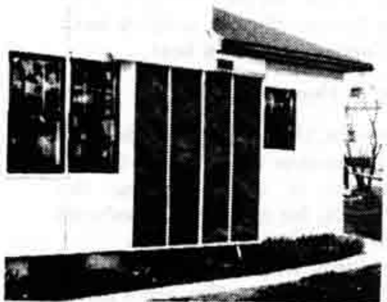
PROJECT FOCUS #3

Small Farm Energy Project

The Solar Vertical Wall Collector

July, 1980
[Revised Edition]

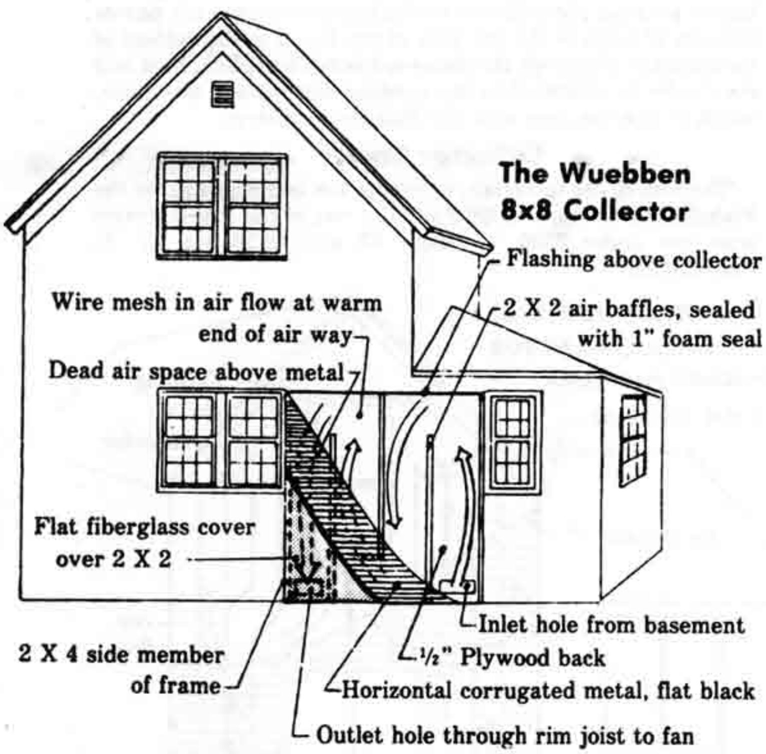


—Edgar Wuebben and his sons built the 8 ft. X 8 ft. vertical wall collector shown above. The collector was constructed in a shop and then mounted to the home. Cost of the collector was about $200. It provided all the heat for the home on sunny winter days.

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.

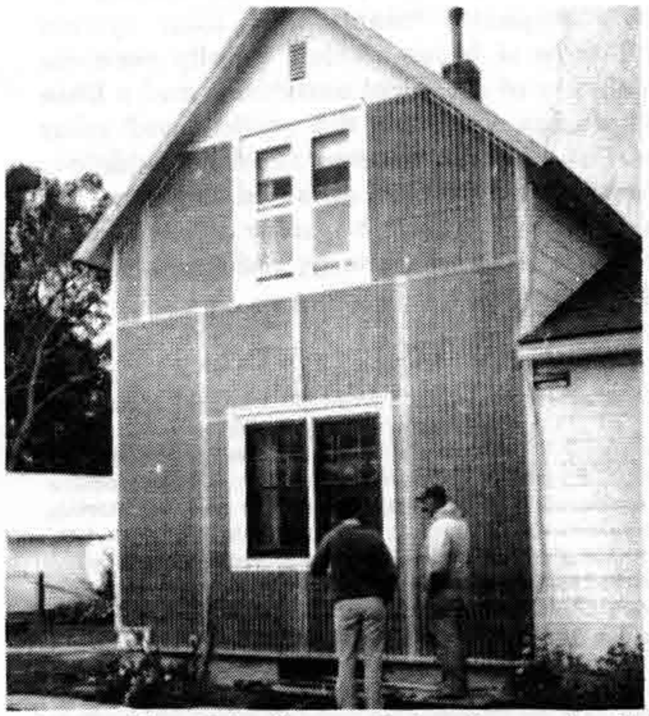
Temperatures of the heated air coming from the collector are dependent on the fan air delivery. For this 8 x 8 ft. solar collector, **a 160 cfm [cubic ft./min.] fan** appears to be the best size, and provides temperatures of between 90 and 100 degrees into the house. A larger fan would provide more air 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.

