Performance Evaluation Process (PEP) for Solar Cookers

Alan Bigelow, Ph.D.

Science Director / Representative at the United Nations

Solar Cookers International, New York

Contact: alan.bigelow@solarcookers.org

SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

Aperture of a solar cooker

(inspired by Bernhard S. Müller)

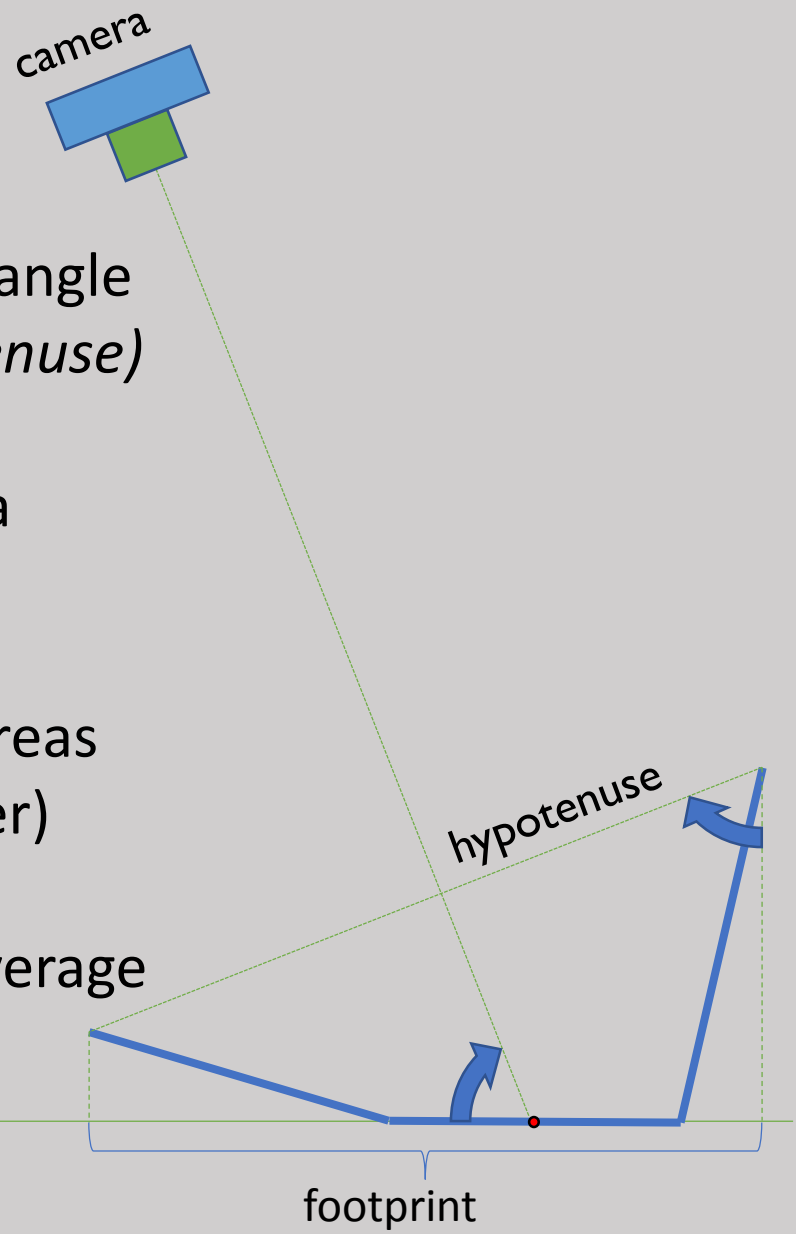
First determine the solar cooker elevation angle

Elevation angle = arcsin (footprint / hypotenuse)

Photograph the solar cooker with a camera parallel to the solar cooker elevation angle

Superimpose geometric shapes and sum areas (areas are scaled according to size of cooker)

Apply a trigonometric correction for the average sun elevation angle for the test date



SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

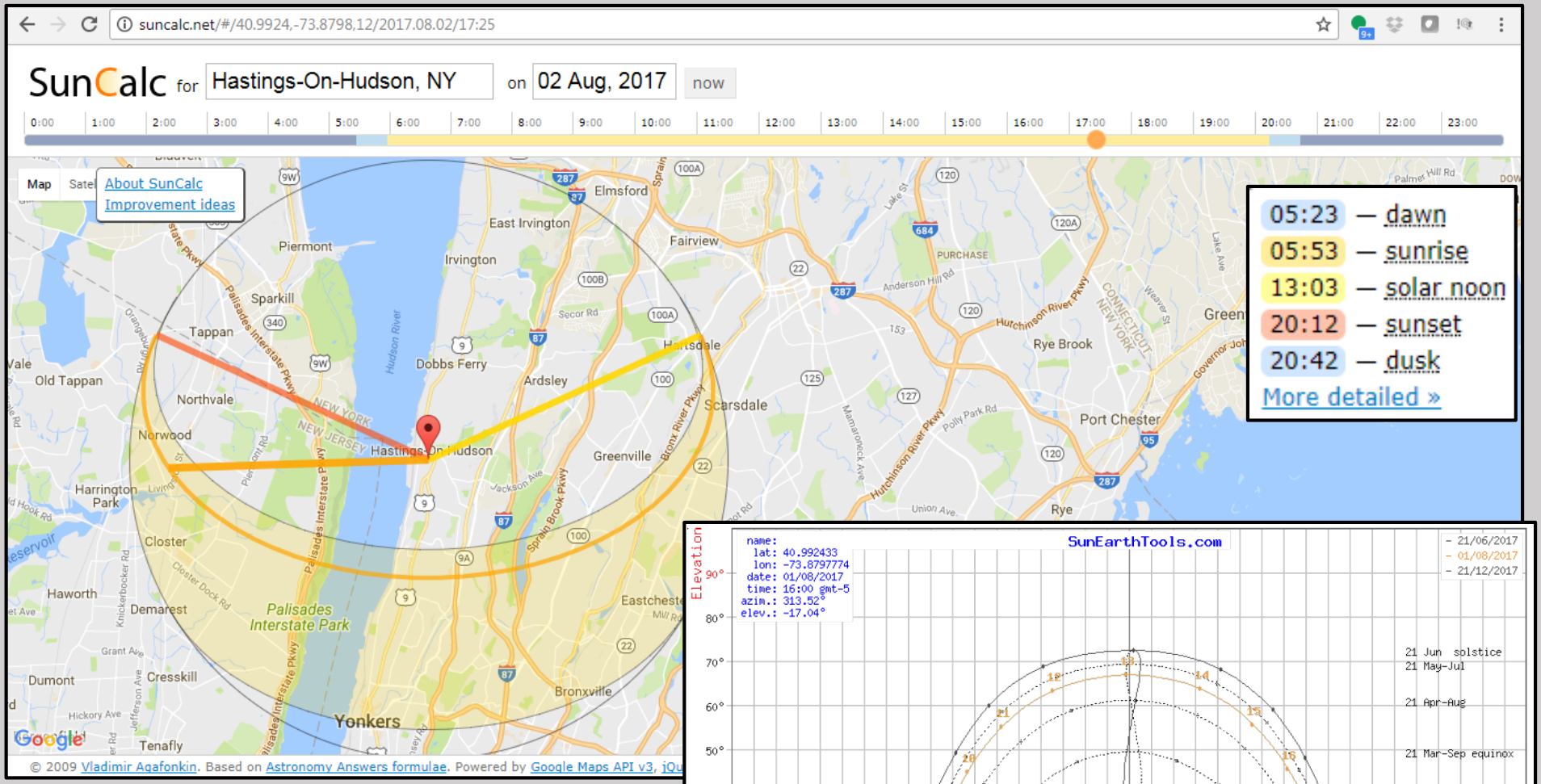
www. solarcookers.org

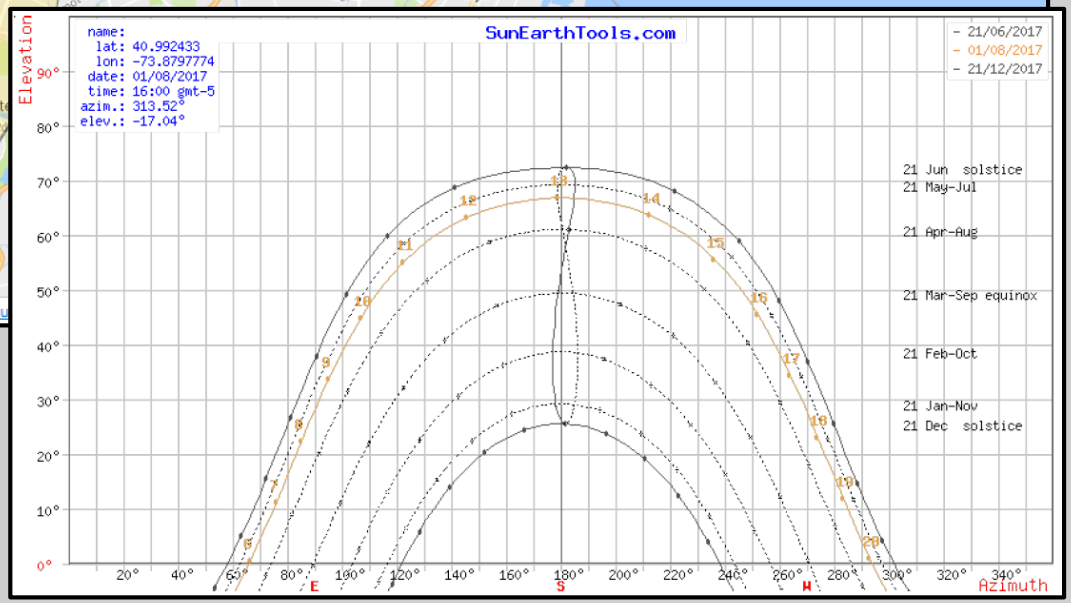
SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

www. solarcookers.org

Internet tools for finding **solar noon** and **average sun elevation angle**, anytime, anywhere





SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

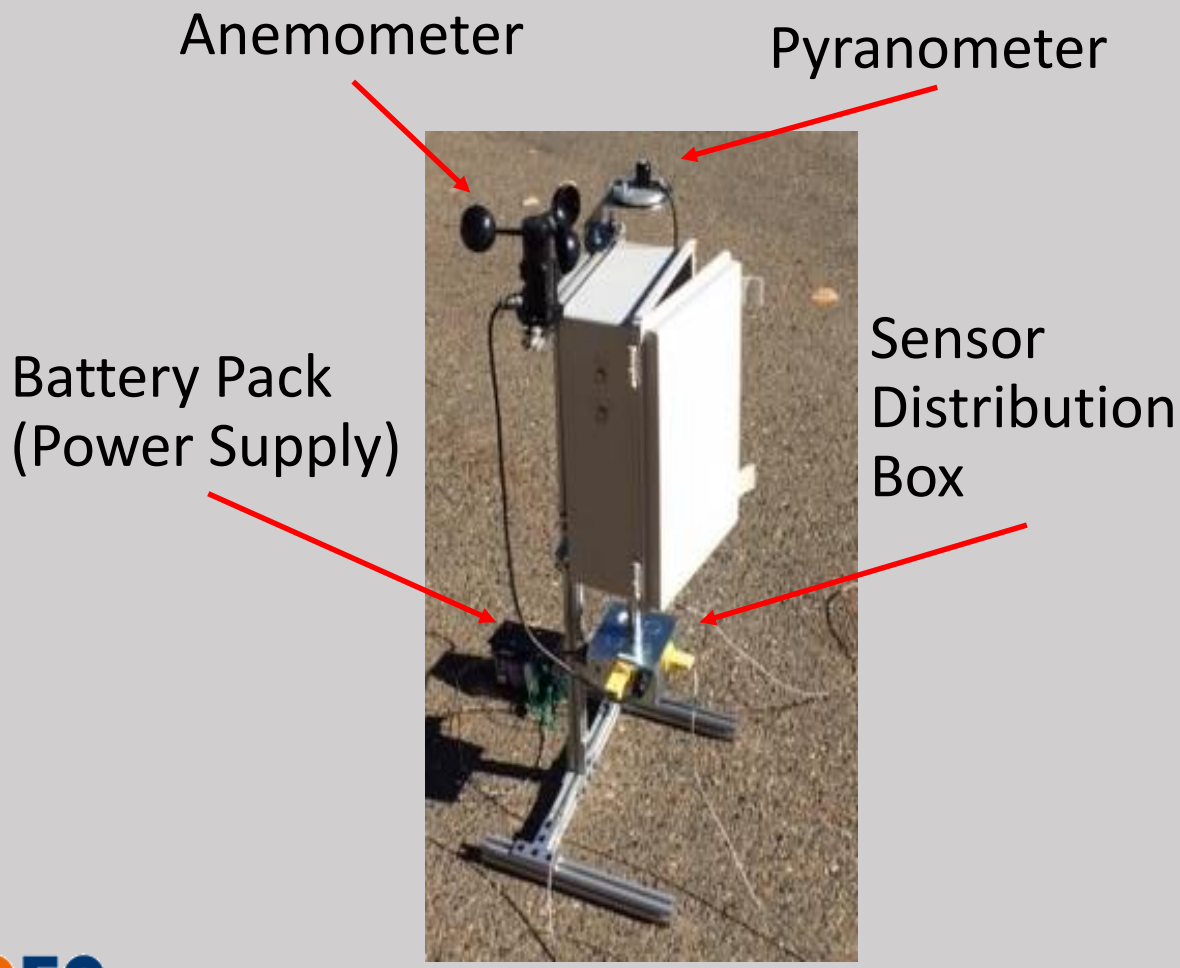
www. solarcookers.org

SCI Testing Station for PEP

Designed and assembled by

Justin Tabatchnick

Solar Cookers International

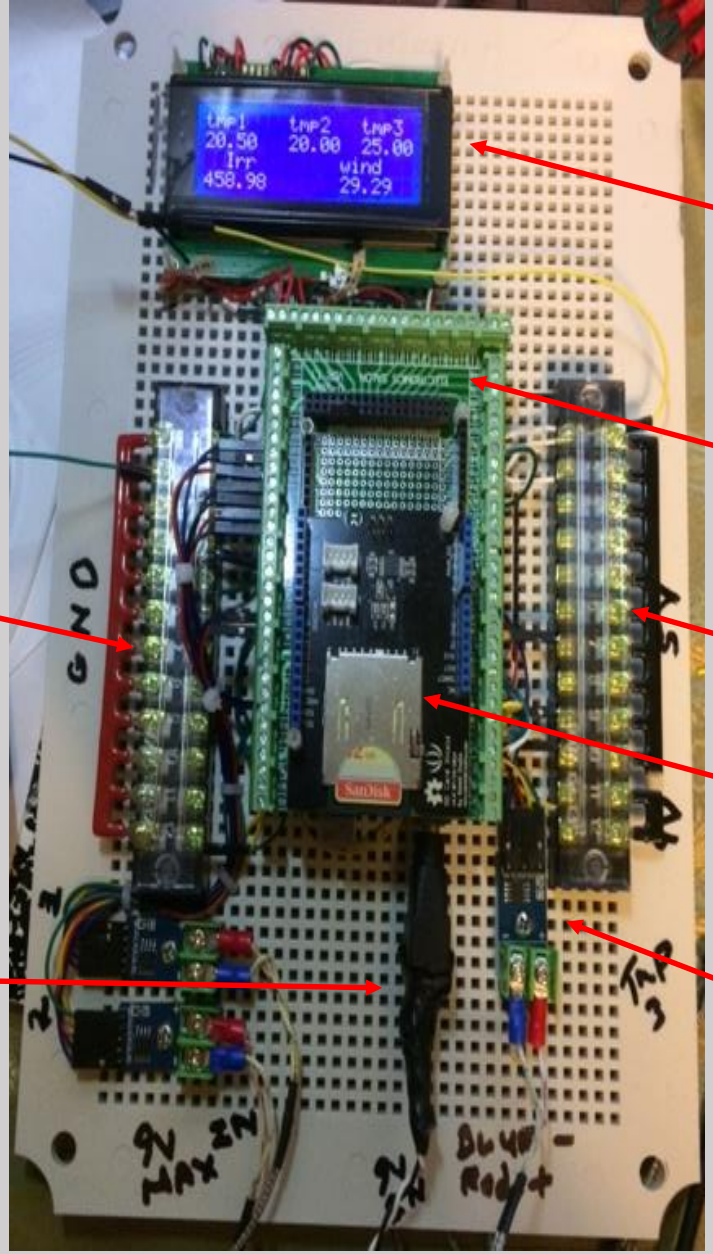


SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

www. solarcookers.org

Electronics Layout



Display

External Wiring Module

Ground Bus

Power Bus

SD module

Input Power

Thermocouple

SCI SOLAR COOKERS INTERNATIONAL

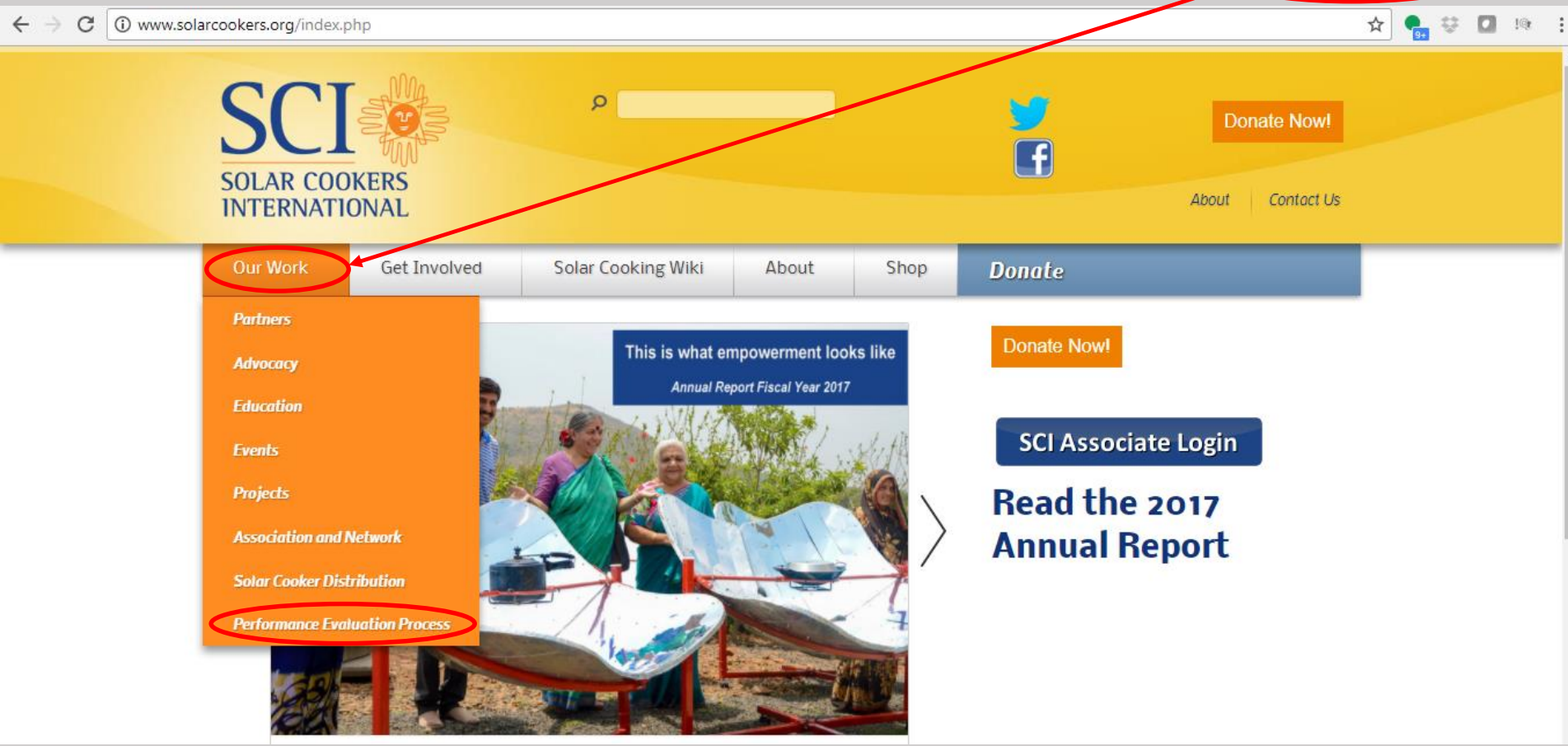
ISES International Solar Energy Society

www. solarcookers.org

Testing station design:

Portable, Robust, Relatively low cost (parts < $1,000)

Simple to use, Data storage on SD card, and Open source



Program Structure (high level)

Initialization	SD card is initialized Data File is opened for writing LCD Display is setup and indicates starting variables Config.txt variables are read into program and checked GPS is setup
Measurements	GPS satellite (global position, altitude, number of satellites, date and time) 3 temperature Wind Speed Irradiance
Calculations	Interval length calculation ADC calculations for analog measurements Temperature data smoothing per test site (3 sites, one per temperature measurement) Temperature calibration (3 sites, one per temperature measurement) Temperature average per time interval (3 sites, one per temperature measurement) Maximum wind speed per time interval Irradiance standard deviation per time interval Irradiance effective aperture calculated Average power per time interval per site Standard power per time interval per site Ambient to site temperature delta per time interval per site
Output	Space delimited text file saved on SD card Data file size is limited by size of SD card Data is time stamped Measurement intervals are clearly delineated Real time measurements (3 temp, wind, irradiance) indicated on LCD display

