# Solar Hot Water Batch Pre-heater
# Shelburne Ontario

## Objectives

- **install** an effective low cost solar hot water batch pre-heater designed to reduce energy consumption and carbon dioxide emissions.
- **document** the design, construction, actual cost and operating data.
- **disseminate** this information to anyone interested.

## Design

The design is a standard flow through "batch" *water pre-heater*. This involves the diversion of the cold water inflow from the regular gas fired water heater. The cold water from the town mains is sent out to a solar collector and then returned to enter the normal hot water tank at a higher temperature. Opening any hot water tap in the house causes the water to flow through the collector. There are no pumps, electrical controls or other expensive devices required. The result is the use of *less* natural gas to heat the water, saving energy, money and carbon dioxide emissions. Please see the schematic for the actual installed unit **(Appendix 1)**
This approach is the lowest cost for water pre-heating. The main constraint in our climate is that this system can only be used in the warmer months of the year. The pre-heater is designed to be hooked up about April 1st each year. It is to be drained and protected for the winter by the end of October. However, the reality of our climate is that most solar gain is to be had in this period. There is much less benefit through the winter months.
It requires twenty to thirty times more capital investment to capture this relatively small extra energy available in winter. If you use a lot of hot water (institutions) or you want to do active solar space heating in winter, then the more expensive units would be appropriate. A local (London ON) manufacturer of **two stage systems** is Enerworks Inc. Their web site is a good place to start but they are not the only providers and this is not an endorsement of any kind.
http://www.enerworks.com/ie.asp
For an excellent description and "how to" with **batch systems** in general, please visit the El Paso Solar Energy Association web site.
http://www.epsea.org/wtr.html#plum
This is the clearest description of general construction and operation that I could find.
The natural instinct is to place the solar collector on a roof and this does have the advantage of longer solar exposure. However, my unit is at ground level. This makes it easier to install and operate. There is no concern about the

weight of the tank or roof damage. In 2005 I ran some tests during the summer to examine the heat relationships between my roof and the ground. I found that water did heat faster and reached a slightly higher temperature on the roof, but it also cooled more quickly once the sun was off. In my opinion there is no real advantage in a batch set up. For a year round system it would be the opposite as we would want solar gain as early as possible and higher temperatures.

## Construction

In constructing my version of this I have been concentrating upon the issue of cost versus gain. To this end I have tried to build it from material I already had or could scrounge. Unfortunately I had to buy the plumbing parts. The bill of material below **(See Appendix 1)** is based upon buying all of the material needed.

This solar box **(Figs 1 to 6)** is constructed from 3/8" and ½"aspenite sheeting. The equivalent of two sheets, four feet by eight feet will be required due to the length of the tank. As we are approximately at latitude 45° north, I cut the end pieces to be identical right triangles with a slope of 45°. I used available "2X4" framing material. You can choose to either frame the ends, or the back and bottom pieces depending upon how much material you have available. The bottom must be properly strengthened to hold the weight of the full water tank (about 150 Kg). In this unit the bottom is actually made from two pieces of ½" aspenite framed together with two pieces of 2X4 fixed inside as tank supports. You can see this in the pictures below.
I am not providing detailed dimensions. You must start out with the size of the tank you have and work from there. The wood was painted with some exterior latex paint but it could be oil based. It will be your choice of colour. Mine was some left over picnic table brown. Because mine is installed on the ground I have placed bricks underneath three 2X4 framing pieces to keep the wood away from the dirt. I chose to avoid pressure treated wood in all projects if possible.

**Figure 1**

The interior of the box was covered in 1” rigid foam insulation, calked and then covered with a layer of reflective silver bubble insulation. There is much discussion amongst my casual group of advisers advocating that a smooth reflective surface would be better.

**Figure 2**

The surface of this material does reflect some energy back out of the box but most is retained inside. In general it is reflective so that the suns energy that doesn’t hit the tank directly will be reflected down and onto the under surfaces of the tank. Testing out all of the design details would require several years and perhaps several separate units. I am prepared to live with what I have but there is an opportunity here for anyone who wants to explore the perfect design. You will see some general data curves below showing results with this unit here in Shelburne. The tank is placed horizontally, resting upon the interior timbers and held in place with blocks nailed to the frame. I would suggest not fixing the tank until all the plumbing is done. The tank is an old oil fired hot water tank, stripped and cleaned of all insulation and painted matte black. My intention was to use an electrical style tank as they are smaller diameter but I was generously given this unit for free. There may be an advantage to this tank style even though it is of larger diameter. The flue runs up the centre of the tank and there is a large fire box at one end. The flue allows warm air access to the middle of the water mass and this should help in warming the water faster. As well the fire box can be partly filled with rock thermal mass and help lengthen the cooling

