Applications of solar thermal engineering in agro-economy

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Contents

- Solar energy in agricultural processes concern:
  - Solar desalination
  - Solar drying
  - Greenhouses

Solar Desalination Systems

WATER

- The most important element for the preservation of life on earth.
- 3/4 of the earth surface covered with water.
- 97% of this water is salty.
- 3% is potable water found in:
  - Underground
  - lakes
  - rivers
  - Ice
- Biggest problem today: Water pollution
  - Sewage effluents and industrial pollution

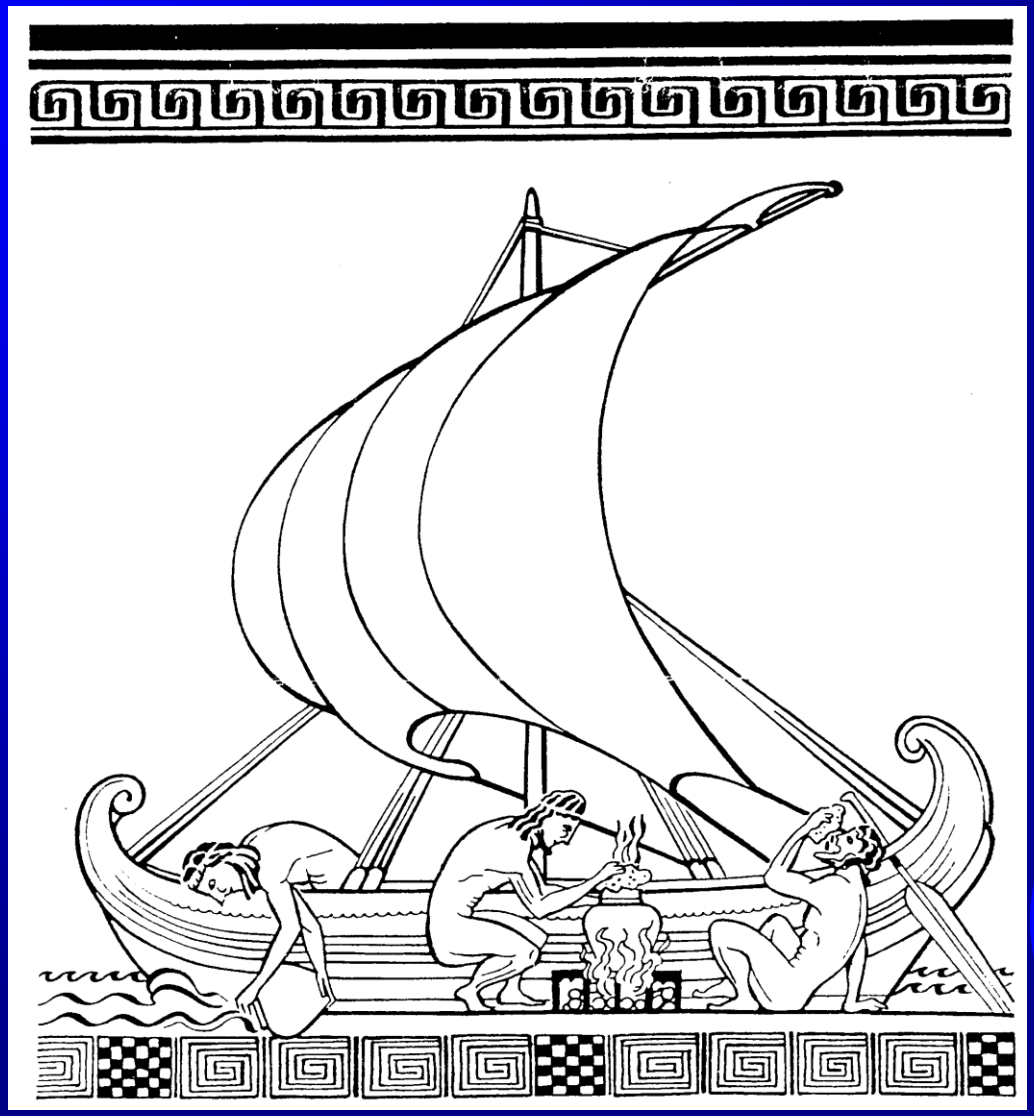
Sea Water

- The oceans is the only inexhaustible source of water.
- This water however salty water that needs to be desalinated.
- Sea water desalination could solve the water shortage problem.
- Desalination can be achieved with:
  - Phase change or thermal processes
  - Membrane or single-phase processes

Desalination processes

PHASE-CHANGE PROCESSES	MEMBRANE PROCESSES
1. Multi-stage flash (MSF) 2. Multiple effect boiling (MEB) 3. Vapour compression (VC) 4. Freezing 5. Humidification/Dehumidification 6. Solar stills - conventional stills - special stills - wick-type stills - multiple-wick-type stills	1. Reverse osmosis (RO) - RO without energy recovery - RO with energy recovery (ER-RO) 2. Electrodialysis (ED)

Desalination during the ancient times



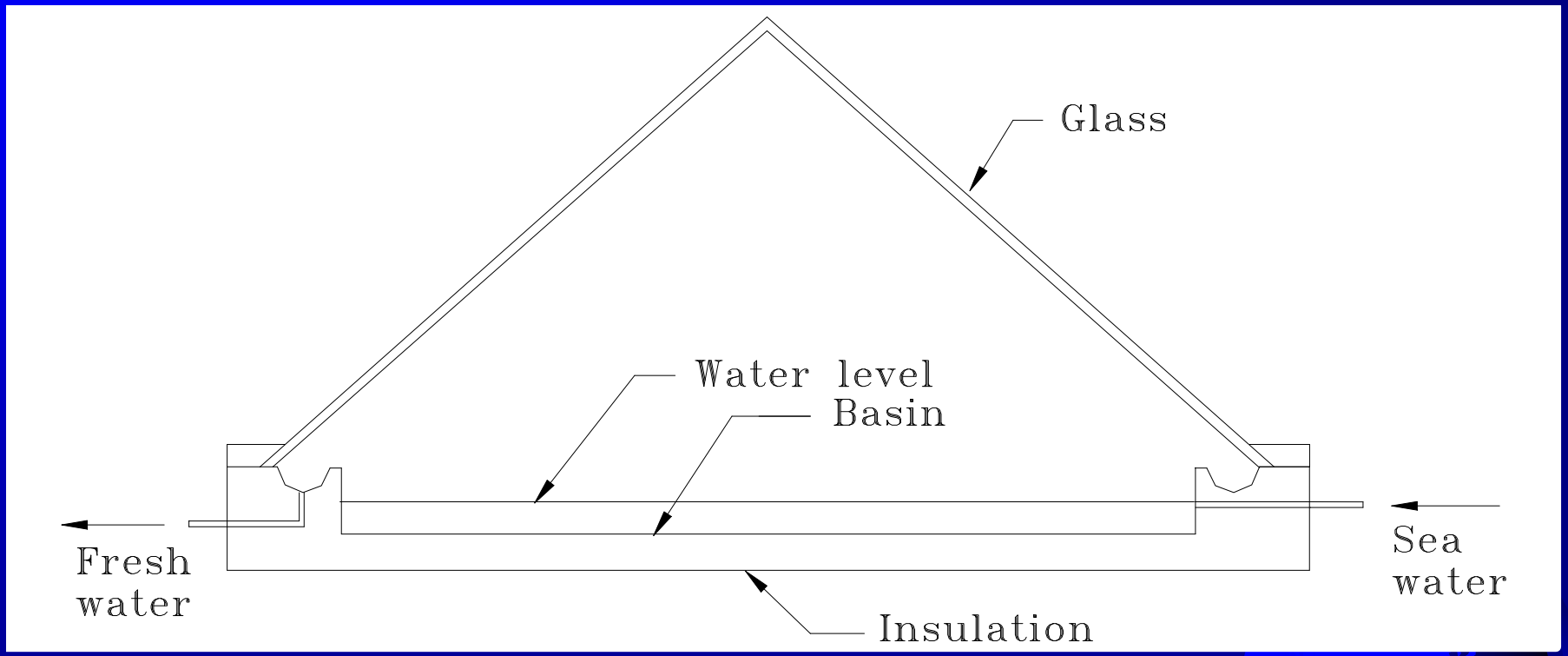
Use of Water

- Desalinated water can be used in:
  - Households
  - Industry
  - Agriculture
- The question is:
  - Who can pay for the cost of the desalinated water.
- Fuels
  - Many countries are based exclusively on fuel imports for their energy needs.
  - These countries cannot control the fuel prices.

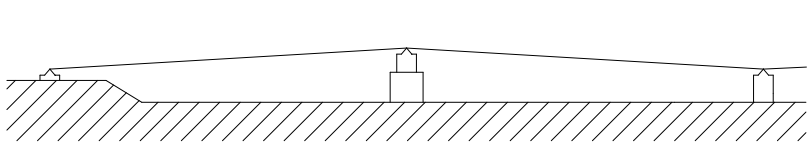
Environmental Effects

- Significant quantities of energy are required to achieve salt separation.
- Question: Even if conventional fuels were very cheap could we use them for sea water desalination?
  - → Pollution of the environment
- Renewable energy sources could offer an alternative solution.
- For many countries solar energy is abundantly available.

