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Introduction

Solar Energy

Until recent years Americans have been accustomed to an unlimited supply of cheap energy. The word "energy" was hardly a household word--it was of little concern. But in a short time most of us have been shaken from our fool's paradise into the harsh reality of a finite and rapidly dwindling supply of fossil fuels. Rapidly rising prices, and in some cases rationing, have finally made the point clear. We need another source of energy if we are to continue our present lifestyle.

Concurrently, we are becoming more aware of the threats to our physical health, and to our environment, from rapidly expanding technology and the indiscriminate use of energy. Too often we have not foreseen the remote but harmful consequences of new technological processes and applications. We are paying the price in increasing cancer rates, a higher incidence of respiratory diseases, and polluted air and water.

We need a solution to both of these problems. Nuclear power seems to offer at least a temporary solution to the energy problem, but it exacerbates the pollution and health problem. The consequences are still a subject of speculation and study, but one fact cannot be denied. For the first time in history, a civilization is dramatically affecting the Earth in a way that is irreversible for tens of thousands of years (i.e. the time for radioactive decay). Another problem with nuclear power is economics--there is growing agreement that it will be much more expensive than originally believed. So what do we do about these two problems: the depletion of fossil fuels, and the harm caused by the unwise use of energy and technology?

A partial answer to both problems is shining in our faces. Solar energy is a practical source for a large fraction of the country's heating requirement. By using the sun to heat buildings we can begin to decrease our dependence on vanishing fossil fuels and reduce the use of polluting energy sources. Solar energy doesn't require transmission lines or pipelines, it produces no dangerous radioactive wastes, no black smoke, no black water and it doesn't ravage the land with strip mines. The technology for home heating with solar is simple, we have it now, and anyone with some building experience can apply it.

Does It Make Sense to Install a Solar Collector?

Solar is becoming a more attractive and sensible alternative to paying ever increasing electricity, gas, and oil bills. There are many different ways one can use solar energy economically, and this manual shows how one particular type of system can be cost-effective. But the decision of whether or not to install a solar collector is complex, involving not only economic factors, but also aesthetic, ecological, and personal considerations.

However, before this decision is made, some other aspects of solar should be discussed. It does not make sense to invest in solar energy for your home without first taking full advantage of energy conservation techniques. Most energy conservation measures are more cost-effective (shorter payback) than solar measures, and since putting heat into a house is so expensive, it should not be wasted. The house should be tight and well-insulated. In most areas of the country, walls should be insulated to R-19 (e.g. 6 in. of fiberglass) and ceilings to at least R-30. Windows should be at least double glazed, and in many areas triple glazing is preferable. The foundation should be insulated, windows and doors weatherstripped, and a vapor barrier should be installed on the inside of all insulated surfaces. All these factors contribute to retaining whatever heat energy the building receives.

Once the house is made energy conserving the simplest and usually most economical way to use solar energy is by direct gain, often referred to as a type of "Passive Solar." Direct gain simply means letting the sun shine through windows; the sunlight heats whatever it strikes, and that heat is retained within the house (the "greenhouse effect"). New houses designed to take advantage of passive solar often have a long east-west dimension, most of the glazing on the south wall, a few windows on the east and west, and hardly any on the north. A greenhouse attached to the south wall is a common application of direct gain. Passive solar systems can easily be integrated with contemporary designs for new homes, but not so easily with traditional designs or with the retrofitting of existing buildings.

A Site Built Active Solar Collector Installation

Active systems such as the MODEL-TEA Solar System have a significant advantage in this regard. Since active systems consist of collectors which can be mounted on either a wall or roof, and delivery systems which can carry the heat to any part of the house or to remote storage, these systems can be easily integrated into any building that has a proper solar exposure. Existing homes frequently do not have sufficient space on the south wall for a reasonably sized solar system, or may not even have a good solar exposure on the wall, but they may have a large roof area exposed to the sun. Thus what may constitute a difficult retrofit for a passive system is straightforward for an active system. New home designs can be traditional, without heavily glazed south walls, and yet still have a large active solar system on a well oriented roof. Active collectors can even be mounted on south walls, with the advantage that the wall is fully insulated and thus does not lose as much heat to the outside as direct gain windows would.

