Minor Processes

Lecture 13

Minor Desalination Processes

- A number of other processes have been used to desalt saline waters, though these processes **have not achieved the level of commercial success** that major processes have, but may prove valuable under special circumstances or with further development.
- The most significant of these processes are **freezing, solar desalination and membrane distillation.**
- Others have proved promising on both laboratory and pilot plant scale and are still to be scaled up to an industrial scale process.

Freezing-Melting (FM)

- In 1786 Lorgna (an Italian scientist Anton Maria Lorgna (1735–1796)) published his first paper on water desalination by freezing and he was wondering why nobody had previously applied it in an artificial process initiating what nature does so well and easily in the cold seas (i.e. blocks of fresh water ice from seawater).
- He also identified that a single freezing of seawater produced an ice block having salinity, although much less than that of seawater.
- This justified the needs of multistage freezing-melting (FM) process.
- Freezing in large bodies of water occurs in nature on the surface of oceans, lakes, and bays

Freezing-Melting (FM)

- Extensive work was done in the **1950's and 1960's** to develop FM desalination basis.
- During the process of freezing, **dissolved salts are naturally excluded during the formation of ice crystals.**
- Seawater can be desalinated by cooling the water to form crystals under controlled conditions.
- Before the entire mass of water has been frozen, the mixture is usually **washed and rinsed to remove the salts** adhering to the ice crystals.

Freezing-Melting (FM)

- In a FM process, first the solution is partially frozen, the ice crystals are physically separated from residual solution (i.e. concentrated solution), and the ice is melted to form the product water.
- The FM process is accomplished in two major stages: ice crystallization (Stage I), and separation and melting (Stage II).
- **In stage I**, nucleation occurs at a suitable supercooling temperature. The nuclei in solution grow to become large ice crystals in a crystallization unit.
- **In stage II**, the crystals are separated from the concentrate by a separator (mechanical) and then melted to produce pure water.
- In some cases, a precooling step is used on the feed, which reduces heat load in the freezer.

Freezing-Melting

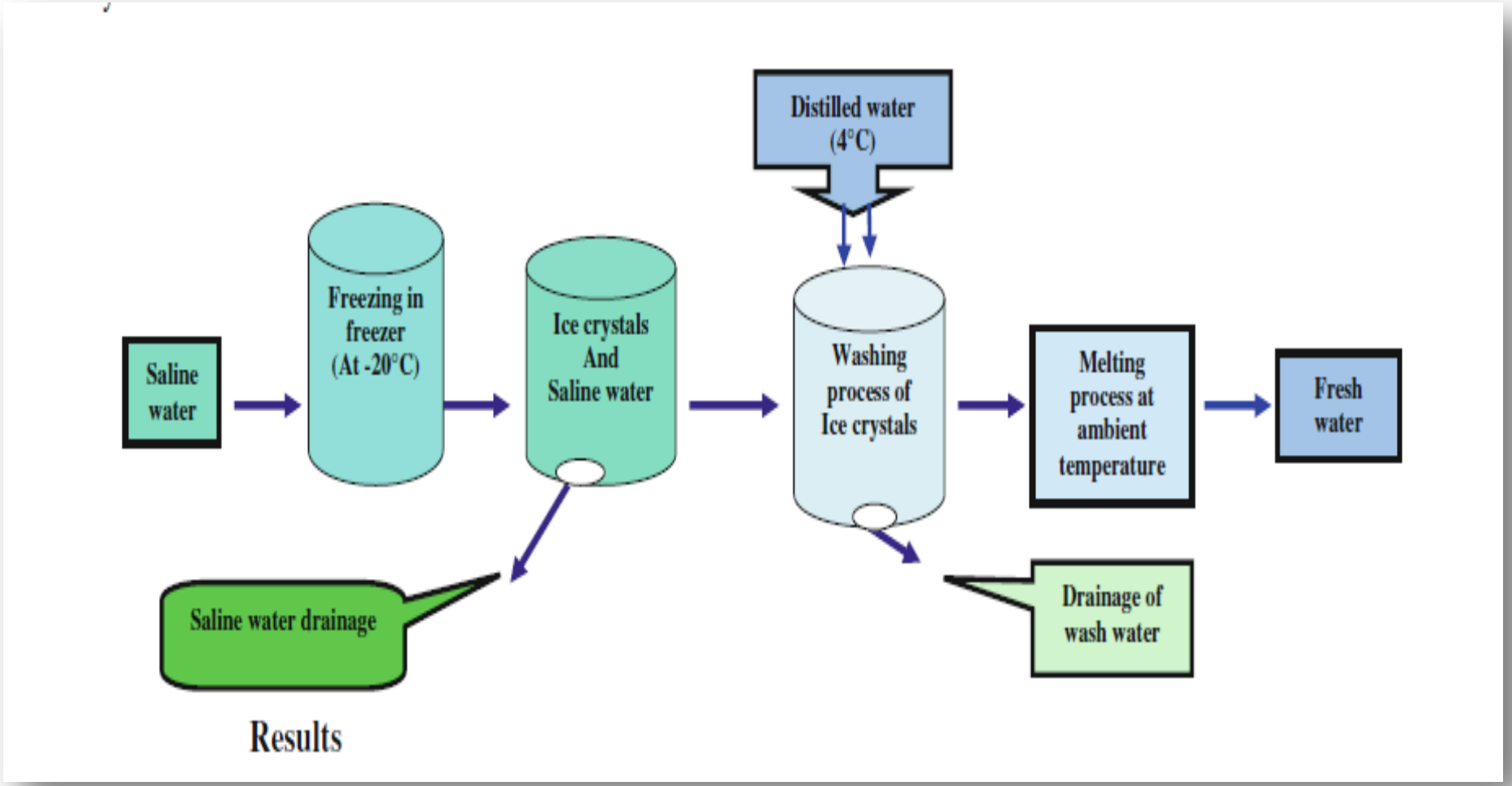
- The washed ice is then separated, and melted to produce fresh water.
- Theoretically, FM has some **advantages** over distillation.

