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Building Integration of Solar Thermal Systems – TU1205 – BISTS

Solar Heating and Cooling Systems

Presented by: Dr. Georgios Florides

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Solar Space–heating and Cooling

- A solar space –heating and Cooling system can consist of a passive system, an active system, or a combination of both
- Passive Solar Systems use the advantages of the sun in a building and are of Low-technology
- Active Solar Systems use the sun to create hot water, hot air or electricity and are of High-technology

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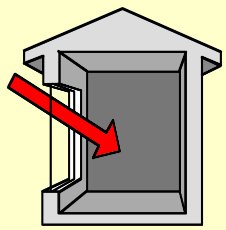
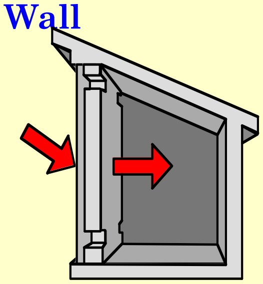
Passive Heating

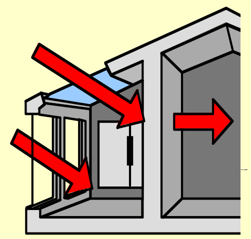
Direct Gain



Thermal Storage Wall



Sunspace



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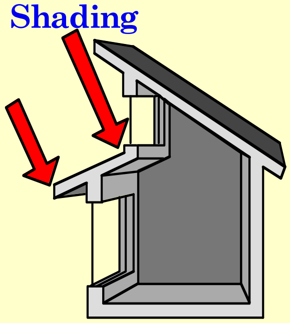
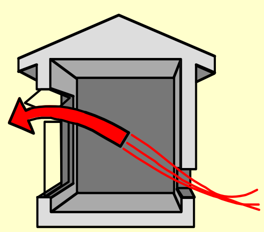
Passive Cooling

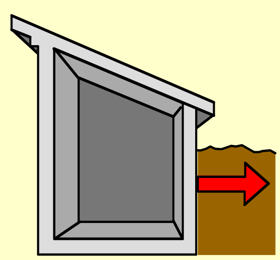
Shading



Ventilation



Earth Contact



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Systems and Parameters of Passive Solar Air-conditioning

- Direct Gain Systems
- Indirect and Isolated Gain systems
- Building Orientation
- Solar Shading
- Thermal Mass
- Glass Type
- Ventilation
- Room Arrangement
- Daylight

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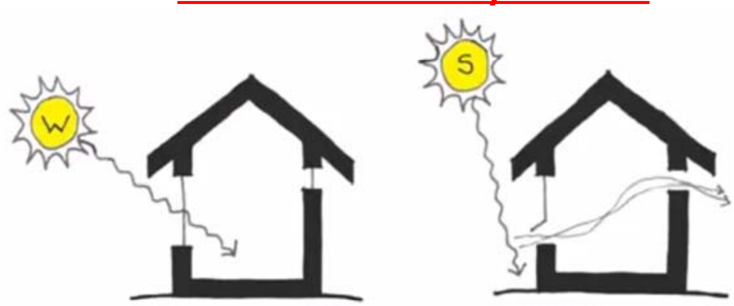
Direct Gain Systems



Heating
In winter the sun is low

Cooling
In summer the sun moves higher

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Design features

Area of Glass on South per Floor Area

Average Winter Temp.	Latitude			
	36° N	40° N	44° N	48° N
20° F, - 7° C	0.24	0.25	0.29	0.31 w/ night insulation
25° F, - 4° C	0.22	0.23	0.25	0.28 w/ night insulation
30° F, - 1° C	0.19	0.20	0.22	0.24
35° F, 2° C	0.16	0.17	0.19	0.21
40° F, 4° C	0.13	0.14	0.16	0.17
45° F, 7° C	0.13	0.14	0.16	0.17
50° F, 10° C	0.10	0.11	0.12	0.13

*clear days in December and January. This can be found online.

