DOCUMENT RESUME

ED 133 907 EA 009 172

TITLE	Schoolhouse. A Newsletter from Educational Facilities Laboratories. No. 26.
INSTITUTION	Educational Facilities Labs., Inc., New York, N.Y.
PUB DATE	Jan 77
NOTE	13p.
AVAILABLE FROM	Educational Facilities Laboratories, 850 Third Avenue, New York, New York 10022 (free)
EDRS PRICE	MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS	Air Conditioning; Elementary Secondary Education; Energy Conservation; *Facility Requirements; *Fuel Consumption; Heating; Heat Recovery; Life Cycle Costing; *School Design; School District Spending; *School Improvement; *Solar Radiation

ABSTRACT

This issue addresses the question frequently asked by administrators, "Is solar energy suitable for new or existing schools?" Various applications of solar energy that schools have installed or are about to install are described. These examples include a new school designed for solar energy, an existing school with solar energy added, a simple system of directly heating through glass rooflights, and a system for heating hot water for washrooms and a cafeteria. The basic techniques for harnessing the sun's energy are also described. (Author/MLF)

Jan. 1977 No. 26

A newsletter from
Educational Facilities Laboratories

Schoolhouse

Can solar energy heat and cool schoolhouses?

For several years EFL has addressed itself to the problems of rising energy costs in schoolhouses. We have published advice on reducing consumption, and we run a service for helping schools analyze and improve their power and fuel consumption. In this issue of *Schoolhouse* we address the question frequently asked by administrators, "Is solar energy suitable for new or existing schools?"

Naturally there is no one answer that fits all circumstances. So we will describe various applications of solar energy that schools in the United States have installed or are about to install. These examples include a new school designed for solar energy, an existing school with solar energy added, a simple system of directly heating through glass rooflights, and a system for heating hot water for washrooms and a cafeteria. We will also describe the basic techniques for harnessing the sun.

The research for this issue was funded by Clay P. Bedford

How the sun can help reduce the climbing cost of fossil fuels

The Federal Energy Administration says that schools spent an average of $29.77 per pupil for fuel in the school year 1974–75. Before the Arab oil embargo the average cost was $20.07. Thus in two years fuel costs shot up 48% and the nation's public schools spent an estimated $514 million more for fuel than in 1972–73. The Administration makes an interesting comparison: The extra cost of fuel is equivalent to 43,000 teaching positions.

This spiral of energy costs places an extremely heavy burden on schools since they must consume fuel, regardless of price, to maintain their services. This comes at a time when taxpayers are reluctant to increase local taxes, teachers' salaries are rising, and parents are demanding expanded programs and services.

School districts can take steps to relieve their energy burden by making changes in operational and maintenance procedures, such as reducing temperature and raising humidity in classrooms, conducting rigorous maintenance programs for heating and cooling systems, and using the school's spaces to their best advantage. They can also make capital modifications, such as additional insulation, reduced window area, improved lighting, automatic controls, and waste heat recovery systems which are environmentally benign and cost-effective. Saving a Btu of fuel is always cheaper than finding an alternative source.

The sun is the most practical alternative energy source to fossil fuels. It is constant, nonpolluting, and free. For all practical purposes, its life span is infinite. The amount of energy reaching earth from the sun in 24 hours is 5,000 times greater than the sum of all future energy sources within the earth.

Although it is plentiful, the solar energy hitting the atmosphere is relatively dilute. As it crosses our atmosphere to reach the earth, it is reduced by local weather, attenuation, and air pollution. As we are all aware, solar energy is received only intermittently at any point on earth. The solar energy that does reach us on the surface of the earth is in two forms: direct and diffuse radiation. Direct radiation travels in parallel lines and is capable of casting a shadow. Diffuse radiation is dispersed or reflected by the atmosphere and cannot cast a shadow. The average intensity of solar energy that strikes 1 sq ft of ground is between 100 and 200 Btu's an hour. Even with a low energy conversion efficiency of 5%, the entire nation's energy needs could be filled with the sun that falls on 4% of the continental land area.

