Optics for Energy
ECE 5962/6962
MSE 5050/6050

Rajesh Menon
http://lons.utah.edu/

Where: WEB 1460
When: Tues/Thurs 12:25 - 13:45

Office Hours: Wednesdays 1:30-2:30pm in MEB 2256

Textbook: Class notes, reading material & online resources will be provided.

http://lons.utah.edu/

Optics (Science & engineering of light) applied to efficient Generation & Utilization of energy

Learning Objectives

* Learn the fundamentals of optical design & engineering

* Apply our knowledge to innovate (create new ideas that are practical, high impact & commercializable)

* Be aware of emerging technologies over the horizon

Topics of interest

Optical Design (non-imaging optics)

Thermodynamics of solar-thermal & photovoltaic devices

Novel approaches to light management in photovoltaic devices

Emerging areas of relevant technology

Grading

30% Mid-term exam on October 3 in class

Team-based projects

40% Four team presentations in class [First one on September 24]

30% Team submission to CU Cleantech new business challenge [Due December 13]

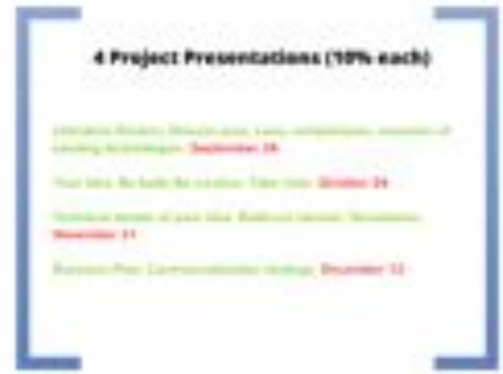
Tentative Schedule

http://lons.utah.edu/

Projects

Teams assigned by me

Project topics



Project Deliverables

Team presentations

National Clean Energy Business Plan Competition

Project Topics

solar cooker
solar water pasteurization
solar water desalination
solar refrigeration
Daylighting
solar water-heating
Photovoltaics

Others (you propose).

Cost
Durability
Storage (space requirements)
Cultural factors
Ease of use
Climate conditions

4 Project Presentations (10% each)

Literature Review; Discuss pros, cons, comparisons, overview of existing technologies. **September 24**

