Sunroom - Gunnison, Colorado

The house orients to the east which left just a few windows on the south side. Originally I built this solar hot air heater in 2006. My wife said I could build a solar project just as long as it wasn't "big and ugly", which is exactly how it turned out! It worked well except that the absorber was made of black polyester felt which added a plastic smell to the indoor air. Nevertheless, we still fondly referred to it as our "flannel panel". Also, of course it was not pretty and it was not multi-purpose. So I tore it down and built this low mass sunroom in 2009. I've been bad about keeping track of total costs but the total is probably around $4,000 - $4,500.

The goals for the sunroom were that it would 1) look decent, 2) blow hot air into the house, 3) dry clothes/food, and 4) be a pleasant hangout for the family. It was not meant for plants. Our location has very cold (but sunny) winters; the sunroom, being low mass, gets hot during day and freezes at night. This allows more heat to go into the home than is possible with a high mass sunroom. See this article on low thermal mass sunspaces.

Sunroom Description

The sunroom was stick-built on top of the existing deck. I chose a gable end design to try to concentrate the heat at the apex to facilitate collection. It also blends nicely with the architecture of

the house. There is a manual vent at the top under the eave that can be opened in the summer by pulling strings. The vent was enlarged this fall but is still probably a bit undersized for the few months of the year when I don't want the heat in the house.

The door into the sunroom from the outdoors has a sliding screen which allows cool air in as well. This door lines up with a new door (converted from window) into the house from the sunroom. By the way, the hot tub won't fit in the sunroom. We never use it and I'd like to find a new home for it.

The sunroom uses single pane Duraplex acrylic plexiglass for the south side glazing. This glazing is very clear and strong. It is also easy to score and cut. As shown in the picture the lower glazing area is 3'x3'. These dimensions handle the wind with no problems. The upper glazing area is 3'x6' , and it wobbles too much in high wind. Someday I may add a brace, but it's nice to have the unobstructed view.

The bottom of the glazing rests in a notch in the wood with caulk to keep out water. This does not work well as the plexiglass expands and contracts quite a bit. Since it doesn't rain much here, leakage has not been much of a problem, however it lets in a bit of cold air in the winter. The sides of the glazing are attached via a screwed on cedar board. The recent addition of some polyester felt to the back of the cedar boards has helped the glazing slide better as it expands/contracts, minimizing loud popping sounds. One other area of concern is the storm door I used from the sunroom to the outside; it has warped a bit and does not seal well. This needs fixing.

I put in fiberglass batt insulation in the fall of 2012 on the ceiling and walls and covered it with 3/8" plywood. The floor is minimally insulated above the wood decking with a layer of polyethylene, 1/2" carpet padding, and inexpensive indoor/outdoor carpet. I don't have numbers on how much difference it has made, but it does seem quite valuable for bitter cold days. Gary measured a big difference after adding insulation to his test sunroom.

Moving Heat into House

It has been a huge challenge to get the sunroom's heat into the house effectively, with acceptable fan noise. I think this is a very important factor for deciding how best to build a sunroom. I have been

disappointed with how little heat moves passively from room to room, even through an open doorway. The high ceilings affect this flow to some extent. Though it would not work for my house, it would be ideal to locate the sunspace adjacent to a living room or kitchen and use "through the wall" fans that are available.

Originally I just blew sunroom air into the adjacent bedroom with a fan located in the wall adjacent to the sunroom. It used a simple polyethylene flap to seal at night. The first problem was that the flap sealed poorly. I added an inclined edge and then magnetic strips but they were not strong enough when the wind blew outside. The second problem was that I had hoped hot air would migrate into the adjacent great room of the house. When this didn't work, I added a 2'x1' hole near the top of the bedroom's interior peaked ceiling adjacent to the great room. This too did not work well enough without more fans.

I now have the duct system as seen in the picture to the right. The hot air delivery ductwork extends 12' from the sunroom, through a closet and into the great room. The return air ductwork extends 5' from the closet to the sunroom and is located just below the hot air duct as shown in this picture.

