Optics for Energy: Lecture 2
Introduction to Projects
http://lons.utah.edu/

Solar Water Pateurization

1 in 6 people on this planet have no access to clean drinking water.
Half of the hospital beds in the world are filled with people suffering from water-related diseases.
80% of deaths in children are due to contaminated water.

What can we do about it ?

Heating water to 149 deg F (65 deg C) pasteurizes water, killing disease-causing microbes.
No need to boil water.

Pasteurization is the use of moderate heat to kill disease microbes.
Milk is pasteurized at 71 deg C for 15 seconds!

Studies show that 99.999% of bacteria in water can be killed at 65 deg C in 60 seconds.

Temperature indicator at 65 deg C

Water Pasteurization Indicator (WAPI)
Wax melts at 65 deg C. Developed by Solar Cookers Intl.

What technologies exist ?

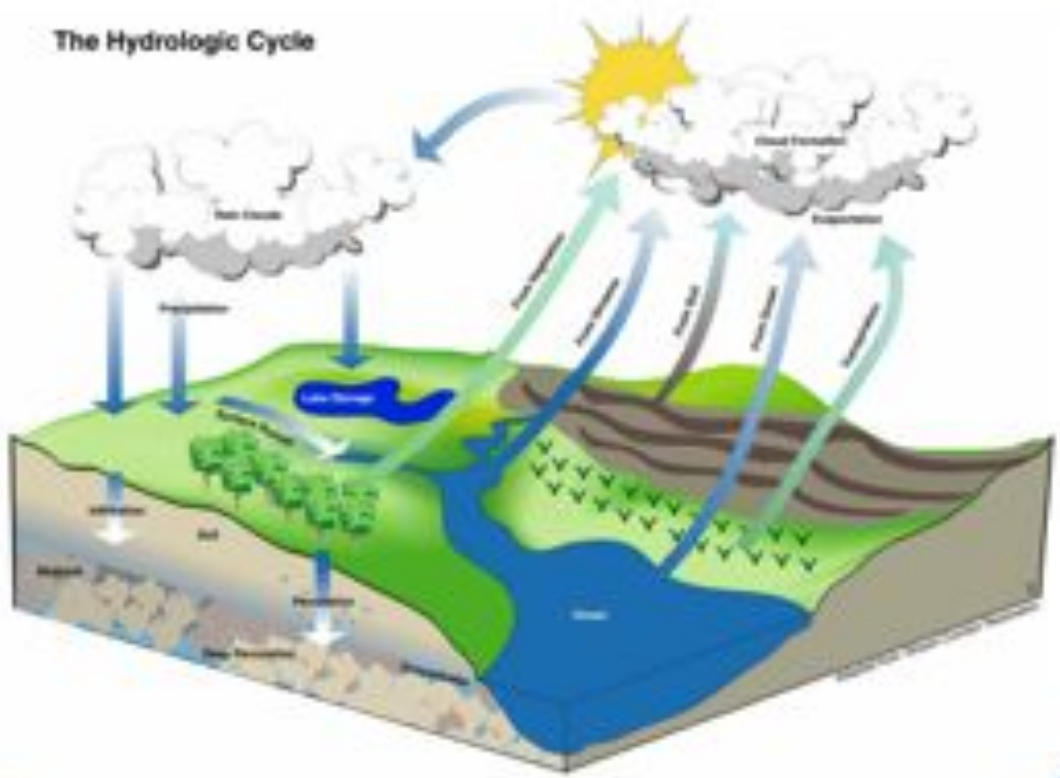
Solar cooker can be used.