**Figure 3**

tail when the sun isn’t shining. The tank has been oriented so that one threaded hole is at the top on the side. All unused holes and couplings must be plugged or capped. The standard thread on these tanks is ¾ IPS. The cold water feed has been attached to the lower of the two nipples at the end of the tank. Unfortunately they align splitting the midpoint of the tank. Nothing has been done to force the cold water to the bottom of the tank allowing gravity to do the work. It would be a minor improvement to direct the inlet flow downward but hard to do on standard tanks. The most benefit from this would be seen when high volumes of water were being used at the height of the heating day.

As can be seen in the picture, I used threaded pipe and fittings to connect to the tank and reduce to ½ IPS to the lines. It might be easier to use threaded fittings for the reducer and coupling and use ½" soldered copper for most of the piping inside the collector. This would allow for final tweaking of the orientation by softening a solder joint instead of trying to seat and seal all of the threaded connections in the right position. I may make this modification next season. Note that you need a bleeder valve or plug to allow for the filling and draining of the tank. I used a valve for convenience but a plug in the tee would have been adequate and cheaper.

**Figure 4**

The main piping is plastic "red stripe" with elbows and worm clamps as required. This will be specific to your own site.

**Before doing any of the following, make sure that your main water valve is closed and you have drained the lines below the level of the pipe you are working on. If plumbing isn't your strength either have a professional do this (very expensive but sure) or ask a competent friend.**

Please see **Appendix 1 and Figs 4 and 5** for the details of the plumbing. My gas fired hot water tank had a convenient cut off valve in the cold water inlet line. This should be standard if your tank was installed by a professional. I simply cut the copper pipe on either side of this, shortened each end ½" and then soldered on tees and a male threaded connector, soldering it back into place so that the original valve was between them. Then I attached an inline valve, a threaded tee and a boiler drain valve on each branch. Boiler drain valves have a male hose thread connection for use when draining the system. A threaded coupling was attached in line and the threaded male connector from the plastic pipe was screwed on. Once the coupling was joined and all valves closed the water was restored. All soldered joints were checked for leaks and the original cut off valve opened so

that water flowed into the gas fired tank in the usual way. (Re-bleed all of the hot water lines that were drained at the beginning of this stage.)
At this point the bleeder valve on the solar tank was opened followed by the one inlet valve from the water mains, allowing water to flow into the solar tank and filling it. All threaded joints and pipe joints in the cold water feed were checked here. We had to tighten some of these to stop minor seepage. Remember that you must use thread sealer, either plumbers stick or sealing tape, on these threads. Once water began to come out of the bleeder on the tank, that valve was closed. The next step was to open the boiler drain on the hot water feed line near the gas fired tank, allowing the air to escape from the line and water to flow down from the solar tank.

**Figure 5**

Once water was flowing from this valve it was closed and the inlet valve opened. The loop through the solar collector was now complete and ready to feed into the gas fired tank. The cut off valve in the original line was closed and we then had water flowing through the solar collector and pre-heating before it went into the gas fired hot water tank. The plastic aperture cover was put into place. My unit uses a double plastic (6 mil) aperture covering (single layer shown) in place of glass or hard plastic. This probably reduces the solar gain and certainly makes it harder to seal and retain heat when the sun is not shining. However it greatly reduces the cost of the unit unless free glass can be found. As can be seen, stretching the plastic properly can be a challenge.

**Figure 6**

The hot water line from the collector to the house should be supported and insulated.  A good refinement for our climate is an insulated aperture cover to be put into place in the evening when the sun goes off.  This makes some extra work as it must be removed each the morning but is of great benefit for cooler nights.  On my unit it will also double for the winter protective cover.

**Operating Data**

**Disclaimer:** This data was not collected with scientific rigor.  It represents temperatures measured with un-calibrated (but reasonably accurate) equipment at the approximate times shown.  Once I win the lottery I will have the time for scientific research and engineering.