Several studies have been made on the possible contribution of solar energy to the national energy budget. At present the heating and cooling of buildings uses 20% of the total amount of energy consumed in the United States. The majority of this is in the form of low-grade, low-temperature energy. To produce this we often burn fossil fuels at 600F or use nuclear fission which operates at 4,000F to provide 140F water for someone's bath. It would seem to make more sense if we started off with low-temperature energy—the sun. All we have to do is collect it.

Schools should lead in solar energy heating and cooling installations

In mid-1976, only 20 of the 88,000 elementary and secondary schools in the United States and about 20 college buildings were solar conditioned. That's a minuscule proportion of educational facilities, but a big potential market lies ahead. The National Science Foundation forecasts that ultimately 30% of the nation's heating requirements will be supplied by the sun.

If and when this comes to pass, we would reduce air pollution by 430,000 tons and solid wastes by 20 million tons annually. The reduction in radioactive discharges into the air and waters would be enormous. And the benefit in knowing that the country would no longer be a potential victim of fuel embargoes would be immeasurable.

Because schools are the most numerous of public institutions, they can exert a strong influence through their leadership in energy conservation. Libraries, hospitals, municipal offices, etc., are more likely to adopt solar energy if they can first see the equipment installed in schools. Schools can also influence the people who use them, and some of the 44 million students have families that could be encouraged to install solar energy systems in their own homes or businesses.

If solar energy is such a good thing for the country, why do we have so few solar heated buildings? The answer is largely that of public attitudes: There is no sense of urgency to conserve fuel because we have always had more than enough low-cost fuel to go around. We are so used to this idea that it is almost impossible for us to believe that we need to invest our own capital to reduce our fuel purchases. The mild winter of 1975–76 lightened consumption of heating fuel and helped to erase our memories of the 1973–74 embargo. We continue to exceed the 55 mph speed limit. Because of our imprudent use of energy, we are currently spending up to $4 million an hour on imported oil.

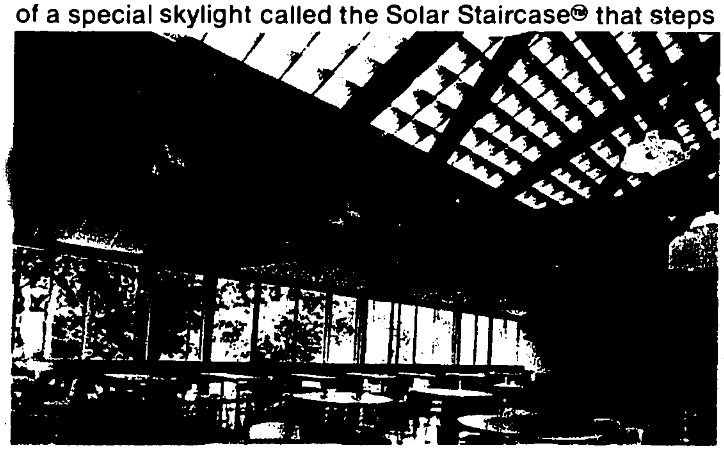
Direct system heats private school in Massachusetts

The simplest form of solar heating is called direct or passive and it converts sunlight into thermal energy within the space to be heated. The most common technique is to install large south-facing windows that trap direct solar radiation during winter daylight hours. Some of the building's heat is stored in the masonry walls and is given back to the room when the sun goes down.