Or a custom device that traps heat

Simplest solution

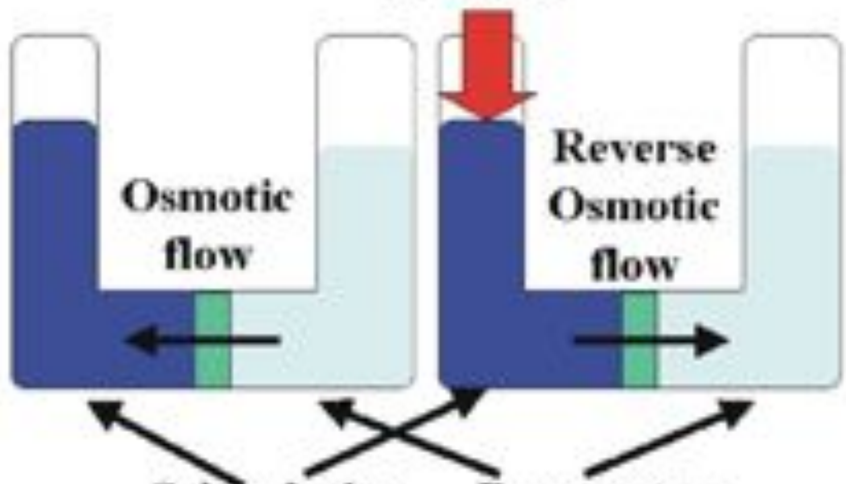
Leave water for several hours in a PET bottle.
Solar water disinfection (SODIS).
UV rays kill most bacteria.


Solar Water Desalination
Water scarcity & solar resource abundance coincide.



Natural Solar Desalination

Photovoltaics as the primary energy source



Reverse Osmosis

Energy required to push water through membrane. Could be PV produced.

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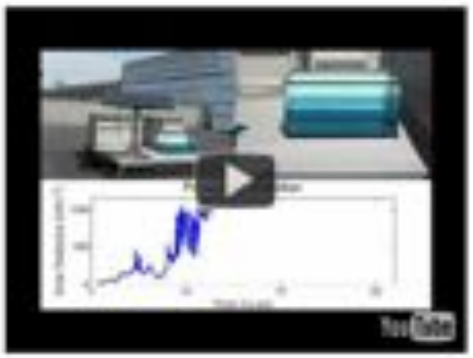
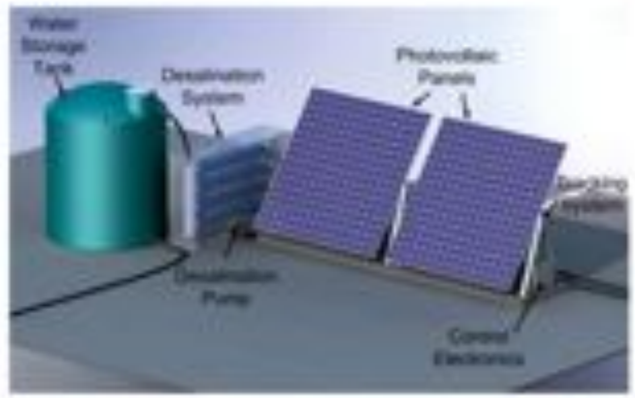
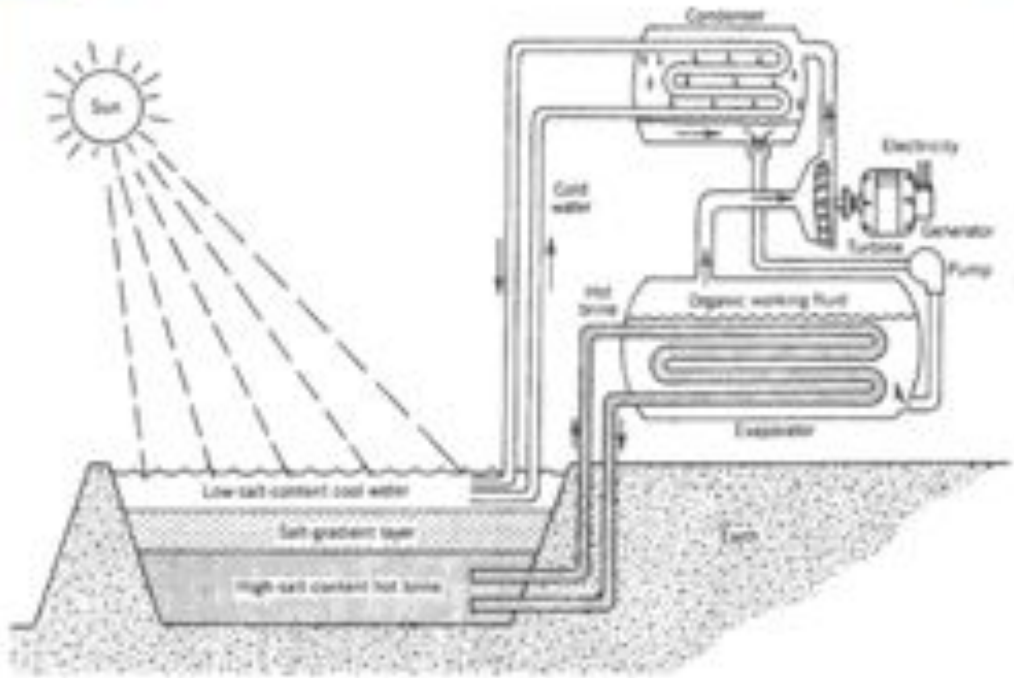
Photovoltaics as the primary energy source