Your idea. Be bold, Be creative. Take risks. **October 24**

Technical details of your idea. Build-out (demo). Simulations. **November 21**

Business Plan, Commercialization strategy. **December 12**

National Clean Energy Business Plan Competition

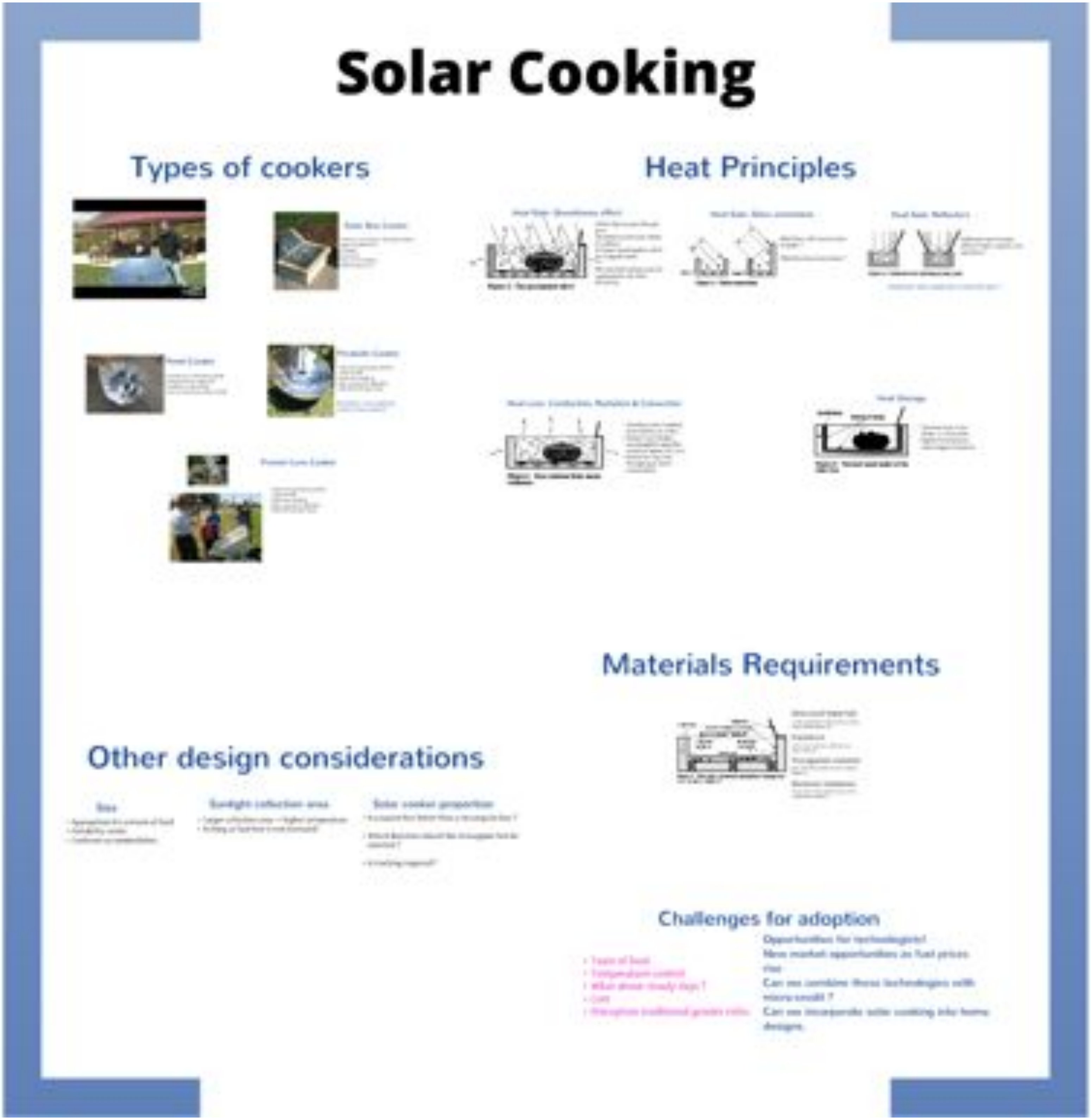
* US Dept. of Energy sponsored. Finalists present in D.C. Significant prizes & resources to launch startups.

* Regional Competition: CU Cleantech New Venture Challenge (http://nvc.cucleantech.org)
  - Submission deadline March 4, 2014. But our class deadline is Dec. 13, 2013.
  - Submission materials:
    - Executive Summary (2 pages): Opportunity, go-to-market strategy, market & industry analysis, technical product description, risks, economics & team.
    - 5-minute Video pitch: Be creative. Can be product demo, elevator pitch, slide presentation, etc.
    - IP declaration: Note any intellectual property that you think can be patented.

  - First-round winners present in Boulder, CO. Monetary prizes & support from National Renewable Energy Laboratory.

Why technologies for the developing world ?

