# Parabolic Solar Collector Proposal

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**Summary**: In order to boil water with solar energy, we propose to design and conceive a parabolic solar collector at under $50 per unit. The global energy crisis is of great concern to us and we believe that a parabolic solar collector may be a possible immediate part of the solution. The design parameters require that the cost must be ≤$50 per unit, be able to boil water efficiently, and be relatively easily manufacturable while still being ergonomically and aesthetically viable. Design concepts such as the fresnel lens and satellite dish mirror were drawn upon in order to come up with our unique design. Implementing such a device would reduce the volume of green house gases emitted by each household, globally reducing the impact of fossil fuels on our planet. The device is portable and adjustable, and should be able to boil water in under 10 minutes with ~90% of the sun's energy absorbed making it ergonomic and economic superior to other solar energy collecting devices already on the commercial market.

**Introduction**
A parabolic solar collector device that would heat a half-liter of water to boiling within two hours is of significant importance to reduce the volume of green house gases emitted by each household, globally reducing the impact of fossil fuels on our planet. It is not uncommon for a household to use unnecessary amounts of electricity or natural gas just to boil water. Once all of that energy is used per household per country, the net amount of energy available drastically decreases. To help the energy deficit decrease in magnitude, this 21W.732 project is to conceive, design, prototype, and evaluate a parabolic solar collector device that will heat a half-liter of water to a boil in less than two hours. In addition to the requirement that the coffee remain hot, the product must satisfy three subsidiary requirements:

- The product must not expose the customer to undo hazard
- The product must be aesthetically pleasing and portable
- The product must have a small ecological footprint, both in terms of the materials used to construct the product and the labor required to produce the product.

These requirements are weighted with the ultimate requirement that the water is heated according to the rubric in Table 1. For environmental and economic reasons, the parabolic solar collector device shall be constructed primarily of wood and paper products with trace amounts of metal and cloth. If the design is successful, the parabolic solar collector device can be marketed to the millions of household owners.

**Table 1** "cost" of subsidiary requirements

| requirement | cost incurred |
|---|---|
| Safe | The product must pass the heat test, the durability test, and the roving eye test for obvious lack of dedication. Any product that does not pass these tests is disqualified. |
| Portability<br>& Aesthetics | A panel of experts will judge your prototype and place it in one of three categories: top quartile, middle quartiles, and bottom quartile.<br>1. Products in the top quartile will have 10 minutes deducted from the time at which the water boils.<br>2. Products in the bottom quartile will have 10 minutes added to the time at which the water boils. |
| Eco-friendly | • If the mass of the product is less than 10 pounds, 10 minutes deducted from the time at which the water boils.<br>• If the mass of the product is more than 15 pounds, 10 minutes will be added to the time at which the water boils.<br>• If the product can be assembled in fewer than 15 minutes, 10 minutes will be deducted from the time at which the water boils<br>• If the product requires more than 15 minutes to assemble, 10 minutes will be added to the time at which the water boils. |

## Background (How we will boil the beaker of water)

*Thermal model*

Power of the sun per square meter over the course of an hour

- 1000 J/s x 60s/min x 60min/hr x 1kJ/1000J x 99% reflectivity =
    - 3,564 kJ/hr

Amount of energy need to bring water to a boil

- 224g x (100C – 20C) (Room temp. to boiling temp) x 4.186 kJ/g (specific heat capacity of water) =
    - 75 kJ

Energy to keep water boiling

- 224g (amount of water in half a liter) x 2261 J/g (energy needed to keep water a boil per gram) =
    - 506.5 kJ

Total energy needed to boil a cup of water

- 581.5 kJ for a cup of water

(3,564 kJ/hr from the sun) / (581.5 kJ for a cup of water) = amount of time to boil water

- It would take about 10 minutes to bring water to a boil under the most ideal conditions.

*Safety analysis*

We have ensured the safety of the consumer by providing guidelines for the operation of the device and labeling the critical points of danger. The device is not meant be looked at directly while it is in use under the sunlight. Under the sunlight, it is in use and the reflectivity can cause skin damage so it is advised not to stand in front of the focal point.

*Aesthetics and portability*

The solar collector has a very strong and solid design that shows an aesthetically-pleasing industrial visage. Its striking design also shows the accuracy that went into making the design. The device is quite large (1-meter by 1-meter area) and weighs about 12lbs. It is able to carried by one person but it is recommended that two people carry it to avoid damage.

*Materials and labor costs*

The materials that we will utilize in the creation of the reflector include the following:

- 10 ft. Aluminum pipe ------------------------- $11 per 10 ft.
- Plywood ----------------------------------------- ESG provided
- Aluminum Foil Tape -------------------------- $7 per roll
- Screws ------------------------------------------- $6 for 40-pack
- Acrylic Plexiglas x3 ---------------------------- $31 each
- Industrial bathroom caulk -------------------- $8
- Black Marker ------------------------------------ $3

The tools are provided by the MIT Hobby shop and the estimated time of construction for the device was about 4 hours total for the first model. The time will be able to be cut down to an hour after all initial procedures are documented.