DataLog Example after import to Excel

time	Temp1	Temp2	Temp3	windspeed	irradiance_meas	irradiance_calc	max_wind	corr_irradiance_mean	corr_irrandiance_stdv	inter_pwr1	inter_pwr2	inter_pwr3	pwr_inter1	pwr_inter2	pwr_inter3	Td1	Td2	Td3	inter_num
95	17.64	21.72	16.87	0.59	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
2074	17.41	21.27	17.32	0.3	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
3806	16.5	21.95	16.87	0.3	966.8	1018.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
5540	17.64	22.87	17.09	0.89	966.8	1018.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
7276	6.19	29.04	17.09	0.79	966.8	1018.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
9008	22.91	8.69	17.55	0.98	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
10741	98.05	-3.43	17.32	0.98	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
12473	85.45	-3.43	17.32	0.79	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
14207	94.39	-3.43	16.87	0.59	965.58	1017.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
15941	94.39	-3.43	17.32	0.5	966.8	1018.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
17676	64	8.3	18.9	0.4	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
19410	56.5	5.9	18.8	0.3	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
21144	72	8.2	18.9	0.01	966.8	1018.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
22877	70.6	8.2	18.8	0.11	970.46	1022.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
24611	75.2	2.4	18.9	0.3	970.46	1022.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
26345	71.5	5.6	18.9	0.59	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
28078	68.9	7.4	18.9	1.08	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
29815	59.7	10.4	18.9	1.38	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
31550	64	7.9	18.9	1.77	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
33283	53.4	12.9	19	1.57	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
35017	44.8	10.4	19	1.18	965.58	1017.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
109589	53	4.3	19.3	0.11	968.02	1019.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
111322	53.2	4.3	19.4	0.01	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
113056	53.2	7	19.4	0.2	965.58	1017.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
114792	56	4.4	19.4	0.2	966.8	1018.31	NA	NA	NA	NA	NA								1
116524	56.1	9.4	19.5	0.2	970.46	1022.17	NA	NA	NA	NA	NA								1
118258	58.5	9	19.3	0.11	966.8	1018.31	NA	NA	NA	NA	NA								1
119990	46.8	13.1	19.4	0.11	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1
121725	41.4	15.6	19.4	0.2	971.68	1023.45	1.77	1005.68	14.19	1657.62	0	176.82	1153.78	0	123.07	52.35	0	12.1	1
123466	36	13.1	19.4	0.3	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
125203	50.5	12.6	19.5	0.3	969.24	1020.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
126937	58	15.1	19.5	0.3	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
128671	50.7	15	19.6	0.3	972.9	1024.74	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
130405	50.7	15.1	19.6	0.79	972.9	1024.74	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
132140	46.3	17.7	19.6	0.79	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
133875	41.3	16.1	19.6	0.69	972.9	1024.74	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
135612	42.2	13.3	19.6	0.5	970.46	1022.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2
137346	50	10.7	19.7	0.5	971.68	1023.45	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2

