SOLAR THERMAL SYSTEMS

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Reference

SOLAR ENGINEERING
OF THERMAL PROCESSES

Second Edition

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A Wiley-Interscience Publication
JOHN WILEY & SONS, INC.
New York Chichester Brisbane Toronto Singapore

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Conversion

- Solar Energy conversion process is divided into three phases:
  - Reception
  - Transfer
  - Accumulation
- Collection Device: For efficient absorption a dark surface is exposed to solar radiation

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Solar Thermal Applications

- Water heating (viable for Uganda)
- Distillation (viable for Uganda)
- Space heating
- Power generation
- Space cooling and refrigeration
- Distillation (viable for Uganda)
- Drying (agro-products, timber etc) (viable for Uganda)
- Cooking (viable for Uganda)

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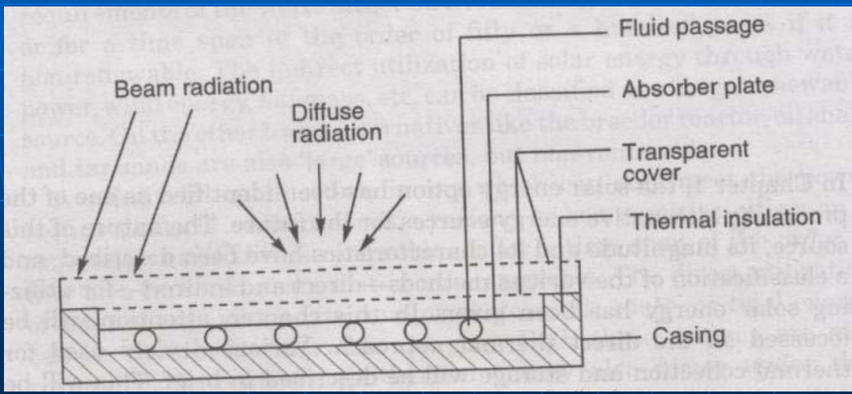
Flat plate collector

- This is the most important type of solar collector
- Simple to design, has no moving part and requires minimal maintenance

