Solar Thermal Heating and Ventilation System

A Step-By-Step Construction Guide

Version 1.0

Special thanks to everyone who helped design, build, install and test the prototype system: James Hendrickson, Mark Miller and Stacy Reed.

Please read all instructions <u>before</u> beginning to build this equipment.

In keeping with our open source philosophy, this document was created with Scribus, an open source desktop publishing software, running on Linux Mint 17.2.

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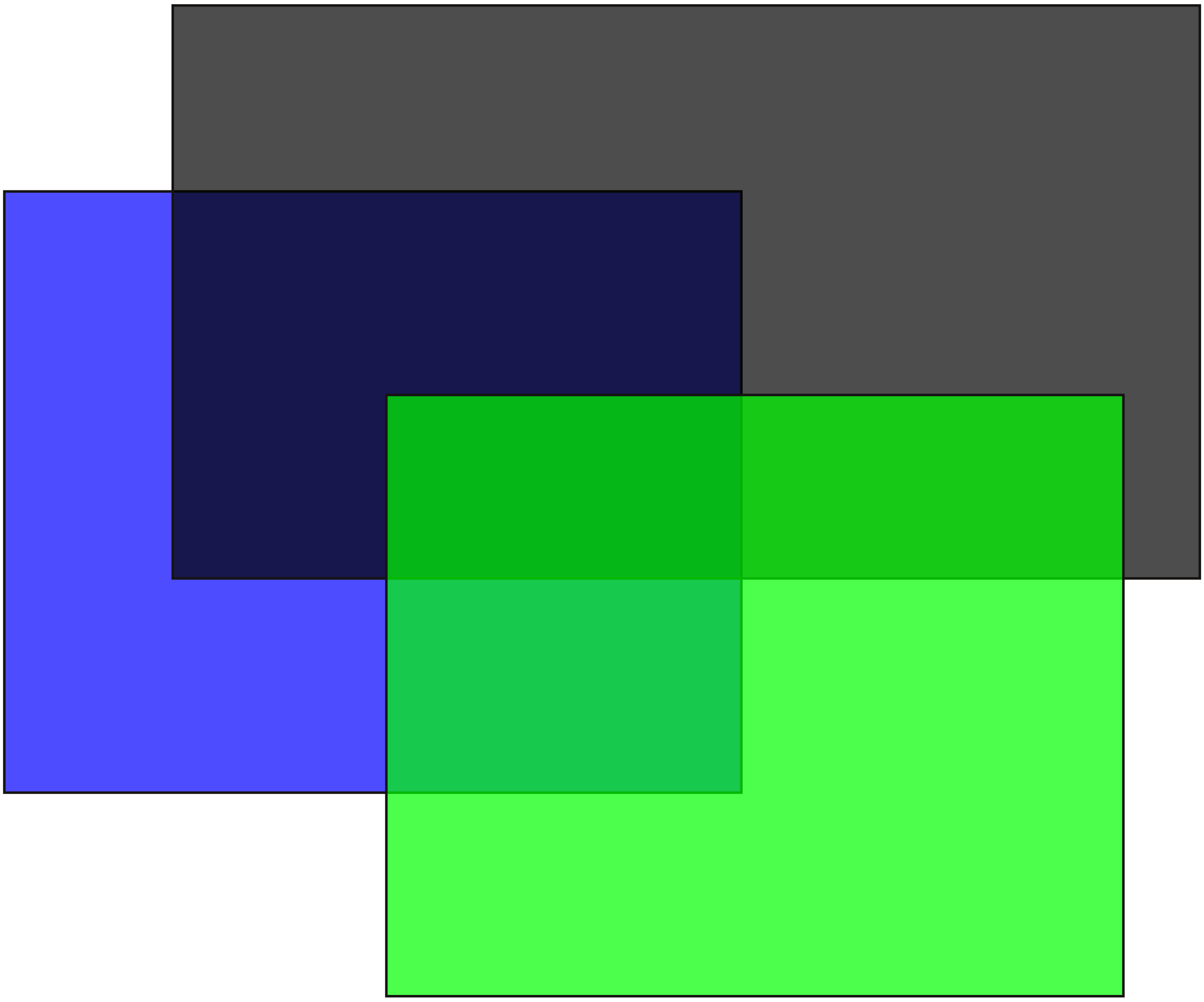
Released through the hapi project: http://hapihq.com.



Solar Thermal Heating and Ventilation System

In central Ohio, where the hapi project was created, we have 4 distinct seasons. Our winters last from December through February, during which outside air temperatures average around 20°F with a record low of -28°F. Sub-zero colds snaps are not uncommon.

