أعوذ بالله من الشيطان الرجيم

بسم الله الرحمن الرحيم

Performance Evaluation of Box Type Solar Cooker

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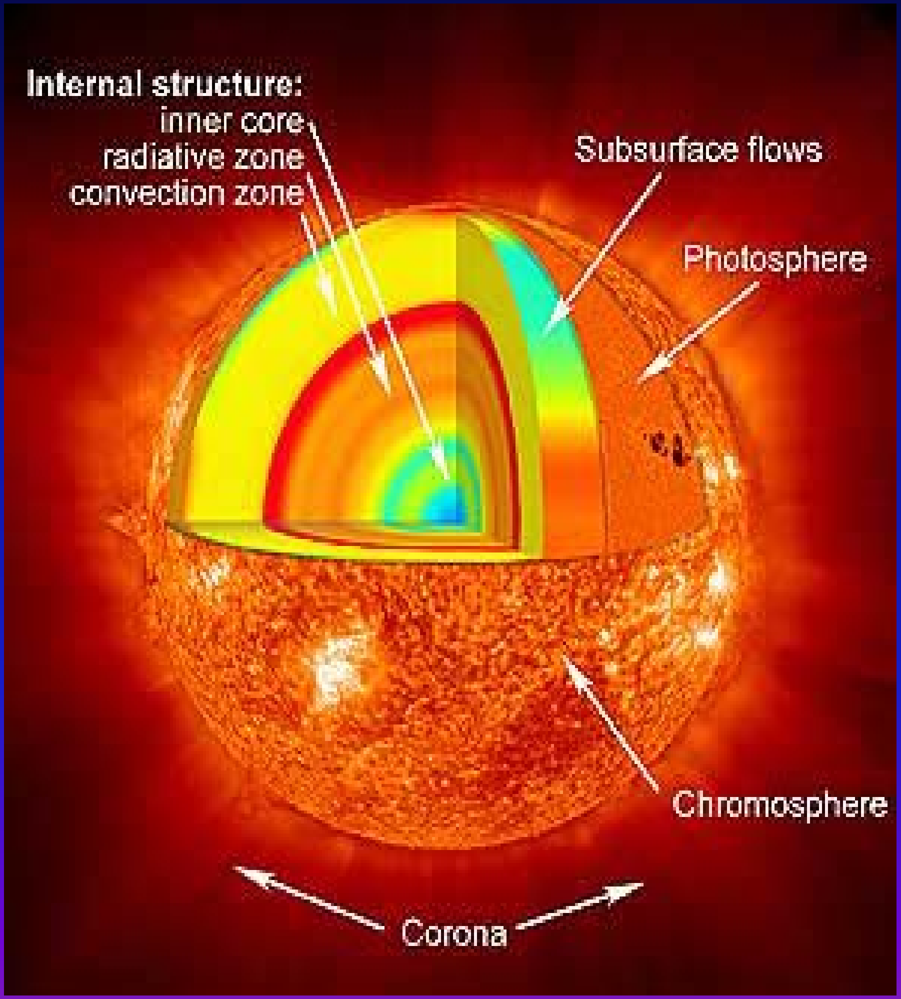
Lay out

