Sun, Wind, Water, Wood —

Using Maine's Renewable Resources through Appropriate Technology

E OF MAINE

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Joseph E. Brennan
Governor

John M. Kerry
Director

To the Citizens of Maine:

This book describes nineteen alternative energy systems in use by Maine homeowners, institutions, and small businesses. These projects include solar heating systems, energy efficient construction, micro hydro sites, solid fuel burners, windmill generators and alternative fuel production. These projects met with varying degrees of success, however they all offer valuable lessons for anyone interested in renewable energy resources and energy conservation.

Funding for many of these projects was provided by the U.S. Department of Energy under the Appropriate Technology Small Grants Program. This program was begun to encourage the development and use of small-scale energy technologies and renewable energy resources.

I want to take this opportunity to congratulate the people whose projects are outlined here for their creativity and innovative use of energy. Similar efforts by homeowners, businesses, institutions and farmers across the state have helped to greatly reduce our dependence on oil over the last 12 years. It's important that we make further efforts to conserve energy and use renewable resources if we are to continue to enjoy the relatively stable fuel prices of today. By using energy well, we have the potential to save literally hundreds of millions of dollars, increase the expendable income of Maine households, improve our businesses' financial health, and increase our energy independence and self-sufficiency.

We hope that as you read this book, you will improve your own use of energy. The Office of Energy Resources can provide information and advice to get you started. Call us at our Augusta State House Office (289-3811) or call our energy extension service agent nearest you, if you have any energy-related questions.

Thank you.

Sincerely,

John M. Kerry

JMK/BR/jr

Acknowledgements

We wish to thank the participants in these projects for their help in preparing this publication: Roger Bickford, Monmouth; Dan Boisclair, University of Maine, Portland; William Carr, University of Maine, Orono; Sandra Dickson, Port Clyde; Lawrence Gamble, Hampden; Captain Havilah Hawkins, Camden; Chris Heinig, Harpswell; Dr. Gordon Johnston, Sanford; Paul Jones, Mechanic Falls; Robert and Susanne Kelly, Lowell; William Kreamer, St. Joseph, Michigan; Jay LeGore, Liberty; Lloyd Lund, Waldoboro; Allen Pinkham, Damariscotta; Arthur Shute, East Sebago; George Sprowl, Searsmont; Peter Talmage, Kennebunkport; Lloyd Weaver, Topsham; Roger and Cheryl Willis, Bar Harbor.

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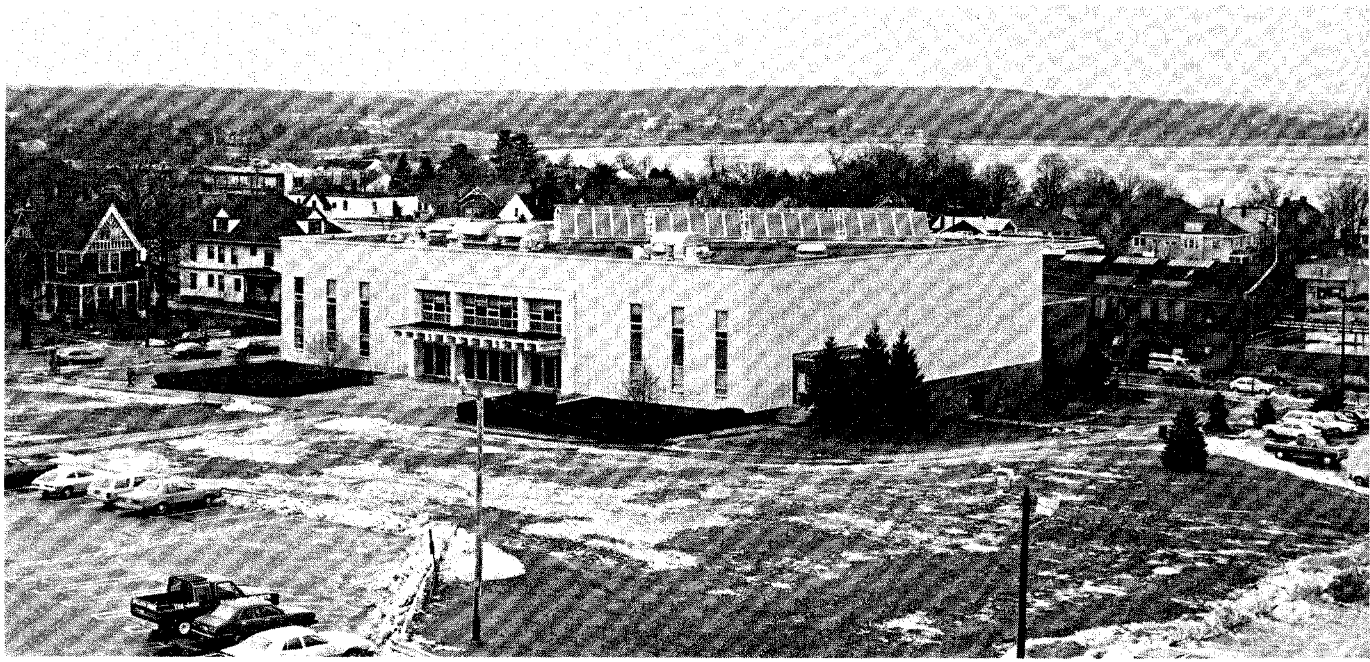
Solar

Institutional Solar Water Heater Installation

The University of Southern Maine is demonstrating the feasibility of high-volume, solar-assisted hot water production. Forty 4' x 8' single-glazed collector panels have been placed on the roof of the gym and the solar energy they collect is used to help meet the gym's 5000 gallon-a-day hot water demand. The project engineers were Dave Merritt and Kirk Bantrum and the system is currently managed by Dan Boisclair, a member of the U.S.M. engineering staff.

The solar system preheats water for showers, using a "closed-loop" heat exchanger. It includes the collector panels, copper heat exchangers and two 1,500 gallon storage tanks. A non-toxic anti-freeze solution of water and glycol is circulated through the south-facing panels. When the temperature differential between the liquid in the panels and the water in the first storage tank reaches 5° Fahrenheit, a circulator pump moves the heated anti-freeze through a copper "shell-in-tube" type heat exchanger where its heat is transferred to the water in the tank. When there is a demand for water for showers, the water is pumped to the second tank where a steam coil boosts the temperature to the desired 110 degree F.

The system is efficient because of the relatively low water temperature required. The potential areas of heat loss (such as exposed piping) are well insulated. A mixing valve located beyond the second storage tank assures that only 110 degree F water is pumped to the showers, which are equipped with low-flow shower heads. The system's overall solar conversion efficiency of 50% is considered excellent.



The U.S.M. gymnasium in Portland. Solar panels preheat water for the showers. Craig Gardner photo

The solar system has been operating since early spring of 1983. It is monitored and controlled by a Honeywell Delta 1000 energy management system. Mr. Bantrum believes that the system's cost of about 45 dollars per square foot of collector surface represents a payback period of 12-15 years at current fuel prices. The life of the system itself is estimated at a minimum of 25 years.

The University of Southern Maine is proving to large consumers of hot water that the solar option is feasible and economical. The price of other fuels will certainly continue to rise, while, once the equipment is paid for, the price of solar energy is fixed at zero. Mr. Bartrum feels that once a solar system like the one at the University can prove a payback period of five years or fewer, commercial applications will increase. ■

Commercial Solar Hot Water

Curly's Restaurant in Monmouth was the first restaurant in Maine to supplement its hot water needs with a solar collector system. Roger Bickford, the owner of Curly's, decided to install a solar system about eight years ago when he became concerned about the amount of money he was spending for hot water. He worked with John Dumont, also of Monmouth, to size a system that would meet as much of the restaurant's demand as possible and still remain cost-effective.

A closed-loop system was selected because it is protected from winter freezing problems. Instead of water, an anti-freeze solution of propylene glycol is pumped through the roof-mounted collectors and heated by the sun. The heated anti-freeze is piped to a water storage tank where the heat is transferred to the water by a heat exchanger. The water and anti-freeze are separated by a special, double-walled heat exchanger and never come in direct contact with each other. The propylene glycol remains within the collector/heat exchanger system, cycling in a closed loop between the components.

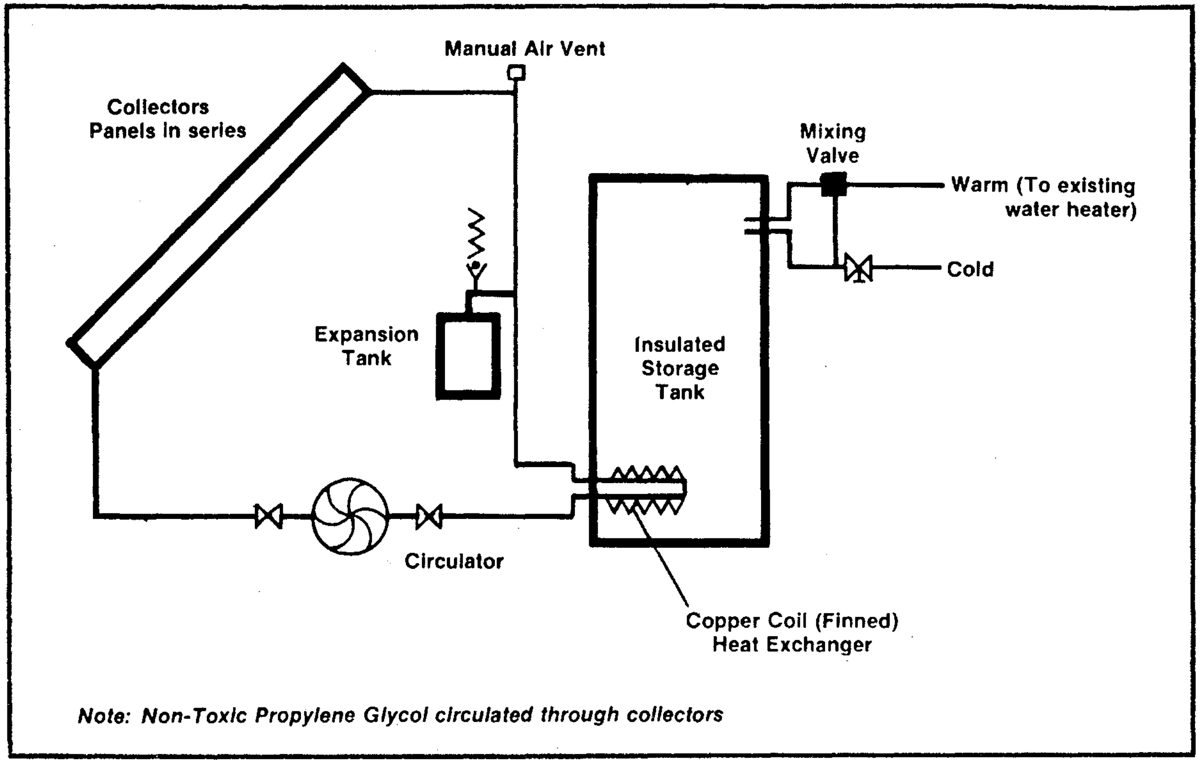
The system at Curly's consists of twelve 6' x 3' insulated, single-glazed collector panels mounted on the building's roof to face due south. The panels are arranged in two separate arrays of six panels each. The 350-gallon water storage tank with a 3/4" finned copper tubing heat exchanger is in the basement. The tank and the pipes leading to and from the storage tank are insulated to reduce heat loss throughout the system. A differential thermostat activates a pump which circulates the anti-freeze though the loop when the temperature in the collectors is 10° Fahrenheit greater than the water within the storage tank. The system shuts down when the water in the tank reaches 120° F.

Roof-mounted Solar Water Heating Panels.

Craig Gardner photo

State health codes require that the water used to wash dishes in a commercial restaurant must be 180° F. The system at Curly's is therefore used as a pre-heat measure. The 120° F water from the storage tank must pass through a conventional propane gas water heater to be boosted to 180° F before it is used.

Mr. Bickford's system has been in service for almost eight years. He estimates that the solar collectors provide about 25% of the energy needed to supply hot water to his restaurant. He believes solar collectors could supply a much greater percent of water heating energy to facilities other than restaurants, which don't have the 180° F



A closed-loop solar collector system.

requirement. Maintenance of this system has been limited to periodic "recharging" of the anti-freeze solution to ensure maximum efficiency. The overall life expectancy of the system is estimated to be at least twenty years.

Mr. Bickford purchased his system before state and federal tax credits were available. He still expects his 5,000 dollar investment to pay for itself in about ten years. He points out that favorable tax credit programs, combined with the increased efficiencies of systems developed since 1978, make solar hot water systems an attractive alternative to conventional water heating systems. ■

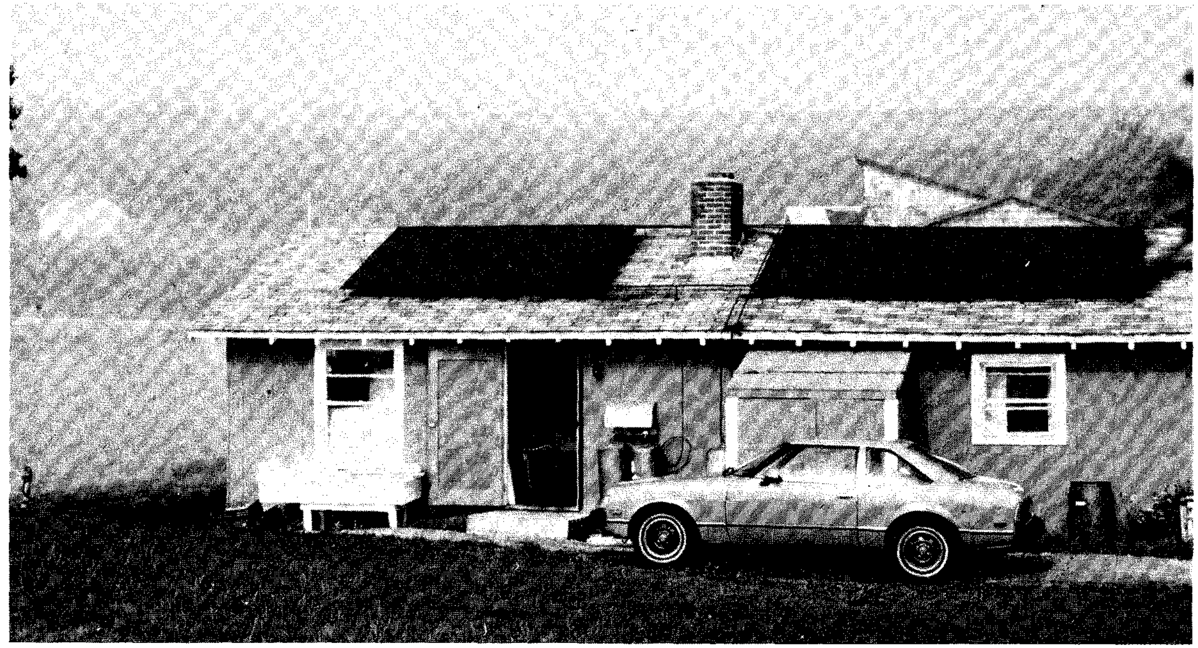
Solar Shellfish Hatchery

Traditional fishing practices rely on the natural productivity of the sea to replenish fish stocks. Management practices may be implemented to protect breeding stock and immature fish or to limit the size of the catch, but little else can be done. Aquaculture, or marine farming, is a more intensive seeding, cultivation, and harvesting operation which combines the husbandry of farming with the richness of the marine environment.

Maine aquaculturist Chris Heinig owns and operates a shellfish hatchery in North Harpswell. He produces immature shellfish, or spat, for "seed" to sell to other aquaculturists up and down the coast. This operation requires heating up to 1,100 gallons of seawater per day to maintain a suitable environment for the spat and the algae upon which they feed. To reduce energy costs at the hatchery, Mr. Heinig has added an active solar water heating system and a passive solar greenhouse. The Department of Energy provided funds for these additions through an Appropriate Technology grant. Much of the labor and ingenuity was supplied by Mr. Heinig.

The solar hot water system reduces energy consumption in the hatchery by heating daily supplies of seawater to 75° Fahrenheit. The system is a solar/sub-ambient heating system which is capable of heating water without any energy input from the sun. The water is generally heated overnight to be used the next day.