Some season extension techniques, such as hoop houses and cold frames, can allow for growing cold-weather crops late into the winter. Similarly these technologies can effectively move spring a few weeks sooner. However, a cold snap can quickly end winter growing activities for all except heated greenhouses.

A core principle for hapi is that the technologies and processes that we create should allow for the production of food year-round. With indoor production facilities, such as our re-purposed shipping containers, keeping the indoor temperature at a level ideal for plant growth can be a challenge, especially in winter months.

A key goal for all of our products is to evolve urban agriculture technologies along multiple, separate but interrelated axis'. First and foremost of these is energy. While it is certainly feasible to burn fossil fuels to heat a grow container, it goes against our commitment to make food production carbon neutral.

Solar thermal is not a new technology. It is often employed to heat water (solar water heaters) and, less commonly/commercially, air. In either case, the units function as follows (example is with air).

A heat absorber is placed in a box with a transparent top/face. The box has an inlet at its lower end and an outlet at its upper end. When sunlight strikes the absorber, the air that is in contact with it warms. This warm air rises and exits through the outlet. This upward air movement creates a convection current. Cooler air moves into the unit from the inlet. This air is in turn warmed and the process continues while sunlight remains.

After watching numerous video and reading websites that discussed the construction and performance of solar thermal air heaters, we decided to build one and mount it on the south end of a 20' food production container.

Our needs and constraints are a bit different from most of what we found online. We needed to mount the unit on the end of a corrugated box made of thick steel, with insulation on the inside. The unit is mounted completely vertical and must help us exceed our daily operational needs during the winter, in order to make up for the short days of January. (this overage implies that we have an efficient way to store excess heat, which we currently do not).

Step 1 - The Box Frame

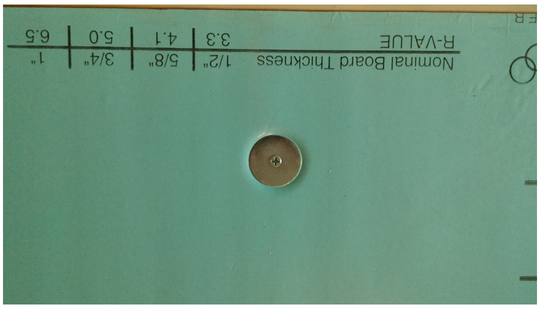
We started with a sheet of 11/32" plywood, standard size 4' x 8'. Then we made a box frame out of three 1" x 6" x 8' planks. The outer edges of the box frame fits exactly to the outer edges of the plywood. We set the plywood on the frame, aligned the edges and screwed it to the frame with 1 1/4” wood screws. The total cost for this step was about $38.

The Box Frame

Step 2 - Insulating The Box Frame

In order to help minimize unintended heat transfer between the solar thermal unit and the container, we secured a sheet of 1" poly-iso insulation (Dow Tuff-R) into the box. As these come in 4'x 8' sheets and the inside dimensions of the box frame are 46 1/2" x 96 1/2", we had to trim off one side and one end. A sharp knife makes quick work of it.

Trimming the insulation



1 of 9 screw/washer assemblies used to attach the insulation to the back board.

We avoided using any kind of adhesives, as the inside of this box could easily top 200 degrees F and many adhesives can't handle that level of heat.

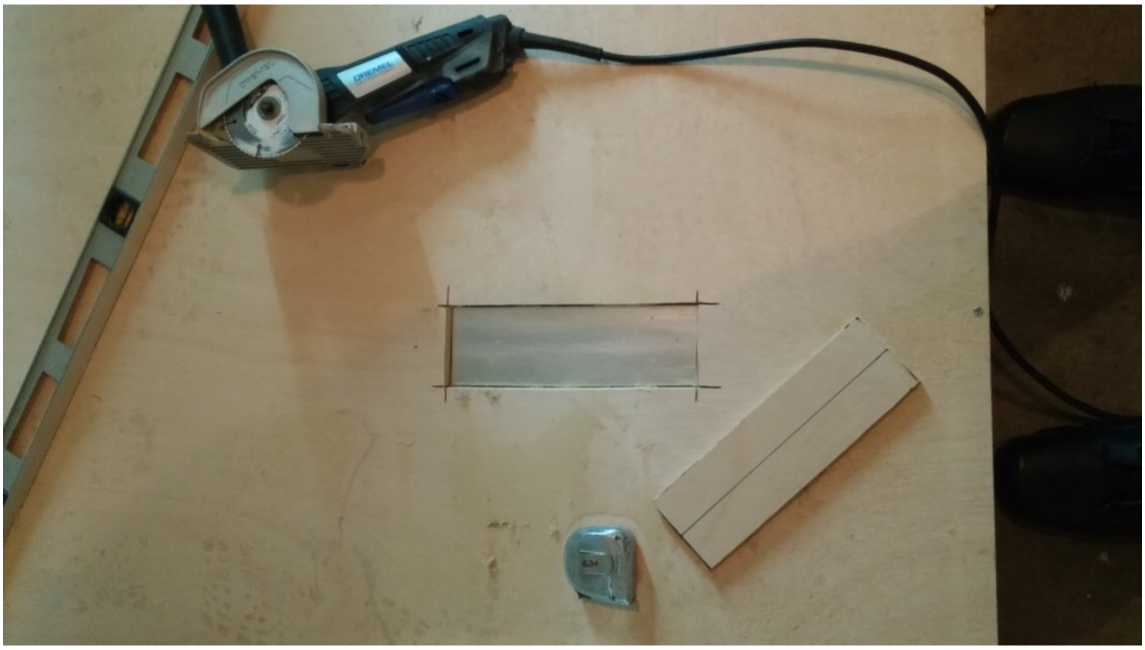
Finally, we used 1 1/4" wood screws with 1 1/4" flat washers to secure the poly-iso to the plywood backing. 3 across the bottom, the middle and the top. Total cost for this step was : $18.