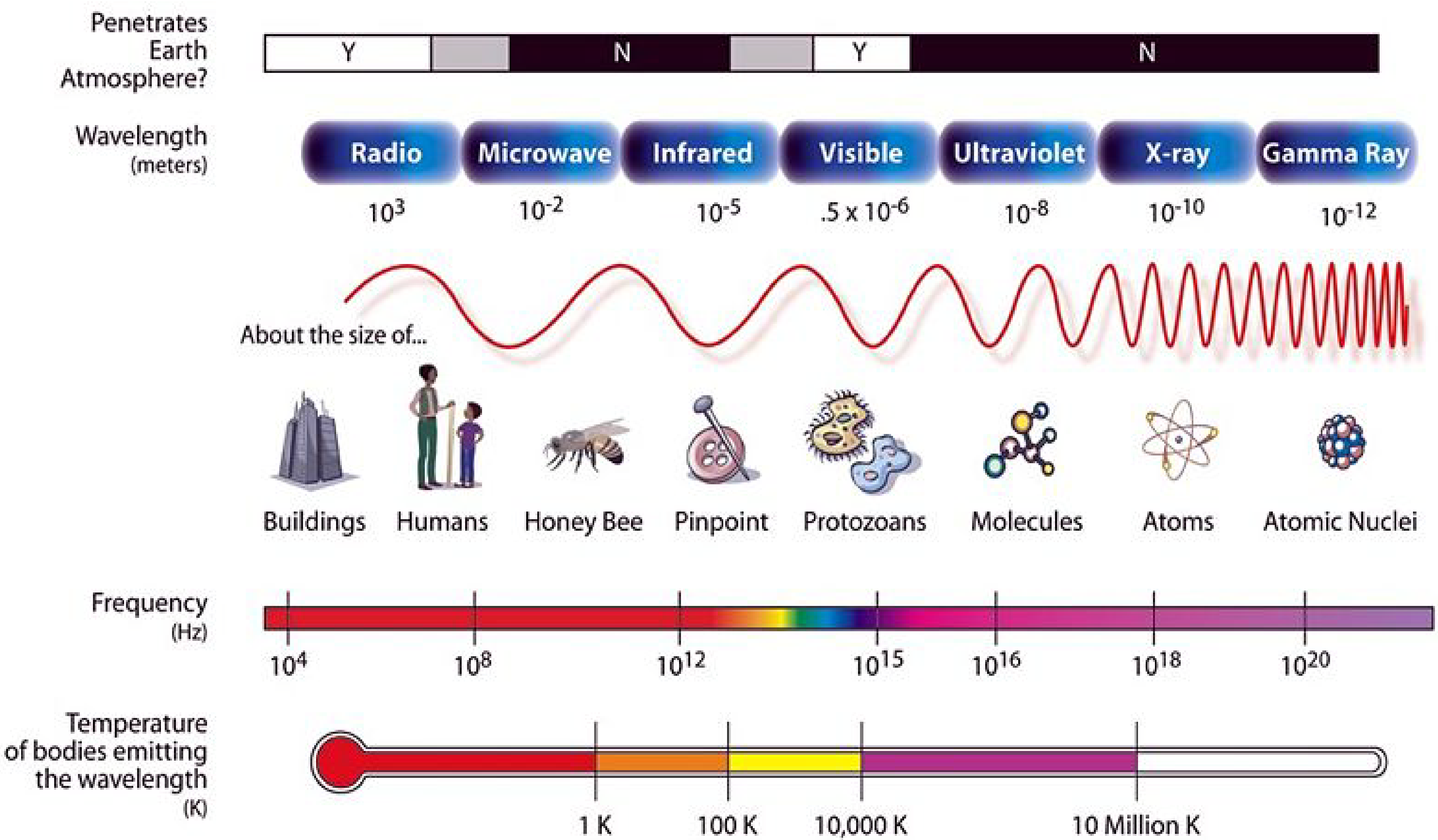
- The energy from sun
- The Spectrum of radiation from sun
- Solar box cooker simplified design parameters
- International standard protocol for performance of solar box cooker
- An indigenously fabricated solar box cooker
- Conclusion and suggestions

The Sun: A Huge Source of Energy

- Sun is composed of about 34% Hydrogen,65% Helium and 1% of other elements
- Temperature of the core of sun is about of $1.5*10^7$ K
- Nuclear fusion



THE ELECTROMAGNETIC SPECTRUM



Solar Energy! Why?