A solar/sub-ambient system operates on the same phase-change principles as a standard refrigeration unit. Liquid freon is pumped to the roof-mounted panels where it evaporates, absorbing some heat energy from



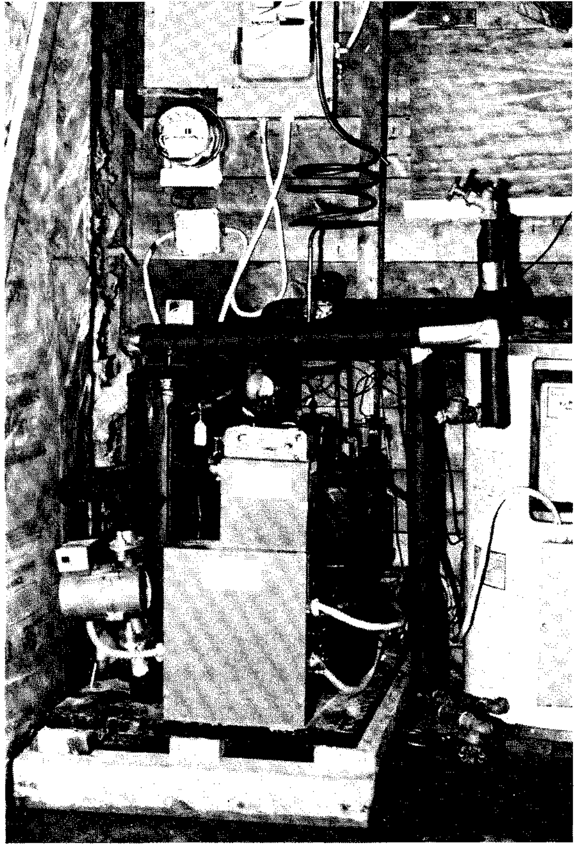
Chris Heinig photo

The solar/evaporation panels where freon undergoes a phase change (liquid to gas) at temperatures as low as -10° Fahrenheit.

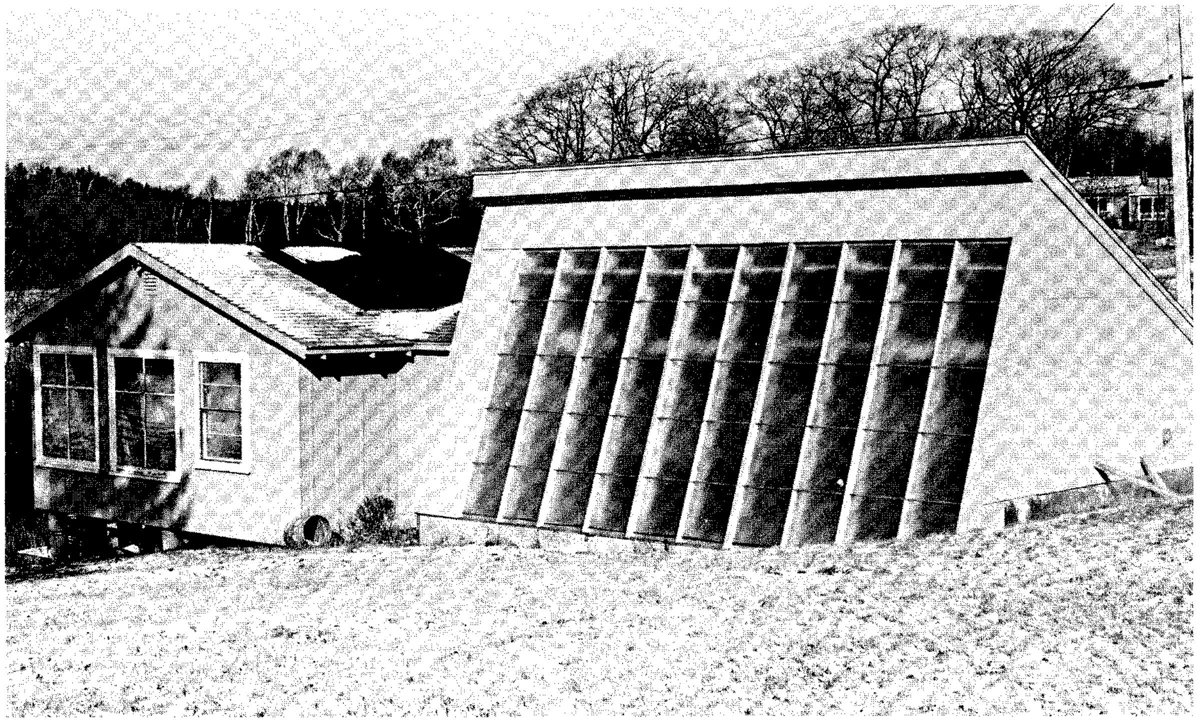
the outside air during the phase change. This evaporation will take place regardless of air temperatures, although the evaporation rate will be faster in warmer weather. The resulting low-temperature, low-pressure gas is then pumped through a compressor which produces a rise in both temperature and pressure. The high-temperature, high-pressure gas is then passed though a primary heat exchanger. Some cooling occurs as heat is transferred from the freon to water and the freon gas returns to a liquid state. The resulting high-temperature, high-pressure liquid undergoes further cooling through depressurization and is returned to the roof panels to start the cycle again.

Heat extracted in the primary heat exchanger is transferred to the seawater, the culture medium, through a secondary heat exchanger made of 100 feet of 1/2 inch polyethylene tubing. This secondary heat exchanger is necessary to prevent any contact between the culture water and the metal tubing of the solar system, a potential source of contamination. When the seawater reaches the desired temperature (75° F), an aquastat in the storage tank shuts down the gas-to-liquid-to-gas freon cycle. The heated seawater is then pumped to the tanks holding the juvenile shellfish.

The solar greenhouse extension was built to reduce the overall space heating needs of the



Above: *the Solar/subambient Heating System heats water overnight.* At right: *south facing wall of the solar greenhouse addition.*



Don Bumpus photos

hatchery. It houses the juvenile shellfish tanks and the algal culture tanks in which algae are grown to feed the shellfish. The structure is 22' by 18', with 200 square feet of double glazing on the south wall. Four 725-gallon fiberglass algal tanks are located along the interior south side with four 325-gallon juvenile shellfish tanks directly opposite them.

The greenhouse is quite effective in stabilizing the interior temperature of the hatchery. In fact, it has not dropped below 48° F, even in winter. This can be attributed to the building's well-insulated construction and the large amount of water (usually 4,200 gallons) stored in the eight tanks which serves as thermal mass. The greenhouse is an energy efficient addition and has proved to be an excellent environment for algal and shellfish production.

Before the solar additions, Mr. Heinig met his energy needs with electricity and propane gas. After switching to solar, he estimates his winter energy bill has been reduced by about 35%. Savings during the summer months have been in excess of 60%. These figures represent a payback period of 6-8 years for Mr. Heinig's $20,000 solar additions. Rising energy costs are cutting into the profits of many small businesses, but Chris Heinig is showing that solar energy use is one way to reduce this expense. ■

Modular Solar Heating/Ventilation System

Conventional solar hot air collectors are an inexpensive way of using the sun's energy to help meet space heating needs. Passive "TAP" (Thermosyphoning Air Panel) collectors operate on a convection cycle in which cool air from inside the building is drawn into the collector, heated by solar radiation, and then circulated back into the building.

In "active" collectors, solar-sensor regulated fans augment the natural convective flow. The operation of these collectors is restricted to the heating season, and they lack the air handling components and distribution components which characterize full-fledged solar systems.

William Kreamer of Sol-Air, Inc. has developed a year-round, modular solar heating and ventilating (H/V) system which he believes represents the "state of the art" in solar hot air systems.

He has experimented with different configurations over the past seven years. His current design has undergone independent performance testing at the Western Michigan University's Energy Learning Center which has disclosed a maximum conversion efficiency (the percentage of available sunlight converted to usable heat) of over 70%. Conventional hot air collectors have conversion factors of 30%-35%.

Mr. Kreamer's modular H/V system possesses many features which are unique. First, the unit functions year round. It automatically provides heating on cold days and ventilation on hot days. Second, the system uses a stagnated, directly irradiated solar sensor which increases the collector's operating time by about twenty minutes per day. This alone provides a 5%-6% increase in heat production during the heating season. Third, Mr. Kreamer uses a glass blanket absorber surface which increases the collector's efficiency by as much as 50% over collectors with the usual type of flat plate absorber. Fourth, the air flow system is controlled by an inexpensive and reliable phase-change component which operates the damper. Fifth, an adjustable setpoint feature invented by Mr. Kreamer (Pat. No. 4,498,457) gives the user the ability to select a room temperature between 60° and 80° Fahrenheit which the system then maintains by varying the heating and ventilation output.

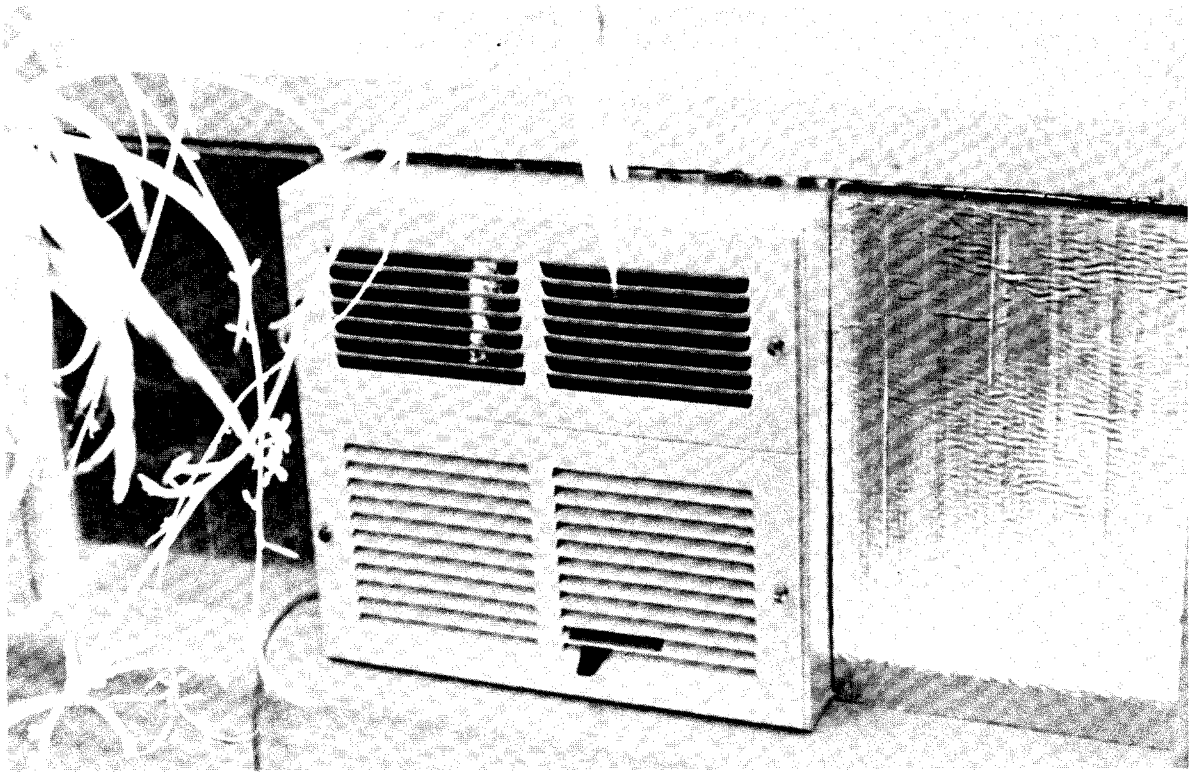
Mr. Kreamer's 4' x 5' solar H/V module is designed to be installed vertically in the lower half of a window or onto a wall.

Installation time is two to four hours, and yearly maintenance is limited to washing the glazing and cleaning the air filter. Aside from these small requirements, the system is automatic and should provide trouble-free heating and ventilation for a large room.

Mr. Kreamer believes his system will provide an annual heat output of 5,000,000 Btu. The system's price tag of $700 retail ($320 after tax credits) represents a payback period of five to six years for the oil user and about three years for the electric heat user at current price levels. The 110-cubic-feet-per-minute fan will cost less than $2 a year to operate at current electricity prices.

William Kreamer feels he has developed a system which can compete with the more expensive liquid medium systems in efficiency, without the added cost. With a life

The Sol-Air Solar Heating/Ventilation System.



William Kreamer photos

Indoor view of Mr. Kreamer's Heating/Ventilation System.

expectancy of 20-25 years, this system should prove to be an economical investment to help supply heating in the winter and ventilation in the summer.

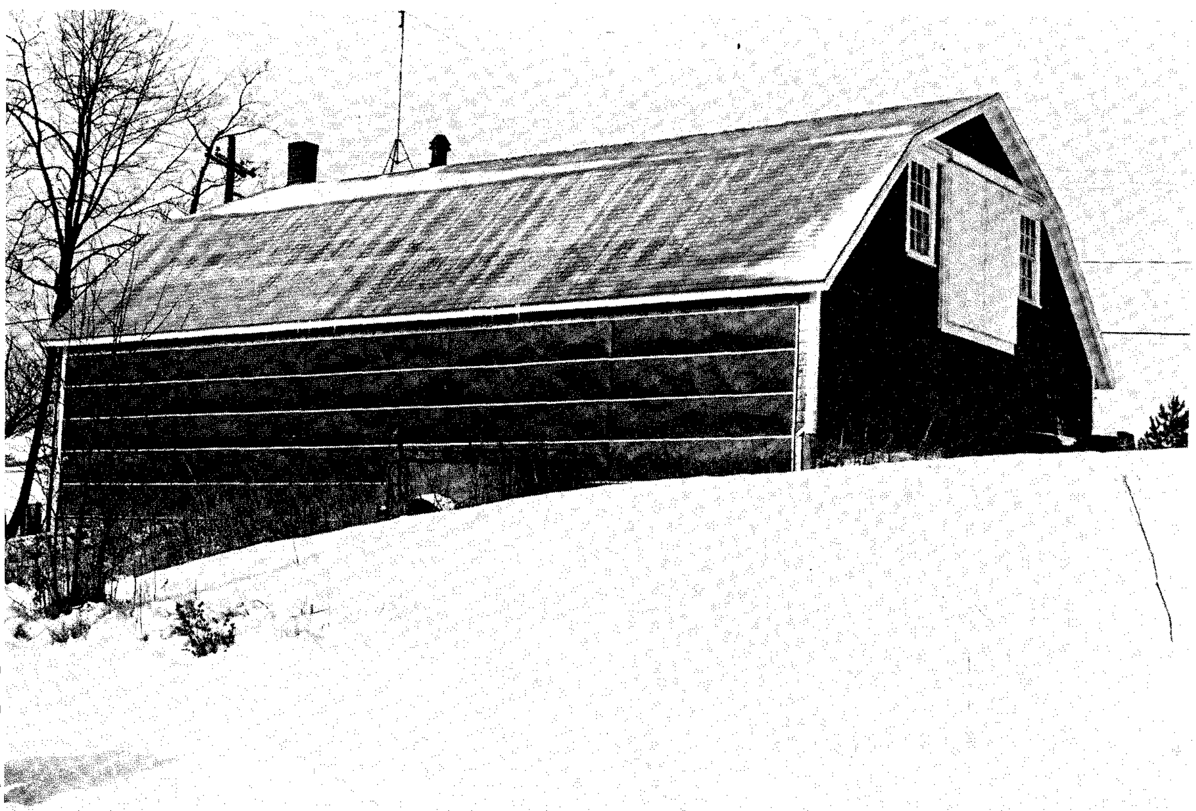
In 1984, Mr. Kreamer was given an "Award for Energy Innovation" by the U.S. Department of Energy for his invention. He has recently moved from Maine to Michigan and is now manufacturing these units for sale in the U.S. and overseas. ■

Solar-Heated Fire Barn

The winter of '78-'79 presented the town of Searsmont with a potentially life threatening problem: a failure of the oil-fired heating system in the local volunteer fire department caused the fire engine and some of its accessories to freeze up. If there had been a fire, the volunteers would have rushed to the station house only to find their equipment useless. Fortunately, an emergency did not occur while the rigs were inoperable. However, the town was obliged to foot a repair bill of over $2,000.

The Searsmont selectmen felt a back-up heating system should be installed to prevent this situation from recurring. But, because of a tight municipal budget (a problem for large and small communities alike), there were no funds available for such an undertaking. The project was tabled until two area residents proposed a plan that proved to be both practical and economical.

