. The bin **uses a 7.5 h.p. drying fan** with capacity of an estimated 7500 to 9000 cu. ft. per min. air flow.

Collector Construction

The Fish "bare plate" **solar collector was completely home built** using materials available from local lumber yards. The collector is mounted over the south two-thirds of the bin wall. It was constructed by bolting **1"x2" lumber as horizontal firring strips** over the bin wall. A second 1"x2" board was nailed to the first layer with ring-shank nails. **Galvanized corrugated sheet metal was then nailed over the lumber and painted flat black as the collector plate.** A housing, 6 ft. wide and extending 10 ft. from the bin, was also built around the fan located on the south side of the bin. Air is then drawn from the north side of the bin, through the 2" space between the bin wall and collector plate, and to the fan housing. As the air passes behind the collector plate, it is heated before being directed to the grain. The air space was sized to provide an air velocity of 1000 feet per minute.

-The solar grain dryer at the Earl Fish farm is mounted on a 6000 bu. bin. Construction cost was under $500 and has saved over $100 per season in energy costs. Air is drawn under the black collector plate from the north side of the collector. The fan housing on the left directs solar heated air into the grain bin. Fish did have a slight problem with paint adhering to the metal at the top of the fan housing. Thorough cleaning and etching of the galvanized metal is important before the paint is applied. Primer is also now recommended, but was not used on the Fish collector.

-Earl Fish, right, of Belden, Nebr. has talked to many neighbors and farm visitors about the 2-year success of his solar grain dryer in the background. Fish was the first cooperator of the Small Farm Energy Project to install a major solar innovation.

Four neighbors and friends helped Fish at various times during the construction of the solar system.

Energy Savings & Solar Research

Energy Use In Conventional Drying

"Energy required for drying corn often exceeds the total amount required for preparing the seedbed, planting, cultivating, and harvesting the crop," reports a Nov., 1976 USDA and ERDA publication on solar grain drying. It suggests that "low temperature drying" by natural air or solar heated air can save considerable energy, when compared to "high-speed drying", which normally makes use of propane or electric heat.

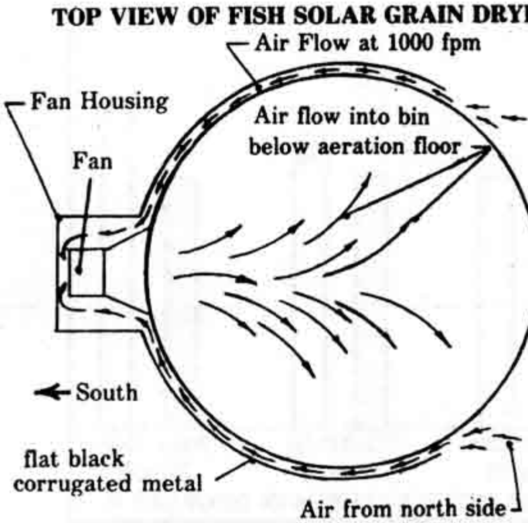
Low Temperature Drying

The objective of low-temperature drying, as in solar drying, **is to lower the relative humidity of air through the bin by raising the temperature from five to ten degrees [F.].** This takes advantage of the natural drying capacity of air. Only 1200 Btu's are needed to remove a pound of water by natural air compared to the 2000 to 3000 Btu's used in "high-speed, high-temperature drying," according to Wm. H. Peterson in his report, "Low-Temperature Drying".

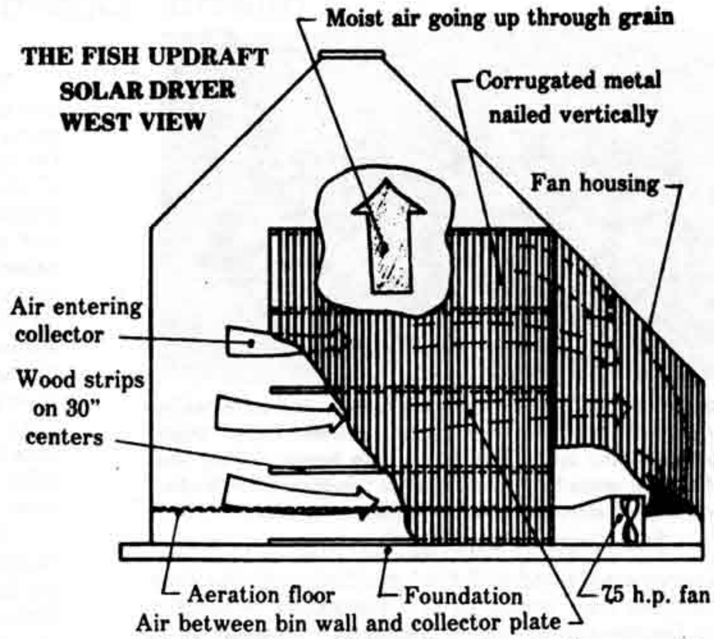
Energy Savings With the Fish Solar Dryer

Nearly 10,000 bu. of corn were dried by Earl Fish in his solar system in 1977, 11,000 bu. in 1978. The first 6000 bu. of corn dried went into the bin averaging about **21% moisture;** some was as high as 23% in 1977, drier in 1978. **The first 6000 bu. of corn in 1977 was dried to 15% moisture in 11 days.** Fish compared his results with a neighbor using propane to dry a similar batch of corn with the same moisture, but in 6 days. **Fish estimated that he saved nearly $100 in drying costs.** In his calculations, he included the cost of running the fan extra days over the time that would have been required for propane drying. The total season fan cost was estimated at $50 in 1977 and determined from extra power used in October when

TOP VIEW OF FISH SOLAR GRAIN DRYER



THE FISH UPDRAFT SOLAR DRYER WEST VIEW



compared to September and November when the fan was not in use. "I was surprised at the savings," Fish comments.

In 1979, Fish harvested corn at over 26% moisture and did have corn damage. Moisture levels should be limited to about 22% maximum.

The solar system used by Earl Fish was **built from plans available from So. Dakota State U.** and developed by extension engineer Bill Peterson. Peterson has conducted farm research on solar dryers in So. Dakota for a number of years. Like Fish, Peterson indicates an annual savings of around $100 for a solar system on a 6000 bu. bin, based on 2 cents per kwh of electric heat.

Solar Monitoring

Several factors complicate the testing of a solar grain dryer including the amount of grain in the bin, the moisture content of the grain, relative humidity and temperature of air, the rate of air flow, the "heat front" passing through the grain as drying begins, etc. As a result the Energy Project used a simple test for the grain dryer by **calculating the amount of heat added to the air going into the collector and noting the change in relative humidity by solar heating.** The number of days needed to dry the grain to the desired level was also recorded.

In 1978, Fish began combining corn at 20% moisture on October 2nd. He filled the 6000 bu. bin by October 10th. On October 14th he transferred 4000 bushels of corn at 15.9% moisture to another storage bin. Under the condition of a clear and sunny day, **the collector gave an average noon temperature rise of 11 degrees and a relative humidity drop of 27%.** The fan motor adds some temperature rise also.

The System Cost and Payback

Dryer Cost

Actual cost of materials for the system was under $500. Most of the materials were purchased new. However, the lumber for the fan housing was recycled from an old building that Fish razed several years ago. If all new materials would have been used, the cost would have been just over $600. "It would probably cost $1000 if built commercially," Fish estimates. One manufacturer reportedly is selling units for even higher prices. **Fish did most of the work himself, and in his spare time over a period of several weeks.**

Five Year Pay-back

Using Fish's estimate of $100 saved in drying the season's first 6000 bu. of corn, and a solar system cost of $500, excluding labor, an **excellent pay-back of five years is realized. Fish has, however, dried more than a batch of 6000 bu. per season, which improves the cost effectiveness.** Usually, though, the second filling of the bin requires less drying time due to dryer grain conditions with the later fall harvest.

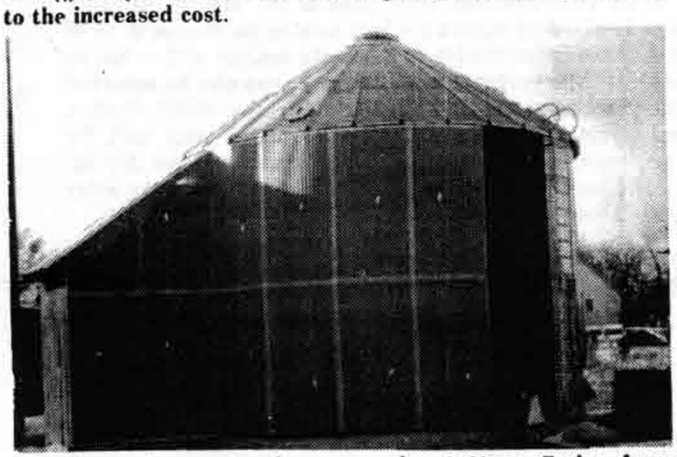
Through the Energy Project, Fish received over 50% cost share as an incentive to test and demonstrate the solar system. Therefore his pay-back is actually half of the above figure.

Energy cost increases will improve the cost effectiveness even further. New tax credits on solar equipment can perhaps also be applied to lowering the cost. Obviously, it can be shown that the home-built solar grain dryer will certainly pay for itself in 5 years or less.

Variations Of Solar Drying

Fiberglass Cover Used

LaVern Truby's solar grain dryer and bin are very similar to that of Earl Fish. **Truby**, however, **volunteered to test a new concept in the Energy Project's research efforts**, and to learn something himself. In the Truby drier, the **corrugated sheet metal collector is covered by Filon fiberglass glazing. Increased collector efficiency was shown in test results, but only in several degrees of temperature rise**, compared to the Fish dryer. **The cost of the system was nearly double** that of the Fish system, and labor was also considerably more for building the collector. Although the efficiency is higher and although testing of the system was limited to only several days in 1978, **the Energy Project is not recommending the fiberglass cover, due to the increased cost.**



-The solar grain dryer on the LaVern Truby farm incorporates a fiberglass cover over the corrugated black metal collector plate shown on the north and right side.

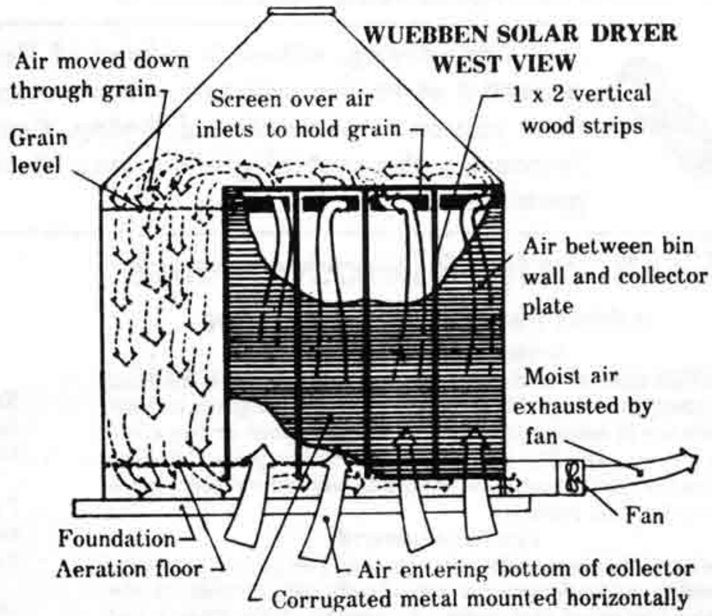
-LaVern Truby, above, installs wood strips over the solar collector plate on his 6000 bu. bin, while Dennis Demmel of the Energy Project assists. The 1 x 2 wood strips were used to support a fiberglass cover. Similar wood strips were used under the corrugated metal plate. The strips were soaked with water for improved flexibility before bolting to bin.

-Don Wuebben, right, is shown preparing the corrugated metal of the Wuebben grain dryer for painting. The photo shows 7" holes in the top of the bin wall before it was covered by the last sheet of metal. The front-end loader on the right speeds up construction. Air enters the collector at the base of the wall, and travels up the wall before entering the bin. The corrugated metal is mounted horizontally to the single, vertical 1 x 2 strips shown, using #10 x ¾" screws. The roof in this bin did not allow for condensation to leave at the eaves; that is another reason for keeping the reversed air flow.

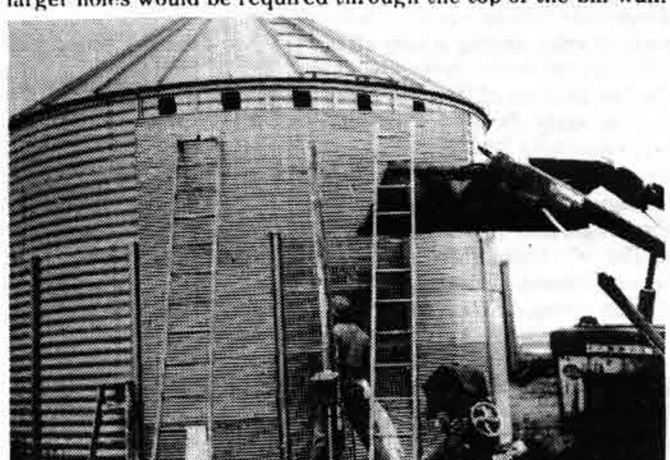
Downdraft or Reversed Air Flow

Edgar Wuebben and sons, Don and Terry, were confronted with several obstacles to installing a solar collector to their 3500 bu. aeration bin. **The fan** pulls air from the top of the bin, through the grain and then **exhausts the moist air to the outside. Exterior vertical reinforcing channels on the bin wall** did not allow for using the design used by Earl Fish. The Wuebbens contemplated the situation for several weeks. Don finally came up with the final design idea. He suggested **cutting holes in the top of the bin walls to draw air from the outer walls and into the top of the bin.** 7" square holes were used.

Air is then drawn from the base of the bin wall, up the wall under the collector plate, and into the top of the bin, before being drawn down through the grain. The Wuebben system has a small ½ h.p. fan, resulting in a low air velocity in the collector. As a result, the temperature rise is higher than that of the Fish system. The bin has an aeration floor. This is more effective than aeration tubes, commonly used for natural aeration, with a small fan and bin as the Wuebbens use. Edgar Wuebben has considered a larger fan, but he notes that the small fan has served his style of operation well for several years. Grain moisture is limited to 20% maximum moisture, and when it is that wet, the bin is not completely filled.



The Wuebben dryer was built for under $200 using old sheet metal. The chief advantage to the design is that it requires no fan housing, and is therefore less expensive. The design, however, may not work well with larger drying fans, because larger holes would be required through the top of the bin wall.



Options To Solar Drying

Natural Aeration

Some researchers indicate that **natural air drying may be sufficient to dry grain in areas like Nebraska without solar drying.** East of the Missouri River, humidity levels are higher, requiring more energy in drying; therefore solar drying can be more beneficial in those areas. Natural drying by aeration without any additional heat may require more fan time and electricity, however many farmers are using this method successfully. Local extension offices have fliers available on the topic.

Harvesting in the Ear

Of course, **another option** in grain drying **is to harvest corn in the ear,** which is an additional method of low-cost "natural" drying. Harvesting in the ear was prominent in the past, but the change was to harvesting in the shelled form due to the capability of lowering field losses when harvest is done at higher grain moisture levels. Convenience was another factor in shelling corn in the field rather than from corn cribs. However, the economics of field losses and energy for drying grain at higher moisture levels may have reversed. **Using "natural aeration" or solar drying** for shelled corn **still uses the electrical energy to run fans, which can be saved if corn is harvested in the ear.** However some regional weather conditions may not allow for ear corn harvest.

High Moisture Storage

High moisture storage, although more costly in capital investment, is yet another option to drying. It **has very low energy costs,** but usually limits use of the grain to the farm feeding operation rather than marketing it.

Considerations For New Grain Bins

The Energy Project has been advising farmers, bin contractors and USDA officials of certain considerations that should be made for new bins, with the **option of adding solar drying equipment in the future.** Here are several. 1) The bin should be located such that **no other buildings or trees to the south obstruct the low sun** of fall harvest season. 2) The **fan is** usually best located **directly south** of the bin, for consistent draw of air from east and west sides of the bin. 3) **Entrance doors** and unloading augers are best located **on the north ⅓** of the circumference of the bin to eliminate conflict with a future collector. 4) **Solar systems for drying grain can also be mounted on other buildings,** including machine sheds or shops. Such a system would allow for "multiple use" of the solar unit for heating shop areas or swine houses, in addition to grain drying. Cost effectiveness is therefore enhanced by utilizing the solar unit over a longer period of the year.

Solar drying, although a form of "low-temperature" drying, has the potential of saving propane and electrical energy, commonly used as a heat source in conventional drying. Costs of both fuels are escalating, increasing the cost of grain drying. Solar drying is one answer to the problem.

Other Benefits & Disadvantages

Added Benefits Of Solar Drying

Grain Quality Improved

Earl Fish cites several advantages of solar drying in addition to the energy savings. **"The quality of the dried grain is what interests me in solar drying",** he says. High speed drying often damages corn. Quality grain brings a better price. "A local cattle feeder said he would be willing to pay several cents more per bushel," Fish reports.

Fan Noise Lowered

Another advantage of the solar system, Fish points out, is **the fan housing,** which **lowers fan noise levels considerably.** "I like it for the control of that noise," he reports. "One drier a half mile west of me makes more noise than mine," Fish adds.

Disadvantages of Solar Drying

There are several disadvantages or conditions that a farmer should consider before adapting solar drying.

The use of **solar drying is only effective when the sun shines.** A cloudy wet fall could mean switching back to propane. The solar drying success of Earl Fish was timed with excellent fall sunshine in early October that later turned to wet, cloudy weather, especially in 1977.

Many farms are accustomed to drying several batches of grain a season with high speed drying, whereas **only one batch on the average may be acceptable for solar drying during one season.** The low temperature process of solar drying is essentially a supplement to natural aeration.

Earl Fish notes, **"Fellows who are in a hurry might want to use their propane heat at night, but for me it worked just fine."** He is also quick to point out that **the longer drying time involved is not something a big operator is probably going to stand still for.**

Bin structural variations, as in the Wuebben case, can also cause complications in building a solar collector.

More Solar Dryer Information

References

"Plans for Solar Grain Driers", Agricultural Extension Engineer, So. Dakota State U., Brookings, S.D. 57006, $1. Plans for constructing a solar collector onto an existing round grain bin. These plans are blueprints.

"Solar Grain Drying, Rules of Thumb", Small Farm Energy Project, P.O. Box 736, Hartington, NE 68739. Includes suggestions for air gaps, paint and other construction points. $.50

"Low-Temperature Drying", by William H. Peterson, EMC 660, Ag. Engineering, S.D. State University, Brookings, S.D. 57006. Includes information of fan sizes, "fill depths" for various moisture conditions of grain, and other valuable information on the topic.

"Catalog Sheet of Solar Heated Building Plans", Dept. of Ag. Engineering, U. of Illinois, Urbana, Ill. 61801. The free, 2-page listing describes some 10 plans that are available from the U. of Ill. Costs of the large blue prints are also included. Half of the plans apply to grain drying, using portable collectors, machine sheds, and other buildings as "multi-use" collectors.

"Project Focus #10 - The Young Portable Solar Collector", available from the Energy Project for 50 cents, reports on the 10 X 24 ft. portable air heater used for grain drying and home heating. Construction plans are also available for $2.

"The Return to Ear Corn Harvest", SFEP Newsletter, Sept., 1979, page 5. Floyd L. Herum, Ohio ag. engineer, indicates the reasons why he believes harvesting corn in the ear is in the future. Available for 25 cents from the Energy Project.

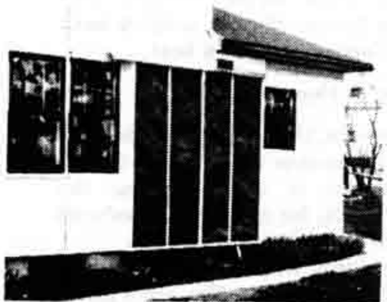
Low Temperature & Solar Grain Drying Handbook, MWPS-22, Ag. Engineering Extension, 101 Ag. Engr. Bldg., U. of Nebr., Lincoln, NE 68583, 1980, $3. This 86-page book includes basic solar information and information on low temperature and solar drying, portable collectors, wrap around collectors, collectors mounted to buildings and charts on static pressures.

PROJECT FOCUS #3

Small Farm Energy Project

The Solar Vertical Wall Collector

July, 1980
[Revised Edition]

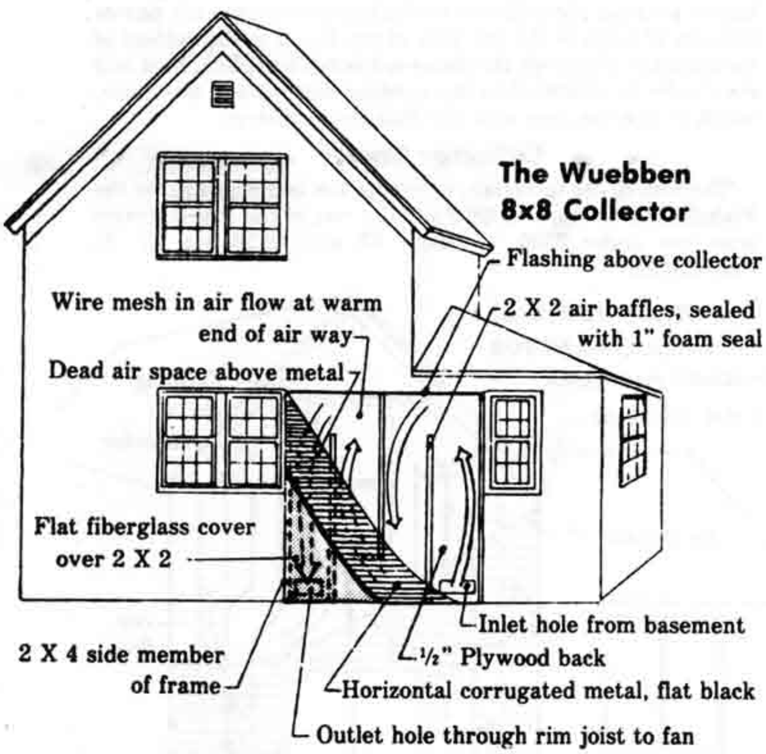


—Edgar Wuebben and his sons built the 8 ft. X 8 ft. vertical wall collector shown above. The collector was constructed in a shop and then mounted to the home. Cost of the collector was about $200. It provided all the heat for the home on sunny winter days.

As one of the more popular energy saving innovations of the Energy Project, the home-built vertical wall solar collector has proven to be a simple, low cost addition to the home. It can be built from locally available materials. Since farmers generally have a variety of construction skills, particularly carpentry talents, this solar system seems very appropriate for the rural home, which usually receives plenty of sunshine. With a minimum of technical assistance and a little imagination, most anyone can design and build the vertical wall solar collector to provide a good portion of home heating needs. In addition, this solar home heating system has a variety of other advantages.

For cooperators of the Energy Project, the solar vertical wall collector has currently provided the greatest energy reduction on the farm, next to that saved by insulation.

The Wuebben 8 X 8 Collector



A Pioneering Effort

The first vertical wall collector built by an Energy Project cooperator was for the home of Edgar and Theodora Wuebben of Wynot. Edgar Wuebben and his sons, Don and Terry, built their 8 ft. x 8 ft. collector in January of 1978. As solar pioneers in the area, they chose the small collector to test its performance, with the possibility of enlarging it in the future. The vertical wall solar collector was originally developed in the San Luis Valley of Colorado by rancher Bill North, and is often referred to as the "North collector". And there are several plans available from Colorado for constructing the collector.

Construction and Air Flow

The Wuebben collector was built in the Energy Project shop and later mounted to the Wuebben home. Some modifications were made to the construction plans to save on materials, and for expected improvements in solar gain. Plywood of ½" thickness was used as the back of the collector. **2 x 2 baffles were nailed to the plywood to provide an air flow pattern in the collector. Corrugated sheet metal was then nailed over the baffles and painted flat black as the collector plate.** Additional wood strips were then nailed over the metal plate to support the fiberglass collector cover. **The air space between the collector plate and fiberglass is a "dead air space" which acts to insulate the collector plate** from outside cool air. **The collector air flow is then beneath the corrugated metal,** absorbing the solar energy as it is available.

Materials used in the collector were **from the local lumber yard and common carpentry tools** were used to build the system.

Operation & Performance

Cold air is drawn into the collector from a duct connected to the existing cold air return ducts in the basement. A canvas damper is used to help control the air at the fan. The heated air is delivered primarily into the living room of the house. The Wuebbens have been very pleased with the collector. **"On a sunny day, the furnace does not run all day,"** Edgar reports. The furnace uses propane. The collector fan is controlled by a manual switch as solar energy is available.

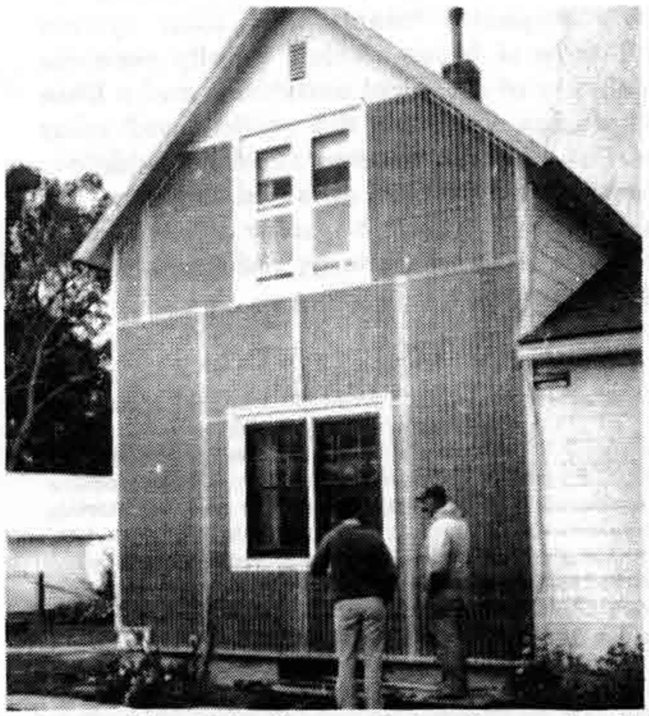
Temperatures of the heated air coming from the collector are dependent on the fan air delivery. For this 8 x 8 ft. solar collector, **a 160 cfm [cubic ft./min.] fan** appears to be the best size, and provides temperatures of between 90 and 100 degrees into the house. A larger fan would provide more air flow, but at lower temperatures that would be uncomfortable. **Desired air flow is about 2.5 cfm per sq. ft. of collector,** although some solar experts suggest a range of from 1 to 4 cfm. The air gap beneath the collector plate is also sized to provide near **1000 ft. per min. of air velocy**. That air velocity provides "turbulent" air flow for good solar collection.

(continued on page 14)

[Wuebben Collector, continued from page 13]

Collector Cost and Paint Problem

The cost of the collector was approximately **$200 for materials**, or just over **$3 per sq. ft. complete with fan and ducting**, and represents **a very low cost collector**. One problem has been encountered with the collector. The black paint on the galvanized metal has begun to peel from the metal. However, improved techniques for proper preparation of the metal before painting flat black have been established by the Energy Project. A solvent should be used to remove factory oils, and the metal should also be primed before painting black. The best alternative is the use of baked enamel steel, which can simply be buffed with sandpaper and then painted. If spray equipment is available, spray painting offers an even better bond due to the thin, consistent coating.



—Edgar Wuebben, right, discusses his home's second vertical wall collector with a farm visitor. The 200 sq. ft. collector, constructed in 1979, replaces a smaller 64 sq. ft. collector used for two previous winters. Wuebben was so pleased with the smaller collector that he decided to build the larger unit, at a cost of about $700.

— The vertical wall collector used at the Ken & Jan Stark home. It covers 220 sq. ft. and is used to provide solar heat to the home.

Larger Stark & Pinkelman Collectors

Bigger Steps to Solar Use

After seeing how well the Wuebben collector performed, Ken and Jan Stark and Rick and Mary Pinkelman, all cooperators of the Energy Project, chose to build larger vertical wall collectors onto their homes. The homes of both couples have large southern exposures for collecting the sun's heat.

Built Directly Onto the House

With larger vertical wall collectors, the systems can be built directly onto the house, which was the case with the Starks and Pinkelmans. Although construction is dependent on the weather conditions, **the cost** per sq. ft. for materials **is reduced somewhat** compared to the small Wuebben collector.

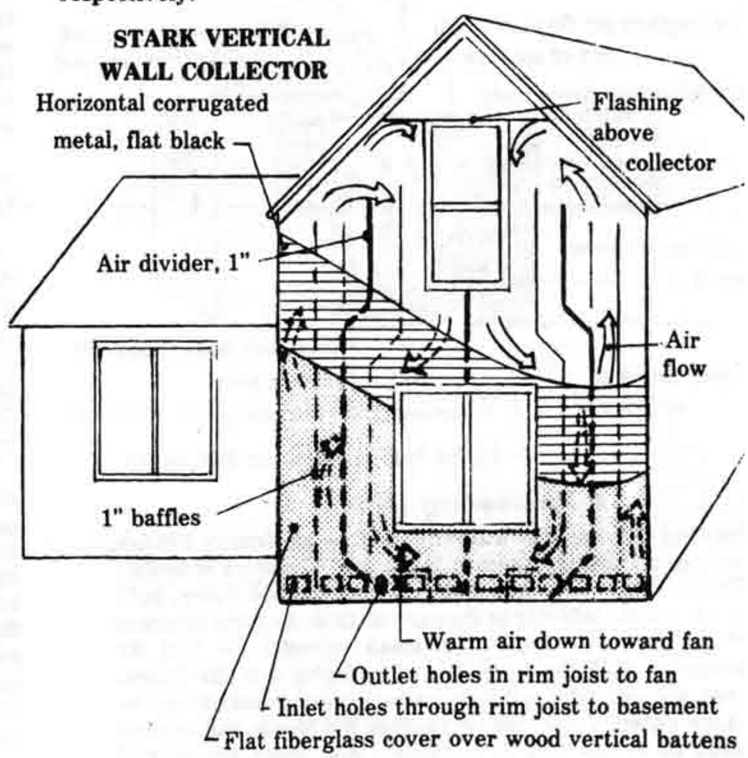
With the Stark collector, the siding was first covered with press plate over the 220 sq. ft. of the collector. The press plate, which was also painted black, is not a major requirement and was not used on the Pinkelman's 290 sq. ft. collector. It was used on the Stark collector since much of the air flow moved across and perpendicular to the siding.

The air gaps were smaller in both collectors compared to the Wuebben system. In the Pinkelman collector, **1 x 2 lumber was used both above and beneath the collector plate.** Used lumber from an old corn crib was used by the Starks for baffles. The Stark collector uses a fan located in the basement to bring solar heated air from the collector to the basement area. Air passes through 12 holes in the rim joist of the house at the bottom of the collector. Although the ductwork is not complete, heat will eventually be delivered to the existing ductwork of the home, which is now the case with the Pinkelman system.