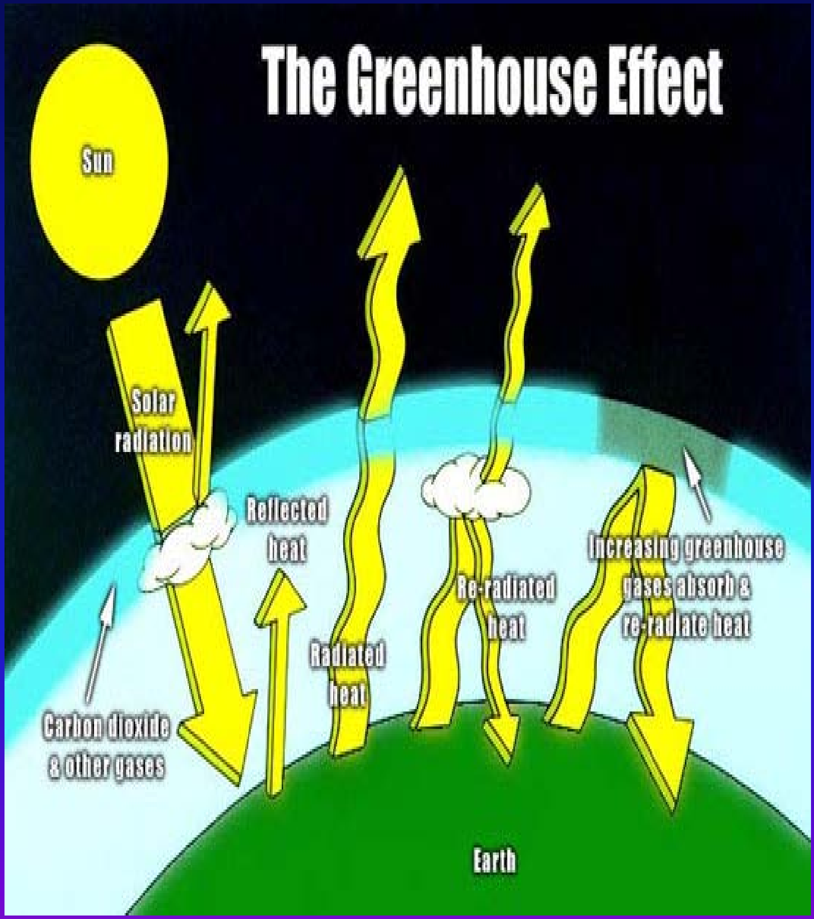
- It is Clean: the extensive fossil fuel consumption has led to some undesirable phenomena not known in human history until 1970s, such as atmospheric and environmental pollution
- No emission of greenhouse gases: global warming, greenhouse effect, climate change, ozone layer depletion and acid rains are the results of extensive use of fossil fuels
- Among other renewable energy resources (geothermal, wind, hydro and tidal etc.) the solar energy is the most abundant and more evenly distributed
- Developing countries have to deal with the lack of appropriate energy supply. Solutions used in industrialized countries are not applicable

Solar Cooking: A brief history

- Some early recorded beginnings of solar cooking in 1767: French-Swiss Physicist Horace de Saussure
- In USA, scattered documented individual efforts in 1940s and 50s, but more work started in 1970s
- Barbara Kerr of Arizona designed and developed first feasible and functional box cooker.

The Principle of Working of a Solar Cooker

- The solar cookers and ovens absorb solar energy and convert it to heat which is captured in enclosed area
- The enclosed cooker works like a green house
- Its upper cover allows visible light to pass through it
- The trapped infrared radiation emitted by the absorber surface results in increased temperature



Types of Solar Cookers

- **Solar Cookers**
  - **Concentrating (Disk Type)**
    - Parabolic
    - Cylindrical
    - Spherical
    - Fresnel
  - **Non Concentrating (Box Type)**
    - With Reflectors
    - Without Reflectors
  - **Indirect Type**
    - Steam based
    - Chemical Based
    - Organic Fluid
    - Compound Parabolic Type