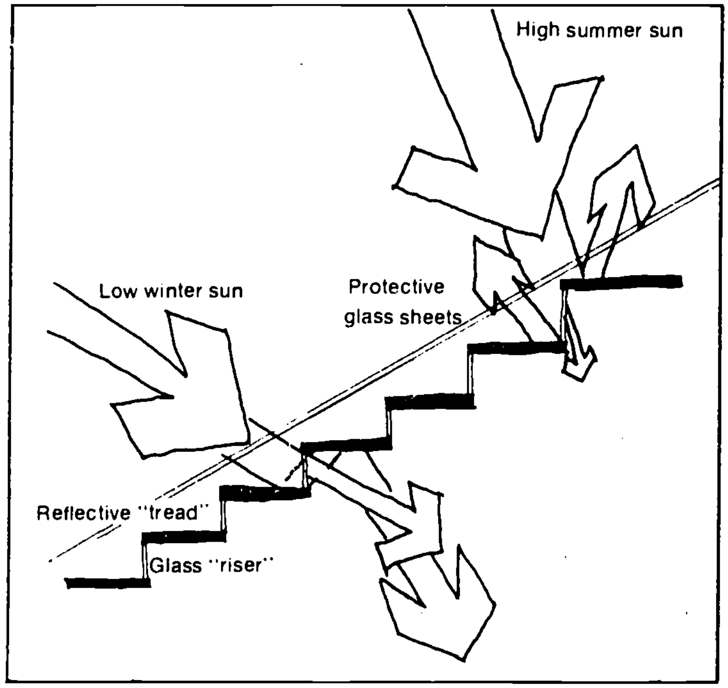
This elementary system provides adequate comfort in a climate with few cloudy days or periods of intense cold such as northern Arizona and New Mexico. In a climate less ideal, more elaborate methods are required, such as thick masonry walls to store heat, large expanses of south glazing, movable insulation (including thick curtains), and carefully located ventilators. In the summer when direct sunlight is not wanted, an overhang is provided on the windows to shade them from the high sun. Incorporating direct solar heating into the design of a building does not require an increase in initial cost or maintenance costs.

There are drawbacks to this approach in that great amounts of south-facing glass can cause overheating, glare, and damage to furniture. In buildings with massive heat-storage walls on the south side, views are impaired and enjoyment of the southern exposure is limited.

The Cambridge School in Weston, Massachusetts, has a direct system in one building. The heat from the sun is collected through south-facing windows and 1,700 sq ft of a special skylight called the Solar Staircase® that steps



up the sloping roof. The stepped roof has 18-in.-wide aluminum covered "treads" and 8½-in.-high glass "risers." During winter, when the angle of the sun is low, the sun shines directly through the risers and reflects off the shiny treads into the risers. In the summer, when the sun is high in the sky, less radiation falls directly on the glass risers and more falls on the treads which block unwanted direct sunlight. The south-facing windows in the walls are protected from the high summer sun by the overhanging roof. Heat is stored in heavy masonry walls that also serve as fire walls.



Schematic drawing of Weston School skylight

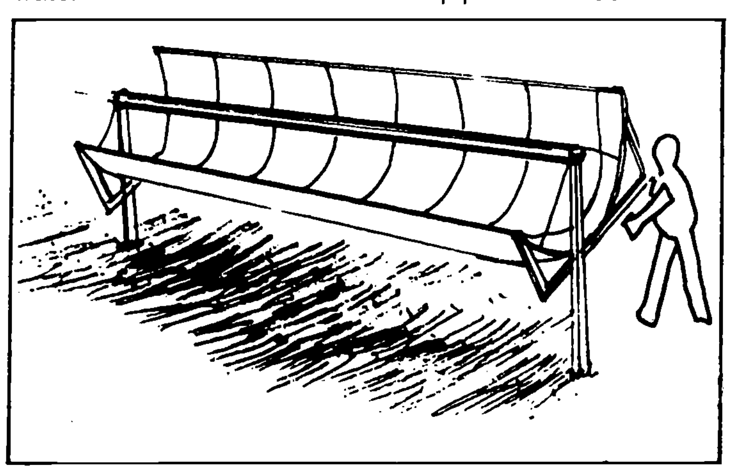
The Solar Staircase costs about $5 per sq ft; an ordinary roof would cost about $2.50 per sq ft. Each year the school expects to save about 28 cents per sq ft of skylight. About 11 cents of this savings is effected through reduced lighting costs and the remaining 17 cents from reduced heating costs. The system is expected to pay for itself in less than 10 years.

Robert Sandoe, Headmaster, Cambridge School of Weston, Georgian Road, Weston, Mass. 02193.

Solar collectors heat the water that heats the building

The other form of solar heating is the indirect system which converts sunlight into thermal energy outside the spaces to be heated and cooled. Such systems require a means of collecting the sunlight, storing its heat until needed, and then distributing it.

