Optics for Energy
ECE 5962/6962
MSE 5050/6050

Rajesh Menon
rmenon@eng.utah.edu
MEB 2256

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

Office Hours: None (Email me: rmenon@eng.utah.edu)

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:

* Execute a project, where we apply what we learn & hopefully learn more
* Become familiar with the fundamentals of optical design & engineering
* Be aware of emerging technologies in 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

Team-based projects

50% Five Mini-reports (3 pages each)

10% Mid-semester presentation

20% Submission to National Clean Energy Business Plan Competition

20% Class quizzes

Projects

- 3 students/team

Project topics

Project Deliverables

National Clean Energy Business Plan Competition

Mid-semester presentations

Project Topics

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

Others (you propose).

Emphasis on the developing world

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

Project Deliverables (~3 pages each)

Mini-report 1: Literature Review; Discuss pros, cons, comparisons, overview of existing technologies. Due 09/13/2012

Mini-report 2: Your idea. Be bold, Be creative. Take risks. Due 10/4/2012

Mini-report 3: How will you implement your idea ? Plan. Budget. Due 10/25/2012

Mini-report 4: Technical details of your idea. Build-out (demo). Simulations. Due 11/20/2012

Mini-report 5: Business Plan, Commercialization strategy. Due 12/06/2012

Deadlines are important! 10% of points docked for each day you are late.

National Clean Energy Business Plan Competition

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

* Regional Competition: CU Cleantech New Venture Challenge (http://nvc.cucleantech.org)
  - Submission deadline March 3, 2013. But our class deadline is Dec. 6, 2012.
  - 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.

Course Schedule

Tentative Schedule for ECE 5962/6961 Optics for Energy. Fall 2012

8/21	Week #1 Tuesday	Overview of course; Intro to project topics
8/23	Week #1 Thursday	Introduction to project topics
8/28	Week #2 Tuesday	Solar Radiation: The basics
8/30	Week #2 Thursday	Thermodynamics of solar heating & cooking
9/4	Week #3 Tuesday	Introduction to Geometrical Optics
9/6	Week #3 Thursday	Optical design for recycling
9/11	Week #4 Tuesday	Lagrangian & Hamiltonian Optics
9/13	Week #4 Thursday	Rays & Wavefronts [Literature reviews due]
9/18	Week #5 Tuesday	Light tools optical design software tutorial (Guest lecture: Dr. Mohit Diwekar)
9/20	Week #5 Thursday	Technology Commercialization (Guest lecture: Frank Norris, TCO UofU)
9/25	Week #6 Tuesday	[No Class]
9/27	Week #6 Thursday	Reflection & Refraction
10/2	Week #7 Tuesday	Symmetry
10/4	Week #7 Thursday	Etendue in phase space [Your idea section due]
10/9, 10/11	Week#8	Fall Break

Course Schedule

10/16 Week #9 Tuesday Review of solar cells (Guest lecture, tentative)
10/18 Week #9 Thursday [No Class]

10/23 Week #10 Tuesday Radiometry, Photometry, Radiation heat transfer
10/25 Week #10 Thursday Fundamental concepts of Non-imaging optics [Project plan section due]

10/30 Week #11 Tuesday Fundamental concepts of Non-imaging optics
11/1 Week #11 Thursday Mid-term project presentations

11/6 Week#12 Tuesday Statistical Ray Optics
11/8 Week#12 Thursday Light trapping

11/13 Week#13 Tuesday Light trapping – Plasmonics & Dielectric scatterers (Guest lecture: Dr. James Nagel)
11/15 Week #13 Thursday Light trapping (guest lecture Dr. James Nagel).

11/20 Week#14 Tuesday Design of 2D concentrators [Build-out / simulation section due]
11/22 Week #14 Thursday Thanksgiving break

11/27 Week#15 Tuesday Spectrum splitting approaches
11/29 Week #15 Thursday Anti-reflection coatings [Business Plan / Commercialization section due]

12/4 Week#16 Tuesday Concentrated Photovoltaics
12/6 Week #16 Thursday Solar Simulators [National Clean Energy Business Plan Application due]

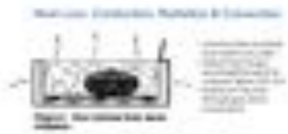
Why technologies for the developing world ?