Geometry of the Solar Cooker

- A SBC is an insulated box with a transparent glass cover
- Top lid with mirror booster on the inside
- Inner part is painted black
- Up to four cooking utensils

All the above parameters greatly affect the performance

Booster Mirrors

- The addition of side mirrors can increase the output of solar Flat plate collectors (at the base of SBC) to permit higher working temperature and enhanced efficiency
- Extra solar radiation can be reflected on the aperture area and thus reducing cooking time
- Cooking is possible at low ambient temperatures
- Retention efficiency (ratio of energy yield to energy reaching and absorbed by the collector) is increased
- Booster mirrors are more effective for rectangular apertures
- Cooker can be used in winter season more effectively

Glazing

- Glazing materials include glass, acrylics, fiberglass etc.
- Single pane glass is effective in warm climates and in seasonal greenhouses
- Cookers with single pane glass typically experience large temperature drifts, increased condensation and provide a minimal buffer from outdoors.

Glazing (contd…)

- Double pane glass is more efficient
- There is a dead air space between the panes which increases resistance to heat transfer.
- However a large air space can actually encourage convective heat transfer within the unit and produce a heat loss.
- The optimum value of air space is 1 to 2 cm
- Glass or other diathermanous (radiation-transmitting) material may be used to transfer sun energy in to the collector/absorber plate
- Glass is opaque to the long wavelengths and transparent to the shorter wavelengths

The Absorber Tray

- It is simply a Flat Plate Collector
- A large portion of radiation falling on the surface of high absorptivity is transferred to the food to be cooked
- The absorptance of the surface for short wavelength depends on the nature and color of coating and on incident angle.
- The conventional materials are copper, aluminum and steel painted with dull black paint.
- Fins on the absorber plate have been found to increase the efficiency resulting in 12% reduction in cooking time.

Insulation

- Optimized value of insulation thickness is 7.5 cm.
- Materials: glass-wool, paper rolls, hay, straw, foam, fiber glass, cork board, cotton, sawdust etc. have thermal conductivities 0.03-0.06 W/m/K
- Materials should be dry and not to be filled too forcefully

International Standard for Testing of Solar Cookers

- Increasing awareness of the growing global need for alternative cooking fuels has resulted in an expansion of solar cooker research and development
- There are different standards used for performance evaluation but most of them are complicated and less universe.
- The protocols are usually difficult to replicate in less developed areas.
- The estimates of solar cooker performance should be consistent

Main Points of the Standard Procedure

- An international standard which was proposed at the Third World Conference on Solar Cooking (India) and reviewed by a committee of experts has been accepted world wide.
- This standard fulfills the requirements by which researchers all over the world can compare the work using a single figure representing the thermal performance of the solar cooker

The Standard

- The final statement on which the testing protocol is based is :

“ The one figure best representing thermal performance is effective cooking power, which accounts for both different cooker sizes and heat gain rates. The unit of power with which most people are familiar is the Watt. The influence test conditions have on results can be minimized if uncontrolled variables are held to certain ranges”.

The Uncontrolled (weather) Variables

- 1. Wind: The wind speed at the elevation of cooker being tested should be less than 1.0 m/s
- If wind speed is more over 2.5 m/s for more than 10 min, discard the test data

  (Reason: heat loss is strongly influenced by wind velocity, wind velocity less than 1 m/s help to maintain a heat loss coefficient close to natural convection loss coefficient)

For higher speeds use wind shelter but do not intercept the solar radiation

Uncontrolled variables…

- Ambient Temperature: Conduct solar cooker test when ambient temperatures between 20-35 celcius.

  Reason: ambient temperature extremes in one location may be difficult to replicate at another location. Cooking power is influenced by temperature difference.

  A range of 15 C keeps variability moderate yet allows test to be conducted for almost half a year

Uncontrolled variables…

- Pot Contents Temperature: Record data for water temperatures between 40 and 90 C.