The heart of the indirect system is the solar collector, which gathers the solar radiation and intensifies it to heat water or air that can be stored and piped into a conven-



Trough-shaped concentrating collector

tional heat distribution system. There are basically two types of collectors in an indirect system: the concentrator and the flat plate.

The concentrating collector usually consists of a highly reflective curved surface which focuses sunlight on a radiation absorbing area. These collectors can easily obtain temperatures above 250F. They are trough- or dish-shaped and require a tracking system that must follow the sun because they can only collect direct radiation.

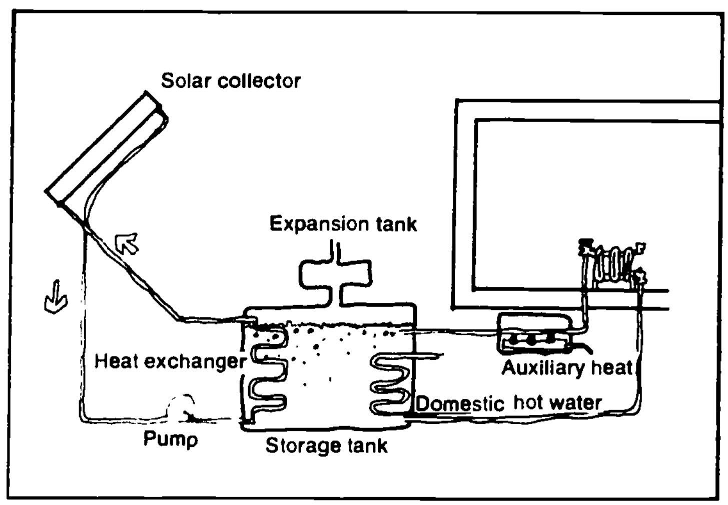
The Padonia Elementary School in Padonia, Maryland, will use 3,000 sq ft of a trough-type concentrating collector to provide 85% of the heating and cooling load for 10,000 sq ft of the school that is now under construction. The cost of the solar energy installation will be paid by the U.S. Energy Research and Development Administration (ERDA).

The Superintendent, Baltimore County Board of Education, 3 East 25th Street, Baltimore, Md. 21218.

Flat plate collectors have a more universal application because they absorb diffuse as well as direct sunlight. The collectors are, in simple terms, large trays of water or air covered with glass to create a "greenhouse" that heats the fluid. The surface of the tray is coated with an absorbent material to soak up the sun's rays and intensify the heat transferred to the water or air. The plates are usually about 4 ft by 8 ft. They can be mounted on a roof or on the ground and are tilted roughly perpendicular to the sun to capture the most direct radiation. Insulation on the back of the collectors prevents heat loss to the air.

The heated fluid is carried from the collector into a storage area where it is held until it is needed. In an indirect system using water, the storage area consists of a large tank capable of holding up to a few days' worth of heat for the entire building. Heat from an air system usually is stored in large bins of stones.

In a water storage system, heat is transferred to the rooms by direct convection, circulating the storage tank water through baseboard convectors, or coils in hot air ducts, or by fan coil units. Domestic hot water can be



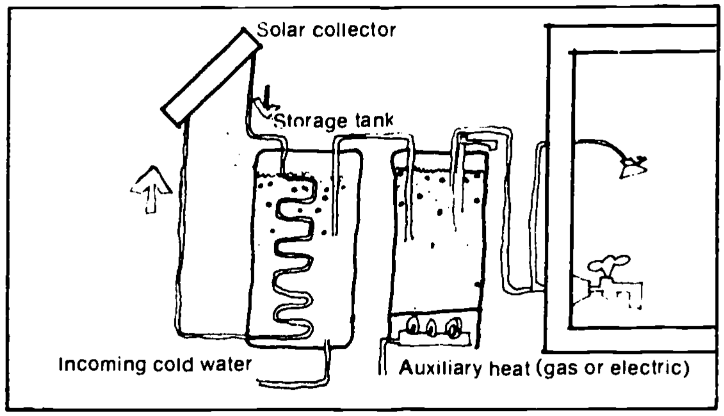
Solar heating system

preheated by routing cold feedwater through the storage tank and then heating it up to 140F by gas. A typical solar heated air system transfers heat to the dwelling spaces by a conventional forced warm-air system.

