2

A SURVEY OF AIR-HEATER OPTIONS

Solar-heated air can be used in a wide variety of applications, but it is a limited resource. Only so much sunshine strikes each square foot of the earth, and a well-built collector system will typically deliver about half of this energy to a house in the form of heat.

The way this heat is used often means the difference between a useful, cost-effective system and one that never seems to perform properly. Effective use of collected solar heat is especially important in retrofitted systems which, because of space limitations, are often undersized for the houses they are serving. Yet even a small collector used as a supplemental heat source can make a substantial difference in a house's fuel consumption if the heat from it is used effectively. There are also limits to cost-effective collector sizing, which are discussed in chapter 3. Even where there is room for a large collector, it is usually not cost-effective to build one so large that it provides 100 percent of a house's space- or water-heating needs. So before diving into the actual design of your system, it is important to look at the best ways of making full use of the heat a collector delivers. There are a number of factors involved in determining the best ways to "manage" your solar heat, including the temperature of the heated air, the type and size of the collector and the size and layout of your house. These are discussed in the following pages.

Technically speaking, the heat generated by a solar air heater is a relatively "low-grade" heat. That's not a disparaging term, for it simply refers to the relatively low temperatures (80 to 140°F) at which air heaters operate. If the airflow rate were reduced, a collector would heat air above this range, but in terms of Btu's delivered, there is a lot more heat in a strong blast of 90°F air than there is in a tiny trickle of 140°F air from the same collector. Why? A collector operating at 90°F has less heat loss than one operating at 140°F and therefore operates more efficiently. In a hotter-running collector, the increased heat losses through the glazing, sides and back of the collector mean that less heat is actually delivered to the living space. This is a very important concept to keep in mind in the design and operation of both small and large systems. This low-grade solar heat is indeed very usable, but it must be handled differently from the 140 to 160°F "high-grade" heat produced by a forced-air furnace. A strong blast of 150°F air from a furnace will feel warm to the occupants of a home, whereas a strong blast of 90°F air from an efficient collector or from rock storage can feel drafty to the occupants, even though it is heating the house. Thus for solar air to heat a living space without drafty discomfort, it must enter the living space slowly and continuously and from several different points. This rule doesn't hold when the collector is very small, in which case it would be impractical and unnecessary to create more than one outlet. We can look again at the different types of air heaters, this time in terms of their specific air handling requirements.

Convective Air Heaters

Maintaining a continuous flow of low-grade heat is the goal of any convective air-heater design. Since a properly built passive air heater will raise the temperature of the air moving through it by about 30 to 40°F, the output temperature in these collectors will typically be close to 110°F. This low-grade heat enters the house very slowly through large openings, and the air movement is hardly noticeable, thereby heating the home in a very comfortable way.

Convective air heaters dump the heat they produce directly into the adjacent room and therefore don't require a heat distribution component. If the south-facing rooms in a house are often occupied by day and thus require a lot of daytime heating, a simple passive collector is an appropriate choice. If these rooms are seldom used and require little heat,

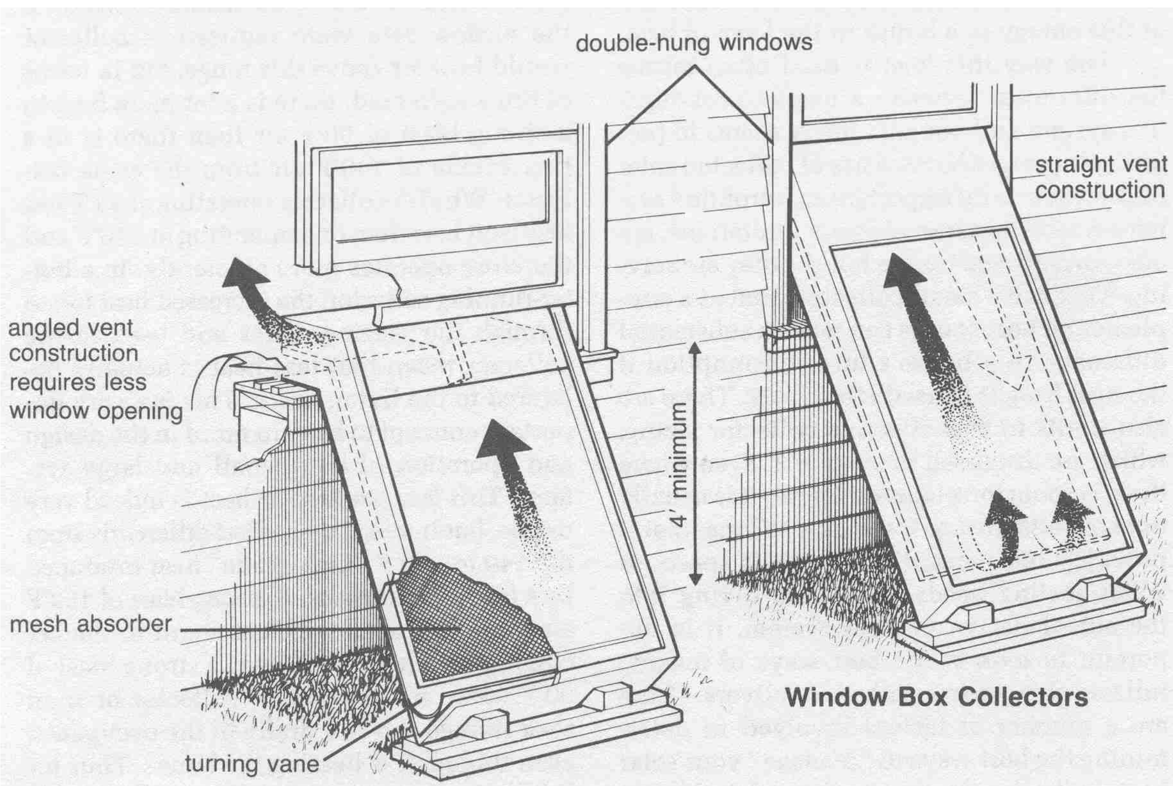
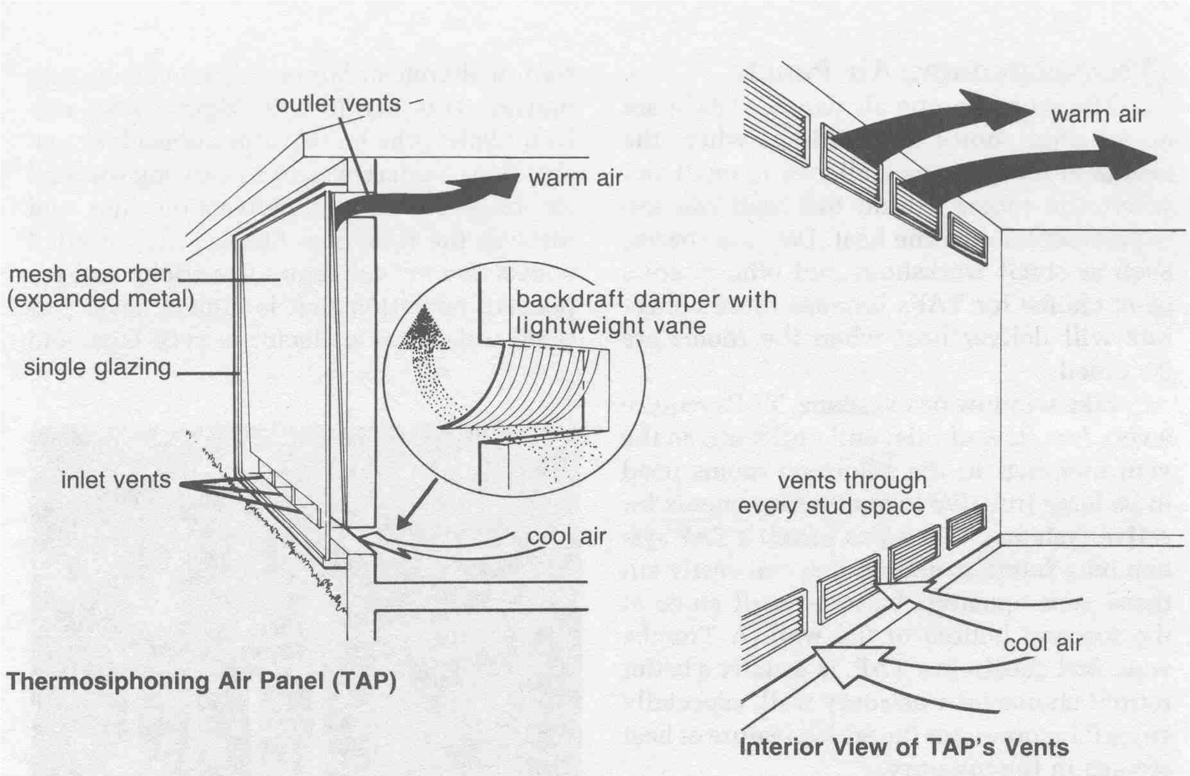


