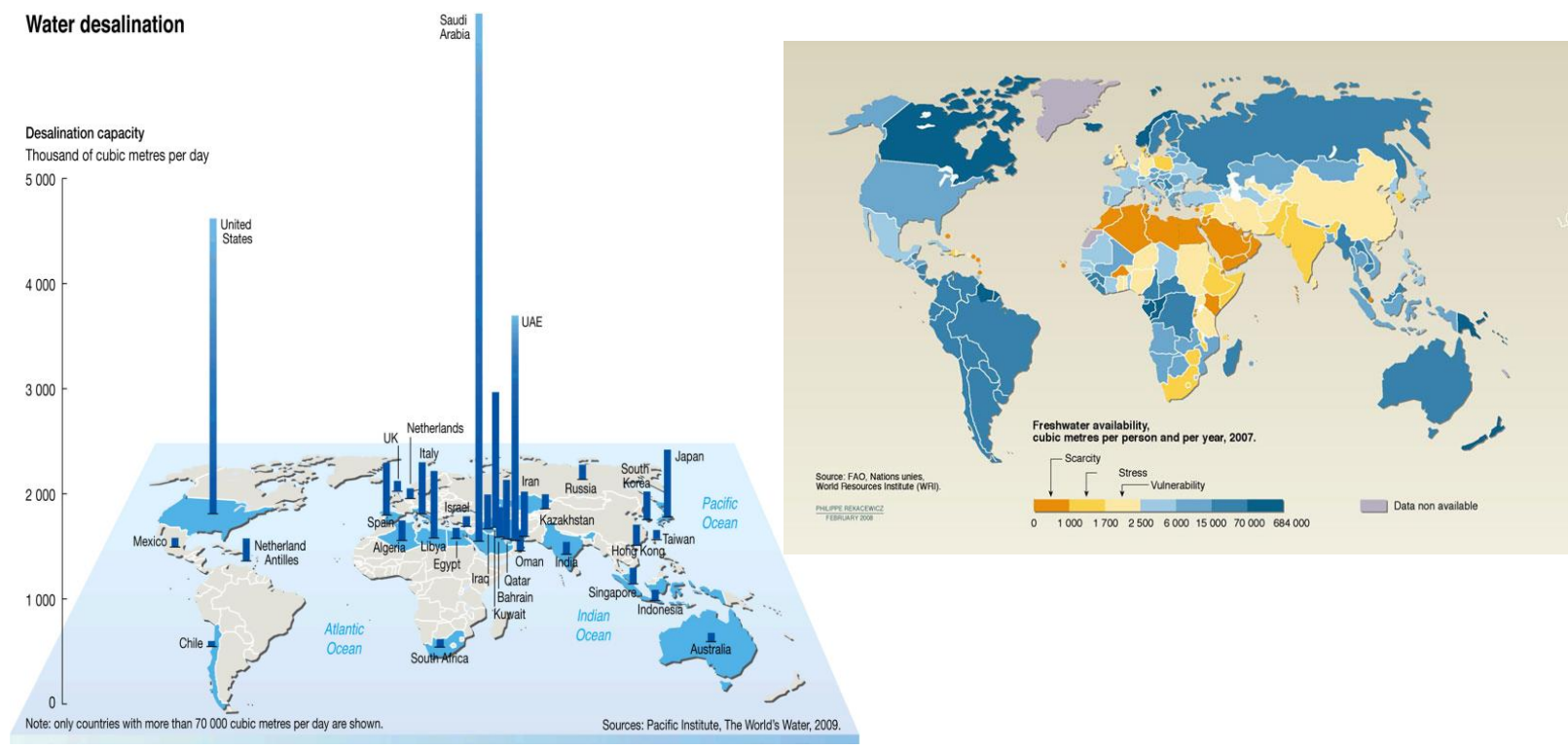


# Multistage Flash Desalination with an Integrated Solar System

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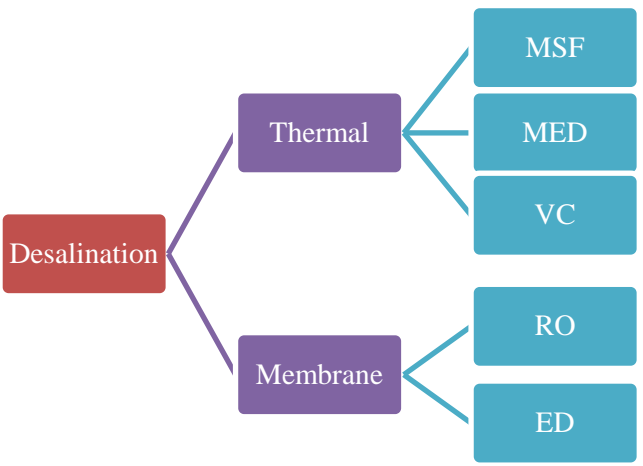
## MOTIVATION

- Many countries around the world continue to suffer from water shortages.
- The current conventional desalination technologies are expensive and energy-consuming.
- The growth in global desalinated installation has been increasing exponentially.

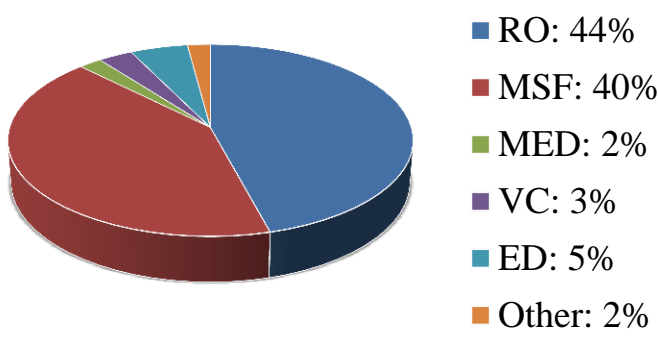


## INTRODUCTION

- Desalination processes are classified as thermal or membrane technology.



- MSF and RO are the most widely used technologies.



MSF: Multistage-Flash  
RO: Reverse Osmosis

## MSF TECHNOLOGY

- High energy consumption.