Sun heats water for sinks, showers, and school cafeteria

Solar radiation may be used to heat domestic hot water, swimming pools, and whirlpool baths without heating any room spaces. The collection system for this type of hot water heating is the same as the flat plate liquid collector system, only smaller.

The Pioneer School in Peoria, Arizona, uses 3,840 sq ft of collection to provide 100% of the domestic hot water (except for the dishwasher) for its 600 students. One bank of collectors supplies hot water to a storage tank for the cafeteria and showers. Separate pairs of collectors that directly supply washrooms or classroom sinks are located on the roof immediately over the individual areas. Each sink has a normal-size hot water storage tank.



Solar hot water heating system

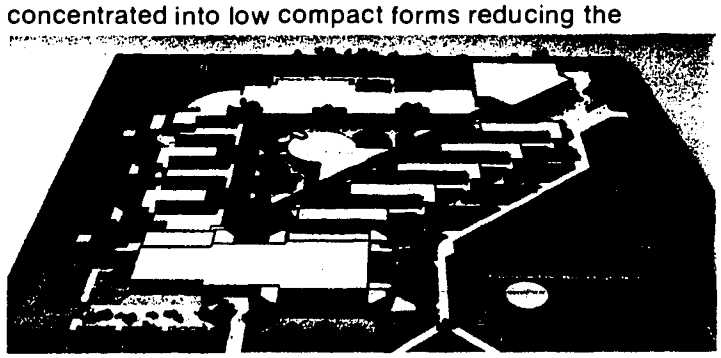
Because the state of Arizona has not permitted natural gas to be installed in new buildings during the past year, the Peoria District was unable to obtain gas for the new school. In an area where over 90% of the days are cloudless, solar energy was the natural alternative. The school expects to pay back the additional cost of the system in 8 years.

Bill French, Business Manager, Peoria School District Office, 11200 North 83rd Avenue, Peoria, Ariz. 85345.

Earth will insulate school with solar heating in Tempe

The Tempe (Arizona) Union High School District plans to complete in December, 1977, a 315,000-sq-ft facility with a 24,000-sq-ft collector that will provide 88% of the thermal energy required for space heating and hot water for 2,000 students. The designers of the school have combined extensive energy conservation measures with the solar energy system.

The building is designed around a central open space that is combined with courts designed for academic and social activities. Energy usage is minimized by several means. Earth is mounded against exterior walls to provide natural insulation to the building. The building mass is concentrated into low compact forms reducing the



amount of surface area that can give up or gain heat. The two-story sections of the school shade the main single-story structure, thus reducing the air-conditioning load. The main structure is also oriented so that it has a minimum of southern exposure. With these and a few other measures, the mechanical system costs 25% less than it would have without the solar energy components. The cost of the solar components will be paid for in fuel savings in about 13 years.

The solar energy system has flat plate collectors coated with a selective surface that absorbs a great deal of solar radiation but emits very little of the longer wave radiation normally given off by the heated absorber plate. The collectors will heat water to be stored in a 60,000-gallon tank from which it will be pumped to preheat water for the potable hot water system. Water from the same storage tank will also heat the coils in the air handling units to provide space heating. An auxiliary electrically heated boiler for space heating and an electric hot water heater will be installed.

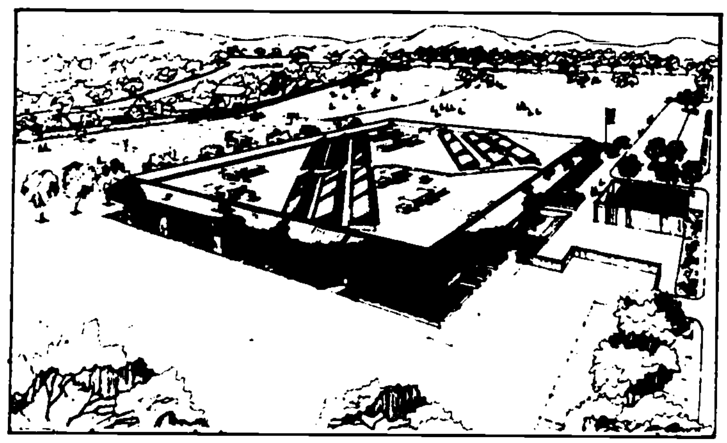
The Tempe High School is the first major application of solar energy for municipal buildings in the western United States. The cost of the solar components will be subsidized by a $700,000 grant from ERDA.