Collector Costs

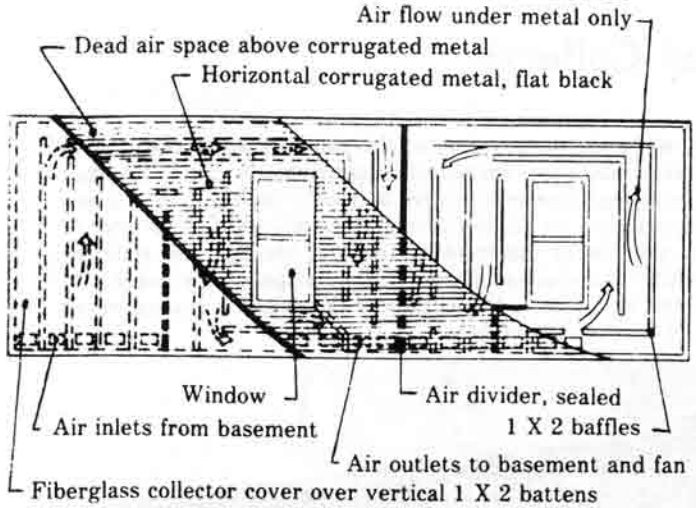
The cost of the materials, including fan and ducting, for the Pinkelman collector was $890 and the cost of the Stark system was just under $500, or about **$3 and $2.30 per sq. ft. respectively.**

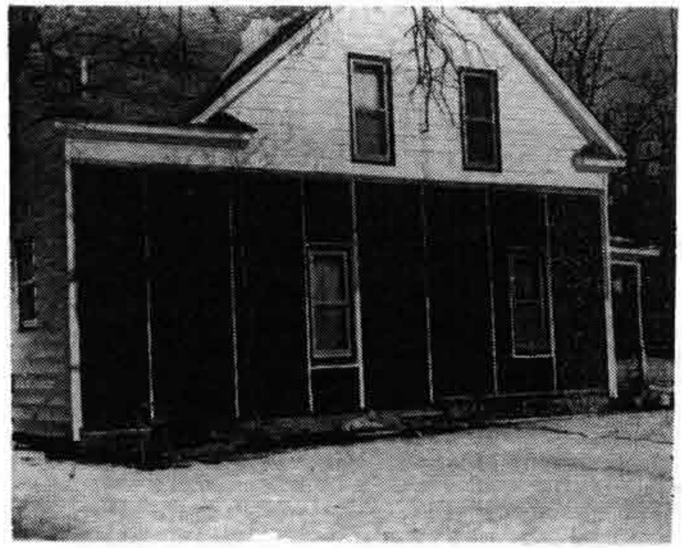
STARK VERTICAL WALL COLLECTOR



[Large Collectors, continued from page 14]

PINKELMAN VERTICAL WALL COLLECTOR





—**The vertical wall collector on the home of Rick and Mary Pinkelman. The 290 sq. ft. collector is home built with conventional construction materials. Heat from the collector is collected in the basement by a squirrel cage fan, which delivers heat to the furnace ductwork.**

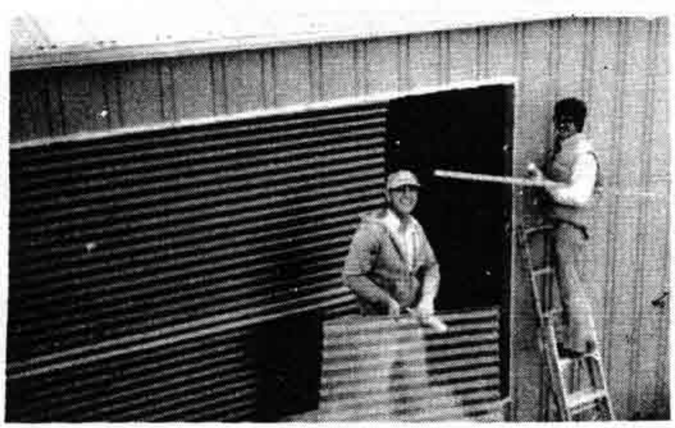
Advantages of Vertical Wall Collectors

Low Cost Collector

The ideal solar collector would be what is called a passive collector. That is a collector which requires no continuous inputs of nonrenewable energy for the operation of motors or pumps. These types of collectors are usually the easiest to design into houses under construction. The attached solar greenhouse is an exception. However, when retrofitting an already existing home, the **vertical wall solar collector as constructed by Project cooperators is about as inexpensive per square foot as other designs,** while at the same time having several other important advantages.

A Variety of Other Advantages

This collector is a very adaptable design that can be added to most homes that have a south wall exposed to the sun. The **use of an existing wall** reduces the collector's construction cost, insulation and structural materials, and therefore labor and



—**The vertical wall collector can also be added to steel farm buildings and other structures. Gary Young, left, is assisted by Rob Aiken in mounting a solar vertical wall collector onto his metal dairy barn. The solar system heats the milk parlor and milk room during the winter.**

the design and construction of the collector is relatively simple and doesn't require any high technology or specialized labor. **This means that with a minimum of technical assistance, a person can design and build a solar collector to meet his or her needs.** The farmer can obtain all **materials at the local lumberyard** and they are materials that he is familiar with. The vertical wall solar collector is at its best angle when the sun is lowest in the sky and this is when the weather is usually the coldest. Any **snow** in front of the collector **improves performance** by reflecting additional solar energy onto the vertical collector. As the sun rises in the sky more of the sunlight is reflected until **during the summer months most of the sunlight is reflected, preventing the collector from overheating.**

The vertical wall collector requires very little maintenance and by being on a wall it is easily accessible to recaulk and to repaint. It is also easier to keep water tight than a collector on a roof.

Some Disadvantages of the Collector

There are a few disadvantages and difficulties with the vertical wall collector. All of the cooperators with vertical wall collectors, except Paul & Wilam Phelps, had **trees** located south of their house that **shaded part of the house in the winter months.** Although they disliked the idea of removing or trimming trees, they decided to do so to make way for optimum solar collection. Experience has shown that **shading of collectors can cut solar output considerably.**

The home-built vertical collector **may not have the efficient performance of commercial collectors** made with factory quality control measures, but the cost is lower, making it more attractive. **The objective** of the Energy Project has been to provide cooperators with collectors which **provide the best Btu output per dollar invested in hardware,** and the "North" vertical wall collector seems to fill the goal.

Cooperators have noted some **damper problems** with the solar systems. When furnace ducts are used, a good damper is required to close well, in order that furnace heated air is not moved through the collector at night. **It is highly recommended that collector air flow be kept separate from furnace ducts,**where possible, to avoid air leakage difficulties.

The Phelps Wall Collector

Different Design Gives Improved Efficiency

The Paul and Wilma Phelps ranch-style home is only several years old, compared to the older homes of other Energy Project cooperators. Designed by Wilma Phelps, the home incorporates 170 sq. ft. of thermopane glass on the lower level which serves as a **passive solar collector** during sunny days. The Phelps decided to add the **active vertical wall collector** to the house in the fall of 1978, **to help lower energy costs of their electric baseboard heating.**

The Phelps collector uses a "straight run" air flow in its 4 ft. x 30 ft. configuration. **Such a design is the simplest to construct, and, according** to monitoring results, **seems to perform better than the other collectors** that use more complicated air flows around windows. Paul Phelps also provided an improvement to the design of the Energy Project staff. He decided to use a **wall stud space** at either end of the collector **as a "manifold" for channelling the air** to the collector and for drawing the heated air from the collector "airways". Such use of wall stud spaces is limited to certain size collectors. As the size of a collector increases, it requires larger ducts for moving the air than a space between wall studs.

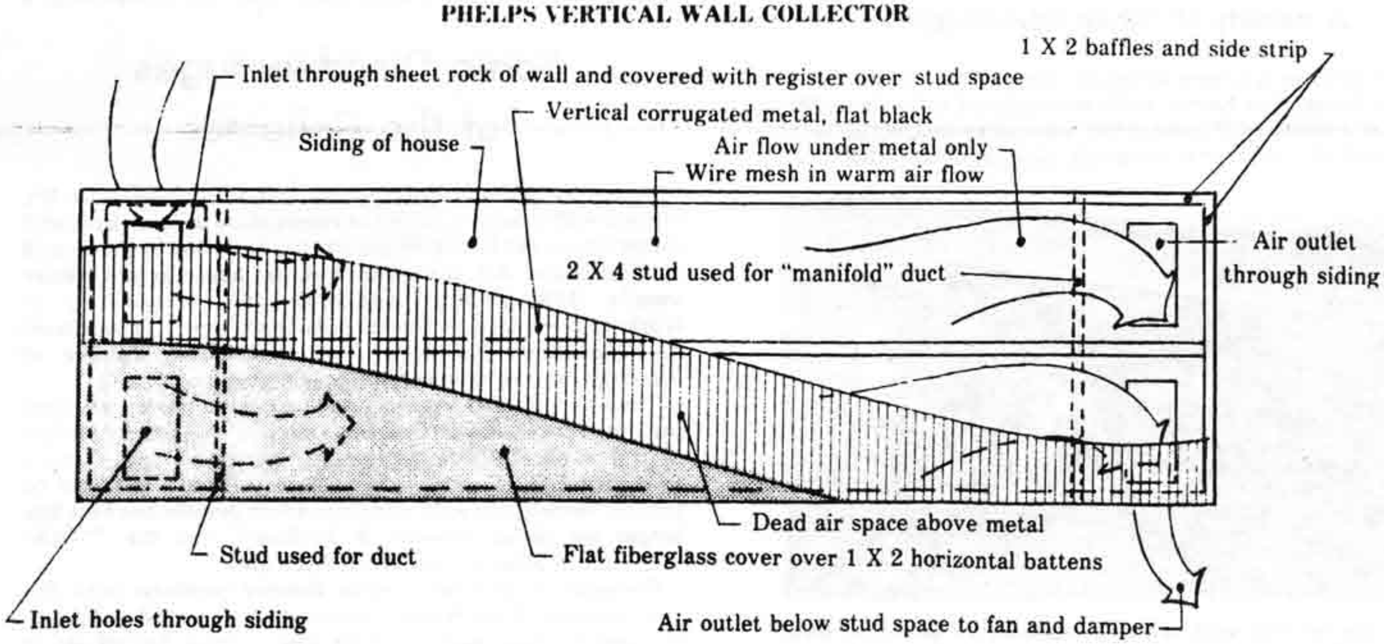
Paul Phelps built the collector with occasional help from his brother and wife, Wilma, over several weeks, as time was available during other farm work activities, and as weather permitted. Phelps figures the labor requirement totalled 43 man hours.

Fan & Controls

A 350 cfm squirrel cage fan is used in the Phelps collector. It is regulated by a **remote bulb thermostat,** adjusted to starting the fan at 70 degrees and to turn the fan off at the end of the day when the temperature of the collector air is down to 65 degrees. Since the thermostat is adjustable, it can be modified to start up later in the day, or sooner at night, if warmer temperatures are desired. Dampers were used at either end of the collector to eliminate air moving through the collector at night by convection. However, the dampers have leaked cold air and as a result, Paul Phelps has devised a manual cover which he closes at night.

— The vertical wall solar collector on the Paul and Wilma Phelps home is shown on the upper floor. It is 4 ft. x 30 ft. in size and uses a "straight run" air flow pattern which has proved to be the most effective design of collectors used by Energy Project cooperators.

PHELPS VERTICAL WALL COLLECTOR



Collector Monitoring

Paul Phelps tends to be skeptical by nature. When he decided to build a solar collector, he wanted to find out just what the collector would produce. So Paul helped develop a procedure used to test solar collectors in the Project.

Every sunny noon Phelps takes readings on the collector when he comes in for lunch. The various things he records include the time of day, wind direction and velocity, intensity of solar energy, outside air temperature, and the temperature of air going into and coming out of the collector. The collector air velocity is an important factor in the heat exchange equation. It was measured with an air velocity meter. Phelps also wired a clock into the electrical circuit of the collector so that the clock records the amount of time the fan operates.

COLLECTOR OUTPUT

To illustrate how Phelps' collector was evaluated, readings taken on January 29, 1979, can be analyzed. It was cold and calm at noon. The thermometer showed -3 degrees F, and the solar radiometer indicated that 240 Btu of solar energy were reaching each square foot of the collector in an hour. So the total energy available to the collector in an hour was 240 Btu/sq. ft-hour X 120 sq. ft. = 28,800 Btu/hour. The difference in temperature between air entering and leaving the collector was 40 degrees F. and air was flowing at a rate of 275 cubic feet per minute (cfm). Taking into account the amount of energy necessary to raise one cubic foot of air one degree Fahrenheit .018 Btu/cu ft./degree F., the energy contributed to the house was 275 cfm X 40 degrees F. X .018 Btu/cu ft./degree F. X 60 min/hour = 11,900 Btu/hour.

The effectiveness of the solar collector can be evaluated by comparing the amount of available energy to what was actually delivered to the house:

$$\frac{\text{energy delivered} = 11{,}900 \text{ Btu/hour}}{\text{energy available} = 28{,}800 \text{ Btu/hour}} = \textbf{41\% efficiency}$$

In an hour, the 350 cfm fan pulling air through the system would draw approximately 200 watts or 700 Btu.

According to a summary of solar radiation records from 1952 to 1970 in the north-central U.S. there is a 80% probability that solar radiation will average at least 590 Btu/sq. ft. each day from October 4 to April 4 in Cedar County, Nebraska. There is 50% probability that in a given year, solar energy may average as much as 1200 Btu/sq. ft. This suggests that if Paul Phelps' collector continues to work as it did January 29, 1979, **in most years it would supply at least 5,200,000 Btu** (equivalent to 1530 kwh) and chances are 50-50 it would contribute as much as 10,700,000 Btu (3150 kwh).

System Costs & Energy Savings

The actual costs of construction are itemized below along with projected costs if Phelps had to purchase lumber rather than using available material. It is reasonable to wonder **how soon the savings on fuel bills would cover the cost of the collector.** The answer to this question is clouded by several variables including the future price of energy and the amount of solar energy available. Rather than make a guess of what the future will bring, two figures have been prepared which take price and solar availability as variables so that one can make his own estimate of future savings.

A range of prices for electricity and fuel oil (60% furnace efficiency is assumed) are presented on the bottom of figures below. Projected annual savings are listed on the left side of each figure. The shaded area in the figures represent conservative (80% probability) and moderate (50% probability) projections of winter solar availability (from October 4 to April 4). For readers wishing to make use of the figures, choose the future price of energy you think is realistic. Then, from the shaded area above your price choice, follow the lines across to find probable annual savings. You may consider the lower number as minimum annual savings and the higher number as average annual savings.

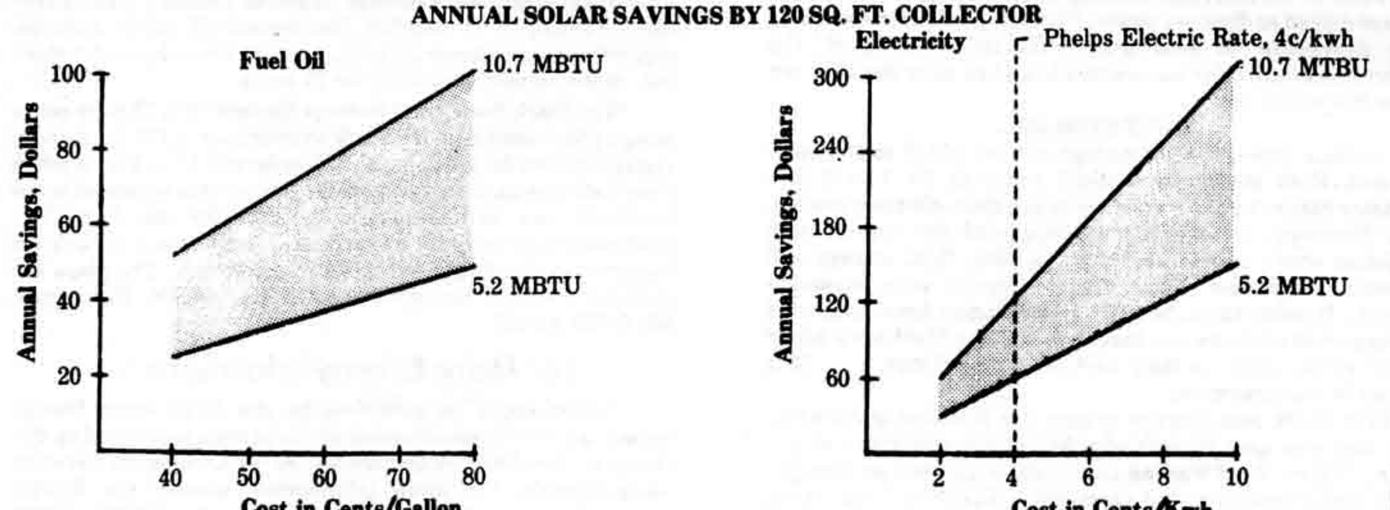
The electrical rate for the Phelps home is about 4 cents/kwh, but **it is estimated that the Phelps system should pay for itself in less than five years.**

Materials cost for 120 sq. ft. solar collector:

	Phelps Cost	New Materials
Collector plate	$49.00	$55.00
Filon fiberglass glazing	72.96	75.00
Paint & sealant	54.91	55.00
Fan & shutters, Grainger	54.78	55.00
Remote bulb thermostat Honeywell T675A 1540	36.88	40.00
Lumber	salvage	35.00
Total cost	**$269.33**	**$315.00**
Cost/sq. ft	**$2.24**	**$2.62**

At the Phelps' electric rate of 4 cents/ kwh the collector should save between $60 and $120 per year.

ANNUAL SOLAR SAVINGS BY 120 SQ. FT. COLLECTOR



Additional Qualifications & Variations

PRELIMINARY CONSIDERATIONS

Insulation and weatherization of the home is the first prerequisite to collector installation. It is by far more cost effective than installing the solar collector. Ken Stark upgraded the insulation in his home before using the solar system. Wood cellulose insulation was added to all home walls and additional insulation was added to ceilings. Last winter before use of the solar collector, fuel use was cut substantially by **insulation. "It cut our propane use in half"**, Stark reports. "You can tell the difference," Stark adds, in describing the warmer home of the past several winters, despite the fact that the winters were about the coldest on record.

Some people are concerned about the attractiveness of the collector on their home. However, collectors in Cedar Co. have indicated that they can be very attractive when carefully constructed. Flat fiberglass, however, tends to lose tension when it warms up, giving a wavey look; corrugated fiberglass can be used for continuous rigidity.

CONSTRUCTION CONSIDERATIONS

For a vertical wall collector to be effective, it **must be carefully built,** particularly to avoid air leaks into the collector. Liberal amounts of quality caulk are required for sealing the system. Basic carpentry skills are required for constructing the collector. Each collector design is **"Site specific"** and calls for the imagination of the builder. **Paint is a critical part of the collector, and requires precise preparation** to give long life to the paint bond. More details on the painting process are given in the "Rules of Thumb" available from the Energy Project. If, in the future, the demand for flat black collector plate material is high, then it is probable that a quality factory baked black metal will be available for the do-it-youself solar project.

The maximum length of run for the airway of a collector should be 32 ft. That is, the length of the path of the air moving through the collector should not exceed 32 ft. from inlet to outlet of the collector. The collector can be vented in the summer months to keep the system cool, although the vertical wall system is not directly exposed to the summer sun. Venting can be accomplished by small holes at the top and bottom of the collector.

COST FACTORS

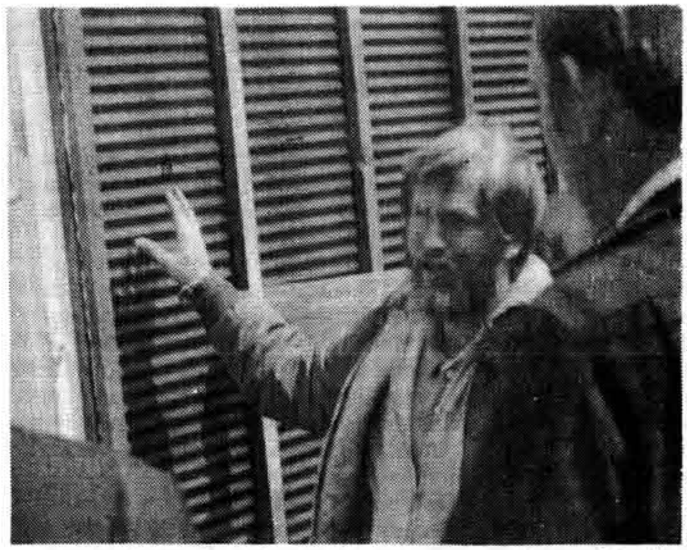
The **energy savings of the vertical wall collector through a season will depend on the local climate.** Some regions receive more sunlight during winter months than other areas. In addition, **fuel costs vary** depending on the region, and the type of fuel being replaced by solar energy will also have different prices, giving different savings in dollars.

Some of the materials used by Energy Project cooperators were acquired at discount prices. Therefore **collector costs may vary depending on local prices.** On the other hand, the application of **the solar tax credit allowed on solar systems can lower the actual cost.**

HEAT STORAGE

Various types of heat storage can be added to the solar systems. Rock storage of washed gravel in the 1 to 2 inch diameter range is often suggested as the most effective and low cost. However, storage is only suggested for vertical wall collectors above about the 250 sq. ft. size. **Heat storage will ususally double the cost,** since it requires more elaborate controls. In some cases, however, crawl spaces have been used to store some of the excess heat. Ken and Jan Stark have added a rock storage unit to their vertical wall collector. It is located in the basement.

(The Stark heat storage system was installed in January, 1980, and was used successfully during the remainder of the winter. 150 cu. ft. of washed river rock were used as storage. Additional information and plans are available in "The Stark Solar Heat Storage System", available for $1.)



—Ken Stark explains the construction materials used in the vertical wall collector to farm visitors. The photo shows the flat black collector plate before fiberglass was mounted over the vertical 1" wood strips shown. A dead air space exists between the collector plate and the fiberglass cover, with air flow behind the collector plate.

More Information

Various plans are available for building the solar vertical wall collector. In addition, the Energy Project has published a "Rules of Thumb" on construction tips. Proper air gap in the collector, for example, is important to optimum collector performances, but varies in size with different collectors.

References

"Building a Vertical Forced-air Solar Collector", San Luis Valley Solar Energy Assn., P.O. Box 1284, Alamosa, CO 81101, $1. Describes several variations of collectors and dimensions. Includes sketches and rules of thumb of collector and fan sizing. Quite helpful.

"Solar Forced Air Heating System Plans", Domestic Technology Institute, 12520 W. Cedar Dr., Lakewood, CO 80215, $7.50. Includes five 18" x 24" blueprints with information on construction details, collector controls, electrical circuits, operation, and maintenance. Also provides information on constructing a rock heat storage unit for the collector system.

"Construction Manual: Solar Can-type Hot Air Furnace", by Bruce Hilde, Northern Solar Power Co., 311 So. Elm St., Moorhead,MN 56560, $2. Describes the use of empty beverage containers for the vertical wall collector surface. Includes excellent detail in plans and material listings.

"Vertical Wall Solar Collector, Rules of Thumb", Small Farm Energy Project, P.O. Box 736, Hartington, NE 68739. Includes suggestions for collector air gaps, painting procedures, fan sizes and other details, available for 75 cents.

"The Stark Solar Heat Storage System" is a 12-page set of design plans used by Ken Stark to construct a 150 cu. ft. heat storage system for his vertical wall collector. 1" to 1½" washed river rock was used for the storage. The system is located in the basement and has automatic controls for air flow. The publication also includes material list and various options for constructing the frame for the storage system. The plans are available from the Energy Project, P.O. Box 736, Hartington, NE 68739, for $1.

For More Energy Information

"Project Focus" is published by the Small Farm Energy Project, a research and demonstration project sponsored by the Center for Rural Affairs and funded by the Community Services Administration. For more information, contact the Energy Project, P.O. Box 736, Hartington, Nebraska 68739, phone 402-254-6893.

PROJECT FOCUS #4

Small Farm Energy Project

The Fish Solar Greenhouse

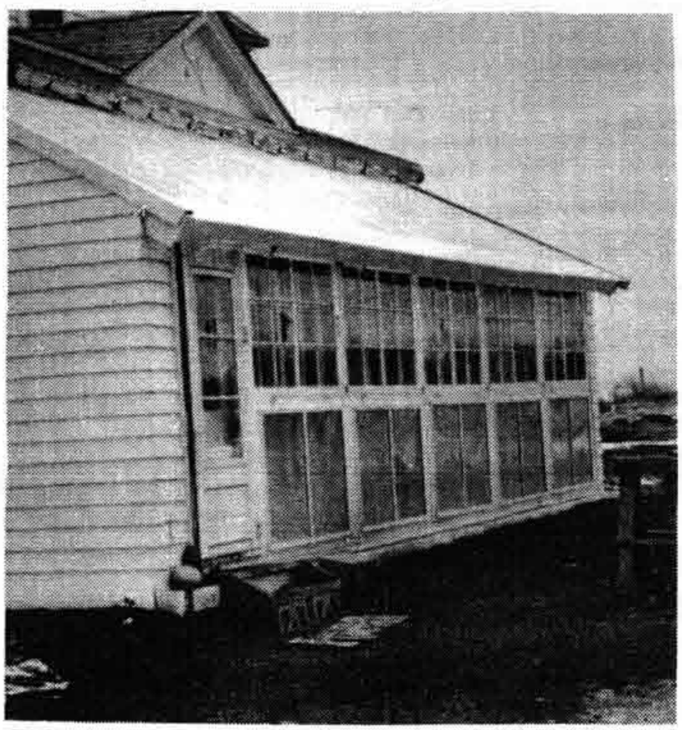
MAY, 1979

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is help small farmers discover and develop viable alternatives for their own farms.

Many visitors to the Earl and Dolores Fish farm of Belden, Nebr., during early 1979 have been attracted to the family's solar greenhouse filled with beautiful green plants. The greenhouse provided a refreshing break from the past winter of record breaking cold temperature. The solar and wood heated greenhouse is attached to the south side of the Fish home providing extra heat and humidity to the home. A major savings in propane heating costs has also been realized. In addition, solar greenhouses can provide fresh vegetables for the family. A well constructed and energy conserving greenhouse, as the Fish family realizes, can provide many benefits.

Fish Family Expands on Use of Solar

The Earl and Dolores Fish family of rural Belden have enjoyed the first winter with their attached **12 ft. x 28 ft. solar greenhouse.** Filled with green plants, the added solar room provides **a comfortable addition to the home.** Earl and Dolores became interested in developing the greenhouse concept after attending a workshop sponsored by the Energy Project on the topic. In addition, the porch which was replaced by the greenhouse needed considerable repair, and the solar room provided an extra bonus to the rehabilitation. Dolores, whose mother operates a commercial greenhouse in Wayne, Nebr., was well acquainted with the care of a greenhouse.



Solar Energy was not new to the Fish family, either. Prior to the greenhouse venture a solar grain dryer was added to a 6000 bu. bin on the farm. The system, installed in the summer of 1977, has provided excellent results in drying corn for two harvest seasons. The Fish farm is a diversified hog/dairy/beef operation on 380 acres. Two of four children, Bonnie and Bryan, are still at home taking in the solar experiences.

—Dolores Fish enjoys the pleasant surroundings of her greenhouse while a visitor inspects the green plants. The greenhouse has provided extra heat and humidity to the home the past winter. An exhaust fan for summer ventilation is shown in the upper center of the photo.

—The southwest view of the solar greenhouse used by the Earl and Dolores Fish family of Belden, Nebr. The 12 x 28 ft. greenhouse provides a home for a variety of plants and vegetables. Extra solar heat is provided to the living area of the home during sunny days. A wood stove is also used in the greenhouse.

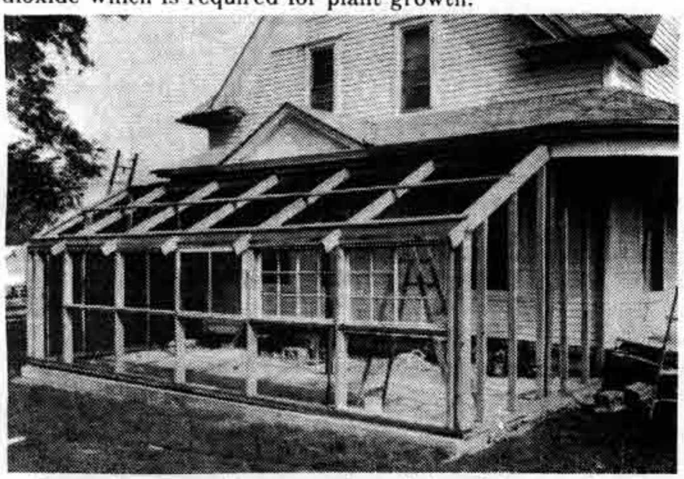
The Greenhouse Design

The Attached Greenhouse

Solar greenhouses are usually categorized into two different types. The "free standing" structure is a building separate from other structures. It lends itself well to commercial greenhousing. The "attached greenhouse" is suitable as an addition to the south side of a house.

There are numerous advantages to the **attached greenhouse.** Because the greenhouse is attached to the home, **lower construction costs can be realized,** and there is the opportunity of **heat exchange between the greenhouse and the home.** The attached unit also serves as an enclosed porch to enhance a family's lifestyle.

As an addition to the home, the attached greenhouse makes use of the south home wall as part of the structure, reducing material cost. There is also reduced heat loss by the greenhouse with the home on the north. The home can also realize a lower heat loss by the protection of the greenhouse on the south. With the home heating system nearby, back-up heating equipment can often be less costly than in the free standing unit, since the home's heating system is shared between the two structures. Plants and humans have a symbiotic relationship; with the attached greenhouse plants give off oxygen for human use, while humans give off carbon dioxide which is required for plant growth.



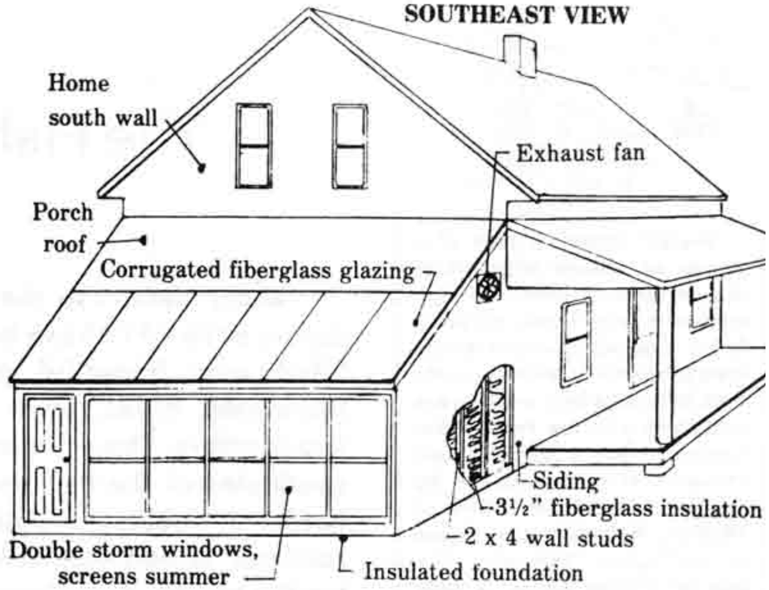
—An early stage of construction of the Fish greenhouse is shown above. The greenhouse is attached to the home as an extension of the existing porch, which required repair.

Energy Conserving Construction

The solar greenhouse requires special care during construction. A well insulated and air tight structure will minimize heating fuel requirements and maintain constant temperature. It therefore will make best use of solar gain. Only the south wall and a portion of the roof are translucent to receive solar energy for the solar reliant greenhouse. East and west walls are insulated.

In the Fish greenhouse, the east and west walls of the greenhouse are fully insulated with 3½" of fiberglass batt insulation. A black "fiberboard" sheeting ½" thick, was placed under the exterior siding. The inside of the insulation was covered by a vapor barrier and additional sheeting. Cedar shingles cover the interior of the side walls as well as the north wall. This choice of shingles gives a warm, attractive look to the interior of the Fish greenhouse, while also lowering the amount of glare from sunlight during the day. For optimum plant growth, however, white walls are preferable to darker ones, in order to reflect more light onto plants, especially for a greenhouse well stocked. Plants in the shade of other plants can receive sunlight indirectly by the reflection of the white walls.

THE FISH SOLAR GREENHOUSE SOUTHEAST VIEW



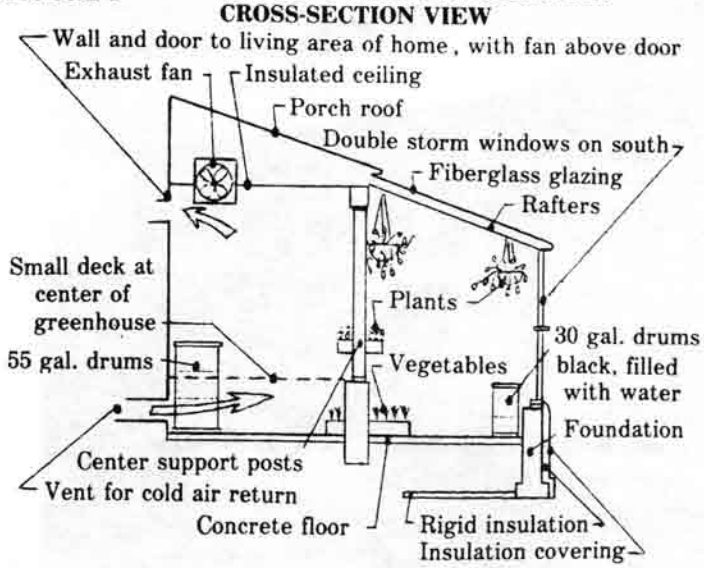
Insulation around the foundation is important to lowering the flow of heat to the cold soil during the winter. (see fig. 1) Earl Fish was only able to install part of the insulation. Proper rigid board insulation was not available at the time of placement of the concrete, which was also hampered by a cement shortage. Water-resistant rigid insulation should be used.