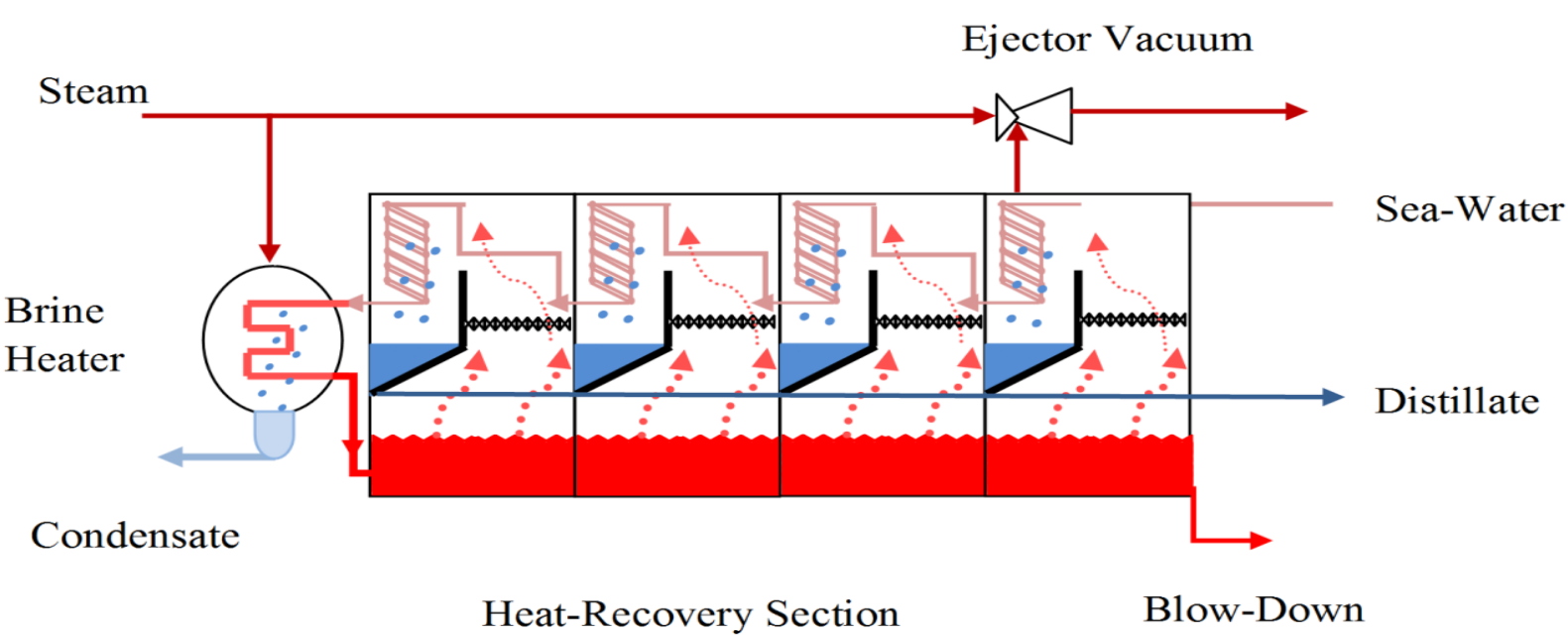
Energy requirements

Thermal energy (kJ/kg): 250–300

Electrical energy (kWh/m<sup>3</sup>): 3.5–5

- Environmental harm.