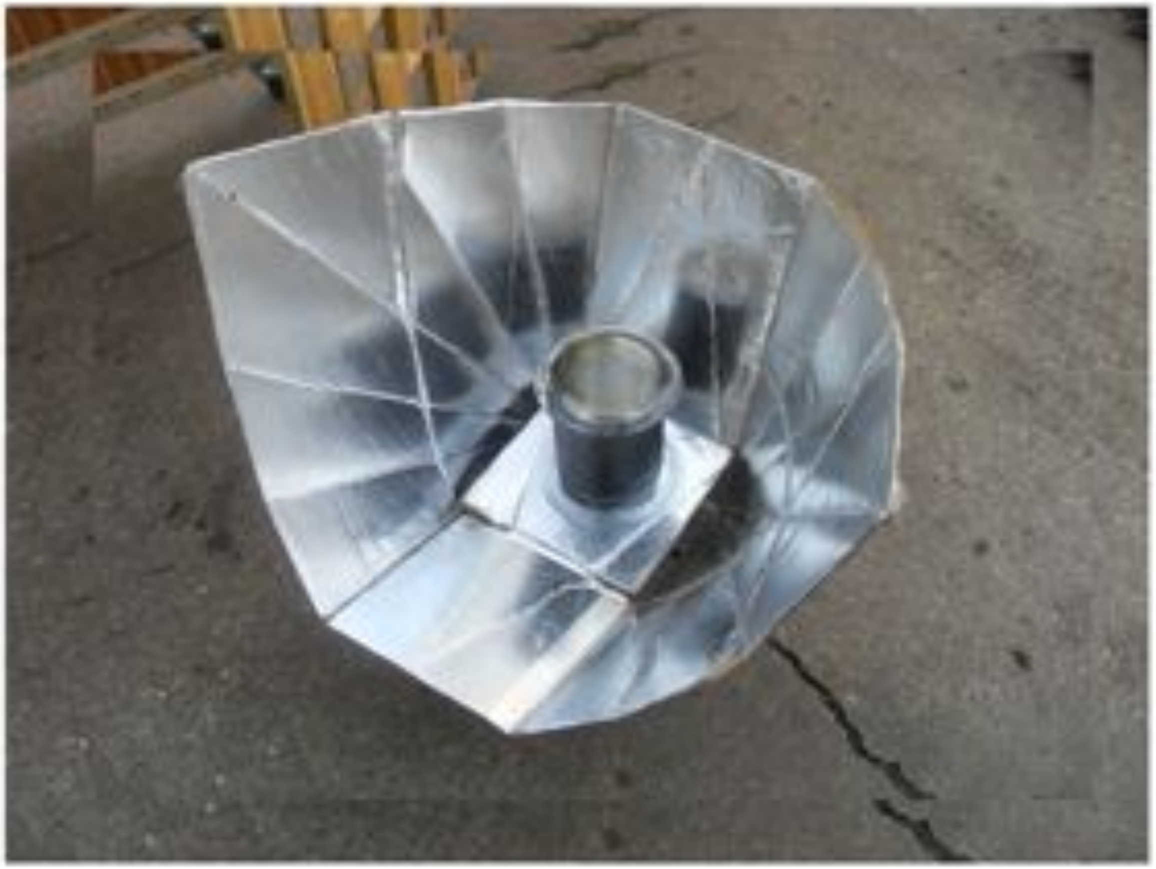
- Abundant solar resources with little access to infra-structure (electric grid, roads, etc.).
- Biomass resources are fast depleting & also contribute to CO2 emissions.
- Huge impact possible: ~ 1 out of every 4 people have no access to electricity.
- Market Opportunity to build sustainable technological solutions.


Solar Cooking
Types of cookers
Heat Principles
Materials Requirements
Other design considerations
Challenges for adoption


YouTube

Solar Box Cooker

Inner box enclosed in clear glass/plastic
Simple construction
Reflector
Insulation
Slow, even cooking
Safe & easy to use



Panel Cooker

No inner box. Reflective panels.
Simplest & least expensive.
Unstable in high winds.
Doesn't retain heat, when cloudy

Parabolic Cooker

Higher temperatures possible
Cooks quickly
Needs sun-tracking
More complex & expensive
Risk of fires & eye injury

Brainstorm: how would you improve these cookers?

Fresnel Lens Cooker

Higher temperatures possible
Cooks quickly
Needs sun-tracking
More complex & expensive
Risk of fires & eye injury

king

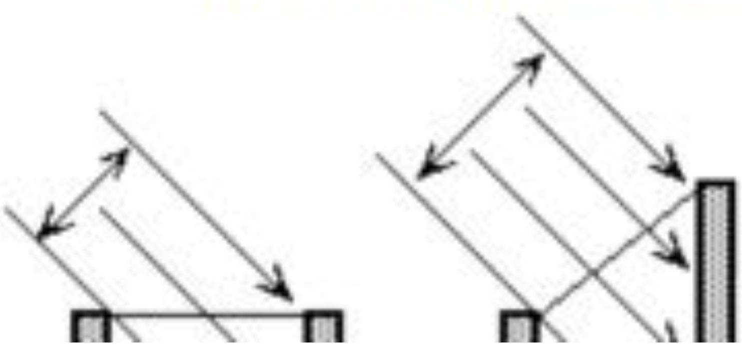
Heat Principles

Heat Gain: Glass orientation

passes through

dark pot, which

velengths, which
inside.



Which box will receive more sunlight ?

Which box has more losses ?