While active systems lend themselves to easier building integration, they are usually more expensive than passive systems. The initial cost may not be much greater, but active systems have shorter lifetimes than passive systems. Commercially manufactured collectors cost roughly $20 to $25 per square foot (installed), and the added cost of controls, delivery system and storage bring the total installed cost to $45 or more per square foot of collector. Thus a typical 400 square foot commercial system might cost $18,000. Such a system is only marginally competitive at current fossil fuel prices.

The MODEL-TEA Solar Heating System differs substantially from these commercially available systems. It is available at a tremendously lower cost because of its innovative design and because it is integrated into the building. The collector can be built for $7 to $11 per square foot, depending on choice of options, and the total installed cost for a 400 square foot system is roughly $8000. This is approximately one-half the cost of a commercially manufactured system.

There are many criteria by which the economics of a solar installation may be judged, including first cost, payback time, return on investment, benefit/cost ratios and so on. Most methods require a prediction of fossil fuel costs many years into the future, leading to uncertain results which, at best, are only useful in defining limits. In Section 2.5 the cost of the MODEL-TEA System is studied in detail and found to be a very attractive economic option.

In any case, few people will probably make the decision based on economics alone. There are other factors which may influence the decision. What will be important for many people is the security of having a totally dependable source of heat, independent from fuel shortages and other unpredictable events. On a seasonal basis, the available solar energy is very predictable and probably more dependable than anything else in our world today. A solar collector provides a hedge against uncertainties of the future. Another reason which may be considered involves the ecological ramifications. A person may be motivated by social concerns to minimize consumption of valuable nonrenewable fuels. A homeowner who uses a solar heating system can have the satisfaction that he is doing his part to conserve our nonrenewable fuels so they may be used in more appropriate applications. It is not sensible to waste a valuable and diminishing resource (e.g. oil) on home heating which could be accomplished just as effectively through solar. People who use active solar now, know that they are the vanguard of a movement which will be not only highly beneficial, but perhaps essential to our civilization. The ultimate decision on using solar will be made by each individual, taking into consideration all of these factors, and probably others.

There is a great deal of available information on solar energy, from both private and public sources. Appendix C lists books, magazines, and government organizations which can help acquaint the public with the rapidly growing solar field.

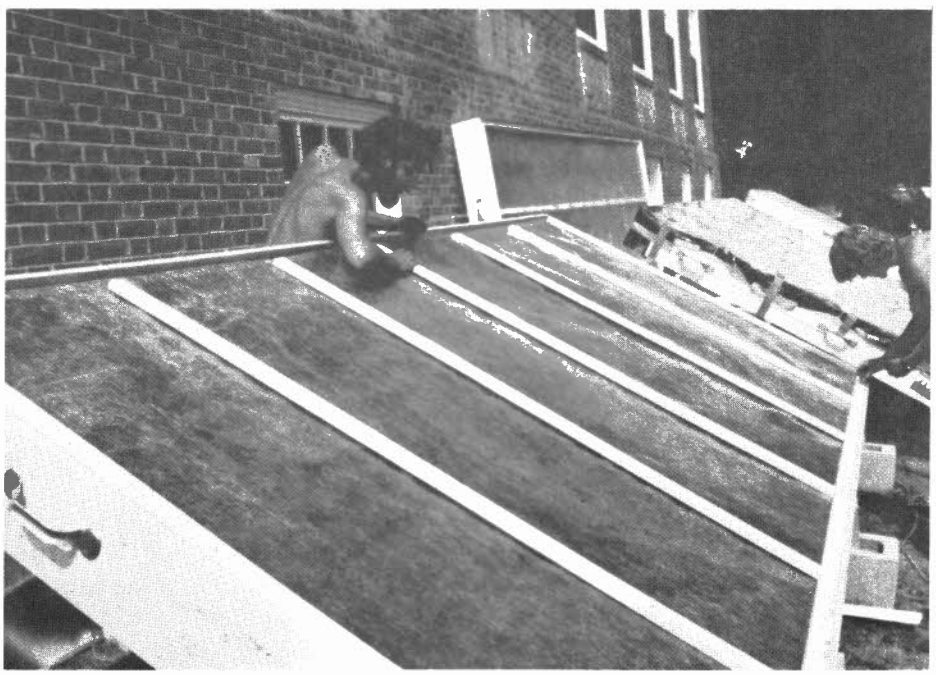
Development of the Model-TEA Solar Heating System