portable, disaster relief, optimal-control problem. Can optical engineering help ?

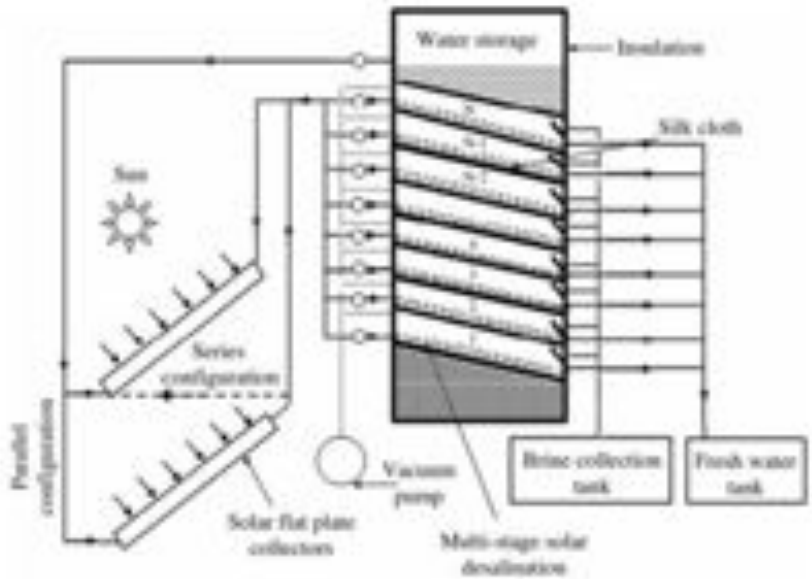
Salinity-gradient solar ponds



Denser saltier water heats up at the bottom. Middle layer acts as insulator. Top layer remains cool. They produce low-grade (<100 degC) thermal energy -> useful for heating, some electricity production.
Eff ~ 10%-15%.
Direct & diffuse sunlight is absorbed.

e coincide.

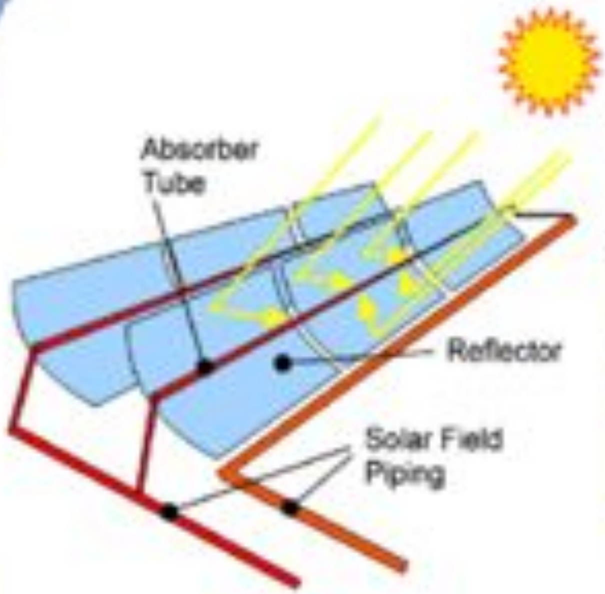
Flat-plate collector



Low-level heat generated by collector used to separate water from brine.
Materials with better absorption properties, anti-reflection coatings, better light collection optics may be used to improve efficiency.