Superintendent John C. Waters, Tempe Union High School, District No. 213, 500 West Guadalupe Road, Tempe, Ariz. 85282.

Solar collectors will supply half the cooling source of an existing California school

Cooling a building with solar energy may sound contradictory, but it works on the time-tested principle of the old gas refrigerators. Solar collectors can be designed to produce extremely hot water to drive an absorption chiller. When the sun's rays are strongest, the most cooling is required and the hottest water is produced. A major problem with absorption machines is their efficiency. It requires almost 2 Btu's of heat to produce 1 Btu of cooling. Therefore this process requires extremely large areas of collectors.

The Irvine Unified School District in California recently received funding from ERDA to install an experimental solar energy system for cooling the existing El Camino



Real elementary school. The system will use a sophisticated solar collector—the evacuated tube collector—mounted on the roof.

The school already has two hot water fired absorption chillers. The solar energy system will provide energy for one chiller and the existing boiler will take care of the other. The two chillers will be installed in series so that when the chiller driven by solar energy is not providing enough cooling, the second chiller picks up the additional load.

A 1,500-gallon solar heated storage tank will be located above ground to provide for the school's small space heating needs.

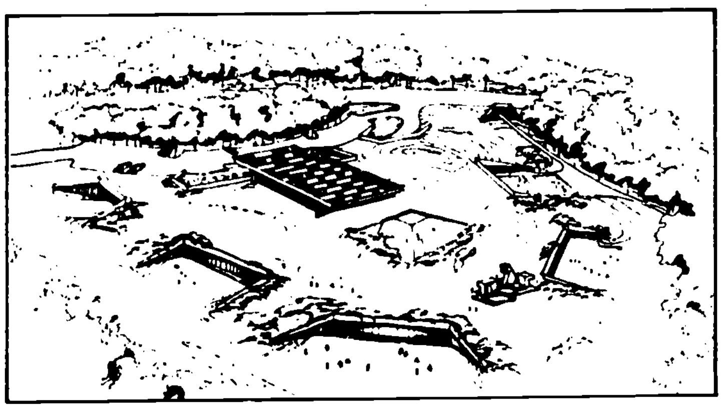
The school expects to save $5,000 a year with this cooling system. However, the installation must be considered an experiment since it costs $329,000 and cannot pay for itself for another 66 years. Estimates for using evacuated tube collectors with a fully integrated mechanical system on a new building suggest that it would pay off in 27 years.

Dave King, Facilities Planner, Irvine Unified School District, P.O. Box 19535, Irvine, Calif. 92713.

Solar collectors will form canopy over school bus drop off area

The Terraset School planned for Reston, Va., will be built underground so that its 2 to 3 ft of cover will develop sufficient thermal mass to make the interior relatively unaffected by the exterior temperatures. In fact, during the winter months the school is expected to be airconditioned during the school day because of the excess heat from lighting and people. When the building is dark and empty, it will require heat, as will areas around its few windows.

Energy for the cooling and heating will be supplied by the sun. About 6,000 sq ft of high-performance evacuat-



ed-tube collectors will be mounted on a frame that forms a covered entrance for children using school buses to the underground school. The energy-conscious design is expected to produce energy costs of $9,000 a year. For comparison, the architects say that a similar size school built above ground and using an all electric system would cost $43,000 a year.

Hot water from the collectors will be piped into a storage tank, and another two tanks will store excess cool water from the chillers when the demand from the airconditioning system is low. If necessary, one of the chilled water tanks can be switched to hot water storage during the fall and spring when the heating and cooling loads vary daily. Also at these fluctuating times, heat can be captured from the electric chiller and used to make hot water for the storage tank.

