CASE 5. ASSESSING THE PAYBACK OF A HOT AIR COLLECTOR

Before we decided to build our own hot water solar system, I had explored building a hot air solar collector. The impetus for pursuing this came from a listing of grants to farmers in a SARE report, which included a note of a farmer who wanted to use a hot air collector to heat the soil in his commercial greenhouse. Through this note I tracked down the solar designer, Jim Duggan. Based on my discussions with him I constructed two test modules and collected data to confirm impressive performance, but was dissuaded from proceeding further by the complexity of ducting heated air from the roof to our cold basement apartment, and by the unavailability of a suitable black screening collector material that didn't off-gas at operating temperatures. I pursued the hot water system instead, but kept my eyes open for a better hot air collector design.

Right: Picture 1. Testing Duggin hot air collector concept with two test modules, 2003

Last winter (2007) I found it. Bill Kreamer has come up with a design that is elegant, low mass, and uses common materials (foamboard, aluminum flashing, and black polyester felt). In a retrofit, you would hang it off a wall, but in our application, we incorporated it as part of our south wall retrofit. Two collectors totaling 50 sq.ft. cost $738. Compare this with a commercial hot air collector half that size selling for over $2,000. For those interested in his approach, you will find his pdf on the "solar space heating page" of the fascinating website "builditsolar": http://www.builditsolar.com/Projects/SpaceHeating/Space_Heating.htm#Active . Scroll down until you find "Wall Mounted Air Collector" by Bill Kreamer, Sol-Air Company.

What sold me was the high efficiency – the highest efficiency of any solar air collector – and the masterful way Kreamer solved a couple of tricky problems of hot air collectors, namely finding a really efficient collector surface and a figuring out how to prevent nighttime reverse thermosiphoning. I admit it took repeated readings of his 20 page pdf to understand his design, but everything is there, including a list of parts, suppliers and part numbers. He was gracious enough to answer several questions via email.

I learned a few things about solar design building his device, and would be happy to answer questions and share my additional suggestions.

With Kreamer's design in mind, my next question was whether his design would produce much heat in my setting. I explored two options: an east wall location and a south wall location. Using data from Kachadorian on solar heat gain factors (SHGF) for vertical windows at 40 degrees latitude for Hartford, CT [1] I calculated how many gallons of fuel oil I could expect to offset during the October-April heating season. From that, I calculated the payback period. I conducted separate calculations for an east and south wall location. Here are the results.

Table 1. East Wall Location

Month	SHGF BTU/day ft^2	Days	% Sun	BTU/ ft^2	Reflec coef glazing	Device effic	Useful BTU/ ft^2
Oct	623	31	55	10,622			
Nov	645	30	46	6,141			
Dec	374	31	46	5,333			
Jan	452	31	46	6,445			
Feb	648	28	55	9,749			
Mar	832	31	56	14,443			
Apr	957	30	54	15,503			
				68,236	x 0.88	x 0.72	= 43,234

Therefore, a 25 sq.ft. collector would produce 25 x 43,234 or 1,081,075 BTUs. Home heating fuel oil produces 140,000 BTU/gal. Our furnace burns at 78% efficiency, so we get only 109,200 BTU worth of heat/gal. Dividing 1,081,075/109,200 we get 9.9 gallons. At $2.90 per gallon, the payback period on the collector cost of $369 is $369/(9.9 x 2.9) = 12.8 years. I didn't find the savings nor payback particularly exciting,

Table 2. South Wall Location

Month	SHGF BTU/day ft^2	Days	% Sun	BTU/ ft^2	Reflec coef glazing	Device effic	Useful BTU/ ft^2
Oct	1582	31	55	26,973			
Nov	1596	30	46	22,045			
Dec	1114	31	46	15,885			
Jan	1626	31	46	23,186			
Feb	1642	28	55	25,286			
Mar	1388	31	56	24,096			
Apr	976	30	54	15,811			
				153,282	x 0.88	x 0.72	= 97,119
50% ↓				76,641	x 0.88	x 0.72	= 48,560

A 25 sq.ft. collector would produce 25 x 97,119 or 2,427,075 BTUs. As above, we divide by 109,200 BTU/gal to get 22.2 gallons, close to the rule of thumb of 1 gallon of fuel oil per sq.ft. of collector. At $2.90 per gallon, the payback period on the collector cost of $369 is $369/(22.2 x 2.9) = 5.7 years.

While this is considerably better, the south wall suffers from shade cast by the branches of tall deciduous trees, increasingly from late October to the solstice, and then decreasing symmetrically from the solstice to late February. Consequently, the useful BTUs have to be debited by a shade coefficient which I am estimating as averaging 50% over the heating season. Running this calculation again in the last line of the table gives us a new total of 48,560 BTUs/sq.ft. For a 25 sq.ft. collector, this yields a savings of 11.1 gallons, half of the previous savings. This doubles the payback to 11.5 years, not much better than the east wall location. We built two collectors, so our total fuel oil savings are 22.2 gallons. Payback period remains the same, as we double the cost with two collectors. We decided to go ahead and build two collectors on the south wall.