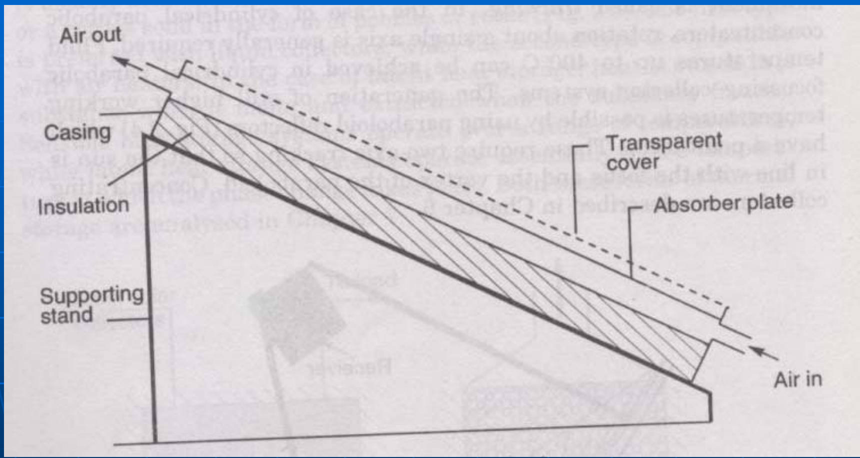


Equation used for practical implementation of flat plate solar collector

$$Q = FA[I(ab) - U(T_i - T_a)]$$

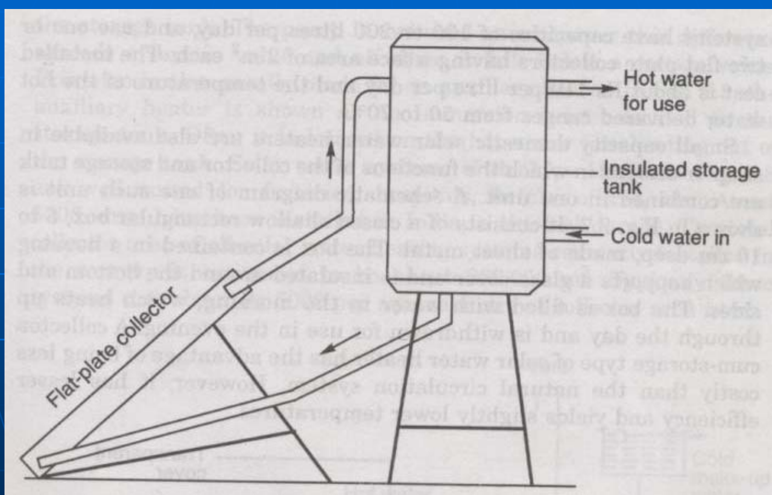
- Q = Energy extracted by the plate (W)
- F = efficiency factor of heat removal from the plate
- A = plate area (m^2)
- I = solar radiation (W/m^2)
- a = Coefficient of solar transmittance of transparent cover
- b = coefficient of solar absorption of the plate sheet
- U = coefficient of energy loss of plate ($W/^0C.m^2$)
- Ti = temperature of the fluid (^0C)
- Ta = ambient temperature (^0C)

Solar Air Heater



- Similar to flat plate water heater
- Applications: Mainly in drying

Natural Circulation Water Heating System



A Thermosyphon solar water heater

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Solar Thermal Power Generation

- The best known technologies are:
- Parabolic trough
- Parabolic dish
- Solar power tower
- Hydrogen production
- Solar Chimney

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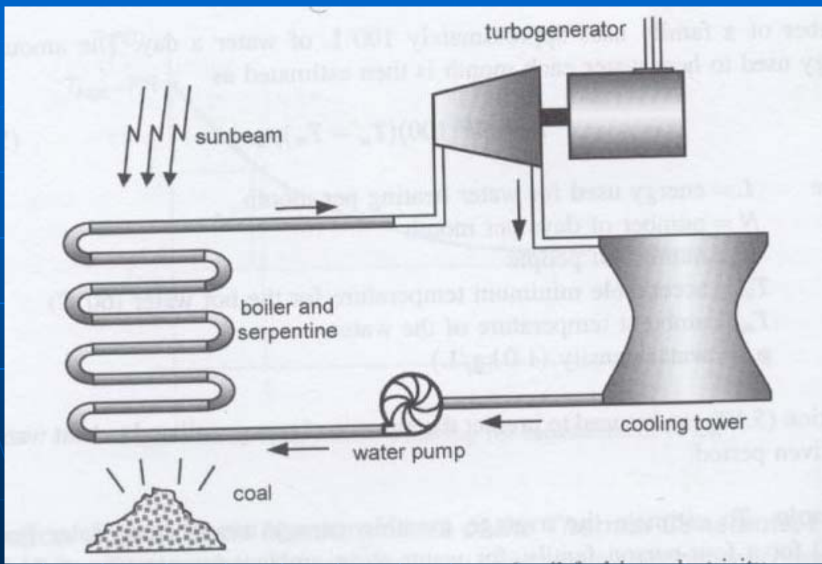
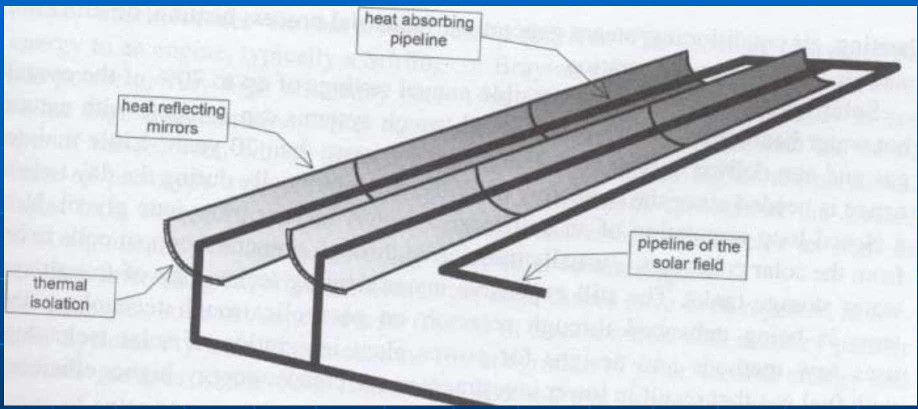
Hybrid: Solar heat and Fossil fuel