Heat Gain: Greenhouse effect

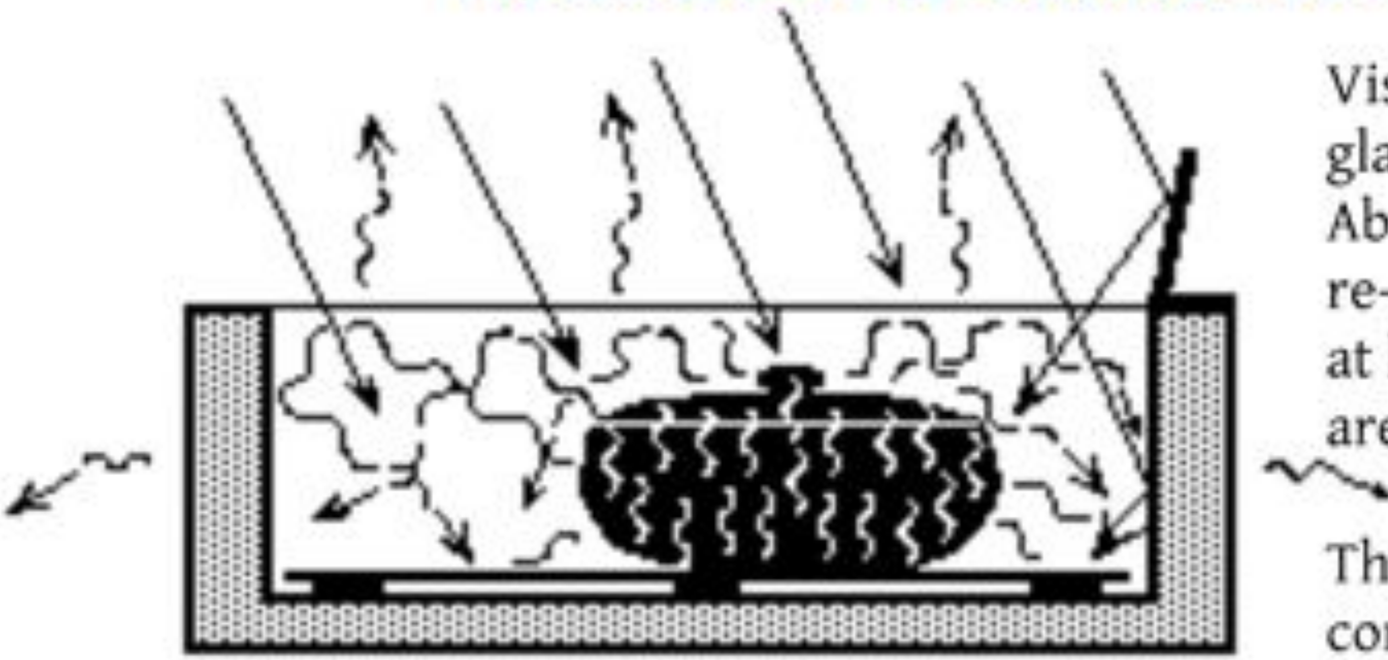


Figure 2. The greenhouse effect

Visible light passes through glass.
Absorbed by dark pot, which re-radiates
at longer wavelengths, which are trapped inside.

The absorbed energy must be conducted to the food efficiently.