Figure 2-1: *Above* and on opposite page. Window box collectors and TAPs are easy-to-build collectors that deliver their heat by natural convection. They are best used to heat rooms that are frequently occupied and that require daytime heating. Window box collectors are self-damping at night. TAPs require lightweight backdraft dampers to prevent reverse thermo siphoning when the sun isn't shining.



Thermosiphoning Air Panel (TAP)

Interior View of TAP's Vents

a more involved active collection and distribution system is needed to satisfy the daytime heating needs of non-south rooms. There's an in-between wrinkle, too: A large passive heater can provide too much heat to adjacent rooms, which necessitates additional passive (vents in walls or floors) or active (blowers and ducting) heat distribution.

Window Box Collectors

Window box collectors are one of the simplest solar heating devices you can build, but since they are quite small in relation to the size of the room they are heating, they don't provide a great percentage of a house's total heating needs unless several are used. These heaters provide a slow, continuous flow of heated air into the adjoining rooms. They are self-operating and, when properly built, have an advantage over other solar heating devices in that no dampers of any kind are needed to prevent nighttime heat losses. Their best application is on houses with wide, south facing, double-hung windows that are 4 feet or more aboveground level. They can be installed on other types of windows, but the modifications required are more difficult and often expensive and unattractive. If the windows are less than 4 feet from the ground, the natural convection that moves air through them and into the house will be weak, and the collectors won't perform as well as they could. Since window box heaters are fairly small and act as a supplemental heat source, no heat distribution or storage is incorporated into their design. They don't involve any major modifications to the house and don't sacrifice any south-facing exposure that later may be desired for a larger collector installation.

Thermosiphoning Air Panels

Thermosiphoning air panels (TAPs) are also a good choice for buildings where the available south-facing wall area is small and where the rooms behind this wall can use supplemental daytime heat. Day-use spaces, such as small workshops and offices, are a good choice for TAPs because these collectors will deliver heat when the rooms are occupied.

Like window box systems, TAPs require a very free flow of inlet and outlet ~air, so the vent openings to the adjoining rooms need to be large (relative to vent requirements for active systems). When you install a TAP system on a frame structure, you can easily cut these vent openings between wall studs at the top and bottom of the wall. A Trombe wall, first cousin to a TAP, is usually a better retrofit choice for a masonry wall, especially since it incorporates the added feature of heat storage in the masonry.

Heat distribution in most TAP systems simply involves a convective flow of air (convective loop) inside the room behind the collector. This steady circulation of warmed air provides comfortable heat but can result in an overheated room if the TAP is large relative to the size of the room (where the collector area is more than 20 percent of the room's floor area).

In single-family dwellings it is often desirable to direct solar-heated air from a large TAP to rooms that aren't adjacent to the TAP. This can be accomplished with a small blower and ductwork, but if the retrofit project calls for extensive heat distribution, it is a better idea to design and build an active solar system to work with an active distribution system.

Even though passive air heaters are generally regarded and used as daytime heaters, heat storage can be incorporated into the design of thermosiphoning air panels on new houses. This involves building a large collector below the house or underneath a massive floor (concrete slab) so that solar-heated air rises by natural convection into and through the rock box. Storage in retrofitted convective air collectors is a tricky and expensive operation that is almost never justified unless the collector is very large and