These advantages include:

1. A lower energy requirement.
2. Minimal potential for corrosion
3. Little scaling or precipitation.

The **disadvantage** is that it involves **handling ice and water** mixtures that are mechanically complex to move and process

Freezing-Melting



Freezing-Melting

- A small number of plants have been built over the past 50 years, but **the process has not been a commercial success** in the production of fresh water for municipal purposes.
- The most recent significant example of a FM desalting plant was an experimental solar-powered unit constructed in Saudi Arabia in the late 1980's.
- Nowadays, FM desalting technology probably has a better application in the **treatment of industrial wastes** rather than the production of municipal drinking water.

Solar distillation

- The use of direct solar energy for desalting saline water has been investigated and used for sometime.
- During World War II, considerable work went into making small solar stills for use on life rafts.
- This work continued after the war with a variety of devices being made and tested.
- In these devices, **the saline water is heated by the sun's rays so that the production of water vapor by humidification increases.**
- The **water vapor** is then **condensed** on a cool surface, and the condensate collected as product water.

Solar distillation

- An example of this type of process is the **greenhouse solar still,** in which the saline water is heated in a basin on the floor and the water vapor condenses on the sloping glass roof that covers the basin.
- Variations of this type of solar still have been made in an effort to increase efficiency, but they all share the following difficulties, which **restrict** the use of this technique for large-scale production:

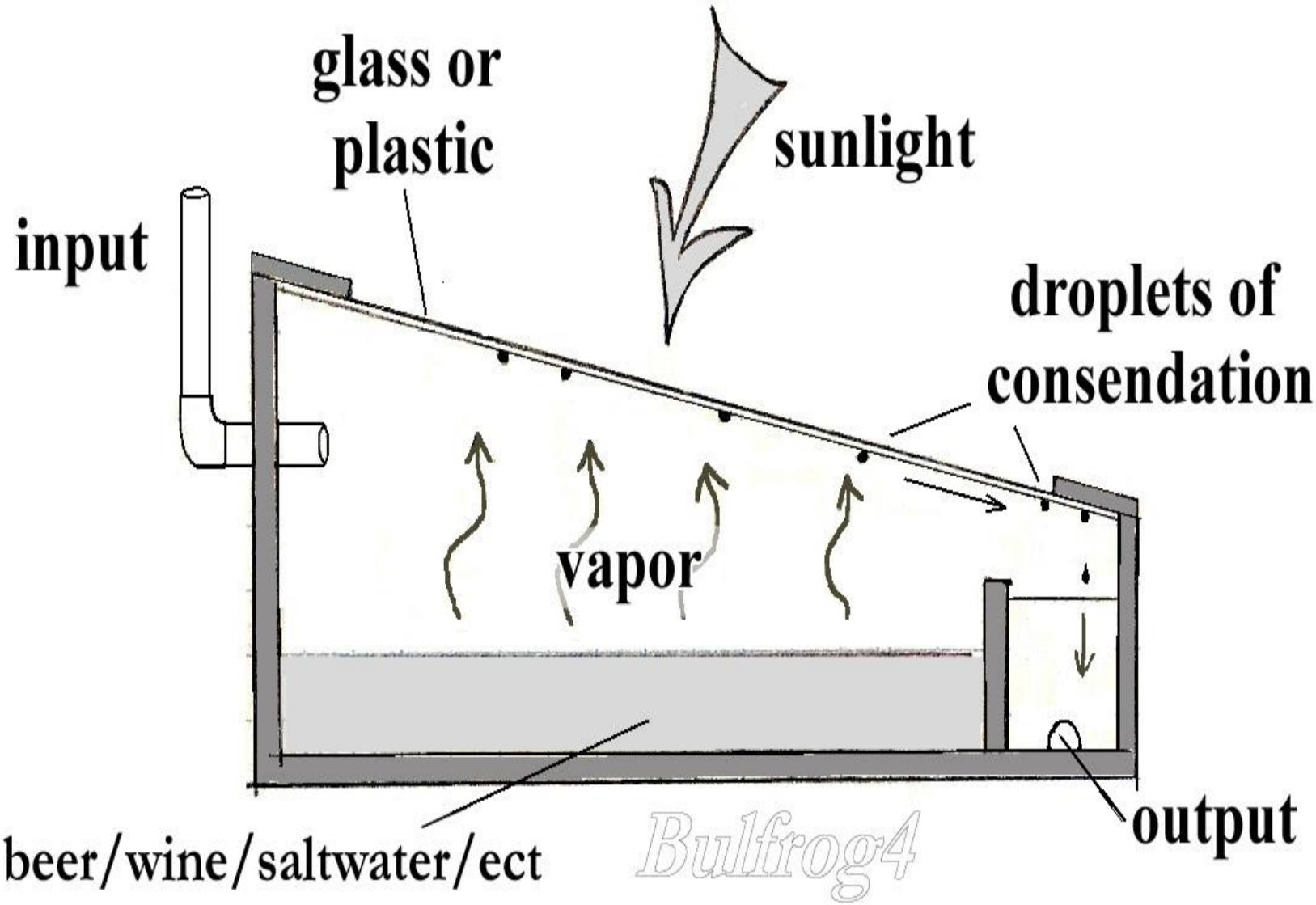
1. Large solar collection area requirement.
2. High capital cost.
3. Vulnerability to weather related damage.