The MODEL-TEA Solar System was developed by Total Environmental Action, Inc. (TEA) under a grant awarded by the United States Department of Energy, Solar Heating and Cooling Research and Development Branch, Office of Conservation and Solar Applications. The concept of the project was to significantly lower the cost of active solar systems by 1) designing a collector which shares several of its components with the building, reducing duplication of materials and 2) developing a low cost delivery and storage system. A collector built on site (site-fabricated) and properly integrated into the building also has the advantages of improved performance, due to decreased side and back losses, and a much improved visual appearance of the building.

A number of builders throughout the country have developed site-fabricated collector designs. Although many of these designs seem to work reasonably well, most have not been subjected to a careful analysis to determine if performance could be improved, durability increased, or cost reduced. Furthermore, construction plans for site-built collectors are usually incomplete, if they are available at all, and very little information is available on designs for delivery systems and storage.

The purpose of the TEA endeavor was first to develop an attractive, durable, low cost site-built collector that would perform as well as commercially manufactured collectors, and that could be easily integrated into the majority of new or existing wood frame buildings. An additional goal was to design low cost, effective air-handling and storage systems appropriate to the various potential collector applications. TEA began by conducting a survey of site-built installations throughout the country to learn about the experiences of others. Information was compiled regarding specific collector designs, materials used, cost of construction, problems experienced and solutions developed. An investigation to determine the materials most suitable for use in a site-built collector was then undertaken. Glazings, absorber plates, paints, caulks, structural materials, and fasteners were evaluated, regarding such factors as performance, cost, durability, ease of handling, and availability.

Six collectors were designed based on the results of the survey, the materials study, and TEA's previous experience with site-built collectors. These designs were rigorously analyzed. The theoretical efficiency was calculated and the annual energy output of each design was computed. Materials lists and construction times were completed to determine the installed cost of each design. The ease of construction, appearance, and durability of each design was assessed, and the best design was then selected.



Collector Test Module

Five collector test modules were constructed and tested according to strict industry test procedures (ASHRAE 93-77 standards and the HUD thirty day stagnation test). The modules satisfactorily passed these tests. The results confirmed that the design selected was durable and provided performance comparable to manufactured collectors at less than one-half the cost. Once glass was chosen as the glazing material, another test was conducted to evaluate three different systems for mounting the glass on the collector. The result of this phase of the project was a thoroughly proven collector design. (For more information on the project development, see Chapter 2 and Appendix B.3.)

A similar philosophy governed the approach to the development of designs for the air-handling systems, controls and storage. After surveying current designs, TEA began work on a simple, low cost design which could be integrated into existing buildings or used in new construction. This system design is straightforward to build and does not depend upon a particular building configuration. TEA also developed an innovative system design specifically for new buildings. This is an even lower cost design, but is only suitable for new construction where the building can be carefully designed to accomodate the solar system.

The final design, collector and sub-systems, was named the MODEL-TEA Solar Heating System. Like the famous automobile it is a classic, durable, reliable design available at a low cost in the marketplace. To paraphrase Henry Ford, it can be painted any color you want, as long as it is black!