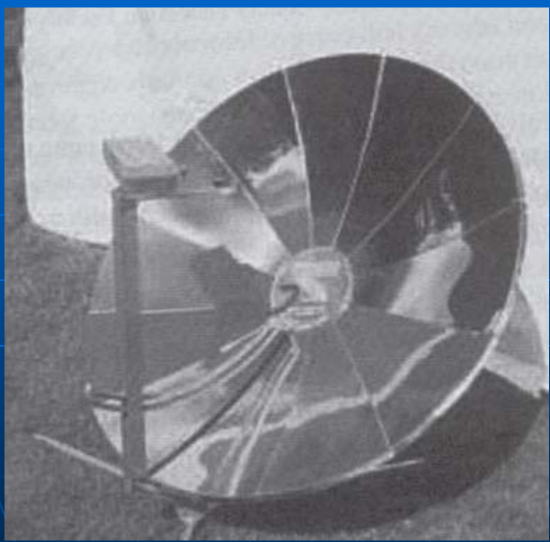
Hybrid: Solar heat and Fossil fuel …

- The hybrid thermal solar power plant is in operation in California
- Fossil fuel is used as a reserve power
- The advantages are: reduction of CO_2, NO_X, SO_X

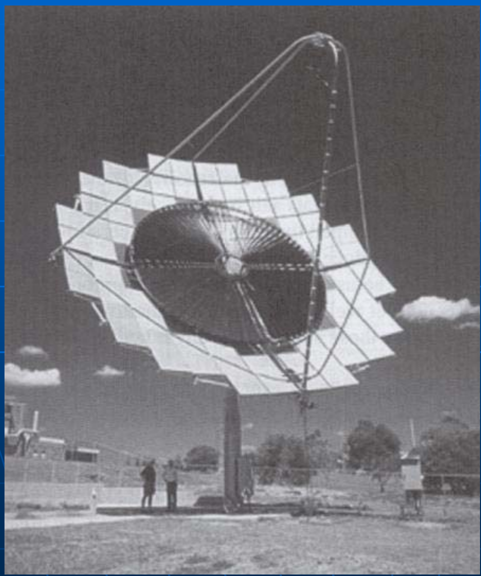
Parabolic Trough



Parabolic Dish



A Solar Dish System in Australia



- Demonstration for integration of solar thermal energy and methane gas

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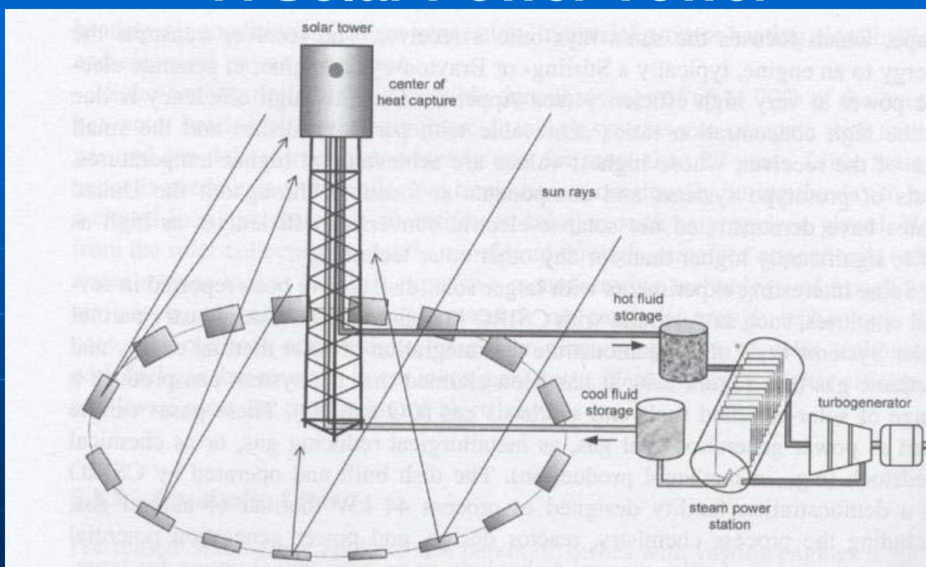
A Solar Power Tower