End of Interval 1 and start of interval 2

Interval Calculations completed

SCI SOLAR COOKERS INTERNATIONAL

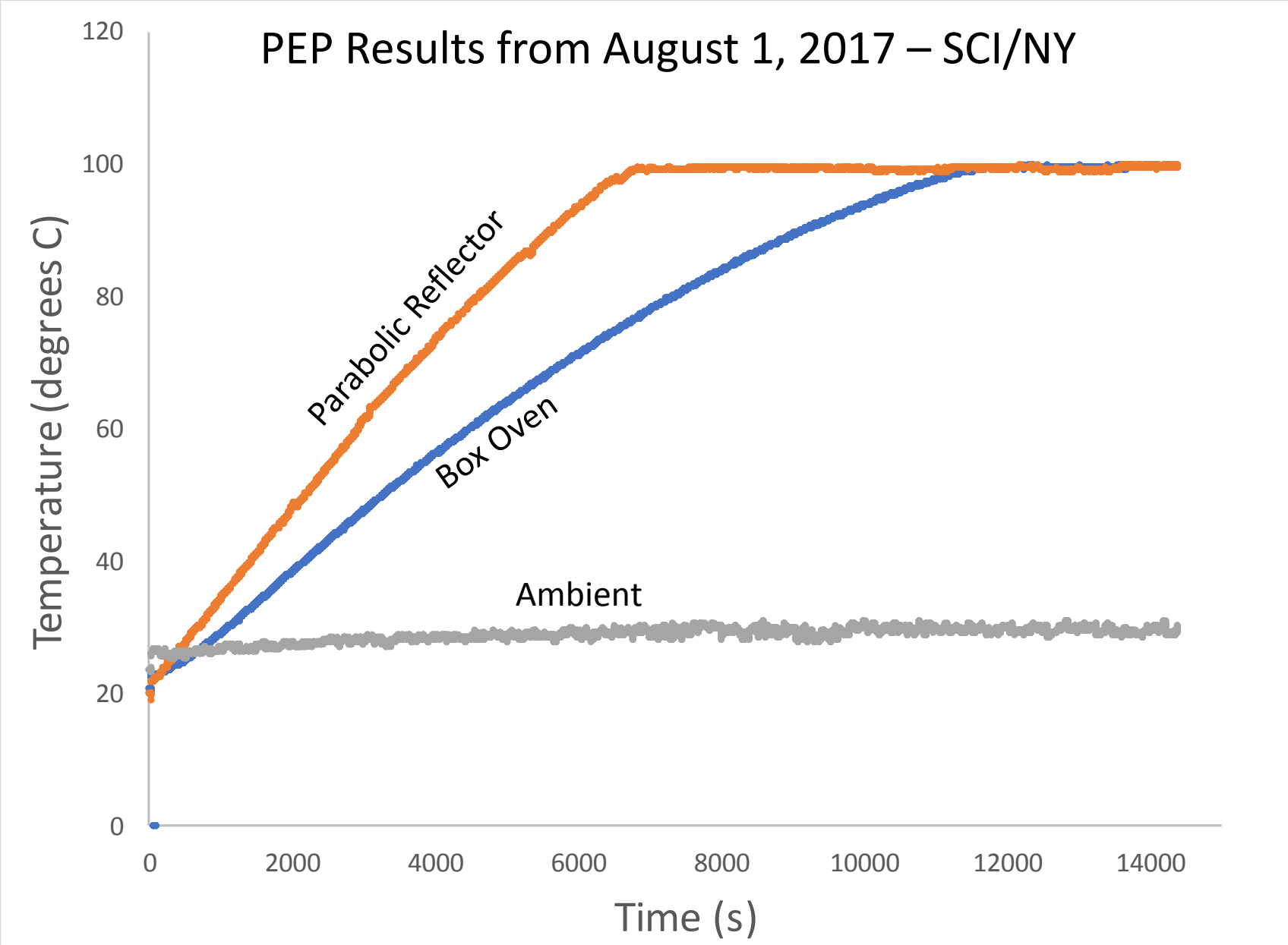
ISES International Solar Energy Society

www. solarcookers.org

SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

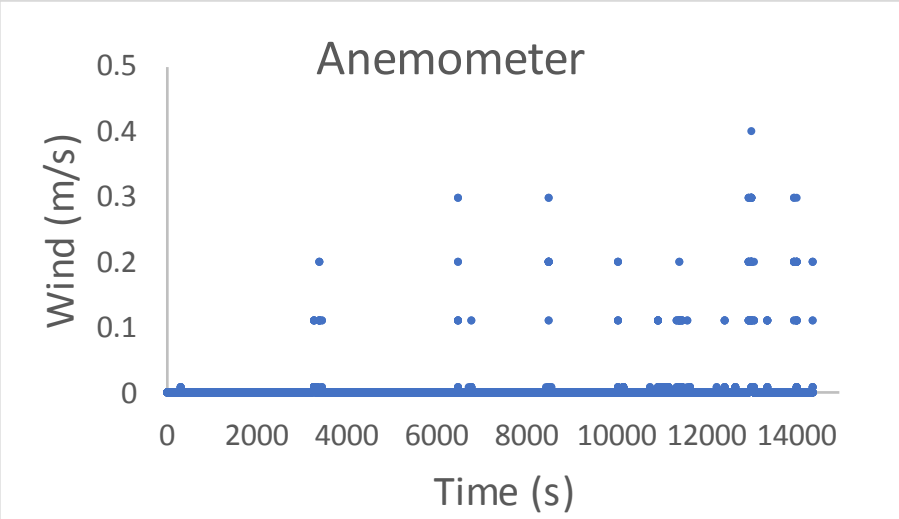
www. solarcookers.org

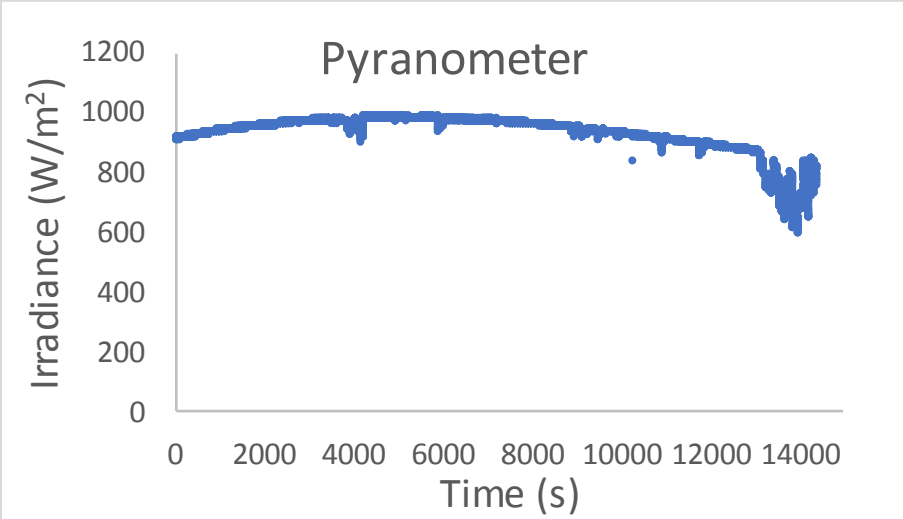