From "The Passive Solar Design and Construction Handbook" by Steven Winter Associates

Table applies when the house has the proper thermal mass, in which case the heating savings can be as much as 80%

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Indirect Gain Systems

- Absorb heat during the day and transfer it slowly into the space during the whole day
- Obstruct daylight and view

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Design features

Area of Thermal Storage Wall per Floor Area

Average Winter Temp.*	Latitude 36° N	40° N	44° N	48° N
20˚ F, - 7˚ C	0.71	0.75	0.85	0.98 Insul.
25˚ F, - 4˚ C	0.59	0.63	0.75	0.84 Insul.
30˚ F, - 1˚ C	0.50	0.53	0.60	0.70
35˚ F, 2˚ C	0.40	0.43	0.50	0.55
40˚ F, 4˚ C	0.32	0.35	0.40	0.44
45˚ F, 7˚ C	0.25	0.26	0.30	0.33
50˚ F, 10˚ C				

*clear days in December and January. This can be found online.
Insul. = with insulation covering glass at night. Recommended for other locations too.
From "The Passive Solar Design and Construction Handbook" by Steven Winter Associates

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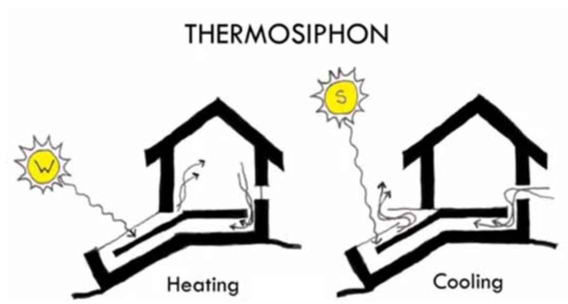
Isolated Gain Systems



- The system uses convection
- Most efficient but expensive system

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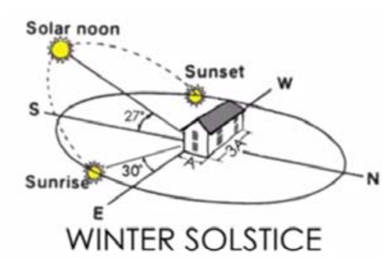
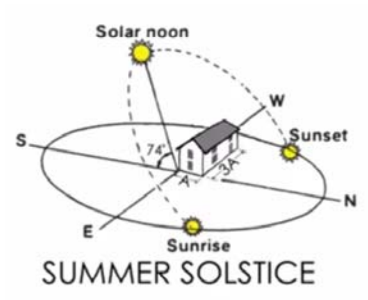
Building Orientation





To avoid heating in summer: Minimize glass on east and west
Plant trees on east and west

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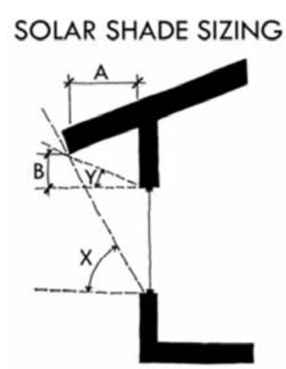
Solar Shading

- Block the high summer sun externally, X=latitute+20°
- Allow the low winter sun in, Y> sun angle at solstice
- Use roof overhangs, external shutters louvers etc



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Thermal Mass

- Any dense material used inside a building to store heat energy
- Most effective when spread out in walls , located in direct sunlight
- At least 0.3-1 m^2 of 10cm thick thermal mass per 0.3m^2 of south glass

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Glass Type

- Use multi-pane glass with U-factor<0.35 and low-E
- Tune glass to solar orientation. Use low SHGC glass on east and west
- Avoid skylights since the roof is the area of the biggest heat gain in summer

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Ventilation

- In summer use convection to bring in cool night air
- Induce cross ventilation for better mixing
- Use ceiling fans to avoid stratification

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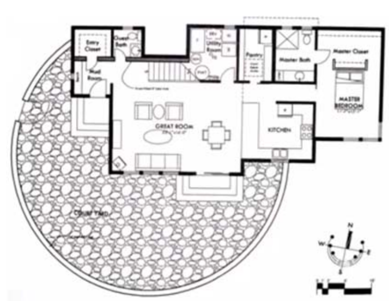
Room Arrangement

- Frequently used rooms must be located on the south and rooms with low use on the north side
- Use an open floor plan for ventilation and heat comfort and increased day-lighting



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Day Lighting

- Sunlighting promotes health and saves energy
- Bring in light with clearstory windows
- Balance light
- Design circulation areas of rooms next to southern glass
- Avoid skylights

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Other important strategies

- Use insulation especially on the roof
- Air-seal the building
- Prefer light-coloured roof
- Use high-efficiency appliances and lighting
- Use local and green materials if possible.