**Methods**
*Design overview*

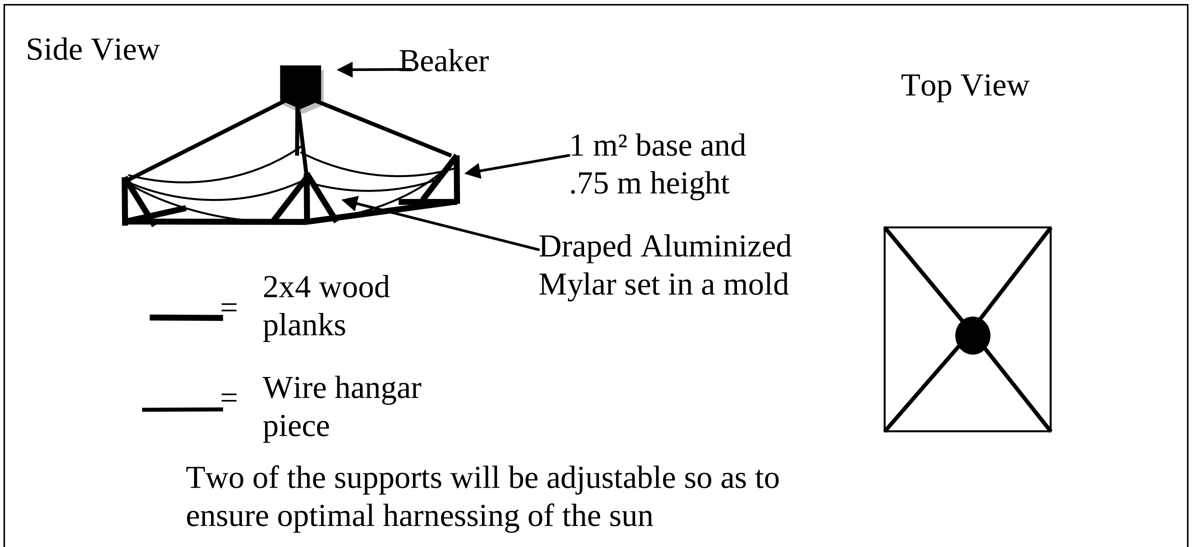


**Fig 1** Overview of the solar powered water heater

**Table 2** Design space selection criteria

| | Technical slam dunk (or challenge) | Team Interest | Time commitment | sure to produce best result (bring water to a boil fastest) | sure to impress parental units, significant others, and potential employers | total |
|---|---|---|---|---|---|---|
| Little Mirrors | + | + | + | - | + | 4 |
| Parabola-shaped Rectangular Mirror | + | x | + | - | + | 3.5 |
| Draped Aluminized Mylar | + | + | + | + | + | 5 |
| baseline | + | + | + | + | + | 5 |

**Table 3** Design FRDPARRC

Legend:

- W = watts (J/s)
- J = Joules
- s= seconds
- L = liters
- K = kilo (x$10^3$)
- m = meter

| Functional Requirements | Design Parameters | Analysis | Research | Risks | Countermeasures |
|---|---|---|---|---|---|
| Boils .5L of Water in under 2 hours | Draped Mylar designed to harness most or all of sun's energy in a $m^2$ area | If all of the energy of the sun is harvested, a cup of water should be brought to boil in a little under 10 minutes and even if the solar output is reduced by half we will still be able to bring the water to a boil in a reasonable amount of time | <http://www.solarnavigator.net/solar_power.htm> The output of the sun is roughly 1020 W/$m^2$ at sea level (we said 1000 to be safe). When it is all said and done, that is about 3,456 KJ/ hour $m^2$ which means 7,128 KJ over the course of two hours. It takes approximately 581.5 KJ to bring water to a boil, and this amount of energy would be achieved in a little less than 10 minutes. This means that our .5 L should be brought to a boil in approximately 21 minutes. | -Mylar could tear<br>-An individual could get burned or hurt eyes | -Reinforce the back with a plaster mould or stiff canvas to increase structural integrity<br>- Explicit instructions to never put limbs, clothes, eyes or flammable materials near focal point (beaker) |
| Takes up no more than a volume equivalent to $1m^3$ (compact) | Base takes up a $m^2$ while the height is about .75 m (refer to above figure) | Satisfies requirement for space | - | - | - |
| Maximum of $50 per unit (economical) | Inexpensive wood<br>And aluminized Mylar | Through good use of inexpensive scrap wood obtained from the Hobby shop as well as using the most inexpensive material, aluminized Mylar, we should be able to stay within budget parameters | <http://www.homefly.com/products.asp?id=3> About $27 for a 1 m by 3 m piece of aluminized Mylar according to this website (after a bit of mathematical fiddling). More than enough for two units actually. Based on this figure, a 1 by 1.5 m piece should be even less (a piece needed for the unit), and thus we will have extra funding needed for the purchasing of any wood or other materials. | Materials may be sub-par | To test each piece and ensure quality. |

Device Recipe

3. Cut all required pieces of wood for the base
4. Construct the base making sure to allow two of the legs to be adjustable
5. Cut required sheet of Aluminized Mylar (square shape)
6. Secure each corner of the sheet to a post of the base
7. Ensure that the Mylar will hold its form either through adhering it to a mold or stiff canvas with the same shape
8. Find the focal point of the unit and set up the hangar pieces so that they meet at the focal point.
9. Secure the water container to these hangar pieces
10. Product is finished, enjoy

*Device testing*

The ability of the Solar Powered Water Heater device to boil .5L of water will be evaluated by placing the device on the roof of ESG for two hours. Aesthetics, ergonomics, and economics will be factored in as noted in Table 1. This test will be executed with the allowance of being able to tilt the device towards the sun as the sun will undoubtedly change positions over the course of two hours. The device will have a $m^3$ box placed over it to determine whether the spatial requirements were met. Finally, a list of expenses acquired during the building of the device will be compiled and review to ensure that the project has met the budget guidelines listed.

**Other**

Sarah Don, Dorma Flemister, Malik Miller and Nathan Porter are first year students at the Massachusetts Institute of Technology. Designing solutions to the global energy crisis is of great importance and interest, hence the continuing work on this solar collector device.