The Superintendent, Fairfax County School District, 10700 Page Avenue, Fairfax, Va. 22030.

Dispersed system provides 25% of the heating and cooling load in new school

Another technique for applying the sun's energy is to heat and cool a building through a heat pump. A heat pump, frequently called a reverse cycle airconditioner, has a reversible valve that can channel the heat transfer liquid in two directions. In the summer the machine operates by cooling the interior space like a conventional airconditioner. Power for the pump is provided by electricity. In the winter the heat pump operates in reverse; it is used to warm the inside space by reversing the flow of the heat transfer fluid so that low-level heat from the atmosphere is raised to temperatures needed for heating a building.

By using a small amount of electricity to power the compressor, the heat pump can take advantage of a free energy source for heating and cooling the building. Heat pumps can provide significant improvement over conventional solar heating systems because the heat pump can work with lower temperatures. This capability results in reduced collector size and higher efficiency of collection. Another bonus is that collectors operate more efficiently at the lower temperatures that heat pumps use, thus requiring fewer collectors. Heat pumps can also operate during the early morning and late afternoon hours when the solar heat is not strong enough for a regular solar system.

The recently completed Parker Junior High School in Douglas County, Colorado, is equipped with almost 3,000 sq ft of flat plate solar collectors and heat pumps that will

Solar collector atop roof of Parker Junior High School

provide about 25% of the building's heating needs. A water and antifreeze solution carries heat from the collectors to a heat exchanger in a 12,000-gallon tank buried in sand below the floor of the boiler room. This tank stores enough heat for three sunless winter days.

The heat storage provides hot water at 60F to 90F for 48 heat pumps and preheats domestic hot water. The heat pumps are dispersed throughout the building in the ceiling space above the classrooms. Cooling will be provided by the reverse action of the heat pumps. Most of the heat for the school is provided by a gas-fired boiler.

Increased thermal insulation complements energy conserving measures of the solar design. Windows are double glazed and are reduced to a minimum in north-facing walls. Only 12% of the building's exterior walls have glass or doors, and all exterior doors are weather-stripped and protected from the wind by projecting walls.

Interior spaces were organized to allow heat to flow from one room to another; any excess heat is transferred back to the solar storage tank.

The complete solar energy system cost almost $55,000, which the district expects will pay for itself in 10 years.

Superintendent Lowell Baumunk, Douglas County School District, Box Q, Castle Rock, Colo. 80104.

What you need to know before you can decide to use solar energy in a school

If you are considering building a facility that will use the sun to meet some of its energy requirements, a few guidelines should be kept in mind. Any cost comparisons with fossil-fuel heating and cooling systems should be based on life-cycle costs, not just initial costs. Make no mistake, solar energy installations are not cheap.

The success of a solar installation depends on a good heat-conserving structure. The building shell should be heavily insulated to obtain an insulation factor of R15 for the walls. (A typical 1950s brick school has a factor of R4, and buildings designed to meet the School Construction Systems Development (SCSD) standards in the 1960s are up to R6.) Windows and door area should be minimized (about 12% of the exposed perimeter) and should be protected from the wind by the use of fins or recesses. The perimeter of the building should be kept to a minimum to reduce heat loss.

A standard for a well-designed solar building is that it only needs about 10 Btu/sq ft/hr to keep it at a comfortable temperature in winter. A school without energy conserving features often requires four to five times that amount of heat.

Climate and location affect the suitability of a schoolhouse for solar energy. In most parts of the country there is not enough solar radiation to economically provide the building with all the heat it needs. Conventional systems must be incorporated into the design to provide additional heat or cooling. For instance, in the Northeast it is not economical for solar heating to provide 100% of a school's heating requirements, but 50% is a reasonable expectation.

To provide the most economical mix of conventional and solar heating methods, the solar energy system must be sized with consideration for the available money, the fuel inflation rate, and the system component cost. If a system is too small, solar energy cannot be economically introduced because of the fixed costs of controls, pumps, and other components that have a minimum size no matter how small the collector system.