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Active solar space heating systems

•Active solar space heating systems consist of collectors that collect and absorb solar radiation combined with electric fans or pumps to transfer and distribute the heat

•Active systems also may have an energy storage system to provide heat when the sun is not shining.

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Basic techniques to provide space heading in cold climates using solar thermal collectors

- **Direct Solar Heating**
- **Water Storage Solar Heating**
- **High Mass Solar Heating**

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Direct Solar Heating

- Direct solar heating systems are the simplest and least expensive solar space heating systems. There is no storage medium for the collected solar energy other than the thermal mass that already exists in the house. On sunny days during the heating season, the heat is simply transferred into the house as it is collected.

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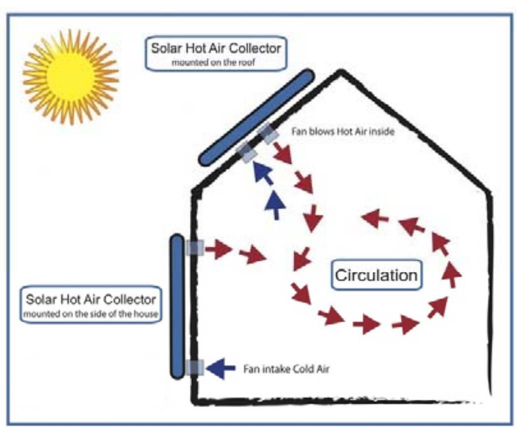
Space heating-Solar Hot Air Collector

Solar Hot Air Collectors use the power of the sun to generate heat. A powered fan is used to distribute the hot air into the desired area.



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Air collectors - SolarDuct®

SolarDuct is a solar heating system that heats ventilation air before it enters the air handling units. The system uses an all-metal collector panel (transpired solar collector). Perforations in the panels allow the heat that normally collects on a dark surface to be uniformly drawn through the SolarDuct panel and then ducted into the conventional HVAC system.

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Water Storage Solar Heating

- A water storage solar heating system stores the collected heat in a water tank. After the heat has been delivered to the storage tank, it can be distributed to the building.

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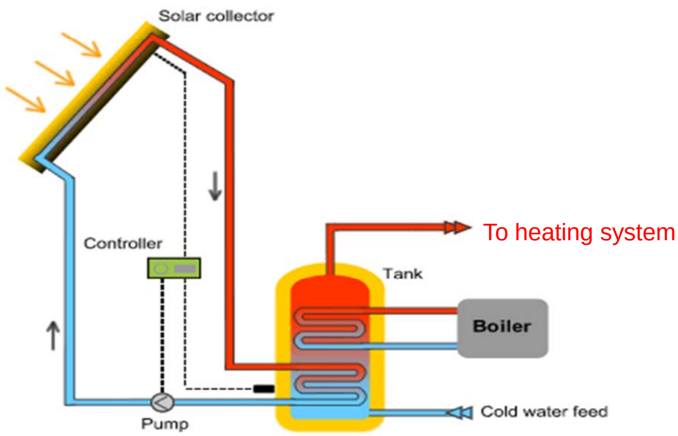
Active solar space heating systems



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Solar Collector types

Motion			Collector Type: Name	Collector Type: Schematic Diagram		Concentration Ratio, C_1 for Direct Insolation	Indicative Temperature Obtained T (K)
Stationary			Non-convecting Solar Pond		Flat Absorbers	$C \leq 1$	$300 < T < 360$
Stationary			Flat-plate Absorber		Flat Absorbers	$C \leq 1$	$300 < T < 350$
Stationary			Evacuated Envelope		Tubular Absorbers	$C \leq 1$	$320 < T < 460$
Stationary			Compound Parabolic Reflector		Tubular Absorbers	$1 \leq C \leq 5$	$340 < T < 510$
Solar Tracking	Single Axis		Compound Parabolic Reflector		Tubular Absorbers	$5 \leq C \leq 15$	$340 < T < 560$
Solar Tracking	Single Axis		Parabolic Reflector		Tubular Absorbers	$15 < C < 40$	$340 < T < 560$
Solar Tracking	Single Axis		Fresnel Refractor		Tubular Absorbers	$10 < C < 40$	$340 < T < 540$
Solar Tracking	Single Axis		Cylindrical Refractor		Tubular Absorbers	$10 < C < 50$	$340 < T < 540$
Solar Tracking	Two Axis		Parabolic Dish Reflector		Point Absorbers	$100 < C < 1000$	$340 < T < 1200$
Solar Tracking	Two Axis		Spherical Bowl Reflector		Point Absorbers	$100 < C < 300$	$340 < T < 1000$
Solar Tracking	Two Axis		Heliostat Field		Point Absorbers	$100 < C < 1500$	$400 < T < 3000$