The ductwork open/closure mechanism between the sunroom and house uses a 1" thick piece of foamboard that pivots on a dowel rod located just above vertical center. The cool air return fan pushes it open and the hot air fan pulls it open. There is a little bit of weight added to the lower portion of the foamboard to help pull it shut at night. This mechanism seals fairly well even during high winds since air pushing from one direction will not open it. Another benefit is that when the fans turn on, the foamboard gets nearly perfectly horizontal (as shown in the picture) minimizing air flow resistance.

The intake fan is a S&P TD-Silent 8" 490 CFM in-line centrifugal duct fan and the return air fan is a 10" 663 CFM axial fan from Grainger. Axial fan's are cheaper but don't work as well as centrifugal fans for pushing or pulling air through ducts. At the duct exit points, I measure about 8 mph (704 fpm) for the centrifugal fan , which has a lower CFM rating and a longer duct, and about 5 mph(440 fpm) for the axial fan.

There's also a cover (removed for picture) that directs return air down, and pulls hot air from the apex of the sunroom. The ducts contain denim batting and the axial fan is suspended via bailing wire to minimize noise. Overall it's still noisier than I'd like, but it's acceptable. I installed an air conditioner thermostat to turn fans on/off, and this allows me to adjust the on/off temperatures as desired

throughout the heating season.

Performance

The sunroom has about 270 sq. ft. of glazing. Assuming 317 btu/hr/sqft (1000 watts/sq m/hr) at noon on a clear day in winter, the sunroom potential is 85,590 btus for the brightest hour in the winter day.

How much heat does the sunroom provide? On January 5th, 2013 at 1:00 with outside temperature of 10 degrees, I took the following measurements:

110 degrees – top of sunroom
93 degrees – bottom of sunroom
101 degrees – fan inlet to house in great room
70 degrees – great room
75 degrees – bedroom adjacent to sunroom
74 degrees – fan inlet back to sunroom

The "wind speed" where the duct blows into the greatroom is about 9.4 mph (827 fpm) in the center and about 6.5 mph (572 fpm) in the extreme corners, according to a Kestrel wind speed measuring device. Perhaps we can say it averages 8.0 mph (704 fpm). It's a rectangular duct about 9″x12″. The air temp exiting the vent is about 101 degrees.

So the heat transferred in the hot air stream is:

Heat flow = (Area)(Velocity)(Temp difference)(air density)(specific heat)

Area = (9)*(12)/144 = 0.75 sq. ft.

Velocity = (8 mi/hr)(5280 ft/mi)(1hr/60 min) = 704 ft/min

Air Density = 0.065 lb/cf (it is 0.075 at sea level, but more like 0.065 at 8,000ft)

Specific Heat = 0.24 BTU/lb-F (that is, it takes 0.24 BTU to heat 1 lb of air by 1 degree Fahrenheit; water is 1 BTU/lb-F)

so,
Heat Flow = (0.75 sqft)*(704 ft/min)*(101F - 65F)*(0.065 lb/cf)*(0.24 BTU/lb-F) = 296 BTU/min or 17,791 BTU/hr

The 65 F in the equation above is the room temperature.

In addition, when we're home we open up the door and the 2 windows between the sunroom and the house. The door is about 2'6"x7' and the windows are about 6.5 sqft each. This adds some thermosyphon heat to the house. If equal amounts of air move in/out between sunroom and house than half the door/window area would be 15 sq. ft. After playing around with Kestrel in the door area I'd estimate about .5 mph (44 fpm) average. It was 1.4 mph at the very top. With an estimated higher room temp of 75 degrees I calculate 12,355 BTUs. Combined with the fan this equates to about 30,000 BTU/hr or 35% of the potential heat available.

Given that these numbers are all very approximate, I plugged the numbers into a spreadsheet to make it easy to play around with various assumptions and see how much impact they have on the result. It seems that the wind speed variation between 7 and 9 doesn't effect the output too much so the average of 8 mph is probably pretty solid. Modifying the intake/outtake temperature numbers within reasonable amounts does show a larger impact.