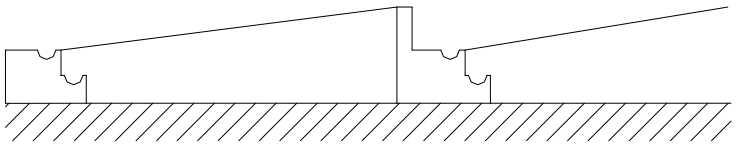
Direct systems-Solar Stills



Variations of basic design combined with rainwater collection

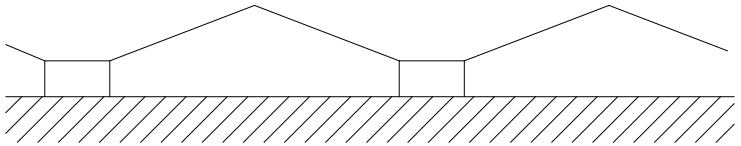


BASIN TYPE SOLAR STILL

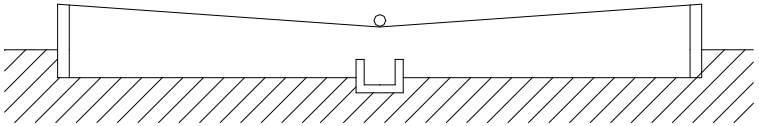


SINGLE SLOPED COVER DESIGN

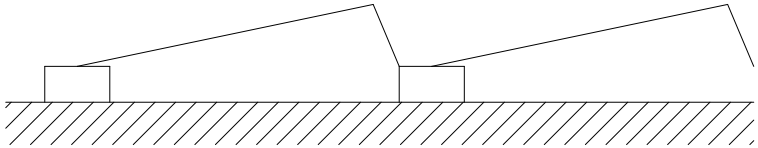
INFLATED PLASTIC COVER DESIGN



GREENHOUSE TYPE SOLAR STILL



V-SHAPE PLASTIC COVER DESIGN

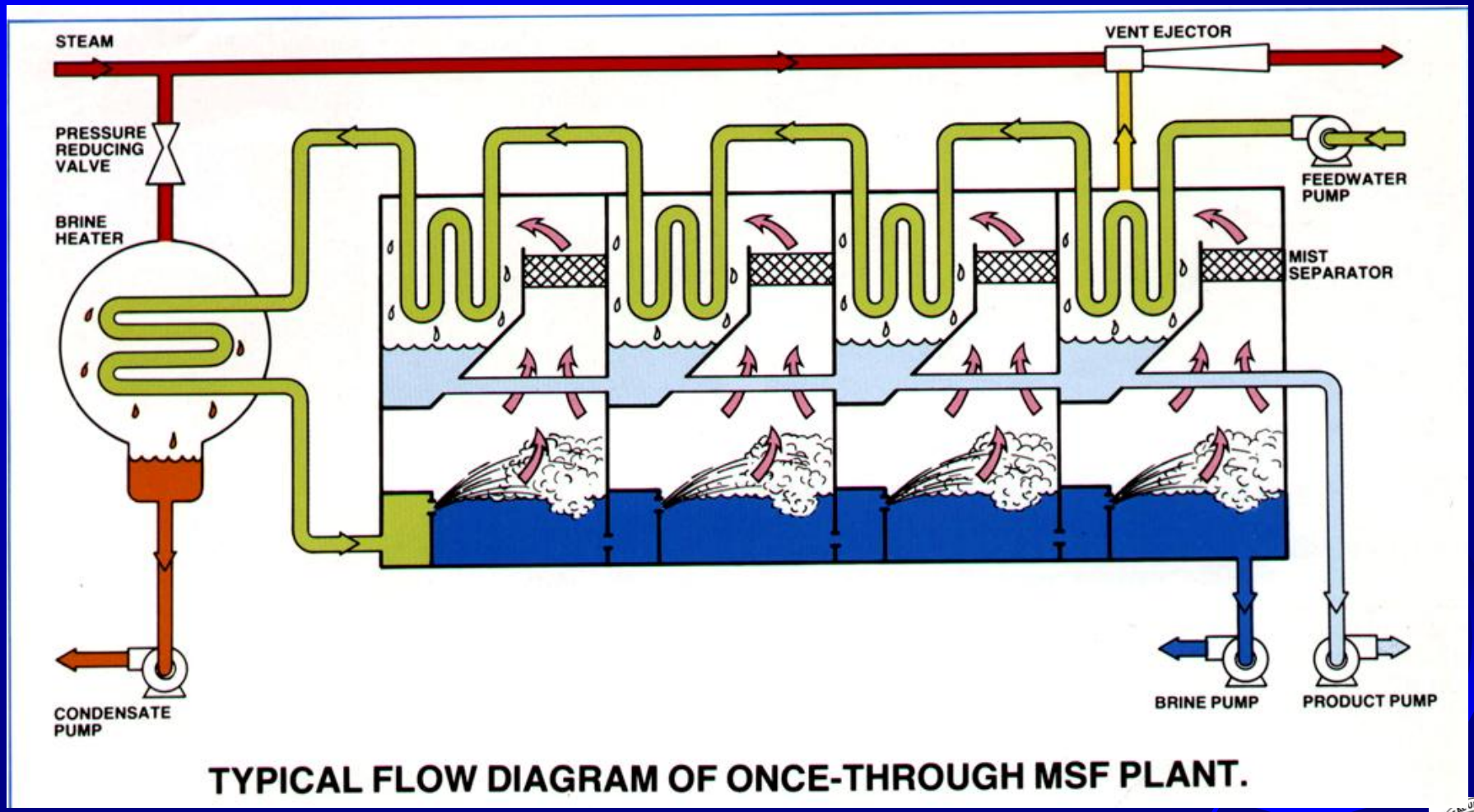


INCLINED GLASS COVER DESIGN

Indirect Systems

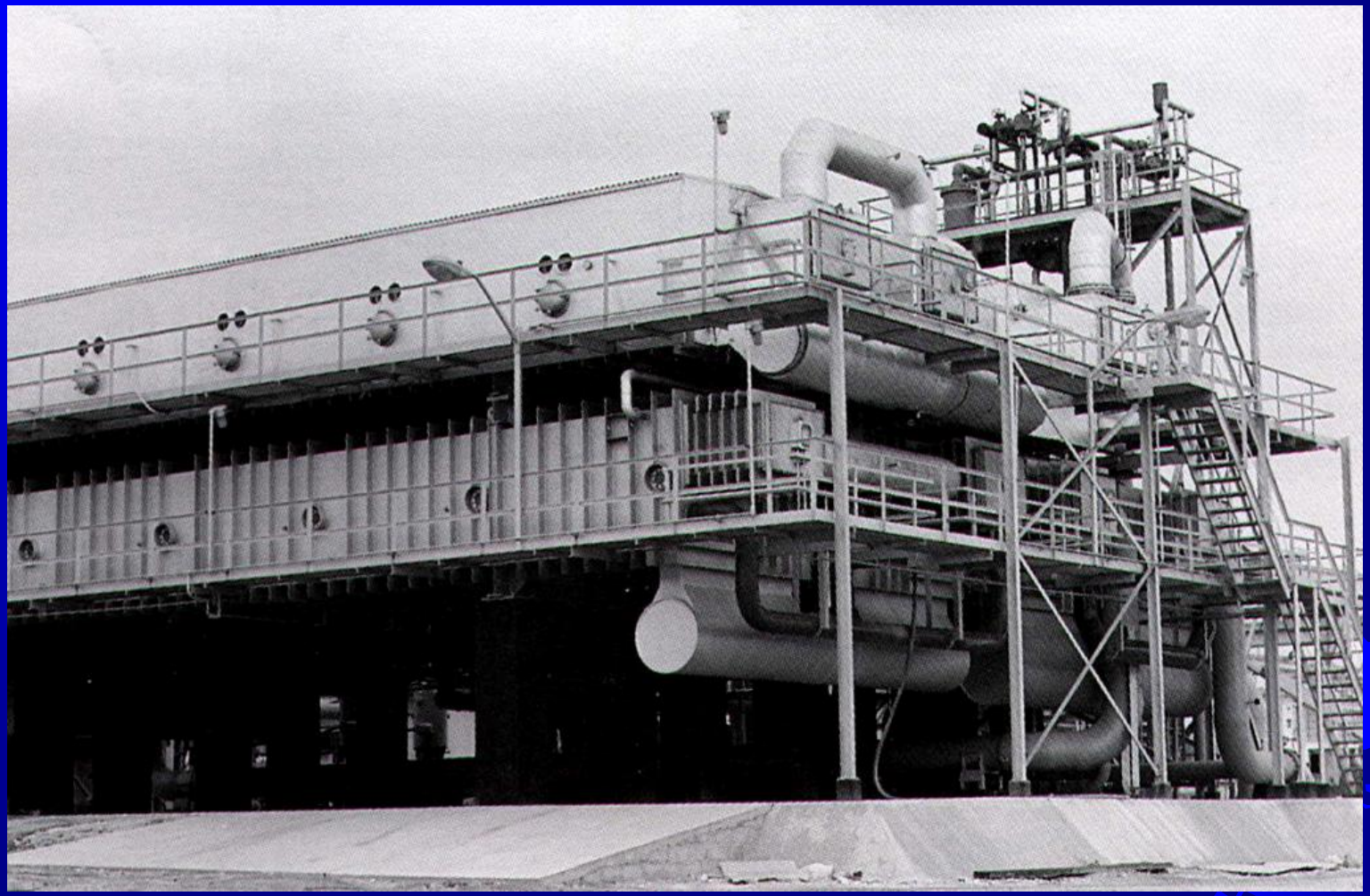
- Use two separate systems one for energy collection and one for desalination
- Conventional desalination systems are used
- Thermal processes
  - Reuse of the latent heat of evaporation to preheat the feed while at the same time condensing steam to produce fresh water.
- Membrane processes
  - Electricity is used for the operation of pumps (RO) or for the ionization of water (ED).

Multi Stage Flash (MSF) Evaporators

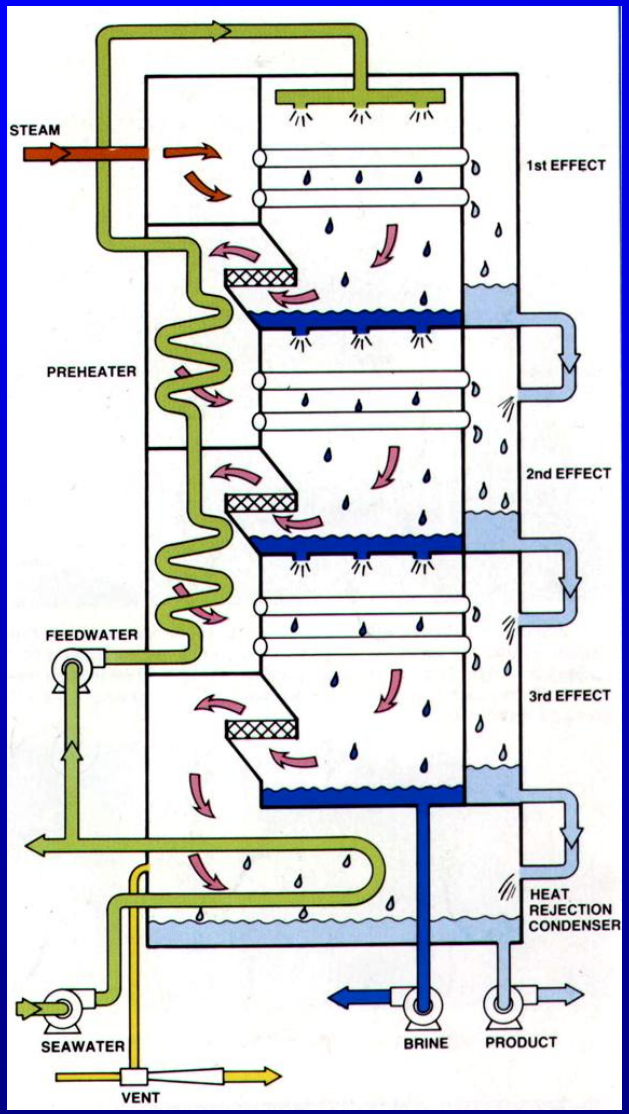


TYPICAL FLOW DIAGRAM OF ONCE-THROUGH MSF PLANT.

