SHE Technical Report no. TR-10

Procedure for determining the intercept area of a solar cooker

Paul Arveson

Director of Research, Solar Household Energy, Inc.

June 7, 2017

Citation: Technical Report no. TR-10, Solar Household Energy, Inc., (Jun 7, 2017)

Solar Household Energy (SHE) strives to unleash the potential of solar cooking to improve social, economic and environmental conditions in sun-rich areas around the world. SHE Technical Reports are intended for use within the solar cooking community, for the rapid dissemination of findings related to solar cookers. They may contain information that is based on limited data, and/or conclusions and recommendations that are solely the opinions of the author, not of the organization. Please contact the author for further correspondence.

Procedure for determining the intercept area of a solar cooker

Paul Arveson
Solar Household Energy, Inc.

Introduction

Many solar cooker power measurement protocols, such as the ASABE S.580.1 standard (1), require a load that depends on the reflector area (in this case, 7 liters of water per square meter of reflector area). Therefore (although unstated) the first step in the protocol is to measure this area, in order to calculate the required load. The following steps are suggested to obtain this measurement.

In some cases, as for a box cooker and reflector with simple geometry (as shown in the ASABE S.580.1 standard), the intercept area is calculated as the apparent width times the apparent height in a plane perpendicular to the sunlight direction. For a circular parabolic reflector, the intercept area is the area of the circle, minus any sections without reflectors. In these cases, the calculation of reflector area is straightforward.

In other cases, such as for panel cookers or offset parabolic reflectors, the shape is complex and not easy to measure.

Procedure

To provide calibrated area measurements, first construct a white, 1 square meter frame. You can use 1-inch molding strips painted white. Put the four corner screws in the frame at exactly 1 meter apart, and paint their heads black. They will be used for the measurements. Also, to maintain a square, you should add angled pieces at the corners. Make sure everything is square using a carpenter's square. (Assemble with wing nuts to allow easy removal for shipping, if desired).

Although optional, it may be convenient to level the solar cooker base using a "tilt table" consisting of two sheets of ½-inch plywood, about 1 meter square each, hinged together at the front edge and painted black.

Select a location to photograph the cookers at a distance that is large compared with the width of the solar cooker, to avoid parallax errors. This will probably be on the roof of a house or a balcony. It should be at least 10 meters away.

Mount a digital camera there. Use a good high-resolution camera, not a smart phone, if available. Using the tilt table and an assistant, take photographs at several angles in order to determine the angle of maximum area of the reflector.

Set the cooker on the ground (or on the tilt table). Set the square meter frame next to or right behind the cooker. Here is an example of how several cookers were arranged for measurements from a house roof:

You will need to include the 1 square meter frame in your photo as a calibration. Zoom in close to get a big image, but include the frame in the image.

Transfer the files to a computer.

3. Measure the reflector area

Using a Windows PC, download and install the **ImageJ** program from:
https://imagej.nih.gov/ij/

Install it in Program Files (x86).

First identify the folder where your image photos are stored.

Start the **ImageJ** program.

File - open - select an image to measure.

Select the tool from the little icon menu. You usually need the polygon tool.

Draw an outline around the square with the polygon tool. Make sure to close the polygon with a double click.

Analyze - Measure

This will open a little window that shows a number. This is the area in pixels. Write it down.

Edit - Selection - Select none. This will clear the polygon you drew. Repeat the measurement a few times.

Then open the program again to measure the reflector area.

Draw a polygon around the reflector.
Analyze - Measure. Write down the result. Repeat a few times.

Analyze – Summarize. This will give the mean of your measurements. Write it down.

Get the mean of both sets of measurements. The SD should be less than 0.5% of the mean if you did good measurements.

Divide the reflector result by the square result to get the area in square meters.