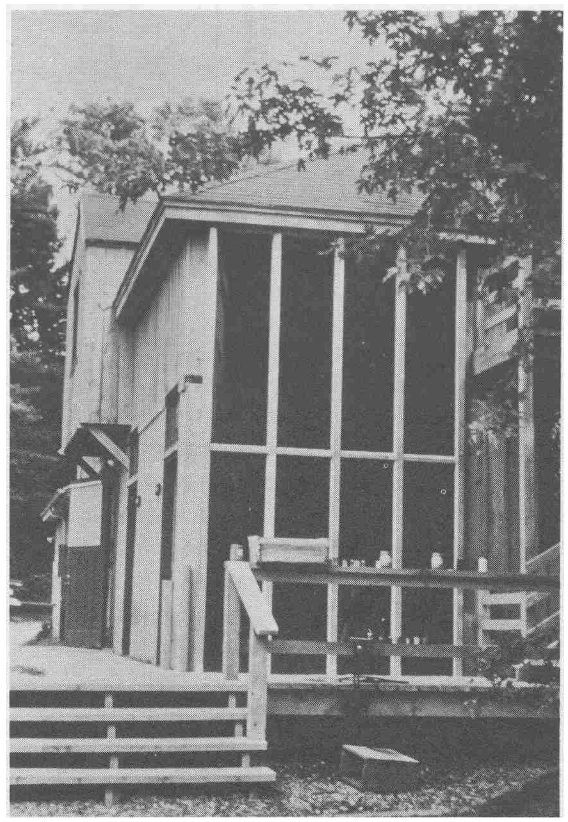


Photo 2-1: This 8-by-14-foot TAP was retrofitted onto the Hitchcock Nature Center in Amherst, Massachusetts. It heats the second-floor office space and uses an open stairwell as the cool-air return. This collector experiences some morning shading, which indicates that a little tree trimming is in order at this site.

located well below the rooms to be heated. (Chapter 11 goes more deeply into heat storage.)

Both window box heaters and thermo-siphoning air panels are quite inexpensive and easy to build, which makes them good projects for first-time solar retrofitters. Since they operate passively, they deliver comfortable heat without the need for wiring, blowers or thermostats. There are no operating costs as there are with active solar systems. Lack of heat distribution and methods of storing heat are two possible disadvantages that can sometimes be solved by using a small fan. Actually, the transition from passive to active operation of these smaller collectors is not a major one, nor is it highly complicated. In the following section we'll look at different ways that active air heaters can give you more control over your solar Btu's.

Active Systems

Active solar air-heating systems are more versatile than convective systems because they allow you to direct the heat to rooms that aren't near the collector. Active systems can be more expensive to build than passive systems, but they are easier to design because of their forced-air operation. With forced-air systems there is less concern about designing to maintain a delicate natural convection airflow. Finally, active systems have often demonstrated better performance than their passive counterparts, delivering more heat per square foot of collector.

A Collector-and-Crawl-Space Distribution System

A solar system that blows solar-heated air directly into a well-insulated crawl space or basement makes good use of low-grade solar heat. Because the flow of solar-heated air is isolated from the living area, 80 or 90°F air from a collector can be used without creating chilly drafts. This is significant because when a collector operates with a relatively high airflow rate, it runs cooler and thus more efficiently than it would with a lower flow rate.

Because heat rises, this system heats the house in a nice way: by warming the floor during the day and early evening. It can create a comfortably warm floor, it eliminates forced-air drafts and, in cold climates, it can help prevent pipes from freezing. A crawlspace system is especially attractive in retrofit applications where the collector is small relative to the size of the house and the added expense of including rock thermal storage or distribution ductwork probably isn't justified. This system heats the house very subtly, and its effectiveness doesn't really show until there is a period of cloudy weather. When the collector doesn't operate for an extended period, the house and floor will be noticeably cooler and the back-up furnace will run more often.

A crawl-space system requires that the floor be uninsulated and that the crawl space (or basement), including foundation vents, be well sealed and insulated at the foundation or stem wall. It is also desirable, but not necessary, that the floors be uncarpeted to increase their ability to radiate heat to the living space. It is inevitable that there will be more heat loss with this system than with other delivery setups, but the higher operating efficiency of the cooler-running collector and the elimination of drafts in the house make up for that.

Ductwork for a crawl-space system should be kept to a minimum while still allowing for good heat distribution. The most desirable method is to duct the hot air from the collector directly to the north side or coldest part of the house and let it find its way back to the collector return inlet located on the south side of the house. A "tee" fitting on the end of the outlet ductwork can help to distribute the air more evenly throughout the crawl space. Distribution ductwork in the crawl space can be left uninsulated since any heat losses from it help to heat the floor above.

Crawl-Space Controls

Controls and dampers for this system are simple. A standard differential thermostat (see chapter 6) turns on a blower whenever the collector plate is warmer than the crawl space and then shuts it off whenever the collector is cooler. A one-way backdraft damper or a motorized damper is mounted in the air return to prevent nighttime convective losses.