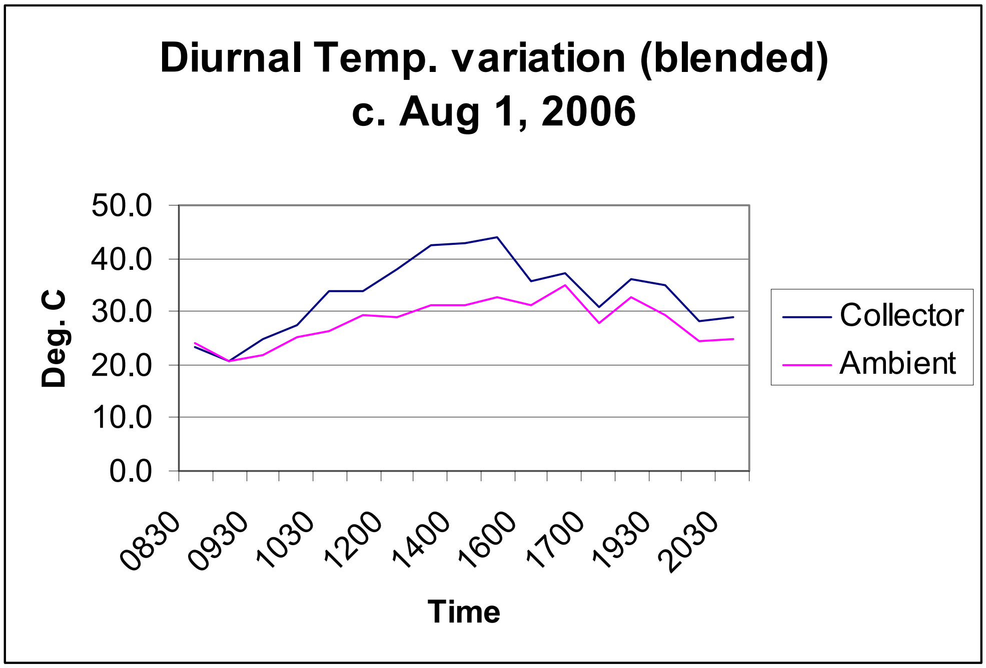


**Figure 7**

The data for the above was collected on several days from July 25, 2006 to August 7, 2006.  A domestic electronic interior/exterior thermometer was used.  The probe inside the solar collector was about 60% of the way down from the top back and shaded by the tank.  The maximum individual temperature recorded was c. 50C.  The actual values are of less importance but the trends indicate a couple of things.  The low nick point at approximately 0900 captures the fact that my site is partially shaded from the east and the solar effect at this time of year does not begin until after then.  Since the ambient and internal temperatures are about the same it reveals the fact that there was no night time insulation over the aperture and perhaps poor sealing elsewhere.  The solar gain is smoothly rising until about 1400 hrs when it plateaus.  Perfecting the aperture seal may raise the temperature but the plateau is probably supported by a feed back effect from the water in the tank. As the solar gain begins to weaken, the water becomes an important factor in stabilizing the internal temperature. The drop off in air temperature in the collector after 1600 could represent a couple of effects. One would be increased hot water usage reducing the water temperature and the feed back. As well, the solar gain is dropping off quickly. This is indicated by the close tracking of the internal and ambient temperatures from 1700 hrs. The actual temperature difference at least partially represents heat lost from the water to the collector. One objective for improvement is to minimize the tracking of the two temperatures by increasing the insulation and seal integrity of the collector. The collector is oriented just east of south. Due to the morning shading I plan to set it west of south in 2007 and predict a later evening drop off in temperature. A higher absolute temperature might also be achieved.