  Reason: at lower end the pot contents must be above ambient for there to be heat losses,

  at higher end: the boiling temperature varies with elevation, and latent heat of vaporization severely depresses the apparent cooking power as water reaches boiling.

Uncontrolled variables…

- Insolation: Available solar energy is to be measured in the plane perpendicular to direct beam radiation (i.e. the maximum reading) using a radiation pyranometer

  Variaton in measured insolation greater than 100 W/m2, in 10 min. interval, or reading below 450 W/m2 or above 1100 W/m2 are invalid.
- Reason: Readings within 65% of the standard insolation level (700 W/m2) reduces error introduced by adjusting cooking power for available insolation.

Uncontrolled variables…

- Variation in solar angle: The test should be conducted between 10:00 and 14:00 time.
- Reason: The solar angle is somewhat constant at midday, and difference between insolation measured in the plane of the cooker aperture and plane perpendicular to the direct beam radiation will vary least

Controlled Variables...

- Loading with water: 7 kg/m2 of the intercept area distributed evenly between pots
- Intercept area is the sum of reflector and aperture areas projected onto the plane perpendicular to direct beam radiation.

  Reason: Water closely resembles food in density and specific heat, but is more consistent, intercepted radiation is best measure of available energy, thermal performance is sensitive to loading rates

Controlled Variables...

- Tracking: Every 15 to 30 minutes or when shadow appears on absorber plate.
- Temperature sensing: Thermocouples should be used, because of accuracy, low cost and rapid response

  Aluminum pots to be used, thermocouple junction immersed in water in pots 10 mm above the post bottom at the center.

  Reason: proper thermocouple placement can minimize errors, the thermal capacity of aluminum is insignificant compared to the water

Test Protocol

- Recording: Average water temperature of all the pots in one cooker recorded every ten minutes, to one tenth of the degree C. The solar insolation and ambient temperature recorded as frequently.
- Cooking Power: Multiply the change in water temperature with mass and specific heat and divide by time (600 seconds) to get cooking power for each interval in watts

Test Protocol…

- Interval averages: the average insolation, average ambient temperature and average pot content temperature are to be found for each interval
- Standardizing cooking power: Cooking power for each interval to be corrected to a standard insolation of 700 W/m2 and dividng by average insolation recorded during the corresponding interval. (This will facilitate the comparison of results)

Test Protocol…

- Temperature difference: Ambient temperature for each interval is to be subtracted from the average pot contents temperature for each corresponding interval.

  Reason: heat loss increases with the difference in temperature between the interior and exterior of cooker

Test Protocol…

- Plotting: The Standardized cooking power against temperature difference for each time interval
- Regression: A linear regression of above (at least 30 points)

  Intercept gives the cooking power. Slope gives variation with temperature

  Single measure of performance: Compute SCP for temperature difference of 50 C.

Performance Evaluation of Solar Cooker

- External box. Chip board of thickness .75″.
- 24-gauge galvanized iron sheet.
- Internal Box.
- 24-gauge copper sheet painted black
- An ordinary transparent glass of 3mm thickness.
- Dimensions 24″ × 24″ × 10″)