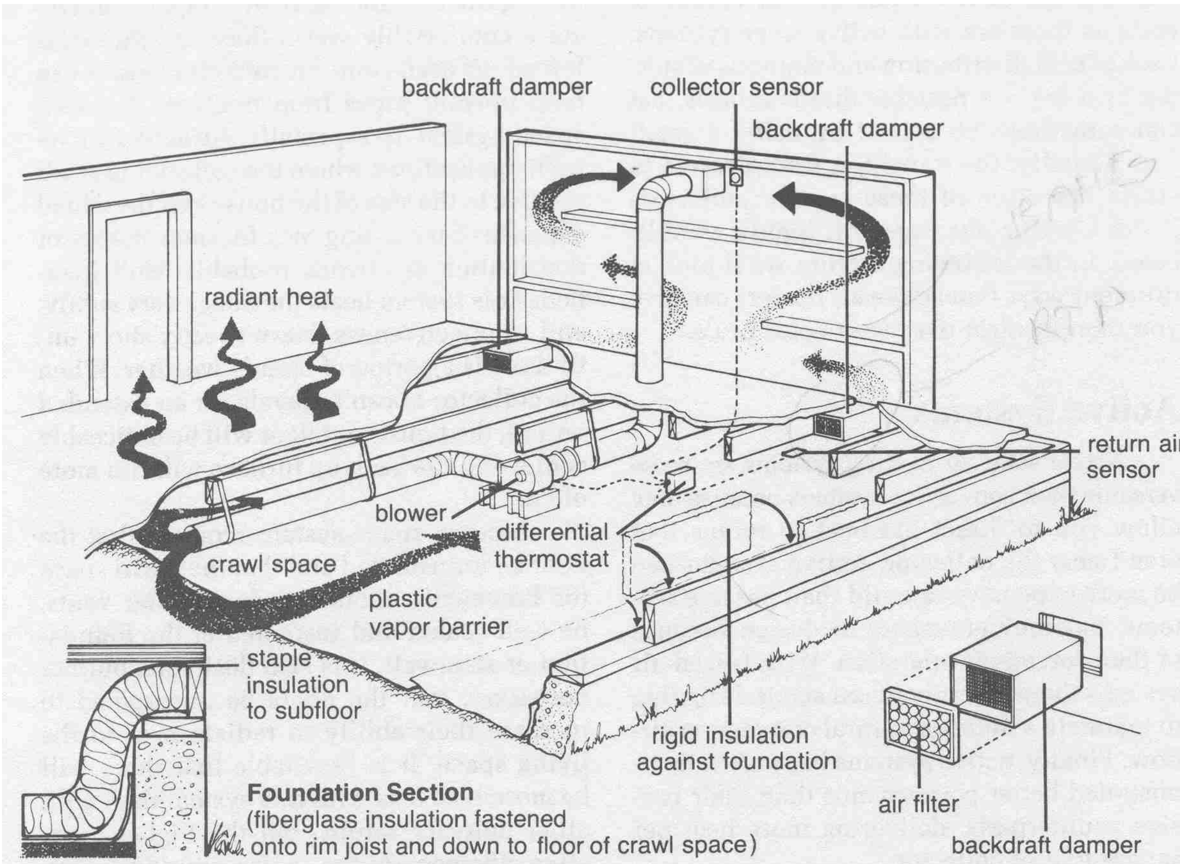


Figure 2-2: Blowing solar-heated air into a crawl space (or basement) is a good way to use the output from a small collector. Controls and wiring are simple. A differential thermostat turns on the blower when the collector is warmer than the crawl space, and a backdraft damper minimizes heat loss at night. During the day and into the evening hours, comfortable radiant heat enters the living area from the floor below. For this delivery system to work properly, the perimeter of the crawl space must be insulated and sealed, and a plastic vapor barrier should be laid over the dirt to minimize evaporative cooling.

The simplicity and effectiveness of this system, along with its low initial cost, make it a good choice for do-it-yourselfers, and many successful home-built installations incorporate this design. More elaborate air distribution schemes or a domestic water preheater can be added later.

Heat storage in most crawl-space systems is limited to the rise in temperature of the crawl-space dirt and the floor above it. The collector works well at keeping a house warm from late morning to bedtime, with backup heat being needed in the early morning hours. Heat storage can be improved slightly by blowing the solar-heated air into a large, black plastic bag in the crawl space. This bag is formed by running a 12-foot or 16-foot sheet of black 6-mil polyethylene down the center of the crawl space and weighing its edges down with rocks or bricks. It inflates when the collector is running and holds the solar air in closer contact with soil in the crawl space. The air then finds its way down the tunnel and out the end of the bag on the north side of the crawl space. At night, when the collector blower is off, the bag deflates and the crawl-space dirt radiates heat to the floor above. With the bag design the mass of dirt is heated more than the crawl-space air, providing more nighttime heat. The bag eliminates the need for distribution ductwork, which can be a major expense in low-cost systems. This approach won't work if you have a high water table, since groundwater will carry the heat out of the crawl-space dirt.

Storage in a Crawl-Space System

Who says there's no storage in a crawl-space system? If you add up the floor joists, subfloor and flooring in a typical frame house, all of this wood has an equivalent thickness of between 2 and 2½ inches. Wood used for framing typically weighs about 32 pounds per cubic foot so a 1,000-square-foot, single-level house has 6,000 pounds of wood in the floor alone. The specific heat of wood (or its ability to hold heat) is 50 percent more than that of gravel (0.33 versus 0.21 Btu/lb/°F), so the floor in a 1,000-square-foot house can store as much heat as 9,000 pounds of gravel. Every 100 square feet of floor is therefore equivalent to a third of a cubic yard of gravel. Since the floor in a comfortable house can vary 15°F in temperature (60 to 75°F), the floor alone (not counting the walls and furnishings inside the house or the footing and crawl-space dirt under the house) can store all of the heat delivered by a collector that represents about 10 percent of the floor area of the house. The heat delivered from the floor is radiant heat so the warmth it provides is comfortable even at lower temperatures. If you can blow solar air into a basement, the amount of storage available there will easily handle a collector area that is 20 percent of the floor area.

Direct-Use Systems

Heating your crawl space or basement with solar-heated air is an effective approach to solar utilization, but in some applications it is more desirable to blow warm air directly into the living space. There is often less heat loss with this method and less time lag in heating the building. This can be a big advantage in spaces that require heat only during the day.

Zone heating is the most successful way to utilize direct solar heating. Rather than trying to heat an entire house or office with an undersized collector, you are blowing the solar heat into the two or three rooms that need it the most. Zone heating is a good way to get more out of your collector than the heat it actually produces. We have all been in houses with poor heat distribution, where the living room had to be heated to 80°F to get the adjoining family room or back bedrooms to a usable temperature. If solar heat were added to the cooler rooms, the total amount of energy needed for comfort could be dramatically reduced.

Once again, since collectors produce lower temperatures than are usually produced by conventional heating systems, the solar heated air must be delivered to the living space slowly or it will feel drafty. But at the same time, you want to move as much air as possible through the collector to get the most heat and the highest operating efficiency. Therefore, several branch ducts are needed to distribute the solar air from a large collector since it can't all be dumped into just one room. In direct-use systems a balance needs to be found between having enough ductwork for good distribution and having too much ductwork, which entails excessive cost and complexity. If the ductwork is very extensive, it can lose a lot of heat even if it is well insulated (as it must be in this type of installation). This is especially important if the ductwork is located in the attic since any heat lost there is completely unusable and won't help heat the house. Long runs of ductwork also present resistance to airflow, thereby increasing the load on the solar blower, not to mention increasing costs.

Controls for direct-use systems are similar to those for the crawl-space system, but instead of using a differential thermostat, a remote bulb thermostat is used to control the collector blower. This thermostat is set to turn the blower on at a fairly high temperature (100 to 120°F) because warmer air is required to provide comfortable heat in a direct-use system. The cold air intake (collector inlet) has a backdraft damper installed in it and feeds the collector from the living area instead of from the crawl space.

Lack of control can be a drawback to an active direct-use system. Hot air enters the living or work area whenever the collector is hot, not necessarily when the space actually calls for heat, and unless the collector is undersized for the load of the space being heated, it's a good idea to have somewhere to dump surplus heat when the needs of the living space have been satisfied. The solution lies in building a system that has a second mode of operation.

Two-Mode Systems

Two-mode solar systems deliver heat to two different points of use and therefore require more electrical controls than do the direct-use or crawl-space systems. This added complexity and expense is usually only justified if the collector is large (more than 15 to 20 percent of the heated floor area) and delivers more heat than is needed in one part of the house. There are many different possibilities for a two-mode system. One option is to combine direct-use and crawl-space heating modes in the same system. Another combines direct-use space heating with domestic water heating, and a third option involves two direct-use heating systems serving different parts of the house.