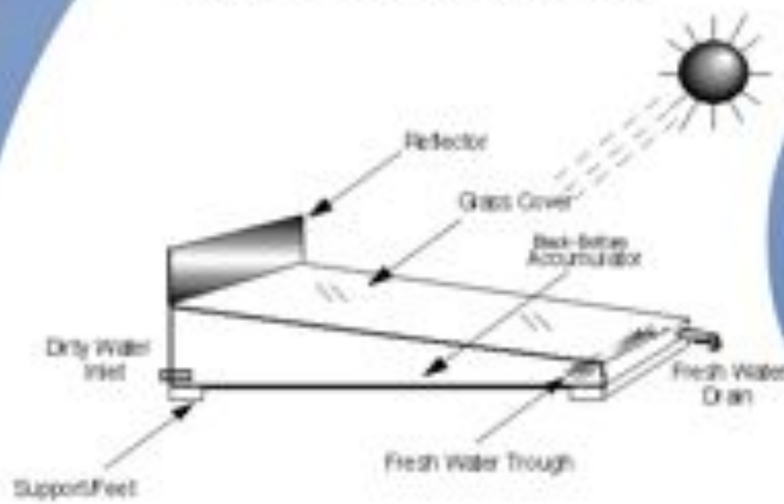
Low-le
brine.
Materi
better

Parabolic trough collector



Heated transfer fluid can be used for high-grade thermal energy or electricity production or thermal distillation. Tracking required. Expensive.

Single-effect solar still

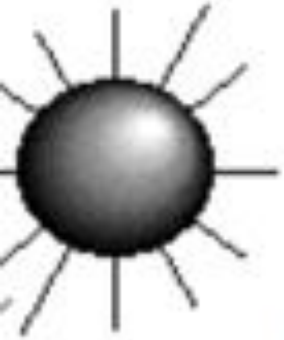


Solar still greenhouse combination

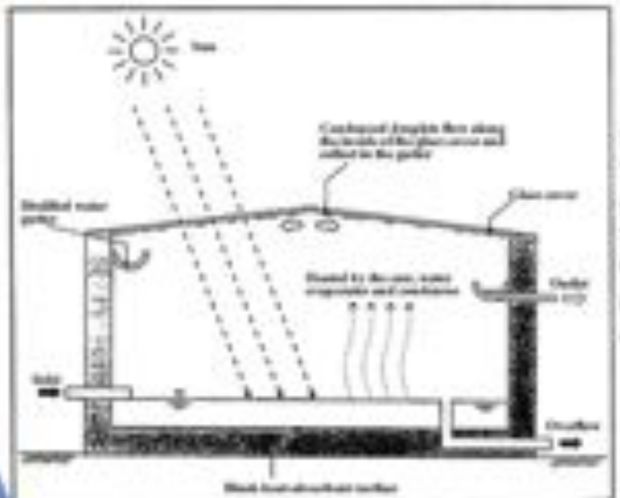
Simple, inexpensive but slow & useful for small amounts of water.
Energy to evaporate 1kg of water at 30 deg C ~ 2.4 X 10^6 J

If solar insolation is 250 W/m^2, how much water can be produced per unit area per unit time ?

Avg. eff ~ 30% - 40%.
Materials selection is important.
Many system design improvements feasible.