Will we actually save 22.2 gallons? I doubt it. We will have a warmer house in October and April, when the furnace doesn't come on much anyway. We will not offset oil heat much when it is really required – during December, January and February. Kreamer acknowledges that solar collectors do not collect much heat one month either side of the solstice. Based on what I have observed so far from his collectors, and from our roof-mounted hot water collectors, I would agree. This is why, in our CASE 2 study, Using Payback to Order Projects, we use a savings of 10 gallons of fuel oil for the Kreamer collectors.

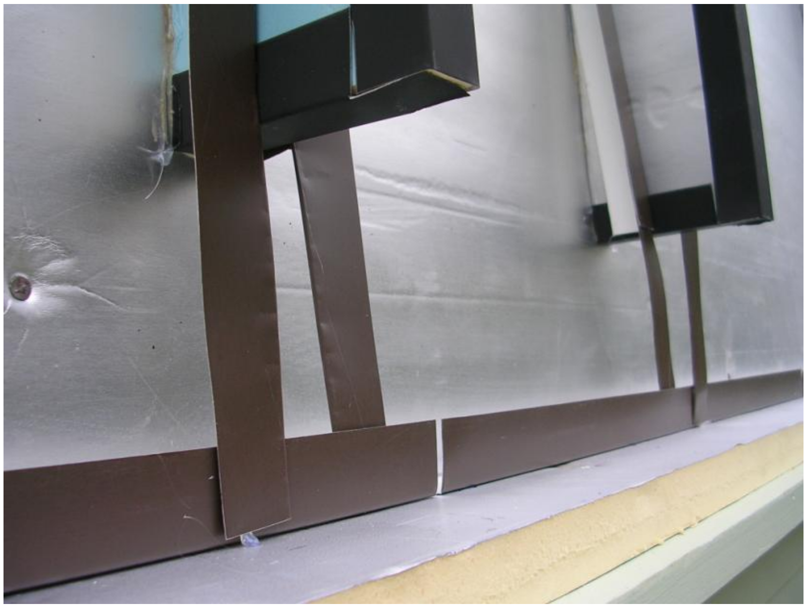
Pictures of Collector Construction

<u>Right: Picture 2</u>. Completed first collector and second prior to gluing black polyester felt onto aluminum rails

Above: Picture 3. Testing thermostat and fan in shroud assembly prior to installation

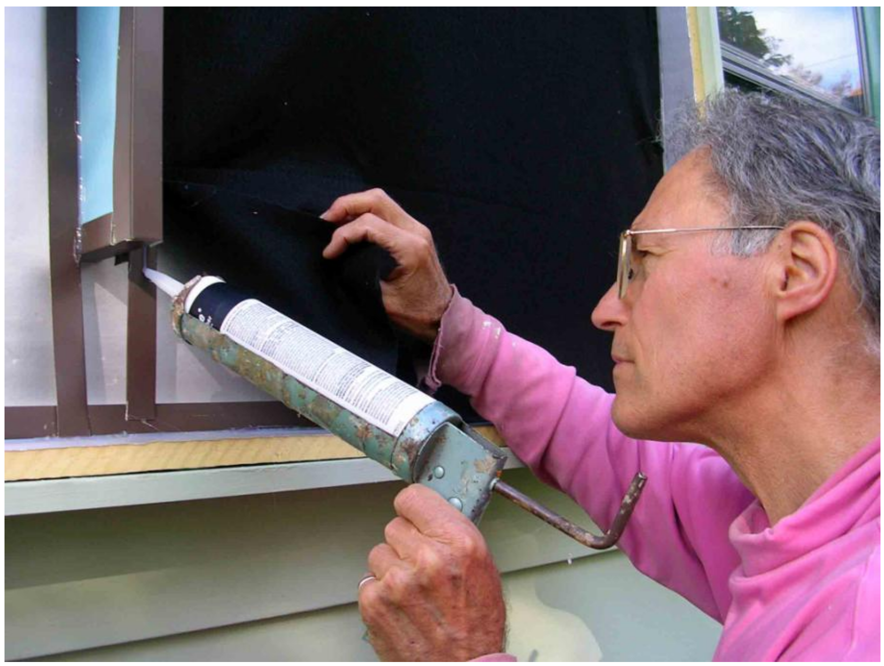
Above: Picture 4. Closeup of fan shroud with thermostat installed in collector

Right: Picture 5. Detail of rails glued to baffle assembly



Left: Picture 6. Close-up of baffle assembly rails as they cross at bottom

Right: Picture 7. Gene gluing black polyester felt using silicone adhesive



Left: Picture 8. Both collectors completed, absorbing heat

Right: Picture 9: Inside vents – cool air inlet to collector on bottom, warm air outlet on top. Close proximity of both vents prevents reverse thermosiphoning at night

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[1] James Kachadorian, *The Passive Solar House.* Chelsea Green Publishing Co. White River Junction, VT, 1997. Tale 6-7, Solar Heat Gain Factors, p. 71.