Houses with central, forced-air furnace systems are a logical choice for retrofitting a two-mode system, since the ductwork is already run to all parts of the house and it can be used for distributing both the solar and the back-up (furnace) heat. Figure 2-3 shows a two-mode system that is tied into an existing forced-air furnace. Note that two thermostats are needed. One is a standard remote bulb thermostat (the collector thermostat) that operates the collector blower. It is located near the collector, with the sensing bulb itself mounted inside the collector. The other is a two-stage house thermostat that controls both the two-mode system and the conventional furnace. The collector thermostat should have an adjustment range of between 90 and 140°F for seasonal adjustment purposes (we'll talk more about this later). The collector thermostat and the solar blower operate independently from the rest of the system: When the collector is hot, the blower comes on.

The two-stage house thermostat operates independently from the collector thermostat and is mounted where a standard house thermostat would be located. The set-points of the two stages are different by about 3 degrees. When the house cools off and calls for heat, the first stage comes on, moving a motorized damper into a position that allows solar air from the collector to enter the furnace's ductwork, but only if the collector itself

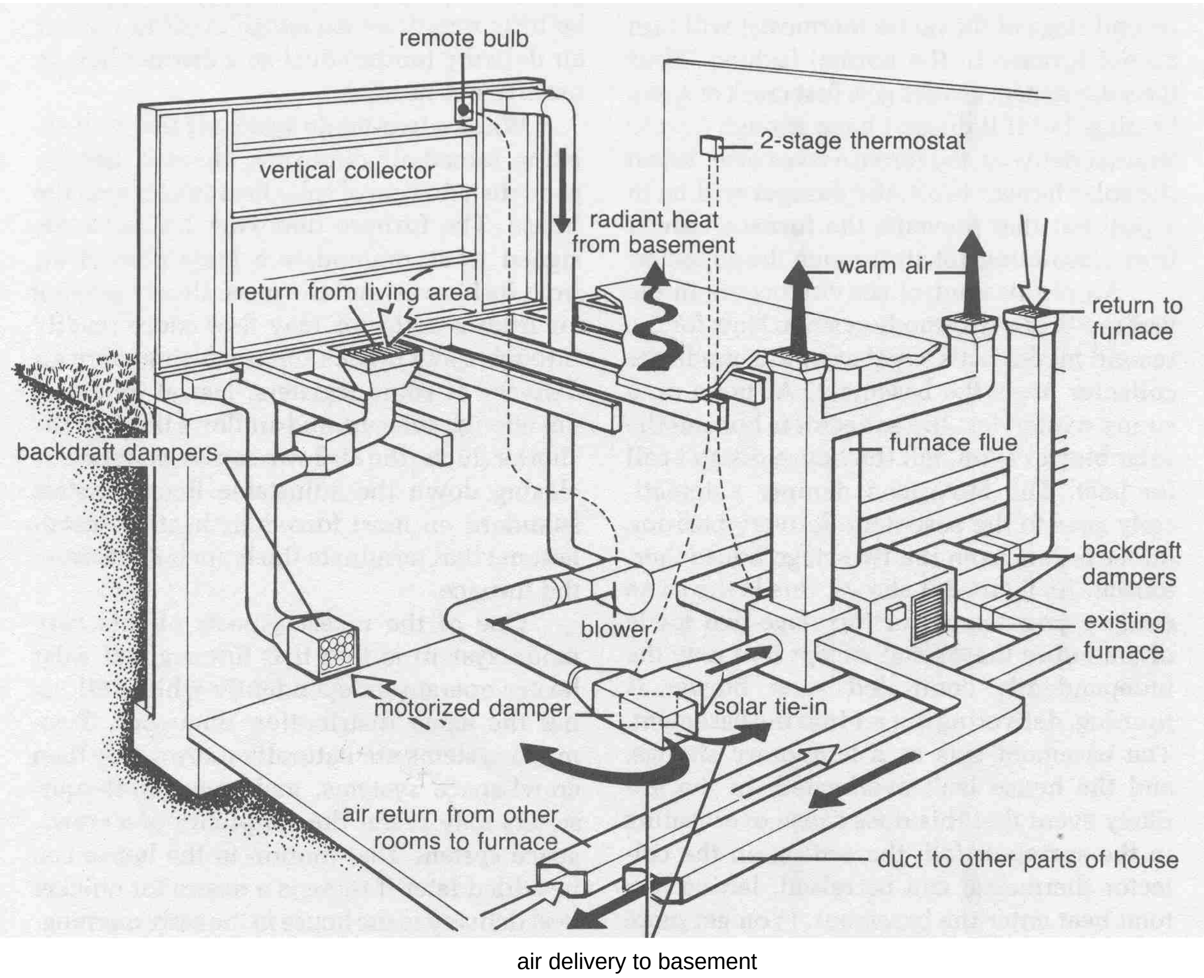


Figure 2-3: This two-mode system is simpler than it first appears. When the upper floor calls for heat and the collector is on, solar air is blown into the existing ductwork to warm the living area. When the needs of the upper floor have been satisfied, the motorized damper changes positions, and solar heat is delivered into the basement and stored in the concrete walls there. Note that two returns (inlets) to the collector, each with a backdraft damper, are required in this system.

is "on." Solar air is then distributed throughout the furnace duct system. Since the collector blower is usually smaller than the furnace blower, the 100 to 120°F solar air enters the living space slowly and comfortably through several registers. If, however, the collector isn't hot enough, the collector blower won't be operating. In this case the house will cool another 3 degrees, and the second stage of the house thermostat will turn on the furnace in the normal fashion. Thus the solar system always gets first crack at space heating, but if it doesn't have enough heat to warrant delivery, the furnace takes over. When the solar blower is off, the damper will be in a position that prevents the furnace blower from circulating hot air through the collector.

All of this control activity occurs in the first mode of a two-mode system. Now for the second mode: Let's say that in this mode the collector heats the basement. At noon on a sunny winter day, the collector is hot and the solar blower is on, but the house doesn't call for heat. The motorized damper automatically goes to the basement-delivery position under orders from the two-stage house thermostat. As figure 2-3 shows, this is the same damper position as for the stage-two mode of the house thermostat except that now the independently controlled solar blower is running, delivering hot air into the basement. The basement acts as a temporary storage, and the house isn't overheated. In the unlikely event that this does cause overheating in the spring or fall, the setting on the collector thermostat can be raised, letting less total heat enter the basement. (You get more total Btu's when the collector thermostat is set at 100°F rather than at 140°F because of reduced collector heat loss.)