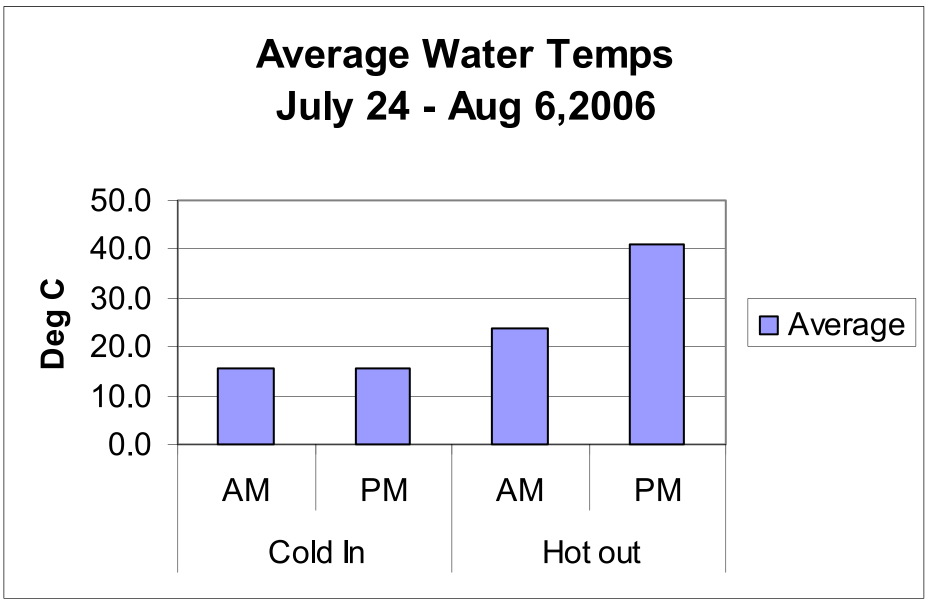


**Figure 8**

| | Cold In | | Hot out | |
|---|---|---|---|---|
| | AM | PM | AM | PM |
| Average | 15.5 | 15.6 | 23.8 | 40.9 |

**Table 1**

The actual temperature benefit can be seen from the above graph and data. The temperatures were measured using a photography grade thermometer accurate to .5$^{o}$F. The water samples were drawn from the boiler drain valves in the water lines at the gas fired heater. The morning tests were about 6AM and the evening sampling about 6PM. Sufficient water was used from a house hot water tap to draw the water from the lines so that water that had just left the solar tank was being measured. Note there is about an 8$^{o}$C temperature gain in the morning measurement but comparing to the ambient

values measured above **(Figure 7)** some of this was due to warm nights. As the nights cool this value will decrease. More data will be collected as the nights cool to study this issue. It will also show the importance of night time insulation. The high temperatures are very encouraging. The maximum water temperature measured was 50$^{o}$C on July 31$^{st}$, a perfect solar day. This was the day I took a shower without having to pay to heat the water. This had never happened before in my life.
The actual value of this energy gain in terms of natural gas, money and $CO_2$ saved will be researched and added in a later revision. In the meantime I am content in knowing that a benefit is occurring.
**Note:** Part of the point of this kind of effort is to **get doing!** Try projects like this if you are inclined, and love tinkering and building. Don't worry too much about economics, building the *perfect system* or justifying it to your friends. If you have the money and economics isn't important, purchase a professionally designed and installed system of any type. As long as you pick the correct one it will usually be better than anything we can build on our own. Just remember that ***when*** times get tough your provider may no longer be around and complicated parts may not be available.

## Working with Lifestyle

This is a water pre-heater simply aimed at *reducing* the energy required to heat water to the normal set point of a conventional water heater. As such it doesn't require any lifestyle changes for benefit. However for the maximum return it is obvious that hot water use should be concentrated in the afternoon or early evening. More effective ways to reduce energy consumption for hot water involve using less. This is the same hard fact connected to all energy sources. Especially in the summer, washing hands, shaving and rinsing in cold water save even more energy and money. Everyone needs to make their own decisions regarding hygiene and comfort. Showering using a water saver type shower head is preferable to taking baths. Front loading clothes washing machines set to cold or warm, not hot, are very much more water efficient. Dish washers, completely filled, set on a shorter cycle and not using temperature boost or heat dry are a good benefit.