The insulated box frame.

Step 3 - The Vent Holes

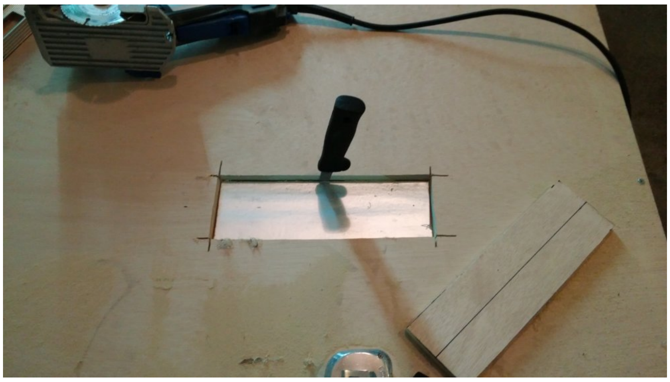
Installing a solar thermal unit on the back of a container is different than a building, primarily due to the corrugations in the container. The inlet and outlet holes need to be cut on and outward corrugation on which the unit will mount flush. Our initial thought was to cut three 3" holes using a drill and a hole saw. This would've given us 21 sq. inches each of inlet and outlet. Instead, we decided to cut two 3" by 10" holes, vertically aligned, one for the inlet and one for the outlet. This gives us 50% more air flow capacity

A vent hole, marked and ready to cut.



Vent hole cut through the back board.

A Dremel Ultrasaw was used to cut the vent holes. As the Dremel couldn't cut deeply enough to penetrate through both the wood and insulation, we finished by cutting the remainder of the way through the insulation with a knife.



The final cut.

Here is the unit with the vent holes cut out. Total cost for this step was **$0**.

Both vent holes cut out.

Step 4 - The Absorber

To make the absorber, we screwed together 1" x 2" boards in a frame that sits just inside the box frame. Then we stapled black aluminum screen to both sides of the absorber frame. We finished the absorber by painting the frame black. Total cost for this step was about $30.

Paint absorber the frame black.

Staple screen to both sides of the absorber frame.

The finished absorber.

Step 5 - Paint It Black

We painted the entire box black with Rustoleum Primer + Paint. Total cost $9.

Step 6 - Prepare The Container

To prepare the container, identify an outward corrugation for the vent holes (it comes out of the container toward you as you view it from the outside). Be sure to select a corrugation that will leave enough space (about 24") on either side to ensure that the entire back of the solar thermal unit is supported by the container. Measure and mark where the vent holes will be and cut holes for them. We used a Dremel Ultrasaw with a metal-cutting blade.

Cutting the lower vent hole.

The upper vent hole, cut out.

The lower vent hole with mounting holes (bolts already installed).

Next, drill four 1/2" holes in through the container where the mounting bolts with go. We put these more or less equal with the top of the upper vent hole and the bottom of the lower vent hole. Total cost for this step: $3 (for the metal-cutting blade).