Notice that this system needs two air returns to the collector, one from the house and one from the basement, since at times each of these areas has air entering it. Both returns have backdraft dampers to prevent dense cold air from settling out of the collector into these spaces at night. Another backdraft damper installed on the furnace return grille or between the furnace and the furnace plenum prevents solar air from blowing into the furnace air return. Since air is taken from the top of the collector in our example, there will be little nighttime exchange of air in the hot air delivery (outlet) duct so a damper here is usually not needed.

When a two-mode system is tied into existing forced-air ductwork, there is usually good distribution of solar heat throughout the house. The furnace ductwork has been designed to accommodate a large flow of air from its blower, and the more slowly moving air from a collector may flow more readily through some branch ducts causing more air delivery at some registers, less at others. If not enough solar-heated air flows through the shorter ducts, the airflows can be balanced by closing down the adjustable floor registers (standard on most forced-air heating installations) that terminate the branch ducts from the furnace.

One of the nicest aspects of this two mode system is that that furnace and solar heater operate independently while still using the same distribution ductwork. Two mode systems are naturally more costly than crawlspace systems, and some do-it-yourselfers may prefer the simplicity of a crawlspace system. Distribution to the house can be added later if there is a desire for quicker heat delivery to the house in the early morning.

Tying into Other Heating Systems

Two-mode systems can be used with other types of heating systems, such as electric or hot water baseboard heating. When there is no existing duct system, hot air registers must be cut through the floor and connected to the collector with ductwork. Once again, it is important to have enough ducts to prevent having strong blasts of air coming from too few outlet registers. In systems like these a separate single-stage thermostat is mounted on the wall next to the thermostat that controls the baseboard system. This solar thermostat is set 2 or 3 degrees higher than the back-up thermostat so that they work together like the two-stage thermostat described earlier, in which solar energy gets the first chance to heat the house. An independent two-mode system such as this is often the best bet in retrofit situations where the existing heating system is electric baseboard since there is, of course, no way to tie the solar system into it.

Solar Water Heating

Heating domestic water often constitutes a large part of the household energy bill, and designing a solar air collector to help offset this expense is a viable option. Air-heating systems built for both space and domestic water heating are useful year-round and not just during the winter space-heating season. In some locations it is economically feasible to build a system that is used only to heat domestic water year-round, but the effectiveness of such a system should be considered next to a standard liquid collector domestic hot water system, which is the more common choice for heating domestic water (see chapter 10).

Collectors that are used for heating domestic water are always installed at a slant (typically at a tilt angle equal to your latitude plus or minus 5 degrees) rather than vertically, in order to take advantage of the high summer sun angles. They are also designed to operate at slightly higher temperatures than space-heating collectors because higher-grade heat is needed to heat water to a usable temperature of 100 to 120°F.

Systems that use air to heat water need an *air-to-water* heat exchanger. There are several options available for this exchanger, but the two most common are the in-duct *radiator* type (fan-coil or fin-tube) heat exchanger and the finned-tank-type exchanger. The radiator type fits inside the ductwork and takes heat from the moving stream of solar-heated air. A small pump is wired in parallel with the solar blower so that water will be circulated through the exchanger whenever the collector is operating. This heated water will then go to a tank that supplies preheated water to the existing water heater. The water heater will then bring the solar-heated water up to a usable temperature if it isn't hot enough. This type of system requires a very tightly sealing motorized damper in the solar ductwork to isolate the heat exchange coil from the collector at night if the coil is located below the collector inlet. Water won't be moving through the exchanger at night, so even a tiny trickle of cold air can freeze the stagnant water and burst the exchanger. The most appropriate design in this system would place the exchanger above the inlet so that cold air couldn't settle through the duct and reach the exchanger.

In the finned-tank exchanger the preheat tank acts as the exchanger. Fins attached to the outside of the tank pick up heat from the moving stream of air that is blown around the tank and transfer this heat to the water inside. This system operates as efficiently as in-duct exchangers. It is less expensive to build and simpler to operate since no pump is required. Freeze-up problems are very unlikely, but a tightly sealing damper is still a must.

A large, tilted space-heating collector can be used effectively for domestic water heating in the summer. A smaller summer-only blower or a variable or multi-speed blower can be installed to move air more slowly through the air-to-water heat exchanger when a larger blast of air isn't required for space heating. A system of this type will deliver very hot air to meet almost all of a family's summer hot water needs. Valves can be installed to completely bypass the conventional water heater so that all hot water comes from the solar preheat tank. If it is cloudy for a couple of days, the water won't be hot, but some folks are willing to put up with this inconvenience.

If a collector is going to be used for both water heating and space heating, a two-mode system is often a good choice. An adjustable thermostat on the hot water preheat tank allows more or less of a collector's air delivery to be used for water heating, depending upon the season. In winter this thermostat is set at a fairly low temperature, say 110°F, and after the water has been heated to this temperature, the hot airflow is used for space heating. In summer the thermostat is set much higher (180°F), and all of the solar air travels in a closed loop between the collector and the airto-water heat exchanger. A two-mode water/ space heating system, which is featured in chapter 12, is a good example of a two-mode design of this type.

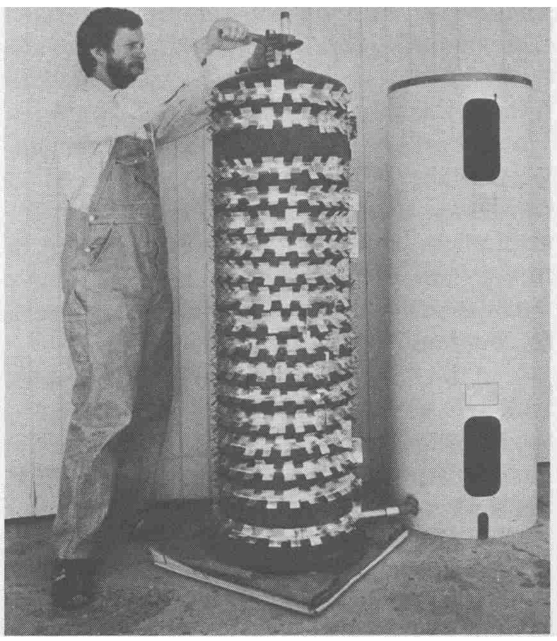


Photo 2-2: Tank-type exchangers for heating water are easy to build and install in active solar air systems. Shown here is a 50-gallon finned exchanger, which will be used for summer water preheating in a small two-mode system.

Systems with Thermal Storage

A system with a separate heat storage component has definite advantages over the simpler systems we have been discussing up to now. Having storage means that a larger collector can be used because any surplus heat can be stored for nighttime use rather than wasted in daytime overheating of the living space. Storage systems add convenience and efficiency in large systems, but not without significant added cost for a rock storage bin and necessary additional controls (dampers, etc.). In fact, this cost can equal the cost of the collector itself.