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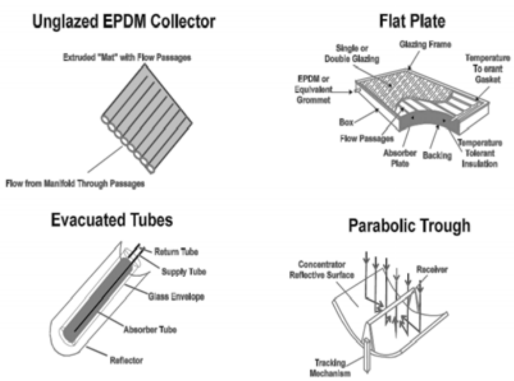
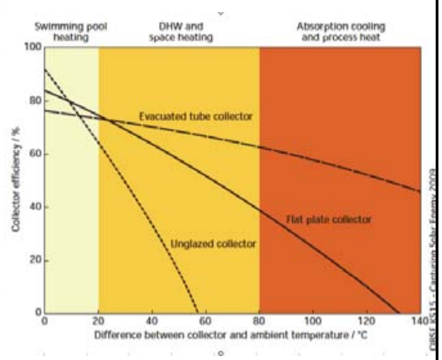
Solar Collector Efficiency





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High Mass Solar Heating

- In this type of system, the solar energy is stored in an insulated, compacted sand bed that is usually 1 m deep and is located directly under the building. Collected heat is delivered to and stored in the sand bed using a grid of tubes. The storing of solar heat begins in late summer. When the sand bed becomes warm, and outside temperatures drop, the stored heat will slowly rise up into the building, warming the floors and the whole building, though provisions for air movement.

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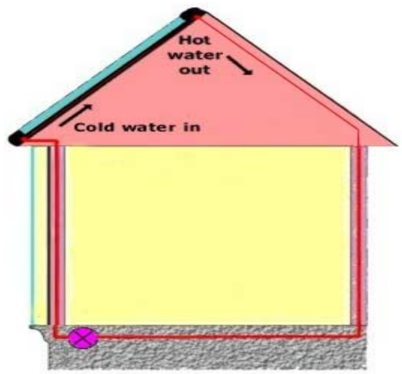
High Mass Solar Heating



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Active solar space cooling systems

- Night cooling
- Adsorption cooling
- Absorption cooling

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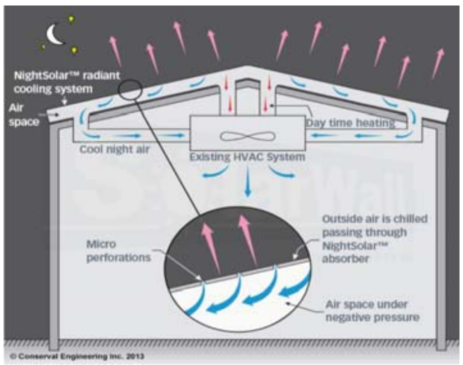
Active Solar Cooling Systems

The NightSolar® system



This technology is partly based on nocturnal sky radiation, which can cool a roof by as much as 10° C below ambient temperature on a clear night. The warm night air touches the cooler surface of the system and it cools. The chilled air is then drawn in through perforations in the collector and enters the HVAC unit via an economizer cycle. This cooling reduces the use of conventional air conditioning. During the daytime, the system reduces daytime heat gains normally received through the roof.