- Abundant solar resources with little access to infra-structure (electric grid, roads, etc.).
- Biomass resources are fast depleting & also contribute to CO_2 emissions.
- Huge impact possible: ~ 1 out of every 4 people have no access to electricity.
- Market Opportunity to build sustainable technological solutions.

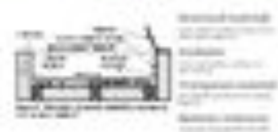
Solar Cooking

Types of cookers

Heat Principles



Materials Requirements



Other design considerations

Size

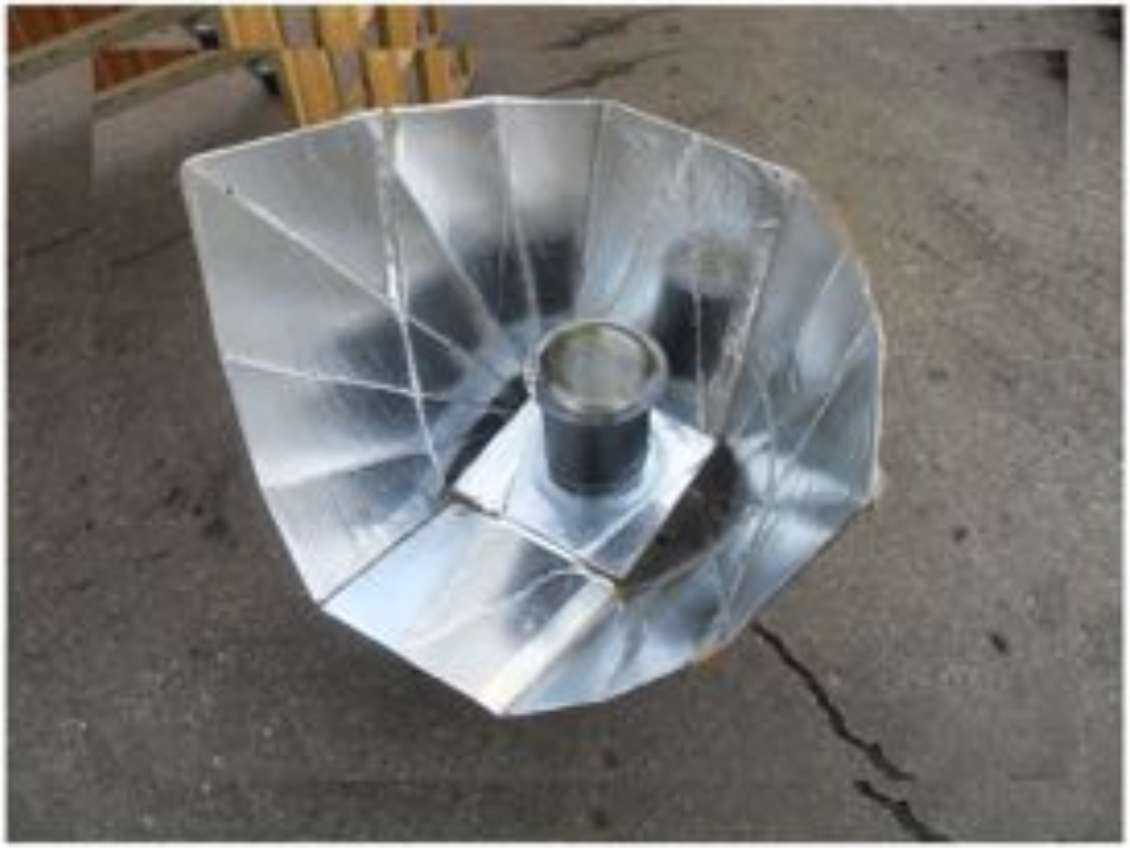
Sunlight collection area

Solar cooker proportion

Challenges for adoption

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

Fresnel Lens Cooker

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

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Heat Principles

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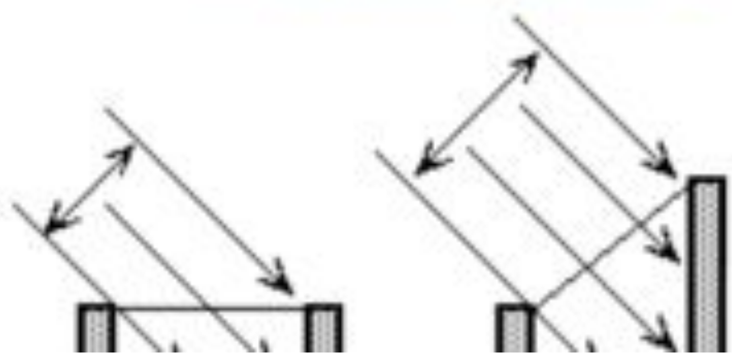
Heat Gain: Glass orientation



Which box will receive more sunlight ?

Which box has more losses ?