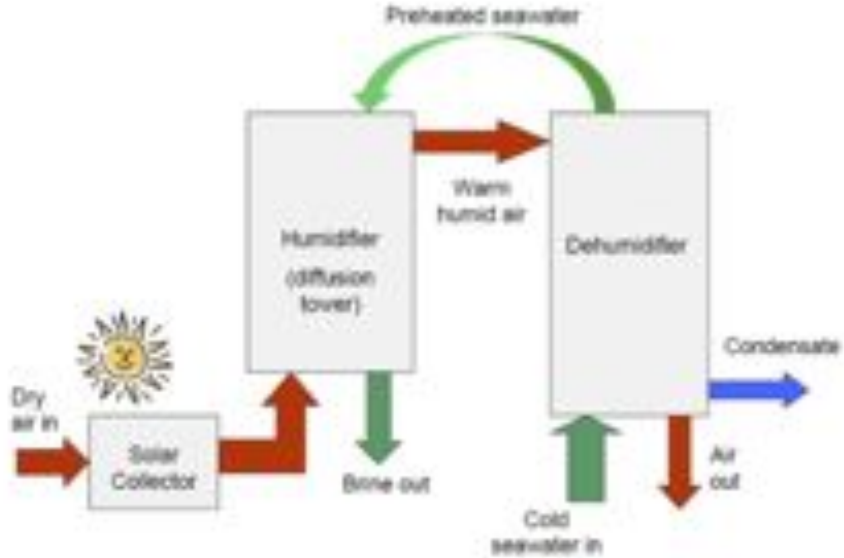
Solar still greenhouse combination



Saline water pumped to south-facing roof.
Top cover of still is glass, but bottom passes wavelengths suitable for photosynthesis (380nm-710nm).
Temperature of greenhouse is lowered.
Water vapor condenses on top surface of still and collected.
Useful for greenhouse agriculture with very little access to fresh water.

Challenge: corrossion of collector due to contact with saline water.

Humidification/De-humidification



Air is the working fluid.
Hot, dry air is carries away water vapor - humidification.
1kg of air can carry 0.5kg of vapor at 80 degC.
Fresh water condenses out of the air - dehumidification.
Low temperature, low pressure process. Can be cost competitive. But now typically more expensive than reverse osmosis.

Wat

Summar: Solar Desalination

Direct

solar to create distillate

small scale, stills, etc.

Indirect

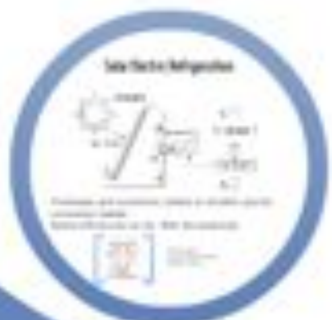
solar to produce energy.
energy used in separate system for distillate.

solar thermal or photovoltaics, humidification/dehumidification, etc.

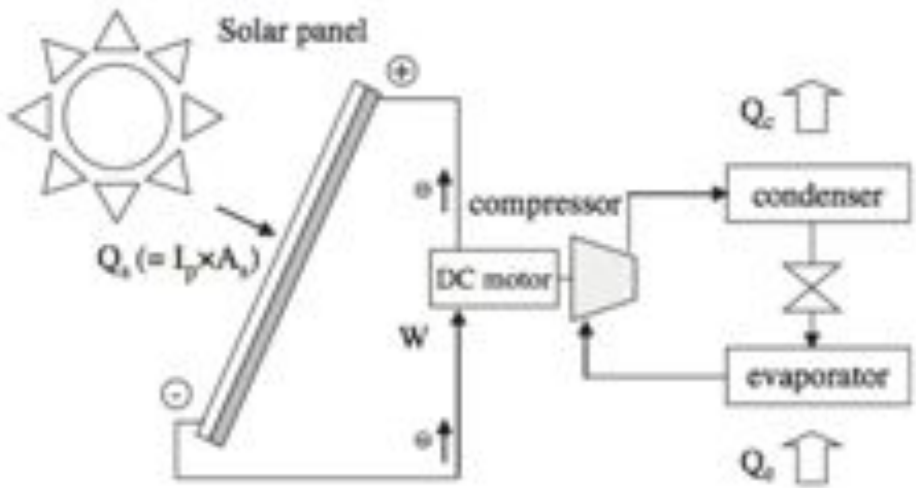
Solar Refrigeration

Vapor compression cooling

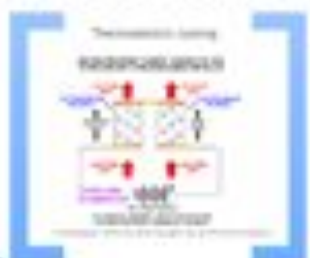
Is it possible to use sunlight
to keep foods, medicines, cold ?
Can we make ice ?