The south wall of the greenhouse has double windows. The south half of the roof is glazed with corrugated greenhouse fiberglass. An additional glazing material would also help to conserve energy. **Insulated shutters** had been considered earlier for the roof glazing, but Earl found it difficult to develop a convenient method of installing, removing and storing the shutters, which were to be made of rigid insulation board. Such insulated shutters should have a fire retardent quality.

The ceiling of the greenhouse, which was also the ceiling of the previous porch, is also insulated. The opaque ceiling contributes to shading in the summer to keep it cooler.

Considerable **caulking and weatherstripping** were also used to limit air infiltration into the greenhouse.

FIGURE 1 THE FISH SOLAR GREENHOUSE CROSS-SECTION VIEW



—Earl Fish points out the used storm windows used for the south glazing of the greenhouse. The lower windows were made from screen frames and flat fiberglass.

Materials and Cost

Since the attached greenhouse requires only the insulated east and west walls, and the glazed portion on the south and part of the roof, it has a lower construction cost than the free standing greenhouse.

To save further dollars in construction, Earl Fish made use of a number of **recycled materials.** Old storm windows, no longer used, were installed in the south wall of the greenhouse. Earl did not have enough windows for a double layer over the entire wall, so he made some additional windows by installing flat fiberglass in old window screen frames. Old lumber from around the farm also provided material for the structure.

Corrugated greenhouse fiberglass is used in the south roof of the structure. "Tedlar" coated fiberglass is recommended for long life.

A concrete floor was poured for the greenhouse; this required a slight slope and outlet to the west for drainage of water. Lower cost, recycled brick, gravel, or wood chips have also been used in other types of greenhouses for the floor. Two fans, and a thermostat control air flow and temperatures of the solar room.

The cost of the Fish greenhouse and materials is listed in Table 1. **The cost of the greenhouse will vary with its size and also with individual preferences for finishing materials.** Greenhouses can be larger or smaller than the Fish unit. The Federation of Southern Cooperatives in Alabama, for example, has promoted small greenhouses costing $300 or about $3 per sq. ft. of floor area.

TABLE 1

Material and Cost List

Exhaust Fan With Shutter, 1625 cfm, Dayton #2C708	$ 70
Squirrel Cage Fan, 525 cfm, Dayton #2C906	40
Thermostat, Dayton #2E206	20
Filon Corrugated Fiberglass	205
Cedar Shingles (optional)	260
Insulation	165
Concrete	220
Lumber, paint & misc. hardware	1420
TOTAL COST	**$2400**

Heat Gain

There are two forms of solar heat available to the interior of the Fish greenhouse. First, **solar energy** combined with "thermal mass" of barrels of water provides heat during the day, and also at night. Secondly a **wood stove** keeps house plants thriving the coldest winter nights.

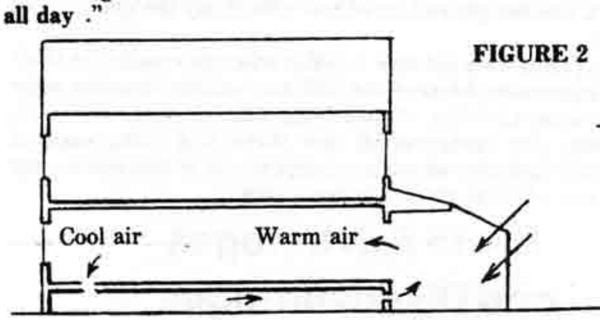
The sun's energy enters the greenhouse through the glass windows of the south wall and half of the roof glazed with fiberglass. The heat is trapped within the structure. "Mass" within the greenhouse, including the concrete floor and black barrels of water stored along the south and north wall, provide **storage for some of the day's excess heat.** The heat then is released at night.

A pot-bellied stove serves as a back-up heat source for the greenhouse. Earl Fish reports using two dead trees the past winter to fire the stove. Both solar and wood heat provide heat to the living area of the home.

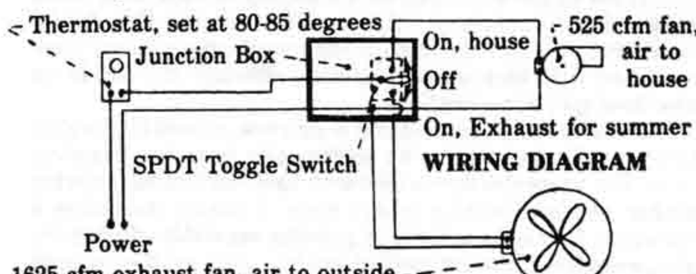
Air Circulation

There are two purposes of air circulation for the Fish greenhouse. During the winter, warm air is provided to the home; during the summer, warm air is removed from the greenhouse to the outside to cool the structure.

In the Fish system, a squirrel cage **fan is used to move warm air from the greenhouse to the home during winter,** when the solar room reaches 85 degrees. It is regulated by a thermostat and is located over the door between the greenhouse and the home. At its height, warmest air is circulated by the fan. The cold air return to the greenhouse is through the crawl space from the kitchen area on the north side of the house. (see fig. 2) As a result the crawl space also tends to act as heat storage during periods of excess heat. It has also been noted that just opening the door to the home offers venting of the greenhouse heat to the living area without the fan. This makes use of convection currents. The Fish family has been pleased with the extra heat provided to the home. Says Earl, **"Even on the coldest days the heat from the greenhouse circulating in the other rooms kept the furnace from kicking on all day ."**



For the summer months, "passive" roof **vents that release warm air** by convection can be used. Wind turbines have also been used. However, in the Fish greenhouse, a ventilation fan is provided and is regulated by the thermostat, although screens will be installed in place of the windows on the south during the warmest season of the year. The ventilation fan will be particularly helpful during the fall and spring when the south windows are required for frost protection but when additional heat may not be needed in the home.



Greenhouse Living

Since Earl completed the greenhouse, the family has received considerable **pleasure from the addition to the house.** The Fish's daughter, Bonnie, does all her studies there and her mother often goes to the greenhouse just to sit during the day. Dolores says its a real treat to see all the greenery in the middle of winter. It must be like a bit of the tropics moved up to an ice box.

Dolores received many houseplants from her mother, who operates a commercial greenhouse, and they all thrived during one of the harshest winters to date. This fall, the Fish family hopes to grow more vegetables in the greenhouse. Fresh tomatoes are to be Earl's Christmas presents for neighbors and friends.

Like other farmhouses with attached greenhouses (see SFEP News, 9/78) the wood stove is an important source of heat. This is especially true because of Earl's reluctance to insulate the windows at night and on cloudy days. On clear, cold January days, the greenhouse becomes warm enough that the fan blows warm (90°F) air into the house, reducing furnace operation. During the evening and on cloudy days Earl stokes the stove, keeping the greenhouse warm and contributing to house heat. Because the higher humidity levels in the greenhouse (30% to 40% this winter) contributed to house humidity, comfort in both areas was improved. The exhaust fan should vent excess humidity in the summer.

Energy Savings

Because both solar and wood energy contribute to heating the greenhouse, it was not possible to analyze the effectiveness of the structure as a passive design, although the **Fish family realized considerable fuel savings.** For those who are interested, a simple test of greenhouse design is to place a thermometer which records maximum and minimum temperatures in the greenhouse and another outside. By comparing the temperature swings for the greenhouse with the outdoors, one can get an idea of how effectively the greenhouse operates.

The Fish's were not able to claim solar tax credits for their energy innovation because the IRS has excluded passive solar systems from their list of qualifying solar devices. However, the ruling was controversial and there was Congressional support for inclusion of passive systems, so greenhouses may qualify for solar tax credits in the future.

Some Advantages and Disadvantages of Solar Greenhouses

Some cooperators of the Energy Project turned thumbs down to the idea of a greenhouse for the winter months. After working all summer in the garden, they were tired of working with plants. That's a respected personal preference. Special care is required in the greenhouse for such difficulties as pest control and for proper lighting, watering and temperatures.

Trees to the south can be a difficulty to cope with when considering a greenhouse addition. However, the Fish family has a large tree directly south of the greenhouse and they have not found it to be a serious problem, although the deciduous tree does give some shading.

The simplicity of the retrofit solar room as used by the Fish family is an advantage to its construction over free standing units. The home also is provided with **heat and humidity during winter months,** lowering energy costs. A family can realize a savings in food costs as well, by **growing vegetables during** the winter months. Growing small plants for resale can also be used for supplementing the family income.

Options for the Greenhouse

The solar greenhouse may have a secondary use of food drying during hot summer months when garden crops are predominant. In Alabama, there has been an interest in converting the greenhouse to a wood kiln to dry wood during the summer. Solar distillation of "hard" water may be another possibility.

Greenhouses may have other options for the farm. For commercial greenhouses, some researchers have suggested that locating greenhouses near livestock buildings can take full advantage of carbon dioxide, moisture and heat exhausted from the livestock housing by ventilation fans. Greenhouses may also be combined with alcohol and methane production systems in the future.

More Information

References

"Solar Reliant Greenhouse Plans," Solstice Publications, 12520 W. Cedar Dr., Lakewood CO 80215, $7.50 plus $1.00 shipping and handling. Detailed plans are included in several pages of blueprints for construction of free-standing and attached greenhouses.

The Food and Heat Producing Solar Greenhouse by R. Fisher and Bill Yanda from John Muir Publications, P.O. Box 613, Santa Fe, NM 87501 for $6.50. A do-it-yourself book, the 160 pages discuss design, construction and performance of various types of greenhouses, including that of 30 innovators. Well illustrated.

The Solar Greenhouse Book edited by James C. McCullagh from Rodale Press, 33 E. Minor St., Emmaus, PA 18049; $8.95 paperback and $10.95 hardcover, 134 pages. Describes design, construction and crop production in low-cost, low-energy units and includes technical and design information for freestanding, attached, and pit greenhouses. Many photographs and illustrations are included.

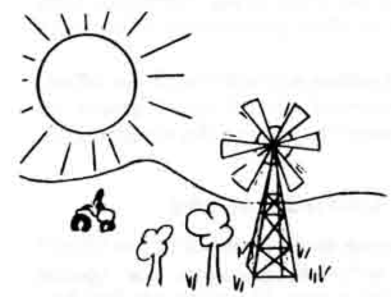
"Solar Greenhouse Annotated Bibliography and Plans List", National Solar Information Center, Box 1607, Rockville, MD 20850, 1977, free. A comprehensive list, including addresses for 11 useful plans.

"Noti Solar Greenhouse: Performance & Analysis", by Hoff, Jenkins & VanDuyn, Center for Environmental Research, School of Architecture, U. of Oregon, Eugene, OR 97403, 1977, 32 pages. A presentation of the design of a greenhouse using the sun as the only heat source for one winter. Uses earthen berm and rock thermal storage. Well illustrated.

Greenhouse Plans, David Kruschke, Route 2, Box 34-A, Wild Rose, WI 54984, $5. Plans for a "live-in" greenhouse or an add-on solar greenhouse. Includes reports on the use of the greenhouse in cold Wisconsin winters.

The Survival Greenhouse by J.B. DeKorne, The Walden Foundation, P.O. Box 5, El Rito, NM 87530, $7.50. Construction and operation details of a pit greenhouse used in southern climates.

The Federation of Southern Cooperatives, P.O. Box 95, Epes, AL 35460, phone 205-652-6976. Two 1979 publications on attached greenhouses are available, each for $3. **Greenhouse Operations Manual** is a 60-page horticultural guide on how to make the solar greenhouse function well. **Pop-Out Front Solar Greenhouse** is a 35-page, detailed construction manual, including material sources and costs. Developed in Alabama, the manuals are oriented for the warmer, southeastern part of the country.



PROJECT FOCUS #5

Small Farm Energy Project

The Solar Food Dryer & Window Box Collector

July, 1979

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

The solar food dryer and solar window box collector are practical items demonstrating the principles of solar energy use. Either of these solar innovations can be constructed during a single-day workshop or for a school shop project, making for an excellent educational opportunity. These two projects complement each other well. The window box collector provides supplemental heat to the home in winter and can contribute to food drying in the summer. The food dryer can also double as a cold frame for starting plants in the spring.

As a creative use of new or recycled materials, the solar food dryer and window box are good introductory projects for the "beginner" of solar energy innovations.

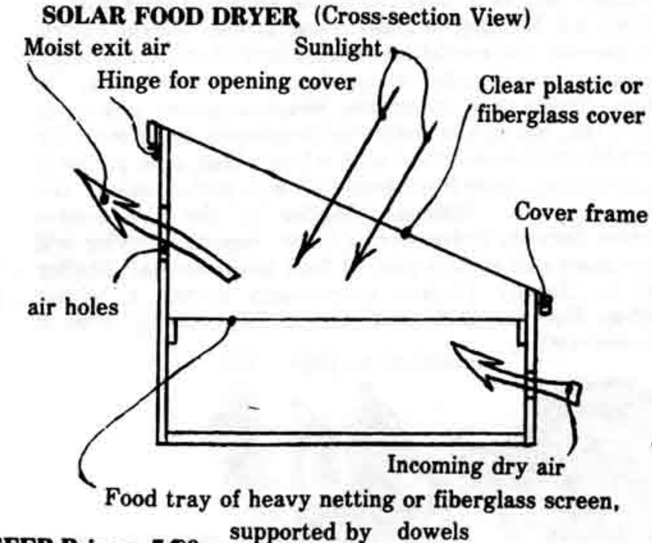
The Solar Food Dryer

A Food Preservation Method

Seven cooperating families of the Energy Project have utilized solar food dryers as a new means of food preservation. Actually, the art of drying fruits and vegetables in the sun is probably as old as the earliest of history, but in recent times lost its appeal to the process of canning and freezing of foods. However, people have become more interested in **solar drying** due to the **benefits of energy savings, improved taste and other features.** An improvement over the old methods of drying food is that **the solar food dryer is enclosed to lower problems with air borne dust and insects.**

Theodora Wuebben, a Project cooperator, has used the solar food dryer for several years. Her husband, Edgar, was the first cooperator of the Energy Project to build such a solar collector, a 2 ft. x 6 ft. wooden box with a glazed surface on the top. The dryer is a simple device with holes drilled and cut into the sides to allow **ventilation air to remove moist air from the food** and the box. The food itself acts like a solar collector, absorbing the sun's heat, which in turn aids the evaporation of the moisture from the food.

SOLAR FOOD DRYER (Cross-section View)



Construction & Cost

Construction of the food dryer **requires some basic carpentry skills.** The solar food drier used by cooperators of the Energy Project is made primarily of ½" plywood with 2 x 2's as the framing structure. The ventilation holes at the front and back of the drier are drilled through the plywood, with more holes in the upper rear side for moisture removal. The front holes are drilled below the food trays to allow dry air to enter the system. **As the air in the collector is warmed, it rises by convection carrying moisture with it.**

Mosquito netting or window screen is used to cover the ventilation holes to keep insects out of the food dryer. **Nylon or fiberglass screen can also be used for the food trays.** Wood dowels help to support the screen on the collector frame. A small soldering iron or woodburner can be used to wrap and bond the screen in a loop around the dowels at the tray ends. Cheese cloth has also been used for trays, but fibers often stick to the food. **Galvanized screen should not be used for the food trays,** since the galvanized material often can leave toxic substances on the food. The trays can be removed from the interior of the dryer. Vegetable trays used for such foods as onions should be kept separate from those used for fruit to avoid the taste on fruit. Or onions can be dried over wax paper on the screen, but will restrict the air flow somewhat.

The interior of the drier box can be painted black to improve the heat absorption of the collector box. For light colored food, it has been suggested that a dark colored gauze will also improve the heat absorption, but it is unnecessary. It is also not necessary to insulate the food dryer.

The cover of the drier is hinged on the taller north side of the drier, for opening. Glazing is used in the cover. An old storm window might be used for this purpose. "Sun-Lite" fiberglass, .025 inch thick, has been used and is available from Kalwall Corp., 1111 Candia Rd., Manchester, NH 03103. Filon flat fiberglass is also available from many lumber yards. Light vinyl plastic can also be used, but may have a lower life.

The cost of the dryer as used by Energy Project cooperators is near $40 for new materials, but many recycled materials can be used to lower the cost.

Using the Food Dryer

Each of the farm women using the food drier last summer and fall tried something different and most of the ideas worked well. **The most popular foods dried were apples and onions.** Apples are plentiful and can be easily reconstituted. Onions are used extensively and keep much better dried than the whole onions which can rot in the winter.

DRIED BEEF. Andrea Sudbeck made excellent beef jerky from brisket this summer. She injected a sugar cure solution into the meat and soaked it in brine for one day. The meat was thinly sliced (1/8" thick) and dried for one day in the solar food drier. Jerky from a three pound chuck disappeared within two days, so it must have been good.

FRUIT. Andrea also dried **Italian plumbs** in three days with good results. The pits were removed prior to drying.

Theodora Wuebben's garden produces a lot of **strawberries** so she used the food drier to make strawberry preserves. For each quart of berries, she cooked one cup of water, one quart of sugar and one tablespoon of corn syrup 'til it reached 230°F (she could spin a thread with it), then the berries were added and allowed to boil for ten minutes. This mixture was poured into pyrex containers in the food drier for two to three days. Theodora also dried **apricots** last year and was satisfied with the taste but disappointed that they turned dark. This year she may be trying an ascorbic acid treatment (1½t/cup of water, according to a flier of the Colorado State University Extension) before drying.

Linda Kleinschmit kept track of the **apples** she dried. **Six loads [the drier measures 2' x 4'] filled one gallon jar with as many apples as it would take to make ten quarts of frozen apples,** Linda reports. In addition to the freezer space she is saving, Linda is pleased her children have something besides candy to snack on in afternoons and on trips.

—Edmund and Andrea Sudbeck and children inspect food being dried on their solar drier. The Sudbecks have used the drier successfully to dry beef, a tasty treat for all.

VEGETABLES. When their solar grain dryer was going up last fall, all the help was treated to Ruth Ellen Truby's food drying handiwork. **Zuccini chips** and a sour cream dip were the big hit at lunch time. Ruth Ellen is also pleased with dried **tomato slices** she uses in soups. She says they dry down to flakes but keep the good flavor.

Linda Kleinschmit tried drying green beans but found they turn hard and brown and do not reconstitute well.

Though Delores Young is not ready to report on results, she is looking forward to making **cottage cheese** in her food dryer. Her recipe calls for 3 qt. of milk combined with ½ cup of good buttermilk in a covered pan. She will let it stand in the food dryer at 90° to 110°F for 12 to 24 hours or until a firm curd forms. "After lining a collander with nylon organdy and setting it over a large pan, pour carefully (so the curd doesn't break and go through the collander). Let the whey drain overnight, then pick up edges and twist gently to allow drainage for a few more hours," says Delores' recipe.

Delores agrees that **dried onions are well worth the effort.** She places the 1/8" thick crescent shaped onion pieces on cellophane over the nylon screens to prevent the screens from taking on an onion flavor.

Other Drying Considerations

It is recommended that some foods be dried in the "dark" without direct sunlight, in order to preserve the special nutrients of those foods. In such a case, the solar window box collector can provide heat for the solar food dryer which is covered. **It is recommended that carrots, herbs and grains, such as corn, be dried in dark conditions. Most fruit and onions can be dried in light conditions.**

Foods can be "re-hydrated" by soaking in water for preparation or cooking.

Not too high a temperature should be used for drying of foods. 110-120 degrees seems to be an appropriate temperature for drying most foods. Excess temperatures can cause nutrient or vitamin losses, like "volatile" vitamin C. Also "case hardening" can occur at higher temperatures above 130 degrees, which prevents the inner portion from drying properly. Often suggested preparation of fruits and vegetables includes the use **of sulfer and salt, primarily to preserve the food's color and some vitamins. However this is questionable and probably unnecessary.** There appears to be a difference of opinion with regard to the necessity of blanching foods, particularly vegetables. **Some experts encourage the use of natural unpeeled, untreated food for the best food drying results.**

Benefits of Food Drying

The food dryer can become an energy saver in the home. In replacing canning or freezing of vegetables and fruits, much of the energy of preparation and preservation of the foods is avoided. It therefore makes the home-maker less dependent on outside energy sources for food preservation. It has been suggested that the shelf life of foods can also be increased by food drying.

Space savings can also be realized by food drying, as less bulk must be stored. Vegetables are often dried to 5% of the original moisture content and fruits to 15-20% of initial moisture. By weighing foods before and after drying, one can calculate the moisture content, if the original moisture is known. Storage should be in a cool, dark place. Glass jars are usually recommended as the best storage containers.

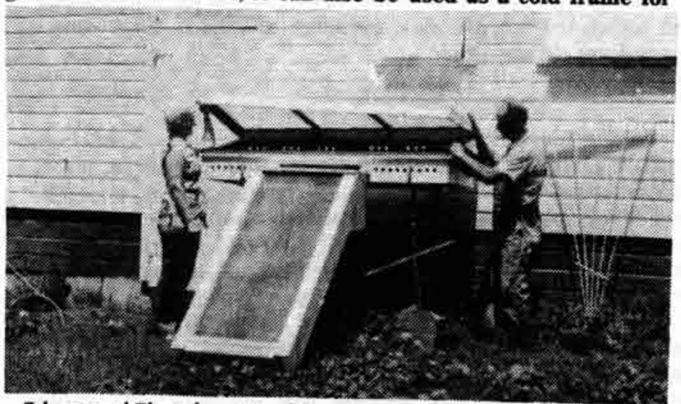
The taste of foods can be enhanced by food drying. "Dehydrating enhances and draws out new flavors and sweetness," reports Arnold and Maria Veldez in their book, **A Cookbook for Building A Solar Food Dryer.** "Dried onions, celery, carrots, and zuccini can be used instead of chips for dips, or powered in a blender to produce a vegetable salt." In addition, "fruits such as apples, peaches, pears, pineapple, bananas, etc., are an alternative to sweeteners, and a must for travel with little ones. Mixed with whole wheat, oats, pumpkin seeds and honey, dried fruits become a high protein snack," the Veldezes report. Theresa Shaffer of the Cooperative Extention Service, University of Nebr., reports, **"Drying will become more and more a part of food preservation."** Shaffer talked to Energy Project cooperators during a winter workshop. She labeled the method as a **"high quality"** type of food preservation.

(continued on page. 25)

Variations in Dryer Use

Most of the cooperators of the Energy Project have chosen the 2 ft. x 4 ft. dimension for food drying, compared to the original 2 ft. x 6 ft. size used by the Wuebbens. Other sizes can be used, although similar width to length ratios are suggested. A corrugated cardboard box can be used for the frame of the food dryer for lower cost. A variety of plans are available for food dryers with various shapes and sizes, so the end product can be the result of the imagination of the builder.

Not only does the food dryer help after the harvest of gardens and orchards; **it can also be used as a cold frame for starting young early plants.** Theodora Wuebben has used the device for starting tomatoes and cabbage in the spring.



—Edgar and Theodora Wuebben inspect food in their solar food drier. The drier can be used alone or with the solar window box collector, shown attached to the drier. The window box improves the efficiency of the system, especially during the fall months. In some cases, where "dark" drying is required, the window box provides all the heat for drying, while the drier itself is shaded.

There are **other methods of drying food.** A solar greenhouse might provide the atmosphere for simple food drying. A pilot light of the gas oven provides adequate heat for drying of fruits and vegetables. Solar food drying requires sunshine for the final result, but if there is no sun for a day, food often can be left on the dryer, awaiting sun a day later.

A solar window box collector is used by Theodora Wuebben during cooler fall months when the sun is lower in the southern skies to improve the efficiency of solar drying during these months. The top end of the window box attaches to the front of the food drier, where the extra heat is received.□

—Edgar Wuebben checks on plant boxes in the solar food dryer which doubles as a cold frame during the early spring.

The Solar Window Box Collector

A Passive Solar Heater

The solar window box collector is essentially an insulated box with a glazing material over a suspended black-painted metal collector plate. The black plate absorbs energy from the sun, warming the air above it. This causes warm air to flow up and out of the collector by convection and into the room behind the collector. As the warm air rises, cool air from the room flows into the area beneath the collector plate.

The window box functions as an extension of a window, and it can provide supplemental heat to a room on a clear, wintry day. Since the collector requires no fan to operate, **it is classified as a "passive" solar collector,** a simple device.

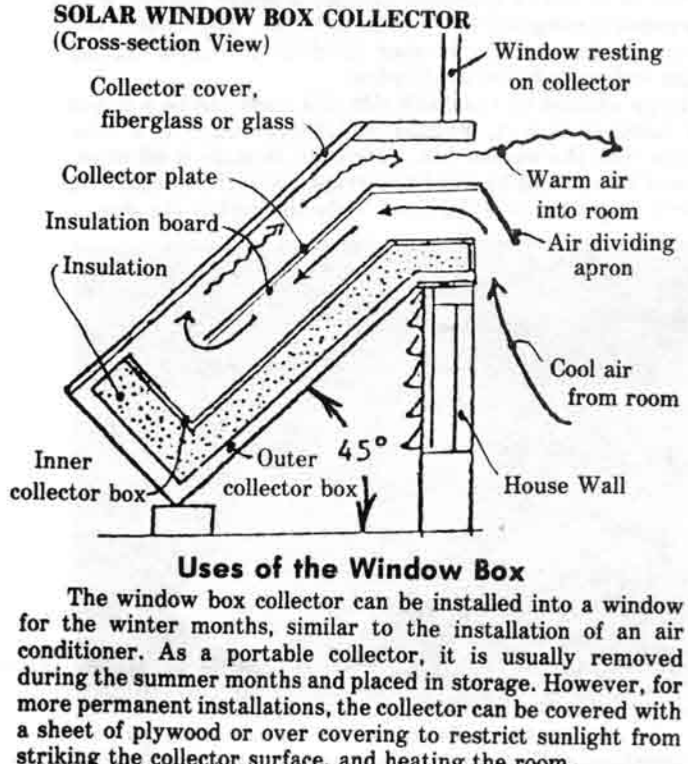
A variety of sizes and shapes are possible options for the builder of the window box collector. The window box should be well insulated on the sides and bottom. During construction of the collector, an inner "box" is built to provide support for the collector plate and a liner for the air flow. A larger box is built to enclose the inner box, with insulation installed between the two. The fiberglass glazing or glass cover is placed onto the top side. Caulking is essential to make an air-tight collector.

A Low-Cost Collector

Rick Pinkelman was the first cooperator of the Energy Project to use the window box collector. **He built the collector for $10, using mostly materials from around the farm.** Encouraged by the results, he and his wife, Mary, went on to build a large solar collector on their farrowing barn, and they also built a 290 sq. ft. vertical wall collector on their home. **The window box collector, for them, represented a valuable learning experience on the assets of solar energy,** before proceeding to uses of larger collectors.

A construction workshop was held for cooperators of the Energy Project two years ago. Fourteen window box collectors were constructed. The workshop used mostly new materials, giving a cost of about $40 per unit. However used materials would lower the cost. A used storm window, for example, can be used for the collector glazing.

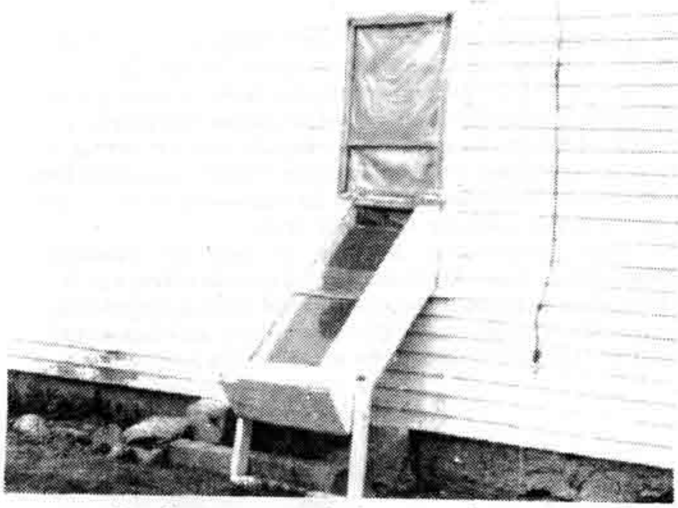
SOLAR WINDOW BOX COLLECTOR
(Cross-section View)



Uses of the Window Box

The window box collector can be installed into a window for the winter months, similar to the installation of an air conditioner. As a portable collector, it is usually removed during the summer months and placed in storage. However, for more permanent installations, the collector can be covered with a sheet of plywood or over covering to restrict sunlight from striking the collector surface, and heating the room.

The window box collector **is effective in improving the efficiency of the solar food dryer,** especially during fall months. It is simply attached to the front of the food dryer.



—The first window box , left, in Cedar Co. was constructed by Rick Pinkelman early in 1977. The success of the device led to the organizing of a workshop where 14 systems were built. The window box represents an educational tool for learning about solar energy. Rick and Mary Pinkelman went on to build large solar collectors on their farrowing barn and home.

Performance of the Window Box

The window box collectors used at the Energy Project utilize about 10 sq. ft. of collector surface, although these collectors can be built considerably larger.

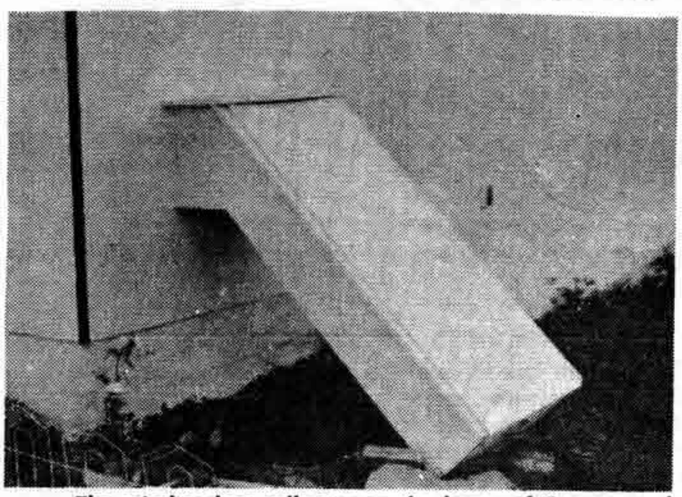
The amount of heat the modest window box collector can produce may be surprising—often enough to keep a room warm during calm, clear wintry days. In late winter (April 1) of 1978, one window box gave a 23°F temperature rise and moved air at a rate of 38 cubic feet per minute (cfm). This was at 4:00 in the afternoon. Later that spring (May 10), a similar window box installed on a dairy barn gave a 55°F temperature rise although the air flow rate was 29 cfm at 2:00 p.m., more than enough to take the chill out of the milking parlor, where it was used.

Special Precautions

The solar window box must be well caulked and well insulated for satisfactory performance. When mounted to the window, it should be weatherstripped to avoid air leaks into the home.

The window box can be mounted to the exterior frame of the window, or it can be extended through a larger window with the window resting on the top of the collector. The window box will not perform properly when used in a window having heating radiators below the window.

A large window on the south side of a room can be a larger solar collector as it is, perhaps performing better as a solar collector than the window box. However, to make it effective, it should be covered by insulated drapes at night to conserve the energy gained as a "passive" collector during the day.



—The window box collector on the home of George and Janet Hamilton of Hartington. This is a permanent installation, therefore it is covered during summer months. Janet is office manager at the Energy Project.

More Information

A variety of plans and books are available for constructing and using the window box collector and solar food dryer. Several are listed below.

References

"Solar Food Dehydrator Plans," Domestic Technology Institute, 12520 West Cedar Dr., Lakewood, CO 80215, $8.50. Contains five 18" x 24" blue-prints for constructing a 2 ft. x 6 ft. food dryer. The plans include details on making a small dryer unit from a corrugated cardboard box and information for building a window box collector. Also includes suggestions for food drying considerations, such as "dark" drying.

A Cookbook for Building A Food Dryer, San Luis Valley Solar Energy Assn., P.O. Box 1284, Alamosa, CO 81101, 16 pages, $3.50. Includes introduction to drying, design and variations of dryer and window box collector with many illustrations and a bibliography. Excellent.

Dry It, You'll Like It, by Gen MacManiman, Living Food Dehydrators, P.O. Box 546, Fall City, WA 98025, 1974, $3.95. Instructions for drying fruit, herbs, meats and other foods, includes solar dryer plans. Highly recommended.

"Solar Energized Food Dehydrator-Plans", Solar Survival, Cherry Hill Road, Harrisville, N.H. 03450, $6. Five 18" x 24" blueprints indicate the construction of a food dryer using a 50 gal. drum for use of solar energy in "dark" drying. Includes suggestions for the drying process and other uses of the system.