This is an ongoing project. Improvements and more data gathering will be done. Please look for revisions to this document over the coming years. Future projects for our house will involve passive and active solar space heating, upgraded seals and insulation. The highest priority is a partially solar charged battery back up system.
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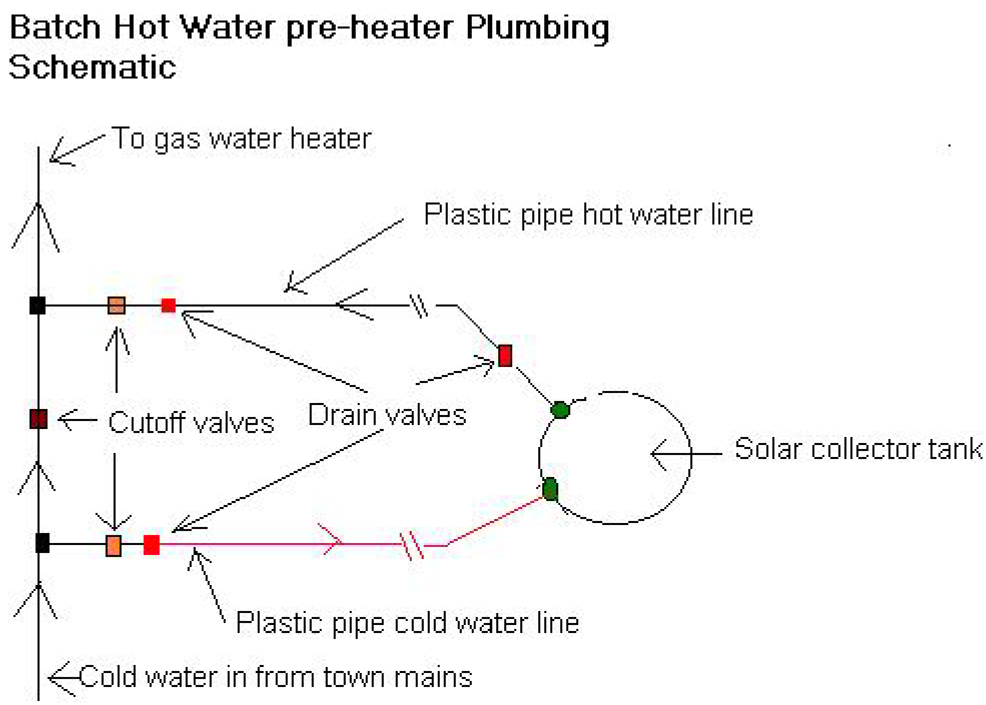
## Appendix 1




**Bill of material is below.**

## Batch Hot Water Pre-heater BOM

| Description | Qty | Unit | Unit cost | Total |
|---|---|---|---|---|
| Standard shut off valve | 2 | ea | 6.87 | 13.74 |
| Boiler drain valves | 3 | ea | 3.97 | 11.91 |
| Plastic "red stripe" water pipe | 33 | M | 0.54 | 17.82 |
| Copper T | 2 | ea | 0.69 | 1.38 |
| Galvanized hot water tank (estimated) | 1 | ea | 150.00 | 150.00 |
| 1/2" copper to 1/2 IPS adaptor | 2 | ea | 0.99 | 1.98 |
| 1/2" copper pipe | 5 | cm | 0.10 | 0.50 |
| Close nipple 1/2 IPS | 4 | ea | 0.75 | 3.00 |
| Galvanized union 1/2 IPS | 4 | ea | 3.86 | 15.44 |
| 90 deg galvanized elbow 1/2 IPS | 2 | | 0.98 | 1.96 |
| Coupling Black 3/4 IPS | 1 | | 1.28 | 1.28 |
| Plastic adaptor male 1/2" to 1/2 IPS | 4 | ea | 0.69 | 2.76 |
| Plastic elbows 1/2" | 4 | ea | 0.39 | 1.56 |
| 90 deg galvanized elbow male/female 3/4 IPS | 1 | ea | 1.58 | 1.58 |
| Male female reducer 3/4 to 1/2 IPS | 2 | ea | 1.39 | 2.78 |
| Galvanized iron T 1/2 IPS | 3 | ea | 1.36 | 4.08 |
| 6" galvanized nipple 1/2 IPS | 3 | ea | 1.39 | 4.17 |
| 4" galvanized nipple 1/2 IPS | 2 | ea | 1.24 | 2.48 |
| !/2" screw clamps | 12 | ea | 0.69 | 8.28 |
| Support straps | 6 | ea | 0.29 | 1.74 |
| 3/8" 4 X 8 aspenite | 3 | ea | 4.00 | 12.00 |
| 2 X 4 spruce | 6 | ea | 1.50 | 9.00 |
| 1" rigid insulation 2 X 8 | 4 | ea | 10.00 | 40.00 |
| Reflective wrap | 1 | roll | 19.97 | 19.97 |
| Reflective tape | 1 | roll | 3.97 | 3.97 |
| 1" X 2" spruce | 3 | ea | 1.00 | 3.00 |
| 6 mil plastic sheeting | 6 | $M^2$ | 0.10 | 0.60 |
| Plastic cement | 1 | ea | 4.79 | 4.79 |
| Caulking exterior acrylic | 2 | ea | 3.49 | 6.98 |
| Hardware screws nails etc | 1 | lot | 5.00 | 5.00 |
| Glass fibre insulation R12 | 2 | bats | 2.50 | 5.00 |
| Total | | | | 358.75 |