Jay Legore and Tom Wills recommended a site-built, solar space heating system to supplement, as well as back up, the existing oil unit. The funding obstacle was overcome by an Appropriate Technology grant from the Department of Energy.



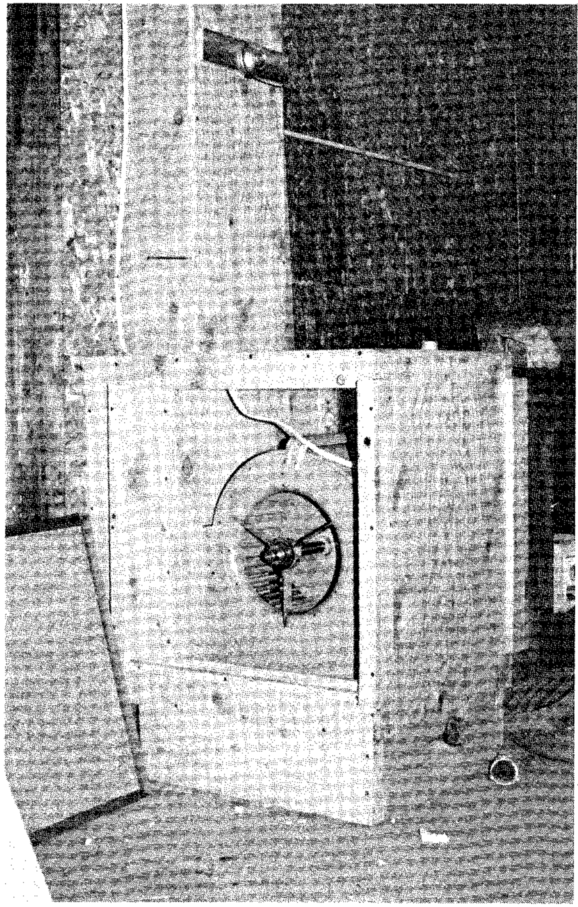
Don Bumpus photo

They designed a 500 square-foot, active, single-glazed solar collector for the south wall of the building. Heat storage was provided by the building, the fire trucks, and sixteen 55-gallon metal drums filled with water. A wall-mounted collector was chosen (as opposed to a roof type) because it was easier to build, had shorter duct runs, would have no ice or snow buildup, and offered increased solar gain due to reflection from the surrounding snow cover.

The active component of the system is a 12" circulating fan. It is controlled by a differential thermostat, activated by heat sensors when the temperature in the collector is 10° Fahrenheit greater than the interior temperature. The fan shuts down when the temperature difference falls below 4° F. An electronic monitoring system is integrated into the control mechanism to record the total Btu produced by the collector. This data was essential in determining the payback period of the design.

A solar air heating system is simple and virtually maintenance free. Since the only active component, the blower fan, is controlled by a thermostat, the collector operates automatically, making it ideal for use in buildings which are frequently left unattended. Once the air in the collector has been heated, the fan starts up. Warm air is forced through duct work to outlets under the drum storage racks. The heated air rises around the barrels, transferring its energy to them. As the air cools, it begins to sink and is

Snow-covered ground reflects additional sunlight onto the collector.


John Carroll photo

A fan circulates air through the collector.

drawn into the blower unit's intake manifold and circulated back to the collector. This cycle repeats itself until the temperature differential falls to less than 4° F.

Legore and Wills' system was operational as of November 16, 1979. The monitoring assembly was added two months later. The solar space heating system collected roughly 100,000 Btu per square foot of glazing surface area during the heating season. The amount of oil used in heating the fire house decreased from 1516 gallons to 758 gallons.

The amount of oil conserved during the system's first year of operation was about 300 gallons more than could be attributed to the solar collector. The reasons for this were the increased R-value of the south wall due to the collector construction and a conscious effort to keep the interior temperature at 50° F.

It was also determined that the building and the fire equipment provided adequate storage mass for the heat generated by the collector. The sixteen barrels of water were not needed for additional storage and were removed following the first year of operation. Nonetheless, the oil required to run the primary heating system was cut in half, constituting a substantial savings for the town.

Initially, the designers projected that the system would pay for itself in six years, however, they now feel that the payback period may be only four years. Such a quick payback may make similar installations economical for other small towns. ■

Municipal Garage Trombe Wall

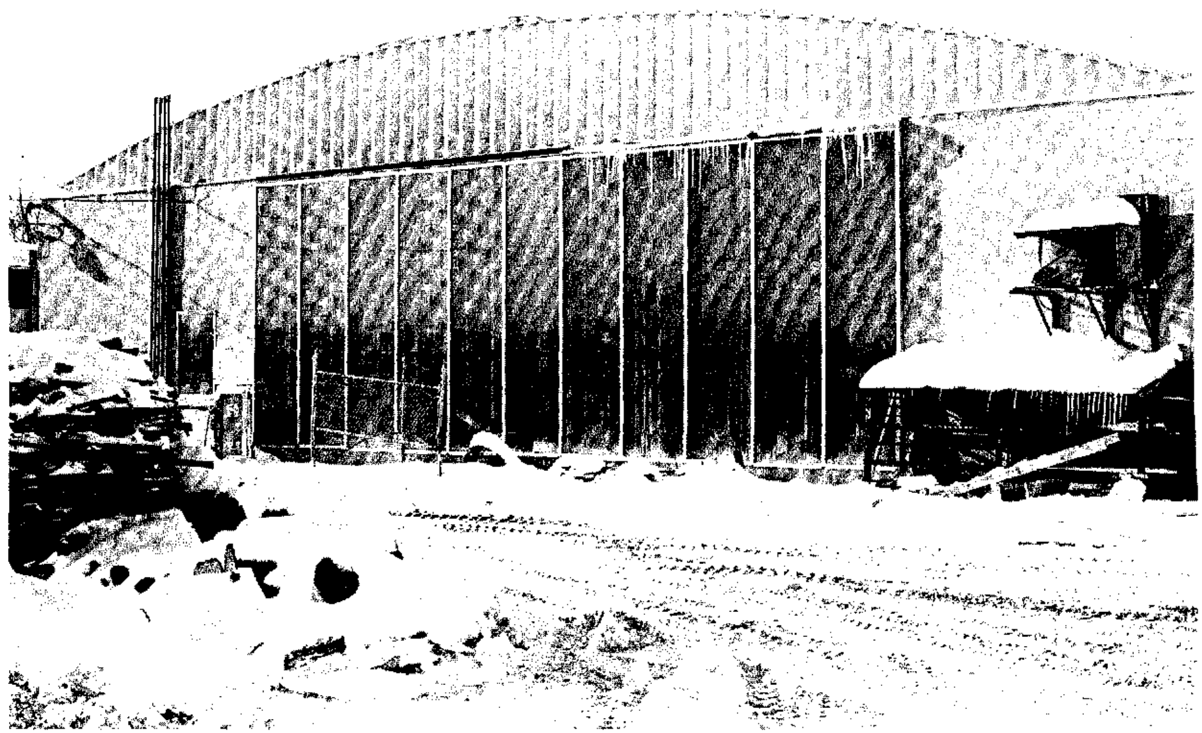
Most cities and towns in Maine have a town garage for storage, maintenance, and repair of their vehicles. Heating these buildings is expensive because they are generally poorly insulated and include large work areas with high ceilings and bay doors which are opened frequently. Many towns accept these heating costs as unavoidable operating expenses, but conservation-minded officials from the City of Sanford have come up with a creative way to save some money.

The Selectmen's office applied for and received an Appropriate Technology grant from the Department of Energy to help fund the construction of a trombe wall to supplement the existing oil-fired heating system at the garage. Dr. Gordon Johnston, a faculty member at Sanford's Regional Vocational Center, supervised construction of the project. Free labor was provided by some of his students, and many of the necessary building materials were donated by area businesses.

A trombe wall is a passive, solar space heater built into or fastened upon a vertical wall. It consists of a large, flat box or chamber with dampered vents at the top and bottom. The outer surface is covered with glazing, and the wall underneath is painted black to absorb solar radiation. The wall acts as a thermal chimney in which sunlight warms the air within the collector cavity and causes it to rise through the upper vents into the space to be heated. As this warm air leaves the collector, it is replaced by cooler air drawn from the building's interior through the lower vents. As long as sunlight strikes the absorber surface, air is warmed and circulated through the venting network.

Sanford's trombe wall was designed by architect David Joy. His goal was to reduce the amount of oil needed to heat one of the work bays by 25%. This necessitated a collector surface of roughly 700 square feet. The collector was mounted on a cinder block wall facing southeast (134 degrees 30' magnetic). The plastic glazing material was available in 4' x 16' sheets, so the collector was designed with eleven independent, 4' wide chambers, each with individual top and bottom vents.

The Sanford Municipal Garage Trombe Wall.



The most time-consuming step in the construction was filling the core of the cinder blocks with ten tons of sand. This was done to increase the R-value and the heat storage capacity of the wall. Next, the wall area that was to be covered by the collectors was painted with black latex paint to provide an absorber surface. The eleven collector chambers were then mounted on the painted wall, leaving a 5-inch air space between the glazing material and the cinder blocks. Finally, additional vents were placed directly

on top of each chamber to prevent warm air from being circulated through the building in the summer.

Dr. Johnston and his students began construction of the trombe wall in November of 1979. Work was completed in March of 1980, with the students providing about 925 hours of free labor. Dr. Johnston felt that the "hands-on" experience gained by the students added greatly to classroom discussion of passive solar space heating methods.

Early testing indicated that two paddle fans were needed to prevent the warm air from stratifying near the 19-foot ceiling. Once they were installed, data were kept on the performance. It began producing usable heat at 7:30 a.m., hit a peak air movement rate of 3603 cubic feet per hour at 10:00 a.m., and tapered off to zero between 1:30 and 2:00 p.m. This mediocre output is a reflection of the poor solar orientation of the wall. Because of the building's orientation, the wall was constructed facing 63 degrees east of true south and therefore receives only about sixty percent of the daily available insolation (includes direct and indirect sources of solar radiation). Despite this siting problem, it is estimated that the system saves roughly 250 gallons of oil per heating season. With a life expectancy of 25 years, the project could have been totally funded by the town and still have paid for itself within fifteen years at current oil prices.

An additional benefit of the project that is more difficult to quantify is the interest it stirred in solar energy and energy conservation. The city adminstration and the schools have taken progressive steps to investigate alternative energy resources, to encourage other solar projects, and to implement energy conservation measures in other city operations. ■

C. Scott Hoar photos

Sanford area students install glazing over the sand-filled wall. Note the openings cut into the top and bottom of the wall to allow for air circulation.

Hybrid Utility-Powered/Photovoltaic House

Photovoltaic cells convert the sun's energy into usable electricity without any moving parts. An electric current is produced when particles of light called photons strike a silicon wafer which has been specially treated with small amounts of boron and phosphorous to enhance electron flow.

Today, photovoltaic systems are frequently installed in remote locations where an electric utility connection is uneconomical. In other cases photovoltaics are used by people who are seeking energy self-sufficiency and independence from their electric utility.

Sandra Dickson of Port Clyde has developed a hybrid domestic system which combines the independence of photovoltaics with the convenience of utility-generated power. She is successfully demonstrating that average homeowners can adapt their homes to use both photovoltaics and utility electricity without great expense or technical expertise.

Ms. Dickson's photovoltaic system is a grid-connected hybrid system; it operates by converting sunlight to electricity and then storing this electricity in batteries for future use. The system consists of four 35-watt (approximately 4 square feet) panels mounted on a stainless steel rack built onto the roof of her home. The panels face south and are angled at about 50° to allow them to capture as much sunlight as possible throughout the year. A circuit runs directly from the panels to six 12-volt D.C. batteries in the basement.There, control meters monitor the condition of the batteries and overall system efficiency. A small, utility-powered battery charger is used to supplement power during the short daylight hours of the winter months.

Ms. Dickson's home is connected to the utility grid, but almost one-third of its electrical needs are met by photovoltaics. Her home is equipped with two separate wiring systems, one carrying direct current (D.C.) and the other, standard alternating current (A.C.). The D.C. circuit receives its power from the photovoltaic panels. It supplies power for all the lighting and operates household appliances such as a T.V. and stereo and some small kitchen appliances. The A.C. circuit uses utility power to operate larger appliances, a refrigerator, and the battery charger.

Ms. Dickson's photovoltaic system cost less than $2000 after applicable state and federal tax credits. The price includes all components, wiring, and installation. When this price is spread over the twenty year life of the system, her monthly payments amount to only $8.33. Her payments to the utility average about $4.00 monthly.

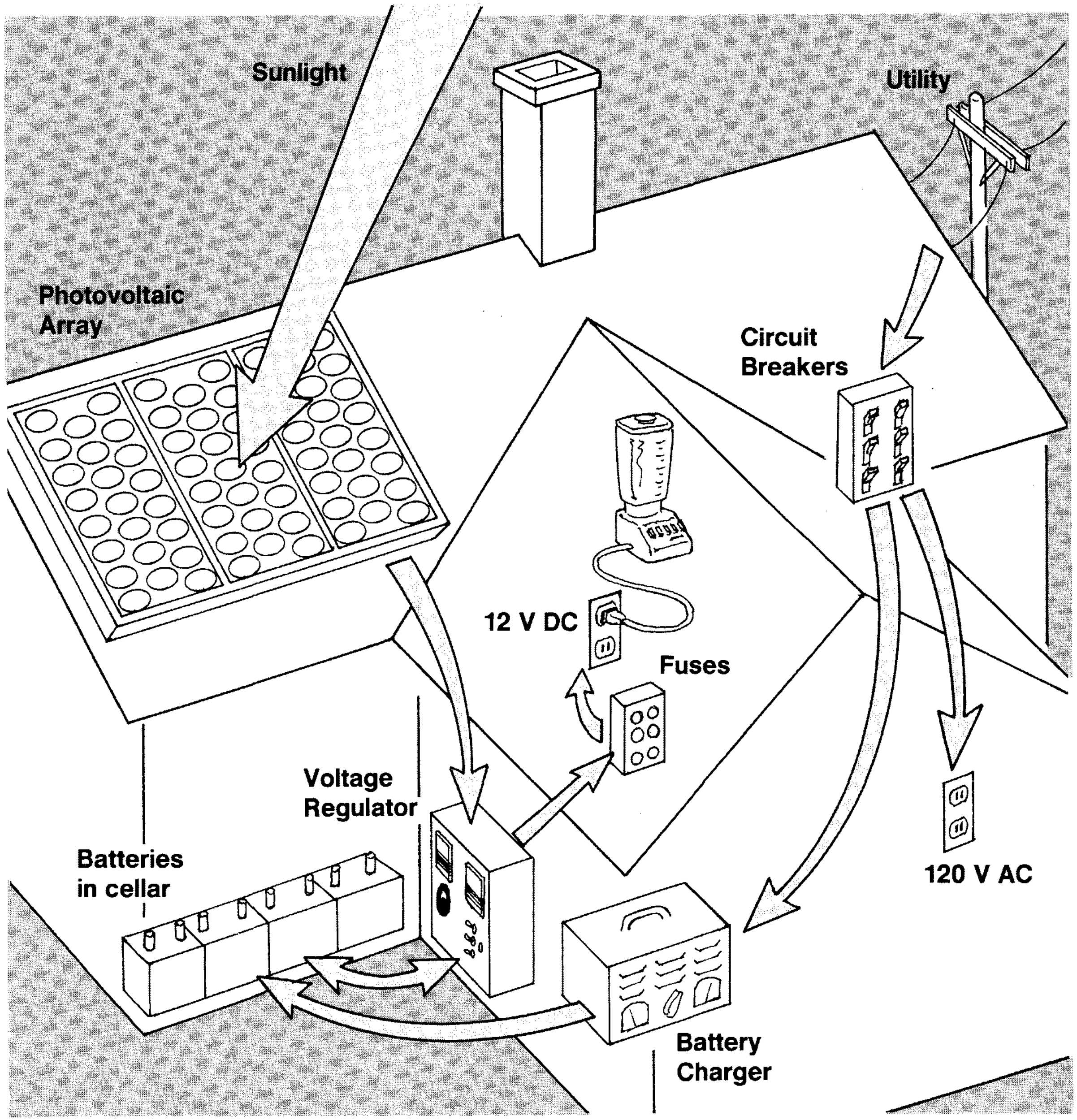
Ms. Dickson's electric bill is low partly

At left: *Ms. Dickson prepares a refreshing drink in her solar-powered blender.* Below: *a voltage regulator monitors energy use and controls battery charging.*

Sandra Dickson photos

because of her photovoltaic system, but also because she has made a conscious effort to reduce her overall electrical consumption. She has not sacrificed many modern conveniences; she simply uses them in an efficient manner.