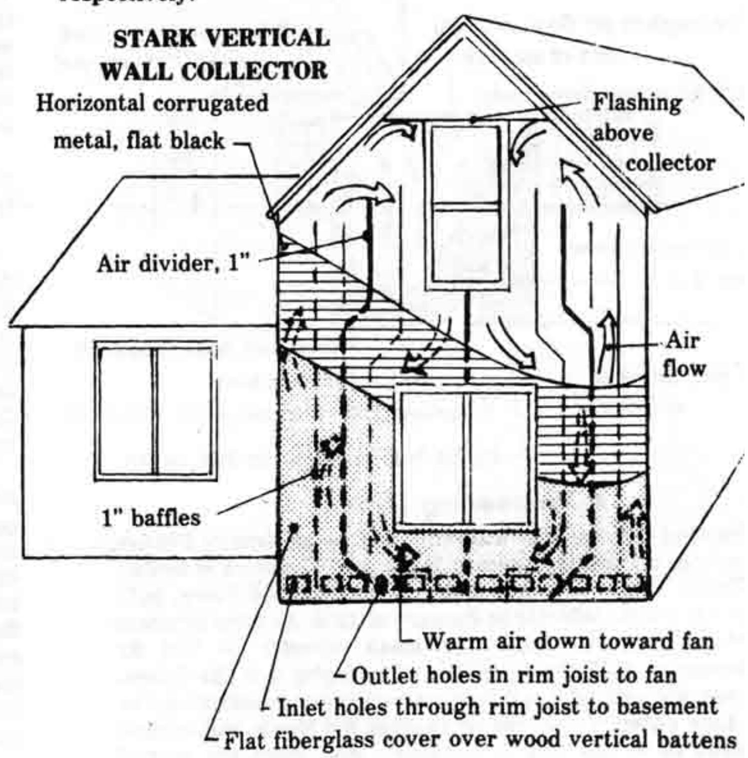
With the Stark collector, the siding was first covered with press plate over the 220 sq. ft. of the collector. The press plate, which was also painted black, is not a major requirement and was not used on the Pinkelman's 290 sq. ft. collector. It was used on the Stark collector since much of the air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

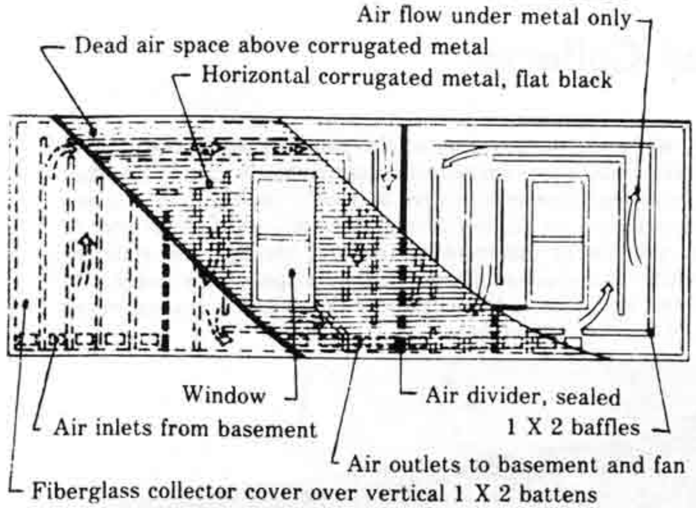
The cost of the materials, including fan and ducting, for the Pinkelman collector was $890 and the cost of the Stark system was just under $500, or about **$3 and $2.30 per sq. ft. respectively.**

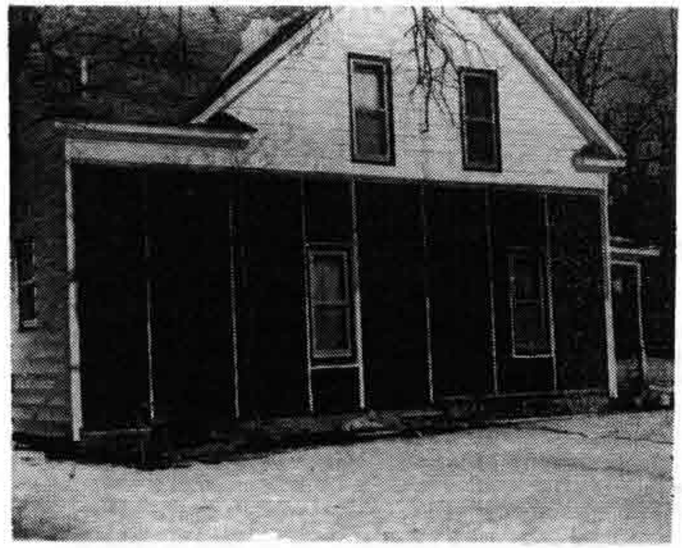
STARK VERTICAL WALL COLLECTOR



[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.