A photo of an actual MSF plant



Multiple Effect Boiling (MEB) Evaporator



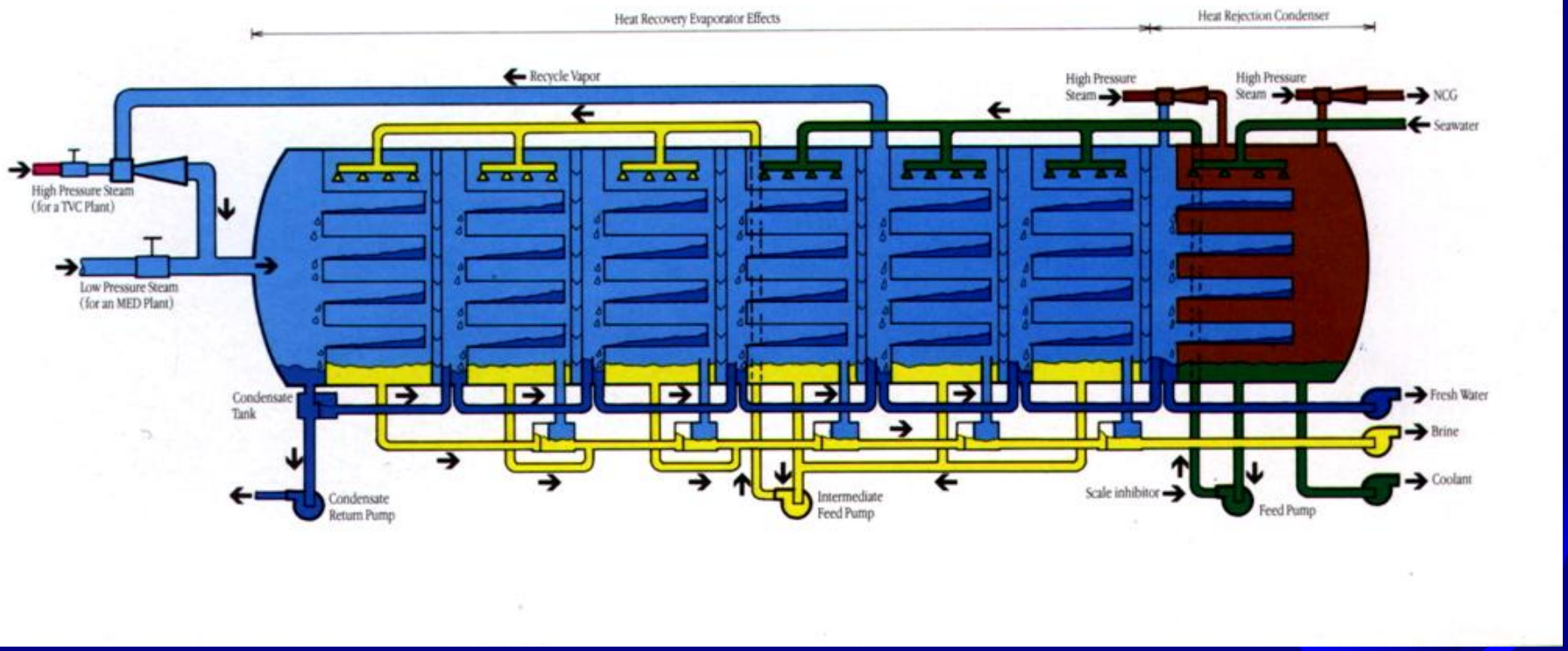
Multiple Effect Stack (MES) type evaporator

This is the most appropriate type for solar energy applications.

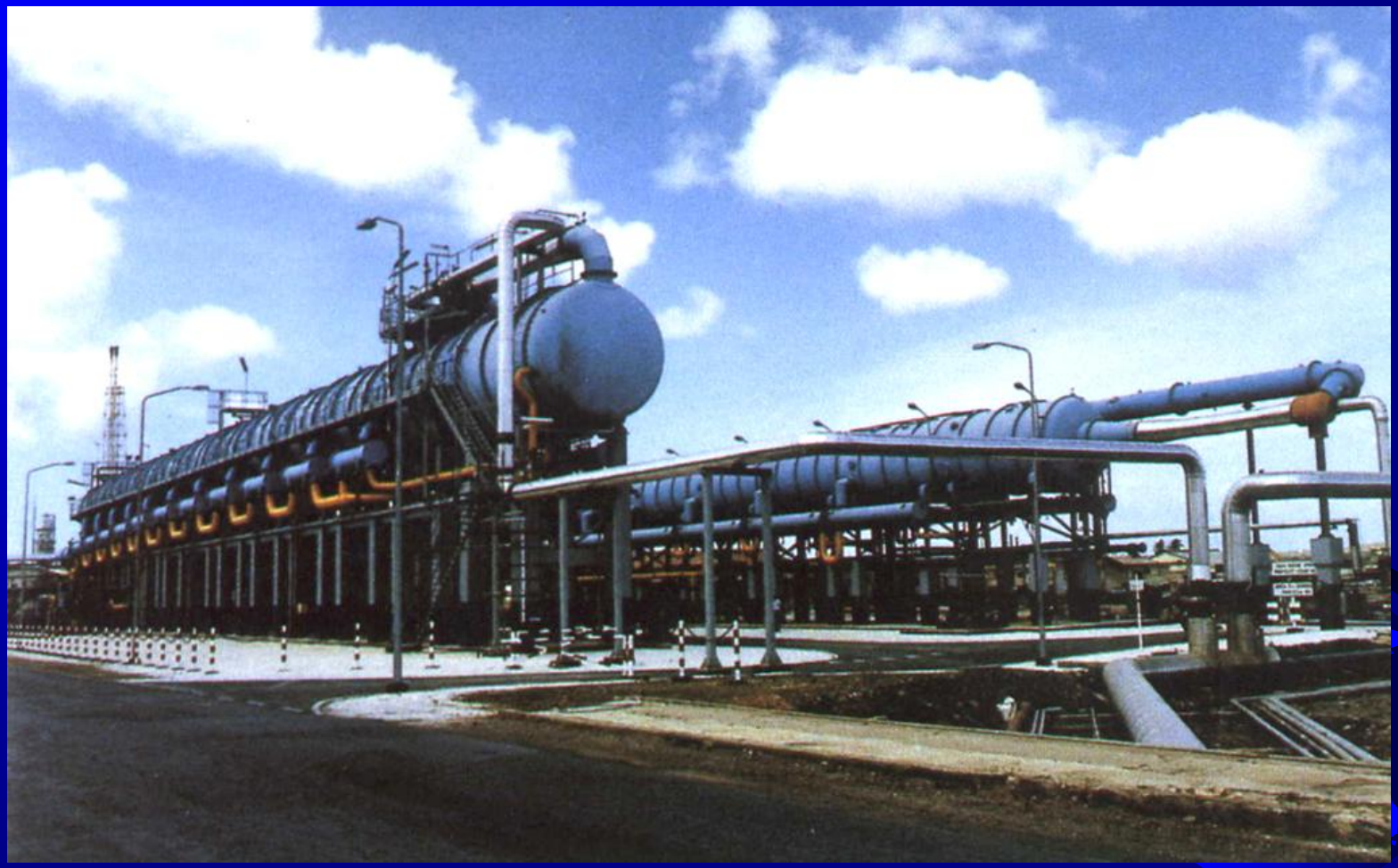
Advantages:

- Stable operation between virtually zero and 100% output even when sudden changes are made (most important).
- Its ability to follow a varying steam supply without upset.

Actual MEB schematic



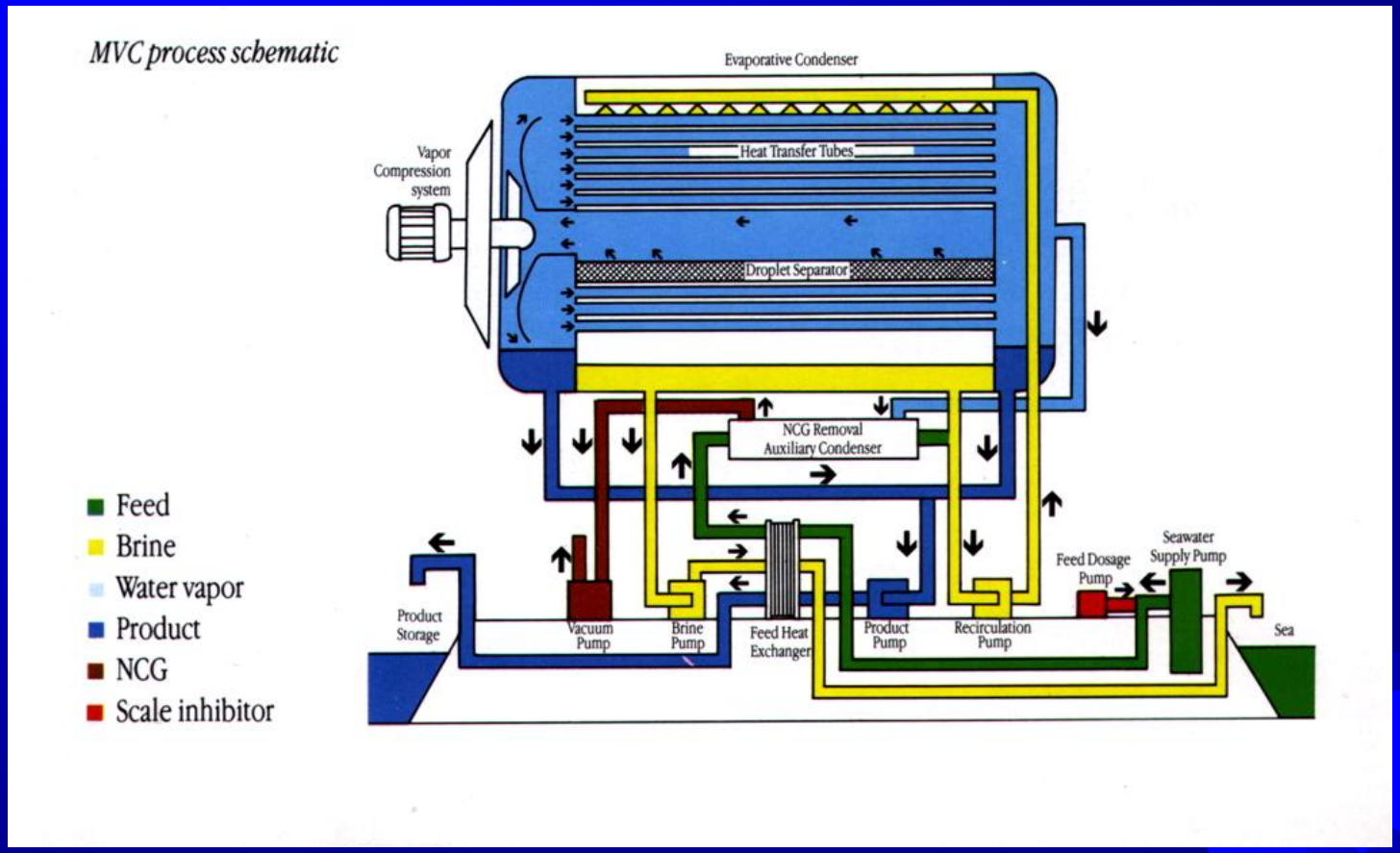
A photo of an actual MEB plant



Actual MES plant

Mechanical Vapour Compression (MVC)