While the price of utility power is expected to rise, photovoltaics will become cheaper as production techniques and the efficiencies of solar cells improve. Furthermore, it is simple to increase the output of a photovoltaic system by adding additional panels and batteries. In the not too distant future, more people may follow Ms. Dickson's lead and choose photovoltaics as a supplement or alternative to utility power. ■



Jon Luoma illustration

Photovoltaic/utility hybrid system.

Superinsulated House

Bar Harbor Times photo

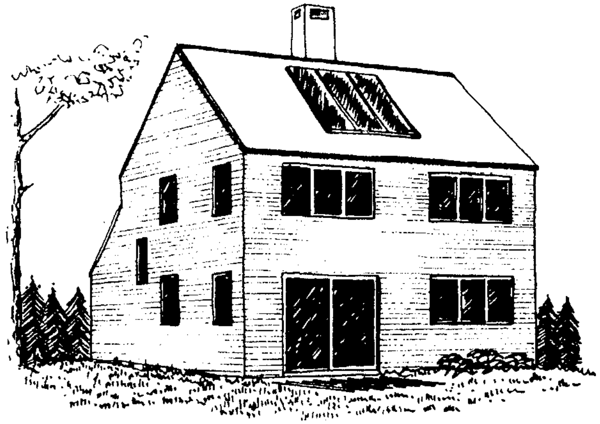
Roger and Cheryl Willis outside their superinsulated home.
Above right: *view from the south.*

Cheryl and Roger Willis of Bar Harbor use less than two-thirds of a cord of wood a year to heat their superinsulated home. The house is so well insulated that most of its heating requirements are met by intrinsic heat sources (heat produced by appliances, lights, and human bodies) and passive solar gain through south-facing triple-pane windows. In winter, the Willises operate their small soapstone woodstove for a few hours each day to supplement these heat sources. They maintain a comfortable interior temperature of 70° year-round for less than fifty dollars.

The house was designed by J.B. Thomas of Southeast Harbor and won first prize in the Office of Energy Resources' 1981 solar design contest. The floor plan and exterior appearance are not unusual but the walls are roughly twice as thick as in conventional construction.

Mr. Thomas' design called for the exterior walls to be built of two 2" x 4" stud walls set 3-1/2 inches apart. This double walled construction allows for 10-1/2 inches of cellulose insulation. The walls are sheathed with 1 inch of rigid foam inside and out, with clapboards on the exterior side. The inside of the walls were lined with a polyethylene air/vapor barrier and then covered with two layers of 5/8 inch sheetrock. These features give the wall an R-value of 46 (R-value is the ability of a material to resist heat loss). This is at least twice that of a conventional house. The ceilings are insulated with 16 inches of cellulose (R-60), and the concrete slab foundation has two inches of rigid board insulation underneath (R-10).

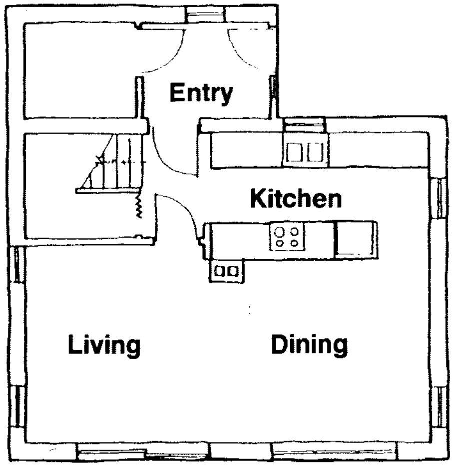
The high levels of insulation and the continuous polyethylene vapor barrier that



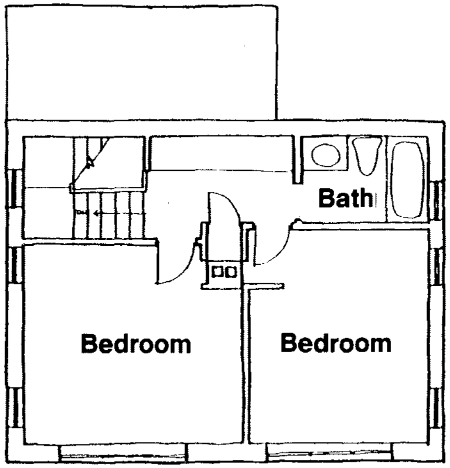
envelopes the house help reduce the Willis' fuel bill. However, the overall tightness of the house can present a problem because of insufficient ventilation; just as heat is kept in, so too is humidity and interior air pollution.

This problem was solved by installing air-to-air heat exchanger/ventilation systems. These prevent interior air pollution and humidity build-up, without causing excessive heat loss, by drawing fresh air into the house and exhausting stale air. The two volumes of air pass each other within the exchanger; about 70% of the heat from the outgoing air is transferred to the incoming air. The Willis' house has two through-the-wall heat exchanger units, one in the downstairs living room and another in an upstairs bathroom.

The house includes other energy-saving features. A solar hot water system with a demand-type gas water heater as back-up is designed to operate at low pressure, so the faucets and showerheads are fitted with low-flow fixtures. The windows are triple pane, there is an airlock entryway, and an



First Floor Plan



Second Floor Plan

exposed brick chimney in the living room and master bedroom provides radiant heating. The Willis' house is so well planned, tightly built, and well insulated that it can be heated primarily by intrinsic heat sources even in Bar Harbor, where there is 7,500 degree day climate — or in even colder locations with up to an 11,000 degree day climate.

The Willises are very happy with the performance of their superinsulated home. With a construction cost of about $45,000, their house is within the budget of many people who are considering a new home. Superinsulated house construction has proven itself in Scandanavia and the Canadian Provinces over the years. The Willis' house shows that it works well and is cost-effective in Maine. ■

Biomass

Small-Scale Alcohol Fuel Project

Using alcohol (ethanol) to fuel internal combustion engines is not a new idea. It is not difficult to convert an engine from gasoline to alcohol fuel, and the process of producing alcohol from agricultural products is elementary. Despite this, small-scale production of alcohol for on-farm fuel use has not traditionally been regarded as an economical alternative to gasoline because of the high cost of building and maintaining a small distillation operation. However, George Sprowl of Sprowl Brothers, Inc., a construction supply company in Searsmont, has experimented with running a small distillation plant at his lumber yard. He has concluded that alcohol production can be an economical project for a farmer if both the alcohol, *and the fermentation by-products*, are incorporated into the farm operation. He developed a system that produced fuel to run his farm equipment and used the residual "mash" from the fermentation process as a valuable feed supplement for livestock.

To produce the alcohol, Mr. Sprowl tested a variety of base stocks which are available to Maine farmers, including cull potatoes, sawdust, and corn. He determined that corn is an exceptionally good base stock because it produces both a high quality fuel and a good feed supplement. In fact, laboratory tests have shown that the percentage of digestible nutrients available in feed corn increases from 31% to almost 90% after it has gone through the distillation process.

During his research, Mr. Sprowl experimented with site-built stills, but he found that the technical problems encountered in building an efficient and reliable system would make it more economical to purchase a manufactured one. He eventually bought a system manufactured in Tennessee, hoping it would give trouble-free operation. Its main components are a large bin equipped with a grinder mechanism, a 1000-gallon capacity fermentation tank, and a specially-designed vapor compression still.

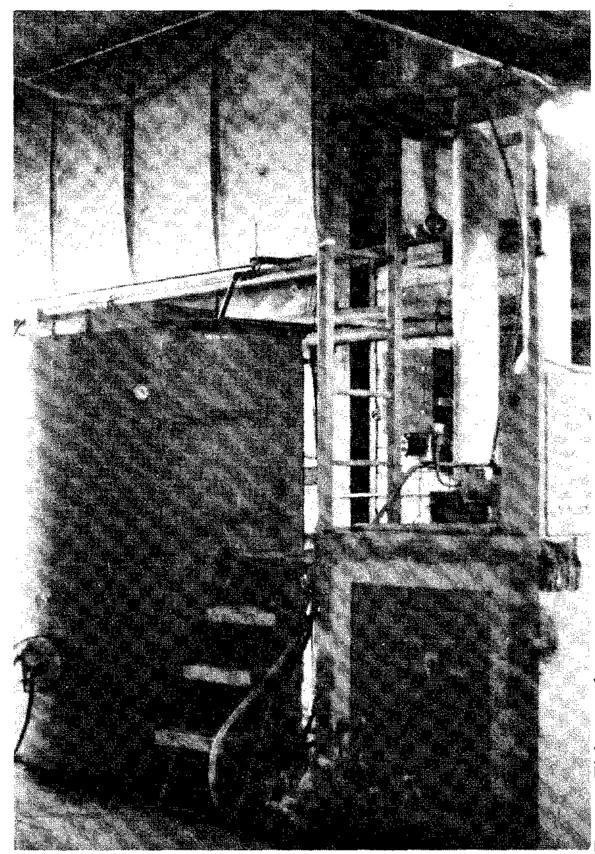
Corn and water are fed into the grinder to create the base for alcohol production. An enzyme is added to this solution, which is then heated to 160° Fahrenheit for twenty minutes. Another enzyme is added as the solution cools to 85° F. At this point, yeast is introduced to the corn solution, and it is allowed to ferment for four days in the storage tank. The fermented solution is then distilled, producing about 70 gallons of 190-proof ethanol. The residue or "mash" is then dried and used as a feed supplement.

About 24 bushels of corn are required for each 70-gallon batch of alcohol. This represents a cost of $ .70 per gallon at current prices. Mr. Sprowl estimated that by using four fermentation tanks in a rotating schedule, a farmer could produce up to 25,000 gallons of alcohol fuel annually. Furthermore he, believes that by using the highly nutritious mash, a farmer can reduce his feed costs without affecting the health and productivity of his livestock.

Unfortunately, Mr. Sprowl has suspended his experiments with the distilling plant. The new equipment he bought has not worked properly and he has not had enough time to work on the project. Nevertheless, the work he has done indicates that a small-scale distillation plant may still be a worthwhile project if it could be perfected. When the value of the feed and fuel produced is combined with the federal tax credit programs, a system costing up to $35,000 could pay for itself in five to six years.

At present, experimenting with these systems may require too much of a farmer's time and effort, but, if fuel and feed prices continue to rise, alcohol fuel may become a valuable farm product. ■

Mr. Sprowl's fermentation tank and distillation apparatus.



Danuta Fishman photo

Kitchen Safety Stove

There are two ways conventional solid fuel stoves transfer combustion heat to a room: radiation and convection. Radiant stoves emit radiant energy from the sides of the combustion chamber directly into the room. This energy is converted to usable heat only after it has been absorbed by the floor, walls, and furnishings, which then warm the air around them. Convection stoves use heat shields or baffles around the combustion chamber to trap the radiant energy and transfer it to the air immediately surrounding the chamber. The heated air is then circulated to the room by convective air movement or small fans.

Radiant stoves can be dangerous because the sides of the combustion chamber are exposed to the room. The stove surfaces can get very hot, and the radiant energy emitted can overheat objects too near the stove. It has been demonstrated that furniture and building materials can ignite at temperatures as low as 200° Fahrenheit after prolonged or repeated exposure to excessive levels of radiant heat. For this reason, regulations governing the distance a stove may be placed from combustible materials are necessary. Currently, the State Fire Marshall's Office requires 36 inches of clearance on all sides of the stove and a 3/4 inch asbestos board, or its equivalent, underneath. Convection stoves do not need the same clearance because they heat by warming air and do not give off large amounts of radiant heat. It is important with these stoves to provide proper air circulation, otherwise heat tends to build up near the stove. Poor air circulation, or stagnation, contributes to uneven room temperatures and unsatisfactory stove performance.

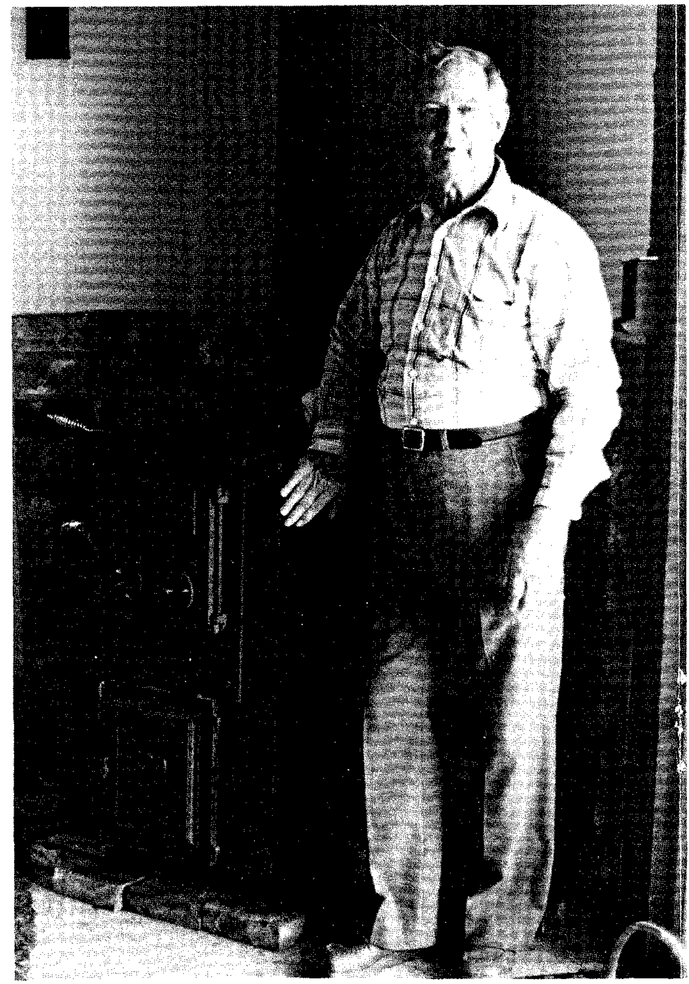
Lloyd Lund of Waldoboro has designed a stove which he believes safely combines elements of both radiant and convective stoves. It is unique because its compact size and efficient convective cooling system permit installation of the stove in a standard kitchen counter arrangement. The stove can be placed right next to other appliances, walls, or cabinets without danger of overheating, while the top of the stove is exposed and can be used for cooking.

Mr. Lund claims that the outer surface of his stove will remain at room temperature during operation. The sides and rear of the stove are protected by a series of sheet metal baffles open to the bottom, front, and top. Louvers covering these baffles permit convective air flow through the assembly. The sides and rear of the combustion chamber are lined with insulating fire brick to reduce the amount of heat conducted to the convection chambers.

The stove is mounted on 4-inch legs with a large, removable ash pit (file drawer size) underneath the combustion chamber. This protects the floor from overheating, insures unobstructed air flow under the stove, and simplifies cleaning. The stove pipe also has baffles on the sides and rear which protect the walls by deflecting heat toward the room. Mr. Lund believes these features will allow his stove to be placed in any standard kitchen counter, against a wall, or in a corner without creating a fire hazard.

The baffle assembly also eliminates the need for a fan to circulate warm air. As the combustion chamber heats up, convective air movement begins. Air in the baffle chambers on the sides and rear warms up. As this warm air rises, it is replaced by cooler air from underneath the stove. The higher the temperature in the combustion chamber, the faster the air is drawn through the baffles. This natural convection distributes the warm air throughout the room without a fan and

Lloyd Lund, inventor of the Lund Safety Stove.