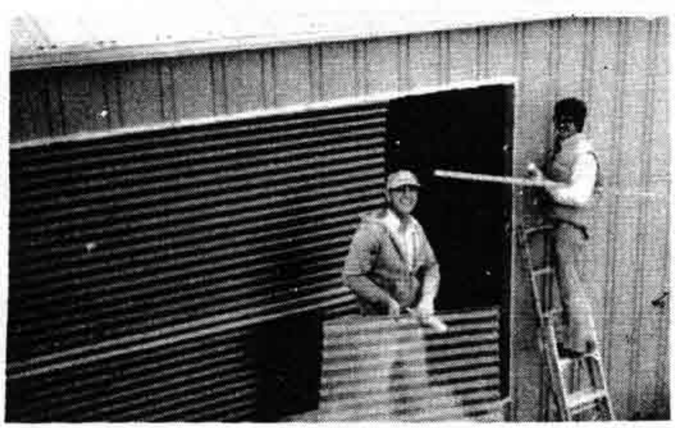
Advantages of Vertical Wall Collectors

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.

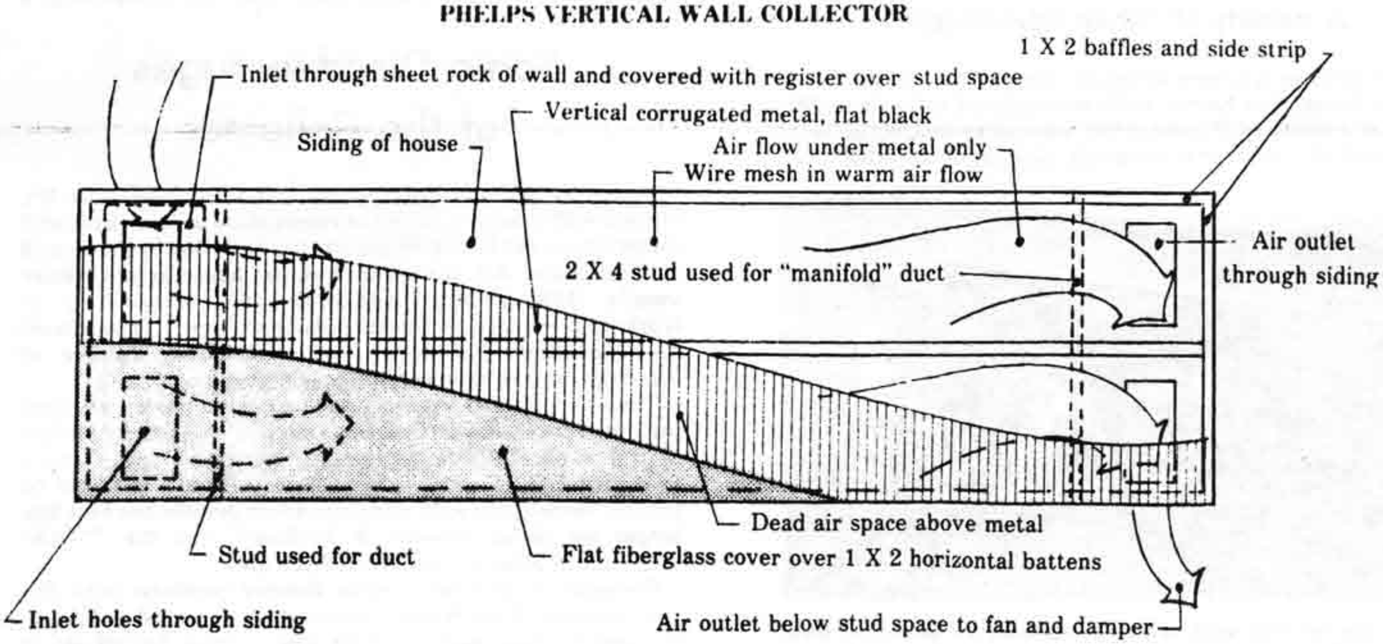
Paul Phelps built the collector with occasional help from his brother and wife, Wilma, over several weeks, as time was available during other farm work activities, and as weather permitted. Phelps figures the labor requirement totalled 43 man hours.