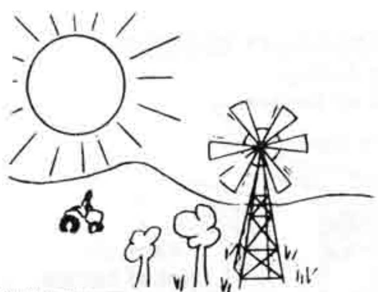
"Solar Window Box Plans", Small Farm Energy Project, P.O. Box 736, Hartington, Nebr., 68739, $2.50. Includes one 18" x 24" blueprint and details for construction of a window size solar heater. Plans were developed for workshop construction of over a dozen window boxes, but are helpful for single collectors also.

"Food Dryer Bibliography", Teresa Shaffer, Extension Specialist in Food And Nutrition, U. of Nebr., Lincoln, NE 68583. Local extension services also have information on drying fruits and vegetables and making leathers and jerkies.

Dry and Save: A Complete Guide To Food Drying at Home. . . . With Recipes, by Dora D. Flack, Woodbridge Press Publishing Co., P.O. Box 6189, Santa Barbara, CA 93111, 118 pages, $2.95. A discussion of the reason for food drying, methods used, pretreatment, storage, food leathers, and various recipes. A good resource, covering many aspects.

The Solar Food Dryer Book, by Stella Andrassy, Morgan and Morgan, 145 Palisade St., Dobbs Ferry, N.Y. 10522, 127 pages, $3.95. Includes instructions for making the "sunhood" dryer, basic information for food drying, recipes for dried food use, and a reading list.

The Solar Cookbook, by S. Andrassy, Morgan & Morgan, 145 Palisade Str., Dobbs Ferry, N.Y. 10522, 128 pages, $3.95. Includes 100 recipes, and information on the portable sun oven, weighing 35 pounds.□

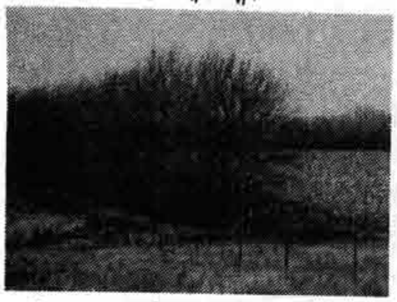


PROJECT FOCUS #6

Small Farm Energy Project

Heating With Wood

September, 1979

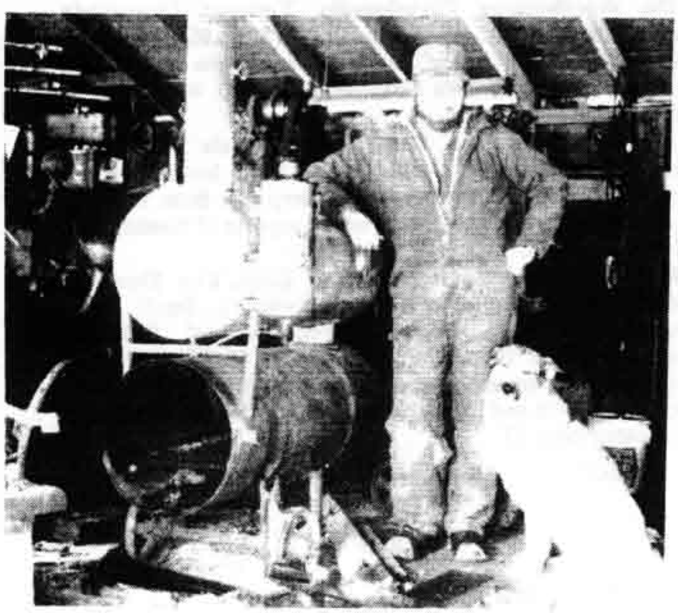


—Trees can be an important resource. There are many benefits available from trees on farms, such as wood for space heating. However, in many areas, including Nebraska, more trees are destroyed annually than are planted. Planting of trees is a major energy conservation step.

Wood heating has gained popularity with cooperators of the Energy Project as the cost of energy rises, although many of these farm families never discontinued wood heating after gas and oil first came into use years ago. A variety of equipment is used for wood heating, including some home-built versions. Wood heating is a low-cost, renewable form of energy particularly suited to rural areas. However, wood use requires responsible replacement of trees for future generations. Wood heating also requires specific safety procedures to avoid serious fires.

An Early Method of Heating

For the settlers of the Plains states wood was a prime concern, not only for construction, but mainly as a home heating source. Since Cedar County, Nebraska is bordered on the north by the Missouri River, the river valley was viewed as a natural wood supply. As a result settlers made tree claims which were used as their source of fire wood. In addition woodlots were established on nearly all farmsteads. Today many of these woodlots which have been mismanaged in the past are coming under use once again. Dutch elm disease has killed many of the American Elms which were widely planted in windbreaks, woodlots, and as shade trees. This has resulted in a short term dry wood supply.



—Martin Kleinschmit, left, and farm friend display the home-built wood heater used in Kleinschmit's shop. The heater was built from used water heater tanks. Wood is fed into the lower tank with flue gases passing through the top tank for better heating efficiency. Kleinschmit had hoped to use the small tank shown at the side of the heater for burning waste oil, but was unsuccessful.

Costs of Wood Heating

Prices for new wood heaters range according to the quality of construction and size of the wood heater. In addition, other accessories will be required for handling wood, including saws and splitting equipment. Rural areas are most suited for wood heating, where wood supplies are nearby. In urban areas, the cost of transporting wood may be prohibitive.

As with other types of alternative energy used in space heating, **insulation of the home is important.** Such conservation will help to make the best use of a resource, like wood.

Tax credits have been considered for wood heating equipment as with solar devices, but to date few credits are available for wood heaters.

Wood Heating Safety

Wood safety is of such importance that it can't be over-stressed. Chimney fires can be avoided if chimneys are kept clean of soot and creosote. The best way to accomplish this is to **burn only dry wood—never green wet wood—and to sweep the chimney periodically.** A chimney in good shape is very important. It should have no cracks and it should be lined. Many of the older chimneys are unlined thus making them dangerous. Wood safety must also be stressed in the making of firewood. Everything from felling the tree to working it up requires the use of buzz saws, chain saws, axes, wedges and sledges which require some skills on the part of the user.

Independent, Renewable Heating

The burning of wood as a fuel is not a total act of consumption like the use of electricity or fossil fuels. Most users of electricity or fossil fuels don't know or care where it comes from or what was required to obtain it. Their only concern is that it is there when the light switch or the furnace is turned on. Instead a user of wood is required to be responsible. Not only must he/she be responsible from the view point of safety but also **responsibility must be assumed for replenishing the trees so that wood can indeed be a renewable form of energy.** Individuals who make their own firewood are fully conscious of where their fuel is coming from and what is required to maintain a long term supply. A long term supply in the Plains region can only be assured if the users of wood make sure that more trees are planted.

A Variety of Wood Equipment

Commercial Systems

Wood stoves were removed from most rural homes because they were "too messy" and fossil fuels were cheaper and much easier to use. But today wood stoves are finding their way back into many homes. Today there are literally a hundred different makes and models available on the market. With this sudden interest again in wood as a fuel resource, several new innovations have been developed. Probably the **most popular innovation** among Energy Project cooperating farmers is the "Convert—A—Furnace", "Furnace-mate", "Side-by-Side", "Helper Furnace", etc. all of which are **supplemental wood heating stoves.** They make use of existing gas or oil furnace air ducts and chimney. These wood furnaces are usually thermostatically controlled so that as long as the wood fire is warm enough it will provide space heating. When the fire dies down the regular gas or oil furnace will provide the heat. As a result these types of wood furnaces prove to be mainly supplementary and don't completely replace the existing furnace. Because the oil or gas furnace is still present, the Energy Project has found that it is easier for the busy farmer to defer use of the wood heater when wood needs to be made or the stove needs to be fed during the night. These tasks couldn't be put off if the wood stove was the only heat source.

Home-built Wood Heaters

Another innovation that has become popular is the **construction of a wood stove from barrels or other materials.** Martin Kleinschmit, an Energy Project cooperator solved his shop heating problems by using two 50-gallon hot water heater tanks. He placed them one on top of each other using the bottom tank for the fire box and the top one as a heat exchanger. The same can be done with barrels. Persons have also built their own wood heater next to their conventional oil or gas furnace.

Fireplaces

Fireplaces generally have low efficiencies in providing heat to the home. Although more efficient systems are now available than in the past, many fireplaces may remove more heat from the home than is provided for space heating, due to the draft created. **Newer designs** of fireplaces incorporate heat exchangers with forced or gravity air circulation to **provide for improved combustion efficiencies** while retaining the attractiveness and appeal of a fireplace. As with other wood heaters, consideration should be given to utilizing air from outside the house for combustion air, therefore lowering the draw on heated interior air, which must be replaced by outside cold replacement air to the living area.

Wood Water Heaters

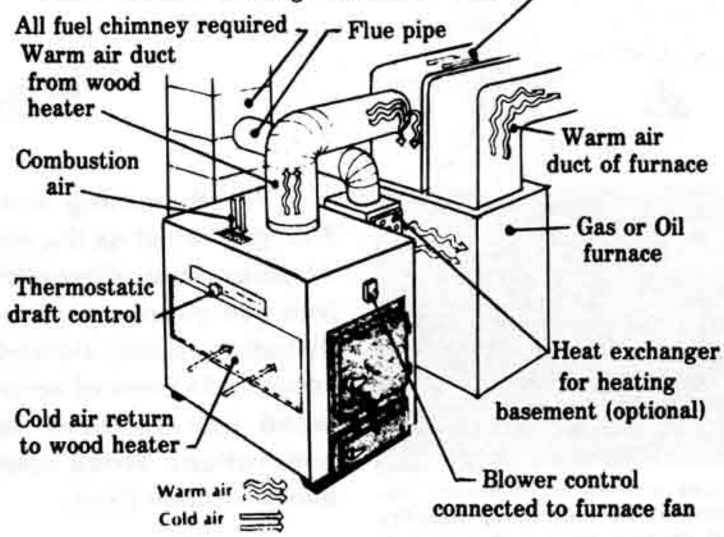
Commercial wood heating devices are also available for heating water with wood energy. In addition, **various ideas have been utilized by the "do-it-yourself" enthusiasts,** including wrapping coils of tubing carrying water around the flue or in the firebox of the wood heater. With a tank separate from the conventional water heater, the wood water heater can function on the convection or "gravity" principle.

The wood water heater can be a low cost heater, that also can be used in conjunction with low cost solar water heaters, where the solar system is used only during the mild months of the year, with the wood water heater used during cold winter months. The solar collector in this case is drained down for the winter.

Stock Tank Heaters

Another farm use for wood heat which is becoming popular again is the use of **"cob burners" to melt the ice in livestock watering tanks.** These consist of nothing more than a metal firebox placed in the stock tank in which cobs, wood scraps, or anything else which will burn are used to heat up the water. □

EXAMPLE OF WOOD SUPPLEMENTAL HEATING
(Convert-a-Furnace by Ashley)



More Information

A variety of plans, books and other resources are available for constructing wood stoves and for utilizing wood as a fuel. The Energy Project has a "Wood Energy" bibliography for 25 cents. Most local and state Extension Service offices have good heating information. Listed below are several other good resources:

References

Convert Your Oil Furnace to Wood by William White. 1976. Firebuilders, 352 Stetson Rd., Brooklyn, Connecticut 06234. $3.00. 55 pp. This booklet tells step by step how to convert an oil furnace to wood by building a brickwork wood furnace right in front of the oil furnace and ducting the hot flue gases through the oil furnace.

How To Build An Oil Barrel Stove by Ole Wik, 1976. Alaska Northwest Publishing Company, Box 4-EEE, Anchorage, Alaska 99509. $1.95. 24 pp. This booklet provides simple directions for making a stove out of an oil barrel entirely without welding equipment or power tools.

The Woodburners Encyclopedia. Vermont Crossroads Press, Box 333, Waitsfield, Vermont 05673. $6.95. 155 pp. It covers the phases of wood heating, combustion properties, economics, a list of system manufacturers and wood system specification charts.

Wood Heat by John Vivian. 1976. Rodale Press, Inc., Emmaus, Pennsylvania 18049. $4.95. This book provides reading that ranges from woodlot to fireplace, from stove to flue, giving practical information on all aspects of heating and cooking with wood.

Woodstove Construction: How to Build Two Excellent Wood Heaters—Materials—Tools—Techniques, Small Farm Energy Conservation Project, Federation of Southern Cooperatives, P.O. Box 95, Epes, Alabama 35460, 46 pp, $3. This booklet is to acquaint persons with the principles of wood stove construction and to provide a basic model and design for their construction. □

PROJECT FOCUS #7

Small Farm Energy Project

Dairy Water Heating

NOVEMBER, 1979

Farmers Try Four Approaches To Cutting Costs

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

For most dairy farmers, the modern pipeline dairy represents a major investment which can bring a stable income. These dairies are dependent on reliable energy. Farmers cooperating with the Small Farm Energy Project are finding ways to cut their operating costs by pre-heating their dairy wash water. Three farmers have tried solar innovations and one farmer is using heat recycled from the bulk tank compressor. Their personal choices have contributed to the Project's emphasis on a common sense approach to on-farm research.

The venture into options for dairy water heating began in February, 1977 as cooperating farmers heard solar architect Gary Harley describe solar water heating systems. After discussion with project staff, several farmers were interested in these systems for dairies and farm homes. In May, 1977, project staff and cooperator Edgar Wuebben helped build a solar water collector at Halsey National Forest in the Nebraska Sand Hills.

At the same time, cooperator Gary Young included a solar water collector in his loan application to FmHA for a new dairy barn. The county supervisor was supportive, but the solar portion of Young's loan request was denied at the state level. Though Project complaints were taken to the federal level, the commercial solar unit Gary wanted to put in was considered uneconomical.

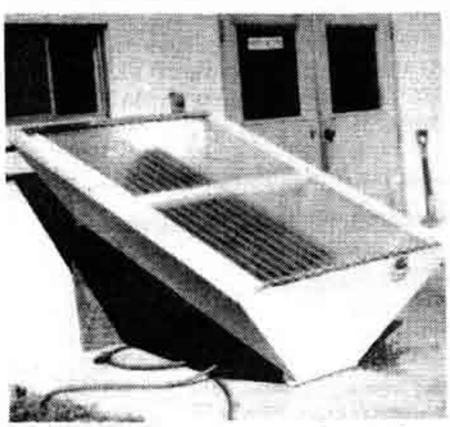
Despite this setback, or perhaps because of it, Wuebben pushed ahead with his own collector by beginning construction in September, 1977. Soon afterwards, cooperator Linus Lange became involved with solar water heating in an October construction workshop. Details on their **drain-down solar water heaters** are on page PF4.

While Edgar and Linus were busy with their solar systems, cooperator Martin Kleinschmit was thinking of ways to use solar energy in his dairy. Since early 1977, Kleinschmit dreamed up several variations of solar water heaters. Finally, early in 1979, he decided on a **thermosiphon system** with a heat exchanger and antifreeze. He built the system in August, 1979. See page PF3 for details.

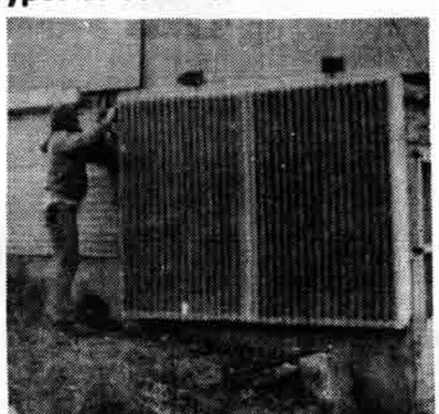
Determined to reduce his energy expenses, Gary Young chose another approach to heating his dairy water. After considering it for a year, Gary had a **heat exchanger installed** in October 1979. As described on page PF5, this commercially available device **uses heat taken from the bulk tank cooler compressor to heat water** for washing dairy equipment.

To add to the farmer's options, the project staff decided to design and build a simple, inexpensive solar water heater. With the help of Tim Bowser, summer intern from Pennsylvania, **the bread box water heater** described on page PF2 was constructed in August, 1979.

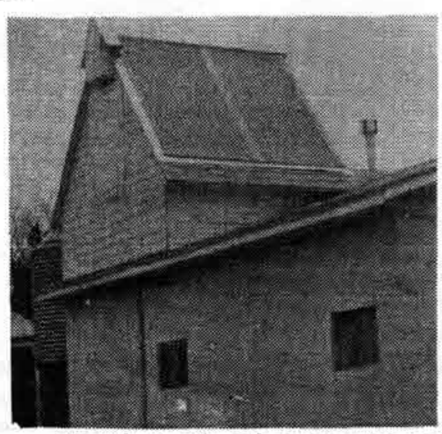
Three Types of Solar Collectors Are Tested



—The breadbox solar water heater is a low cost heater using a black tank under fiberglass.



—Martin Kleinschmit connects hoses to carry antifreeze to and from his solar water heater at the dairy barn.



—The 8 ft. X 8 ft. solar water heater on the roof of the dairy barn of the Edgar Wuebben farm, Wynot, Nebr.

The Breadbox, A Simple Solar Collector

The breadbox solar water heater is simply a black water tank, placed in an insulated box, which is heated by the sun. It may remind some resourceful people of a black barrel they put on a tower for hot showers after a long summer's day. The bread box solar collector can be used during warm seasons but must be **drained during winter months** to prevent damage from freezing. A simple design was developed by Project staff so farmers could quickly construct a collector using salvaged materials.

A 30-gallon propane-fired water heater tank was used as the collector/storage tank because its long, narrow shape provides a large surface area to collect solar heat and transfer the heat to the water. The flue pipe through the center of the tank adds to the surface area and increases heat transfer to the water.

The black tank was placed in a well insulated U-shaped box. The inside of the box was covered with **aluminum foil to reflect the sunlight onto the tank** and increase the amount of heat gained. A fiberglass covering over the box keeps the weather out and the heat in. The 4' x 6' box can be installed in the roof of a dairy barn, or a home, and between the rafters, if it is properly supported. (see figure 1).

Plumbing connections are quite simple with this system. A hose or pipe brings cold water to the bottom of the tank, and another hose or pipe takes the warmed water from the top of the tank directly to use or to the cold water inlet of the conventional water heater. Well pressure provides sufficient water flow so that no pumps or controls are necessary. Cold water flows into the tank as hot water is used.

Options and Operation

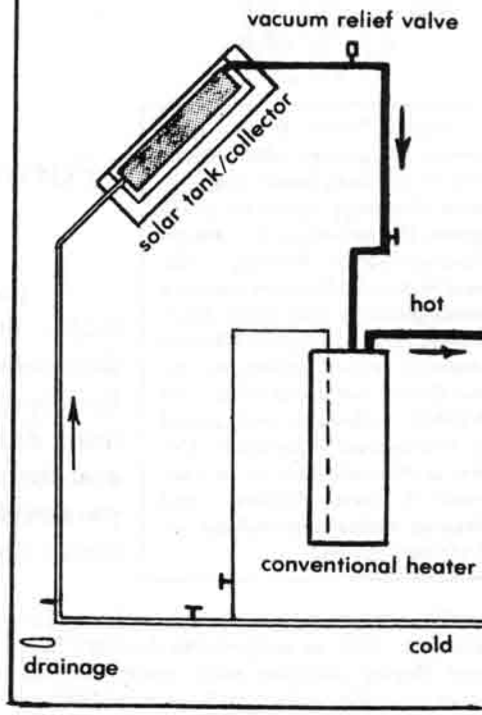
Some persons may wish to place an **insulated cover over the breadbox** water heater at night to conserve the heat generated during the day unless most of the water is used in the evening. Another storage method would be to place a second fully insulated tank over the breadbox water heater, such that heated water rises to the insulated tank, where it retains its heat until it is used. This minimizes the requirement of covering the breadbox at night.

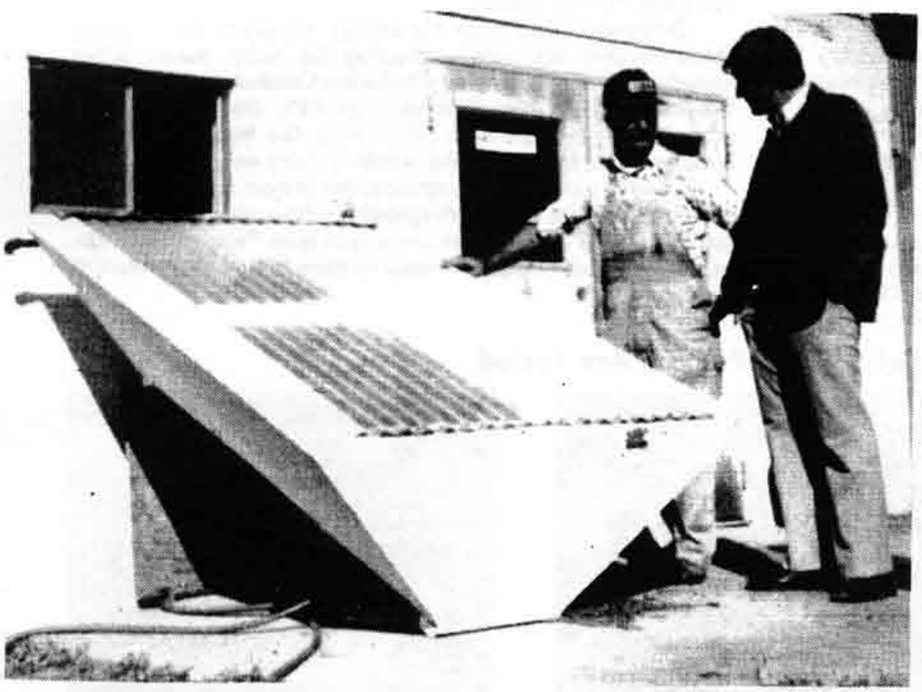
To find out how well the breadbox system works, the tank was filled with cold water at 54°F on **September 7, 1979;** a crisp, clear fall day. Because of shading, the collector was in full sunlight from 10:30 a.m. to 5:30 p.m. That evening, the tank was drained from the bottom inlet into a five-gallon pail. Temperatures of the water were taken each time the pail was filled. Water at the bottom of the tank was 98°F but at the top of the tank it was 120°F. **The average temperature was 110°F. The water temperature was raised an average of 56°F for a collection of 14,450 Btu that day.**

The well-known fact that hot water rises shows that solar heated water works like any other tank of water. It explains why hot water should be taken from the top of the tank and cold water fed into the bottom. This fact also makes possible the thermosiphon water heater that Martin Kleinschmit uses on his dairy barn.

Figure 1

One Type of Breadbox Design





—Edgar Wuebben describes the function of the breadbox water heater with Spencer Schram of Minn., a visitor to the Wuebben farm. The 30 gallon tank, painted black, rests in the insulated box beneath corrugated fiberglass. Aluminum foil is used to line the interior of the box and reflect sunlight onto the tank. The system has proved quite effective for its low cost of approximately $175.

Breadbox Materials Cost

Lumber and fiberglass	$ 65.00
Paint and caulk	27.00
Copper tubing and fittings	27.00
Tank and repair	25.50
Misc. materials	30.50
Total Cost	**$175.00**

A Passive Design

It took Martin Kleinschmit a while to decide just how he was going to rig up his solar collector but he is well pleased with his arrangement. Basically, his system involves a **flat-plate liquid solar collector and a storage tank/heat exchanger.** Antifreeze solution circulates through the collector and into the larger of two tanks. The **antifreeze then heats a smaller tank within the large tank. Water contained in the small tank is then heated for use in the dairy.**

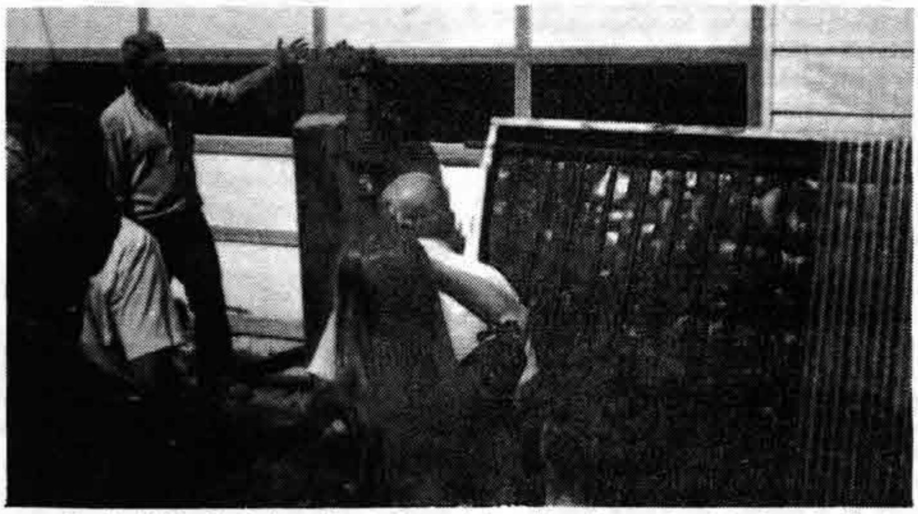
No pumps are used because the system operates on the principle that hot liquids tend to rise. As the black collector becomes hot from the sun, the liquid in the pipes absorbs heat and rises from the top of the collector into the outer storage tank. From the bottom of the tank, cooled liquid flows into the bottom of the collector to be warmed again. As the liquid continues to make this cycle, water in the inner storage tank picks up the heat for use in dairy washing. It is **necessary that the storage tank be located above the collector [See Figure 2].**

Because only antifreeze circulates through the collector, the system may be operated throughout the winter (it has not been through a winter yet). The 4:1 mixture of propylene glycol and water should not freeze above -20°F.

Construction and Safety

Safety considerations would not allow this design for home water heating systems because antifreeze might leak into the inner tank and contaminate the water supply. Most safety codes require two metal surfaces separating antifreeze from potable water. Kleinschmit has incorporated two safety features into his system. First of all, the propylene glycol is classified as non-toxic. Secondly, a one-way valve is used on the cold water line from the farm water well, to prevent water flowing back to the well, especially if the inner tank leaked at that time, allowing antifreeze to also potentially flow to the well.

The Kleinschmit Thermosiphon Collector



—Martin Kleinschmit describes to farm visitors his solar pre-heat tank and collector under construction at the time.

The collector plate was made from special tubing designed for solar collectors. The 5' long copper tubes have copper fins which are electronically treated with a black finish. The half-inch tubing is soldered to 1" tubing to form the 5' x 8' collector. Corrugated fiberglass covers the collector.

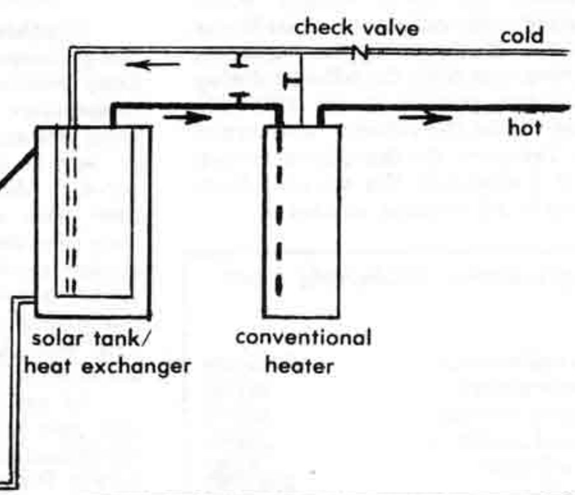
Kleinschmit built his **storage tank/heat exchanger from 50 and 80 gallon tanks** salvaged from around the area. He cut the top out of the 80 gallon tank so the 50 gallon tank would fit into it. The seam was sealed with an epoxy. Fittings to connect the outer tank with the flat plate collector were installed at the top and bottom of the outer tank. Because the 50 gallon inner tank came from a water heater, fittings for cold water inlet and hot water outlet were intact on the top of the tank.

Operating Results

To find out how well his system worked, Kleinschmit kept track of temperatures before morning and evening milkings over a 1½ week spell of clear weather in late September, 1979. At about 8:00 in the morning the average temperature of water going into the collector from the bottom of the outer tank was 74°F. Average temperature at the top of the outer tank was 103°F. At about 6:30 in the evening, the average temperature at the bottom of the tank was 106°F and at the top of the tank, 124°F. This means that in the evening there was 18,000 Btu more heat in the tanks than there was in the mornings. However, Kleinschmit uses about 30 gallons of water each milking. One evening, he found that the temperatures in the tank had dropped from 126°F to 123° at the top, and from 110° to 85° at the bottom after milking. That amounts to 10,000 Btu that went to warm 30 gallons of water 40°. **So an estimate of clear-day heat gain from Kleinschmit's thermosiphon collector is 28,000 Btu,** giving an estimated efficiency of near 40% for the system.

Figure 2

The Passive Thermosiphon System



Thermosiphon Materials Cost

Copper tubing and fittings	$275.50
Two tanks	150.00
Propylene glycol	141.00
Insulation	138.50
Lumber and fiberglass	104.00
Misc. materials	70.00
Total Cost	**$879.00**

The First Effort

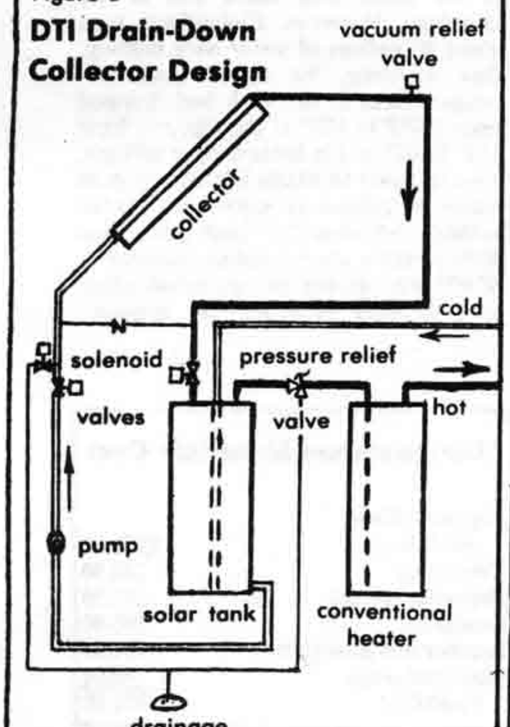
The drain-down system adopted by Edgar Wuebben for his dairy provides for year-round use by depending on thermostatic controls to protect the plumbing from freeze damage. The system includes a flat plate liquid collector, a storage tank and a pump with control devices for automatic operation. **The drain-down system may be more efficient than the antifreeze type system, since water is heated directly in the collector, but the system may have a higher initial cost,** due to special controls.

Wuebben's adoption of this system is the result of a pioneering effort. Though Project staff were not aware of any on-farm experience with dairy solar water heaters in the region, Wuebben travelled to a Halsey, Nebraska workshop to learn about the solar innovation. It may have been easier to sit back and watch others break the ice, but Wuebben took the lead in constructing his collector. Wuebben soon had company as Linus Lange became involved with a solar water heater for his dairy.

The system functions with a pump that circulates water from the 120 gallon storage tank through the 8 ft. x 8 ft. collector and back to the storage tank. As hot water is used from the electric water heater, solar heated water flows from the top of the storage tank into the electric water heater. Cold water simultaneously flows into the bottom of the storage tank. (see figure 3).

Figure 3

DTI Drain-Down Collector Design



The Wuebben/Lange Drain-Down Collector

—Edgar Wuebben, left, and Linus Lange, both cooperators of the Energy Project, constructed one of the first solar water heaters at the Energy Project during the fall of 1977. Copper tubing is mounted to corrugated metal to provide the collector plate.

Construction and Operation

Wuebben and Lange built their collector plates using corrugated sheet metal and copper tubing set in the corrugations and bonded together with a heat transfer cement. The 8' x 8' collectors were set in well-insulated boxes to increase the heat efficiency. After modification of the roof, the collectors were mounted. Plumbing to control panels was installed.

A defective sensor in a component of the drain-down mechanisms did pose problems for Linus Lange. Until it was replaced, the collector had to be manually drained during the crisp fall weather in 1978. **The Lange collector also had a defective vacuum relief valve.** Though it had apparently drained on November 11, 1978; enough water remained in the collector to **cause freeze damage.** Because of this concern, Wuebben shut down the collector during the coldest portion of the 1978-1979 winter. When the collector was turned on in February, the drain-down system operated efficiently. The system collected heat in sub-freezing weather.

Drain-Down Materials Cost

Pump and controls	$ 455.00
Collector materials	331.50
Housing materials	220.00
Tank and insulation	204.00
Misc. materials	67.50
Total Cost	**$1278.00**

Wuebben has had to live with one minor problem in his system. The design, by Domestic Technology Institute of Lakewood, Colo., called for a pump which was inadequate for pumping water to the collector at the specified flow rate. As a consequence, **a low water flow rate of 9 gallons/hour** resulted in excessive heating of the water. Visitors were well impressed with the high temperatures coming out of the collector but more heat escaped the collector than would occur if greater flow rates were attained. **Though partially corrective measures increased the flow rate to 11.4 gallons/hour** in March, 1979, the expenses of a larger pump may be necessary to substantially increase flow rates.