Heat Gain: Glass orientation

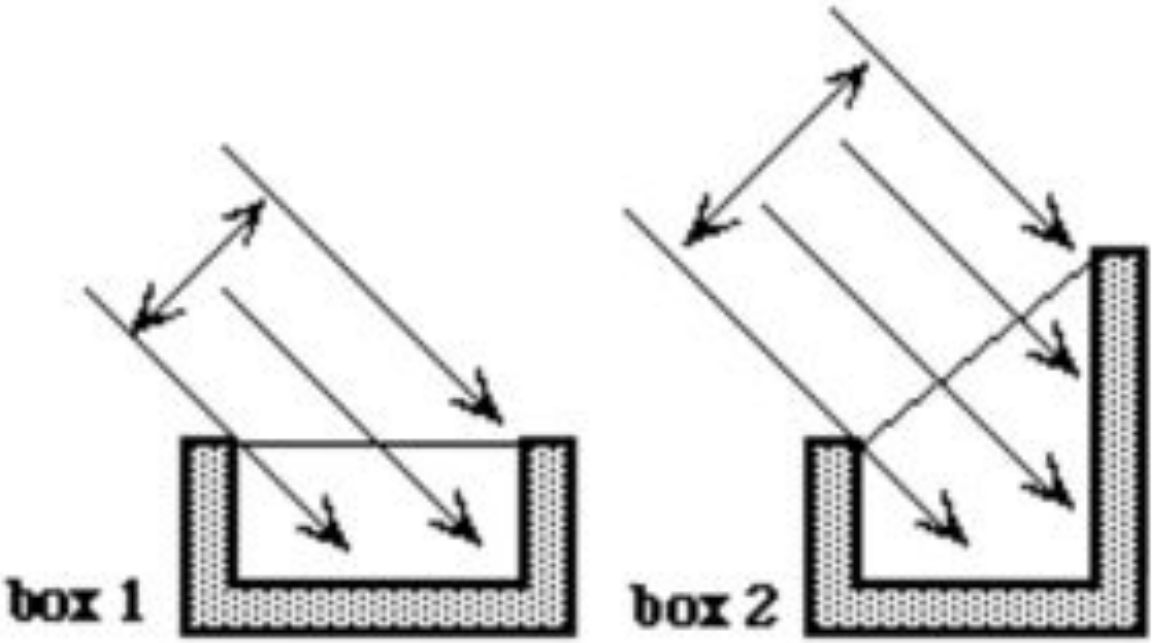
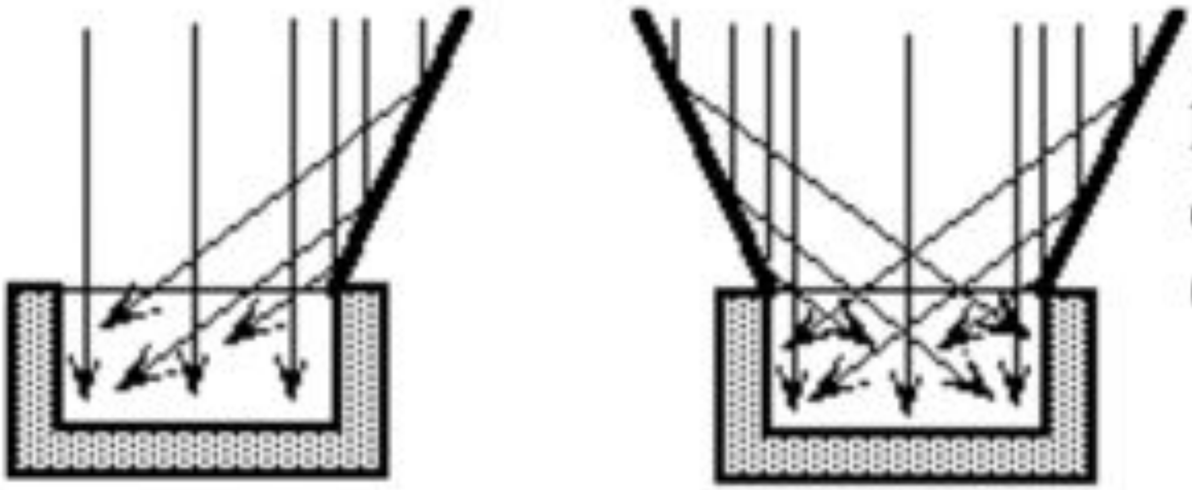


Figure 3. Glass orientation

Which box will receive more sunlight ?

Which box has more losses ?

Heat Gain: Reflectors



Reflectors can increase effective light capture area (aperture).

Figure 4. Reflectors for additional solar gain

Brainstorm: How would you increase this gain ?