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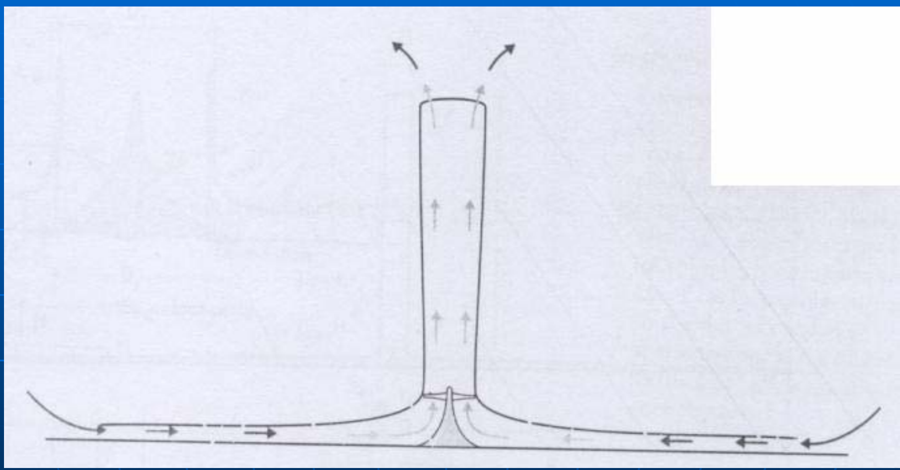
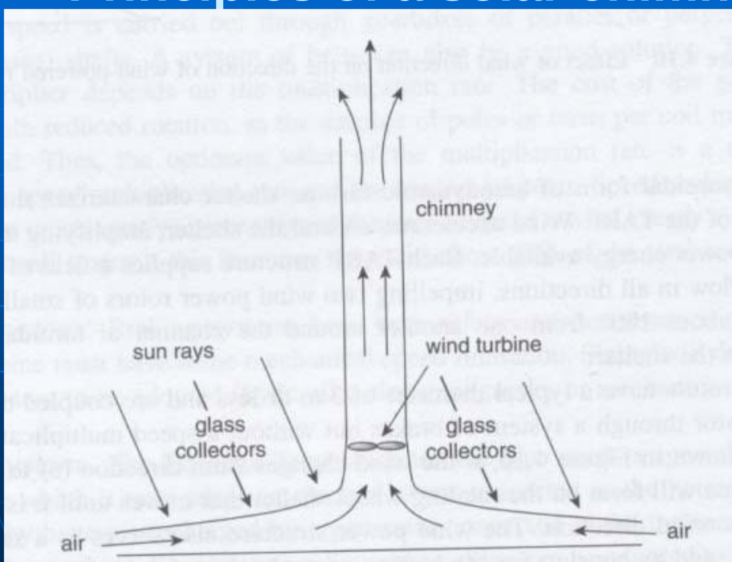
Solar Chimney



Main parts: collector, turbines and chimney

Principles of a solar chimney



Example in Spain

- Pilot plat of 50 kW output built in Spain
- Chimney 200 m high 10.3 m diameter
- Collector extends to radius of 126 m
- Glazing – transparent plastic
- Wind turbine – 4 blade, 5 m long and 1500 rpm
- Overall effciency: about 0.1%

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Plant planed in Australia

- Planned 200 MW
- Chimney 1 km high
- Collector extends to diameter of 5 km
- Possible wind turbines
  - single turbine with vertical axis
  - 24 to 36 small turbines with horizontal axes
- Estmented cost: US$ 700 million and cost per kW US$ 3500

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Solar Cooking for a Better Tomorrow

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Woman Carrying Firewood

Chapungu Sculpture Park, Harare

(David Ndlovu)

COMMON FEATURE IN DEVELOPING COUNTRIES EVERYDAY

CAUSED BY

- Abject/horrible poverty
- Trees are free for everyone, provided by God?
- All people want to eat cooked food

CAUSES

- Extensive deforestation
- Deterioration of health
- Inefficiency because people are tired
- Gender oppression
- Abject poverty

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Why Solar Cook?