Solar Electric Refrigeration

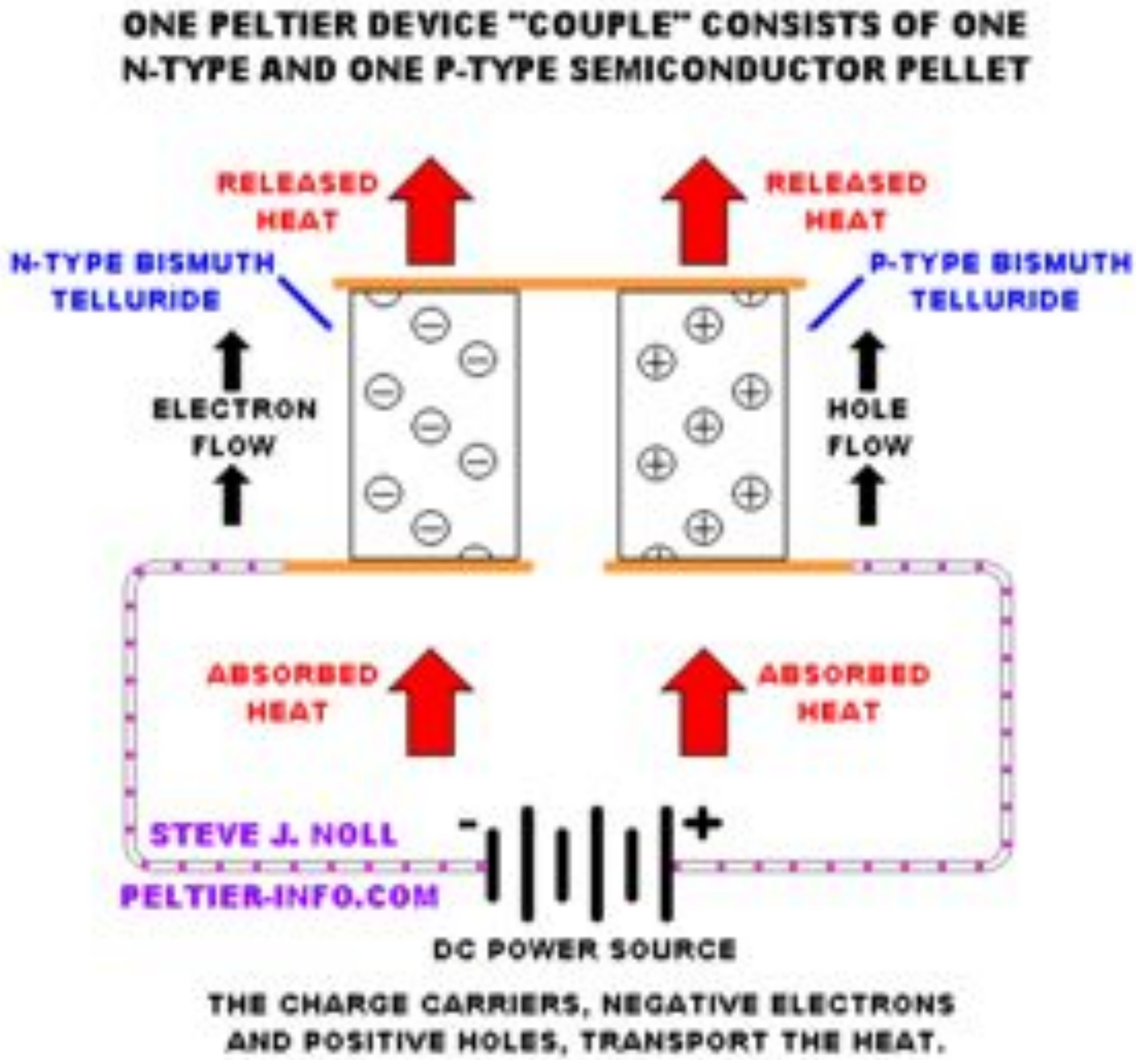


Challenges: grid-connection, battery or variable-capacity compressor needed.
Overall efficiencies can be ~30%. But expensive.



