

## A house-heating solar greenhouse

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Victorian houses often had a heated, greenhouse style room, called a solarium, for sitting in during inclement weather. And many an old farmhouse had a greenhouse attached, so heat from the living space could moderate the cold in the greenhouse. But modern glazing materials and building techniques make it practical to reverse the heat flow and use the greenhouse to heat the living space.

This creates a large volume, passive solar, heat collector and storage unit, or solar greenhouse for short. My wife Jj and I designed one to convert our hundred year old, Wisconsin city house to solar heat. We built it ourselves, for under \$1,000 and it reduced our winter fuel use, for a 9-bedroom house, to less than one cord of firewood and about \$50 worth of natural gas.

### Southern exposure

Before you can build such a solar greenhouse, you must evaluate your site. Two factors will influence your decision: the direction your house faces, and local obstructions to light, if any. Most of the heat energy associated with sunlight comes from the south during the cold months, so it's best if your house has a long, south-facing wall, but it's not essential. A wall angled as much as 20 degrees from true south loses less than 5% of the heat gain from direct sunlight, even less if most of the light during fall, winter, and spring is diffused by cloudy weather. The cloudier your weather during the heating season, the less important a perfect southern orientation becomes.

Note that these orientations are relative to "true" south, not "magnetic" south, which is shown by a compass. Aeronautical navigation maps and many topographical maps show the magnetic variation throughout north

America. Translation: They show the number of degrees you must add to or subtract from the true direction to get the magnetic direction. Since we want to convert magnetic directions to true ones, we must reverse the signs, adding negative variations and subtracting positive ones. So a magnetic variation of + 3 degrees means you have to subtract 3 degrees from the compass reading to find out the "true" orientation. One way to beat this confusing situation is to go outside on a clear night and find the **North Star**. Lay a straight stick on the ground so it points toward the North Star. Its opposite end will point directly "true" south.

### Avoid sun obstructions

If your house has a south-facing corner instead of a south-facing wall, it's probably more important to pay attention to local obstructions than to worry about which side faces nearest to true south. Major obstructions to sunlight can shorten your effective "day," reducing the total amount of energy reaching a greenhouse much more than a few degrees of orientation would. You might not mind cutting down a tree or two to get more sunlight, but it can be real inconvenient to move a barn, for example.

### Sun charts

There are two ways to tell if obstructions will seriously affect your greenhouse. You can use sun charts, or you can plot the actual position of the sun every couple of hours from dawn till dusk, on the 21st of every solar heating month. The great advantage of sun charts is time. You can figure where the sun will be any time during the year, right now. The disadvantage is that many people find sun charts confusing, including me. The most lucid instructions for using sun charts I've ever found are in *The Food & Heat Producing Solar Greenhouse*, by Rick Fisher and Bill Yanda. There are also

devices you can buy that will plot your obstructions for you, 'right on the charts, making them much easier to use I'm told. I've never actually used one, since they hadn't been invented when we designed our greenhouse. They are not cheap. Sun positions can be plotted on ordinary graph paper using only a ruler, a protractor, and a level, and even I can interpret them easily. The worst disadvantage of plotting actual sun positions is that it takes an actual heating season to do it.

Whichever way you plot obstructions, you'll end up with 3 groups of them -the visual horizon (distant obstructions), medium range obstructions, and close ones. The close ones are probably the only ones you can do anything about. If the main business of your greenhouse is heating your dwelling, you may very well want to leave some deciduous (leaf-dropping) trees nearby. The energy they save in summertime cooling may far overshadow the few fall and spring heating hours they cost. Growing seedlings require light as well as heat, so you may wish to eliminate close-in trees if your greenhouse will be primarily used for growing and only secondarily for heating. We left a 60-foot tall cottonwood right in front of our greenhouse and still raised plenty of seedlings every spring.

In deciding whether obstructions will prevent you from getting a useful amount of heat energy from your greenhouse, remember that more sun energy reaches the earth during an hour near noon than during an hour near dawn or dusk, when the sun is low on the horizon and there's more dust or haze in the way. So an obstruction that blocks the sun during midday in January for 2 hours is much more serious than one that obscures it for an hour at dawn and dusk. Once you know how much energy you'll lose to unavoidable obstructions, you can decide whether or not to go ahead with the project.

### Thermal efficiency

When they think of thermal efficiency, most people think in terms of total

BTUs of heat input, and high “R factor” insulation. These are ways of measuring some of the effects of “insolation” (solar energy entering the greenhouse) and of measuring the thoroughness with which the system is isolated from the ambient air and ground temperatures.