Emits GHG (kg CO<sub>2</sub>/m<sup>3</sup>H<sub>2</sub>O): 15-25



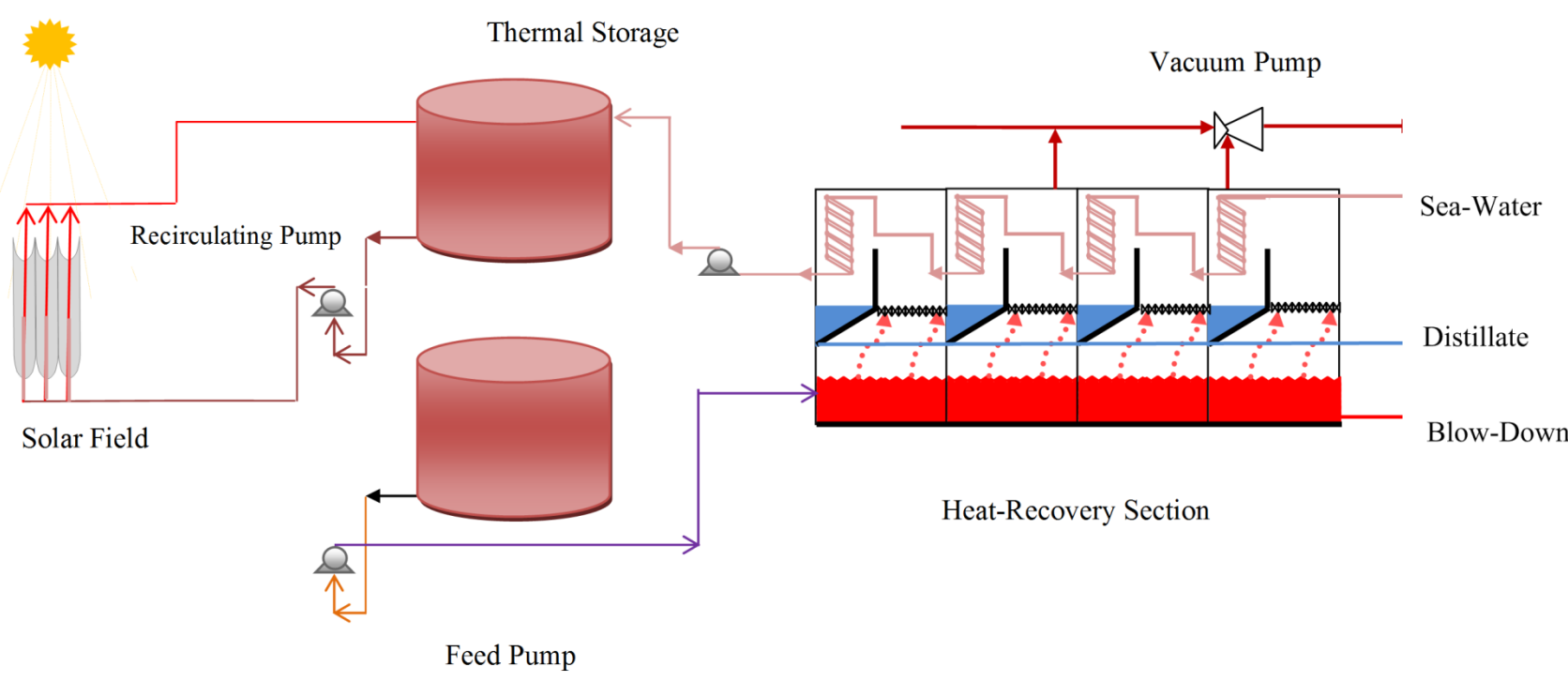
## MSF WITH INTEGRATED SOLAR SYSTEM

- The structure of the system is divided into three blocks:

- MSF.
- Solar Collector.
- Thermal Storage Tank.

- Two main advantages :

- The expected fuel saving is about 80%.
- Minimizes land use of solar field.



## FRAMEWORK

- Location:  
Latitude  
Longitude  
Date
- Meteorological  
Hourly Horizontal  
Daily Horizontal  
Daily Average Horizontal  
Ambient Air Temperature
- MSF Unit  