Stirling cooling.
Thermo-acoustic cooling.
Magnetic cooling.

Thermoelectric cooling

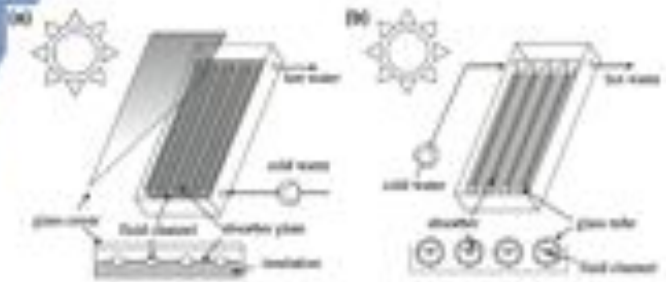


No moving parts. Can be very small & portable. But low efficiency & expensive.

Stirling cooling.
Thermo-acoustic cooling.
Magnetic cooling.

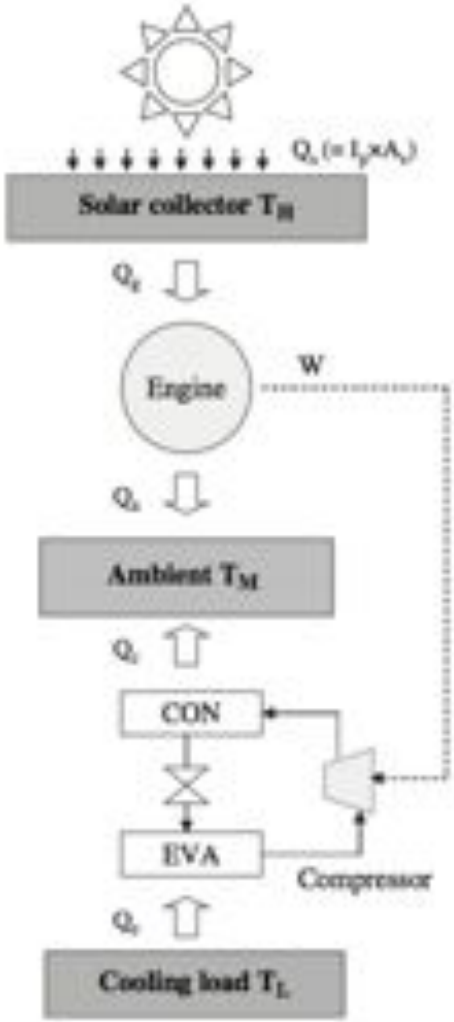
Solar Thermal Refrigeration

solar heat rather than electricity.



Heat is input to engine for cooling.
Challenge: collector loses more heat at higher temp. But cooling engine works better at higher temperature differences.

Thermo-mechanical Refrigeration



solar -> heat -> engine

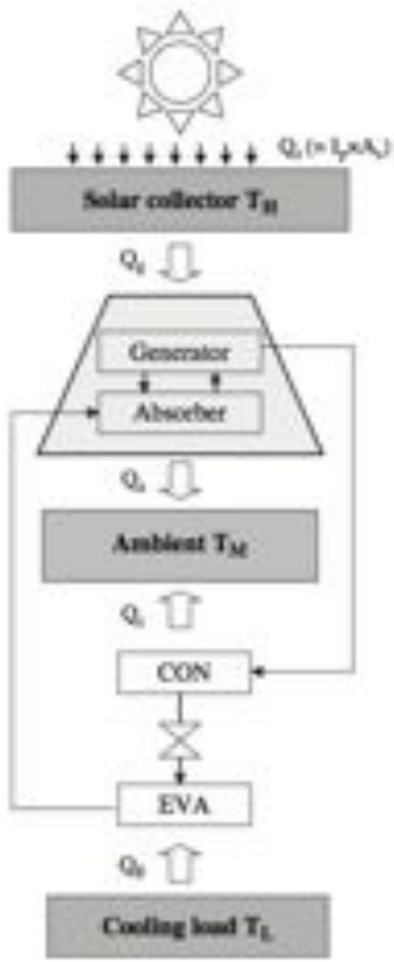
engine -> mechanical work -> compressor

compressor -> remove heat (cooling)

Lower efficiency (10%-15%).
Refrigeration could be more expensive than solar-electrica.

