A COMPARISON OF COPENHAGEN SOLAR COOKERS WITH OTHER SIMILAR SIZED SOLAR COOKERS

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The Copenhagen Solar Cooker was invented in 2009 by the author, Sharon Clausson[1]. The Fun-Panel Solar Cooker directions were published in 2008 by Teong Tan[2]. The Copenhagen Solar Cooker was made with self-stick reflective Vinyl on a polypropylene substrate. The Fun-Panel was built out of cardboard and foil. The Fun-Panel and the Copenhagen were built with approximately .75 square meters of material. The tests are to determine how much cooking power each design produces. Two different cooking evaluations were used. The first was the WBT designed by Bernhard Muller[3]. The second was the PEP testing protocol designed by Dr. Alan Bigelow Ph.D. Science Director for SCI and built by Glenn Clausson[4]. The pans used were both 4.251 and each held 2000ml. of water. The pictures were from a thermal camera Pure Thermal 1 Camera by GroupGets.com [5] and were used to show heat distribution pattern of each cooker.

The Fun-Panel Cooker   Copenhagen Solar Cooker

PEP Control Unit
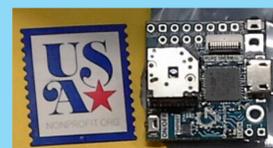
Pure Thermal 1 Camera (Not to scale)

WATER BOILING TEST WBT

The Water Boiling Test for Solar Cookers WBT SC allows comparison with other cook stoves and open fires. The test is for cooking ability only. It is easy to understand and record test results.
It can be set up in the field with a minimum of equipment.

Equipment:
Accessories needed to run the test
- A solar cooker on a horizontal surface
- A thermocouple or thermometer
- A precision scale to weigh the water
- A blacked pot with a lid
- An appropriate amount of water
- A measuring devise to calculate aperture area

Fixed and variable parameters

The WBT SC has a fixed parameter; the amount of water. In smaller or weaker solar cookers use 1 liter and for larger ones use 2.5 liters.
The variable parameters are:

- location mainly latitude
- position of the sun
- type of cooker
- aperature area
- reflector material
- insulation if any
- heat trapping material
- date and time
- initial water temperature local boiling point

To avoid confusion, the test should not be conducted if sun is less than 30 degrees above horizon (zenith angle more than 60 degrees), and if the ambient and/or water temperature is the less 0C (32F).

PEP TEST

Two types of panel solar cookers were used in the evaluation:
- Copenhagen Solar Cooker by the author Sharon Clausson (adjusted to .75 square meters)[1]
- Fun-Panel by Teong Tan (adjusted to .75 square meters)[2]

For the quantitative portion of my evaluation I used:
- The Water Boiling Test by Bernhard Muller [3]
- PEP testing station designed by Alan Bigelow for SCI and built by Glenn Clausson[4]
- Pure Thermal 1 Camera by GroupGets.com[5]

Electronics platform	Arduino Mega open source electronics, liquid crystal display and removable SD card
Temperature	Type K thermocouples to measure water and ambient temperatures
Wind speed	Anemometer (Adafruit)
Solar irradiance	SP-215 amplified pyranometer (Apogee) mounted to a horizontal bubble-leveled plane
Additional	Global positioning system

PEP TESTING STEPS
- Align testing station with the pyranometer wire connector at a North/South compass direction.
- Use bubble level on mount fixture to level the pyranometer.
- Put thermocouple plugs into sockets with ambient probe out of direct sunlight.
- Push thermocouple probes through pot lids and secure with threaded nuts.
- Align solar cookers for maximum sun and put empty pots on racks in the solar cookers.
- Connect 12 VDC to testing station.
- Premeasure equal amounts of water and add to pots then cover with lids.
- Compare ambient temperature to water in pots, if they are within 2C then press button to start new test. If water temperature is below ambient then wait for equalization and restart by pressing reset. If water temperatures are more than 2C above ambient then change water and add new ambient Temperature water.
- Adjust cooker every 20 minutes to track the sun format.