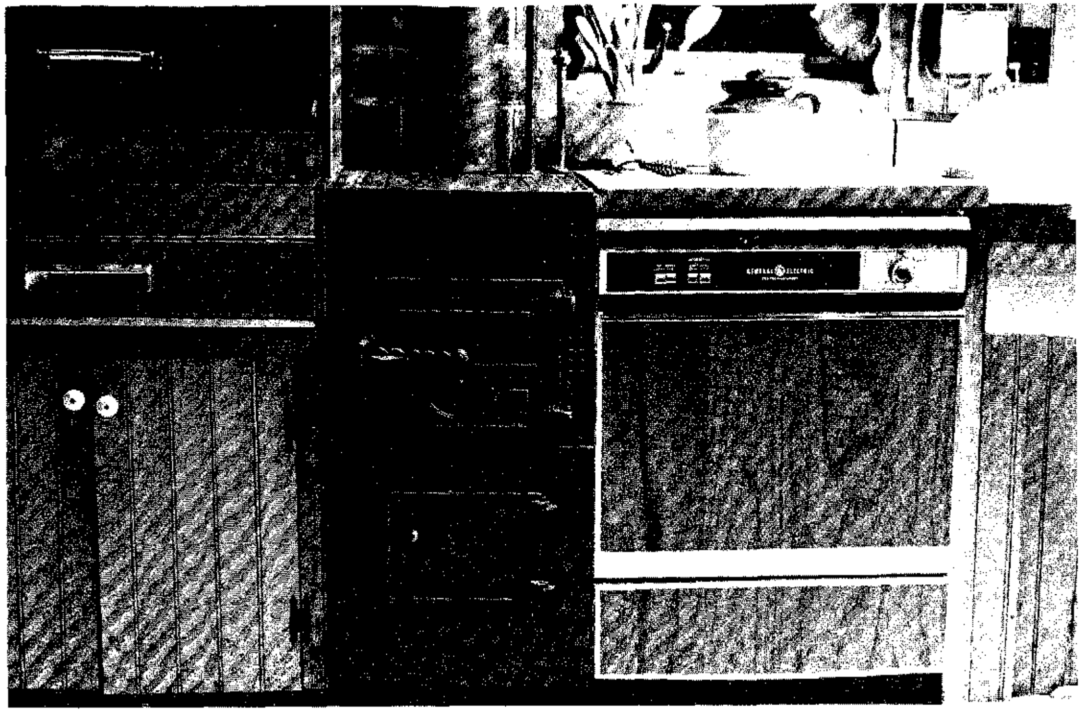


Danuta Fishman photos

keeps the exterior stove surfaces at room temperature by preventing stagnant heat buildup.

The job of removing ashes is simple and can be done without shutting down the stove. The fire is above the ash pit on a perforated platform. As the fire burns, ashes fall into the container which slides out for emptying. Mr. Lund states that he has had to empty the pit only once or twice per heating season, and the job is as simple as pulling out the drawer and emptying it.

Mr. Lund uses two of his stoves to heat his home. One is installed in the kitchen counter between the sink and electric range. The other, a slightly larger model, is in the living room. The counter unit serves as a heater and cookstove, as well as a trash incinerator. The living room model works primarily as a convection heater. Mr. Lund plans to have his design independently tested. If it works as well as he expects, it may become commercially available. ■



Mr. Lund's stove installed in a kitchen counter. The sides and back are cooled by convective air currents.

Wood Chip Feeder System

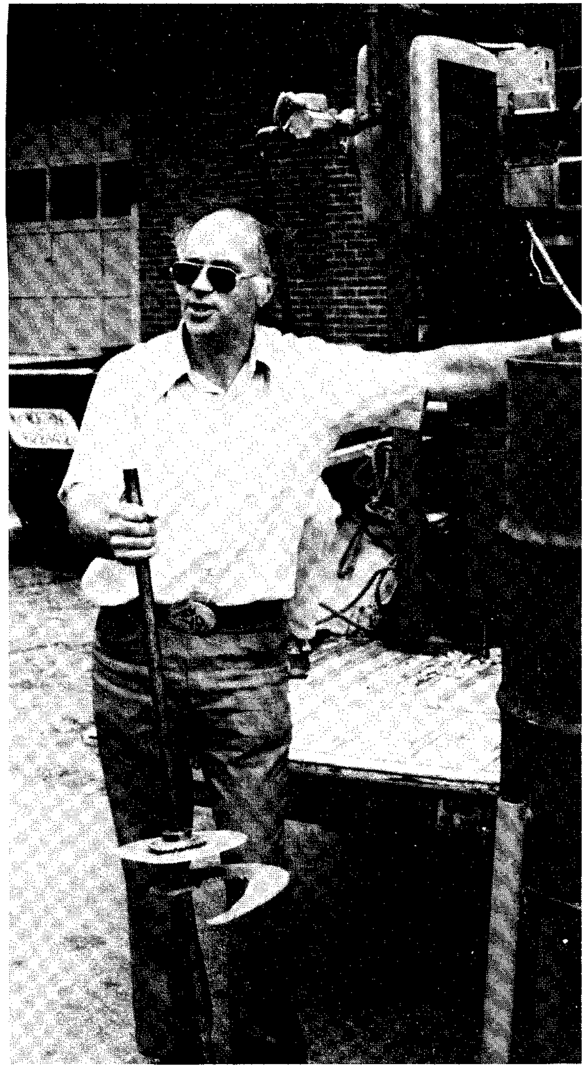
Whole tree wood chips are a valuable renewable fuel resource. They are produced by "chipping" unhealthy trees and leftover logging slash that traditionally has had little or no market value.

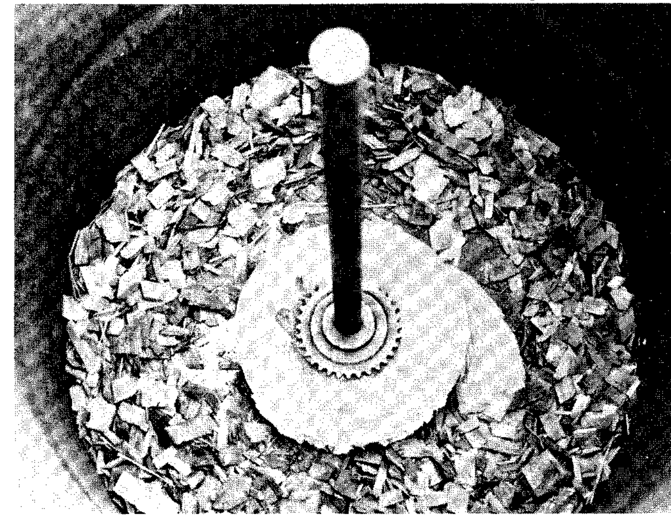
Currently, wood chips are primarily used in large industrial boilers. One factor inhibiting their use in the residential sector has been the difficulty in developing a reliable automatic fuel feed system. Wood chips are not uniform in size or shape and have a tendency to jam in the small-diameter, auger tube feed systems usually used by homeowners. However, Lloyd Weaver of Ashland has developed a new type of fuel-feed mechanism that is well suited to handling wood chips without the jamming problems associated with auger tubes.

Mr. Weaver has spent five years researching and developing biomass burners. He developed his feed system with partial funding provided by the Department of Energy through an Appropriate Technology grant. The unique feature of the feed system is a circular storage bin with a rotating arm in the bottom. The rotor arm is designed to draw wood chips to the center of the bin where they drop through a specially sized hole. A metal shield suspended above the feeder prevents the free fall of chips and serves to guide them to the outer edge of the bin where they are collected by the arm. As the wood chips are fed through the hole, they drop onto a conveyor which delivers them to the heating system's combustion chamber.

Mr. Weaver has also developed an electronic monitoring system to control the amount of fuel delivered to the combustion chamber. A mechanical sensor located within the chamber measures the height of the fuel pile. When the height falls below a pre-set level, a microswitch activates the fuel-feed cycle. The feeder will deliver chips to the combustion chamber until the sensor sends a signal that it is full. This cycle repeats itself as heating needs dictate.

Bill Seekins photos

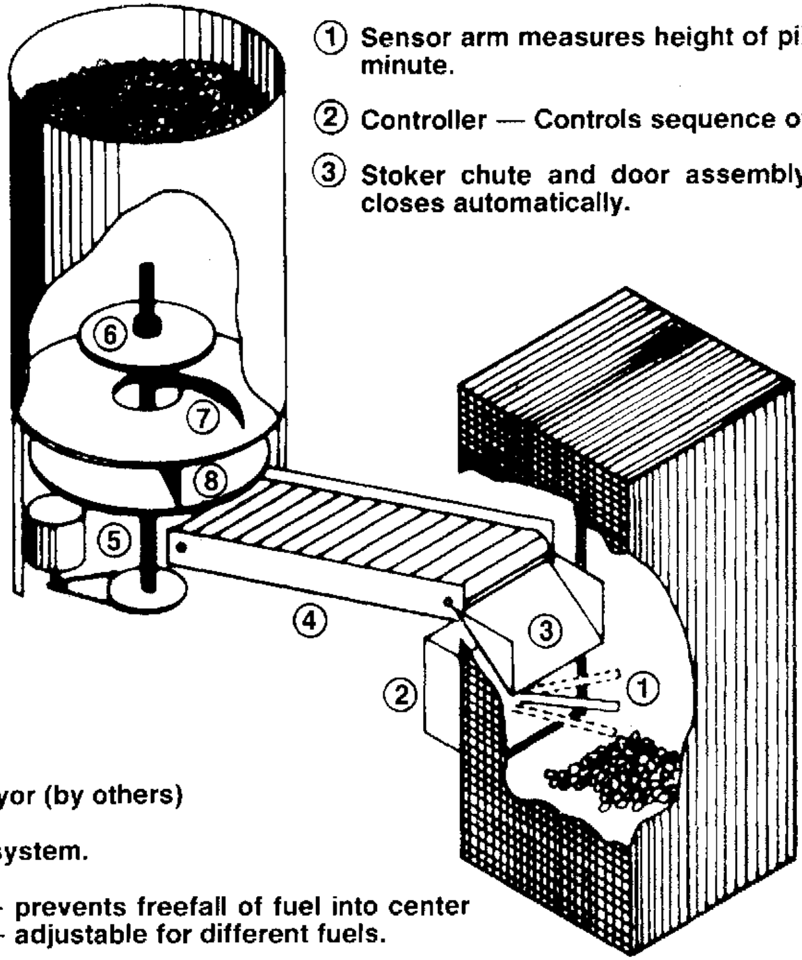




At left: *Lloyd Weaver discusses his rotor arm fuel feed system.* Above: *The metal disc over the arm prevents the free fall of wood chips through the feeder hole.*

Mr. Weaver feels his system can accommodate almost any type of bulk fuel and can be adapted for large- and small-scale use. The only maintenance requirements are periodic removal of ash from the combustion chamber and refilling of the storage bin. If something should go wrong, an automatic interlock switch prevents additional fuel from being delivered to the combustion chamber.

One ton of wood chips costs 15-25 dollars, and has the heating value equivalent of 50 gallons of oil, making chips domestic and commercial an economical fuel for heating systems. ■



① Sensor arm measures height of pile once each minute.

② Controller — Controls sequence of operation.

③ Stoker chute and door assembly opens and closes automatically.

④ Conveyor (by others)

⑤ Drive system.

⑥ Cap — prevents freefall of fuel into center hole — adjustable for different fuels.

⑦ Rotor — pulls fuel to center hole.

⑧ Revolving disc and plow — (used only when vertical space is limited — chute alone is adequate when space permits) dumps fuel on conveyor.

Lloyd Weaver illustration

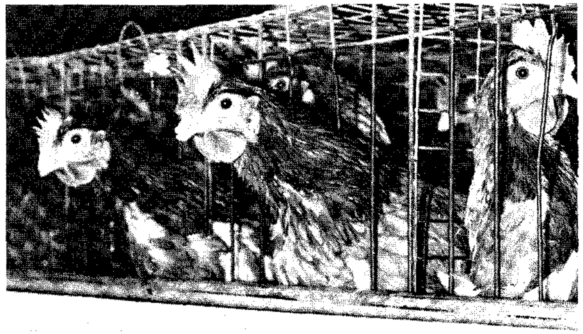
The Weaver Automatic Feed System.

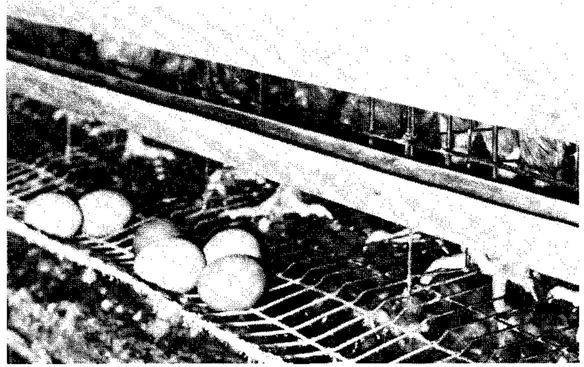
Poultry Litter-Fired Boiler

One problem facing chicken farmers is how to dispose of the many tons of "litter" (manure combined with sawdust) that accumulates over the course of the year. Typically, this litter is trucked off for use as fertilizer. Many farmers provide it free or at a nominal fee to those willing to take it off the premises. However, Paul Jones, owner and operator of the Maple Grove Egg Farms in Mechanic Falls, has developed a much more cost effective method of disposal.

Mr. Jones felt that the litter he had been disposing of could be used as heating fuel to reduce his oil usage. He contacted the Department of Agro-Engineering at the University of Maine at Orono and with their help designed a combustion chamber that could be connected to Jones' existing boiler, burning litter as the fuel.

The combustion chamber is constructed of refractory cement and is heavily insulated on all sides. The temperature inside the combustion chamber gets up to 2,200 degrees Fahrenheit, resulting in a very efficient burn. It takes about 24 hours to "fire-up" to this temperature, and, once the system is fired, a continuous fuel feed rate of about 60 lbs/hr is required to maintain the boiler's capacity of





John Carroll photos

Above: *These chickens are doing their part to keep the hen house cozy.* At left: *Two of Mr. Jones' farmhands tend the burner system. The fuel hopper and boiler houses are in the background.*

300,000 Btu/hr.

The fuel-feed mechanism that supplies the burner is simple and works well. A hopper is located outside the boiler house and holds a one day supply of fuel. An auger feed tube runs from the bottom of the hopper into the boiler house and loads fuel into the combustion chamber. The auger is controlled by a variable speed D.C. motor that allows for adjustments in the fuel feed rate.

The hot air produced in the combustion

chamber is funneled through an induction tube to the boiler. Water is heated within the boiler and then pumped through an above-ground insulated pipe to a 12,000 square foot barn. In extremely cold conditions an oil furnace can be used to back up the litter combustor, but last winter the litter combustor provided all the heat the barn needed for 60 straight days.

Operation of the litter combustor requires some labor. The ash pit must be emptied twice daily, and periodic monitoring of the unit is required to ensure that it is functioning properly. Mr. Jones feels that the litter combustor is probably not an economical system unless you operate your own farm and are willing to put in the extra time and effort.

Mr. Jones estimates that a cord of litter (3500 lbs) is equivalent to about 170 gallons of oil. He has determined that, by burning the litter, he is saving about 400 gallons of oil a week. Because the unit is the first of its kind, completion of the project was delayed by experimentation and breakdowns. However, now that the burner is in operation, Mr. Jones feels a system similar to his own could be developed for under $5,000, with a corresponding payback period of two winters or less. ■

Sawdust-Fired Boiler

Heating a commercial greenhouse year-round in Maine is expensive. In the past, Allen Pinkham of Pinkham's Plantation in Damariscotta has used more than 10,000 gallons of oil per heating season. As oil prices climbed, Mr. Pinkham searched for a more economical fuel. He began experimenting with a sawdust-fired boiler after seeing one in operation in northern Maine.