- Save energy, time, money
- Protect and empower women
- Good nutrition, better taste
- Reduce rate of deforestation
- Have fun, socialise and network
- Test scientific prowess
- Make money, run self owned companies
- Improved health through low cost water pasteurisation

Principles of Solar Cooking

- Absorption of solar radiation (Ultraviolet and Visible)
- Conversion of solar radiation into heat (Infrared)
- Heat transfer to the food

Basic Solar Cooker Designs

Reflector Solar Cooker

- Directs solar radiation to the pot,
  (Various configurations: plane reflectors, conical, parabolic, etc)
- Requires beam radiation
- Very hot and fast, but no storage
- Any type of food, can fry, stew, roast, but cannot bake
- Normally outdoor use - User must stand in the sun (Limited indoor use possibility)

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Basic Solar Cooker Designs

Box solar cooker (oven)

- **Greenhouse effect, (insulated box with top cover transparent to UV and visible radiation, but opaque to infrared (heat) radiation)**
- **Can use both diffuse and beam radiation**
- **Not so hot, can keep food warm for hours after sunset**
- **Any type of food, can stew, bake, but can not fry**
- **Normally outdoor use (Better indoor use possibility)**

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Basic Solar Cooker Designs

- **Compound box – reflector cooker**
  Combination of the above (1 and 2)
- **Cookers with storage**
- **Solar-water-heater-type with oil as the heat transport and storage medium, and pebble storage**
- **Could also have reflectors to enhance aperture area**
- **Greater indoor use possibilities**
- **Very high cost**

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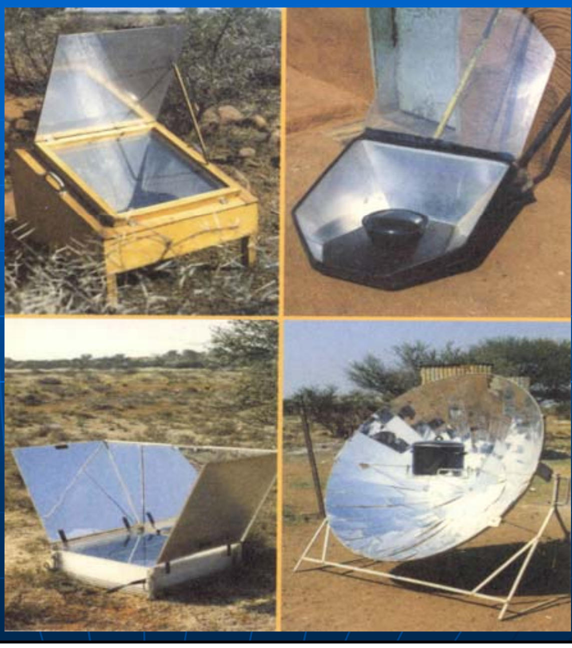
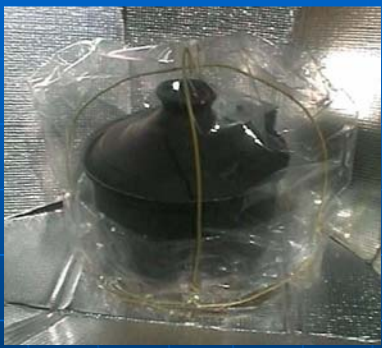
Potential use of Renewable Energy

Solar Cookers

Types



Solar Cooker Design Examples



Reflecting solar radiation onto a black pot enclosed in a simple air filled polythene bag, or in an airtight glass container (Green house effect)