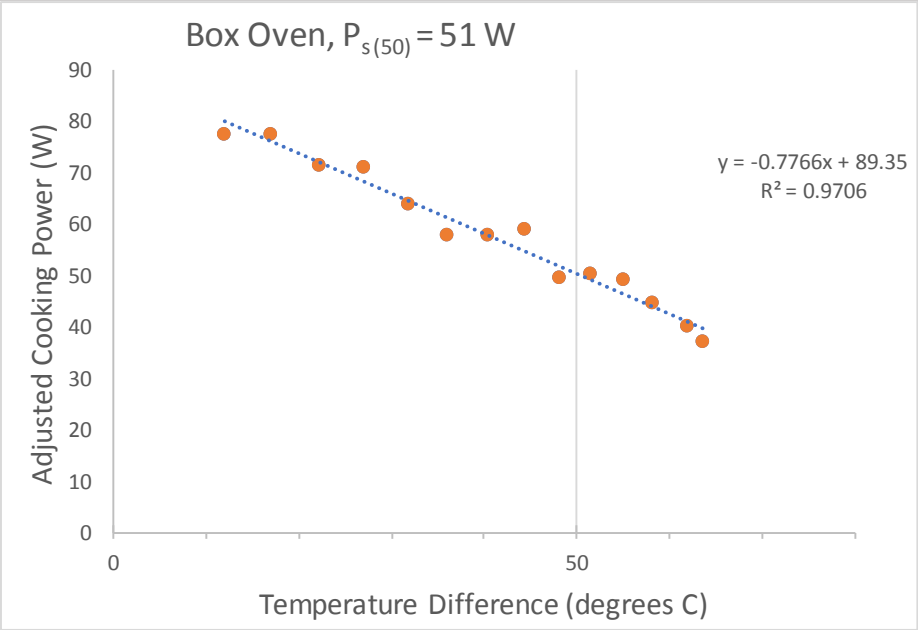
SCI SOLAR COOKERS INTERNATIONAL

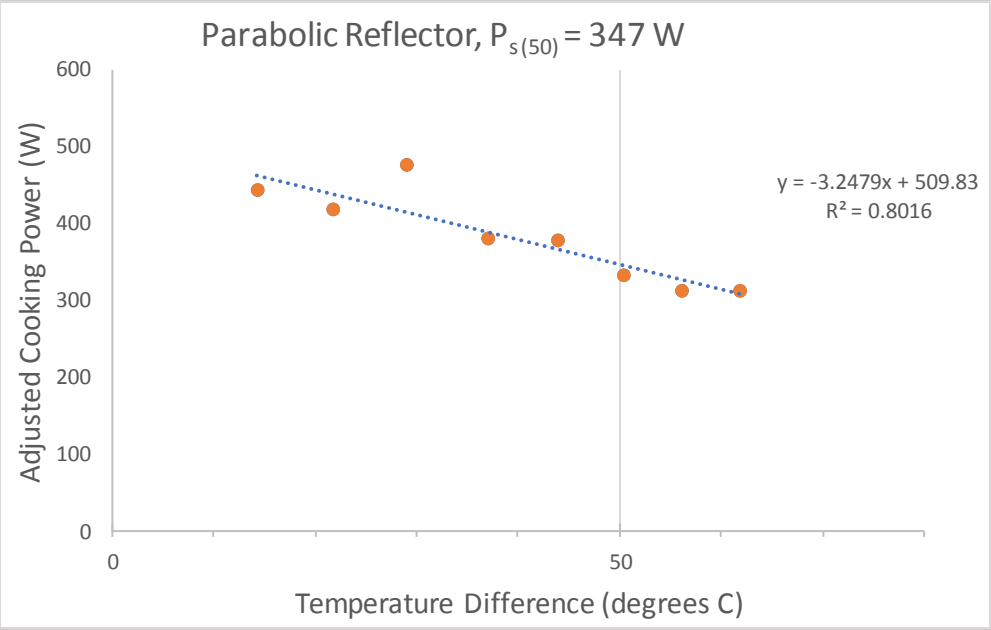
ISES International Solar Energy Society

www. solarcookers.org


Anemometer
Wind (m/s)
0.5
0.4
0.3
0.2
0.1
0
0
2000
4000
6000
8000
10000
12000
14000
Time (s)


Pyranometer
Irradiance (W/m2)
1200
1000
800
600
400
200
0
0
2000
4000
6000
8000
10000
12000
14000
Time (s)