Heat Loss: Conduction, Radiation & Convection

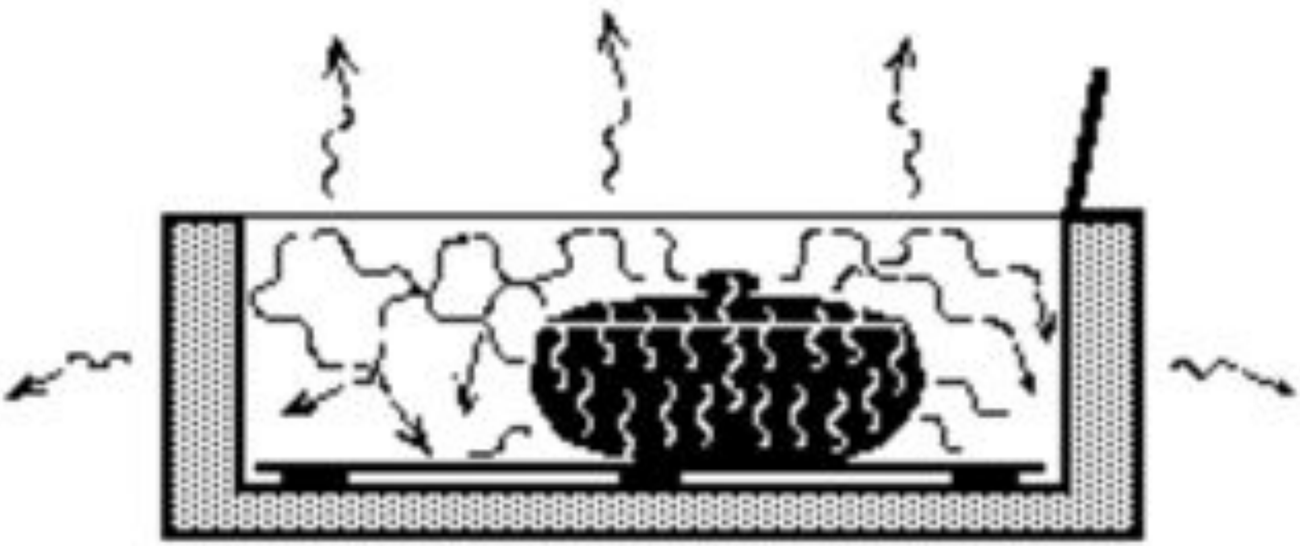


Figure 6. Heat radiates from warm cookware.

- Absorber plate insulated from bottom of cooker.
- Radiant heat (longer wavelength) trapped by container (glass, foil, etc.)
- Heated air may leak through gaps, doors (convection).

Heat Storage

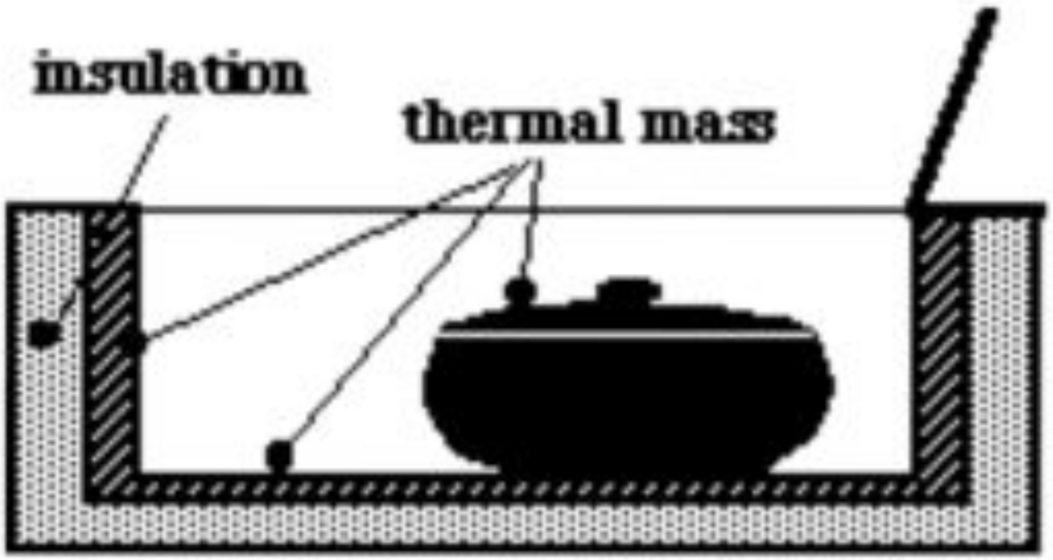


Figure 8. Thermal mass inside of the solar box.

- Thermal mass is the ability to retain heat.
- Higher thermal mass takes longer to heat up.