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Solar Cooker Design Examples

Box cooker woven by Eritrean women

A through the wall woven accessible from a kitchen in Mexico

A cardboard box solar cooker collapsible to 8 cm

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Solar Cooker Design Examples

Commercial box solar cooker in the 1960's

Another box cooker design

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Solar Cooker Design Examples

Zambia (solar Cooker International)

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Solar Cooker Design Examples

Kenya


LAS COCINAS SOLARES SON YA COMUNES

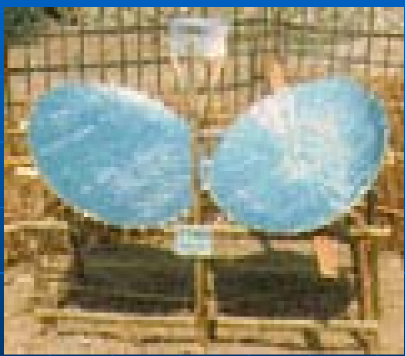
Bolivia

Solar Cooker Design Examples

Design of the inner box

Pan inside the cooker

Solar Cooker Design Examples



Nepal

Chilean village experiment with solar ovens

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Solar Cooker Design Examples

Conical solar cooker design

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Solar Cooker Design Examples

Conical design

Parabolic design

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Solar Cooker Designs

A rooftop parabolic solar cooker in India

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Specifications of a Solar Cooker

- When I buy a solar cooker, what exactly am I buying, is it the design, the materials, the time employed in making it, its capabilities?
- How can I compare different solar cookers?
- International testing standards
- Cooking power = mC[T(pot contents) –T(ambient)] / time [W]
- for a temperature difference of 50ºC, standardised to 700W/m^2
- + the linear equation obtained during the test.

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Problems with Dissemination

- High initial cost, (Government or Non-Governmental subsidies)
- Lack of consultation with target groups
- Exclusion of the community in the planning phase
- Exclusion of the “After sales service” component from planning level
- Inadequate education of the customer on the possibilities and limitations of the cooker
- In general, not comfortable to use, or store

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Problems with Acceptance

- Not adapted to the local environment
- Does not fit with the accepted normal practice
- Not enough education provided to the recipients
- Availability of cheaper and more convenient options
- Targeted to the poor and the rural (very negative)
- Cannot cook the staple food in the "normal" way
- Food tastes different
- Reflection of sunrays into eyes of the cook
- Heavy, or difficult to set up
- Technology dumping

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Conclusions

- Solar cooking cannot be employed as a complete substitute of other existing technologies and sources of cooking energy but as a compliment, in varying percentage, to them!
- The technology is proven and available, we need actors! YOU are needed.

WAY FORWARD

- Solar cooking should be given attention by all concerned stakeholders

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Let us have a short break.

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SOLAR DRYING

Potential Uses of Renewable Energy Sources

SUN DRYING

SOLAR DRYING

Natural Convection Dryers

- Sun Drying with Plastic Cover
- Solar Greenhouse Dryer
- Solar Cabinet Dryer

Forced Convection Dryers

- Solar Tunnel Dryer
- Solar Flat Bed Dryer
- Solar Greenhouse Dryer
- Solar Dryers with Roof-integrated Collector

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SOLAR DRYING

Objectives for Drying of Agricultural Products

- Reduction of moisture content in order to avoid biological and biochemical processes during storage
- Reduction of mass losses
- Conservation of nutritional, biological and technological properties
- Extension of shelf life
- Reduction of weight to ease transportation

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SOLAR DRYING

Products to be dried

- Cereals
- Grain legumes
- Oil seeds
- Fodder plants
- Medicinal plants
- Spices
- Fruits
- Vegetables
- Meat
- Fishes

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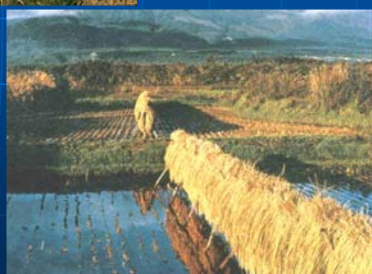
SOLAR DRYING