Performance Evaluation of Solar Cooker

- Front reflector

  length × width

  (0.6m) (0.47m)=0.282m^2

- Left side reflector

  length × width

  (0.35m) (0.28m)=0.10317m^2

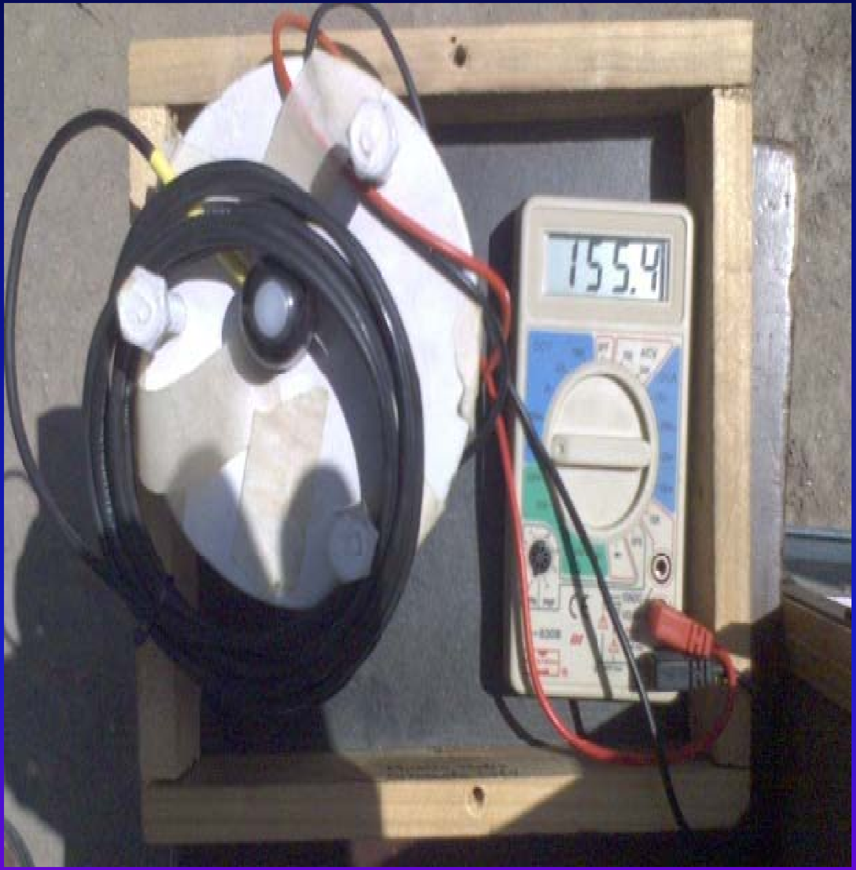
- Right reflector

  length × width

  (0.249m) (0.248m)=0.061752m^2

- Total sum is=(0.4469m^2).

Pyranometer and Thermocouple



Performance Evaluation of Solar Cooker

Time H:min	Ambient Temp (^0C)	Avg. water Temp (^0C)	Average Insolation W/m^2
10:02	36	42.35	806.25
10:12	38	66.65	815.5
10:22	38.75	76.1	846.25
10:32	39.25	81.45	847.25
10:42	39.75	85.8	861.25
10:52	40	88.95	877.5
11:02	40	92.45	960.25
11:12	40	81.65	437.5
11:22	39.5	73.4	717.75
11:32	40	84.65	737.25
11:42	40	92.35	887.5
11:52	40	95.1	860.75
12:02	41	97.9	883.25
12:12	40.25	96.85	900.5
12:22	40.5	93.7	891.5
12:32	41	93.35	867.5
12:42	41	94.4	864.5
12:52	41	94.4	863.75
1:02	41	95.4	853.5
1:12	41	96.3	861

Adjusted Cooking Power

- Using the data and following the protocol mentioned above, the adjusted cooking power was 105 Watts.
- $P = 105 - 1.69\ \Delta T$
- Without mirrors the cooking power was 83 Watts
- (The fabrication cost of this oven is Pak Rs. 5000 to 6000)

Conclusion

- The international standard for evaluating the performance of box type solar cooker is useful to evaluate the relative performance of different designs.
- The resulting solar cooker power curve is a useful device for interpreting the capacity and heat retention ability of a solar cooker.
- The cooking power curve is independent of location and date provided that protocol is followed.

Suggestions and Future Prospects

- The solar box cookers can be effectively used in wide regions of world.
- In Pakistan, there is a great potential for the use in most parts of the country.
- Particularly useful in case of calamity, like earthquake and floods

Thanks for listening