Judging by these criteria alone, local engineers employed by Wisconsin Natural Gas & Electric Company determined that our greenhouse couldn’t possibly produce a usable amount of heat for us, and our request for a special “alternative energy” payment schedule was denied.

Fortunately, these two measurements do not reflect the total energy picture around a greenhouse. They contain unstated assumptions that may not always be true. BTUs, for example, measure the energy needed to raise a given volume of fluid (such as air) a given number of degrees F. This assumes that the ambient temperature around the fluid has no effect, which is never true in practice. The engineers further assumed that the air would be heated in a cold (initially) container, then the heat would be transferred to a different volume of air (in the house), with loss of energy at every exchange. We avoided these inefficiencies by heating a large volume of air in a pre-warmed container just a little bit, then exchanging it for the air in the house. Since the process is continuous, we didn’t have to raise the air temperature **much**.

## The 40 degree floor

Another assumption made by standard thermal engineering is that it’s necessary to isolate the collector (greenhouse) from all ambient temperatures. True, the air is cold, and so is the ground near the surface. But lower down, the earth rarely drops below about 40 degrees F.

In central Wisconsin, this level is about 5 feet below the surface. It varies throughout the country, but your local extension agent, U.S. Soil Conservation Agent, or county building inspector should be able to provide this information. To provide a “warm” environment for the green-

house air, we dug down 5 feet below grade and built a foundation of cement blocks, insulated on the sides, **but not on the bottom**. We filled the open box thus formed with rock for good thermal conductance, and poured concrete on top. Even when the air outside was 30 degrees below 0, our concrete floor was radiating at 40 degrees, because concrete and rock are good conductors of heat.

With a 40-degree floor, it never actually froze in our greenhouse, so even on cloudy days it was no trouble heating the air up another 20 degrees or so. True, many people don’t think of 60 degrees as a comfortable temperature, but in the middle of winter, when the body is adjusted to cold outdoor temperatures, 60 degrees feels like a nice, warm Spring day! Our preference is to heat people with sweaters rather than houses with fuel, so most days 60 degrees was fine for us. There were times, though, when illness or the presence of guests dictated higher indoor temperatures. At such times, it required very little fuel to raise the air temperature another 15 degrees to 75 degrees F.

## Passive air circulation

Since hot air rises, many greenhouse designs incorporate features whose only purpose is to bring it back down to a useful level. Once again, we did the opposite. We lowered the greenhouse, -making the floor 2 feet below ground level, with the peak of the ceiling just above the windows on the old south side of the house. Whenever our greenhouse thermometer indicated 60 degrees, we just opened the windows.

For passive air heating to work, there must be good circulation of air throughout the house. For circulation to occur, there must be some way for hot air to enter each room, and some other way for cold air to return and be heated. Many old houses have upstairs rooms which are cold, because there are no cold air returns. We converted such a room to the warmest in the house, just by cutting a hole in the floor and covering it with a grate.

With good circulation, the volume of air in a 9 x 30 foot greenhouse is great

enough to keep an 1800 square foot house warm as long as the sun shines. There is no need for a heat storage system in this kind of greenhouse. The earth’s heat is virtually inexhaustible, and there’s nothing one greenhouse can do to raise or lower its temperature.

## Specific designs

There are **lots** of different designs for greenhouse/solariums available, but in general they tend to fall into three types of structures: angled walls, curved wall/roofs, and vertical walls with glazed or partly glazed roofs.

The further north you are, the less difference the angle of glazing makes. The rule of thumb for glazing angle is supposed to be “latitude plus 20 degrees. With a latitude of 49 degrees N, our best angle for receiving solar radiation would have been right around 70 degrees. This angle is hard to build and results in a tall thin greenhouse that concentrates all the heat at the top. Instead, we built a 5-foot tall south wall, vertically, topped by a 40 degree roof with the lower 4 feet glazed. These were easy to build, fit on our house, and didn’t cost us much energy. Even a difference of 20 degrees only cuts insulation by 2-3%. To prevent leaks and hail damage, we glazed the roof with one continuous sheet of Kalwall “Sunlite” greenhouse plastic. For strength, we braced the plastic with cross-braces between the rafters every 2 feet, glued it to rafters and braces with 100% silicone, and nailed it with caulked, gasketed roofing nails. During the five years we lived there it never leaked.