Materials Requirements

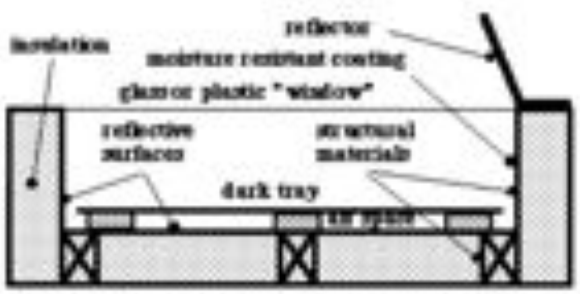


Figure 9: Materials: structural, insulation, transparent, and moisture resistant.

Structural materials

wood, cardboard, metals, bamboo, bricks, stone, plastic, rattan, etc.

Insulation

Al foil, down feathers, cellulose, rice hulls, wool, etc.

Transparent material

glass, high-temp plastics (oven roasting bags), etc.

Moisture resistance

Inner walls must protect the rest of the cooker from moisture.

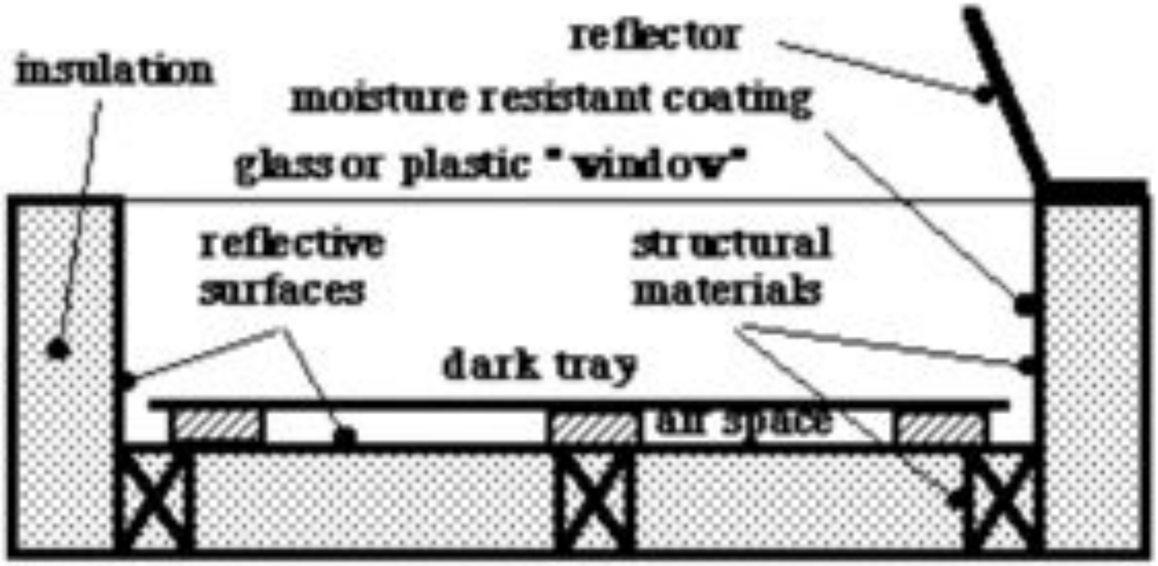


Figure 9: Materials: structural, insulation, transparent, and moisture resistant.

Structural materials

wood, cardboard, metals, bamboo, bricks, stone, plastic, rattan, etc.

Insulation

Al foil, down feathers, cellulose, rice hulls, wool, etc.

Transparent material

glass, high-temp plastics (oven roasting bags), etc.

Moisture resistance

Inner walls must protect the rest of the cooker from moisture.

Other design considerations

Size

- Appropriate for amount of food.
- Portability needs.
- Cookware accommodation.

Sunlight collection area

- Larger collection area -> higher temperature
- As long as heat loss is not increased

Solar cooker proportion

- Is a square box better than a rectangular box ?
- Which direction should the rectangular box be oriented ?
- Is tracking required ?

Challenges for adoption

- Taste of food
- Temperature control
- What about cloudy days ?
- Cost
- Disruption traditional gender roles.

Opportunities for technologists!

New market opportunities as fuel prices rise

Can we combine these technologies with micro-credit ?

Can we incorporate solar cooking into home designs.