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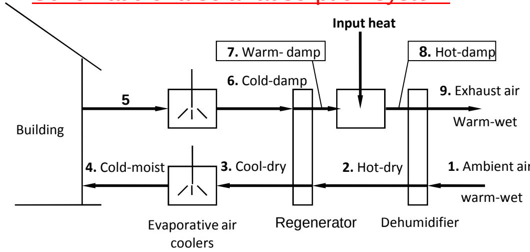
Adsorption cooling

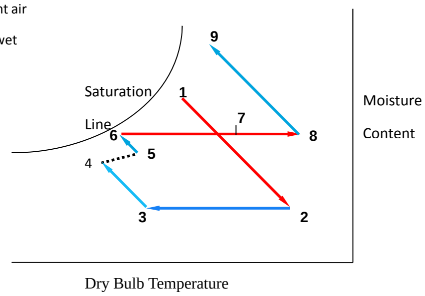
Schematic of a solar adsorption system



Adsorption cooling is a group of sorption air conditioners that utilises an agent to adsorb the moisture from the air and then uses the evaporative cooling effect to produce cooling. Solar energy can be used to regenerate the drying agent.

Solid adsorbents: silica gels, zeolites, activated aluminas, carbons and synthetic polymers. Liquid adsorbents: triethylene glycol solutions of lithium chloride and lithium bromide solutions.

Psychrometric diagram of a solar adsorption process



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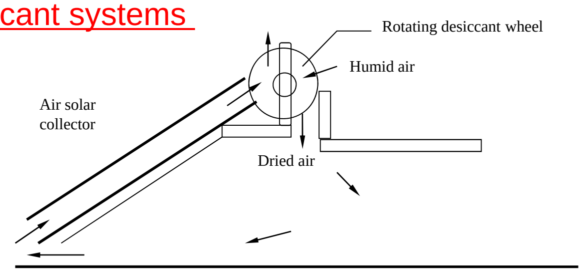
Adsorption cooling

Rotary solid desiccant systems



•Most common systems for continuous removal of moisture from the air.
•The desiccant wheel rotates through two separate air streams.
•In the first stream the process air is dehumidified by adsorption, which does not change the physical characteristics of the desiccant.
•In the second stream the reactivation or regeneration air, which is first heated, dries the desiccant

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Absorption machines

- Absorption machines are thermally activated and for this reason, high input (shaft) power is not required. In this way, where power is unavailable or expensive then gas, geothermal or solar heat can be used. Absorption machines provide reliable and quiet cooling
- In absorption systems an absorbent, on the low-pressure side, absorbs an evaporating refrigerant. The most usual combinations of fluids include lithium bromide-water (LiBr-H2O) where water vapor is the refrigerant and ammonia-water (NH3-H2O) systems where ammonia is the refrigerant
- Lithium bromide-water chillers are available in two types, the single and the double effect. The single effect absorption chiller is mainly used for building cooling loads, where chilled water is required at 6-7° C. Their coefficient of performance (COP) is about 0.7. They *operate with a hot water temperature ranging from about* 80° C to 120° C when water is pressurized, whereas for the double effect much higher temperatures are required.