Mechanical compressor is used

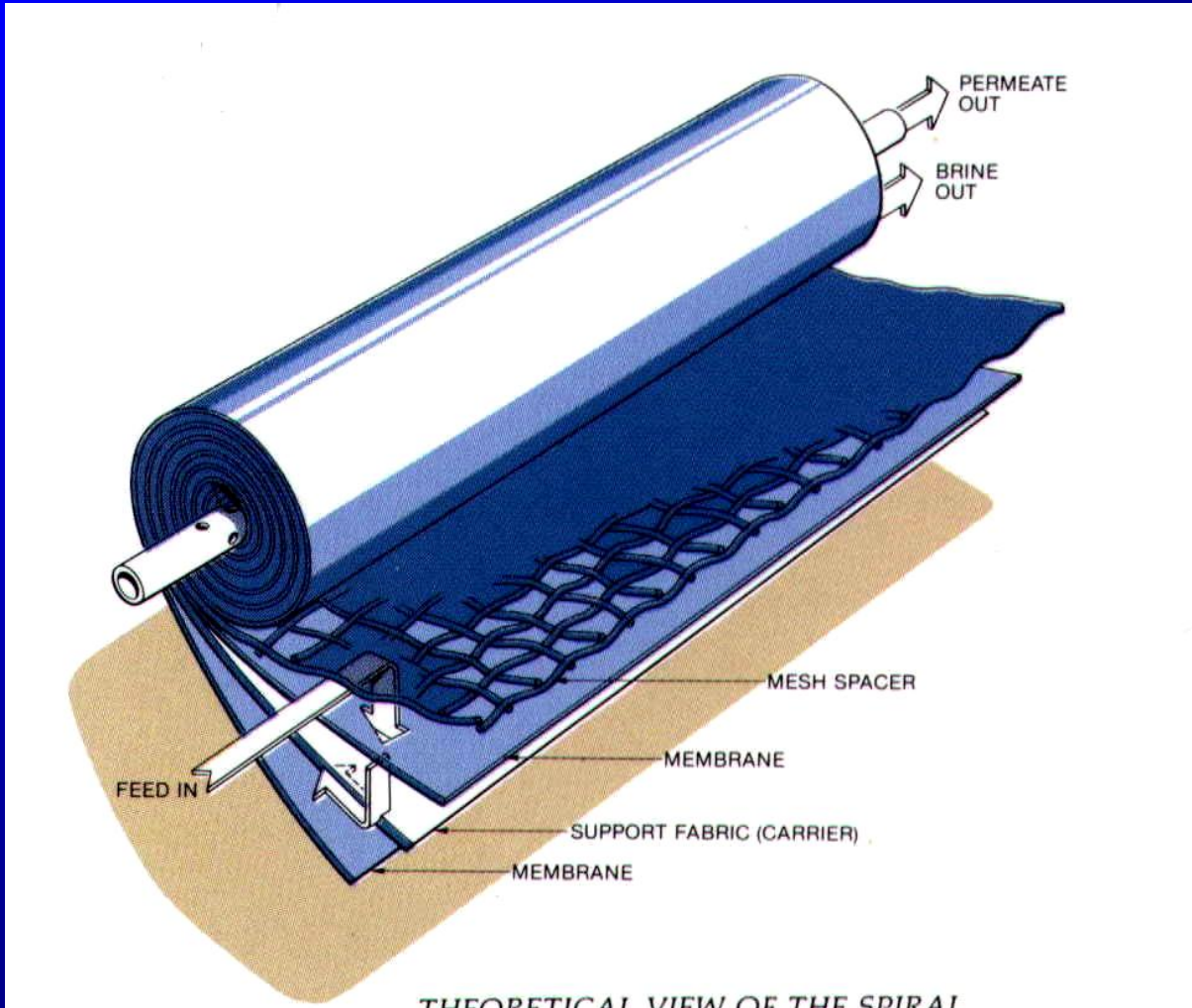


Principle: By pressurizing the steam condensation temperature increases thus steam can be used to provide energy for the evaporation of more seawater.

Thermal Vapour Compression (TVC)

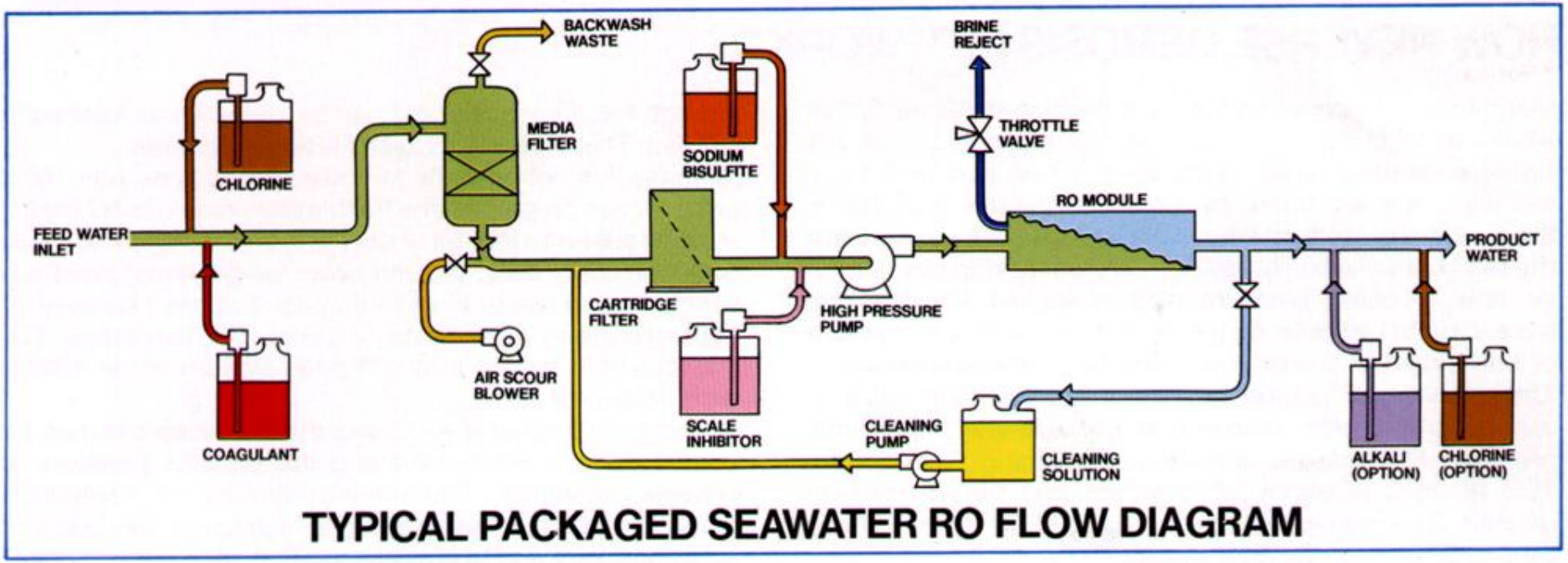
Jet ejector is used

Reverse Osmosis (RO) - element



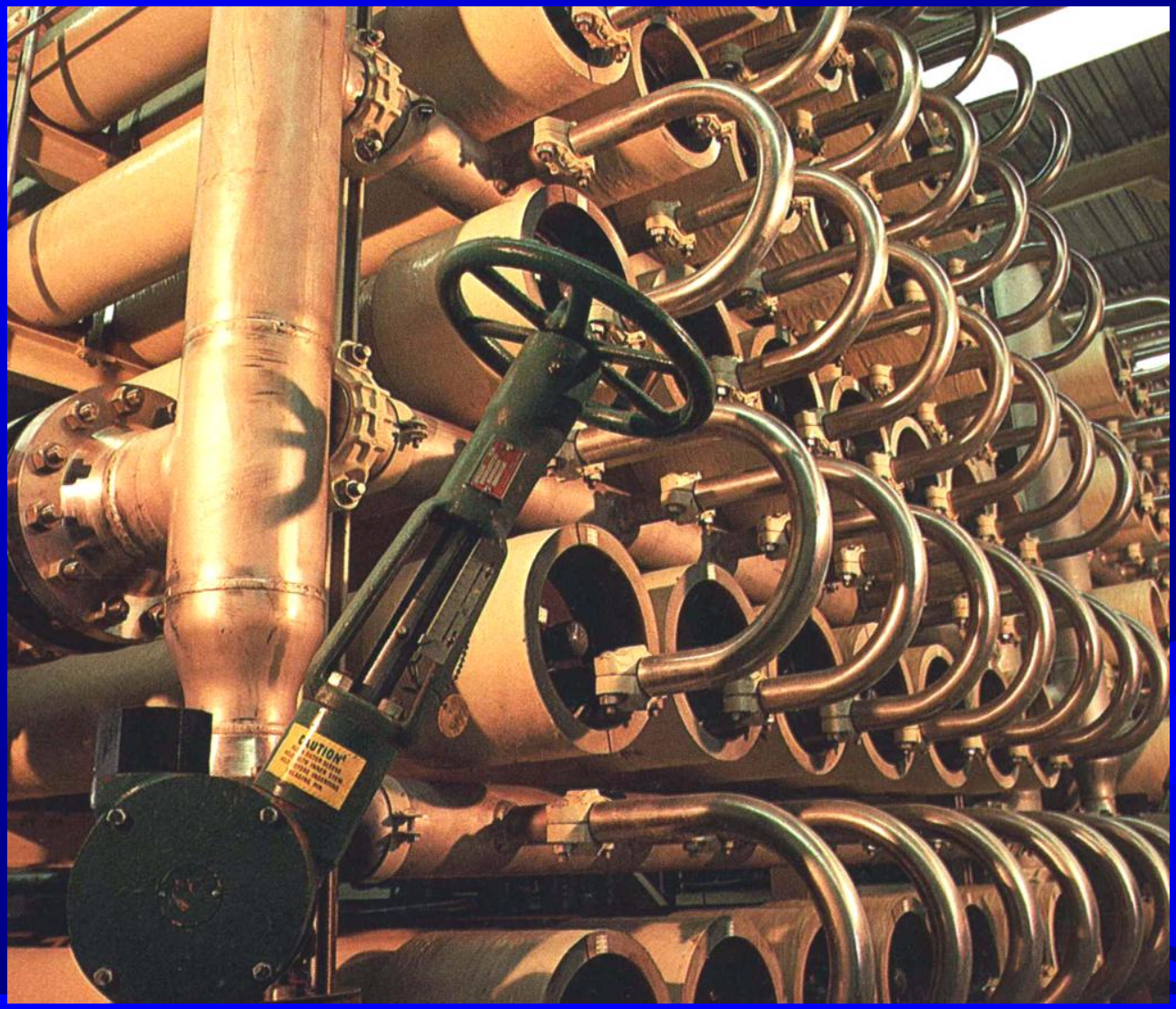
THEORETICAL VIEW OF THE SPIRAL WOUND ELEMENT