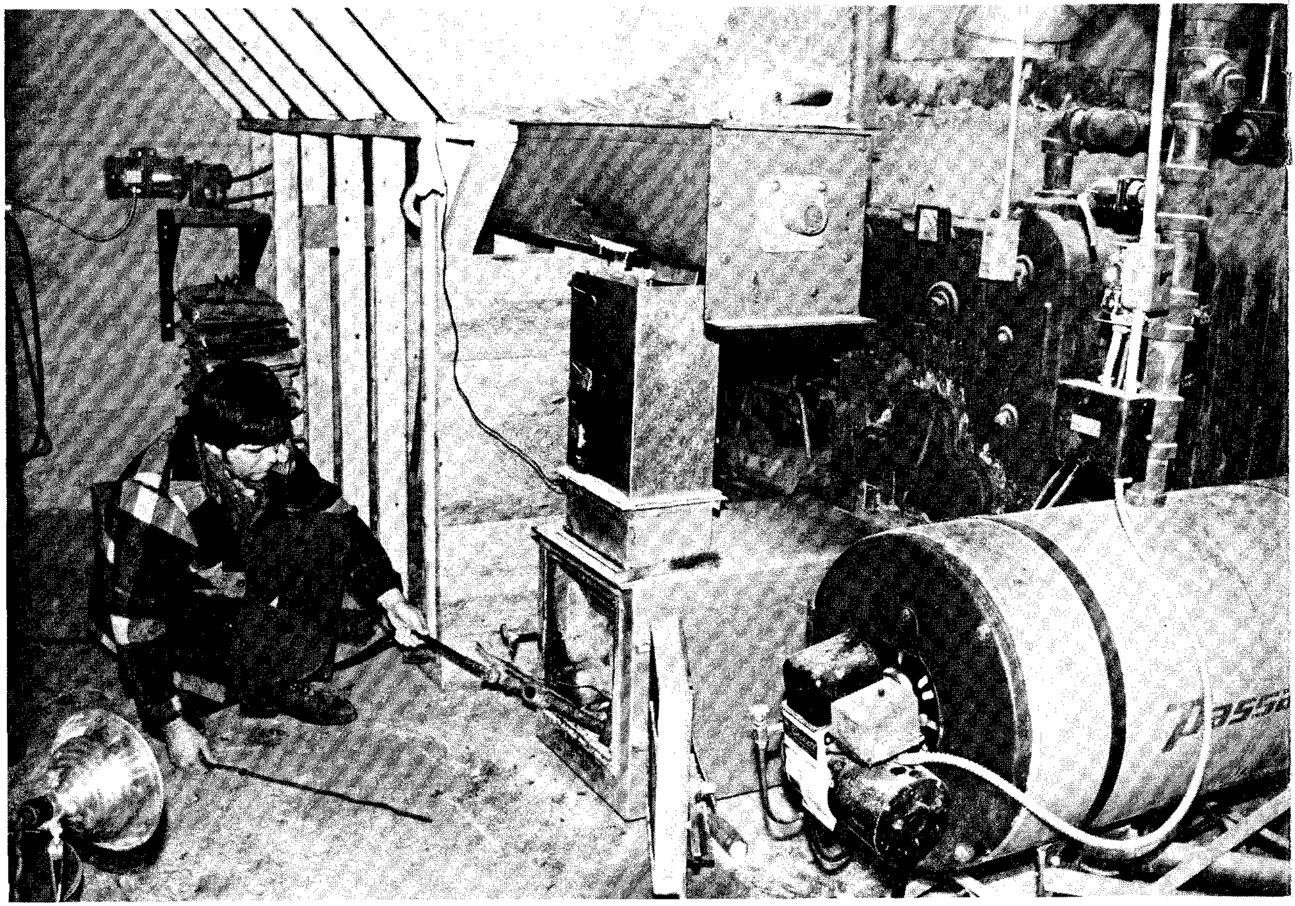
Mr. Pinkham bought an old boiler for $300 and fitted it with a 2' by 4' external steel combustion chamber. The chamber is lined with firebricks and insulating mono-block to withstand combustion temperatures over 2,000° Fahrenheit.

An area above the boiler room was then converted to store a one-week supply (approximately 4-5 tons) of hardwood sawdust. A 9-inch auger moves the sawdust to a smaller, vertical hopper. When the boiler calls for fuel, a second auger feeds the combustion chamber from this hopper. As the sawdust burns, a draft inducer draws the hot air into the boiler and through the air-to-water heat exchanger.

The boiler must be ignited by hand, but, once in operation, a conventional thermostatic system regulates fuel feed rates, draft, and hydronic circulation. An oil burner is used as a back-up to supplement the sawdust burner in very cold weather or to replace it in the event of a failure.

Maintenance of the system is limited to weekly deliveries of sawdust and periodic emptying of the ash pit. The burner produces approximately 5 gallons of ash per ton of sawdust.

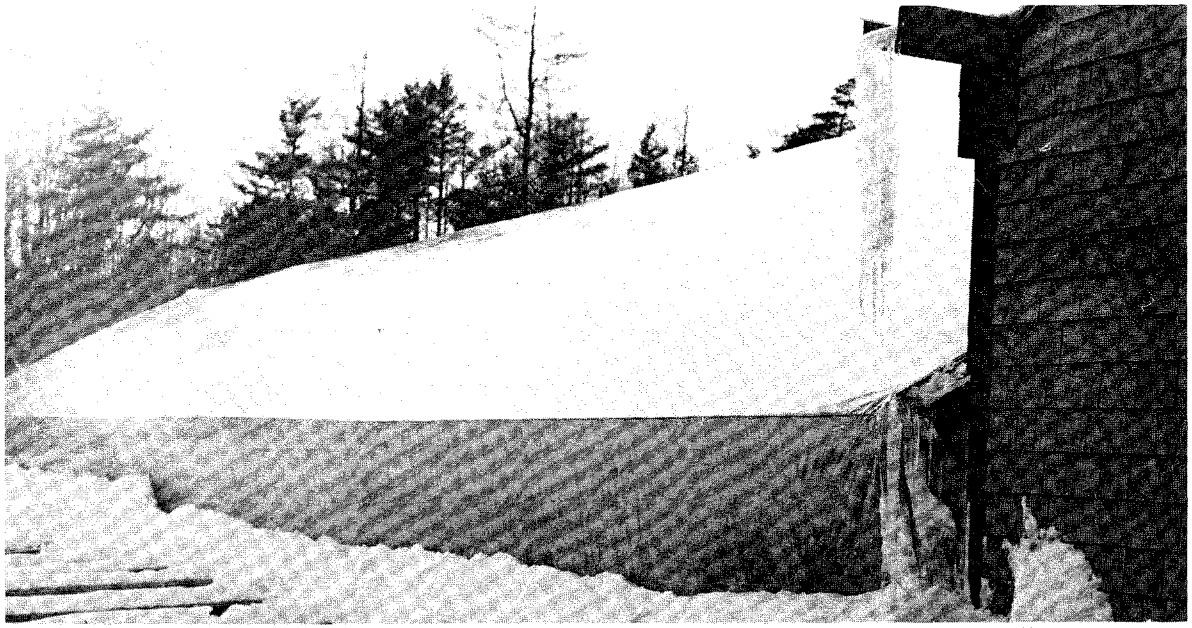
Mr. Pinkham estimates that his combustor burns about 4 tons of sawdust per week. With sawdust costing only 10-12 dollars per ton, the weekly maintenance required is well worth the effort.



Allen Pinkham fires up his sawdust burner. Note the fuel hopper and auger feed overhead. The back-up oil burner is in the foreground.

Since installing the system in 1981, Mr. Pinkham has cut his annual oil consumption by over 50%. He estimates that the system paid for itself in two to three years. Mr. Pinkham says that in recent years there has been some difficulty in finding an adequate supply of good quality hardwood sawdust. However, he is convinced that the system will remain economical as long as the sawdust is available. ■

The greenhouse keeps plants flowering . . . .



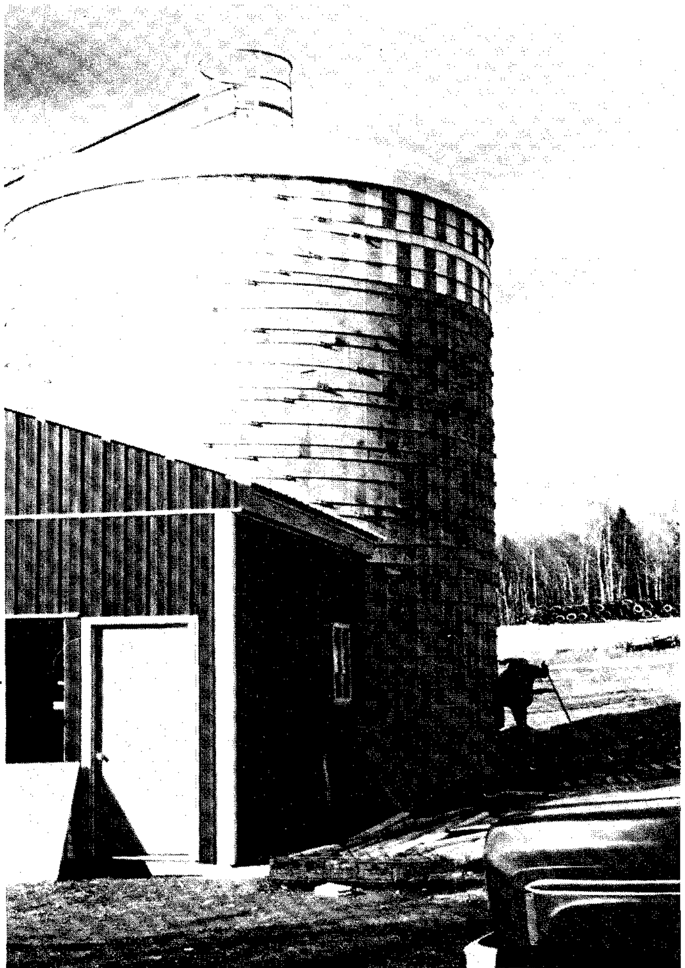
. . . even in the coldest weather.

John Carroll photos

Anaerobic Digester

The Franklin P. Witter experimental dairy farm, located near the University of Maine's Orono Campus, was the first Maine dairy farm to install an anaerobic digester. The digester produces biogas from cow manure through the natural action of bacteria working in an oxygen-free (anaerobic) environment. Biogas is approximately 60 percent methane and 40 percent carbon dioxide (CO_2). The University uses this biogas to run an engine, which drives a 23

The digester is in a silo-shaped building next to the barn.



Bill Seekins photo

Potential for methane production on Maine's dairy farms*

farm size — # of cows	50 - 100	100+
number of farms	318	95
number of animals	20,500	13,300
ft^3 gas/animal/day	35	35
ft^3 gas/farm/day	1750-3500	3500+
total gas/year (million cubic feet)	262	170
total fuel oil equivalent/year (gallons)	1,164,444	755,556
total electricity equivalent/year** (1000 KWH)	9200	5980

* This includes only those farms with the potential daily biogas production equivalent of a dairy herd of 50 or more cows. This represents approximately 38% of Maine's 1100 dairy farms.

** at 20% generating efficiency.

kilowatt generator. It is estimated that the generator will produce over 110,000 kilowatt hours of electricity annually, using the farm's 140-200 cows as its "fuel source."

The Witter Farm digester was designed by Agway Incorporated and is similar in appearance to a small silo. The digester was designed to be slightly larger than currently necessary, to allow for future increases in the size of the herd or an increase in per-cow manure production.

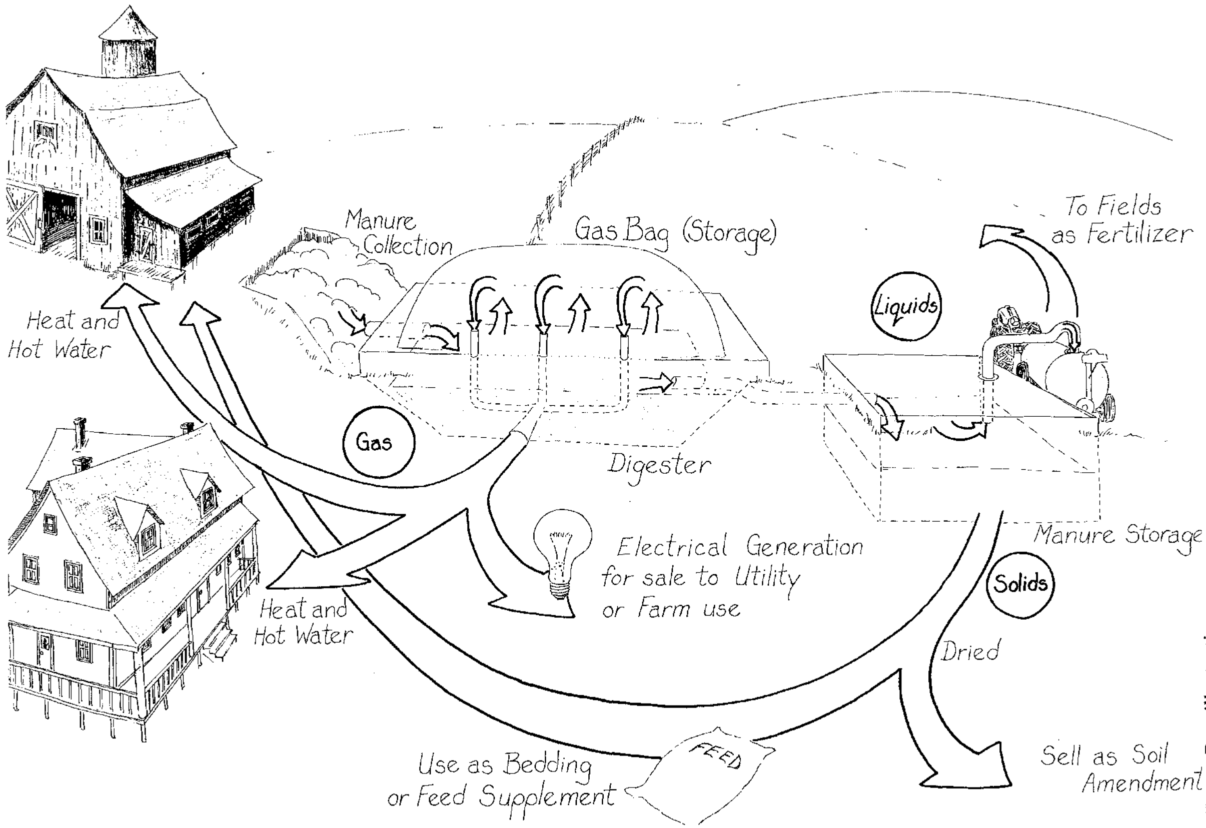
Manure is collected by an automatic floor scraper and funneled through a submerged chopper pump. The action of the pump, plus the addition of small quantities of water, produces a fluid mix of roughly 9% - 15% solids. The liquified manure is then pumped via piping to the digester, entering through an opening in the floor.

Fresh manure is loaded into the digester silo twice a day. The liquid manure fills the lower two-thirds of the silo and the biogas is collected in the upper one-third. It takes 25-30 days for the manure to complete the digestion process. A circulator pump provides some mixing of the fresh and processed manure. This ensures more uniform temperatures throughout the digester and improves the efficiency of the system. The digester is designed to allow the digested

manure to flow out as it is replaced by fresh manure. The digested manure flows to storage tanks and is eventually used as fertilizer.

The biogas collected at the top of the silo is fed under slight natural pressure to the generator building located immediately next door. A six cylinder engine burns the biogas as it is produced, eliminating the need for a pressurized storage facility and ensuring that the generator will operate 24 hours a day. The heat co-generated by the engine is used to heat water for the milk processing operations at the farm and is expected to save an additional 5000 gallons of oil per year. The digested manure has less odor, and has been shown to be slightly better than non-digested manure when used as a fertilizer. It has been estimated that the extra

Bill Seekins photo



Wayne Day illustration

Integration of a methane digester into the farm operation.
At left: *Making meat, milk and methane down on the farm.*

yield is roughly 10 percent, which could provide the University with approximately $11,000 in extra crop value per year. This is a very conservative figure. The University expects its system to save or earn roughly $16,000 a year by offsetting electrical and oil purchases and by increasing crop yields.