Distillate Flow Rate  
Total Number of Stages  
Inlet Seawater Temperature  
Salinity of Seawater
- Solar Field  
Receiver Diameter  
Cover Tube Diameter  
Length of Collector  
Focal Length of Collector  
Aperture Width63
- Storage Tank  
Material and Insulation Type

Feed Flow Rate

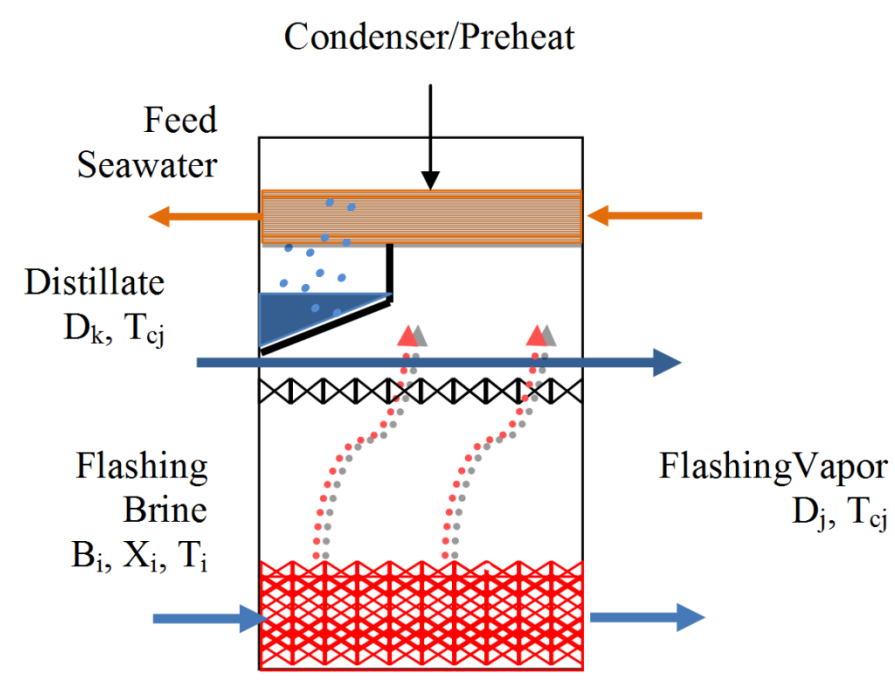
Useful Heat Gain  
Solar Field Fluid Outlet Temperature

Water Temperature in Storage Tank  
(Top Brine Temperature)

## MODEL

- Each part is modeled as a single unit with both mass and energy balance.