Reverse Osmosis system

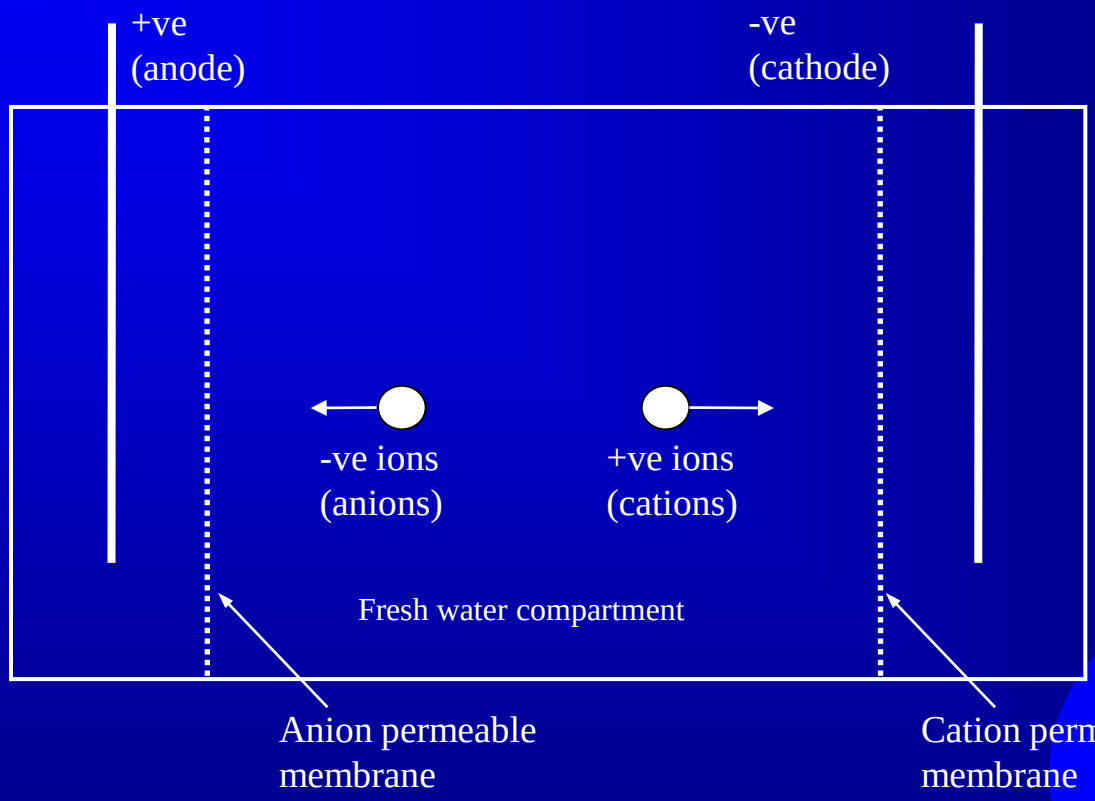


RO can be powered with solar photovoltaics

Reverse Osmosis - Banks

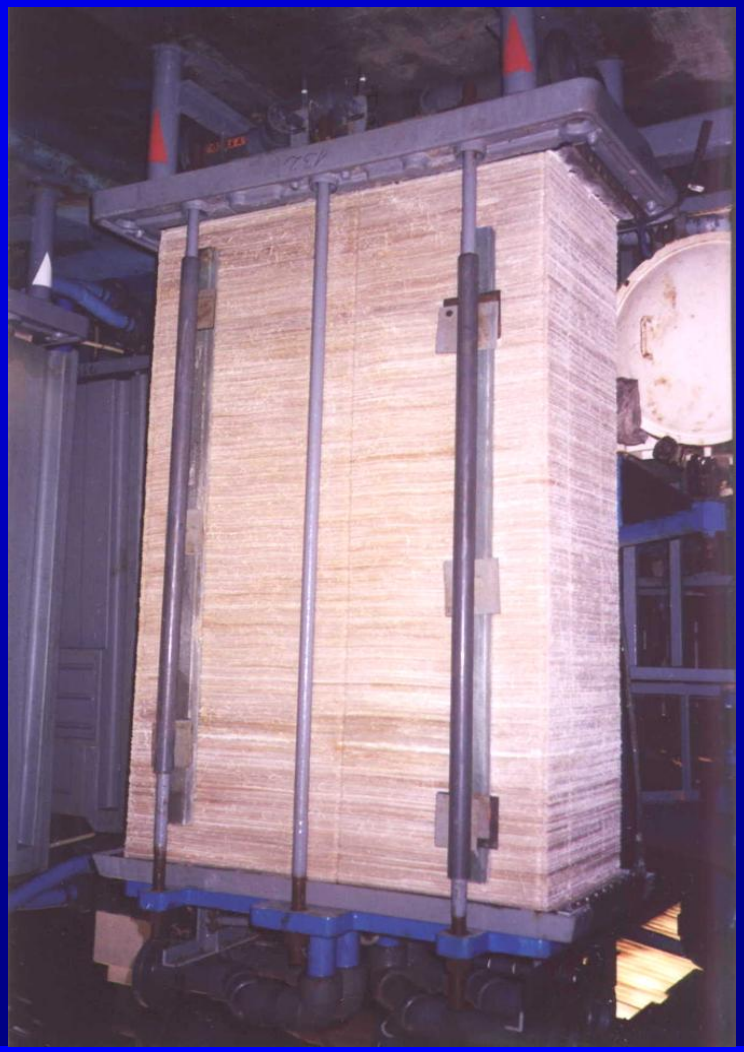


Electrodialysis (ED)



ED can be powered with solar photovoltaics

Electrodialysis unit during maintenance



Renewable Energy Sources

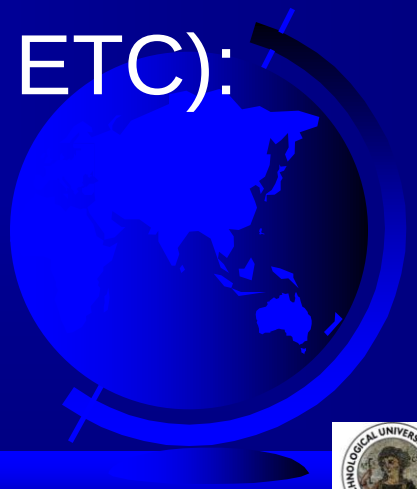
- Solar Energy
  - Thermal energy (solar collectors)
  - Electric energy (photovoltaic panels)
- Wind Energy
  - Electric energy (wind turbines)
  - Mechanical energy (pumps)
- Hydroelectric Energy
  - Electric Energy
- Geothermal Energy
  - Thermal Energy

Solar Desalination Methods

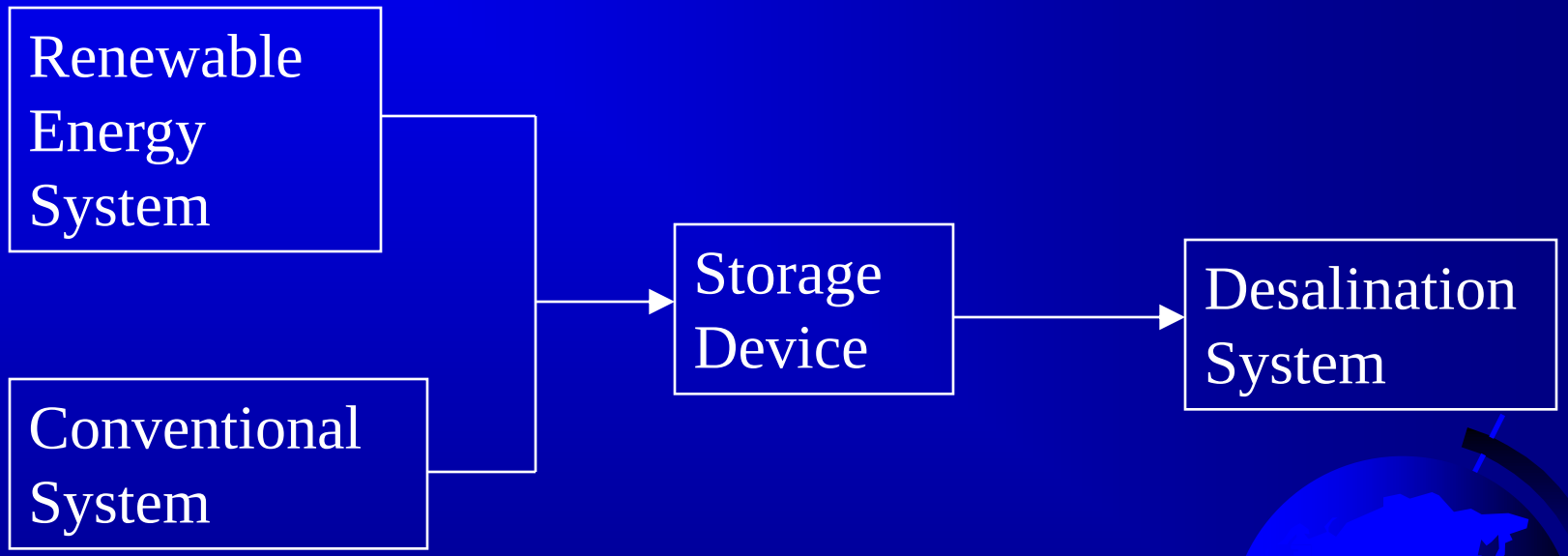
- Solar desalination is used in nature to produce rain.
- Solar Energy can be converted into:
  - Thermal energy (Thermal processes)
  - Electricity (Membrane processes)

Renewable Energy Sources and Desalination Combination of Technologies

- Photovoltaic panels and wind turbines:
  - Reverse Osmosis
  - Electrodialysis
  - Vapour compression systems
- Solar Collectors (FP, CPC, PTC, ETC):
  - Multistage flash evaporators
  - Multiple effect boiling evaporators



Combination of RE with conventional desalination systems



Solar Drying

Solar drying

- Solar drying is another very important application of solar energy.
- Solar dryers are using air collectors for the collection of solar energy.
- Solar dryers are used primarily by the agricultural industry.
- The purpose of drying an agricultural product is to reduce its moisture contents to that level which will prevent its deterioration-preserve food.
- In drying, two processes take place:
  - heat transfer to the product using energy from the heating source
  - mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air.

Dried food-Raisins

Natural drying

- Traditionally the farmers use the open-to-sun or natural drying technique, which achieve drying by using solar radiation, ambient temperature, relative humidity of ambient air and natural wind.
- The crop is placed on the ground or on concrete floors, which can get higher temperature in open sun and left there for a number of days to dry.
- Capacity wise, and despite the very rudimentary nature of the process, natural drying remain the most common method of solar drying (free energy).

Limitations of natural drying

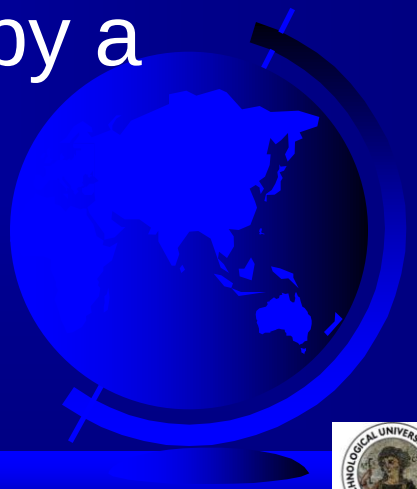
- The most obvious ones are that the crops suffer the undesirable effects of dust, dirt, atmospheric pollution, and insect and rodent attacks.
- Because of these limitations, the quality of the resulting product can be degraded sometimes beyond edibility.
- These disadvantages can be eliminated by using a solar dryer.