In spite of these impressive savings, the people responsible for the research and development of the Witter Farm Research-Biogas Generator feel it is still too early to give a final analysis of the system. ■

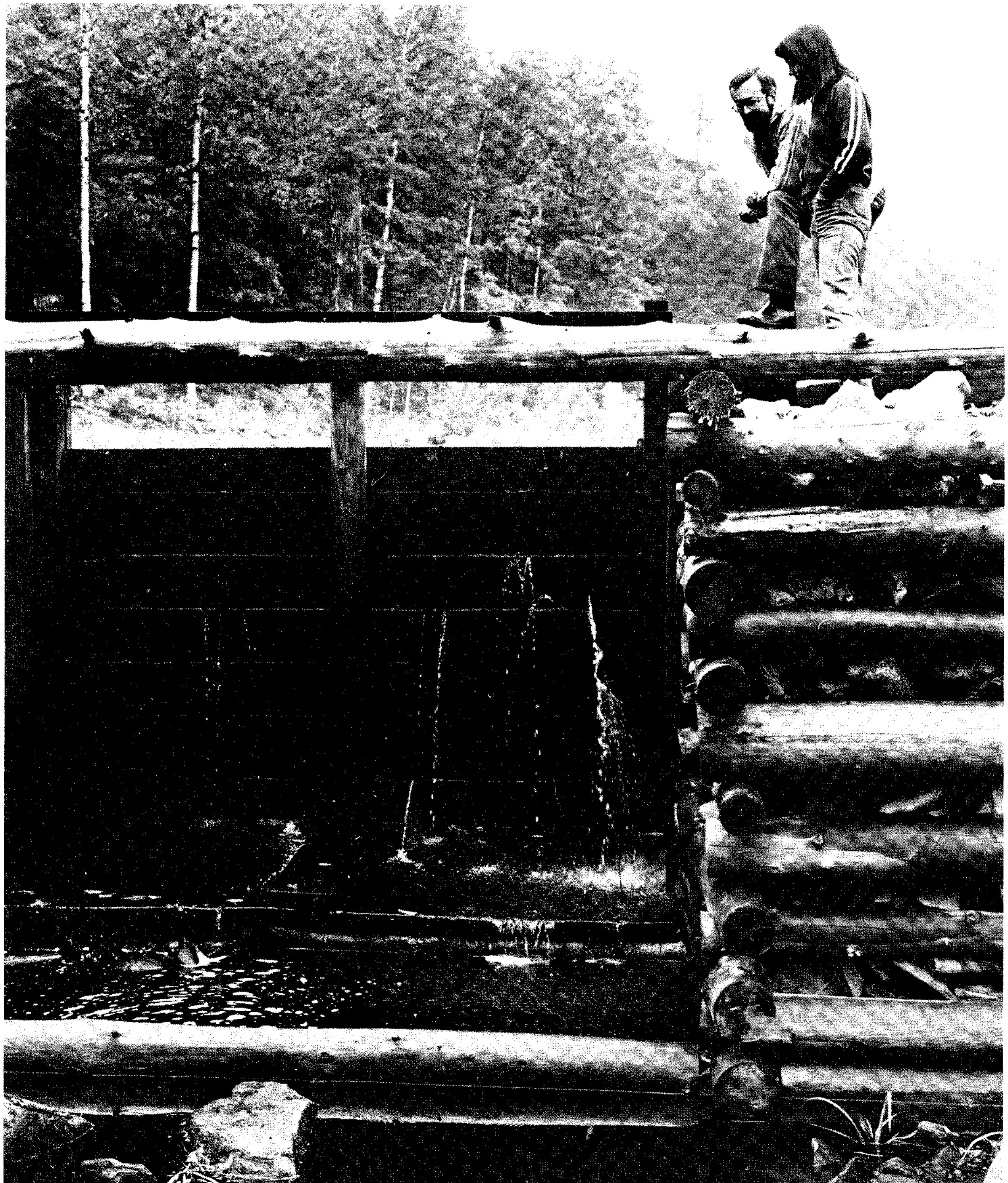
Water & Wind Power

Small-Scale Hydro Project

In recent years, the high price of fossil fuels has stimulated renewed interest in hydroelectric development. One of Maine's smallest hydroelectric facilities is owned and operated by Robert and Suzanne Kelly of Lowell. The amount of electricity they generate is enough to supply most of their home's electrical needs.

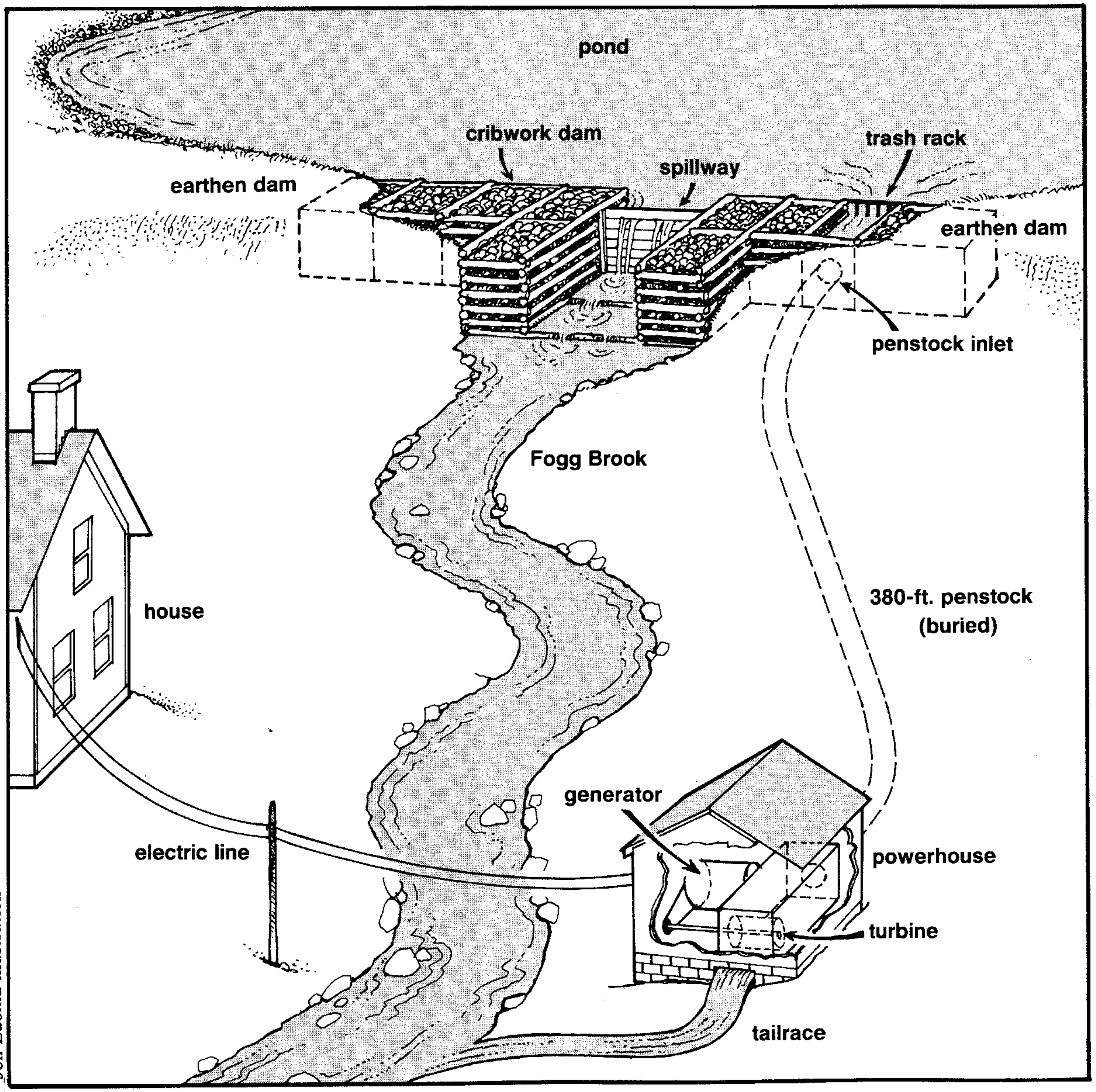
The Kellys' home is located far enough from the existing utility lines to make it uneconomical for them to be connected to the grid. They chose instead to generate their own electricity using a small stream which runs through their property, about 175 feet from the back door. The average flow of the stream, combined with the natural slope of the land, convinced the Kellys that a small-scale hydro facility would be a cost-effective answer to their household electrical demands. They submitted their plans to the Department of Energy and were awarded an Appropriate Technology grant to help finance the construction of their hydro system.

The Kellys' facility operates on the same basic principle as large-scale hydroelectric installations. The weight of falling water is used to turn a turbine. The mechanical energy of the turbine is then converted to electricity by a generator. The distance the water falls (known as "head") and the average flow of the stream are critically important, since the amount of power a hydro system can generate is proportional to these values.



Mary Anne Lagasse photo

Suzanne and Robert Kelly atop their hand-built rock crib dam. Friends helped cut and peel 200 logs and move more than 4000 cubic feet of rock to build the dam.



Jon Luoma illustration

The Kelly hydro site.

The three basic components of the Kellys' hydro system are the dam, penstock, and powerhouse. The dam is used to store water and create more "head." The penstock is a tube which funnels water from the dam to the turbine inside the powerhouse. As water travels across the turbine blades, the mechanical energy created is converted to electricity by the generator. After the water leaves the turbine, it travels out of the powerhouse through the "trailrace" to continue its journey downstream.

The Kellys' hydro system is special because it was truly a do-it-yourself project. The Kellys first cleared the land around the stream to create a holding pond. As they leveled out this area, they pushed dirt up to create embankments. Between these outer embankments they constructed a 75-foot-long "rock-crib" dam. The face of the dam was covered with two-inch hemlock planks and then the clay subsoil of the holding pond was pushed up against the planks with a bulldozer. The clay was treated with calcium chloride to produce a cement-like substance. With the dam completed, work on the penstock was begun.

The dam itself provided eight feet of "head," but the Kellys had planned on at

Dimensions
Cribwork dam, spillway, and penstock inlet:
75' x 7' x 8'
spillway: 10' x 8'
penstock inlet: 5'
Penstock: 380'
Powerhouse: 10' x 10'8"
Power line from powerhouse to residence: 75'

least 20 feet. To reach this figure, they built a 380-foot penstock. The penstock length incorporated a 12-foot vertical drop which gave the Kellys the 20 feet of "head" they wanted. Steel culvert pipe of 15" diameter was run underground from an opening in the bottom of the dam to the powerhouse. The pipe's diameter was decreased to 10" at the turbine to concentrate the force of the water traveling through the pipe. A butterfly valve was placed just before the turbine to allow the flow of water to be stopped on demand.

The powerhouse is a 10' x 10' wooden building in which the Kellys house the turbine and generator. They have a cross-flow turbine connected to a 110/220 volt AC 60 cycle generator. A flapper valve is used to "throttle" or control the flow of water. By tightening the flapper, the pressure of the jet stream leaving the nozzle of the penstock can be kept at a constant level, even if the actual flow of water is reduced. This adds to the overall efficiency of the system. Also, to control the turbine speed, Robert designed a homemade "governor" from an ordinary automobile cruise-control mechanism. This governor system saved quite a bit of money (commercial units are $5,000 for a turbine like the Kellys') and after slight modifications it has worked well.

The generator has a capacity of about 5 kilowatts. However, because of inefficiencies in the system, over 50% is lost (commercial systems are about 75 - 80% efficient). Nevertheless, the Kellys produce enough electricity to meet their lighting requirements, as well as operate a TV, stereo, and numerous small household appliances. They find it necessary to fire up their diesel generator only at times of low stream flow (usually late summer and early fall).

Robert Kelly feels construction of the plant was an important learning experience. He believes that by incorporating what he has learned, others could develop a similar system more easily. He thinks that the project could be done without a grant and still pay for itself out of the savings it creates in roughly fifteen years. Thus, hydroelectric generation can be a cost-effective solution to the energy problems of some Mainers. ■

Turbulent Chamber Water Brake

Arthur Shute of East Sebago has been experimenting with hydropower for over twenty years. His home is built on the site of an old gristmill, and in the backyard is a hydro facility complete with an 11' high dam and a 235' penstock with a total available head of 33'. A restored powerhouse has two hydropowered turbines that provide space heating and electricity for his large workshop.

Mr. Shute has adapted a technology developed in the 1920's, known as a turbulent chamber water brake, to heat his workshop. A water brake is a device which converts mechanical energy directly into heat energy. The action and effect of a water brake can be compared to an eggbeater spinning in a bowl of water. Heat is generated as the turbulence created by the beater's blades causes friction among the water molecules. The mechanical energy applied to the beater is converted into heat energy by friction.

In Mr. Shute's heating system, the water brake is substituted for a conventional oil, gas, or solid-fuel burner. A drive belt from a separate, water-driven turbines supplies mechanical energy to the system. Inside the brake chamber are two sets of closely spaced blades. One set is stationary, and the other is turned by the turbine. Water from the heating system flows into the chamber and is heated to 180° Fahrenheit by the turbulence created by the spinning blades. The heated

Below: *The spillway at Mr. Shute's hydro site.* At right: *Arthur Shute at the controls of his turbulent chamber water brake.*

Craig Gardner photos

water circulates through the heating system and then returns to the water brake to be reheated.

Mr. Shute's water heater is driven by a water-powered turbine. The turbine develops up to sixty-two horsepower, spinning the water brake at speeds up to 900 rotations per minute. Mr. Shute estimates that at that speed it is capable of generating 121,000 Btu per hour, with a 77% conversion efficiency rate from mechanical to heat energy.

Mr. Shute also has a 12.5 kilowatt electrical generator connected to a second water turbine. This supplies electricity to run lighting, a small computer, and small power tools in his shop.

Although suitable sites for systems like Mr. Shute's are limited, he feels that turbulent chamber water brake heaters might have some industrial applications. Firms that use large quantities of hot water and have access to hydro power or any low cost mechanical power source such as a windmill could use a water brake to cut their energy costs. ■

Wind-Powered Telephone Company

The telephone industry relies on automatic electronic equipment to supply service to its customers. Energy costs for running this equipment contribute significantly to a telephone company's overall operating costs. Hampden Telephone Company, a small firm serving the Hampden and Etna areas, has experimented with reducing its energy costs by installing a wind generator system to supplement utility power at its switching station in Etna. Lonnie Gamble, an electrical engineer with the company, received an Appropriate Technology grant from the Department of Energy to fund the project.

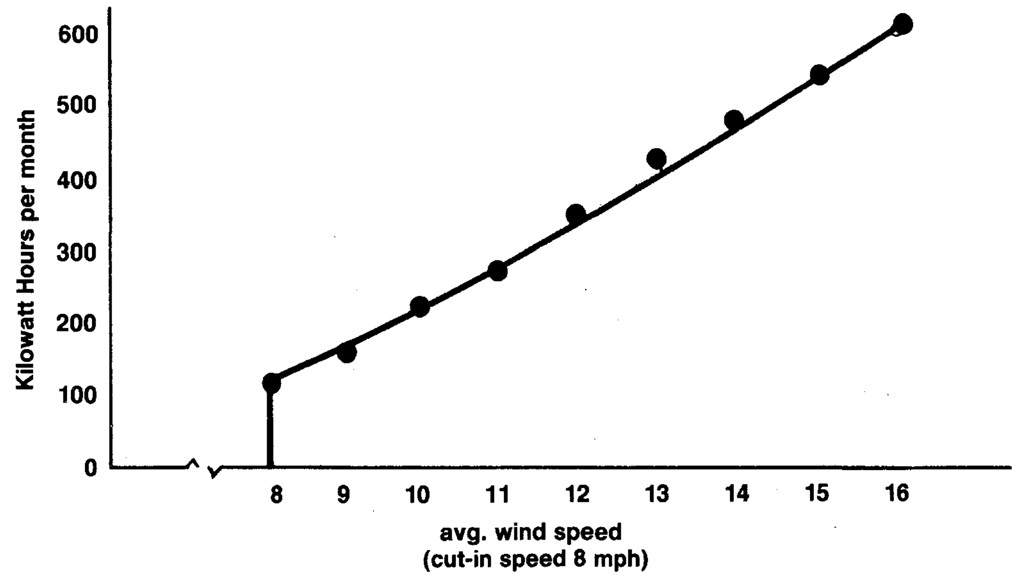
The station is powered by a 48 volt D.C. battery system. In normal operation, the batteries are kept fully charged by electricity bought from the utility, which must be rectified (converted from A.C. to D.C.) before going to the switching and storage systems. Using a battery powered system ensures that phone service will not be interrupted if the utility power fails.

Mr. Gamble proposed that the company install a 48 volt D.C. wind generator to charge the batteries, bypassing the rectifier system and reducing dependence on utility-supplied power. Based on his observations of wind conditions at the site, he predicted an average monthly wind speed of 10-12 miles per hour at a height of sixty feet. He calculated that a 3-5 kilowatt (kw) wind generator at that height could supply 90% of the electricity needed to run the switching station.

The project was hampered by a shortage of funds, and several changes were made to stay within budget. These changes included using a smaller turbine and an A.C. generator.

Enertech 1800 performance projections*

* Marien, Donald, *Wind Power for the Homeowner,* Rodale, 1981



BETZ'S LAW: the power in the wind is proportional to the cube of the wind speed

Once in operation, the system supplied only 11% of the power needed to run the station.