Heat Gain: Greenhouse effect

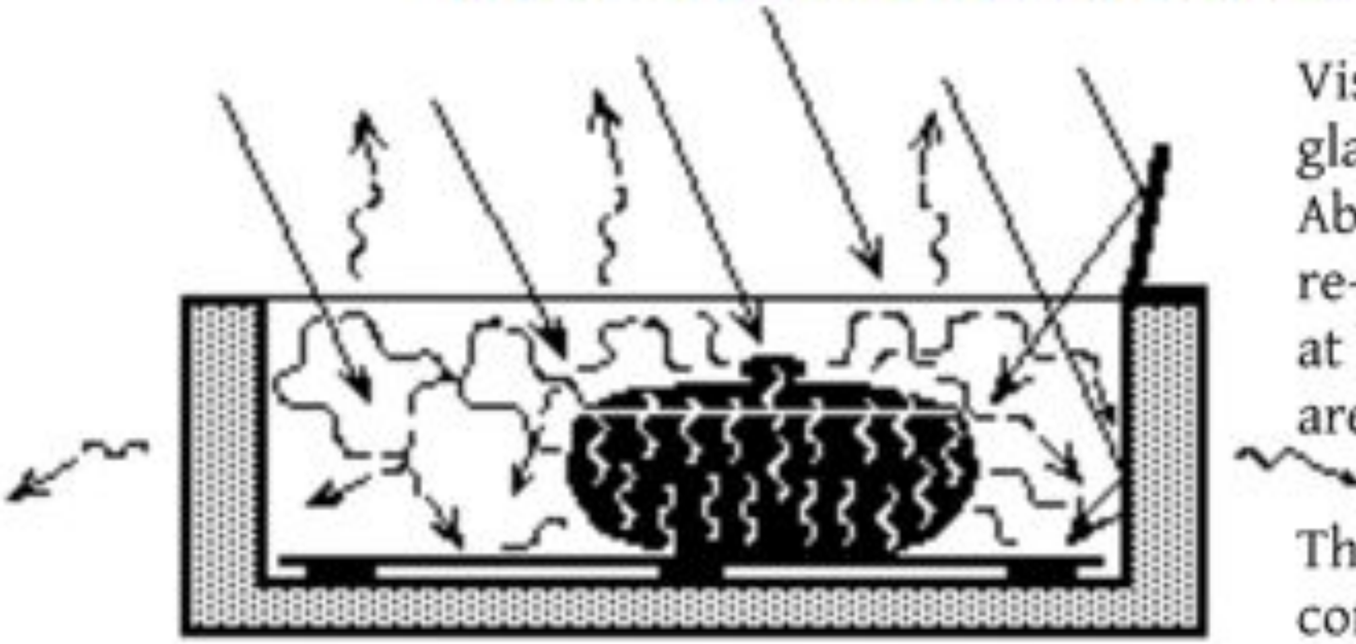


Figure 2. The greenhouse effect

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