We framed the end walls conventionally, with openable vent windows up high on the down-wind side and low on the windward side. The south wall was post-and-beam construction, with windows framed right in between the posts. The last 2 feet at each end were skinned with plywood to resist racking. All the south wall windows were removable, and could be replaced with screens in summer, converting the greenhouse into a summer kitchen. The large cottonwood tree provided shade in summer yet lost its leaves in the fall. We used to refer to

it as our, “automatic, solar powered, organic, self-deploying sun shade.”

## Details

All walls were covered in sheetrock, including what used to be the exterior of the house. There was no actual north wall of the greenhouse. We just nailed a 2x6 across the exterior of the house to support the north ends of the rafters. All exterior walls were insulated with fiber glass batts, and **all** surfaces within the greenhouse were painted. This is very important, as greenhouses “sweat” like cold-water pipes, and unpainted wood or plasterboard will quickly rot or dissolve. If I had realized just how much water we were going to collect in the greenhouse, I’d have installed a drain when we poured the slab. It would have saved a lot of bailing.

We painted the slab floor dark green, to absorb heat and not show dirt, but the rest of the greenhouse was painted gloss white, to reflect as much light as possible. It’s only storage that needs to be painted dark. We wanted to reflect as much light as we could, so it would heat up the air.

The foundation we built of cement block on top of a poured concrete footing. We stacked the blocks in a brickwork pattern, but without mortar, then plastered both sides of the wall with Shurwall, a surface bonding cement. It’s easy to do, but the stuff eats skin worse than fiber glass, which it contains. We wore rubber gloves under cotton work gloves (to protect the rubber). It worked. We laid 4 courses of blocks, filled them with sand, backfilled, filled the box thus formed with rocks, and poured a slab on top of everything. Then we laid 3 more courses of blocks, filled them with cement, and set L-bolts in the top course. The easy, way to lay this is to lay the bottom plate of your wall on top of the foundation first, and drill holes for the bolts so they’ll come out in the right places. Build the wall, loosely attach the bolts, pour the last 8 inches of concrete, and set the wall in place, forcing the bolts down into the concrete. After the concrete is dry, tighten the nuts, and the wall won’t move.

We insulated the outside of the foundation with 2 inches of foam board. The kind that’s covered with foil won’t deteriorate, and is well worth the extra expense. If you must economize, as we were forced to do, switch to 1 inch of insulation for the bottom foot or two. We did not insulate between the foundation of the house and the new foundation, along the north wall of the greenhouse, because our house had a basement. If it had had a crawlspace instead, we’d have insulated there too.

## Analysis

Performance turned out even better than we hoped. All windows were single-glazed, and some of the recycled storm windows we used for glazing were cracked, yet we were able to maintain “frost hardy” vegetables, even with outdoor temperatures in the minus 30’s. We sometimes recorded temperature differentials between the inside of the greenhouse and the outside air of 60 degrees! We were able to “harvest” heat from our greenhouse every day that it wasn’t actually snowing, as long as I kept snow from accumulating on the glazed portion of the roof. Using actual performance figures for the first year of our operation, we were eventually able to get the special rates we wanted from the gas company. A few years later, we discovered they were using OUR figures to encourage their customers to invest in “alternative” energy strategies!

## And a few problems

Post and beam construction is the oldest way of building houses, so you’d think building inspectors would be familiar with it. Ours weren’t, and we had to show them all our design figures to prove the roof wasn’t going to collapse. It took us a while to prove it to them. Non-standard designs tend to upset building inspectors, so be sure you can back up your drawings with figures, if there’s anything “different” about your design.

A worse problem was the “rain forest” atmosphere in the greenhouse all winter long, when we had to keep the

vent windows closed. Eventually, we covered the glazed part of the ceiling and the south windows with clear plastic, on the inside, so we could channel the run-off into the growing containers. The plastic did absorb some of the light, but it didn’t affect the temperature much, and it sure helped control the moisture.

You may have noticed that this whole article is written in the past tense. To my mind, the biggest problem we had with our solar greenhouse occurred when we moved to our homestead in the backwoods. We were unable to take it with us!

## For more information

I most highly recommend *The Solar Greenhouse Book*; edited by James C. McCullagh. It’s the definitive work on solar greenhouses, containing hundreds of photos, drawings, charts, graphs, and tables. Easy to read. Rodale Press.

*The Food and Heat Producing Solar Greenhouse Design, Construction, Operation*, by Rick Fisher and Bill Yanda. It’s not as complete, not as well-illustrated, or as well-documented as the Solar Greenhouse Book, but it covers some aspects better, and is devoted only to greenhouses that produce both food and heat. John Muir Publication. Δ