Solar distillation

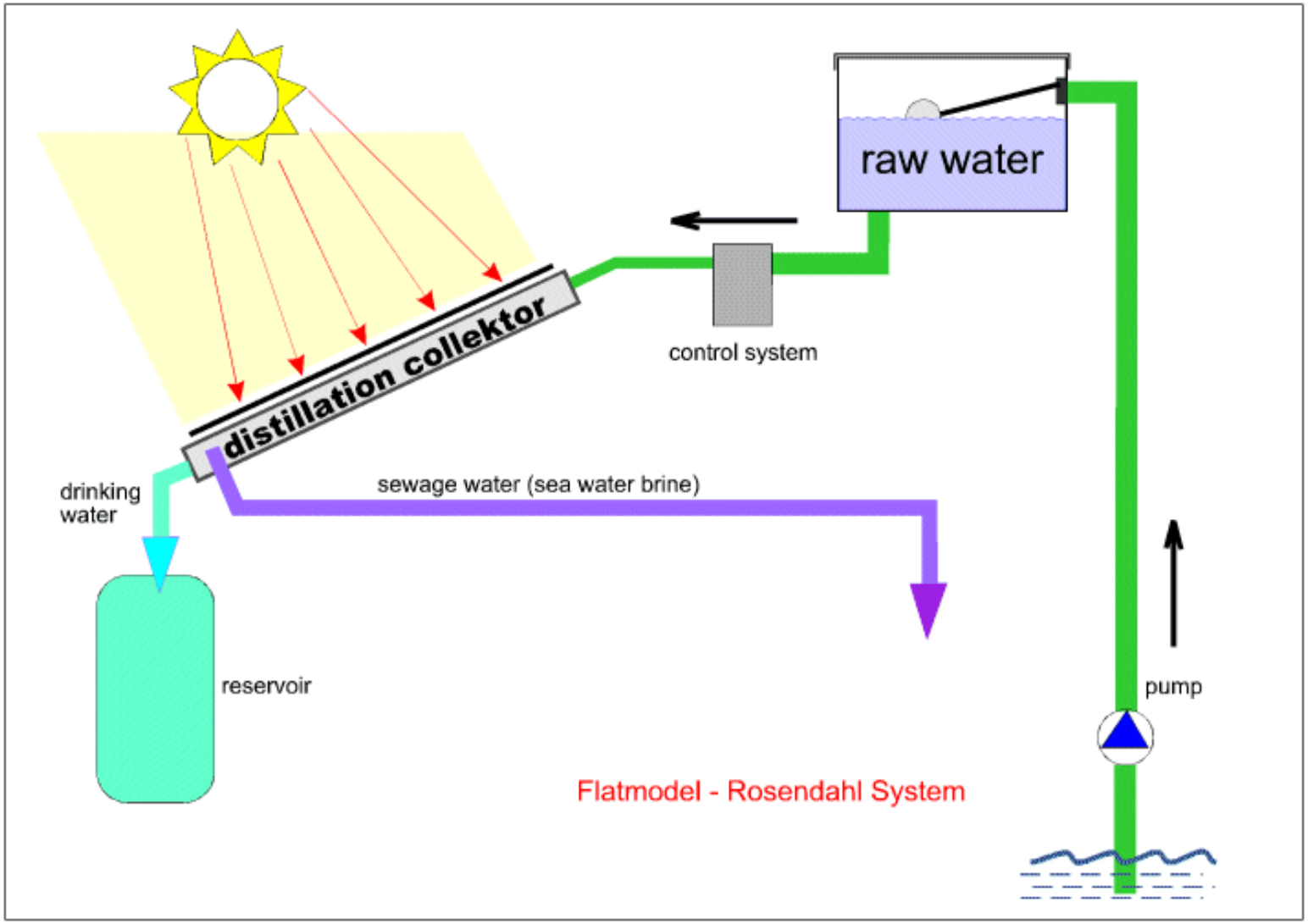
- Types of solar stills are generally:

1. Basin water still.
2. Cascade type still.
3. Wick-type stills.
4. Multistage solar stills, plus many others.

Basin water still



Solar distillation



Solar distillation

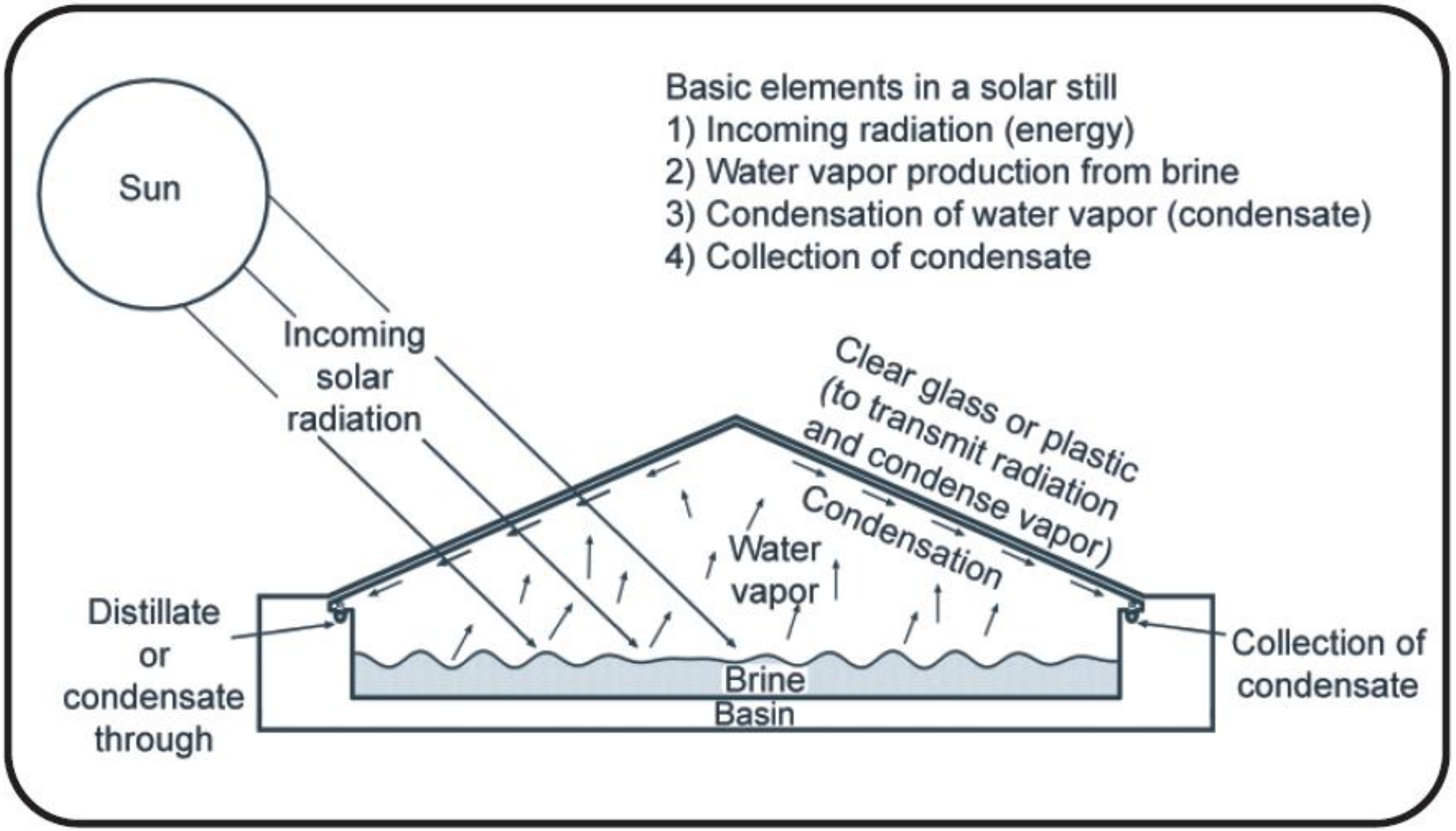
- In the aforementioned stills, the distance between the brine surface and the clear inclined glass plate tends to become smaller from (1-4 in) in an effort to **minimize heat loss** through convection currents in the space between the brine surface and the inclined glass cover, which assists in **increasing the efficiency of** the still, i.e., the productivity (fresh water in L/d).

Solar distillation

- **Theory of solar distillation:**
- As shown in the diagram of a solar still:

1. Solar radiation penetration through the clear glass cover at the top of the still and as soon as it falls on the brine water surface it is converted into long wave length radiation (infra red rays) which give heat to the water in the basin.
2. Evaporation a portion of saline water which rises up through the vapor space.
3. Condensation of water vapor on the cooler slanting glass cover.
4. Running down of condensate in a thin sheet of fresh water to be collected in the side troughs running the length of the still.

Solar still


Basic elements in a solar still
1) Incoming radiation (energy)
2) Water vapor production from brine
3) Condensation of water vapor (condensate)
4) Collection of condensate
Sun
Incoming solar radiation
Clear glass or plastic (to transmit radiation and condense vapor)
Condensation
Water vapor
Distillate or condensate through
Brine
Basin
Collection of condensate