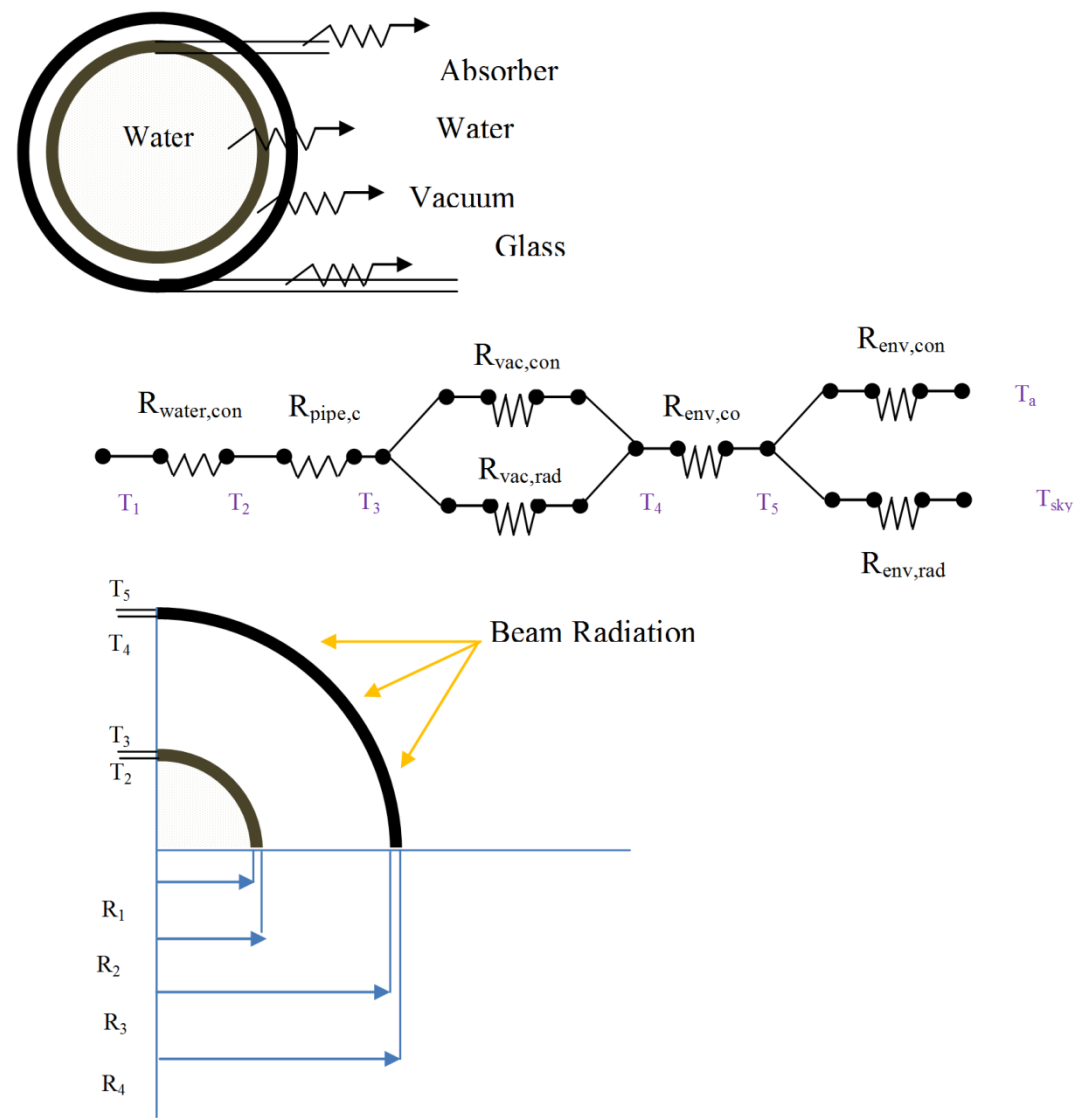
- MSF



Brine flow rate in stage i:  $B = M_f - D$

Distillate flow rate in stage i:  $D_i = yM_f(1 - y)^{(i-1)}$

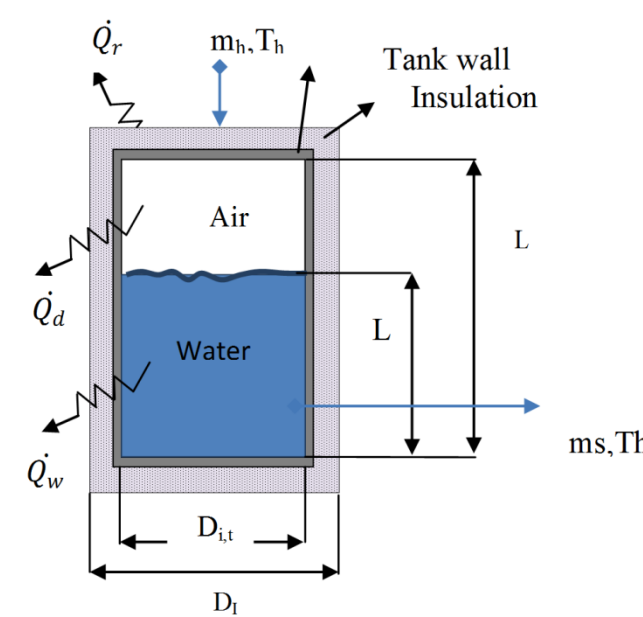
- Solar Collector