In-Field Drying



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SOLAR DRYING

Sun Drying

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SOLAR DRYING

Problems

- High losses during storage
- Inadequate quality

Priority Objectives

- Minimisation of drying costs
- Drying to storable conditions
- Preservation of nutritional properties

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SOLAR DRYING

Relevance of Solar Dryers in Uganda

- Solar drying is a promising alternative to reduce the post-harvest losses and to improve the products quality
- Solar drying enables farmers to produce high quality marketable products as a prerequisite for a sustainable income
- Due to comparably high insulation solar drying is competitive to natural sun drying and mechanical batch dryers
- Existing conditions in developing countries favour decentralised drying
- Solar drying reduces firewood consumption and can have a significant impact on deforestation

Potential Uses of Renewable Energy Sources

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SOLAR DRYING

Air Drying of Timber

- Target: pre-drying before conventional heat drying or processing
- Losses by micro-organisms (mould)
- Extended drying time, mostly too high final moisture content

Potential Uses of Renewable Energy Sources

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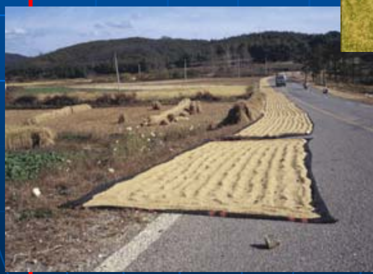
SOLAR DRYING

On-Farm Drying on Mats and Pavements



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SOLAR DRYING

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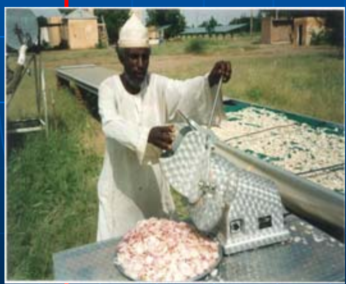
SOLAR DRYING

Drying of vegetables



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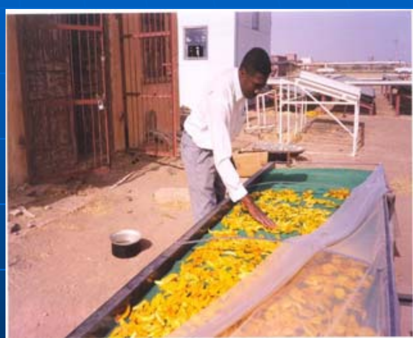
SOLAR DRYING

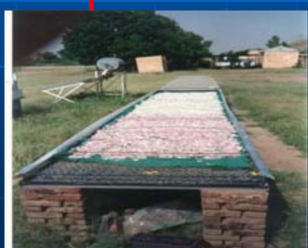
Drying of fruits and vegetables

SOLAR DRYING

Natural Convection Dryers

Sun Drying with Plastic Cover





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SOLAR DRYING

Drying of Chilli

SOLAR DRYING

Natural Convection Dryers

Sun Drying with Plastic Cover

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SOLAR DRYING

Solar Box Dryer

SOLAR DRYING

Natural Convection Dryers

Sun Drying with Plastic Cover

Solar Tent / Solar Box Dryer

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SOLAR DRYING

Solar Tent Dryer

SOLAR DRYING

Natural Convection Dryers

Sun Drying with Plastic Cover

Solar Tent / Solar Box Dryer

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SOLAR DRYING

Evaluation of Natural Convection Drying

- Protection against weather - insects - rodents
- Slight reduction of the drying time
- High weather depending risk
- Convection can not be maintained during night and cloudy weather
- Moisture can not be removed from the environment of the drying product

  → growth of micro-organisms
  → formation of respiration heat
- Low drying capacity
- High investment cost in relation to drying capacity

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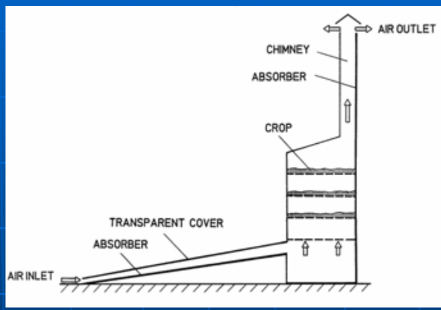
SOLAR DRYING