** The results on the first 2 tests are the beta testing of the equipment. A wiring error occurred which reversed the polarity. After that was corrected the reading were in the normal range.
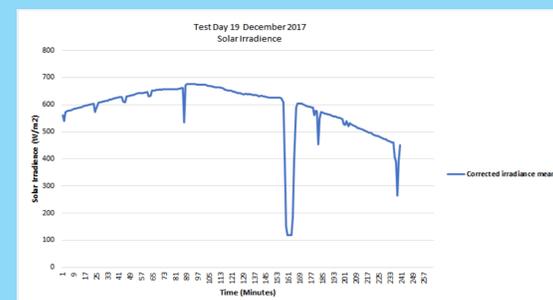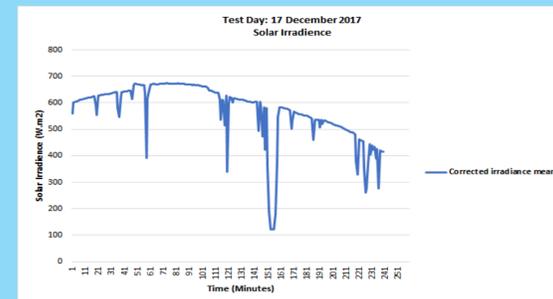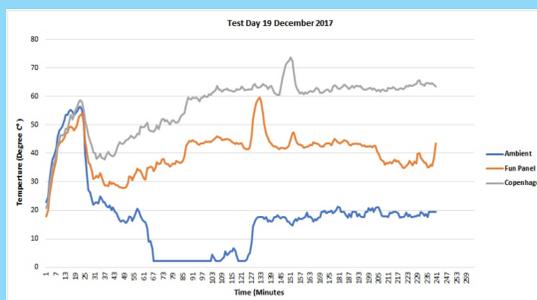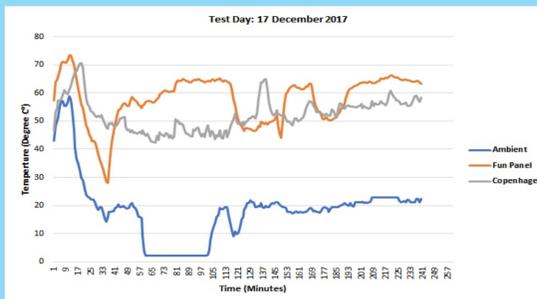
THERMAL IMAGING COMPARISONS

Thermal imaging equipment:
- Pure Thermal 1 camera by GroupGets.com
- USB cable
- Laptop computer with Windows XP using Windows Pictures and Fax Viewer

Thermal imaging test steps
- Set up cookers in the sun
- Put correct measure of water in pans and put in solar cookers
- When pots are hot attach camera to USB and cord to laptop.
- Use keyboard to take pictures

BOTH SOLAR COOKERS   FUN-PANEL COOKER   COPENHAGEN COOKER

CONCLUSIONS:
The comparison of these two solar cookers combined with three evaluation methods highlighted their difference and similarities. It showed the weaknesses and strengths of the different testing methods.

- To do the PEP test the author's husband built the PEP Station from directions offered on the Solar Cookers International website and designed by Dr. Alan Bigelow Ph.D. The build went well. Testing some components took more time than expected. Not having familiarity with graphing software author had difficulty interpreting the raw data.
- Bernhard Mullers' WBT SC test was much simpler and less expensive. The reading from the PEP were used to populate most of the WBT SC form. This method is much easier for field testing and just as accurate. The equipment is also minimal.
- The purpose of using the Pure Thermal 1 Camera was to look at solar cooker performance. More tests with this camera are needed to learn how to utilize the information it provides. A clear difference can be seen by looking at the thermal images of the Fun-Panel and the Copenhagen side by side.
- The shape of both cookers is very similar when is use. Observations in the early day and later day, not included in the tests, showed the water in the Copenhagen Solar Cooker getting hotter than the water in the Fun-Panel. However during test hours they were quite similar. After the test ended the water in both cookers had the same temperature.
- The Copenhagen was enlarged to match the .75 square meter size of the Fun-Panel. Further research needs to be done with a Fun-Panel made of the same material as the Copenhagen.
- The Copenhagen could benefit from the addition of booster panels between the points. Both cookers reached higher temperatures with a supporting dowel to hold the "wings" open. Teong Tan invented the Fun-Panel from an aeronautical engineering point of view. The author invented the Copenhagen from an intuitive artistic maker point of view. The similarities in the performance of both is notable.
- An hour after sunset the water in the Fun-Panel was 30.1 C and the water in the Copenhagen was 42.4 C and the ambient was 19.01 C. It must be noted that because of its adjustable design the Copenhagen panels can be clipped into a cone shape with holds the heat in a little longer.
- More research is needed to see if adding an insulated wrap to the pans left in the cookers would hold the heat longer.
- This paper reflects the evaluations of a previous paper by Dane Dormino and Steve Jone[6].
- Both the Fun-Panel and the Copenhagen Solar Cooker perform well enough to cook and food chosen and in very similar amounts of time.

REFERENCES:

[1] Clausson. SL Copenhagen Solar Cooker inventor, 2009 Author of this paper
[2] Tan, T. Fun-Panel Solar Cooker construction plan July 2008 www.freewebs.com/sunnycooker.
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[4] Bigelow, A PEP ASAE S580.1 protocol solar cooker performance testing unit.
[5] https://hackaday.io/project/8796-pure-thermal-1-development-board
[6]..http://solarcooking.org/research/Dormio-report.htm

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