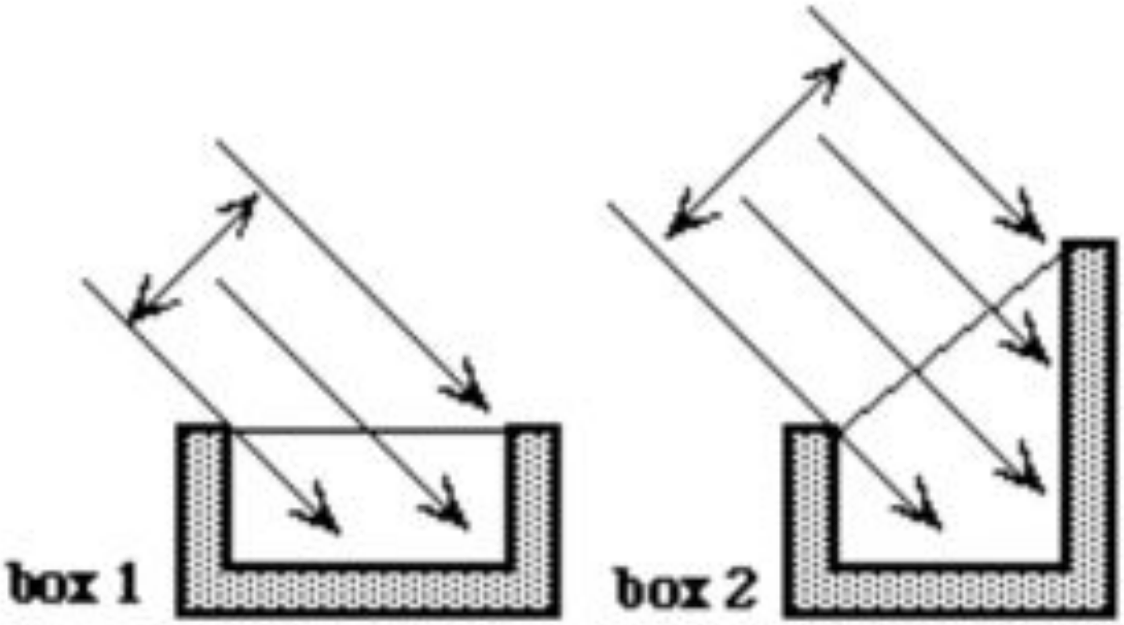


Figure 3. Glass orientation

Which box will receive more sunlight ?

Which box has more losses ?