However, I think the biggest realistic impact would be increasing the amount of air moved. Doubling the current amount, doubles the heat output. This could probably be done by reversing a whole house fan located in the attic, such as this one Quiet Cool fan. This would probably also require some electronically activated closure so you don't lose heat to the attic at night.

In comparison, my old hot air collector (insulated sides and back, single pane glazing, black polyester felt, fan) got much hotter inside that my current sunroom does. It routinely reached well over 150 degrees. Back then I measured about 125 degree air coming into the house via a poorly design duct system. However, the air volume was less.

Some perspective on the relatively low efficiency of the sunroom:

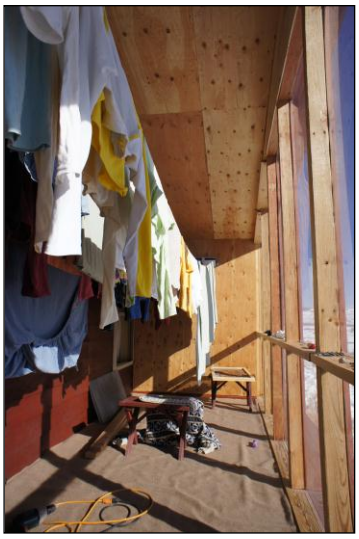
1. These numbers are for the coldest few months. The sunroom provides all the heat needed in the shoulder months when the sun shines.
2. I rarely have a problem with overheating the house, although if I did, opening windows is easy.
3. There is lots of extra heat capacity for other uses like heating water and drying clothes.
4. Partially cloudy days will have less negative effect.
5. I hope to add a means to extract extra heat for use in preheating domestic water. My current thinking is to preheat the incoming water by running it through a radiator near the apex with a small fan to boost heat transfer. Then move the water to finned copper tubing (typical solar design) running horizontally along the top inside edge of the glazing where thw water gets hotter before going to a DIY storage tank in the crawlspace. Perhaps add an adjustable reflector on the outside of the sunroom that also doubles as a summer shade for the lower glazing. The reflector would help offset the inefficiencies of the vertical glazing.

Other Considerations

Figuring out a good curtain arrangement is important too. I've experimented a bit using polyethylene (75% coverage type) outdoor sunshade material. It's nice in that you can see through it fairly well and it

blocks much of the sun when the sun is high. It blocks less well in winter due to the sun's angle. Another approach would be to install attractive curtains that can be easily slid back and forth to provide view or shade as desired. It is best to keep curtains over a foot away from the glazing to avoid excessive heat loss through the glazing, but you have to temper this with your need to keep curtains out of your way.

I've experimented with pulling heat from between 2 layers of sunshade fabric and the glazing, in a manner that pulls air through the sunshade. My arrangement was not idealized but nonetheless the result was temperatures a bit lower than the peak of the ceiling. Perhaps it would allow the fan to turn on earlier in the morning though. On the flip side, it does probably add to heat loss by increasing air movement near glazing. Unless others demonstrate a significant enough benefit from this approach, I'm thinking it's not worthwhile for my circumstances.



We use the sunroom quite a bit for sitting during the times when it is warming up or cooling off. It can also be nice in the heat of the partly sunny day if you're not in direct sunlight, such as behind a curtain. We like knowing that we are getting relatively free energy while we are sitting there! The kids also use it as a play area since it's so long and the windows are tough. Think badminton, keep-away, etc.

The sunroom is great for drying food and clothes as shown in this picture. Gary of Build-it-Solar says that a dryer load uses about 2 - 3 kwh per load, especially when you consider that the air that the dryer exhausts outside has to be pulled in and heated by the furnace. We dry virtually all the laundry generated by an active household of four.

In sum, if you're going to build a sunroom with the main intent being heat, then my experience recommends the following:

1) make it as reasonably big as you can,
2) keep mass to a minimum,
3) insulate it,
4) figure out a very quiet fan system that can move lots of air,
5) add an adjustable curtain setup,
6) do not undersize the summer vent to the outside like I did, and
7) make it attractive with multiple uses in mind so that everyone can appreciate its value.

A big thanks to Gary Reysa, Nick Pine, and others for all sharing their solar experiences.