Extensive Records

Wuebben kept detailed records on the performance of his solar collector. Daily readings of solar intensity, air temperature and water temperatures going into and coming from the collector as well as in the storage tank were noted. In addition, electric meters on the dairy barn and electric water heater were read daily. From this information an estimate of heat gain on clear summer days was made. The seasonal contribution of solar energy to the water heating load was determined as well as a indication of collector efficiency.

An estimate of clear-day summer heat gain is based on readings taken throughout the day from June 1 to July 7, 1978. The average temperature rise of

(continued on page 33)

Using Waste Heat

Though FmHA decided solar water heating wasn't economical for Gary Young's dairy barn in 1977, he was determined to try something to cut back on his energy expenses. The heat exchanger he purchased is a commercial item which **heats water by heat taken from the bulk tank coolant lines.** Cool water is pumped from a storage tank to pick up heat from the coolant when it flows from the bulk tank.

The idea behind the heat exchanger suggests that when heat is taken from the process of cooling milk, 50% or more of the heat can be transferred to wash water. For example, about 82,000 Btu are given off by the milk Young cools on an average day. About 160,000 Btu of propane* are needed to heat the 95 gallons used daily. Young has one water heater set at 110° for washing udders and another water heater set at 160° for washing pipes and bulk tank. The heat exchanger pre-heats the wash water so less propane is needed.

The heat exchanger is simply a box which pumps water from the warm wash tank into a four foot coil which contains the coolant lines from the bulk tank compressor (see figure 4). Water used to wash udders is taken directly from the warm tank (or heat exchanger if its pump is operating). When hot water is taken from the hot tank it is replaced by water from the warm tank (or the heat exchanger if its pump is operating). So all the heated water used in the dairy is pre-heated by the heat exchanger.

The Young Heat Exchanger

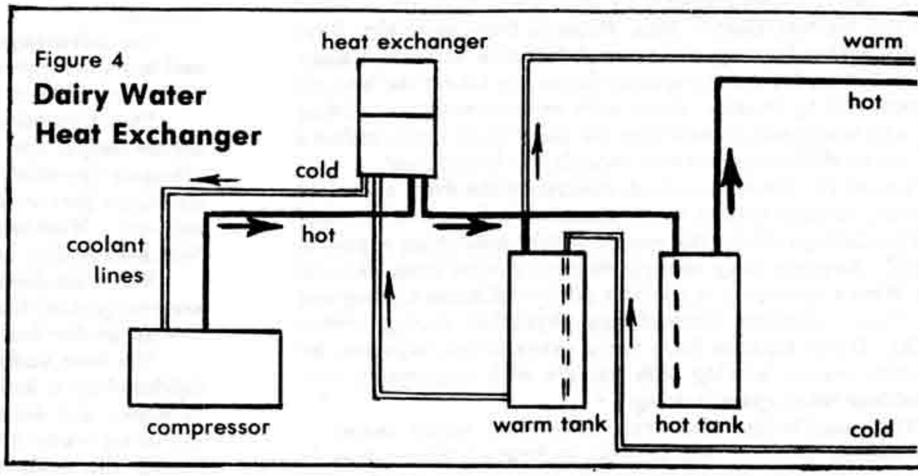


Figure 4
Dairy Water Heat Exchanger

As a new commercial item, Young did have difficulty locating the heat exchanger and it took four months from order date to time of installation. Though it was the first unit installed in the area, two men installed the system in five hours. **Installed cost including labor was $630.**

From September 17, 1979 to October 31, 1979, **an average of 1.7 gallons of propane were used to heat Young's dairy water each day.** According to Young's observations, the heat exchanger adds 50°F to the temperature of the 95 gallons he uses daily. That's a **contribution of 41,000 Btu or 36% of his daily water heating requirement.*** In addition the compressor fan operates one third of the time that it originally did, because its workload is reduced by the heat exchanger.

Young is very pleased with his dairy heat exchanger, and he says he will "promote" the concept with other dairymen.

*Assuming 70% efficiency of propane water heater.

[DRAIN DOWN, continued from page 32]

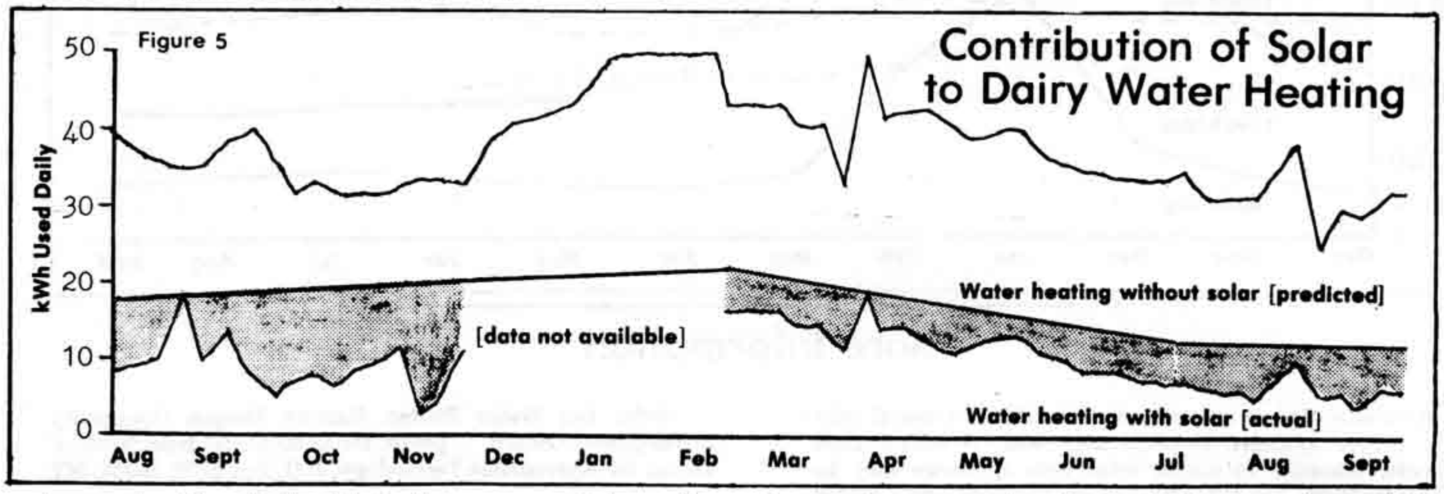


Figure 5
Contribution of Solar to Dairy Water Heating

water passing through the 64 sq. ft. collector was determined for each hour between 9:00 a.m. and 8:00 p.m. Because it takes one Btu to raise the temperature of one pound of water one degree Fahrenheit it is possible to **estimate clear day summer heat gain at 48,000 Btu.**

An indication of the substantial contribution the solar collector made to dairy energy needs may be seen in figure 5. Actual daily electric consumption of the dairy and water heater are presented as well as estimates of water heating demand without solar (based on actual cloudy day readings). The shaded area indicates the energy contribution of the solar collector.

From Wuebben's extensive records, collector efficiency averaged 39.9% from July 10 to November 8, 1978. This figure is based on the flow rate of water through the collector, the increase in water temperature after going through the collector and solar energy readings. As recommended in **Analysis of Collector Array Performance from Field Derived Measurements** by W.H. McCumber and M.W. Weston, 1978 the following conditions were held: 1) a steady state collector temperature environment; 2) insolation greater than 200 Btu/sq. ft. hr; 3) wind speed less than 10 mph; 4) a range of ambient temperature, of less than 55 degrees during the testing. Supplemental data from the National Climatic Center was used to determine days of low wind velocity.

Dairy Water Heating, A Major Energy Use

According to the detailed production and expense records kept by the 48 farms cooperating with the Project, dairy farms have the highest electric bills. **Records from one dairy farm indicate water heating can account for 35% of normal dairy electric demand.** Four of the dairy farms are taking the bite out of those bills by heating water with on-farm resources. Using solar and waste compressor heat for dairy wash water makes a substantial difference as their records are bearing out.

To get an idea of how much electricity the dairy operation requires, electric meters were placed on selected dairies and weekly readings taken. The results of this monitoring appear in figure 6. Average daily electric demand ranges from 10 to 60 kwh. Where electricity is used for additional space heating and tank water heaters, demand can skyrocket during winter months. Dairy farmers have found ways to cut expenses by insulating barns, heating milk parlors with compressor heat and adding solar space heating.

The contribution of a drain-down solar water heater to dairy energy demand may be seen in figure 5 where over 14 months of records are summarized. Projected water heating without solar may be compared with actual electric demand with the solar contribution.

By applying ingenuity, determination and common sense, these farmers have demonstrated four options to cutting back operating expenses using on-farm resources. The particular designs these farmers chose are only a sample of the variety of solar water heating and heat exchanger designs available. For example, several designs for drain-down water heaters are available which reduce the complexity and expense of the system.

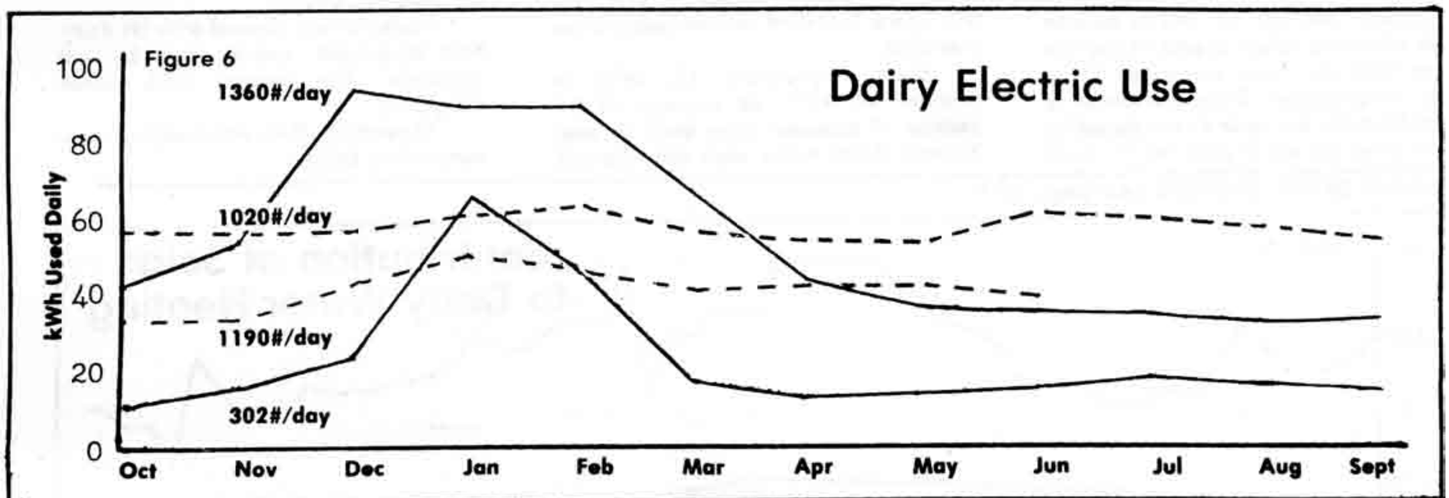
The advantage of the bread-box collector is its simplicity and low cost. For some, this may offset low heating capacity and restricted use to the warm months.

The thermosiphon collector can be a simple design too, yet higher output and year-round operation are also values. The sensitive operation of this system may not fit in many situations because the **storage tank must be located above the collector.** Whether this particular system can weather a Nebraska winter has yet to be proven.

The drain-down collector has the advantages of year-round use and greater heat gain although the complexity and cost of this particular design may discourage some.

The heat exchanger may be an effective device for some dairies since it has the advantage of operating daily, without sunshine, and throughout the year. It has the capability of capturing waste heat that otherwise may be lost, especially during the summer months. There are a variety of heat exchanger models on the market with a wide range of costs and efficiencies. Buyers should use caution in their selection.

All of the solar designs described previously offer other uses on the farm in addition to the dairy and are not limited to just dairy farms. **A solar water on the home may be a very cost effective energy saver,** especially with large families. For the family heating the home with wood during the winter, wood water heating makes a wonderful combination to solar water heating in the summer.



More Information

A variety of plans are available for different types of solar water heater systems. Readers may wish to assess their particular situation to decide what type of device may be suitable for them. The following sources comprise only a partial listing, some of the best the Energy Project has found for home-built systems. Many commercial systems are also available.

"Bread Box Water Heater Plans", Zomeworks Corp., P.O. Box 712, Albuquerque, NM 87103, $3.50. Plans for building a water heater from tanks painted black; includes 24" x 35" blueprints and a description of the principals involved.

"Solar Domestic Hot Water System Plans", Domestic Technology Institute, 12520 W. Cedar Dr., Lakewood, CO 80215. $25.00. Five basic low-cost solar hot water heating designs are provided in eight 18" x 24" blueprints with construction, performance and maintenance specifications.

Solar Hot Water Heater, Eastern Oregon Community Development Council, 72 pages, for $2.00. Order from National Center for Appropriate Technology, P.O. Box 3838, Butte, MT

Solar Hot Water Heater Manual, Akira Kawanabe and Arnie Valdez, San Luis Valley Solar Energy Association, P.O. Box 1284, Alamosa, CO 81101, $8.50. Fully illustrated with over 50 diagrams and photos, complete with blueprints, and material and tool lists for constructing a thermosiphon hot water heater.

"Direct Solar Hot Water System" available from the Solar Project, Community Action Program of Lancaster County, 127-133 North Concord St., Lancaster, PA 17602, $1.00. A seven page set of plans for construction of a simplified and low-cost, drain-down solar water heater.

PROJECT FOCUS #8

Small Farm Energy Project

Composting of Farm Manure

JANUARY, 1980

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

Sir Albert Howard utilized the composting process in India decades ago. He developed the technique to assist impoverished farmers increase soil fertility by making better use of organic wastes. Now a popular gardening technique and a waste disposal alternative for municipalities and large feedlots, composting has been slowly receiving greater attention as a valuable tool for the family livestock farm. Although composting of farm manures requires time and energy, which is difficult to measure, researchers have found a wide range of benefits in the composting process. The unique feature of composting is its biological process, which is completely different from the conventional N,P,K approach to soil fertility. As energy and commercial fertilizer costs continue to rise, composting will more than likely become more important in the future.

Managing Manure As A Resource

After learning of the relationship of rising energy costs to higher commercial fertilizer prices, cooperators of the Energy Project have considered various alternatives of lowering commerical fertilizer purchases. **Nitrogen fertilizers, in particular, require large amounts of natural gas during production. One alternative has been to better manage livestock manure, and thereby make better use of nutrients available in manures.**

Conventional Manure Handling

Conventional manure handling practices include the spreading of manure onto fields whenever convenient for the farmer. Often these times are during wet or frozen soil conditions, which do not allow the farmer to incorporate the nutrients into the soil to avoid leaching and volatilization of nutrients, particularly nitrogen. USDA figures indicate that **50-75% of the nitrogen can be lost during conventional manure handling,** with 25% lost within 4 days of field application.

Composting As An Alternative

—Phil and Mike Helmes, above, have used the "loader-spreader" method of compost turning. Although the method involves extra handling time, it makes use of common equipment most farmers already have.

—Edgar Wuebben, left, records temperature readings of his windrows of compost. Although composting is difficult to analyze, Wuebben is pleased with the results of using composted dairy manure in place of commercial fertilizers. Compost is the result of a biological process and a completely different nutrient source than the conventional N,P, and K approach to fertility.

Composting has been attempted by cooperators of the Energy Project as a manure management tool. Of the nearly 10 farms that began composting three years ago, four have continued their efforts yielding considerable information about the process. **Composting, basically, is a controlled microbial decomposition of livestock, crop and other residues.**

Composting, like many other energy conservation alternatives, is **"site specific."** Some farms can more easily adapt the process than others. Hog farmers in Cedar Co., for example, have low volumes of manure compared to dairy operations, making composting less "time effective" for swine enterprises. However, **where composting is not utilized, raw manures are best incorporated into the soil to conserve nutrients.**

Prior to composting, manures removed from livestock yards during winter and spring are piled in windrows at the end of a field and near the farmstead to minimize hauling costs.

The windrows are usually about 4 to 5 ft. high and from 8 to 12 ft. wide at the base, with about a 2 ft. flat top, and they are formed with a P.T.O. driven manure spreader, moving slowly forward to form the windrow. The beaters of the spreader break up and aerate the manure, blending bedding and crop residue with the manure. The composting process can begin immediately if conditions of moisture, temperatures and carbon content are proper.

Later compost windrows are "turned" to "aerate" the material.

The Composting Process

Decomposition by Aerobic Bacteria

In composting of manure and crop residue, the material is "aerated" by turning the piles, thereby incorporating oxygen into the pile. **Tiny microbes, bacteria and other organisms use the oxygen to consume the waste material.** Carbon dioxide, water vapor and heat are given off, just as in other biological activities.

Dr. Dan Dindal, soil ecologist from State University, Syracuse, N.Y., spoke to cooperators of the Energy Project on composting. He suggests that **organisms in the compost take various nutrients into their body tissue.** "They merely hold them in tiny banks to avoid leaching," Dindal explains, "until the nutrients are required by plants in the soil."

During composting, temperatures can exceed 150 degrees F. within the compost pile, as various organisms do their work. However, **temperatures should not be allowed to exceed 150 degrees,** notes Leon Chesnin, soil chemist at the U. of Nebraska. Higher temperatures will cause ammonia losses, which can be reduced by turning at the times of the higher temperature levels. However, researchers point out that nitrogen losses will always occur to a certain extent in composting. Dr. Hardy Vogtmann, a Swiss researcher, suggests losses can be 30% for nitrogen.

Moisture and Carbon Content Important

Optimum moisture content for composting manures is near 60% or about like that of silage. **Carbon-nitrogen ratios of between 20 and 30 to 1 are also recommended. Additions of straw bedding or crop residues provide for both carbon and moisture levels near the optimum ranges.** In their first composting efforts, cooperators of the Energy Project often had very wet manure, low in carbon content, that was difficult to compost. Edgar Wuebben and his two sons, Don and Terry, corrected the difficulty by using large quantities of straw bedding in the yards of the dairy herd, which also utilizes the residue for feed. Manure from a loafing barn is also scraped periodically and mixed with straw and other manure before being placed in windrows. Straw is harvested from stubble fields in late summer after the oats crop is chopped for silage. Corn stover is also being considered as a carbon source.

Bob Steffen, a farmer and Cedar Co. native, who has studied composting for several decades, suggests that with a low carbon to nitrogen ratio, composting requires more time and turning due to lack of air and usually due to very wet conditions. "The low carbon content, of course, will provide insufficient food for the nitrogen loving bacteria to reproduce fast enough in order to handle all the nitrogen," Steffen reports. "That is why a manure pile without bedding will always have a stronger ammonia odor than one with enough bedding. The nitrogen is escaping as a gas." Steffen also has a rule of thumb for checking carbon content when "stacking" piles 4 or 5 ft. high: "If it won't stack up you need more bedding material." H.H. Koepf, a German soil scientist, suggests additions of 5-15 lb. of bedding to livestock areas for every 1000 lb. of animal weight on a daily basis.

Compost Turning

Cooperators of the Energy Project process manure in the composting operation during late summer months. Farmers find extra time during August for composting, between the busy planting and harvesting seasons. The compost is "turned" once a week for four weeks using various types of equipment. Compost is usually "finished" when the compost cools to under 100 degrees and no ammonia odors are evident. **Although August may be convenient for composting, it is always best to compost the stockpiled manures as soon as possible,** to avoid nutrient losses, particularly ammonia. Initial results of Energy Project studies seem to indicate that **considerable nutrients can be lost from livestock yards and windrows before composting begins.** Manure upon leaving an animal can have over 5% N, which can be reduced to much less than 1% with delayed and improper handling. Chesnin reports, "Fresh beef cattle manure has about 3.5 per cent nitrogen. A considerable amount of this nutrient can be lost if the waste is not managed properly. Composting under controlled conditions will conserve and concentrate the nitrogen in the manure." **However, time and energy inputs into the compost process should be minimized to hold processing costs down.**

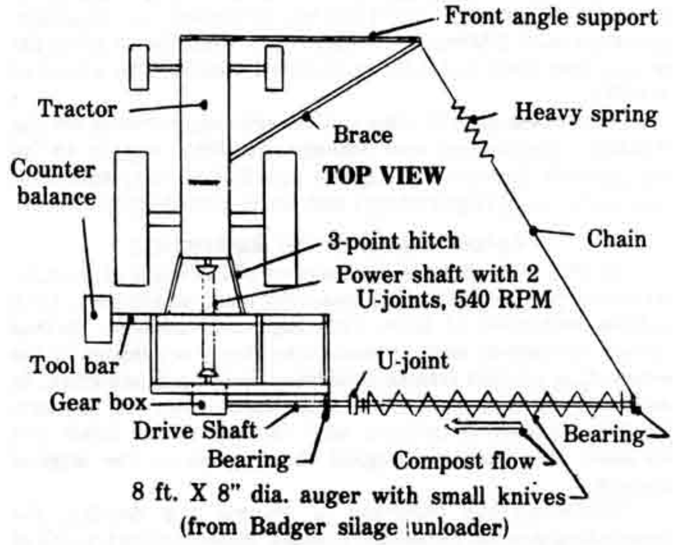
Composting Equipment

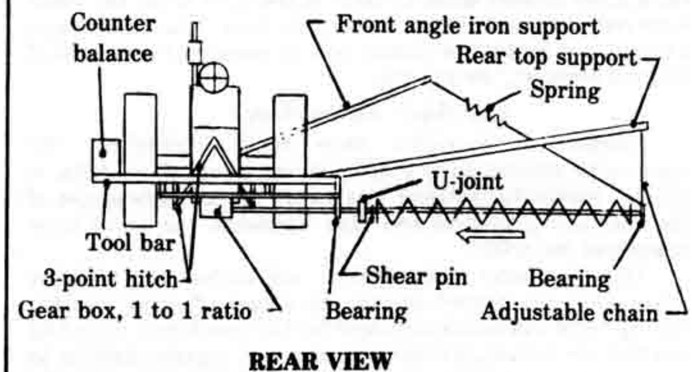
—Edgar Wuebben built his own compost turning machine entirely from old equipment on the farm. An old tool bar, gear box, and silage auger make the major components. The auger on the right opens up the compost windrow, aerating the material. Later a front-end loader repiles the windrow.

—The home-built compost turner constructed by Bill and Martin Kleinschmit from an old windrower. The system straddles the manure windrow in the compost "turning" process. A 9 ft. wide by 24" diameter rotating drum replaces the cutting head of the windrower. Hydraulic power is used for the ground drive and slow forward motion.

(continued on page 37)

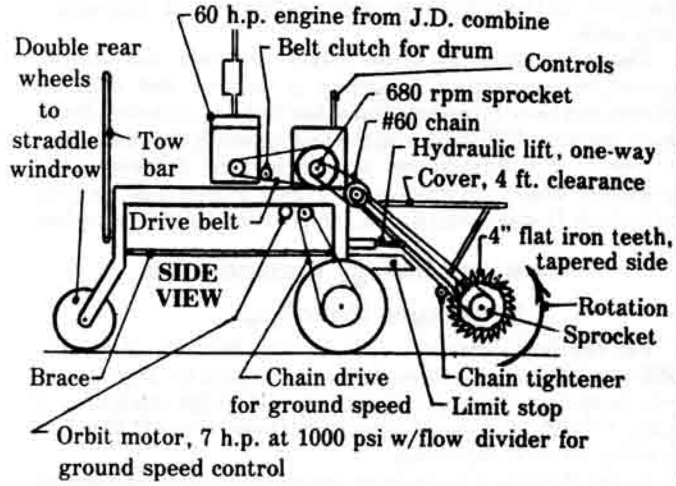
Wuebben Home-Built Compost Turner

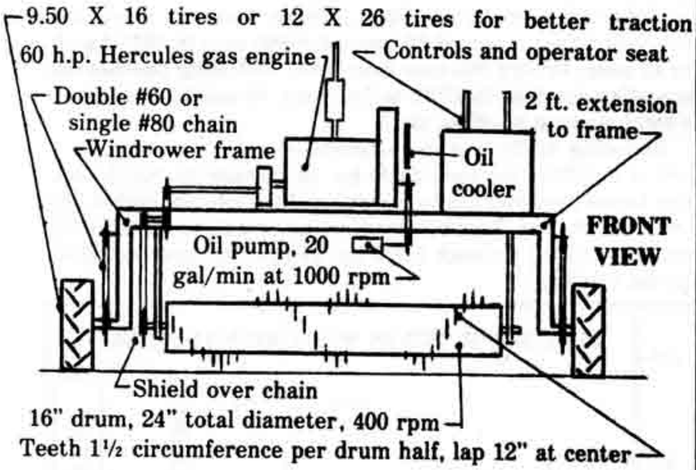




NOTE: PTO shaft should be long enough to allow raising & lowering of system by 3-point hitch

Kleinschmit Home-Built Compost Turner





Home-built Compost Turners

Edgar Wuebben built his own compost-turning device from discarded materials at the farm, including a gear box, tool bar and silage unloading auger. The device is mounted to the tractor by a 3-point hitch and is driven by the P.T.O., as the small tractor "idles" down the pile. The process takes about six passes down both sides of the compost windrow, "opening" the pile and spreading the pile out over the soil. After the aeration, a tractor front-end loader is used to repile the material.

Bill Kleinschmit, another cooperator of the Energy Project, **has used a home-built turner constructed from a used forage crop windrower and other materials** for just over $1100. The turner straddles 4 ft. X 8 ft. compost windrows. A rotating drum with flat iron teeth replaces the cutting head of the conventional windrower and is driven by a roller chain from the 60 h.p. engine. The drum lifts the material up and toward the rear of the turner, and can be raised or lowered by hydraulic cylinders. The turner uses a hydraulic pump, orbit motor and flow control valve for the ground drive to obtain slow forward motion, although much of the drive assembly is the same as used by the original windrower. The frame of the windrower was also raised to a level 2 ft. higher above the ground, in order to straddle the four foot high windrows. Kleinschmit uses a belt and chain drive for the drum rotation, but recommends a hydraulic drive to avoid problems with chains near the windrow, although that would require more power and a larger cooling device for hydraulic fluid.

Loader-Spreader Method

A common procedure for composting used by many farmers is the **use of the manure spreader and front-end loader,** commonly available to most farmers. The manure, after it is in a windrow, is loaded back onto the spreader with the loader and passed through the spreader into another parallel windrow, aerating and mixing the material so that organisms can process the material effectively. Mike Heimes, also an Energy Project cooperator, used the loader-spreader method in 1977, turning compost four times. However, Heimes has found that the great amount of time required by this method is a disadvantage to composting. During 1979, he used the commerical "Easy Over" composter to speed up the operation.

Commercial Composter Saves Time

In 1978, the Wuebben's acquired the "Easy Over" commercial composting machine. The machine costs over $4000 but is capable of processing 400 to 500 tons of compost per hour. Therefore, it can save time in composting, although it requires a larger tractor with at least 100 h.p. The machine resembles a large garden tiller, which lifts the material up and back into the windrow, aerating one-half of the windrow with each pass of the machine. A tractor with hydrostatic drive is preferred for slowest possible ground speed. The machine can be towed easily over county roads for custom services. The Wuebben's have also rented the device to farmers, including Mike Heimes.

Energy, Labor and Nutrient Considerations

Extensive experience has been gained by Energy Project cooperators in the compost process, yielding much information on the topic.

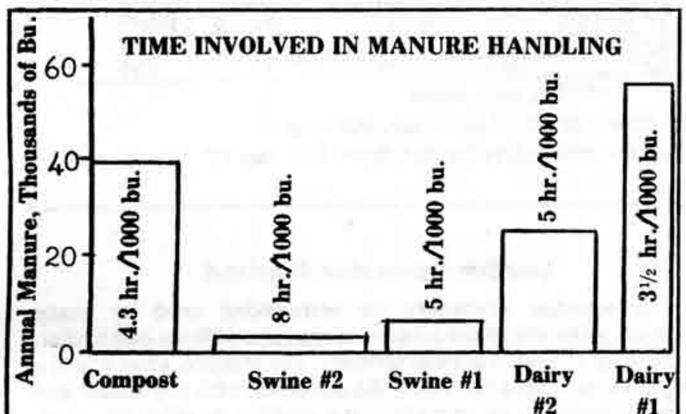
The information gathered relates to time and energy required in composting, reduction in volume and mass of manures, nutrient retention, and other factors. Although **these factors are very difficult to analyze** and although the results are not precise, the information is sufficient to develop initial impressions about the process. The data is based on records kept by four farmers who do not compost and two farmers who do.

Time and Energy Consumption in Manure Handling

For the hog producers with limited volumes of manure (3,000 to 6,000 bu./yr.), three days were enough to clear out the yards in spring. But dairy operators with large quantities of manure (25,000 to 55,000 bu.) required three weeks (130 hours) of hauling to clear the yards.

In the Wuebben composting operation, it took two people an equivalent of one week to haul manure to the windrow in 1978 and an equivalent amount of time to haul finished compost from the windrow to the field. Three turnings with the home-built auger required 30 hours for 300 tons **in 1977** but **it took 12 hours to turn 600 tons four times with their commercial composting machine in 1978, or between 10 and 15 percent of the total manure handling time.**

Reducing all figures to comparative units, it took 5 to 8 hours of handling for each 1,000 bu. of manure on hog farms. Dairy farms required 2½ to 5 hours of handling for each 1,000 bu. of manure. The Wuebben composting operation required 4.3 hours of handling for each 1,000 bu. of raw manure, including compost turning.



1978 FARM TIME AND ENERGY RECORDS

Farm	Total loads	Spreader cap., bu.	Loads/hour	Total Volume, bu.	Total hours	Hours/1000 bu.	MBtu/1000 bu.	Total gas use, gal.
Dairy #1	280	150	2.1	56,000	130	2.5	.4	127
Dairy #2	160	160	1.2	26,000	130	5	1.1	230
Swine #1	100	60	3.6	6,000	28	5	1.3	62
Swine #2	42	75	1.7	3,000	25	8	2.1	53
Compost #1	260	150	3.2	39,000	80	2	.2	
Turnings					12	.3	.3	
Application	200	150	2.5	30,000	80	2	.3	
Compost Total					172	4.3	.8	220

Energy requirements paralleled patterns of the labor requirements. The hog operations used from 1.3 to 2.1 MBtu for each 1,000 bu. hauled. Dairy farmers used from .4 to 1.3 MBtu for each 1,000 bu. For each 1,000 bu. of manure, the Wuebben operation used .2 MBtu for hauling to the windrow, .3 MBtu for turning four times and .3 MBtu hauling to the field for a total of .8 MBtu.

From these figures, time and energy requirements for the Wuebben composting and manure handling appear to be intermediate between the highest and lowest dairy operation time and energy requirements and lower than hog operations.

Volume and Mass Reduction

In 1978, Wuebben made windrows of 260 loads of manure. After composting, he hauled away 200 loads of compost, for **a volume reduction of 25%.** This happened because various carbon compounds were consumed by decay organisms in the composting process releasing carbon dioxide and moisture. In addition, the compost became less dense than the manure. Similar volumes of manure and compost were dried and weighed. **The compost weighed ½ as much as the original manure.**

Combining the reduction in volume and density, **the composting process reduced the entire mass [weight] to 3/8 of the original manure mass.** Chesnin at the U. of Nebr. has noted mass reduction up to 1/6 of the original mass. "On the average, 4 to 6 tons of beef cattle manure will be converted to one ton of finished compost," he reports.

Nutrient Retention

Samples of nutrients were taken throughout the composting process on two dairy farms. From the results, it appears **substantial nutrient loss occurs during early stages of the composting process and that nutrients can leach from composted materials.**

Organic matter content (OM) and carbon to nitrogen ratios (C:N) are plotted against the stages of compost (first, second, third and fourth turnings) for the two farms. Both OM and C:N are indicators of the proportion of organic material to mineral content. Both measures are based on dry weight. An increase in organic matter content means a relative decrease in mineral content.