Heat Gain: Reflectors

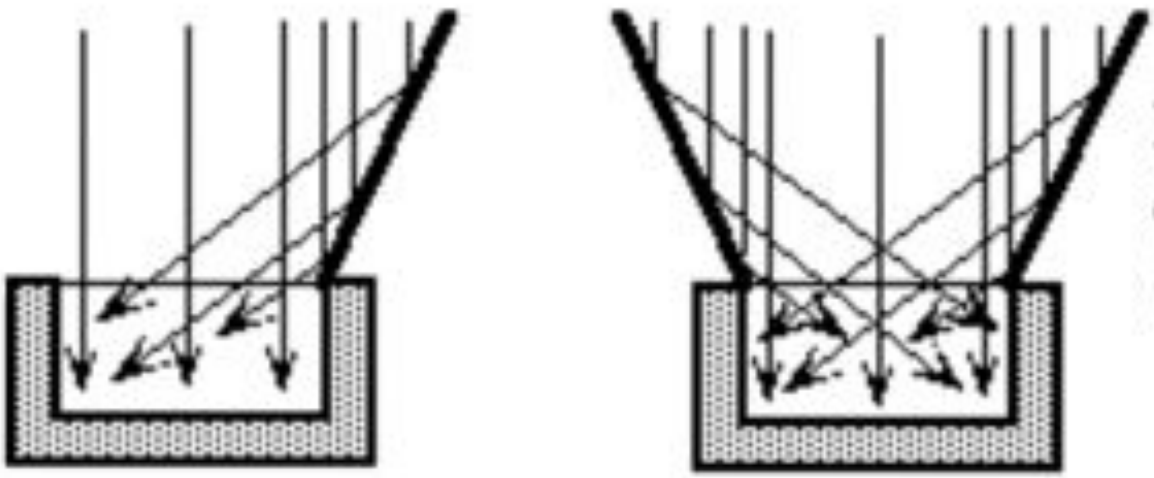


Figure 4. Reflectors for additional solar gain

Reflectors can increase effective light capture area (aperture).

Heat Loss: Conduction, Radiation & Convection

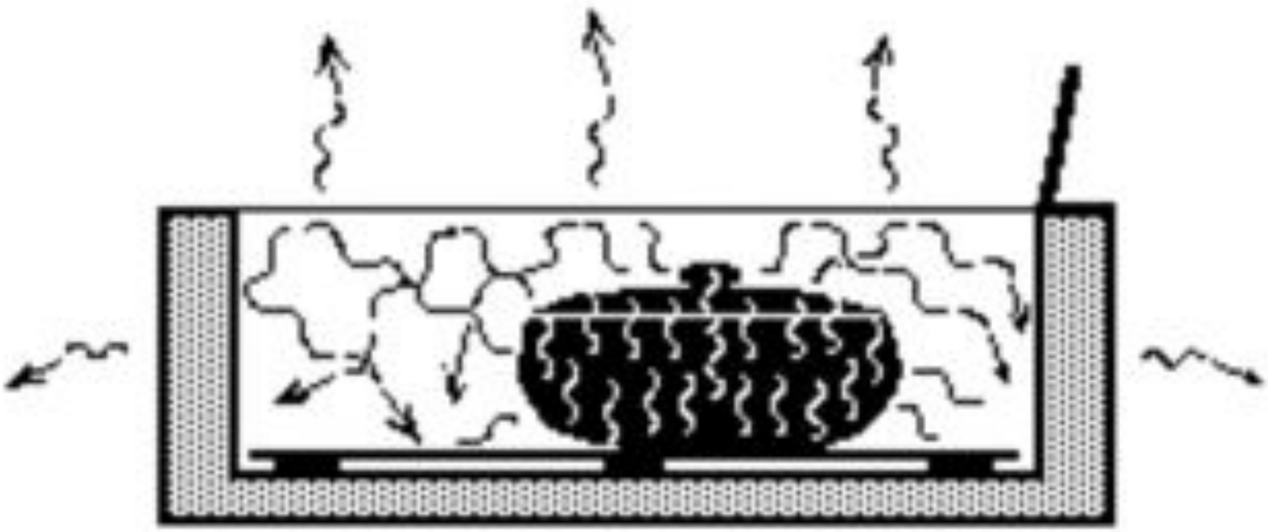


Figure 6. Heat radiates from warm cookware.