Preliminary Area Measurements of Some Solar Cookers

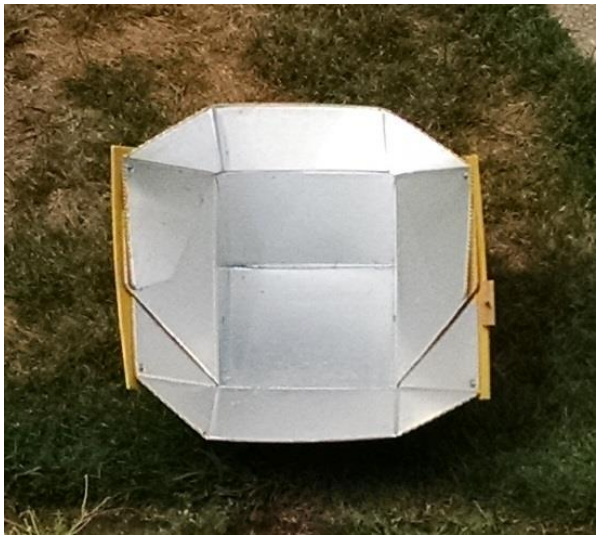
These are measurements based on photographs taken at normal incidence to maximum area; analyzed with *ImageJ*. Note: For some types of solar cookers, some non-reflective parts may extend beyond the reflector area, and hence increase size and weight of the device. This is a kind of "inefficiency" and should be kept to a minimum, because this adds to the storage and shipping space requirements.

For the measurements below, the various solar cookers were lined up and a square meter frame was placed across the solar cooker to provide a calibration (the screw heads at the corners of the square are exactly 1 meter apart). Then photographs of the cookers were made at a long distance normal to the square.

HotPot:
Zenith angle: approx.. 45 deg.
Calibration: 1 sq. m. = 346400
Run 1: 0.3325
Run 2: 0.3321
Average: 0.332 sq. m.
Load: 2.324 liters

Solavore Sport (with reflectors):
Zenith angle: TBD
Calibration: 1 sq. m. = 228500
Run 1: 0.4326
Run 2: 0.4252
Run 3: 0.4252
Average: 0.429 sq. m.
Load: 3.003 liters

Repeated measurement:
Calibration: 1 sq m = 927370
Run 1: 0.4301
Run 2: 0.4286
Average: 0.43 sq. m.
Load: 3.01 liters



All-Season Solar Cooker 1.0: (camera is slightly off axis, about 20 deg.)
same calibration as for Solavore above
Zenith angle: TBD
Run 1: 0.3396
Run 2: 0.3378
Average: 0.339 sq. m.
Load: 2.373 liters

All-Season Solar Cooker 2.0:

Average of 4 runs: 0.412 sq. m.
Load: 2.886 liters

Solar Clutch "Polyfurnace"
same calibration as above
Zenith angle: 50 deg.
Run 1: 0.4945
Run 2: 0.4957
Average: 0.495 sq. m.
Load: 3.45 liters

Haines Solar Cooker reflector:
Vertical angle: 30 deg.
Run 1: .3634
Run 2: .3497
Average: 0.35 sq. m.
Load: 2.45 liters

These preliminary measurements will be repeated to check as time permits. Measurements of reflector area of other solar cookers will be compiled and reported as they are made available.

Conclusions and Recommendations

Reliable and consistent reporting of solar cooker power and efficiency depend on use of a standard protocol, which is provided by the open source ASABE S.580.1 standard. Correct use of this protocol in turn prescribes measurement of the intercept area of the solar cooker. This measurement in turn requires determination of the vertical and horizontal angles of maximum power of the solar cooker. For some designs with simple shapes, these angles and areas may be calculated from the geometry, by inspection. However, for many designs, these values are not obvious and experimental methods are needed in order to measure them directly. Such methods have been outlined above.

In the future, it is hoped that all solar cooker manufacturers will make an effort to provide these parameters as part of the specifications of their products. This will allow consistent power measurements to be made at testing centers, and fair comparisons of all products to be reported. Hence it is in the best interest of the manufacturers to measure and publish this information in their product documentation.

References

1. American Society for Agricultural and Biological Engineers ASABE S.580.1, “Testing and Reporting Solar Cooker Performance”, Nov. 2013

2. National Institutes of Health, “ImageJ”, https://imagej.nih.gov/ij/