Natural Convection Type Dryers - Indirect Mode

Solar Cabinet Dryer



- Solar air heater is connected to a drying chamber
- Drying air is heated in a solar air heater and passes crops spread out in thin layers on vertically stacked trays
- Air movement is caused by ascending forces supported by wind or chimney

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SOLAR DRYING

Natural Convection Type Dryers - Indirect Mode

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SOLAR DRYING

Natural Convection Type Dryers - Indirect Mode

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SOLAR DRYING

Evaluation of Natural Convection Indirect Type Dryers

- Complete protection against weather, dust, insects, birds and rodents
- Improvement of the product quality in terms of colour, and contamination by dust
- Suitable for drying of crops sensitive to solar radiation
- Forcing the air through the crop causes high air resistance and limits numbers of trays or thickness of layers
- High risk of spoilage since moisture removal is depending on weather conditions
- High investment cost in relation to drying capacity

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SOLAR DRYING

Solar Drying with Forced Convection

Principle

- Fan is generating or supporting air flow
- Fan is driven by electric motor

Advantages

- Continuous air movement independent on weather conditions
- Possibility to force air through a thick layer

Disadvantages

- Requirement of electrical energy
- High cost for energy
- Insufficient supply

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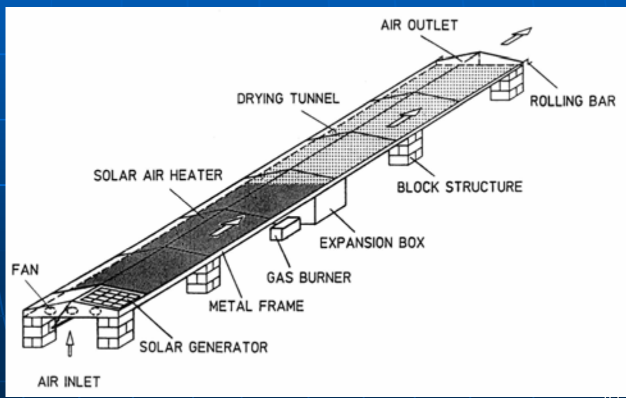
SOLAR DRYING

Solar Dryer with Integrated Solar Air Heater

- Solar air heater and dryer are arranged in series
- Product is spread out in a thin layer
- Solar air heater and dryer are covered with a transparent plastic foil
- Air flow is generated by fans



SOLAR DRYING

Types of Solar Tunnel Dryers

- Transparent cover made of UV-resistant PE or PVC plastic foil
- Fixing of plastic foil with reinforced plastic clamps to ease fixing and replacement
- Shape of cover depends on weather conditions during harvest period

arid areas: flat cover

humid areas/roof shaped cove

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SOLAR DRYING

Loading

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SOLAR DRYING

Loading and Unloading

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SOLAR DRYING

Solar Flat Bed Dryer with Forced Convection

- Coupling of solar air heater to a flat bed dryer
- Possibility for drying of light sensitive products

SOLAR DRYING
- Natural Convection Dryers
  - Sun Drying with Plastic Cover
  - Solar Tent / Solar Box Dryer
  - Solar Greenhouse Dryer
  - Solar Cabinet Dryer
- Forced Convection Dryers
  - Solar Tunnel Dryer
  - Solar Flat Bed Dryer

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Thanks to NTNU for funding the course

Special thanks are also to the Faculty of Technology, Makerere University

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SOLAR DRYING

Questions

1. Solar energy is the biggest primary energy potential among the primary sources of energy on earth. As a Solar Energy expert give reasons that limit the wide use of solar energy
2. What are the Solar Thermal applications that can be used in Uganda? Give sectors where the suggested systems can be used.
3. What are the advantages and limitations of the following solar thermal systems?
   i. Solar Cookers
   ii. Water heaters
   iii. Solar dryers

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