The first thing to consider when planning for storage is whether or not the size of the collector justifies it. Building a separate heat storage area isn't usually cost-effective unless your collector is larger than 20 percent of the floor area to be heated (see chapter 3). The collector itself should also be larger than 200 square feet. Smaller collectors find their best use in heating a crawl space or in direct use systems that heat two or three rooms in a house. Controls and dampers for these simple installations are straightforward and fairly inexpensive, and payback for these systems

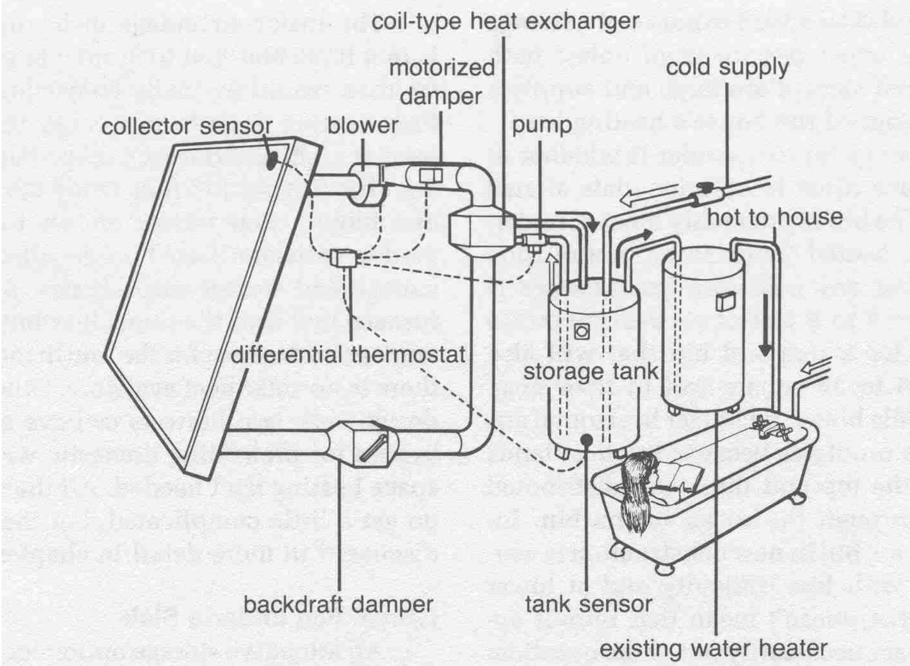
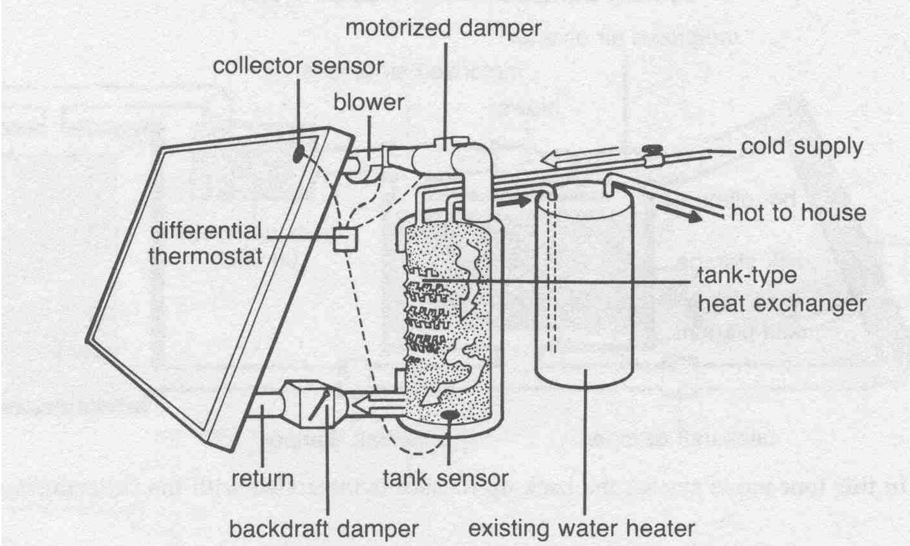


Figure 2-4: An air-to-water heat exchanger is required for heating domestic water with a solar air collector. A coil-type heat exchanger can be mounted inside a duct to take heat from solar air. Heated water is then circulated by a pump to a storage tank. Or a tank-type heat exchanger can transfer heat by blowing solar air directly over and around the storage tank.



will be rapid. The added expense of a storage component won't pay for itself unless both collector and storage are large and supply a big percentage of the house's heating load.

Another factor to consider is whether or not you have room to accommodate a large rock bin. The bin is preferably located under, or even in, heated living space, not outside of it, so that any heat loss from storage is used. Some 7 to 8 feet of vertical clearance is needed for a standard bin that will also take up 25 to 35 square feet of floor area. Lower-profile bins with longer horizontal airflows have problems because the heat tends to rise to the top and thus isn't distributed properly through the rocks in the bin. Installing a rock bin in new construction is usually done with less difficulty and at lower cost, but that doesn't mean that retrofit applications are necessarily out of the question. They just have to be considered carefully. Heat delivery from storage is also more easily integrated into the back-up heating system of a new house since they can both use the same distribution ductwork.

The major advantage of having storage is that it enables you to build a larger collector than would normally be needed for daytime heating. Heat from storage can thus be used at night and during sunless days. Figure 2-5 shows a simple four-mode system with one blower that moves air for three solar modes: collector heats house, collector heats storage and storage heats house. A back-up furnace that uses the same distribution ductwork provides heat for the fourth mode when there is no solar heat available. Other system designs use two blowers or have a summer bypass for preheating domestic water when space heating isn't needed. All these options do get a little complicated, but they will be discussed in more detail in chapter 11.