Results from the Wuebben farm (A) demonstrate the expected patterns in figures 1 & 2 with OM content and C:N ratios declining as the decay organisms consume the available carbohydrates. Results from the Heimes windrow fit the pattern up to the third and final turnings. OM content and C:N ratios double. It is unlikely the increase was caused by production of carbon and organic matter in the midst of a decay process. The dramatic change is more likely **the result of nutrients leaching during heavy rains** (4" to 5") which occurred during the week of October 15th after the last Wuebben sample was taken, but three weeks before the final Heimes sample was taken. **A 1978 compost sample stored by Wuebben for a year also showed low nutrients after one year.**

Nitrogen content is plotted against the composting process in figure 3 indicating fairly consistent levels for the Wuebben operation but substantial decline in nitrogen for the Heimes farm (B) after the second turning. Because this figure doesn't take into account the reduction in mass during the composting process, in figure 4 is presented nitrogen content relative to the nutrients in the manure at initial phases of the composting process. In the Wuebben case, 20% of the original nitrogen after the first turning was retained while the Heimes operation retained from 10 to 15%, based on constant mineral content.

Techniques which may prevent this nutrient loss include covering the windrow to prevent ammonification and leaching, greater use of straw to absorb liquid nutrients, early turning after windrowing in the spring, and prompt field applications of the finished compost. Further research would be valuable to confirm some of the initial results of Energy Project studies and to find ways of improving nutrient and energy conservation.

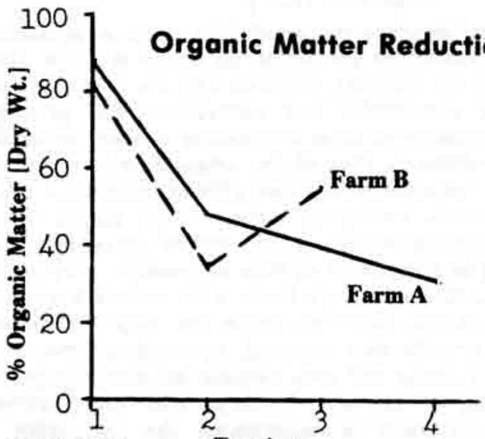


FIGURE 1

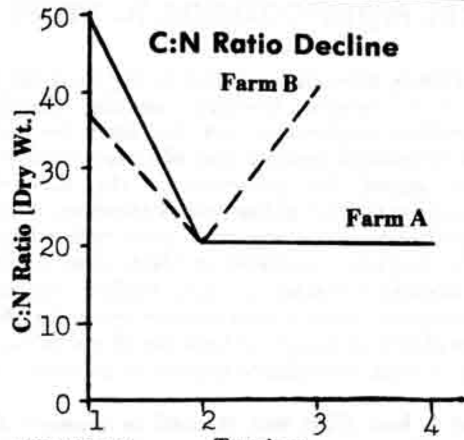


FIGURE 2

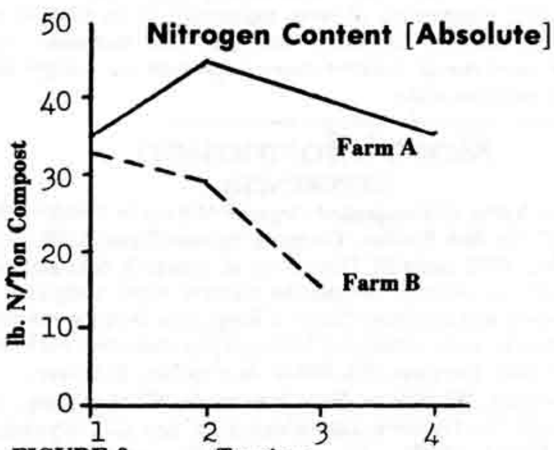


FIGURE 3

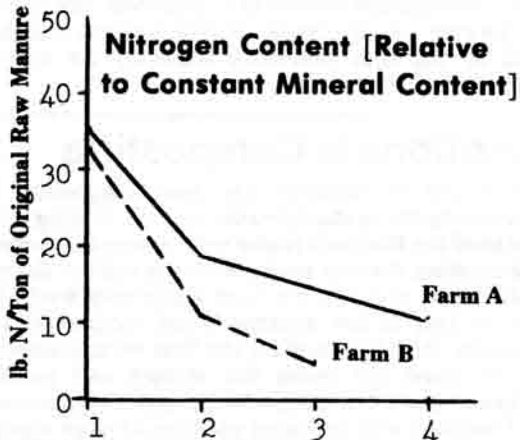


FIGURE 4

Advantages of Composting

Variety of Benefits

Although nutrient conservation was thought to be a major advantage of composting, preliminary studies have shown otherwise, as indicated previously. It may be possible to improve the various nutrient factors by utilizing more care and timeliness in the process. However, it should be emphasized that **N,P, and K nutrients probably comprise only a small portion of the many benefits that farmers can realize from the composting process.**

Heat is generated in the compost piles by the micro-organisms up to temperatures of 150 degrees. Such **temperatures can destroy the germination potential of weed seeds** in manures and crop residue. Edgar Wuebben sees better weed control without herbicides as another plus in composting. The high temperatures can also help to control flies.

Researchers have found that **compost improves the tilth of the soil, its resistance to erosion, and the soil's capacity to hold water for plant growth,** thereby requiring less rainfall or irrigation for productive crop growth. **Compost can also improve the availability of plant nutrients,** both in the compost and in the soil to which compost is added. Phosphates, for example, can be added to manures during composting, making the mineral more available to plants, especially in soils where such minerals are often "tied up" and not made available to plants.

Bob Steffen states, **"The most significant contribution made by the composting process is its long term effect on soil fertility, especially on accumulated fertility."** Steffen has followed European researchers in their studies of farm composting, which appear to be more advanced than that of the U.S. Steffen notes that the German H.H. Koepf has found that raw manures will stimulate biological activity in the soil, but only for short periods. "Composted material, on the other hand," Steffen reports, "not only stimulates these biological processes, but also enhances the supply of accumulated fertility, which is the real basis of a fertile, productive soil." He further notes that compost encourages root growth, while raw manure can inhibit it. "Improved root growth, in turn, loosens the soil, improves tilth, and adds to the organic matter content."

The Swiss researcher, Hardy Vogtmann, suggests that nitrogen fixing bacteria exist in the compost pile and continue fixation when compost is applied to the field. In addition, he reports that European research indicates composts will include natural antibiotics, hormones and other properties beneficial to plants.

Mass Reduction & Proper Application

Chesnin of the U. of Nebr. indicates that one of the chief benefits of **composting** manures is that it **lowers the costs of hauling manures,** often containing as high as 95% moisture, to fields. "It costs to process, but it costs more to haul water to the field," Chesnin reports. "Fewer trips across the field are required in compost applications.

The over-all reduction in weight and volume also means less total soil compaction. Soil compaction by heavy equipment and the weight of manure can damage the soil structure, lowering productivity, especially during wet soil conditions.

Yields and Fertility Expenses

Compost, when substituted for commerical fertilizer, not only saves money, but also **provides most of the nutrients for productive crop yields.** In the fall of 1977, Edgar Wuebben applied 7 tons of compost per acre to one of his fields. In 1978,

(continued on page 40)

Compost Applications to Soils

Spreading of finely processed compost at low rates can be difficult with some manure spreader models. Modified spinner-type fertilizer applicators can be used for light applications. The Wuebbens process over 600 tons of compost per year. They spread the materials in the fall with conventional manure spreaders at the rate of about seven tons per acre. Such **applications are made every three to four years,** with much of the nutrients available to plants over several years. The late German soil scientist, E.E. Pfeiffer, indicates that most farm composts "have a total nitrogen content of .5 to .7% at a moisture of 50% and more, or between 10 and 15 lbs. of N per ton. Energy Project experience appears to be within this range.

The compost is best tilled into the soil to conserve the bacterial activity of the compost. This is usually done with a chisel plow or a disk. The Wuebbens have also spread the compost onto fields planted to corn as a "sidedress" fertilizer in June when the corn was six inches tall. The compost was then incorporated by the first cultivation following the manure spreader, which straddles the corn rows.

Summary

The time and energy expenses of dairy manure composting and compost applications are within the range of other dairy farmers who do not compost manures, and are relatively less than those of comparable hog operations. **The principal measurable advantage of farm composting appears to be the reduction in volume to 75% of the original volume and an over-all weight reduction to less than 40% of the original mass. Substantial nutrient losses can occur** in early stages of the process and leaching losses are not always prevented. **Raw manure should be composted as soon as possible.** Crop yields appear to be maintained at high levels with moderate levels of compost applications. However, these are only preliminary research findings. **Further research** by various groups on energy use in turning and crop residue handling, long-term effects of compost on soil fertility, and also nutrient conservation **will assist in determining the real value of composting at the farm level.** Improvements in equipment will help to further improve time and energy conservation. But it appears that composting of farm manures can be feasible on farms with sizeable livestock numbers. **The technique will probably continue to become more important as energy and fertilizer costs escalate.**

Variations in Composting

LaVern Truby of Randolph has been composting for several years using the loader-spreader method. During 1978, however, he **used the front-end loader only to turn the compost for the final aeration,** thereby saving time and energy. Energy Project staff believe that the front-end loader only method is appropriate, as long as the material is not compacted. The manure spreader should be used for the first several aerating operations, to blend and refine the manure and residue. Europeans have reported on using a feeder-type wagon to make windrows of compost with continual additions of more manure to one side of the windrow and removal of finished compost from the other side. **No turning is used** after the initial aeration when the material is added to the pile. Single windrows have also been used without turning. **However, proper moisture and carbon content are essential** for good composting by this method, and such conditions are often difficult to obtain.

For manure stored in windrows during cold winter months, the piles may be larger and near 9 ft. tall to aid initial composting action and to retain heat, suggests Dr. Leon Chesnin. Some farmers have considered "dumping" the manure into windrows, using special dump wagons to hasten the hauling process. Composting can begin later during the first aeration when convenient. However, the manure spreader is beneficial in mixing and aerating the manure, and making properly shaped piles.

Small additions of soil are recognized as beneficial to composting processes. Adding some mature compost to the process as an "innoculant" is also suggested. **Cooperators of the Energy Project use no commercial bacterial innoculants in composting.** The Wuebbens have found that waste paper and feed sacks make a good addition to the compost. Several people from nearby towns are disposing of waste paper for composting at the Wuebben farm. Paper goods are thoroughly decomposed, converting another waste to a resource.

[Compost Advantages, continued from page 39]

that field yielded an average of 80 bu./acre. The application amounted to 112 lbs. of N, 84 lbs. of P and 161 lbs. of K per acre. That same year Wuebben also spent an average of $13.70/acre for commercial fertilizer on 145 acres of another corn field. The application amounted to 43, 21, and 10 pounds respectively of N,P and K. That corn yielded an average of 71 bu./acre.

Yield comparsions for 1979 are not meaningful because of a late July hailstorm occurring just after the tasseling period.

More Information

REFERENCES

"The Value of Composted Organic Matter in Building Soil Fertility", by Bob Steffen, **Compost Science/Land Utilization,** Sept./Oct., 1979, page 34. Discussion of research data showing the greater benefits of composted manure when compared to raw manure, and the importance of long-term fertility reserves and humus in soils; extensive bibliography included. JG Press, Inc., Box 351, Emmaus, PA 18049, bi-monthly, $15/year.

"Compost, What it is, How it is made, What it does," by H.H. Koepf, Bio-Dynamic Literature, P.O. Box 253, Wyoming, Rhode Island 02898, 18 pages, $1.00, reprinted from **Bio-Dynamics** Issue No. 77, 1966. Basic introduction to composting for farmers and gardeners on the what, why, and how of composting, various inputs to compost piles, carbon-nitrogen ratios, equipment use, micro-organisms, how much to apply and much more. Excellent!

"Biodynamic Composting on the Farm," by Peter Blazer and **"How Much Compost Should We Use?"** by Ehrenfried E. Pfeiffer, a booklet from Biodynamic Literature, Box 253, Wymong, Rhode Island 02898, 23 pages, $1.65. Comments on composting methods and conditions, equipment used, and "further suggestions for composting operations." Includes information on soils, organic matter levels, soil life, compost application rates and affects under various soil conditions.

"Composting Pointers," Small Farm Energy Project, P.O. Box 736, Hartington, NE 68739, 25 cents. A one-page review of suggestions made by Dr. Hardy Vogtmann, Swiss compost expert during his Nebr. visit in May, 1977.

"Composting Converts Waste Into Valuable Resources," by Leon Chesnin, **Farm, Ranch, and Home Quarterly,** Fall, 1977, U. of Nebr., Lincoln, Nebr., page 19. Discusses the value and operations of composting for agricultural and municipal wastes, as well as nutrient and large energy saving resulting from composting various wastes in Nebraska.

"Compost", by C.J. Fenzau, **Acres, U.S.A.,** Dec., 1975, page 8. Fenzau lists "18 merits of pre-digested manure." Includes suggestions on composting and gives activities of compost microorganisms that make it valuable to soils. Also includes some "lab data" and hints on pricing compost.

PROJECT FOCUS #9

Small Farm Energy Project

The Pinkelman Solar Farrowing Barn

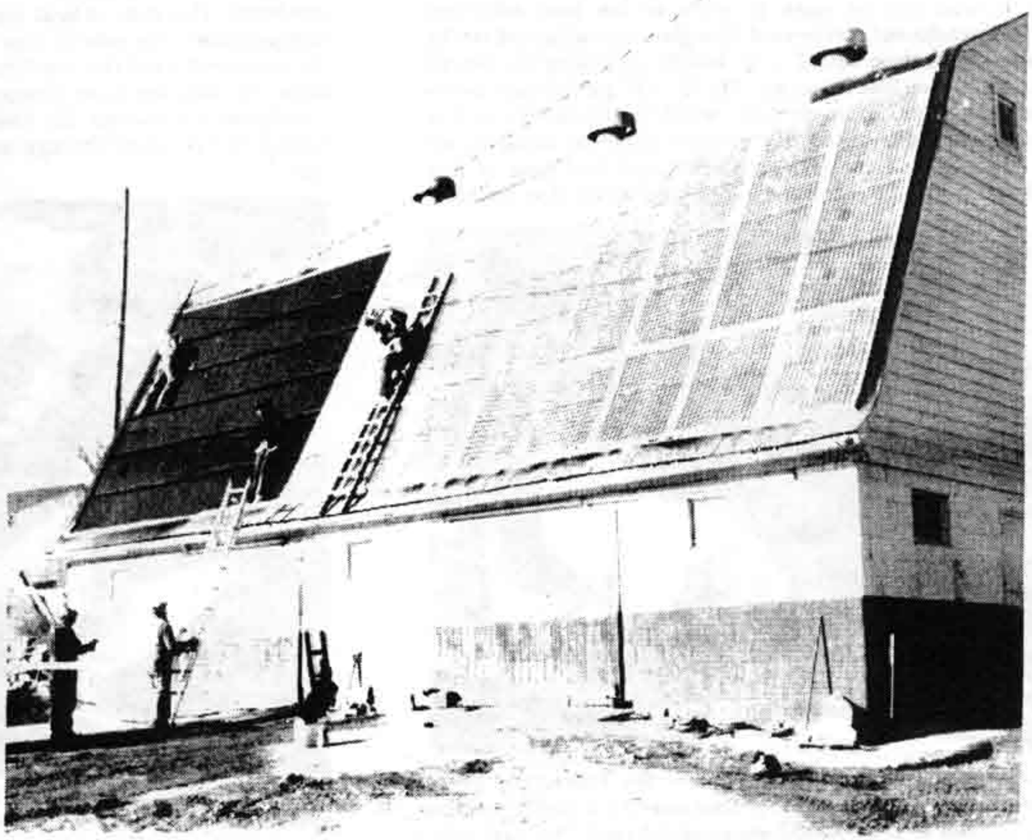
MARCH, 1980

—Rick Pinkelman.

When Rick and Mary Pinkelman took over the family farm, they decided to change the primary livestock of the farm from dairy to hogs. While planning the conversion of the dairy barn to a farrowing barn, the Pinkelmans joined the Small Farm Energy Project.

The Pinkelmans have found that solar energy can be used effectively in the hog farrowing enterprise. They constructed one of the first major solar innovations of the Energy Project onto an existing barn. They first insulated the structure well. Much was learned from the experience, including the importance of keeping a solar system air-tight. But the project demonstrated how a good innovation is developed when the farmer, and not just the engineer, is involved in the design. Other farmers will undoubtedly benefit from the Pinkelmans experience.

—Mary Pinkelman.



—Shown above is the 850 sq. ft. solar collector used for heating ventilation air in the farrowing barn of Rick and Mary Pinkelman. The 17 X 50 ft. solar collector was mounted onto the roof of an old dairy barn. The solar system was one of the first major solar devices used by Energy Project cooperators on an existing building.

First Solar Collector in the Area

Rick Pinkelman got interested in making use of solar energy after hearing about the simple window box collector at an Energy Project workshop early in 1977. Not one for delays, **Rick found an old storm window and enough spare lumber to build the first solar collector in the county.** After hooking up a small fan from an old slide projector, be became convinced that solar energy could work for him.

Renovating a Dairy Barn

Though solar energy seemed to be an idea with promise, it was hard for farmers to be optimistic that winter. The previous three years were dry as farmers in the plains experienced the worst drought in 20 years. Many farmers received FmHA disaster loans and the Pinkelmans decided to make their investment in livestock facilities.

With a disaster loan in hand and conversion of dairy barn to a 22-sow farrowing facility in sight, it wasn't long before Rick included elements of solar design in his renovation plans. **Bill Peterson, an extension engineer at South Dakota State University, provided imagination and timely technical assistance in the design of the Pinkelman's solar ventilation system.**

The 17' x 50' roof facing the south at a 70° angle from the horizontal was an ideal application for a flat plate solar air collector. So Rick and Mary were among the first cooperators to prepare for a solar installation by insulating the area to be heated.

Insulation Is the First Step

Weatherization and insulation measures are the first steps to be taken for solar heating projects. In the farrowing house this was accomplished by studding out concrete block walls, insulating with 3½" of fiberglass insulation, and covering it with chip board. The north wall is well protected from the elements as the barn, built into a hillside, was provided with a "berm" years ago. The ceiling of the farrowing unit was insulated economically by stacking bales of hay in the hay mow above. A bale of hay 1½' thick has an R' value of 14, according to experts.

The Solar Project Design

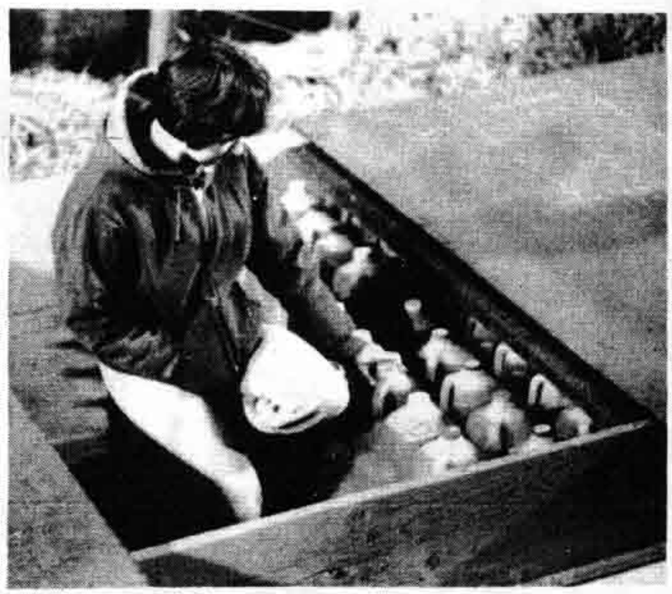
The basic ideas for the solar heating unit are fairly simple, but the actual application of the solar principles required careful design work and construction. William Peterson was most helpful in assisting Pinkelman with the solar design.

Designing and Building the System

The roof of the barn was previously covered with sheet **metal.** It was painted black to serve **as the heat collecting surface. Translucent corrugated fiberglass was attached to the roof/collectorsurface** with 2" x 2" boards extending the length of the roof at two foot intervals. The 2" x 2" purlins also serve as separations for the six air ducts which the air follows as it is drawn through the collector. In other collector designs, air often flows behind the collector plate and less heat is lost though the front of the collector. Redwood strips that matched the corrugations of the sheet metal and fiberglass were used with silicone caulk to minimize air leaks in the collector. Collectors have been known to lose heat through leaks before the warm air is delivered to the structuce.

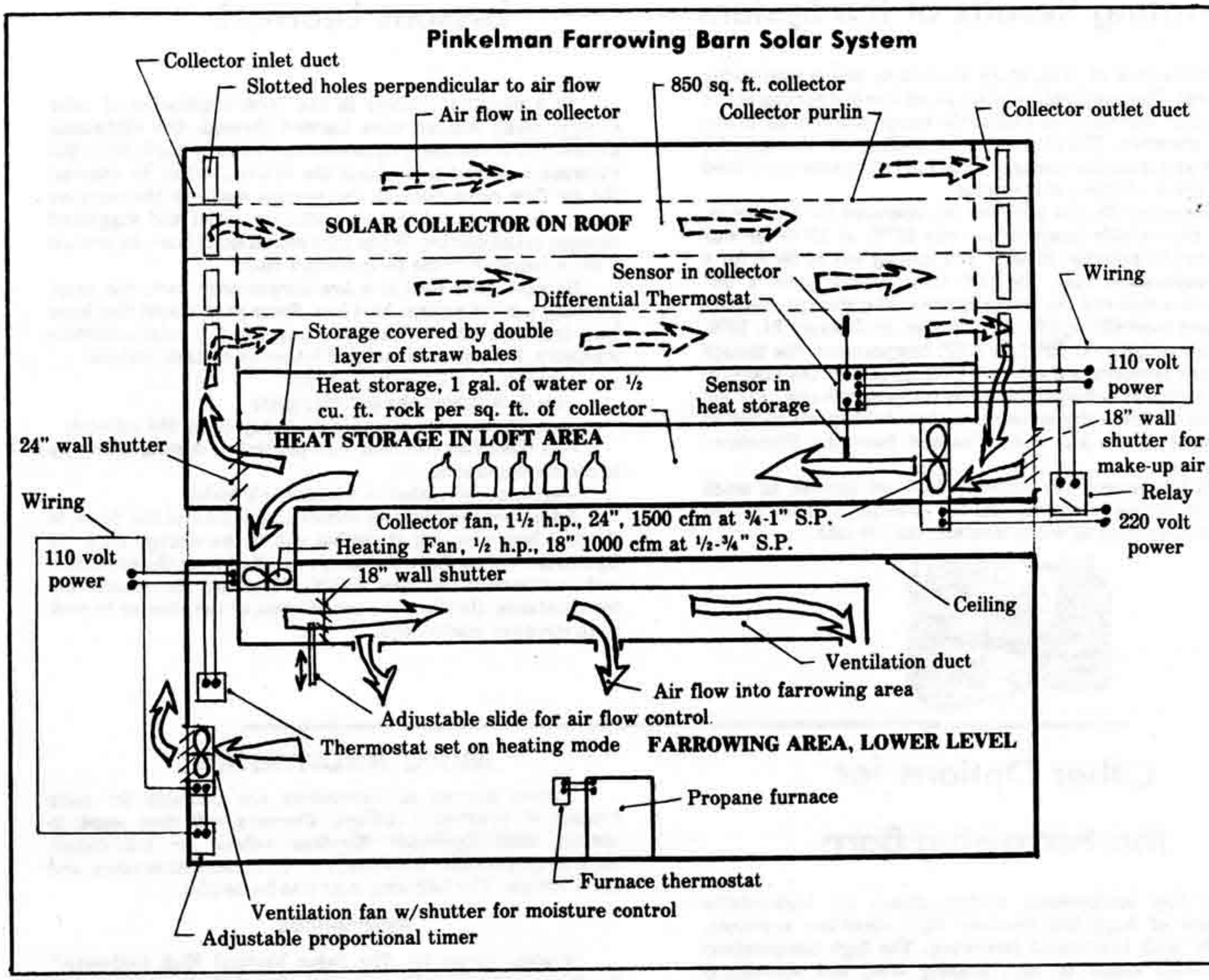
Air from the barn is pulled through the collector by a 2000 cfm fan; the warm air is blown through a wide duct filled with 850 gallon milk jugs containing a mixture of water and methanol. This type of heat storage proved quite inexpensive and practical. The cubical jugs were donated by individuals in the community and the 1 to 8 ratio of methanol to water should keep the mixture from freezing to 0° F. A second fan pulls ventilation air through the heat storage duct where the air is heated before going through another duct into the farrowing unit.

—Construction work underway on the Pinkelman solar farrowing barn. Fiberglass was placed over 2 X 2 purlins, which were mounted to the original sheet metal roof. The roof was painted black. Holes at either end of the roof are used to move air between the barn and the collector. Heat storage is located in the loft of the barn, which has a capacity for farrowing 22 sows at a time.



—Mary Pinkelman assists in the construction of the solar system for the Pinkelman farm's farrowing barn by placing plastic milk jugs filled with water into the heat storage area. 850 one-gallon milk jugs were used for the storage system. Some difficulty has developed with leakage of the jugs.

(continued on page 43)



Integrating the System Controls

The four elements of the solar system: the collector, heat storage, air flow components, and propane back-up heater had to be integrated so they would work together. Bill Peterson's expertise was helpful in matching the size of the storage capacity with the collector size, figuring optimal flow rates, duct size and control instruments, as well as construction hints, which made the system more effective.

A differential thermostat controls the solar fan. A heating/cooling type thermostat regulates the second fan. A third fan also aids ventilation and is controlled by a timer.

Rick used his innovative talents to integrate the heating/cooling thermostat, which controls the storage fan, with the thermostat controlling the propane furnace. The furnace provides back-up heat for the solar system. **The combination of Rick's talents and Bill Peterson's expertise represents how a good system is developed when the farmer is a part of the design process.**

Rick built the collector himself with the help of neighbors when putting up the large fiberglass sections. **The cost of materials for insulating the barn and building the solar system was just over $1900.** Rick figures he built most of the system over a period of three weeks, while doing the rest of the usual farm operations.

Rick has found that the solar innovation and the added insulation have saved considerable amounts of propane, although the savings have varied from year to year, making it difficult to estimate actual return on the investment. The insulation of the barn is probably as effective or more effective in saving energy as the solar system.

Cooling Used in the Summer

The Pinkelmans have been using their system to **pre-heat ventilation air in the winter and to cool the facility in the summer.** The system is shifted from heating to cooling by reversing sensor connections on the differential thermostat. At **night, the water jugs in the storage compartment are cooled** so that the ventilation air can be tempered during the daytime. This saves the investment and expense of other air cooling devises.

The Cost of the Project

MATERIALS COST FOR BARN RENOVATION	
Insulation	550
Collector (850 sq. ft.)	600
Heat Storage & Ducts	500
Fans and Controls	310
Total Cost	**$1960**

Operating Results of the System

In November of 1978, Mary Pinkelman began **monitoring** the system. The temperature of air going into and coming out of the collector was noted as well as the temperature of air in the storage chamber. Clocks on the fan pulling air through the collector and from the storage to the farrowing area were used to keep track of hours of operation.

On November 30, the collector fan operated for 5½ hours. Though the outside temperature was 22°F, at 10:15 air was going into the collector at 46°F and coming out at 66°F for a **20°F temperature rise**. By 1:00 the collector gave **a 34° temperature rise** and the temperature in the storage chamber was raised from 52° to 58°. At 1:00 p.m. on January 24, 1979, air left the collector at 80°F for a 32° temperature rise though the outside temperature was 18°F. About 15% of the available solar energy was collected, based on temperature rise and air flow rates. Similar solar systems could probably perform better using some of the knowledge learned from the Pinkelman experiences.

Rick has noticed the collector does not provide as much heat when strong winds cool off the collector surface. It also provides more heat in warm weather than in cold.

Lessons Learned

As a pioneering effort in the farm application of solar energy, **many lessons were learned through the Pinkelman experience.** When the system was completed in April, 1978, Bill Peterson returned to evaluate the system. When he checked the air flow rates through the various ducts in the complex system, he concluded that air leaks may exist and suggested changes in the ducting. When Rick sealed leaks later, he noticed a 10° F increase in the temperature rise.

Because solar heat is a low-temperature heat, one must jealously protect against heat loss. **Some precautions that have been taken on later collectors** to improve the solar collection efficiency, but not used on the Pinkelman system, include:

—insulation behind the collector
—air flow behind the collector plate
—air filters in ducts where dust may cover the collector
—all fiberglass installed with protective coating facing up to reduce discoloring
—system well-sealed to minimize air leaks

After operating for two winters, Rick noticed the liquid in the jugs began leaking at the hot end of the storage duct. He figures the cracks along the seams resulted from the expansion and contraction of the liquid occurring in fluctuating temperatures. He plans to convert some of the storage to rock or to stronger plastic jugs.

Other Options for the Farrowing Barn

The hog confinement facility allows for high-volume production of hogs but involves high operating expenses, especially with year-round farrowing. **The high temperature requirements result in high heating bills,** and substantial ventilation is necessary to reduce moisture and minimize disease problems. **The heat lost in ventilation further contributes to the heating load.** By renovating an existing building, the Pinkelmans have reduced their initial investments, but alternative approaches do exist.

A heat exchanger is one alternative which reduces heat-loss in the ventilation system. It may be constructed in well-sealed buildings so that the **heat from exhaust air is transferred to cold ventilation air,** thereby saving considerable amounts of energy. In some cases the heat exchanger may be more cost effective than a solar system. Advantages of the exchanger are that it provides a more consistent humidity level than the solar system, and it operates daily without the sun.

A simple alternative to the confinement system is **portable huts** provided for each sow, located in alfalfa pasture or other areas, which may be moved to new locations for each farrowing. The **low investment and operating expenses** of such an approach may result in the most practical system.

Some cooperating farmers have adopted a European technique of building **hovers** in finishing sheds to conserve heat given off by feeder pigs. The simple concept involves straw bales suspended two feet above the floor. The same concept can be used for pigs in the farrowing pen. Some farmers have **built hovers of plywood located at the ends of the pens that are 1 ft. wide and 1 ft. above the floor**. The pigs congregate under the the hover where it is warm. The idea is to conserve the heat of the pigs for better health and also to conserve energy.

More Information

Various sources of information are available for solar heating of livestock buildings. **Farmers will first want to contact local Extension Services offices** for information regarding insulation, ventilation devices, ventilation rates, and other details. The following may also be helpful.

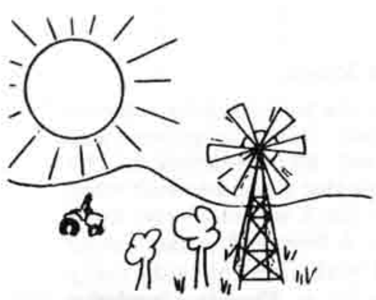
References

"Project Focus #3, The Solar Vertical Wall Collector," Small Farm Energy Project, P.O. Box 736, Hartington, NE 68739, 50 cents. A summary of various sizes of wall-type collectors used on homes for space heating. Many of the concepts could be applied to vertical walls for other buildings as well.

"Vertical Wall Solar Collector, Rules of Thumb", also available from the Energy Project for 75 cents. Includes suggestions for collector air gaps, painting procedures, fan sizes and other details.

"Catalog Sheet of Solar Heated Building Plans," Dept. of Agricultural Engineering, U. of Illinois, Urbana, IL 61801. The free, 2-page listing describes some 10 plans that are available from the U. of Illinois. Costs of the large blueprints are also included. Half of the plans apply to grain drying, but several provide information on solar heated farrowing barns.

"Heat Exchangers for Livestock Barns," Small Farm Energy Project Newsletter, March, 1979, page 10. A description of the heat exchangers developed by George Rauenhorst of Olivia, Minn. and used in various livestock barns to extract heat from exhaust ventilation air to pre-heat incoming cold air. For a copy, send 25 cents.



PROJECT FOCUS #10

Small Farm Energy Project

The Young Portable Solar Collector

MAY, 1980

The portable solar collector built by Gary Young of McLean, Nebraska has created considerable interest among farmers and others, including some USDA officials. Young has used the unique collector for both grain drying in the fall and space heating of the home during the winter. Since the collector is portable, it is quite flexible as a "multi-use" system. Young designed and built most of the collector himself. "Anybody can build it," says Young. And with much of the construction material recycled, the home-built collector proved considerably less expensive than commercial systems available. The portable collector may not be easily integrated into all farms, or be as cost effective as other options on some farms. But, based on energy savings achieved by the Young collector, it has been a major success for the Young farm and should pay for itself in four or five years.

Development of An Idea

Gary and Delores Young of McLean, Nebr. farm 320 acres in the southwest corner of Cedar County, raising corn, soybeans, milo, oats and alfalfa. Having 5 daughters and a 40-cow diary, they call their farm "Five Queens Dairy". A new dairy barn was built in 1977 and, as cooperators of the Energy Project, Gary and Delores pursued at that time the possibility of using solar energy for water and space heating in their dairy. They sought FmHA financing for a rather expensive commercial solar system, but the loan agency ruled that the system "was not economically feasible," which dampened the Young's solar enthusiasm for a time.