Useful output of the collector:

$$Q_u = F_R A_a \left[ S - \frac{A_{ro}}{A_a} U_L (T_{fi} - T_a) \right]$$

- Thermal Storage Tank:

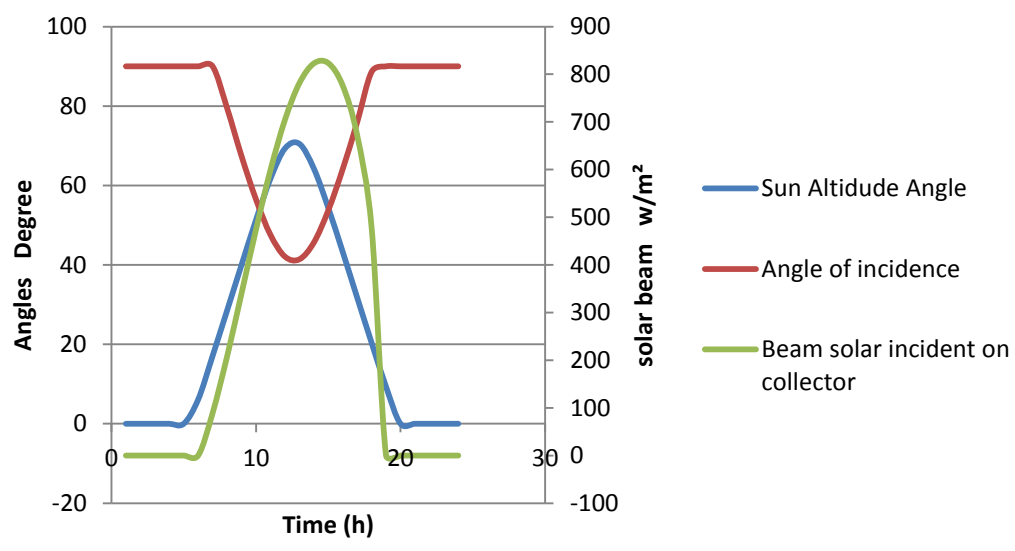


The rate change of internal energy:

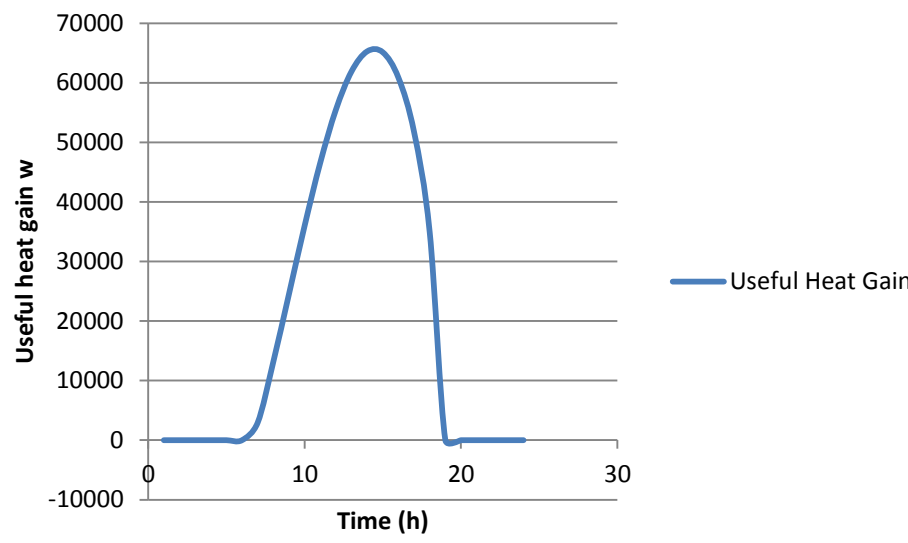
$$C_{Pf} \frac{dM}{dt} = \dot{m}_i C_p T_h - \dot{m}_o C_p T_h - (UA)_t (T - T_{env})$$

## RESULTS

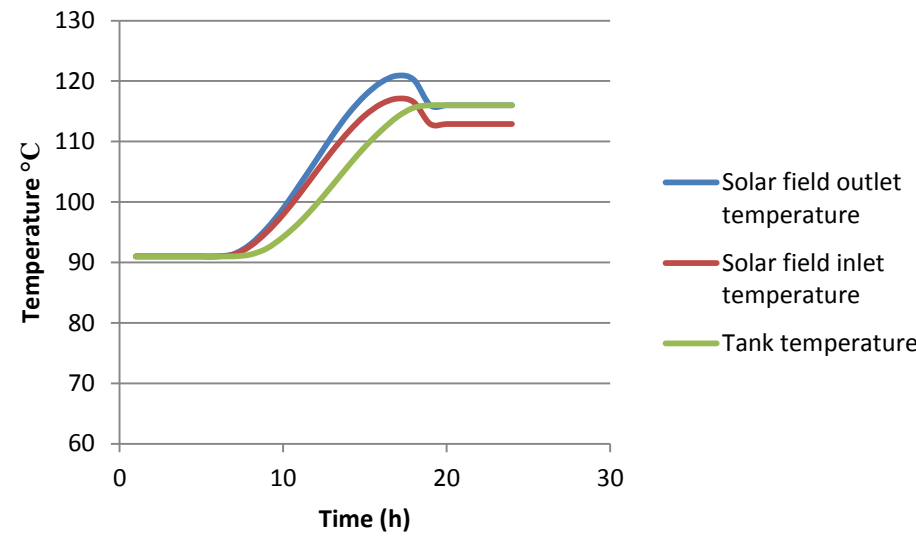
- The variations in sun altitude angle, angle of incidence and solar beam during the day



- Useful heat gain



- The MSF temperature, solar field outlet temperature and tank temperature



## CONCLUSION

- The storage tank provides the plant with thermal energy for entire day at full capacity.
- The total area of solar field is small compared to a another design's solar field with the same heat gain.
- The fuel saving is around eighty percent of total energy of conventional MSF.

## REFERENCES

- Hamed, O.A., et al. Prospects of improving energy consumption of the multi-stage flash distillation process. in Proceedings of the Fourth Annual Workshop on Water Conservation in Dhahran the Kingdom of Saudi Arabia. 2001.
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- Gude, V.G., N. Nirmalakhandan, and S. Deng, *Renewable and sustainable approaches for desalination*. Renewable and Sustainable Energy Reviews, 2010. 14(9): p. 2641-2654.