Gravel Bed under a Slab

An attractive storage option for new construction uses a gravel bed located under a slab-on-grade floor. Solar-heated air is blown through the gravel, which then heats the slab to provide comfortable, radiant heat to the house. This system works like the radiant

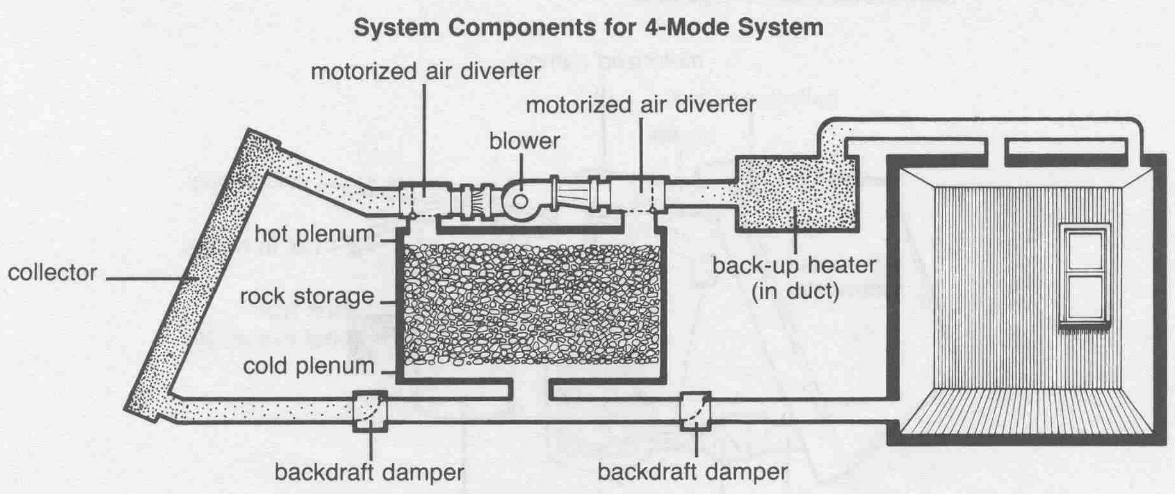


Figure 2-5: In this four-mode system the back-up furnace is integrated with the collector/storage ductwork.

floor heating systems that were popular in the 1950s in which hot water was pumped through pipes embedded in a slab. An air heat distribution system will never leak, however, like many of the hot water systems did. Since the solar loop is closed to the living space, low temperature air (70 to 80°F) can be used in this type of system to increase the output and efficiency of the collector without making the house drafty.

Controls for a gravel-bed system are fairly simple. A differential thermostat turns on the blower whenever the collector is warmer than the rocks, and a motorized damper wired in parallel with the blower prevents nighttime heat loss through the ductwork and collector.

This type of system requires a lot of storage, about five times more by weight than a conventional rock box. It has many advantages in new buildings, especially those that feature passive hybrid systems, but is very difficult to add on to an existing house.

Commercial Installations

Until now we have been discussing the use of solar heat in residential installations,

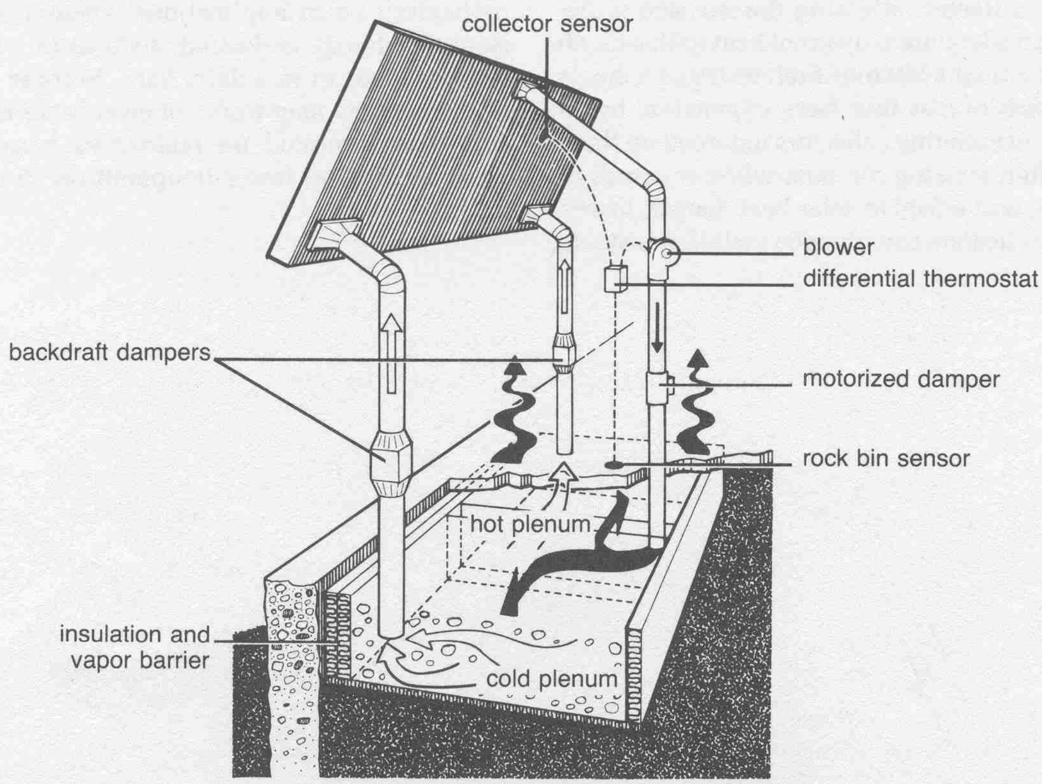


Figure 2-6: A good technique for storing solar heat in new construction involves blowing solar-heated air through an insulated gravel bed under a concrete slab floor. With this arrangement the collector operates very efficiently and the floor provides comfortable, radiant heat. Dampers prevent heat loss from storage at night.

but solar-heated air also has many commercial applications. Perhaps the best ones are in schools, hospitals, restaurants, and industrial shops-buildings that need a constant and extensive air change throughout the day. If the outside air being fed to the furnaces in these buildings can be preheated by a large, low-cost collector, the total heat consumption of the buildings can be greatly reduced. Air collectors operate best when they are fed cold, outside air and when they have a high airflow through them. Thus a great deal of preheated solar air can be delivered to the furnace quite economically from a relatively small collector, allowing the furnace to deliver an adequate amount of heat with a much lower consumption of fuel. Existing schools and post offices that have expensive, tracking, concentrating collectors mounted on them are often missing the boat when it comes to getting cost-effective solar heat. Larger, lower cost air heaters can often be installed instead, at one-quarter of the total cost while still providing the same contribution to the heating load.

Solar heaters are also useful around the farm. Portable solar dryers can be used for drying grain in the fall and then moved to the south side of a house or outbuilding for wintertime space heating. Grain drying usually requires a larger airflow through the collector than does space heating so, when used for these two different functions, the same collector will need either a variable-speed blower or two separate blowers.

Farmstead collectors are also useful in preheating air in applications where a constant air change is desired, such as in a farrowing house or in a dairy barn. In these applications they may work out even better than collectors mounted on residences because solar air of even lower temperatures can be useful.