Step 7 - Mount The Unit

Remove the screws that hold the Tuff-R insulation to the back of the unit and remove it. Align the unit so that the vent holes in it match up with the vent holes in the container. With the unit held in place, drill mounting holes in the unit by going inside the container and drilling through the mounting holes that were made in the last step. Secure a bolt with a 1 1/2” washer through each hole and put another washer on the container side followed by a 1/2” nut. Secure all mounting bolts tightly. To help keep the unit in place while drilling holes and securing bolts, we put a scrap 2”x4” on the ground beneath it, propped it with rocks until it was level and the appropriate height, and then had one person push the unit tight to the container while a second person drilled it. Total cost: $2

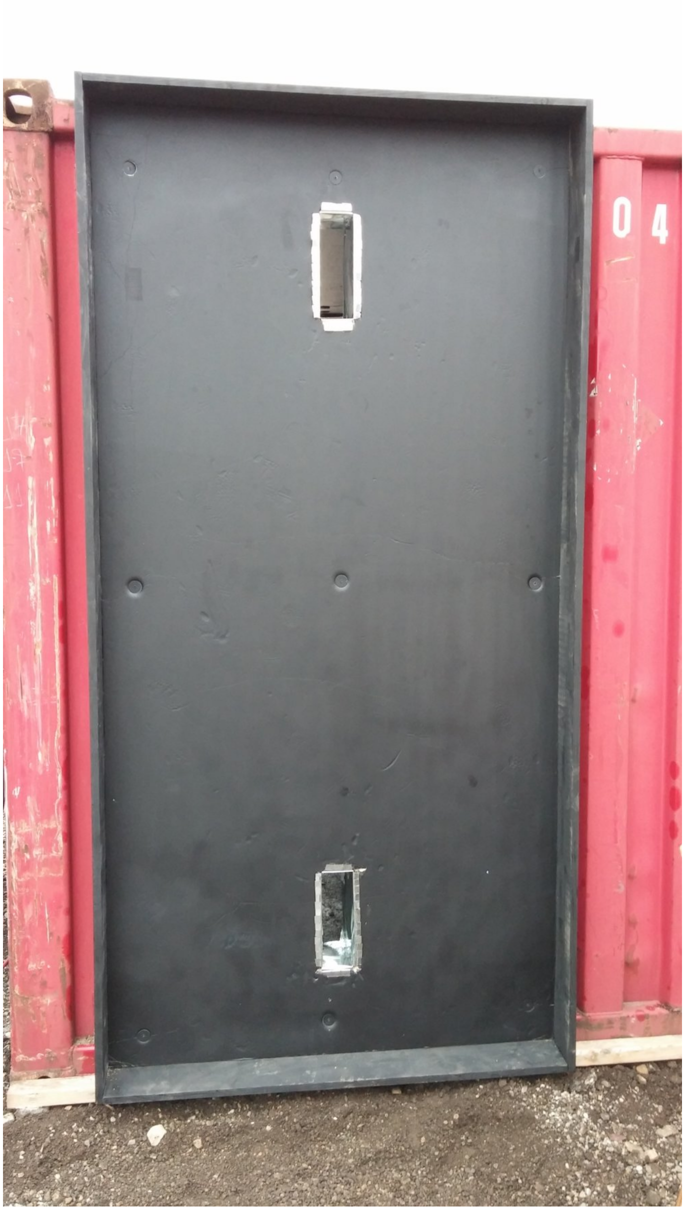
The mounted unit.

Note: Be sure to replace the insulation and secure it with the screws you removed in the last step.

Step 8 - Install The Vents

We used **3" x 10"** duct for this. When you cut the vent holes in the container, making them slightly larger than the vents will help immensely with this step. Slide the vents into the vent holes and tap down the retaining clips. Total Cost: **$20**

The upper vent.



Both vents installed.

Step 9 - Install The Front Glazing

We found sheets of corrugated UV-resistant plastic in the roofing department of our local store. In the same area we also found weather stripping made especially for corrugated panels. A roll of standard 5/8” weather stripping and a handful of #10 x 3/4” stainless steel screws and washers round out the materials for this step.

Have one person hold the first panel in place while a second person secures it to the top edge of the box frame with screws and washers. The corrugated weather stripping goes between the panel and the box frame edge. This step is easier if you drill small pilot holes. Work from the outside toward the center line. Before you install the last screw on the top of the first panel, put the second panel up against the box. Align the two panels so that they overlap in the middle. Then continue installing screws across the top until each inward corrugation of both panels is secured to the box with a screw and washer.

Two corrugated panels, attached on all edges and about to be "stitched" together.