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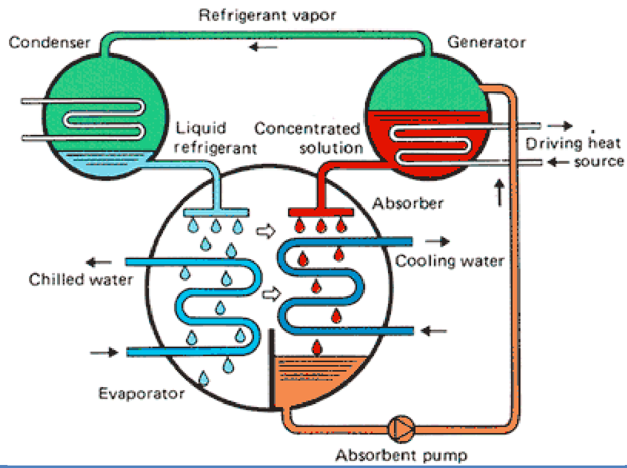
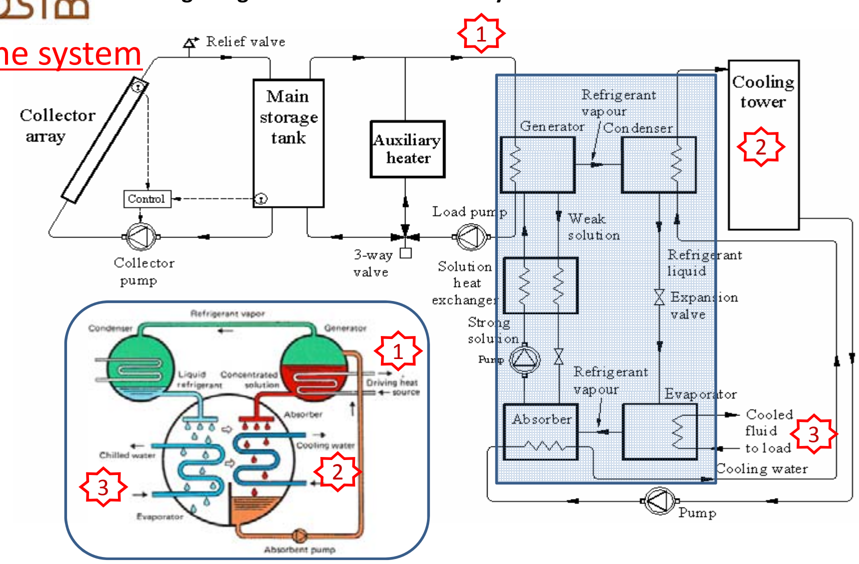
Operation of LiBr- Water Refrigerator



The system



Solar collectors



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LiBr Absorption cooler

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Auxiliary system

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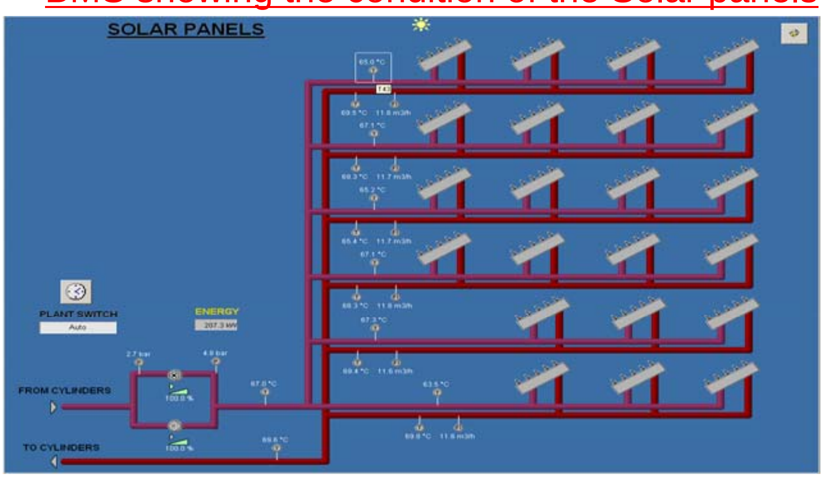
BMS showing the condition of the Solar panels



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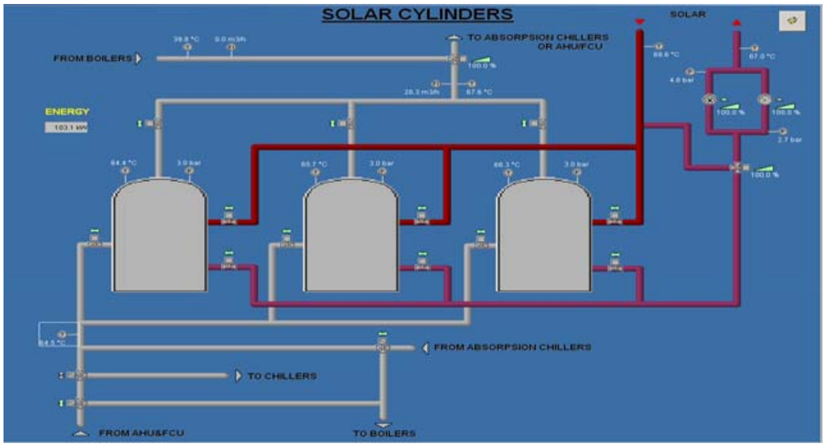
BMS showing the condition of the Solar cylinders



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