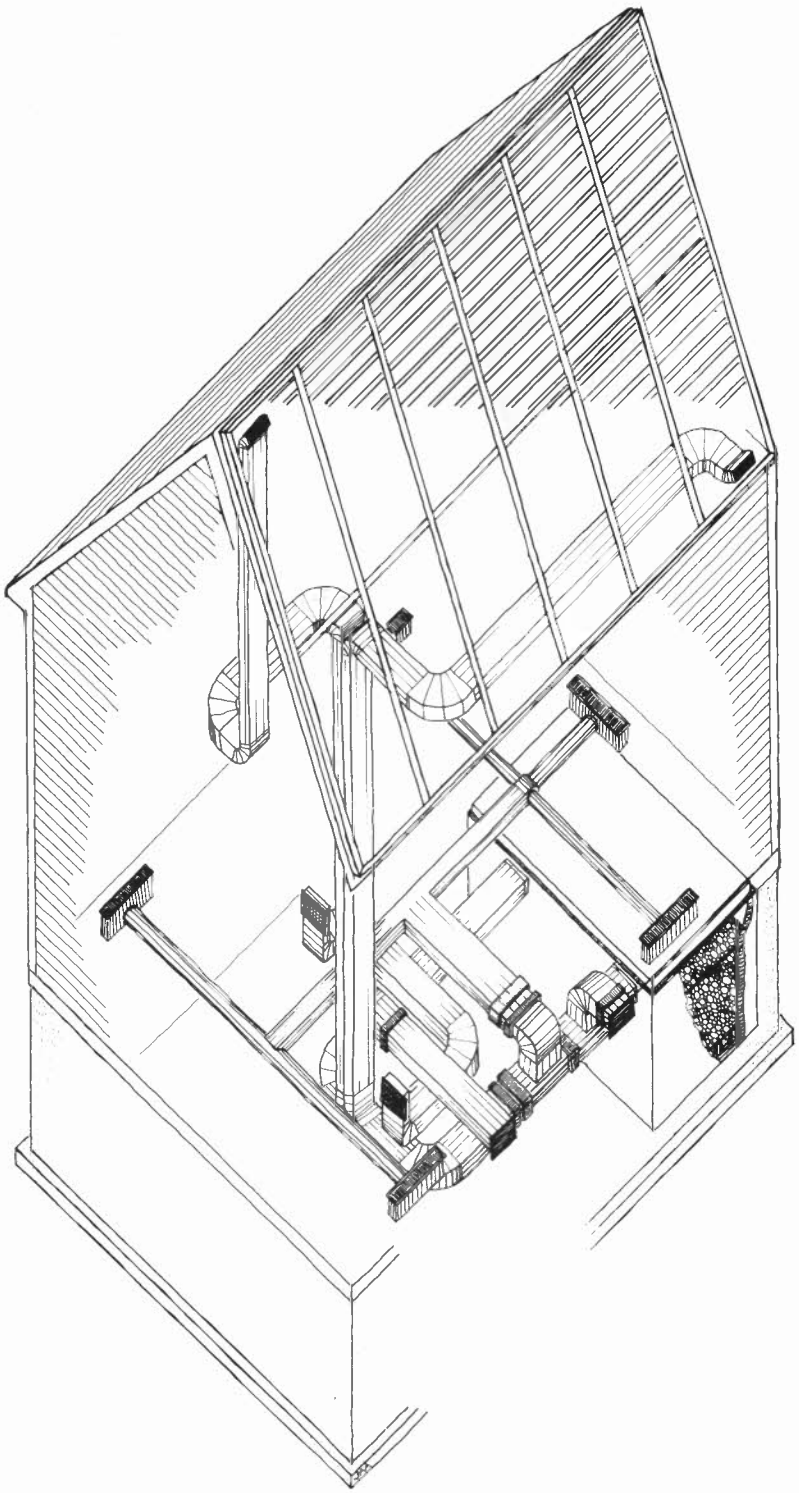


Figure 1.1 Example of Complete System