Mr. Gamble cites three reasons for this disappointing performance. First, the use of a 120 volt A.C. induction generator required that the current be rectified before it could be used. Rectifier losses in this system account for 50% of the total wind turbine output. Second, a 3-5 kw turbine was judged to be too expensive, so a 2 kw machine was used instead. The smaller machine has a turbine diameter of 13.2 feet (length from blade tip to blade tip), whereas Mr. Gamble had intended to use a 3-5 kw unit with a turbine diameter of 15' to 20'. The power output of a windmill varies with the square of the turbine diameter, so substituting the smaller turbine further reduced the system's effectiveness. Third, the actual wind speed at turbine height (60') averaged only 8 to 10 miles per hour. Mr. Gamble had predicted an average wind speed of 10 to 12 mph at that height and had sized and designed the system based on that prediction. The difference between 8-10 mph

and 10-12 mph is a significant factor in the success or failure of a wind system, because the power available in the wind is proportional to the cube of the wind speed. An increase in wind speed from 8 mph to 12 mph will increase the available power by as much as 300%.

Mr. Gamble plans to modify his system to increase its overall efficiency. First, the wind turbine will be raised to 100 feet. This should supply the 12 mph average wind speed he needs to increase the power output adequately. Secondly, he wants to replace the A.C. induction generator he now uses with a 48 volt D.C. system. This will eliminate the losses in rectifying the power before it can be fed into the switching equipment.

Mr. Gamble is convinced that these improvements will make the wind system more cost-effective, with a payback period of fifteen years. He believes that wind power can be an economical alternative, provided the system is carefully designed and properly sized and the site has been thoroughly evaluated. ■

Self-Sufficient Homestead

Homes that are energy self-sufficient are usually in remote areas where conventional energy supplies are not readily available. The energy demands of these "homesteads" are generally limited to small amounts of electricity to provide lighting and enough firewood to meet heating and cooking needs. However, Peter Talmage of Kennebunkport, who lives less than half a mile from utility electric lines, has a self-sufficient homestead that provides enough energy for electrical appliances, lighting, and some hot water for his home and a small workshop.

Mr. Talmage meets his electrical demands with a "hybrid" system that incorporates solar photovoltaic cells and a 2.5 kilowatt wind generator. Heating requirements in his well-insulated home are met by a woodstove and solar gain through south-facing windows. Hot water is supplied by a solar hot water system throughout the spring, summer, and fall and by a heating coil in the woodstove in the winter.

The Talmage house showing south-facing glazing, photovoltaic panels on roof, and the wind generator.

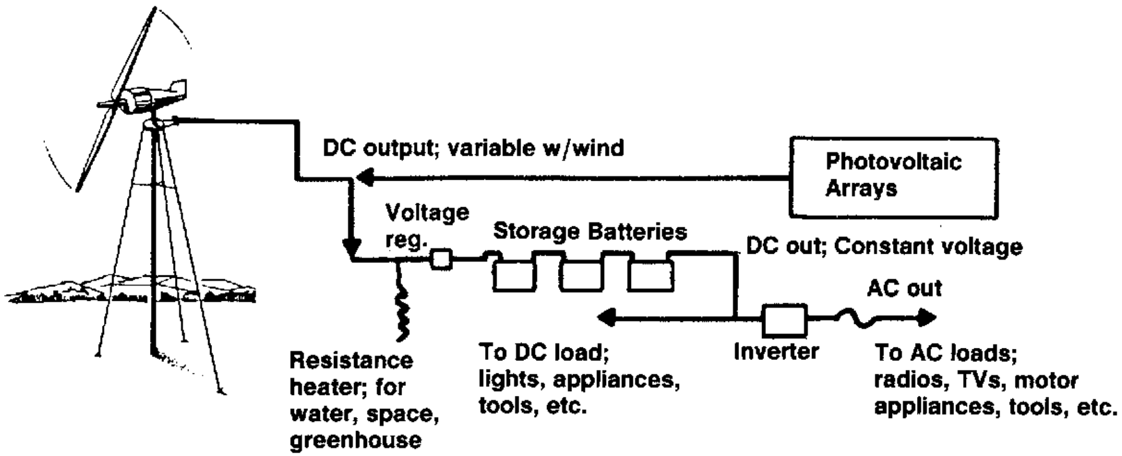
Scott Perry photo

Mr. Talmage installed complementary wind and solar power systems to ensure a steady power supply as the weather changes. Photovoltaic cells, which convert the sun's energy to electricity, are most effective during fair, clear weather when the largest amount of direct sunlight is available. Wind generators are more effective in cloudy, stormy weather when average wind speeds tend to be higher.

Electricity from the systems is stored in deep cycle batteries so that power is available even when neither system is producing electricity. Surplus power is diverted to an electric element in the hot water tank.

The house is built on a small ledge. The sloped north roof reduces heat loss by minimizing exposure to the winter winds. The south side has a large sunspace on the lower level, and the living area above also has large windows to increase solar gain. The house was designed to be energy efficient, so it is better insulated than a conventional home. The R-values (ability of a material to resist heat loss) are R-34 in the walls, R-40 in the sloped roof, and R-50 in the attic floor. Controlled, continuous air infiltration moderates humidity levels and provides fresh air to the house.

The sunspace, combined with an open basement, provides heating in the winter and cooling in the summer. In winter, it acts as a



A hybrid wind/photovoltaic system with battery storage. "Wind Machines", *National Science Foundation, 1975.*

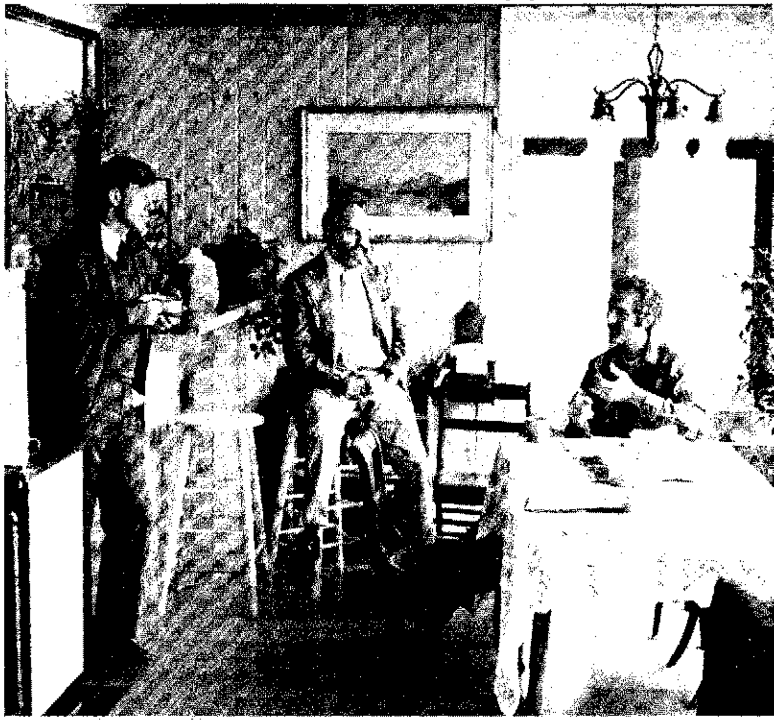
solar collector. Thirty 55-gallon drums filled with water store excess heat during the day, and natural convection circulates the heat through the house as it is needed. In summer, a door is opened to expose the ledge rock underneath the house. The rock remains at about 55° Fahrenheit all summer, and the natural thermal drafts draw cool air from around the ledge up through the house.

A solar water heating system provides hot water in the summer and during mild spring and fall weather. It consists of two 6' by 3' collector panels, an 80-gallon, insulated storage tank and a photovoltaic-powered pump. Potable water is heated in the panels and then circulates back to the storage tank. Because the pump is also solar powered, the water is always circulated at a rate proportional to the suns intensity. This ensures an optimal heat exchange rate within the collector panel.

During the cooler weather of spring and fall, the system is protected from freezing on cold nights by a temperature sensor that turns the pump on, circulating warm water into the collector if the temperature drops to freezing. The system is not used during cold weather when all the water is heated in the woodstove.

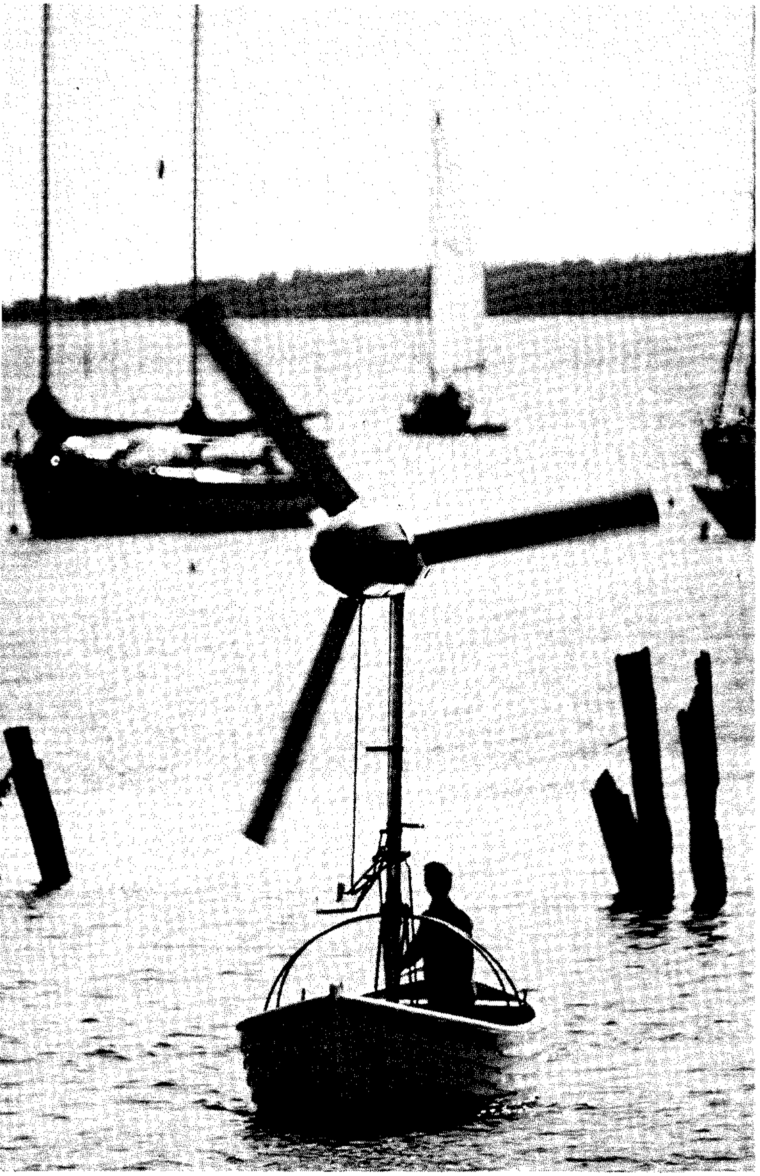
Mr. Talmage estimates that it would cost between $17,000 and $25,000 to retrofit a modern home for energy self-sufficiency. This would include the addition of solar and wind energy systems (where appropriate) and the installation of new, energy-efficient appliances. The cost would also be dependent upon the location and siting of the house and the individual's needs or preferences. At present, these measures are only cost-effective in areas where the cost of bringing utility power to the site is in the same range. However, Mr. Talmage feels that these systems will become more economical as the price of energy rises and as the prices for specialized materials and equipment drop due to an expanding market. ■

Bob Cummings photo



Mr. Talmage (seated at table) discusses his work with guests from the Office of Energy Resources.

Windmill Boat



Captain Hawkins sails his windmill boat through the harbor.

photo by Kevin Flemming© 1985, National Georgraphic Society

Captain Havilah Hawkins of Camden has worked on sailing ships much of his life. He is a firm believer in the efficiency of wind-powered vessels and in the need to reduce our use of nonrenewable resources. He hopes that in the future, commercial ships will be able to reduce their fuel consumption through the use of auxiliary wind-power systems. He realizes, however, that there are limitations associated with conventional sailing rigs because of the added labor and maintenance requirements. In his search for an alternative, he has been conducting tests on the use of windmills as an auxiliary power source for small to mid-sized cargo ships. He hopes to demonstrate that in certain situations they perform better, with fewer labor requirements, than sails.

The funding for his research was provided by the Department of Energy through an Appropriate Technology grant.

Captain Hawkins hypothesized that, when traveling into the wind, a vessel equipped with a windmill drive system would arrive at a given point ahead of a sailboat of similar size and weight.

He began his experiments with windmill propulsion by constructing model boats in which the mechanical energy created by a windmill was transferred directly to a conventional propeller by a drive shaft. He later conducted performance tests using two twenty-foot lifeboats, each carrying 800 pounds of ballast. The first boat was outfitted with conventional sails and served as the control. The second was equipped with a 14-foot diameter windmill linked through a gearbox to a 20" propeller. To ensure the reliability of the tests, the area swept by the windmill was equal to the surface area of the sails.

The results of these performance tests supported Captain Hawkins' hypothesis; with a wind speed of ten knots or greater, the windmill boat out-performed the sailboat in some situations.

When making for a destination directly upwind, the windmill boat could be sailed directly into the wind, traveling in a straight line to the destination. The conventional sailboat, in the same situation, was forced to tack (zig-zag back and forth) in order to maintain the proper angle to the wind. This necessitated sailing a considerably longer course to reach the same point. In this case, the sailboat's speed through the water was faster, but the windmill boat reached the destination first because it sailed a shorter distance.

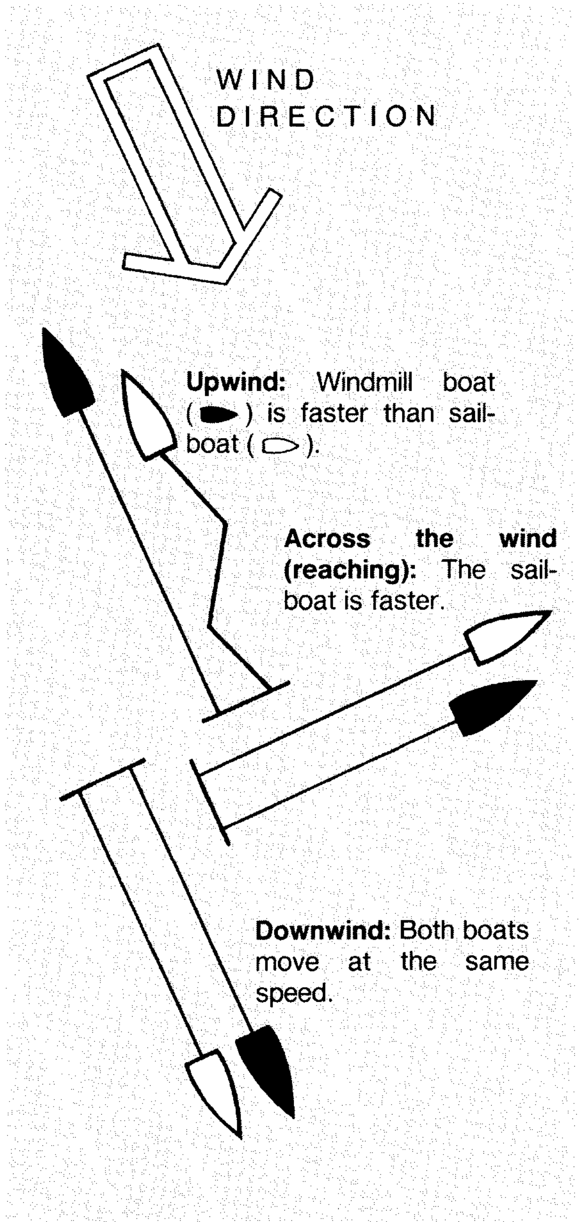
Further tests showed that the two boats sailed downwind equally well. However, the conventional sailboat was somewhat faster when on a beam reach (with the wind blowing perpendicular to the boat's course).

Mr. Hawkins feels that windmills would be better suited than sails for use on cargo ships because they are easier to manage. Windmills would always be in place, ready for use, and they would require little attention other than routine maintenance. In high winds, the windmill's rotational speed could easily be limited by feathering the blades (adjusting the relative angle of the blade to the wind). This would prevent damage to the windmill assembly and control the load on the drive unit.

In similar situations, sails would require considerably more time and effort. They must be set and trimmed when getting underway,

reefed and shaken out as the weather changes, and properly stowed when not in use.

In the future, Captain Hawkins plans to refine his design and construction plans and fit out a 100' cargo ship with auxiliary windmills. This will enable him to measure the ship's maintenance requirements and performance more precisely. ■



Jon Luoma illustration

Relative performance of windmill and sail boats on different points of sail.

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