However, in the fall of 1978, Gary Young planned on using a solar vertical wall collector to dry grain in his old dairy barn, which was being converted to store corn. A similar collector had been considered for heating the home, but various circumstances made that difficult. The barn collector was fully designed when Young noticed an ad in a farm magazine for a portable solar collector. Suddenly, the Young solar plans changed again, but this time with increasing enthusiasm. A **portable collector could be used for both drying grain and heating the home.** And since the farm had an old running gear with four good wheels that was no longer used, Young decided that a **home-built collector on the running gear** was what he wanted, especially after he found out that the **estimated cost of the home-built rig was about one-fourth the cost of the commerical system. Young designed most of the portable collector himself, with some technical help from the Energy Project.**

—The 240 sq. ft. portable solar collector built by Gary Young is used for space heating in the home during winter months. Special ductwork is used to move air to and from the basement area through a basement window. Collector cost was about $1300.

Collector Construction

Recycled Materials

Young constructed the 10 ft. X 24 ft. collector over several winter months beginning in December, 1978, during good weather and when he had extra time. **Recycled materials were a key factor on the shopping list.** Besides the trailer, Young had a good supply of used lumber, mostly 2 X 4's and sheathing lumber from an old hog barn, that was useful for the collector.

"It isn't half as hard to build as most people think," notes Young. "Anybody can build it." Young built his collector using common carpentry tools and a welder that he had on the farm.

Unique Features

Other essential materials for the collector included **insulated ducts** to move heated air to the home and bring cold return air to the solar collector. A 700 cfm fan (rated at ½" static pressure) is used for home heating. A winch, cable and **pulley system is used to change the angle of the collector:** 60 degrees above horizontal for home heating during the winter, 45 degrees for fall grain drying, and 30 degrees for transport. Anchors and cables are used to anchor the collector to the ground when in use in order to avoid wind movement.

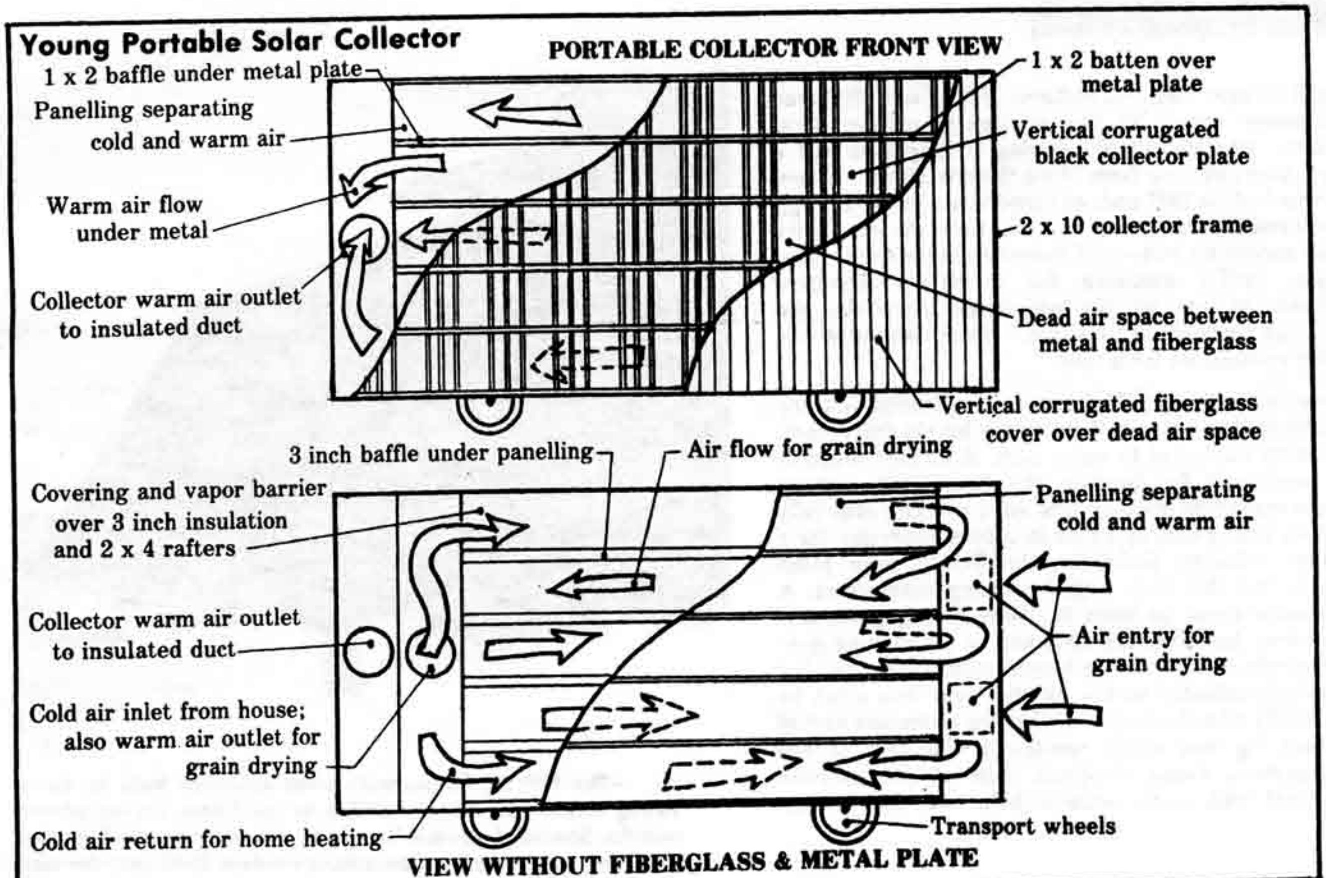
The Young collector was one of the first collectors of the Energy Project to **use baked enamel painted corrugated aluminum for the collector plate.** Although the metal is not available in black, the factory baking process insures a good paint bond to the metal. It requires repainting black. Some of the earlier collectors of the Energy Project had used galvanized metal, which is difficult for securing a good paint bond. Another unique feature of the Young system is the **protective weather-proof covering over the insulated ducts** carrying air to and from the collector. An exhaustive search by Energy Project staff resulted in the use of 18" diameter corrugated drain tile for the covering. The material, in 30" lengths, was flexible and easily cut and riveted to desired lengths.

Construction Steps

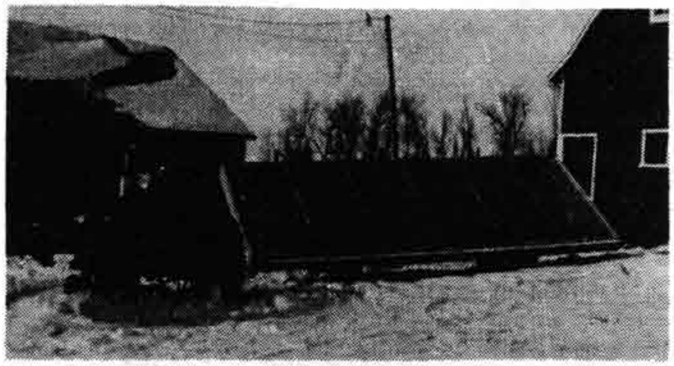
Young started construction of the portable solar collector by first modifying the running gear. It was lengthened and framed to accomodate hinges and lift equipment of the collector. Then **the 10 ft. X 24 ft. collector frame was built using 2 X 10 lumber.** It was studded out like a wall of a house using old 2 X 4's and 1 inch sheathing. A front-end tractor loader and several neighbors helped with mounting the heavy collector to the transport rig. Then **3½ in. fiberglass insulation was used** between studs, and then covered by a vapor barrier and press plates. Next an air way was made to move cold air from the inlet end of the collector to the opposite end. Young then mounted a layer of wall panelling to separate that airway from the warm airway behind the aluminum collector plate. 1 X 2 lumber was used to form the air gap under the collector plate. Above the collector plate, 1 X 2 lumber was also used to support the fiberglass cover over the metal. The collector was then connected to the house at a basement window. One duct moves cold air to the collector and a second duct carries heated air to the basement. The fan was added in the basement. **A duct is used to direct cold air from the floor of the basement to the collector as the fan pulls air across the collector, moving heat to the ceiling of the basement.**

Young also constructed an adapter for his **grain drying** fan to accept both ducts of the collector. However, in the grain drying mode, a 2000 cfm fan moves more air than in the home heating process, requiring a different air flow. In that case both ducts carry air from the collector to the fan. Young opens air inlets at the opposite end of the collector for outside fresh air to enter. In the future, if Young were to use a larger grain drying fan, he would blend in some outside air at the fan, rather than forcing high volumes of air through the collector, in order to avoid damage to the collector by high static pressure drops.

Young Portable Solar Collector



Collector Operation



—Since the portable solar collector is mounted on wheels, it is easily moved from one location to another. Gary Young uses his collector for space heating in the home during the winter and drying grain in the fall. Such a "multi-use" collector can be more cost effective than other collectors on some farms.

Substantial Energy Savings

The Youngs are pleased with the contribution of solar heat to their home, as Gary described to a community evaluation team of the Congressional Office of Technology Assessment:

"Well, the basement in the house is always cool, not cold, but cool. You can't just sit down there in the wintertime and be comfortable. We have heat down there, but it isn't enough because heat rises, and it just goes upstairs. But putting this on, we just dump all the air into the basement and it makes the basement hot at times, but in order to get away from too much heat, we just open a window and balance it out a little bit."

Even though his portable solar collector afforded the luxury of fresh air in early spring, the **Young's used 255 fewer gallons of propane in 1979 than in 1978**, although the solar collector operated for only four months of the six-month heating season. Because the heating demands of the two years were comparable, the Youngs can expect to realize greater fuel savings in years to come.

Though 1979 was the first year Gary dried shelled corn, he was pleased with his portable collector as a grain drier. While he and other farmers were docked 4 cents/bushel and more at the local elevator for drying costs for each percentage point of moisture over 15.5%, **Young dried 2,000 bushels of his grain harvest from 18.5% moisture content to 15% moisture.** The collector delivered air to his wooden bin at 2,000 cfm with an average temperature rise of 17°F on the calm, clear October days. Relative humidity typically dropped from 62% to 27% after being heated by the collector. Collector efficiency averaged 65% on the clear days of the drying season.

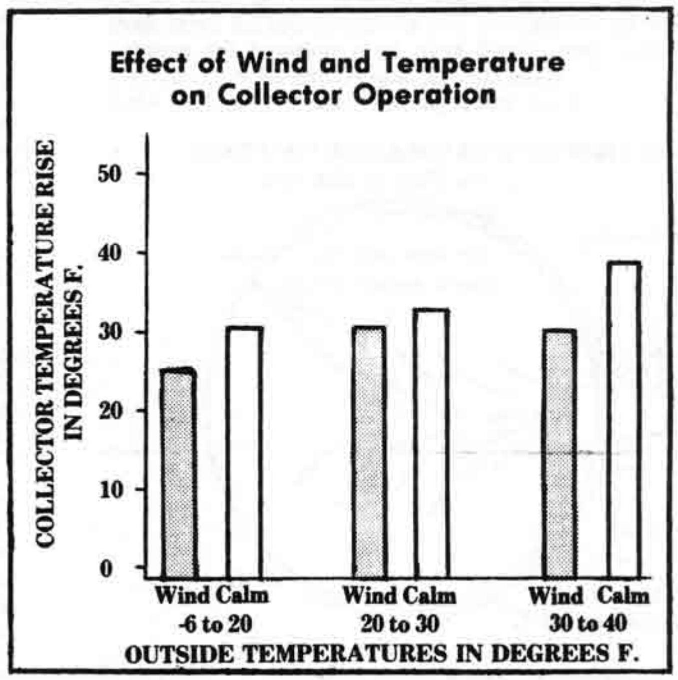
Though his electric bills were $25 more than usual, **Gary figures he saved $275 on grain drying expenses,** based on the local elevator drying charge, for a net savings of $250. **In addition, he saved $105 on home space heating in 1979.** "This year I figure I saved over half," says Young, regarding propane use for heating during the 1979-80 winter.

Collector Monitoring

Young maintained detailed records on the operation of the portable collector. In addition to the temperature of cool air going into the collector and warm air coming out, he monitored the amount of solar energy reaching the collector, the number of hours the collector operated each day, and weather conditions including temperatures, wind direction and velocity, and sky conditions. From this daily journal, a summary of collector operation throughout the seasons of space heating and grain drying use has been prepared.

On days of moderate sunshine (200 Btu/sq. ft.-hr. or more), low temperatures and strong winds reduced the amount of heat delivered by the solar collector. As the accompanying figure shows, the collector heats air over 40°F at noon on calm, clear days when outside temperatures range from 30° to 40°F. On cold windy days (between -6 to 20°F temperatures and more than 10 mph wind velocity) the air is typically heated 24°F at noon.

Heat is lost from the collector during cold and windy weather. To reduce the heat loss, Gary changed the pulleys on the fan to move more air through the collector (from 450 cfm to 550 cfm). With more air absorbing the heat, the collector operates at a lower temperature, resulting in less heat loss. His experiment worked because the collector was operating slightly more efficiently, but the Youngs were not satisfied with the lower temperatures coming from the collector, and returned to use of the original fan speed.



Collector Cost

Portable Collector Cost

Trailer	No Cost
Transport & Collector Lift Equipment	140
Collector, 24 ft. X 10 ft., with Frame	610
Collector Fiberglass Cover with Seals, Filon	140
Ducts and Adapters	260
House Fan and Controls	135
Anchors & Miscellaneous	25
Total Cost ($5.50 per sq. ft. of collector)	**$1310**

After building the portable solar collector himself, **Young notes that he prefers the home-built method for several reasons.** Not only did the system cost him much less than a manufactured system, but Young found that building the collector over several months allowed him a "pay as you build" method of financing the collector from his dairy income, rather than making an investment all at once.

Based on the energy savings of over $300 that the Youngs experienced during 1979 for both home heating and grain drying, **the portable solar collector should pay for itself in four to five years.** Increasing energy prices would of course decrease the pay-back period, as would solar tax credits and other tax advantages for farm solar systems.

Other Considerations

Integrating the Collector to the Farm

One of the key advantages of the Young portable solar collector is that is is a **multi-use collector** and therefore can be **integrated into the farm for various tasks,** like grain drying and home space heating. In some cases, this makes for **a more cost effective solar system** since it is used more days out of a year. However, as with many other energy innovations used by Energy Project cooperators, the nature of the farm will indicate its effectiveness. Some farms can easily make use of the portable unit for several tasks, where other farms will not. Perhaps another farm could find even another use during the summer for some unusual purpose. Therefore **the use of a portable collector is "farm or site specific"** depending on the particular farm in question, and whether or not the collector can be adapted and integrated into the existing farm.

Since the collector is portable, there is flexibility in its use. For instance, a farmer with two grain bins could move the collector from one to the other. For the farmer who is renting a farm, he can build the collector and move it with him, should he rent or buy a different farmstead. Some homes will not easily accomodate a vertical wall collector mounted to the house, and therefore the portable collector may solve the dilemma, with the advantage that the collector can be moved to a shaded area in the summer.

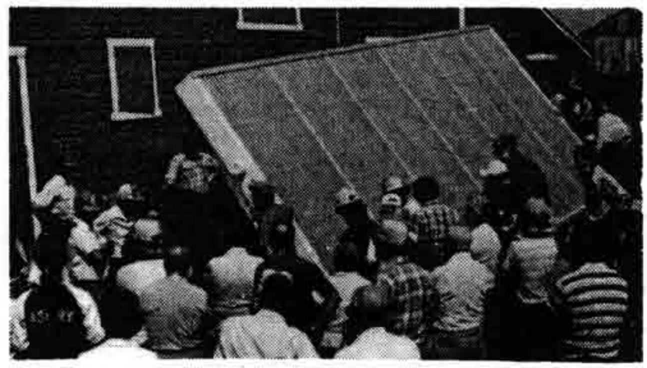
Other Options

With some farms, **it may be more economical to construct a collector onto the home and one onto a grain bin than to build the portable collector.** Since it is free standing, the portable collector is more expensive per sq. ft. than the other collectors, because it requires more structural material. For home heating it also requires insulation. This is not the case with the vertical wall collector, since it is mounted to the insulated wall of the home.

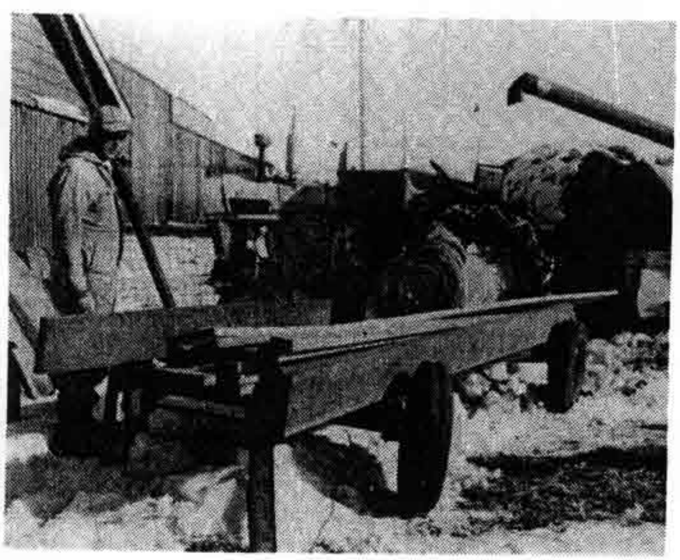
In addition, the vertical wall collector on the home can be more efficient than the portable collector. This is due to the additional heat losses of exterior ducting and more exterior surface area of the collector. The portable unit requires more effort in keeping the system air tight. The Energy Project has monitored the efficiency of the portable collector and vertical wall collectors. As an example, records taken of the collectors during sunny weather between 30 and 40 degrees F. of outside temperature indicate a collector efficiency of nearly 50% for the vertical wall collector, whereas the portable system has shown approximately 30% efficiency in making use of available solar energy, under similar conditions.

If a farmer were planning to use a portable collector for only grain drying and perhaps shop heating, a lower cost non-insulated collector could be used, if it were not used for home heating. Gary Young has also suggested several changes that could be utilized for portable systems. He indicates that the collector could easily be mounted on skids rather than wheels, and the angle of the collector could be made permanent to eliminate the lift apparatus. **Other design changes have been incorporated** into plans for the Young collector after construction was completed, **to improve performance.** The detailed plans, including materials list, are available from the Energy Project, for $2.

For the Gary Young family, use of the portable collector has been a successful experience. Gary's resulting enthusiasm for using solar energy led to his construction of **another solar collector onto his dairy barn.** The collector is mounted directly to the south wall for space heating. In addition, Young added a heat exchanger to his milk cooling system for heating dairy water as another energy saver.



—Farmers have been particularly interested in the 240 sq. ft. portable solar collector built by Gary Young of McLean, Nebr. The collector is used for heating the home in the winter and for drying grain in the building, shown above, during the fall.



—Gary Young locates one of the special pipes used to change the angle of his portable solar collector. The above photo also shows the old running gear that Young modified for carrying the collector.

More Information

References

"Portable Solar Air Heater Plans", includes 25-8½ X 11 pages of notes and sketches for the portable collector built by Gary Young for home heating and grain drying. Available for $2 from the Energy Project.

"The Fish Solar Grain Dryer", Project Focus #2, describes 3 solar "wrap-around" collectors mounted onto round grain bins, 6000 bu. and smaller.50 cents from the Energy Project.

"The Vertical Wall Solar Collector," Project Focus #3, is a another flier on one of the most popular innovations used by Energy Project cooperating farmers. The information describes wall type collectors mounted directly to homes for space heating. Cost is 50 cents.

"Portable Solar Collector", plan No. SP 546 is available for $1 from Dept. of Ag. Engineering, U. of Illinois, Urbana, IL 61801. The 2-page blueprints are for a low-cost 10 X 24 ft. collector for low temperature grain drying or shop heating, but not recommended for home heating.

For More Energy Information

"Project Focus" is published by the Small Farm Energy Project, a research and demonstration project sponsored by the Center for Rural Affairs and funded by the Community Services Administration. For more information, contact the Energy Project, P.O. Box 736, Hartington, Nebr. 68739, phone 402-254-6893.

PROJECT FOCUS #11

Small Farm Energy Project

Energy Conservation on the Farm

July, 1980

"Project Focus" is part of a primer on energy alternatives that would help lower the high costs of energy inputs on small farms. The examples are drawn from innovations built by northeast Nebraska farmers who are participants in the Small Farm Energy Project, a special 3-year research effort sponsored by the Center for Rural Affairs of Walthill, Nebraska and based in Hartington, Nebraska. The aim of Project Focus is to help small farmers discover and develop viable alternatives for their own farms.

Conservation of energy for the farm and home has been a major factor for the success of Energy Project cooperating farmers in lowering energy costs. "Innovative" farmers cooperating in the Small Farm Energy Project for over three years have made a variety of energy use changes. Results indicate an average savings of $1100 per year per farm when compared to a comparable group of farms making no changes in energy use patterns.

Although the more elaborate solar projects may have received the greatest publicity, energy conservation has proved to be the most effective step in saving energy. Energy conservation is an important primary step before more sophisticated solar, wind, or alcohol projects are utilized for producing energy. It is normally less costly to save a portion of energy consumed than to produce an alternative energy.

This Project Focus concentrates on a variety of conservation techniques used by Energy Project cooperators in dry land farming operations.

Farm Yard Energy Savings

—A pressure, vacuum-relief filler cap used to lower evaporation losses on farm fuel tanks. The inexpensive device should pay for itself during one summer of warm weather. Fuel tanks should also be painted white or located in shade to save additional energy.

Saving Energy At Fuel Tanks

WHITE OR SHADED TANKS

Fuel tanks can be a source of a number of energy losses during the year. Leaking hoses or valves should be repaired. During summer months, **fuel tanks should have a white color, or be shaded.** Researchers indicate that **a white fuel tank will have one-third less loss of fuel due to evaporation during warm weather than red tanks,** particularly with volatile gasoline. A white tank in the shade will save even more fuel.

PRESSURE-VACUUM RELIEF FILLER CAPS

A pressure-vacuum relief filler cap will also lower evaporation losses. **It reportedly will lower evaporation losses as much as one-half during warm weather.** They are available for about $10 from many hardware stores and fuel suppliers.

Research indicates that **a conventional sized farm fuel storage tank,** especially in the case of gasoline, **can lose as high as $75 or more worth of fuel per year,** when not protected from warm weather. **It is quite obvious that a can of paint and a pressure-vacuum relief filler cap can pay for themselves in a year or less.**

EVAPORATION LOSSES FROM COMMON—300 GAL. GASOLINE TANKS

(Information from the University of Nebr.)

Tank Configuration	Representative Losses Gallons/month
Red tank in sun	9 to 10
White tank in sun	6
Red tank in sun with pressure-vacuum relief value	5.5
White tank in sun with pressure vacuum relief value	3.2
Tank in shade	2.4
Tank in shade with pressure-vacuum relief valve	1.3
Underground tank	less than 1

Stock Tanks and Waterers

A major energy consumer on the livestock farm during the winter months is the **livestock waterer, resulting in high electric bills.** Thermostats should be in good working order to avoid excess electrical use. Stock tank **waterers should be reinsulated where possible** using a rigid board insulation. On large tanks, rigid styrofoam insulation can be floated on water surfaces that are not used.

There are **several energy saving waterers** and tanks available on the market, and farmers should shop around to find good efficient systems when purchasing new units. Some have a floating cover. Others are animal regulated, as in the "nipple" hog waterers which contain no reservoirs. This requires considerably less heat. Other ideas include making better use of ground heat, by making a hole beneath the waterer in the ground. Or the reservoir itself may extend into the ground.

Ed Lange of Cedar County, Nebr. uses a simple method to keep his round cow tank providing water to cows without heating the tank. He allows ice to build up over the water and, in addition, runs water over the ice to make the ice cover quite thick. Then he chops a hole in the ice for access to water by the cows. Next the float is lowered to keep a lower water level. And the system is basically maintenance free. The concept works best in the shade so the ice doesn't melt in warmer weather, and a fair number of cows are required so continual water flow is maintained.

Shelterbelts Save Energy

Researchers indicate that **tree shelterbelts around the farmstead can save eight to thirteen percent of heating cost in the home.** Other studies indicated higher savings. Many other benefits can be realized with shelterbelts, including shade and fire wood.

Saving Energy in the Home

Home Heating

INSULATION

Heat loss from a home is determined by several factors including the **insulating value of walls,** windows and ceilings; and the amount of **air infiltration present.**

Older homes can usually be upgraded in insulating value by the addition of insulation to walls and ceilings. Usually the "blow in" type insulation is used. **Basement masonry walls can also be insulated** on the exterior to a depth of four feet or to the frost line. A "closed cell" rigid board insulation should be used to avoid water penetration. The insulation should be covered at the top to prevent damage to it. Insulating the exterior side of the wall allows the wall to act as a "heat sink", thereby stabilizing the temperature of the home, especially when solar systems are utilized, when all of the solar heat is provided during the day. Basement walls can also be insulated on the interior of masonary walls by "studding" the wall out and adding batt insulation.

For new wall construction, a vapor barrier is recommended. A polyethylene sheet is placed over the wall on the inside of the insulation to protect the insulation from moisture condensation.

AIR INFILTRATION

Air infiltration into the home during cold weather is a major factor in heat loss. This takes place at cracks around doors, windows, and other openings. **Caulking and weather-stripping** are two methods of tightening up a house to prevent infiltration of cold air. A candle can be used to check for points of potential air leaks.

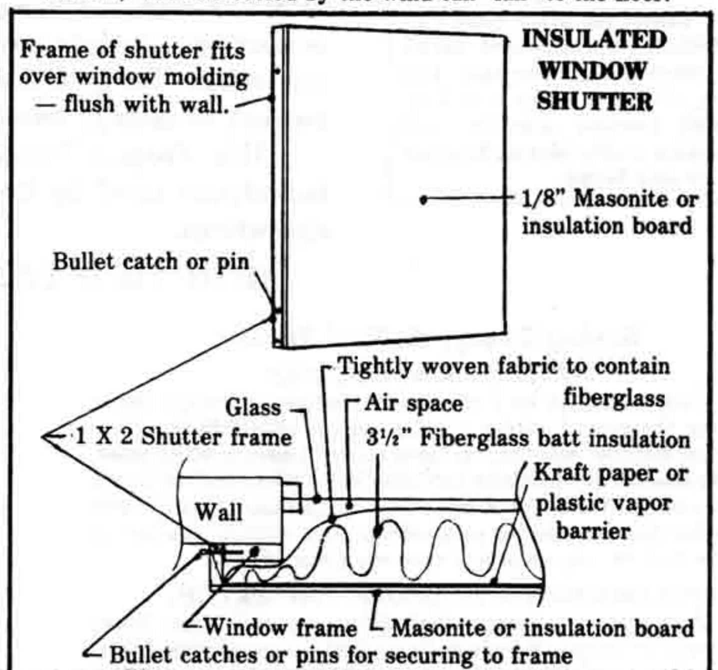
HEATING SYSTEMS

Furnaces used for space heating **should be well tuned** prior to each heating season. This includes replacing furnace filters, replacing jets on fuel oil systems, and other steps. Chimneys used for wood heating should be cleaned to remove creosote as a step to prevent dangerous fires.

Heat Pumps usually operate effectively only **above a certain outside temperature.** When it gets very cold the system will use electric resistance heating within the system, which is more costly. If one is aware of this, operation might be avoided during very cold nights, substituting wood or other heat. The newest innovation in the heat pump area is to use the "water to air" type systems where well water is used to improve the efficiency. This may require two wells, one to receive cooled water from the system, unless there is other use for the water.

INSULATED WINDOW SHUTTERS

Paul and Wilma Phelps of rural Hartington **have built several insulated window shutters,** in addition to their vertical wall solar collector. The two shutters are used to cut down on heat loss through north windows. They are made of wood framing with a masonite cover facing the interior of the house. Fiberglass batt insulation is used inside of the shutter. The shutter is made to fit over the window frame and is pinned with brads to the sides of the window frame. Paul Phelps built the shutters with the intention of leaving them attached to the windows most of the winter. A decorative covering will be used over the interior of the shutter. Phelps used a set of plans from Wisconsin to construct the shutters. **There are a variety of methods of constructing shutters, all of which can be quite valuable, since windows are a major source of heat loss in homes. Insulated drapes can also be helpful,** but should extend to the floor and be covered with a valance or other device at the top of the drapes to lower air flow between drapes and the window, since air cooled by the wind can "fall" to the floor.



Summer Home Cooling

AIR CONDITIONERS

Air conditioning systems should be kept clean and properly maintained. Condenser units are best located in the shade of the house or trees. Thermostat should be maintained between 78 to 80 degrees. Stoves should be vented to the outside. Windows should be shaded to lower heat load.

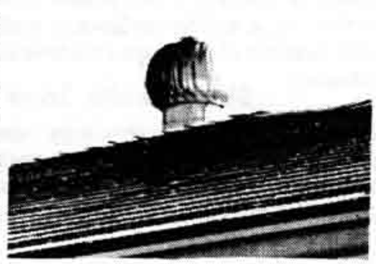
VENTILATION FOR COOLING

Wind turbine vents help to draw heat out of home attics during hot summer days, bringing in outside cooler air. The turbine vents operate in very low wind speeds. Such winds are usually always available. The turbines **can eliminate the need for power vents in the attic, and they will also lower the air conditioning loads** in homes where power vents are not used.

Vent tubes can also be used with wind turbines to move warm air directly from room ceilings. Dampers at room ceilings and at the tube opening can be opened during cool nights and closed during the day.

Other vents are available, including the continuous ridge vent, for venting attics. Such vents should be combined with soffit vents in the eaves, to allow for cooler air to enter the base of the attic. These vents will also lower moisture and condensation problems in the winter, which lower the effectiveness of insulation.

—Wind turbines can be quite effective in keeping attic temperatures cool during summer months. Homes can be kept cooler with such devices, lowering electrical demands when air conditioning is used.



Water Heating

Water heaters should be reinsulated; kits are available from hardware stores. In some cases timers may be effective on the heater. **Water pipes should be insulated,** especially the warm water pipe above the heater. Water heaters should be located near use, and should be drained and flushed every 6 months. Water leaks should be repaired. Choose the lowest water temperature setting possible. Lowering the temperature setting 10 degrees can save over a kwh per day when 40 gallons of hot water are used each day.

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Livestock Buildings

Many of the same considerations for home weatherization apply to heated shops and livestock buildings, particularly with insulation and prevention of air infiltration. Heating systems should also be properly maintained.

Farrowing Barns

HEAT EXCHANGERS

For the livestock building that uses considerable ventilation during the winter heating season, various heat exchangers are now on the market to lower energy demands. **"Air to air" heat exchangers are designed to utilize the heat of moist exhaust ventilation air to heat incoming fresh air.** Corrosion and dust are difficulties with the heat exchanger, but some designs have addressed these areas. The systems can be quite expensive, but home-built, low cost systems seem possible.

FARROWING OPERATIONS

Livestock operations, such as hog **farrowing enterprises** may be more feasible if **timed to avoid the worst of cold winter weather.**

Russell Perkinson of Illinois uses a **"hover" of plywood over new-born pigs** in his farrowing stalls. The hovers are located at the ends of the pens and are 1 ft. wide and 1 ft. above the floor. The pigs congregate under the hover where it is warm. **The idea is to conserve the heat of the pigs for better pig health and to also conserve energy.**

The **"straw bale hover"** concept has also been used by LaVern Truby, an Energy Project cooperator, for pigs of the "nursery" size. The technique improves the conversion of feed to weight gain rather than to hog "maintenance" energy requirements.

Energy Conservation in the Dairy

WATER HEATING

Water heating requires a high energy demand in the dairy. A relatively new concept in heating water in the dairy is the use of the commercially available **heat exchanger.** Refrigeration coolant is used to **transfer heat from the milk at the bulk tank to heat water** which is used for cleaning equipment and udders. Energy Project cooperator Gary Young uses such a system and is quite pleased with its performance.

—Rob Aiken, left, assists Edgar Wuebben with insulation of his dairy barn. A vapor barrier was placed over the concrete block wall before mounting double 2 X 2's using concrete nails. Then fiberglass batt insulation and galvanized metal were installed. Fuel use for heating was cut in half.