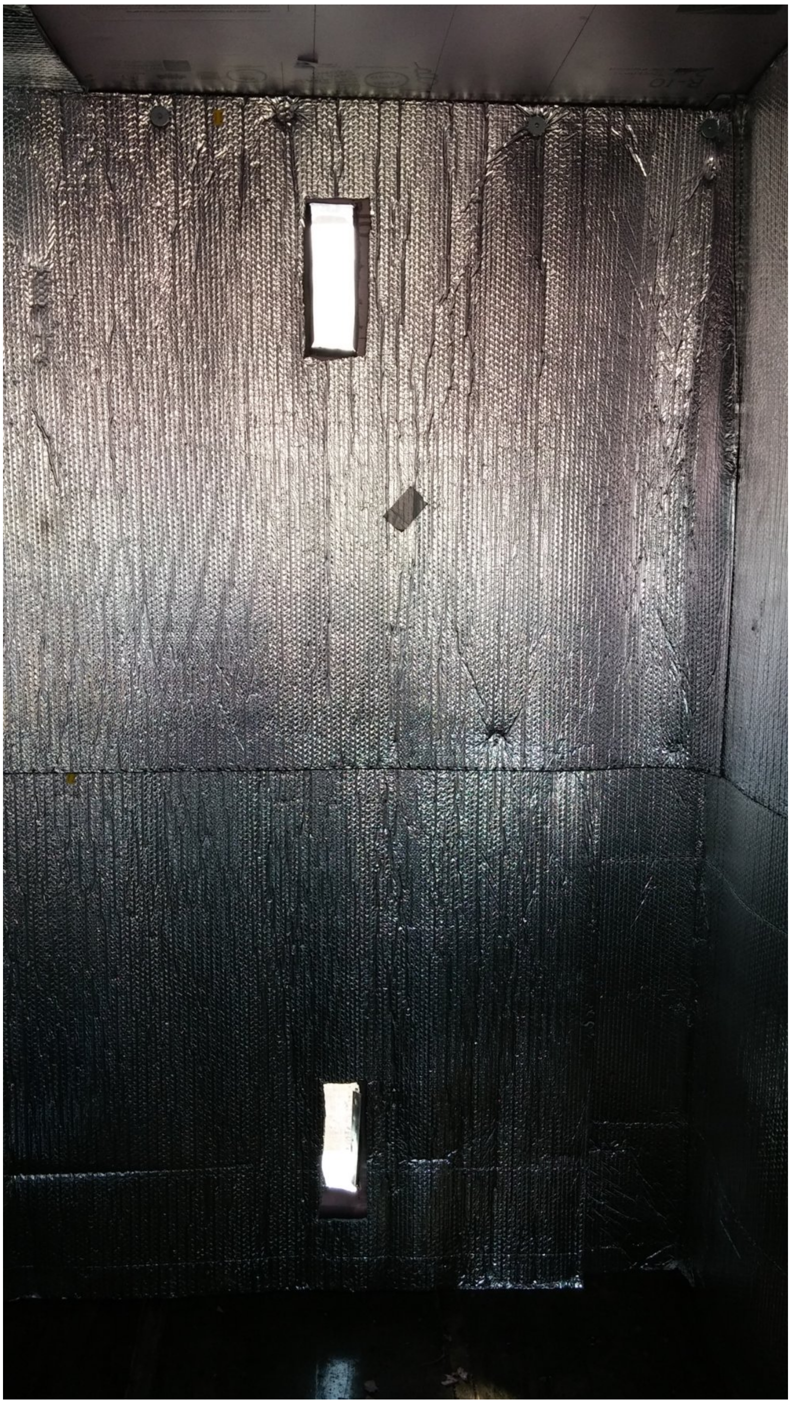
Use a similar approach in screwing the sides down. Put a strip of weather stripping between the edge of the panel and the box and install the screws working from the top down. Do one side, then the other.

Next, secure the bottom of the panels in a manner identical to the top.

Finally, we secured the two panels where they overlap inthe center. We drilled 1/8" holes about every 5" down the seam, and then used a rivet tool to install a white aluminum pop rivet into each hole. Total cost for this step was about $70 (not including the $10 we paid for a rivet tool).

The two panels stitched together with about 20 rivets.


A bad closeup showing a few of the rivets.



A view from the inside of the container, once the unit is installed and with the inside insulation and reflective barrier in-place.

Next Steps

We have three further steps that we will be taking over the near future, all designed to make this solar thermal unit as effective as possible.

First, we will be installing low-voltage fans in front of the unit outlet. These will allow us to draw more air through the system than by convection alone.

Second, we will install controllable air dampers on both the inlet and the outlet. This will allow us to block air flow through the system, thus avoiding heat loss on cold nights.

Third, we will install a vent on the top of the unit, so that during hot summer months, we can close the outlet (hot air coming into the container) and open the top vent. In this configuration, the thermal unit will act as a solar air pump, drawing air out of the container and venting it through the top of the unit.

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