Objective of a dryer

- The purpose of a dryer is to supply more heat to the product than that available naturally under ambient conditions, thus increasing sufficiently the vapor pressure of the crop moisture.
  - Moisture migration from the crop is improved.
- The dryer decreases also significantly the relative humidity of the drying air, and by doing so, its moisture carrying capability increases, thus ensuring a sufficiently low equilibrium moisture content.

Type of dryers

- There are two types of solar dryers; the ones that use solar energy as the only source of heat and the ones that use solar energy as a supplemental source.
- The airflow can be either natural convection or forced, generated by a fan.



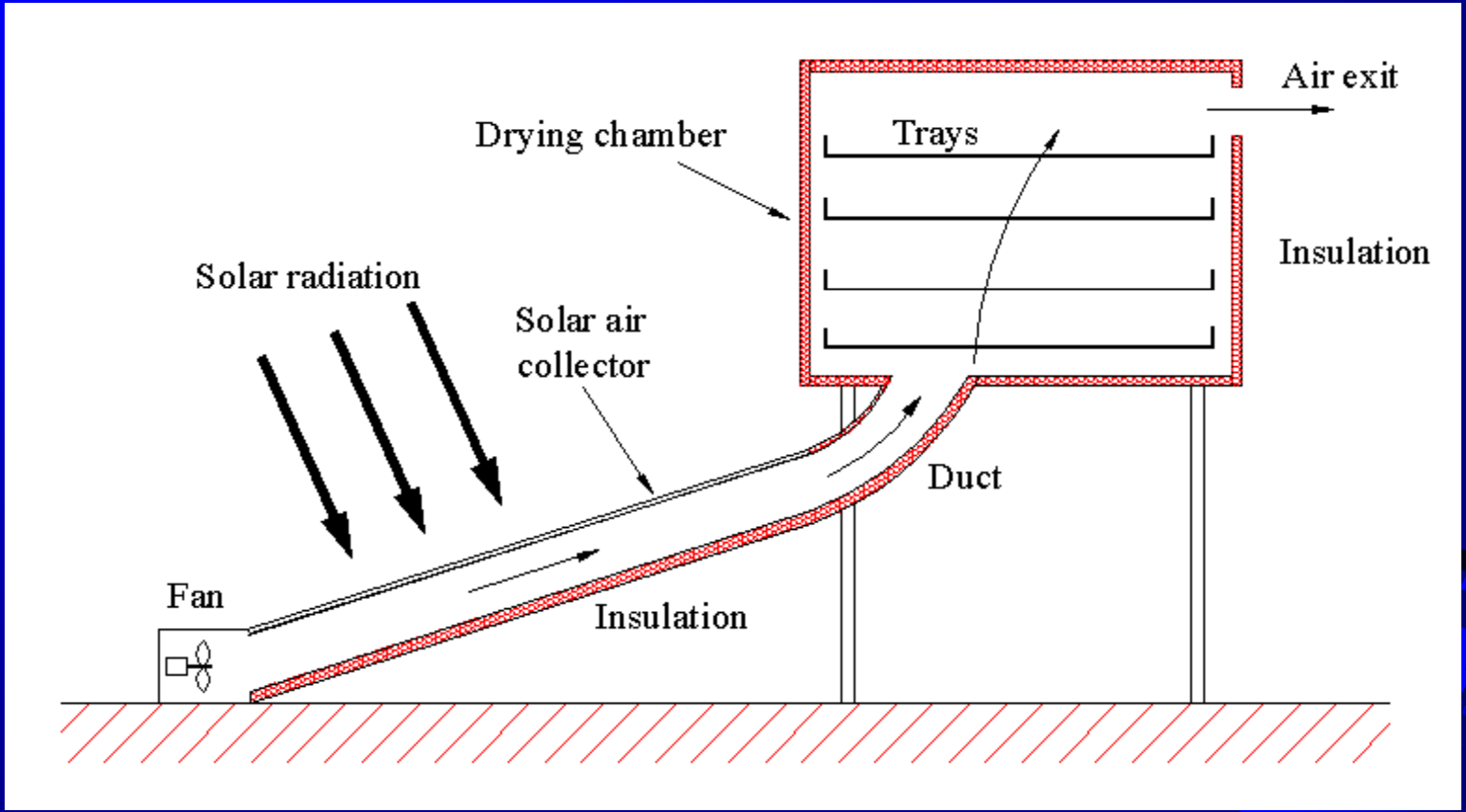
Classification of solar dryers

- Solar energy dryers are classified according to the
  - heating mode employed,
  - way the solar heat is utilized and
  - their structural arrangement.
- With respect to the heating mode employed, two main categories exists the active and passive dryers.
  - In active systems a fan is used to circulate air through the air collector to the product (Require some form of non-renewable energy form).
  - In passive or natural-circulation solar energy dryers, solar-heated air is circulated through the crop by buoyancy forces as a result of wind pressure and temperature difference.

Sub-classes

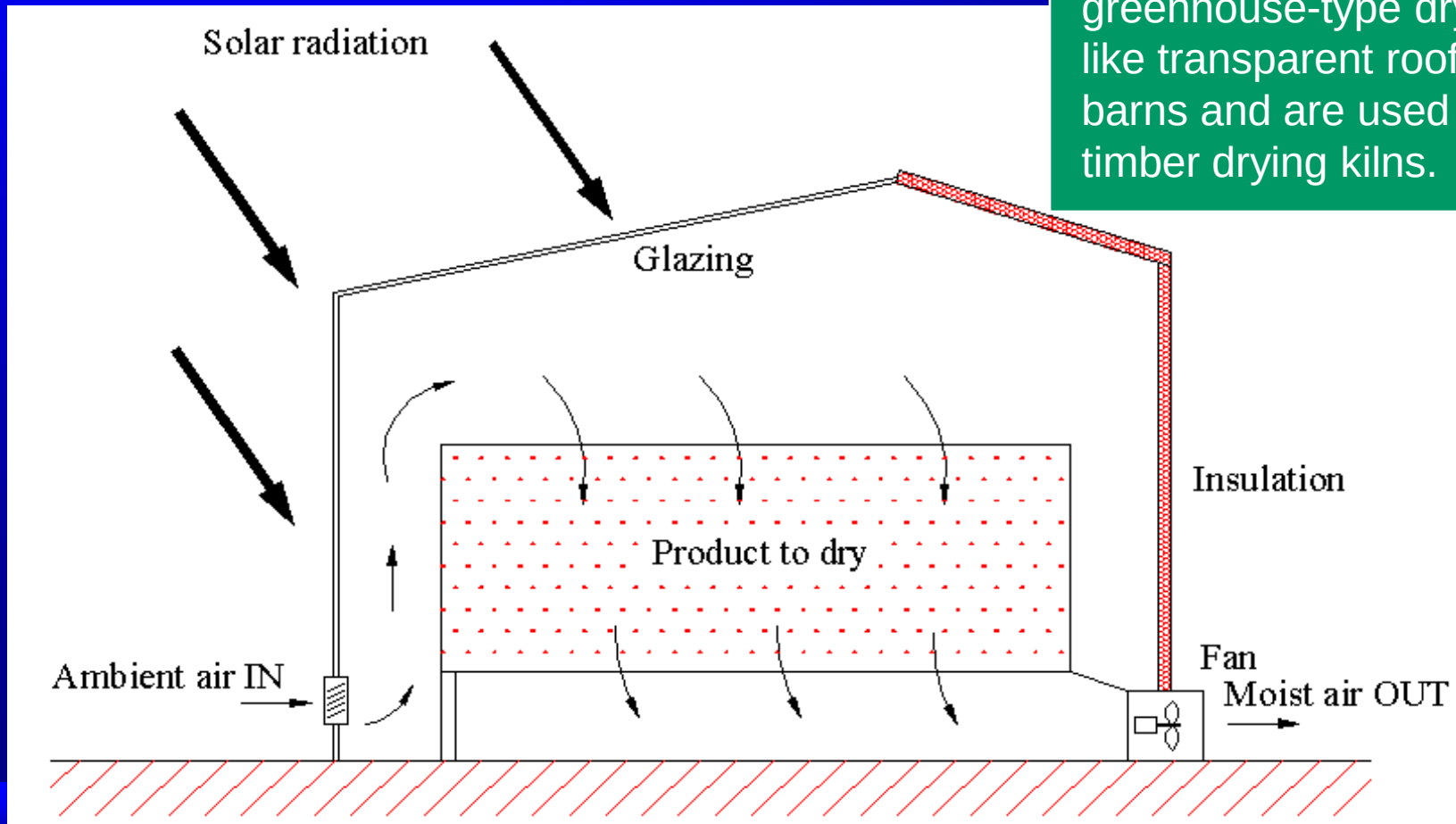
- With respect to the mode of solar energy utilization and structural arrangements three major sub-classes exists;
  - distributed-type,
  - integral-type and
  - mixed-mode type dryers.
- These sub-classes belong to both active and passive solar energy dryers.
- In a distributed-type solar energy dryer, the solar energy collector and the drying chamber are separate units.
- In integral-type solar energy dryer, the same piece of equipment is used for both solar energy collection and dryer, i.e., the dryer is capable of collecting solar energy directly, and no solar collectors are required.
- In the mixed mode-type, the two systems are combined, i.e., the dryer is able to absorb heat directly but the process is enhanced by the use of a solar collector.