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.

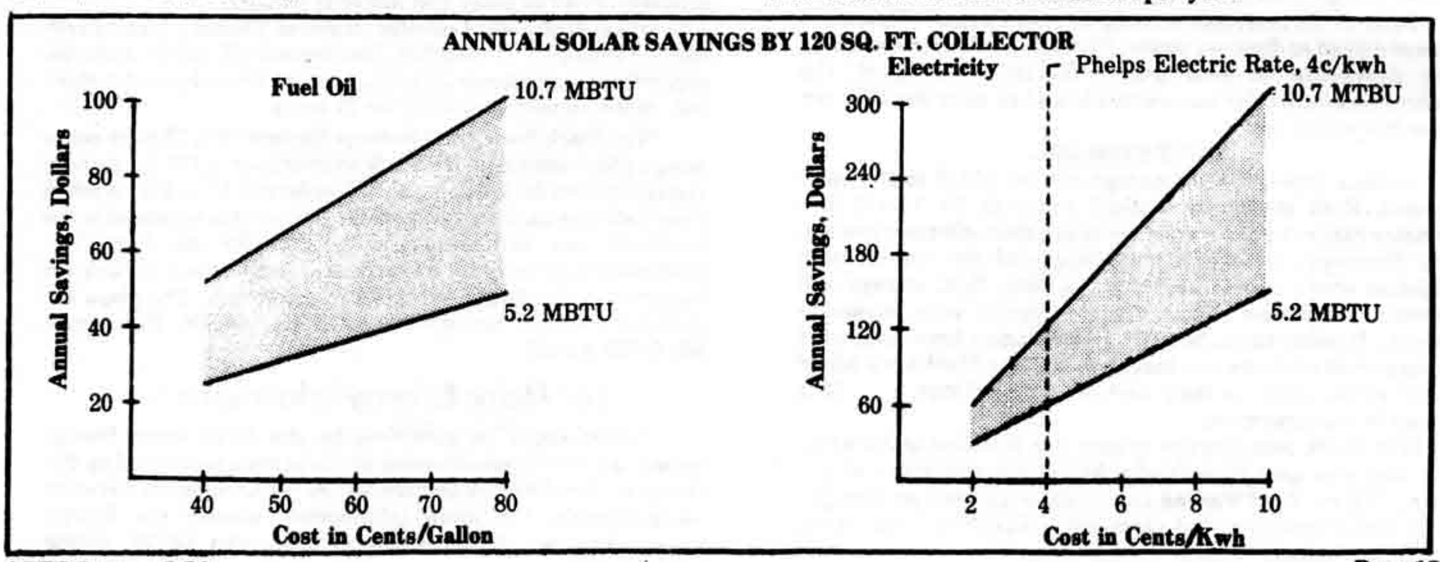
A range of prices for electricity and fuel oil (60% furnace efficiency is assumed) are presented on the bottom of figures below. Projected annual savings are listed on the left side of each figure. The shaded area in the figures represent conservative (80% probability) and moderate (50% probability) 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.



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

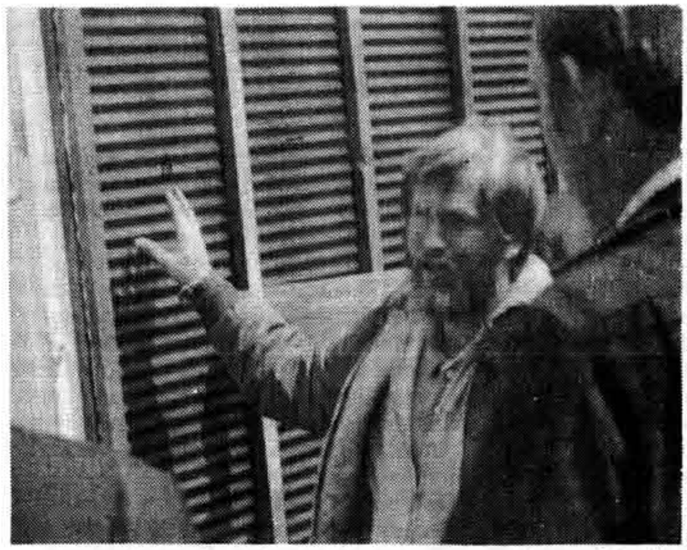
The **energy savings of the vertical wall collector through a season will depend on the local climate.** Some regions receive more sunlight during winter months than other areas. In addition, **fuel costs vary** depending on the region, and the type of fuel being replaced by solar energy will also have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