- 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

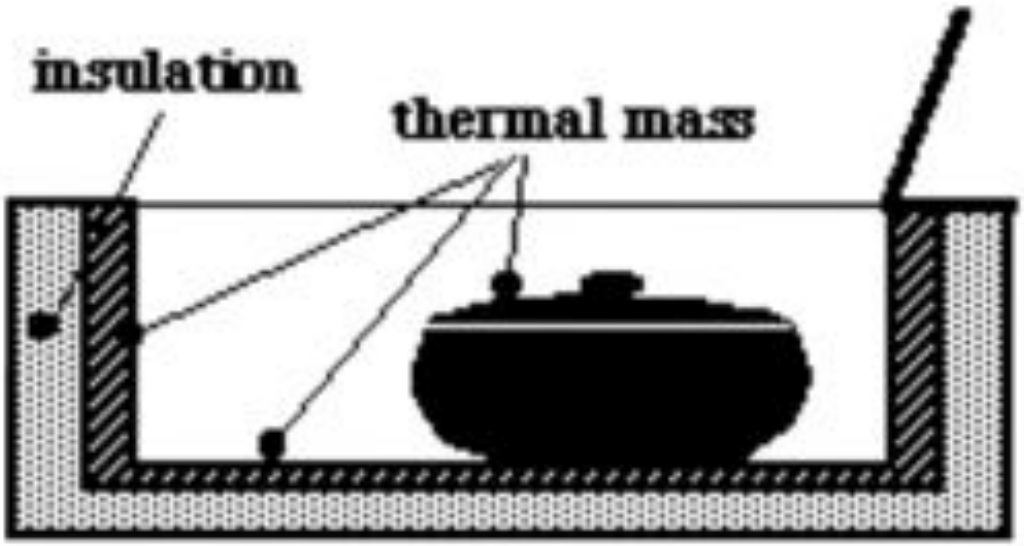


Figure 8. Thermal mass inside of the solar box.

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

Materials Requirements

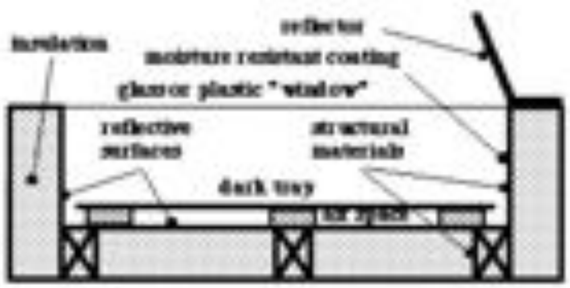


Figure 9: Materials: structural, insulation, transparent, and moisture resistant.

Structural materials

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

Insulation

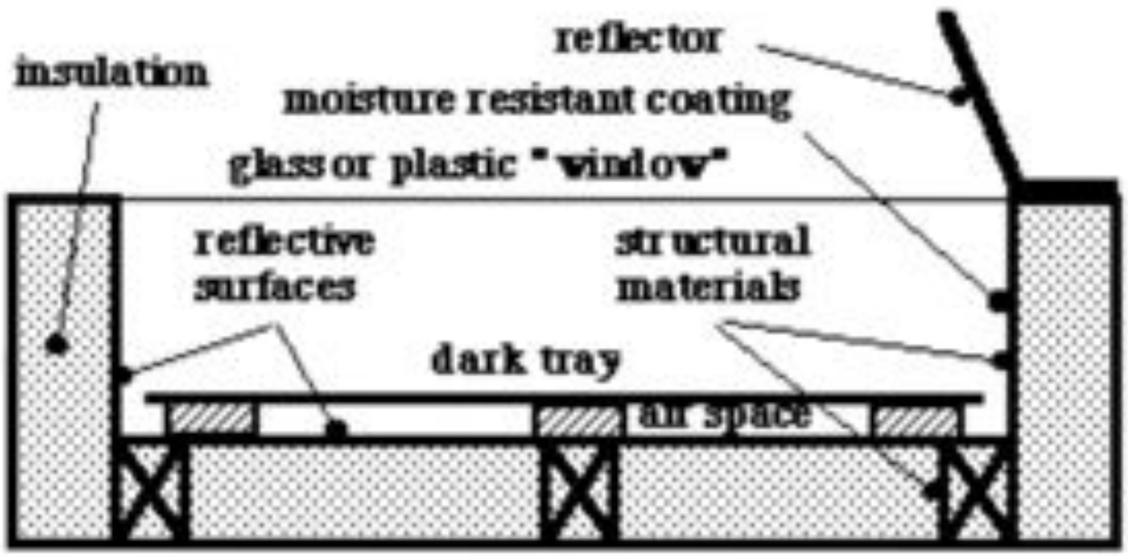
Al foil, down feathers, cellulose, rice hulls, wool, etc.

Transparent material

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

Moisture resistance

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



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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 ?