Active solar energy dryers
Distributed type



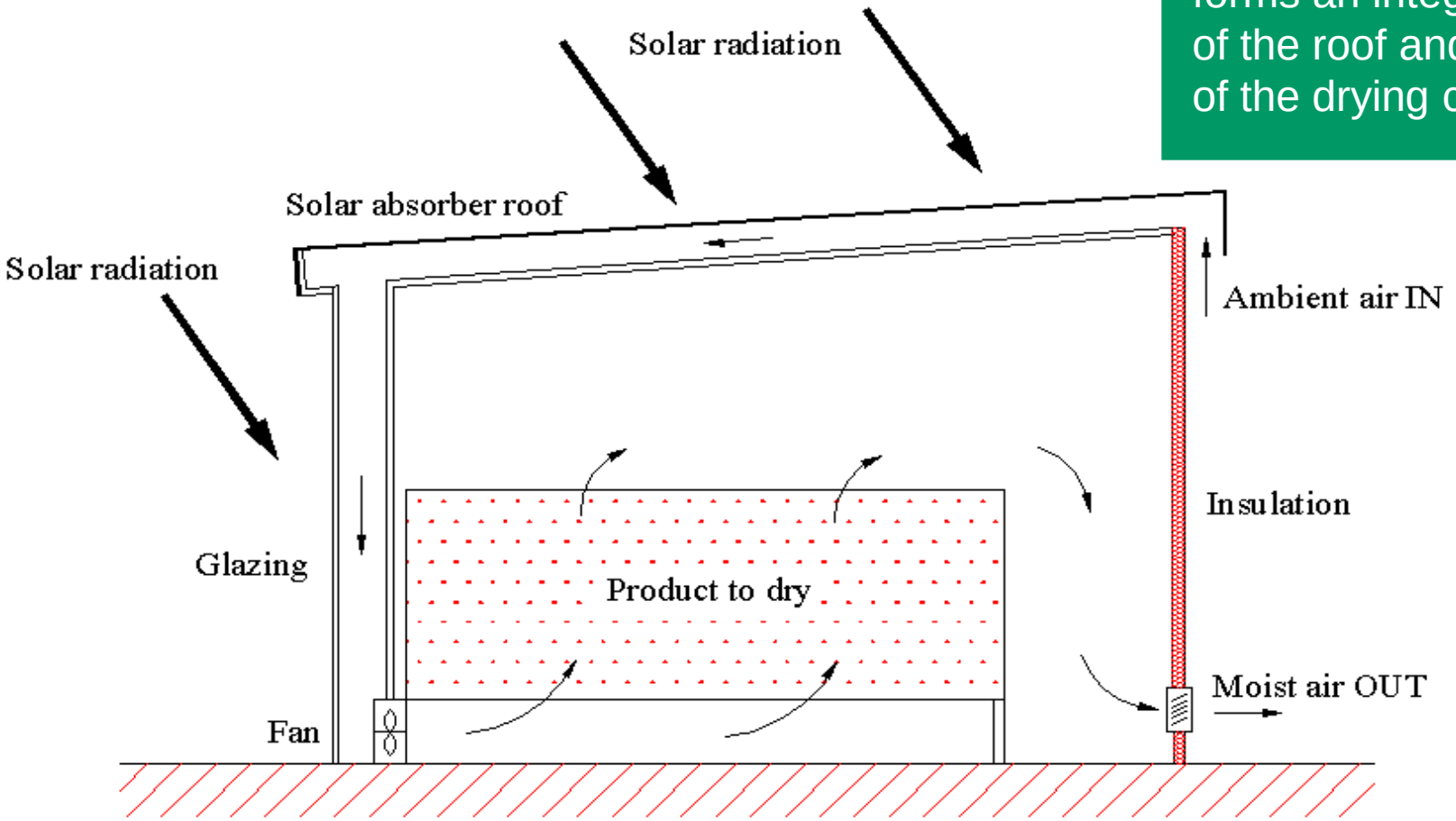
Active solar energy dryers
Integral type

Large-scale commercial forced-convection greenhouse-type dryers are like transparent roof solar barns and are used for solar timber drying kilns.

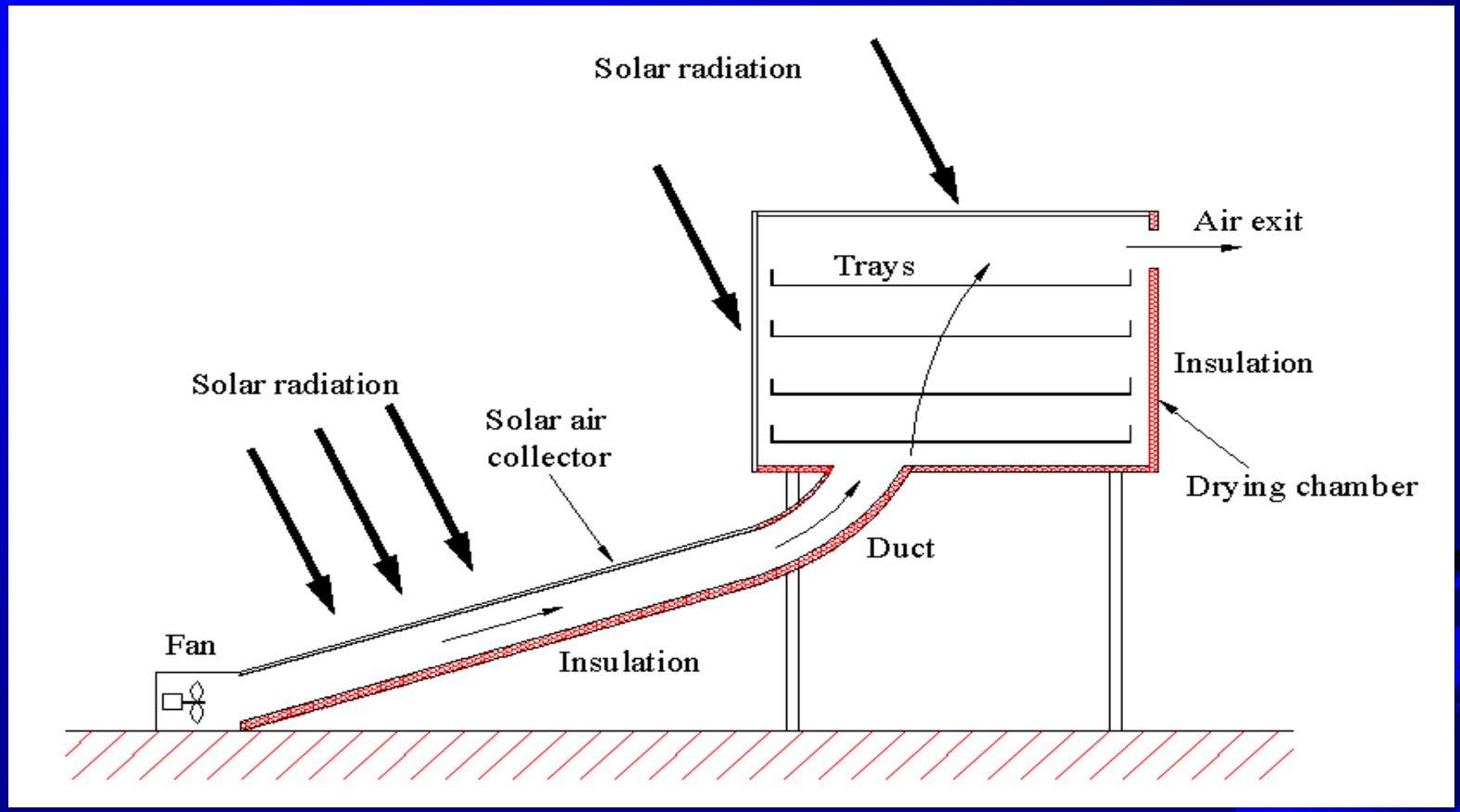


Another variation

This is a collector-roof/wall in which the solar heat collector forms an integral part of the roof and/or wall of the drying chamber.



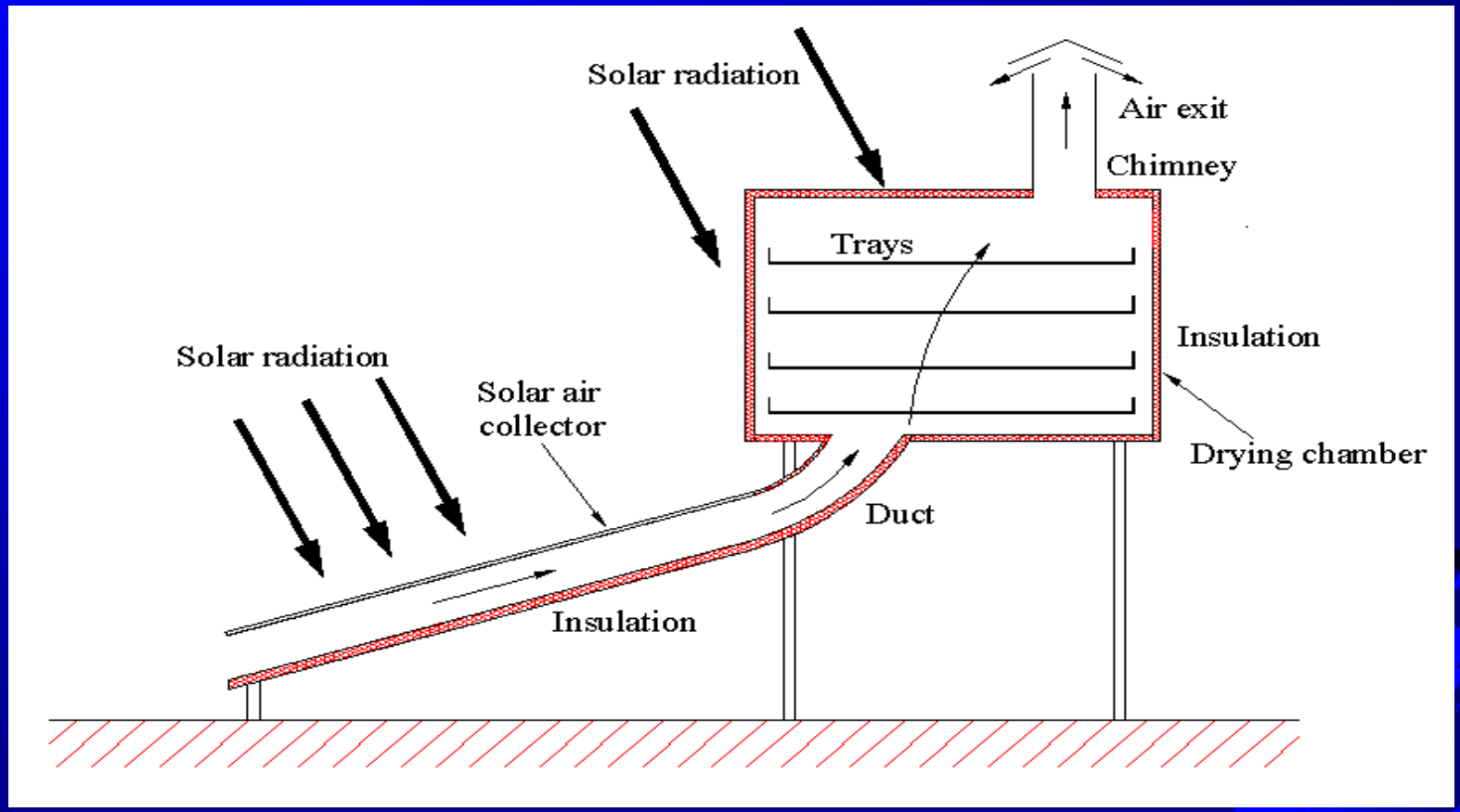
Active solar energy dryers
Mixed-mode type