Sorption Refrigeration

Sorption = physical/chemical attraction between 2 substances to produce cooling.



solar -> heat -> generator

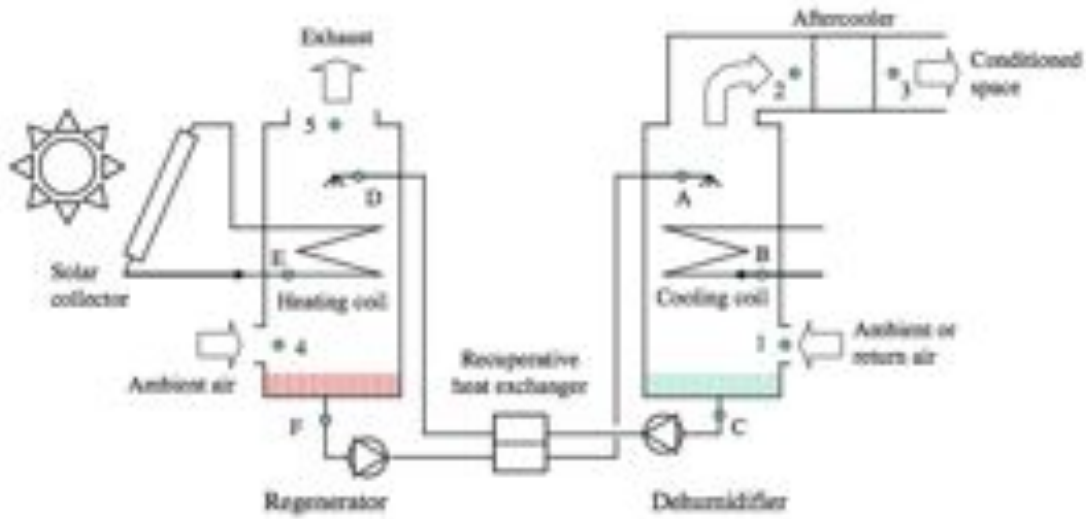
generator -> regenerates sorbent -> condenses refrigerant

sorbent absorbs refrigerant vapor

Liquified refrigerant evaporates -> cooling

Can be absorption (physical or chemical change after absorbing refrigerant) or adsorption (no change, just attracts refrigerant on sorbent surface).

Dessicant Cooling



Dehumidifier:

Liquid absorbs moisture from air and is cooled by coil. -> cool, dry air at 2 & diluted solution at C. Air cools space at 3.

Regenerator:

Diluted solution sprayed over heating coil (heated by solar collector). Ambient air is blown over solution stream. Some water is removed by the air & concentrated solution is collected at F. Hot, humid air is rejected at 5.

Sorbent can be solid.

This is an efficient technology for large-scale dehumidification.

Project Teams

Solar Refrigeration/Air conditioning
Xiaoyu Wei, Ryan Snowball, Faisal K.C, Tyler Hafen.

Solar Desalination (and pasteurization if interested)
Mak K, Olutosin Fawole, Halley Allred, Na Wu.

Solar-thermal applications (heating, hot-water, greenhouses, etc.)
Jacob Soto, Trevor Nichols, Chen Wang, Apratim Majumder.

Photovoltaics (could be concentrated PV, other approaches)
Erik Johnson, Jinqi Wang, Xiaowei Wan, Farhana Masid.

Hybrid systems (combining different technologies, system level).
Trevor Dick, Shayan Barzegari, Ben Bunes, Zongshi Hu

Daylighting
Rob Shapper, Long Shen, Dan Jacobs, Peng Wang