If a collector takes over a large amount of the load, it will work at full capacity for only a small part of the year; thus its load factor for the rest of the year becomes too small to be economical. Rules of thumb are no substitute for engineering calculations, but a simple guide for an indirect system is that collectors equal to half the floor space will provide about 70% of a building's heat requirements.

Installed systems can cost anywhere from $10 to $75 per sq ft of installed collector. This includes the price of tanks, pumps, heat exchangers, piping, and thermostats. The average cost is around $20.00 per sq ft. In new construction a solar energy system can represent from 3% to 5% of the total building cost. About 1% of the building cost covers increased structural expenses for supporting the collectors on the roof. Collectors represent almost 50% of the total cost of a heating and cooling system. This is mainly because few, if any, collectors are mass-produced. As more buildings become solar, industry will mechanize and collector prices will drop. If you can't afford a complete system, consider installing everything but the collectors. Later, if your area runs out of fuel, you will be able to add collectors.

Generally, most systems that cost over $25 per sq ft will not pay for themselves in energy saving within the 20- to 30-year life of a bond. A well-designed system can produce energy that is competitive in price with the cost of electrical energy as a heat source over a 10- to 15-year span. In the near future, with improved technology and rising fossil-fuel prices, solar heat will be competitive with oil and gas heat.

At present, solar hot water heating is the most cost-effective of all low-temperature solar applications. This is because the initial investment is small and hot water is used throughout the year. This heavy and constant use gives a larger load factor than in a solar space heating system that stands idle all summer.

If the building also requires cooling, solar assisted heat pumps provide a very economical approach. These systems have projected payouts in 10 years, primarily because of the small collector size and improved performance.

Maintenance and operating costs usually represent about 1% of any mechanical heating system cost. Some systems require more maintenance than others to protect them from corrosion and dielectric difficulties. Solar systems that use water must be protected by antifreeze solutions or have automatic drain down systems that switch on when night approaches. Initial costs can be high because contractors add contingencies to cover their lack of experience in this field. In a study by Westinghouse, contractors were rated second only to power companies in order of resistance to the idea of solar energy.

The problem of sun rights must be solved before solar energy can be fully accepted. No established legal rights to solar radiation exist. The closest anyone has come to granting solar rights is in Great Britain. The old English doctrine of "Ancient Lights" gives the landowner the right to receive the customary amount of light and air. The U.S. courts, however, have specifically repudiated this doctrine. Although there are no specific laws governing solar rights, there are legal principles such as zoning, law of nuisance, easements, and pollution control laws which may be applicable to the problems.

Determine the best conditions for solar heating before you throw out your boiler

Adding solar energy systems to existing buildings generally costs $10 a sq ft more than in new buildings. If you are thinking about adding a system you should consider the following: Does the building already conserve energy? Is the building shell adequately insulated? It should be at least the equivalent of an electrically heated school. Is a solar energy system compatible with the existing system? Solar systems often provide heat at a lower temperature than conventional systems and so require larger radiator or convector heating surface areas. A water system is not always compatible with a steam system because two different kinds of radiators are required. Is there a place to put the collectors? If the collectors are placed on the roof, structural modification can add $2 to $4 per sq ft to the price of a system. Plumbing costs are also increased by breaking through existing walls, roofs, and floors. If collectors are placed on the ground, make sure the pipes into the building are well insulated. Make sure no buildings or trees will block the sun's rays.

Equipment currently available is a reasonable long-term investment, but the cost is expected to drop as more solar energy systems are built. But why wait for the perfect system to arrive? The longer you wait to make a decision concerning solar energy, the more money you are going to spend on fuel from a nonrenewable source. If you can save money now, why wait?

Further information on solar energy in schools may be obtained free from EFL. The material contains brief descriptions of other schools with solar energy plans, a guide to computing life-cycle costs of solar energy systems, and two *Schoolhouse* reports on four existing schools equipped with solar-powered heating and cooling systems financed by the National Science Foundation.

Educational Facilities Laboratories is a nonprofit organization established in 1958 by The Ford Foundation to encourage and guide constructive changes in educational and related facilities.