Solar still

Solar still

Solar still

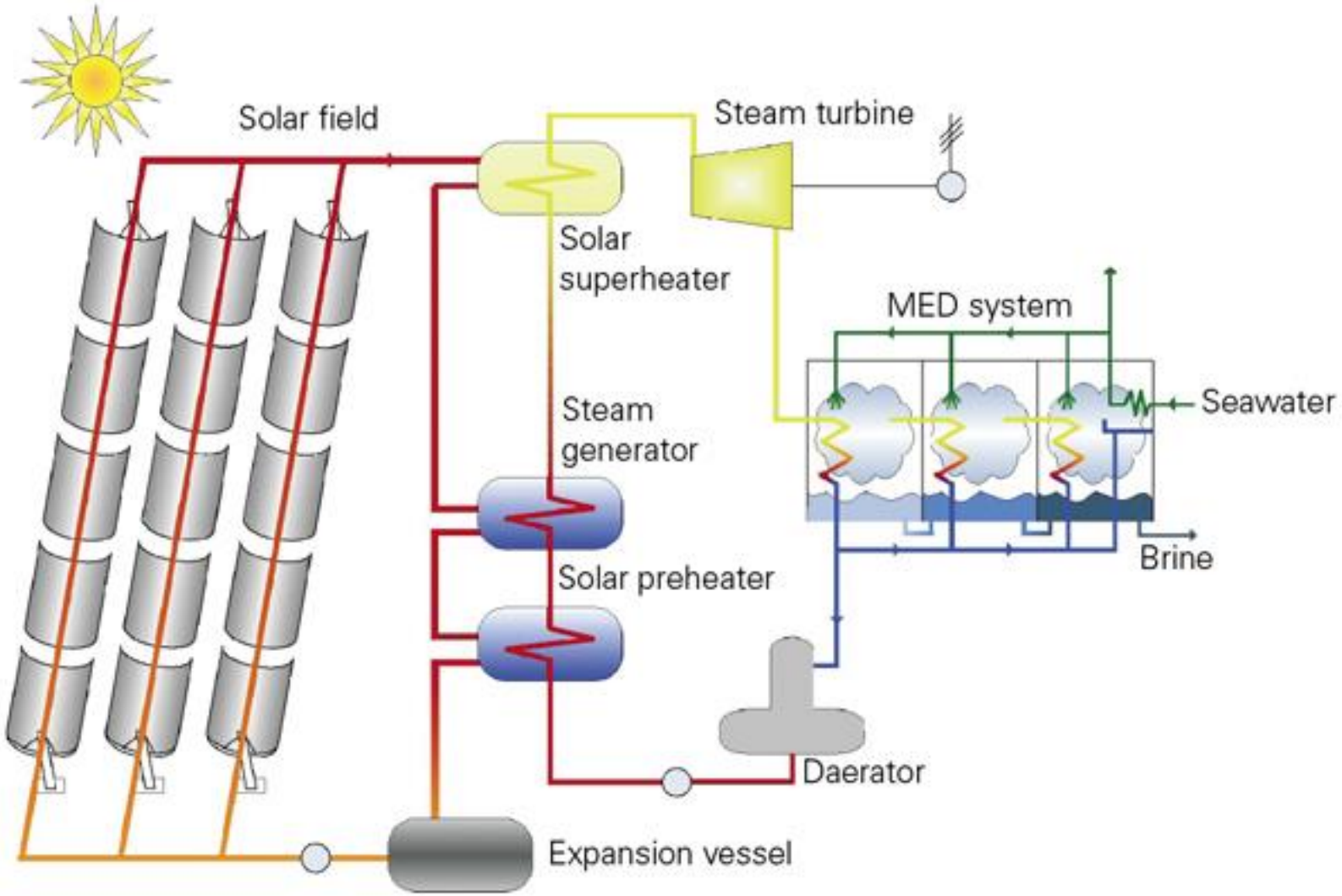
Solar distillation

- The cover is made from **glass or plastic** which transmit solar radiation to a great extent (91%), whereas, they trap **long IR rays** by preventing them from passing to the outside.
- A general rule for solar stills is that a solar collection area of about **$1m^2$** is needed to produce **4 L of water /day**, thus for a 4,000 $m^{3/}$day facility, a land area of about **100 hectares (1 hectare = 10,000 square meter)** would be needed.
- This observation would take up a **tremendous area** and could creates problems if located near a city where land was scarce and expensive.

Solar distillation

- The **stills themselves are expensive** to construct, and although the **thermal energy** is free, additional energy is needed to **pump** the water to and from the facility.
- In addition, **careful operation and maintenance are needed** to prevent scale formation caused by the basins drying out and to repair glass or vapor leaks in the stills.
- An application of these types of solar humidification units has been used for desalting saline water on a **small scale** for a **small village** where solar energy is abundant but electricity is not.

Using solar energy in MED desalination plants



Questions

- Answer with Yes or No, correct the false ones:

1. The minor desalination processes have been achieved the level of commercial success.
2. Nowadays, FM desalting technology probably has a better application in the production of municipal drinking water.
3. Solar desalination stills need small area to built on.
4. Careful operation and maintenance are not needed to prevent scale formation in solar distillation plants.

Questions

- Answer the following questions:

1. Mention the advantages and disadvantages of the desalination by FM.
2. There are restrictions on the use of solar desalination technique for large-scale production, discuss this statement.
3. There are various types of solar stills, mention them.
4. Draw a schematic diagram of the basin water still.
5. Discuss briefly the theory of solar desalination.