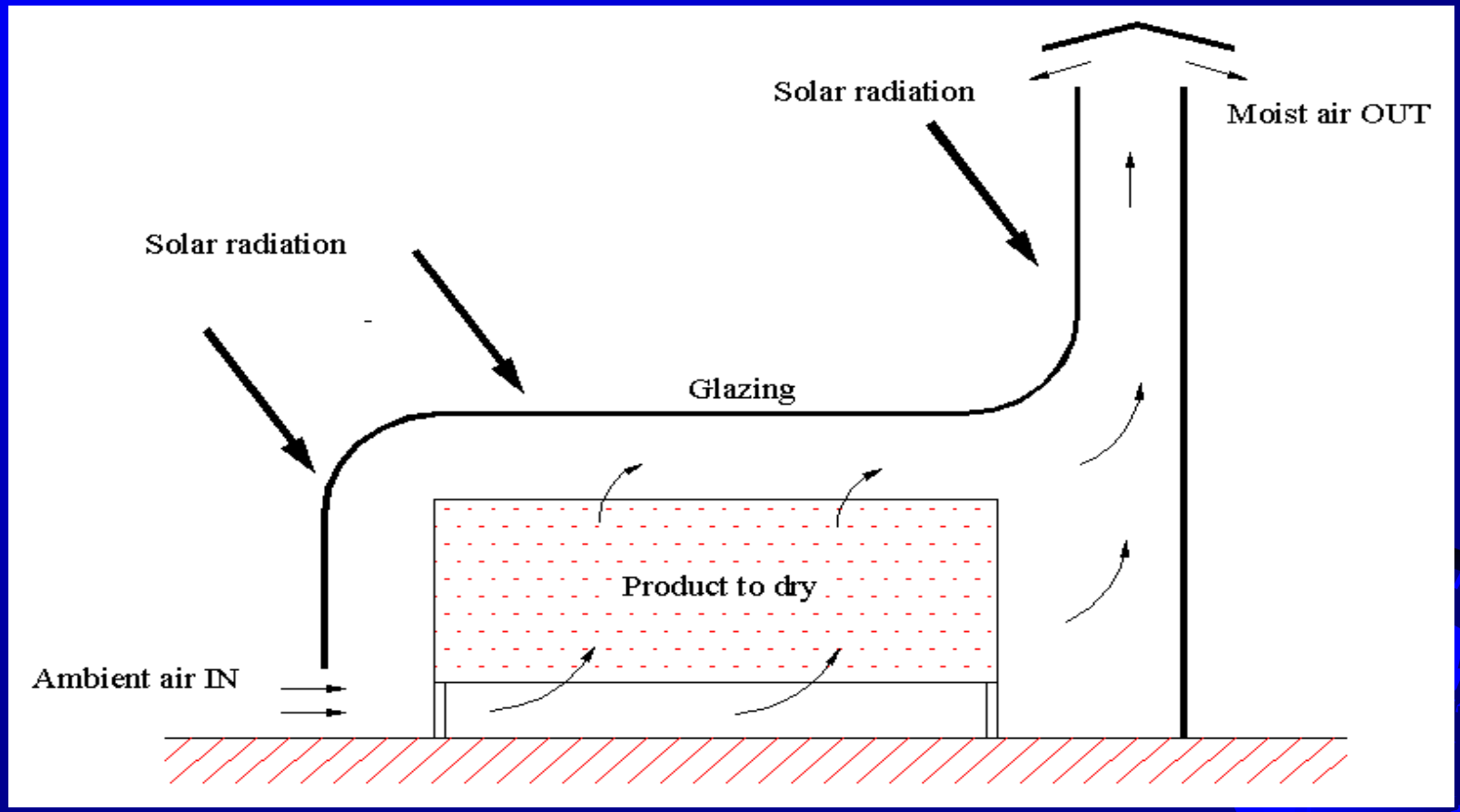
Passive solar energy dryers

Passive or natural-circulation solar energy dryers operate by using entirely renewable sources of energy such as solar and wind.

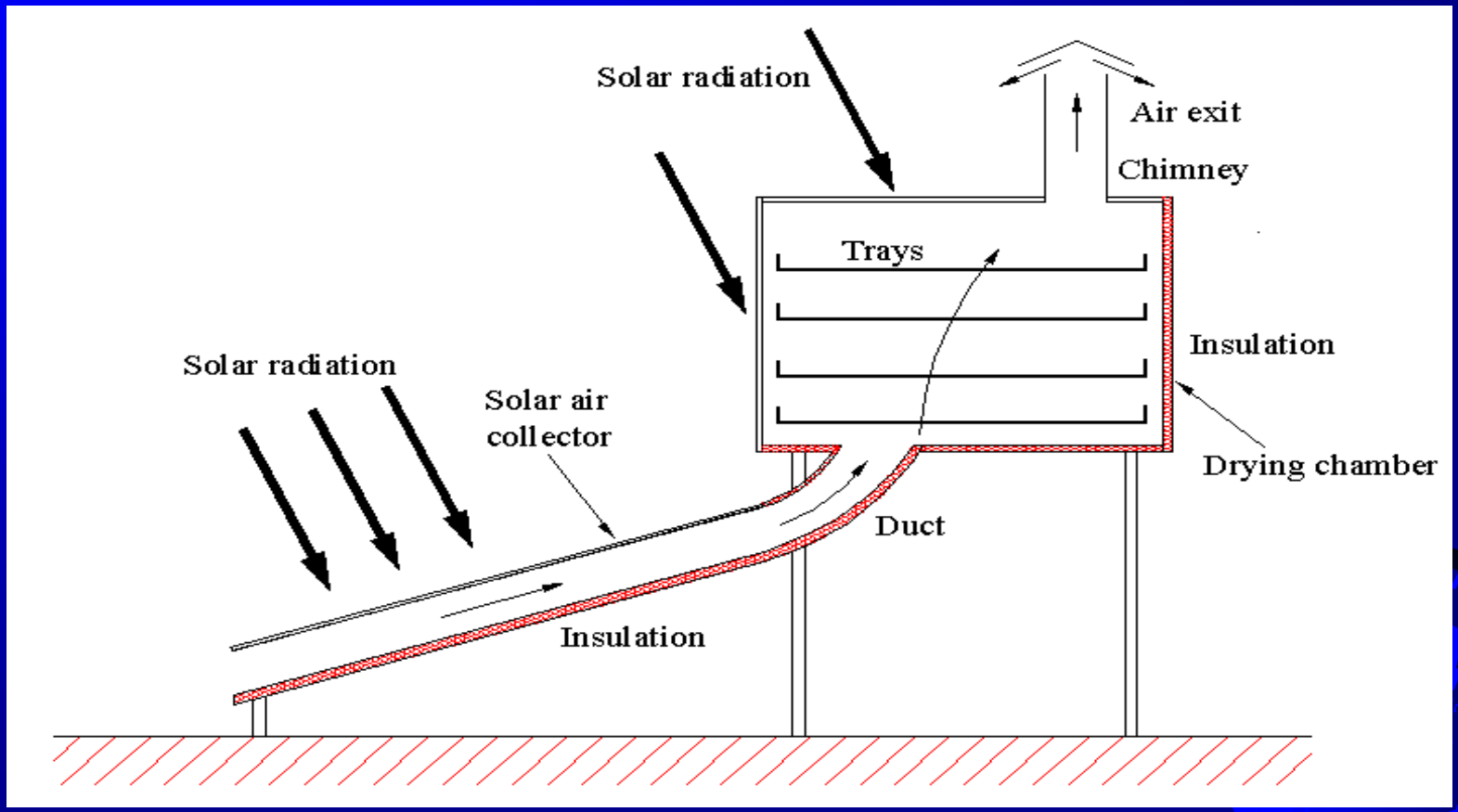
Passive solar energy dryers
Distributed-type



Passive solar energy dryers
Integral type



Passive solar energy dryers
Mixed-mode type



Greenhouses

General characteristics

- The basic function of a greenhouse is to provide environmental conditions, which accelerate the process of photosynthesis, which is highly sensitive to environmental factors.
- The requirements for the interior microclimate of a greenhouse vary according to the particular plant species and its stage of growth, characterized by the:
  - temperature,
  - illumination and
  - interior atmosphere, i.e., water vapor, carbon dioxide and pollutants (nitrogen oxides and sulphur).

General characteristics-cont.

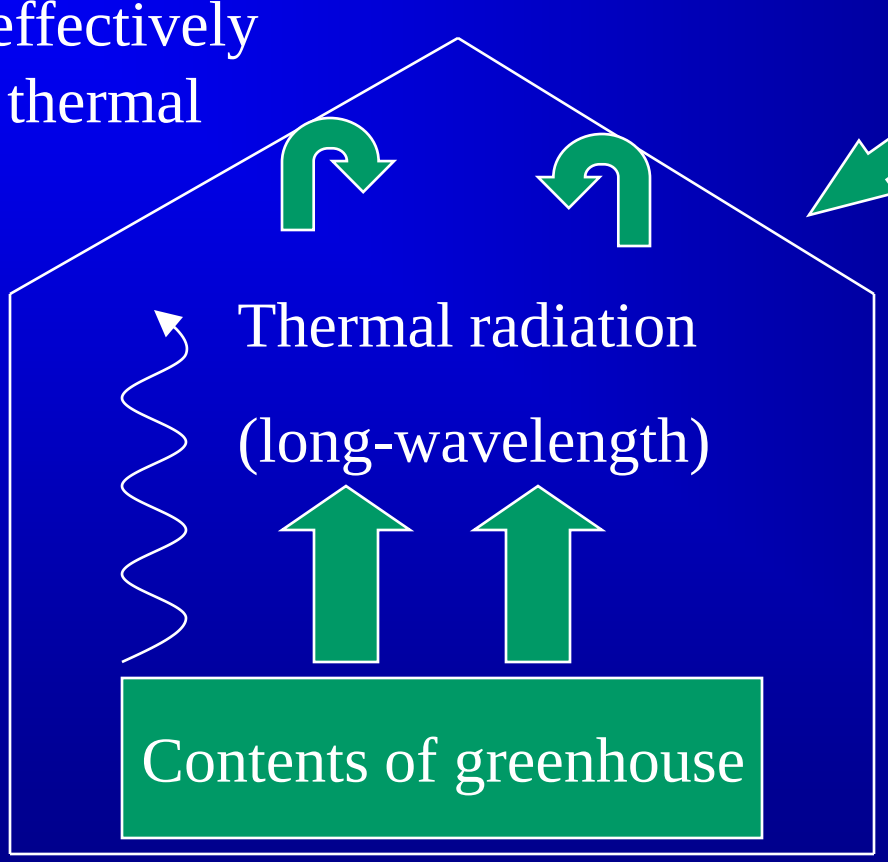
- It should be noted that a greenhouse designed for a particular climate can produce an environment suitable for a specific crop type.
- The same greenhouse, in another location or at a different time of the year, may be unsuitable for that same type of crop.
- Therefore, the plant varieties to be grown in a greenhouse should be chosen to suit the artificial environment, which can be achieved economically within the greenhouse.

Basic principle

- The main objective for the development of covered areas for growing food was the need for frost protection.
- Heat is usually obtained from solar radiation and from auxiliary sources.
- By “greenhouse effect”, we mean the internal environment of a space which is heated by the short-wave solar insolation which is transmitted through the cover and absorbed by its internal surfaces (see fig.).
- These surfaces re-emit heat radiation, which is at longer wavelengths that cannot escape through the cover and in this way, the heat is trapped into the space.

Greenhouse effect

Plastic is effectively opaque to thermal radiation



Solar radiation
(short-wavelength)

Greenhouse materials

- Traditionally, the first material used for greenhouse cover was glass.
- From the time clear plastic materials were produced on a commercial scale, their potential for replacing glass has been recognized.
- Polyethylene is very popular because it is available in wider sections than most other films and is of low cost, despite its short lifetime of about a year, when exposed to typical weather conditions.

Kew gardens-London (glass)

Characteristics of plastics

- Generally, plastic materials have inferior light-transmission properties compared with glass.
- Additionally, as they degrade when exposed to heat and ultraviolet light, their useful live is much shorter, typically, a few years compared with decades for glass.
- The advantages of plastic materials however, are their low specific mass and high strength, requiring a lightweight structure and lower cost, resulting in lower initial investments.

Greenhouse with plastic film

Large greenhouses

Thank you for your attention

Any question please…