MILK COOLING SYSTEMS

In the dairy barn, **one of the big consumers is the electric bulk tank cooling compressor.** The compressor should be well serviced. Fan and condensor coils should be kept clean in order to maintain peak efficiency. In the winter, heat can be recycled in the building; in summer, the system should be well ventilated for best efficiency and lowest electrical use.

NEW DAIRY FACILITIES

Edgar Wuebben , Energy Project cooperator, has some suggestions for the farmer designing a **new dairy barn:**

—build walls low and use a "pit design (cows remain on ground level) to reduce building exposure to wind and cold

—place water heater in center of building to minimize plumbing expenses and heat losses from hot water lines.

—insulate walls and foundation

—use compressor heat for pre-heating water

—install a low-cost vertical wall solar collector on the south wall

—run the roof-peak east and west for a south-facing roof for future solar collectors

—locate cow entrance and exit to the south and east to minimize winter drafts.

Field and Farmstead Operations

Pumping Water With Wind

Pumping farm water may seem to require little energy when electricity is used. However, **wind pumping can add to energy savings.** Many farms have wind water pumping equipment available, which, with a little repair work, can be put back into service.

Transportation

Transporation can be reduced by planning and combining trips from farm to field or to town. Keeping a record of trips and energy use may help to better manage them.

Machinery Maintenance

University researchers make the following energy saving **suggestions for farm machinery:**

—Read and understand operator's manuals

—Check machinery adjustment; keep lubricated

—Keep engines tuned up; check air filters

—Keep cutting edges sharp

—Don't overfuel an engine

—Minimize engine block heating during winter with a timer to avoid heating around the clock.

Grain Drying

"Natural air drying" methods can often be used to lower energy inputs into drying of corn. **Harvesting corn in the ear** is still a very good method of reducing energy during harvest and many farmers are returning to the method. This method eliminates the need for electrical fan energy for drying and aeration.

Field Operations

Here are **suggestions for field operations:**

—Use a smaller tractor for light loads or throttle back with large tractor

—Limit engine idling. A medium size tractor uses ¼-½ gallon per hour when idling.

—Plan machine movement between fields and farmstead for minimum travel.

—Plan fields for long rows; limit turning

—Plan fields to reduce bottlenecks or unnecessary operations.

—Utilize "minimum tillage" methods where practical

—Use proper ballast for tillage

Using Horses

Some farmers have continued over the years to maintain a team of horses for light farm work. They foresee the potential of horses being used more in the future as energy prices rise.

Irrigation

Irrigation is the largest farm energy consumer in Nebraska. The University of Nebraska has done considerable work in the area of **improving irrigation pump efficiency.** Extension Service offices have energy saving tips for irrigators.

As the cost of energy rises, **the feasibility of irrigation** of farms in Eastern Nebraska and related areas **becomes more questionable.** Small farmers may be wiser in **practicing better soil and water conservation practices,** like terracing, mulch tillage and manure composting to assist in water conservation in soils.

Soil Conservation and Fertility

Fertility Practices

SOIL FERTILITY

Soil fertility requirements account for a major share of energy use on Nebraska farms. **Nitrogen fertilizer requires considerable amounts of energy during its manufacture. Crop rotations with legumes can provide a large amount of the nitrogen needs.** Energy Project cooperators have also adapted **manure composting** techniques in an attempt to conserve nutrients of livestock manures for soil fertility purposes.

Cooperators of the Energy Project have utilized **soil testing** as a valuable tool for gauging soil management, but they prefer to consider results of the tests with a "grain of salt" rather than following them as an absolute rule.

NUTRIENT LOSS WITH SOIL EROSION

Until recently, researchers were only concerned with soil losses due to soil erosion. A 7-year study done in southwest Iowa indicates that nutrient losses can be substantial when there are soil losses. A comparison was made with contour farming and terraced land, both in corn production. The major portion of N and P lost was in sediment when compared to water run-off. In addition, over **10 times more nitrogen was lost throughout the year on the contoured fields compared to the terraced land.** The results of the study show that **a major reduction in the loss of plant nutrients is another primary benefit for using conservation practices.**

Value of Trees in Fields

Trees not only can provide shelter and wood fuel, they can be used as "field belts" in single or double rows across fields. Such belts can help to control wind erosion, hold snow on fields during winter months, and provide a wildlife habitat. In addition, various research efforts have indicated that such **tree belts across fields can greatly reduce evaporation losses** in conventional crops by hot dry winds **during the summer.** This helps to provide good crop yields during dry years, or to lower the demand on irrigation water and energy, where irrigation is used. Research also indicates that the value of the trees to field crops is more than offset by the land required by the trees. Of course, recommended varieties of trees should be used. Trees with primarily vertical root systems will be better than those with horizontal systems which will rob moisture from the field crops.

—Trees in rows across fields, called "field belts", can provide a variety of advantages. Soil erosion is reduced as well as evaporation losses caused by summer winds. Benefits can add up in the form of indirect energy savings.

Home Energy [continued from page 50]

Lighting and Appliances

Correct lighting levels should be used for the task. Dimmer switches may be helpful. Remember to turn off lights when not is use. Florescent lights are the most efficient.

Heat from electric clothes dryers can provide both heat and humidity to the home in the winter. A lint collector can be placed over the exhaust. Appliances with the best EER, Energy Efficiency Ratings, should be purchased.

For **refrigerators and freezers,** avoid placing warm dishes into these appliances, and keep containers covered. Maintain gaskets of doors in good condition. Defrosting should be done often; "frost-free" units consume more energy. "Multi-door" refrigerator-freezer conbinations should be used rather than single door units. Condensor coils should be kept clean to allow efficient operation; and if heat released from the coils could be vented easily to the outside during the summer, it would lower heat build up inside the house. Chest freezers are less energy consumptive than upright types. Door opening, of course, should be minimized.

Ovens can be turned off early in the baking cycle to make use of "residual" heat. Combine baking tasks, perhaps the total meal. Pressure cookers can use as little as one-fourth the energy as other methods of cooking. Use lids on pans and minimize water. Use lowest possible heat settings. Avoid baking and cooking when air conditioner is used.

—Pumping farm water with wind can add to energy savings, even though pumping with electricity may seem to require little energy. Many farms have wind water pumping equipment available, which can be put back into service.

More Information

From the Energy Project

"Home Energy Conservation Checklist" is a 5-page list of suggestions covering such items as insulation, appliance use, lighting, windows, heating and more. Available for 50 cents.

"Farm Energy Conservation Checklist" is a 2-page checklist of conservation ideas for fuel handling, dairies, tractors, equipment, harvesting and more. Available for 25 cents.

"Energy Conservation Bibliography" is a 3-page annotated listing of books and various periodicals on saving energy in the home and on the farm. Price is 25 cents.

"Project Focus" includes #6 on heating with wood, #7 on heating water in the dairy, and #8 on composting farm manures. These three are especially useful for farm energy conservation. Available for 50 cents each.

"Heat Exchangers for Livestock Barns," SFEP Newsletter, March, 1979, page 10. A description of heat exchangers used in Minn. for various livestock barns to extract heat from exhaust ventilation air to pre-heat incoming cold air. 25 cents.

"The Return to Ear Corn Harvest", SFEP Newsletter, Sept., 1979, page 5. Floyd L. Herum, Ohio ag. engineer, indicates the reasons why he thinks harvesting corn in the ear is in the future. Available for 25 cents.

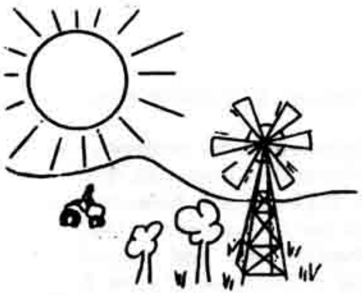
Other Good References

"What About Windows: A Report on Thermal Window Coverings With Six Design Options", Center for Community Technology, 2909 Stevens St., Madison, Wis., $1.25. Includes several designs for insulated shutters and shades. Used by Paul Phelps, Energy Project cooperator.

"Small Farmer's Journal", P.O. Box 197, Junction City, OR 97448, $10/year for four issues. This publication features practical horse farming and a variety of other energy saving topics. Excellent.

"Nebraska Energy Saving Manual", Nebraska Energy Office, Box 95085, Lincoln, NE 68509. This publication is designed specifically for the home owner, covering such topics as insulation, water heating, furnace maintenance, and also some solar energy concepts. Other states have a similar publication. Available for 50 cents.

Local Extension Service offices also have fliers on various energy conservation topics.



Small Farm Energy Project

JULY, 1979

SPECIAL REPORT

An Analysis of Farm Methane

Methane Project Cancelled Due To Poor Feasibility

A typical farm of the Energy Project farms 350 acres, 250 of which is cultivated. The operations include livestock, primarily dairy, hogs and beef.

NUMEROUS DIFFICULTIES UNCOVERED

The potential of methane generation was studied for one of the farms, having a 30-cow dairy and 100-hog finishing operation. The **project was cancelled by the farmer due to escalation of cost and low return on investment.** The study **included provisions for electrical generation,** although power companies are reluctant to pay for farm electricity provided to the power grid.

Several other problems were encountered, including manure handling difficulties with the solid manure system, availability of enough quality manure, and high labor requirements. Gaseous fuel use on the **farm** was non-existent, requiring conversions of equipment to utilize methane gas.

The study seems to conclude that **methane generation may only be feasible for quite large systems or for very small demonstration devices,** and not for current conditions of the average farm of the Energy Project. Certain unique situations, including summer gas use, other than electrical generation, could improve the potential.

OTHER ALTERNATIVES

Other **alternatives to methane generation** are considered in this "Special Report" **including aerobic composting of the manure.** For composted manure, as much as 50% less weight is hauled to the field when compared to the original raw manure. Effluent from methane generators would have increased weight when diluted for the process. Less capital is required for composting than for methane generation.

AN "APPROPRIATE" TECHNOLOGY QUESTION

Despite the negative aspects of methane generation for small farms, anaerobic digestion should be considered for the future as energy prices continue to rise, perhaps making the process more feasible. However, **the results of this study indicate that not all forms of alternative energy are "appropriate" for the small farm,** and should be closely analyzed before being adapted. Most energy innovations adapted by Energy Project cooperators are simple, home-built, and low-cost systems. Methane production is considerably more complicated and expensive for the farmer to implement.

The Study of Farm Methane

ENERGY USE BY PROJECT FARMS

Average energy use by farms cooperating in the Energy Project has been studied. Major energy costs are for electricity and motor fuels in addition to fertilizer purchases. Total direct energy costs are over $3000 per year, excluding fertilizer costs. Average gross income in 1977 was $33,800 for 16 general livestock cooperating farms.

FARM USED IN THE METHANE STUDY

One farm cooperator showed particular interest in development of a methane system. The livestock on the farm includes 30 cows of the dairy operation, 100 head of 150 lb. hogs on the average at any given time, and 200 laying hens.

Energy use by the farm is given in Table 2. Energy consumption is similar to that of the average farm of the Energy Project. Car and truck gas, however, is considerably higher. **Electrical peak demand during winter months** has been near 4800 kwh/month for this particular farm, about **double the summer demand.**

TABLE 2. Farm Energy Purchases, 1976-1978, of Farm in Methane Study

	Unit Purchases		
	1976	1977	1978
ELECTRICITY (kwh)	32,950	33,980	33,130
FUEL OIL (gal.)	820	860	1180
PROPANE (gal.)	—	—	—
DIESEL (gal.)	885	1306	1100
TRACTOR GAS (gal.)	1040	1115	1100
CAR GAS (gal.)	1500 (est.)	2057	2700

BACKGROUND OF THE STUDY PROCESS

It should be noted that the digester under consideration was of interest to the farmer for energy production purposes. Most methane systems in use in this country today, however, seem to have started with a primary objective of pollution control for environmental control purposes. Workshops on the topic of methane generation were held. A proto-type scaled down version was planned, but construction was never fully completed.

The design work for potential systems involved several processes. Energy Project staff reviewed much of the literature and worked closely with the farmer to design a system to meet the farm's needs. The eventual design was reviewed by 8 different consultants. Ted Landers of Missouri, who has cooperated with the U. of Missouri, Rolla, on methane generation, was selected to develop a final design for final feasibility study. Throughout the process, **the farmer was consulted for adapting the design to his farm** and various modifications were made by him. Salvage equipment, including 4000 gal. fuel tanks and a 30 h.p. engine, were considered in the analysis.

Methane Production and Economics

Various Options Considered

The very first design for a methane system included solar air heating for the digester, with a rock heat storage unit. Later, electrical production capability was incorporated in the design, since **electrical energy was a major energy need on the dairy farm under consideration.** In the option of electrical generation, the system was **sized to provide winter peak electrical demand.** With electrical generation, considerable heat is available for providing winter heat requirements of the digester, and the solar heating concept was abandoned. However, in this first design, the efficiency of conversion of methane to electricity was over-estimated. The resulting correction increased cost of equipment to $3000 for a 15 kw generator. **The designs included a pre-mix tank for diluting and heating the incoming solid manure. "Plug flow" through the 7 ft. diameter digester tanks was included, along with a horizontal mixing device.**

Later designs were developed; comparisons of those considered are given in Table 3. **Sizes of the systems ranged from 8000 to 16,000 gallons in digester volumes, with gas production ranging from 850 to 1700 cu. ft. of scrubbed methane per day.** "Gas use only," electrical generaton, and also compressed gas for mobile motor fuel were considered for methane use. For the "gas only" option, sizing of the system was that which would provide sufficient methane for potential space and water heating, but would probably operate only during winter months. The compressed gas option had good potential with regard to the high use of gasoline on the farm for a combine, tractor, pick-up, car, and truck, costing in excess of $2000 annually.

Economic Factors of the Analysis

Various economic factors were utilized in the results shown in Table 3. The **value of electric generation** is based on **2c/kwh** overall, assuming little benefit of dumping power onto the grid, currently at no return. **Operating cost** was included. **It includes labor at $4/hour for feeding the digester and the cost of energy and labor of running motors and grinding crop residue.** A $10/month charge by the Rural Electric Cooperative was used as the minimum or stand-by charge by the REC. The **costs charged to the system included an 8% "opportunity investment cost"**, the above labor and energy costs of operation, **and 3% maintenance costs** (3% of capital investment per year). The latter two **costs were escalated at 7%/year.** The **savings in energy benefits were given a 13½% fuel price escalation.** The options did not consider the cost of a honey wagon, or the benefit of investment credit, which along with other energy tax breaks could improve the pay-back. **Cost of construction labor was also not considered,** as is the case with most innovations of the Energy Project, where the cooperator performs most of the construction work.

—Tanks under consideration for use on the Bill Kleinschmit farm for methane production. The system, which was cancelled for various reasons, would have incorporated an electric generator powered by methane.

Return on Investment & Project Cancellation

The **best return on investment appeared to be realized in the process of compressing the gas for mobile transport. The cost was near $17,000 with a pay-back of 11-12 years. However, the feasibility was questionable.** The use of the gas by that method would have required additional labor and special handling of the gas, and conversions to most all of 5 or 6 engines. See Table 3 for "pay-back" periods.

TABLE 3. Methane Equipment Options

Digester Size in Gallons	Gas Output, Scrubbed, Cu. ft./day	Gas Use	Waste Input	Invested Capital Required	Approx. Pay-back
1. 16,000	1700	15 kw, Synchronous Electric Generator	Hog Manure & Crop Residue	$14,500	17-18 yr.
2. 16,000	1700	15 kw, Synchronous Electric Generator	Hog Manure & Crop Residue	$13,000	15 yr.
3. 8,000	850	Gas Only	Hog Manure & Some Dairy	$8,000	15 yr.
4. 16,000	1700	Compressed Gas for Vehicles	Hog Manure & Crop Residue	$17,000	11-12 yr.

In #1, 2, and 4 options above, the big cost is harvest of crop residue at $500/year.

In #2, the savings in capital over #1 is in reduced housing cost, using an old shed and buried tank.

In #3, the system cost includes conversion of water heaters and other equipment to gas use and it includes the installation of gas lines. Plant operation probably limited to winter only.

The #4 investment cost includes compressed gas storage bottles, compressor for 2200 psi, and a generous figure for converting gasoline engines to compressed gas. Most of tractor gasoline goes to a combine just at harvest, a $1000 value annually. A car, pick-up and truck have fuel use spread over more of the year, which allows for lower storage cost. This fuel use is also costing about $1000 per year. But this latter option requires conversion of several vehicles.

The farmer cooperating in the venture participated in the eventual cancellation of the proposed project, just as he participated in the design. He made the final decision that **the innovation was not appropriate for his farm,** and probably not for the average farm similar to his. **He was not interested in demonstrating an innovation that would not have the potential of being adapted by many farmers.** He made the decision, despite the potential of 50 to 75 percent cost share assistance. It appears that methane systems are only feasible for very large scale livestock production and for farms larger than those considered here, or for the small scale approach as is used in India or China for limited use of cooking and lighting. The results indicate that the **technology may not be appropriate for the average small farm of the Energy Project.** Unique circumstances may make the potential more feasible, however.

Difficulties of the Methane Project

A number of circumstances made it difficult to justify the methane system proposed. Farmers interested in utilizing methane production should consider the factors when planning changes or adding livestock structures to their farms.

Solid Manure Handling

The farm in the study has a solid manure handling process, rather than automated liquid manure handling. **The solid system requires more handling labor** for use with methane production. **Freezing is a difficulty in the winter months.** The farmer had plans for installing a manure scraper system in a proposed hog finishing unit, if and when it was constructed. The farm studied did not have enough quality manure available to feed the most feasible system adequately and, therefore, crop residue was entered into the equation. However, labor and cost of harvest increased the operating cost substantially. The labor for the basic operation of the plant also appears to be high.

—Bill Kleinschmit inspects parts that were considered for a proposed methane digester for his farm. The project was cancelled in Sept. of 1978 due to high costs and other factors.

Gas Storage Difficulties

One of the major problems associated with methane production **is its storage** for later use. It requires considerable energy and capital equipment to compress the fuel into a liquid form. In the scenario of production of electricity, waste heat must be well utilized for the system to be feasible. Such consideration requires the integration of a number of facilities on the farm and involves a more complicated planning and development process. **The REC is also not willing to pay for farm produced electricity.**

Low Gas Use

Gaseous fuel use on the farm was low. As Table 2 indicates, no propane is used. A basic difficulty is that farm energy use and equipment is oriented to purchased energy. **Conversion of energy-use equipment,** such as electric water heaters and refrigeration equipment, to gas **would have been required to make efficient use of the gas.** This, too, increased the cost of the project. In this case, stock tank heaters were also electric and the home was heated by a fuel oil furnace. These are retrofit difficulties inherent in any transition from one energy source to another. Economical transition requires judicious investment in energy end-use equipment. In addition to conversion difficulties, **gas production would be highest in the summer during optimum weather conditions, but gas use for heating would be low at that time.**

Dennis Demmel, Co-director of the Energy Project, presented a paper, entitled "Aenerobic Digestion for Methane Generation on Small Farms in Northeast Nebraska", at the Mid-American Biomass Energy Workshop at Purdue U. in May. This "Special Report" includes excerpts from that presentation.

Power Companies & Rural Electric Cooperatives

The installation of wind electric system equipment by one cooperating farmer of the Energy Project represented the first cooperative venture between the Energy Project and a Rural Electric Cooperative. However, the REC is not willing to pay for power placed onto the power grid by the wind system. Wind generated electricity is thought to have the potential of reducing sales, but not peak demands. **If an REC did agree to purchase the power, it could well be at the wholesale price, which is about 1/3 of the retail price of an average 3.2 cents per kwh paid by Energy Project cooperators.** The reasoning used by the REC's in their reluctance for purchasing power is that **they must maintain the lines of distribution and all of the other back-up machinery necessary** for the farmer to be able to sell any of his excess power.

With regard to the wind electric system, a ratchet or detent was placed on the electric meter to eliminate the potential of the farm meter from turning backwards, essentially not allowing credit for "dump" power at the retail rate. A monthly demand charge of $3 per KVA transformer capacity was also established.

Methane used for electrical generation **does have advantages over wind power. The REC in the local area of the Energy Project has a seasonal electrical peak demand during the summer months, when methane generation is optimum. The methane can be manipulated to provide electricity during peak demand when** most needed by the power company during the day. **However, any "premium" for such power is not likely to exceed retail prices for the reasoning given above. During the winter months, cooperating farmers experience electrical peak demands, when the REC least needs the power. Therefore, the combination appears to have merit, to the benefit of both, if the REC were to cooperate further.**

Other Alternatives

Options For Anaerobic Digestion

An **induction generator** was not considered for electrical generation in the analysis, but warrants consideration as equipment of lower capital cost. **Methanol can be produced from** methane, but the conversion requires expensive equipment currently. Methanol has the advantage of being stored easily as a liquid fuel. **Methane might more easily be integrated into an ethanol production system, where waste heat from alcohol distillation could provide the heat needed for anaerobic digestion.** The methane produced could then provide some of the higher temperatures required for the distillery.

Methane gas has been placed into **pipelines** for commercial distribution, but that option is open to only those farms near to a gas pipeline. In Oklahoma, such a project required an FPC permit. For the farm studied here, the nearest pipeline is 10 miles from the farm. Pressures of 500 to 1000 psi would be required. **Irrigation** powered by methane may be practical for farms requiring irrigation, since methane production is optimum during summer months during irrigation periods. Irrigation was not used by the farm in question.

Gasification may be an option to anaerobic digestion, particularly where crop residue is the major input rather than manure. Such "producer gas" production from the partial combustion process may require considerably less capital investment, although the quality of the gas produced would be lower than methane.

Aerobic Composting As An Alternative

A better use of farm manure may be in the aerobic composting process. Although no fuel is produced, **composting requires no water pumping as** in the dilution of manure for methane production. **Much less weight is hauled to the field,** potentially saving energy in the hauling of the compost, which is reduced to as much as 50% less weight compared to the original manure. **Less capital is expended in initiating composting** than with methane production hardware, since conventional farm equipment can be utilized in composting. **Compost may perhaps have qualities better for the soil** than the effluent of the methane digester.

Future Research

Several areas of continued research should be considered. The potential of REC's cooperating with farmers in paying for electricity generated at peak demands would potentially benefit both parties involved. Other uses of the gas should be studied. As an example, many of the small farmers in the Energy Project locale have dairy operations that require considerable energy for refrigeration. Gas refrigeration at one time was popular, but hardware for that use is difficult to locate today.

Comparisons of the value of effluent nutrients from the anaerobic digester should be compared to the value of compost to soils, with consideration given to a wide range of aspects including soil tilth, water retention, aerobic soil biology, and other areas, in addition to just N-P-K values.

Presently, considerable research efforts are used to analyze large methane production systems. In the future, more small farm considerations might be made.

Small Scale Plant Demonstrations

Several organizations are conducting innovative demonstration work on small scale methane plants. Such systems would be tailored to farms smaller than those of the Small Farm Energy Project, and may have greater feasibility due to lower costs and simpler designs. Two organizations are listed here.

New Life Farm, Inc., is conducting a "Rural Gasification Project" to determine feasibility of low-cost digesters for rural families. The Project will provide week long training workshops in small digester construction, starting in August. Participants are eligible for cost share for their own plants. For details, contact Ted Landers, New Life Farm, Drury, MO 65638, phone 417-261-2553.

Omega-Alpha Recycling Systems, has taken a wholistic approach to the anaerobic process. The OARS designs include the incorporation of greenhouses, algae ponds, and aquatic plants. The research is directed by Robert A. Hamburg. Contact Hamburg at Route 1, Box 51, Orma, WV 25268, phone 304-655-8662.

Conclusion

Methane production does not appear to meet the feasibility requirements of the average farmer cooperating in the Energy Project. **The cooperating farmer involved in the study concluded that the technology was not appropriate for his farm.** Methane systems are probably only feasible for very large scale livestock production systems, or for small scale approaches as used in India and China, where energy consumption is lower. However, **some farmers may approve of the pay-backs presented here, especially if tax credits are useful and unique circumstances enhance the potential. Future energy prices will continue to rise and REC's may offer premiums for electrical generation. These developments would improve the feasibilities of methane systems.** Further research on these aspects is needed. Farmers should consider methane production in their farm planning and changes in operations. End use of the fuel is a major consideration.

More Information

BIBLIOGRAPHY AVAILABLE

The Energy Project has available a bibliography, "Methane Energy". The 2-page, annotated bibliography has 16 entries covering a variety of books and fliers on the subject. Several plans listed. For a copy, send 25 cents, to cover postage and handling, to the Energy Project.

FOR MORE INFORMATION

This "Special Report" was published by the Small Farm Energy Project, a research and demonstration project sponsored by the Center for Rural Affairs and funded by the Community Services Administration. 24 farm families in Cedar County, Nebr., are cooperating in the study. Additional copies of this report are available for 50 cents. For more information, contact the Energy Project, P.O. Box 736, Hartington, NE 68739, phone 402-254-6893. □

Publication List

BIBLIOGRAPHIES

Annotated bibliographies from the Small Farm Energy Project. Most bibliographies are two or three pages. Order by number. $.25 each.

1. Alternative Energy-General
1B. Alternative Energy Periodicals
2. Bio-Fuels, Alcohol
3. Composting-General
4. Composting-Toilets
5. Energy Conservation
6. Energy in Agriculture
7. Farmers Market
8. Films, Energy
9. Food Coops
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15. Organic Farming
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17. Solar Energy, Ag.
18. Solar Energy Gen.
18B. Solar Water Heating
19. Solar Food Drying
20. Solid Waste Handling
21. Technology, App.
22. Tillage, Minimum
22C. Underground Homes
23. Wind Energy
24. Wood Energy

ENERGY CONSERVATION

—**"Farm Energy Conservation Checklist"**. An Energy Project Checklist for dry-land farming operations with energy saving tips for farm yard, farm buildings, fuel handling, dairies, tractors and other areas outside the home. 2 pages $.25

—**Home Energy Conservation Checklist"**. A result of listing of home energy saving steps. $.50

BROCHURES

—**Center for Rural Affairs Annual Report**—Summarizes the overall policies and activities of the Center, sponsoring agency of the Small Farm Energy Project. 10 pages.

—**Small Farm Energy Project Brochure**, "Final Report Summary", summarizes preliminary research findings, energy innovations used on cooperative farms, and energy projections, besides a publication list.

NEWSLETTER

—**Small Farm Energy Project Newsletter.** This Newsletter is published bi-monthly for $5/year. It is designed to disseminate information on renewable alternative energy sources for small farms. Sample, $.50; subscription, $5/year. Canada and foreign subscriptions, $7/yr.

PROJECT FOCUS & PRIMER

—**Project Focus**, a series of fliers on energy alternatives used to lower energy costs for Energy Project cooperators, including solar, wind and other innovations. $.50 each

#1. "The Kaiser Wind Electric System". Connecting a wind system to the REA.

#2. "The Fish Solar Grain Dryer". Describes 3 solar systems on round grain bins, 6000 bu. and smaller.

#3. "The Vertical Wall Solar Collector" is a flier on solar energy for heating several different types of homes.

#4. "The Fish Solar Greenhouse". A description of the solar and wood heated greenhouse attached to the home.

#5. "The Solar Food Dryer & Window Box Collector", describes one type of food dryer used by Project cooperators, in addition to the solar window box used for space heating.

#6. "Heating With Wood." Home-built and commercial systems.

#7. "Solar Water Heating". This focus discusses various types of water heaters used on primarily dairy barns at the Energy Project.

#8. "Composting of Farm Manure". Composting is recognized as a process of handling manure with the potential of conserving nutrients and lowering fertilizer purchases.

#9. "Solar Farrowing Barn", an analysis of a solar system retrofitted to an old barn used for farrowing hogs.

#10. "Portable Solar Collector". This collector is on wheels and is used for home heating and grain drying.

#11. "Farm Energy Conservation" includes discussion on conservation of energy in the home and on the farm.

—**"Small Farm Energy Primer"**, includes all of the Project Focus and special report on methane. Over 50 pages. $3.00

RULES OF THUMB AND PLANS

—**"Solar Grain Drying, Rules of Thumb"** includes suggestions for air gaps, paint, and other construction points for building the "wrap-around" solar grain dryer mounted to a round steel bin. $.50 (See also Project Focus #1.)

—**"Vertical Wall Solar Collector, Rules of Thumb"** includes construction suggestions for the vertical wall collector, including paint details, air gaps, fan sizes, wiring and much more. $.75 (Ask for Project Focus #3 also.)

—**Portable Solar Collector Plans**, includes 23-8½x11 pages of notes and sketches of the 10 ft. x 24 ft. portable collector used for home heating and grain drying. $2.00

—**Solar Window Box Plans**, developed by the Small Farm Energy Project for building a window size solar heater for around $35 if new material is required. For heating one room. Includes blueprint, construction steps and material list. $2.50

—**"The Stark Solar Heat Storage System"**. A description, including design details, of the rock heat storage system used by Ken Stark (Project Focus #3) with his 220 sq. ft. vertical wall solar collector. $1.00

REPRINTS & REPORTS

—**"Final Report"** of the Energy Project is a full discussion of the Project's three year research effort. Includes "Energy Primer". $5.00

—**"An Analysis of Farm Methane"**, a report on the results of a study of farm produced methane. A proposed methane project was cancelled due to high capital cost and low return on investment. 4 pages. $.50

—**"An Analysis of Farm Alcohol Fuel"**, a brief overview of the various considerations required for implementing farm alcohol production, including discussion of economics, net energy, and various technologies. 4 pages. $.50

—**"Alcohol As A Fuel"**, a special reprint of articles from back issues of SFEP News describing potentials of farm alcohol production. 10 pages. $.75

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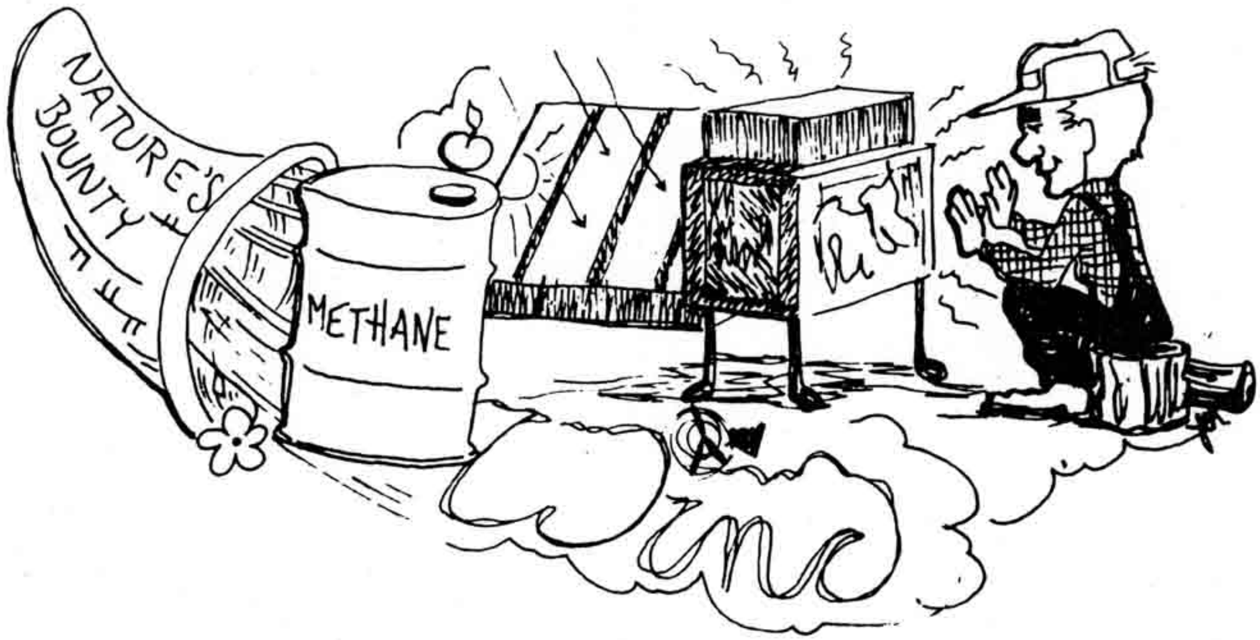

SMALL FARM ENERGY PRIMER

More Information

The Energy Project maintains several tools of communication to provide small farmers with energy information.

A bi-monthly **newsletter** is published for $5 per yr.; $7 foreign and Canada.

A **news column** is available on a regular basis to newspapers and other publications.

A 17-min. **slide/tape program** on the Energy Project is available for $10 rental, $100 purchase. Call or write for scheduling.

A **library** is maintained at the Hartington office on farm energy saving techniques and is open to the public.

Special **farm tours** are conducted to see energy innovations.

For **additional information,** complete the coupon below. See opposite side for ordering publications.

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