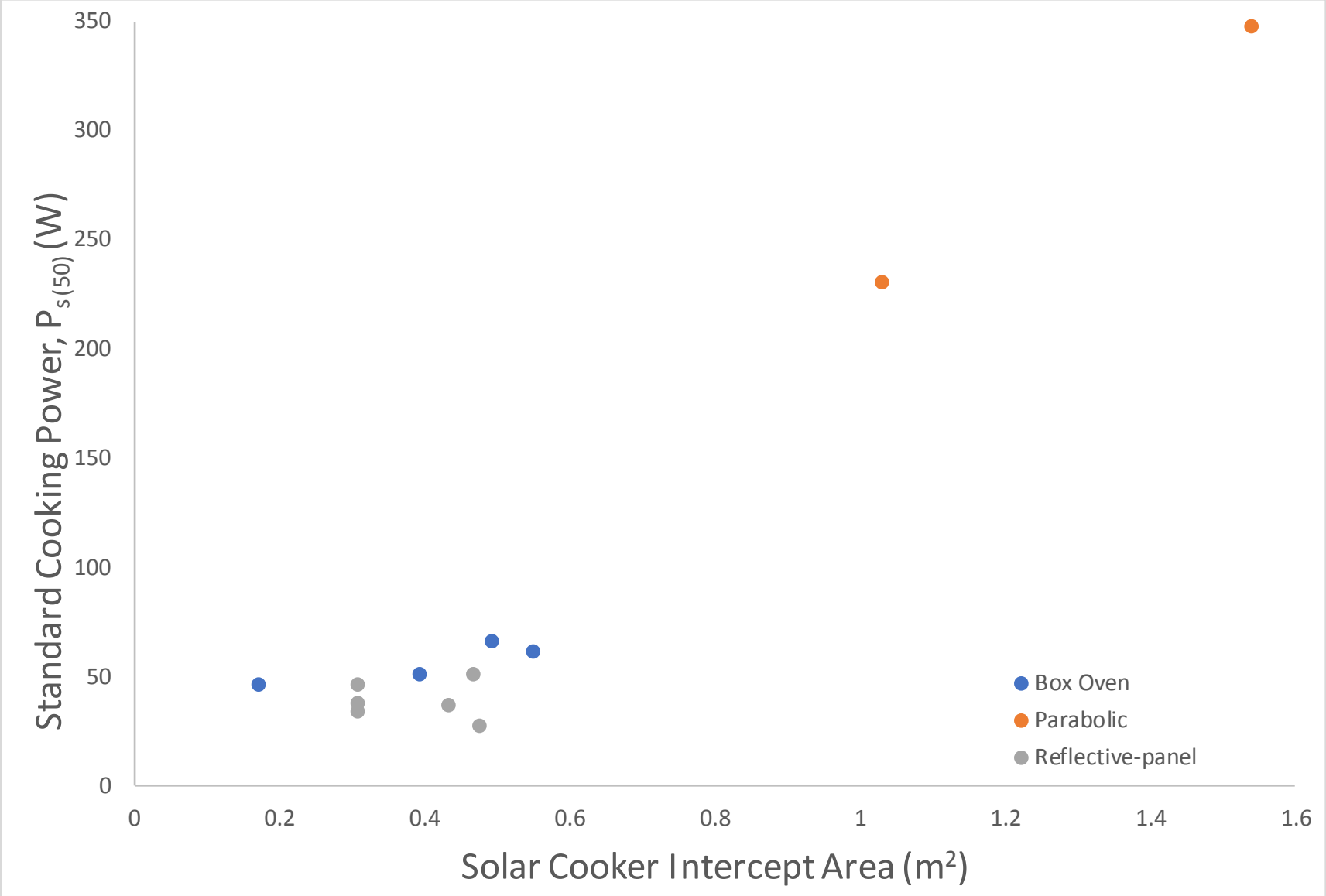




SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

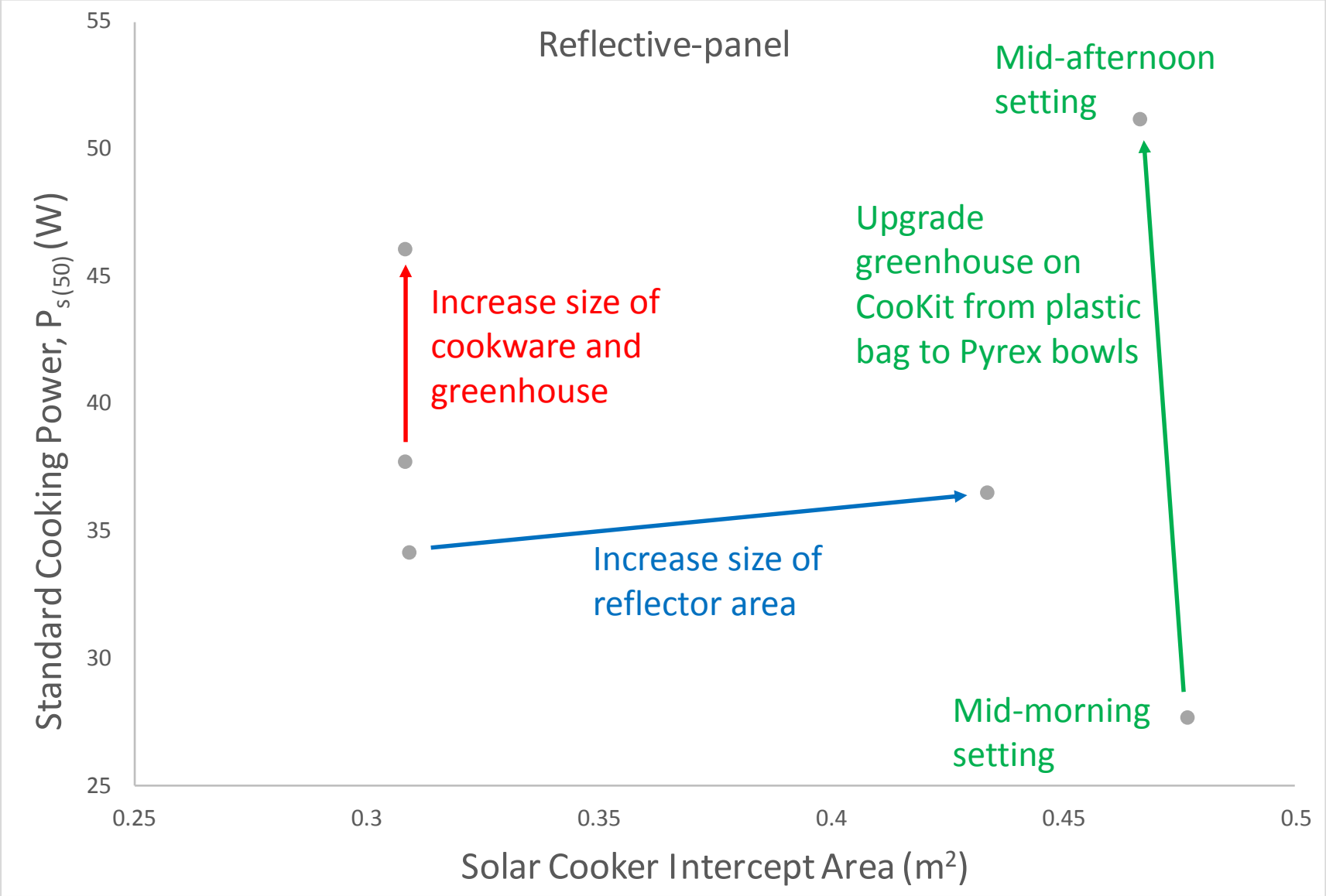
www. solarcookers.org



SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

www. solarcookers.org



SCI SOLAR COOKERS INTERNATIONAL

ISES International Solar Energy Society

www. solarcookers.org

Observations:

- Preliminary SCI PEP results suggest these average Standard Cooking Powers, $P_{s(50)}$ (W), per solar cooker type:
  - ✓ Box Oven: 56 W
  - ✓ Parabolic: 289 W
  - ✓ Reflective-panel: 39 W

- Applying these values to SCI's known global solar cooker distribution by type, this suggests a global installed solar-thermal cooking capacity of at least **377 MW**

Ongoing:

- Comparing PEP results: SCI/California and SCI/New York
- Manufacturers, please provide information about: intercept area, elevation angle, and suggested cookware
- Solar-cooking sector, please continue to post distribution data on this SCI webpage: http://www.solarcookers.org/our-work/solar-cooker-distribution/

Next Steps:

- More testing stations for additional test sites
- Develop SCI PEP web page for reporting results
- Launch SCI PEP testing centers – watch the *SCI Digest*