

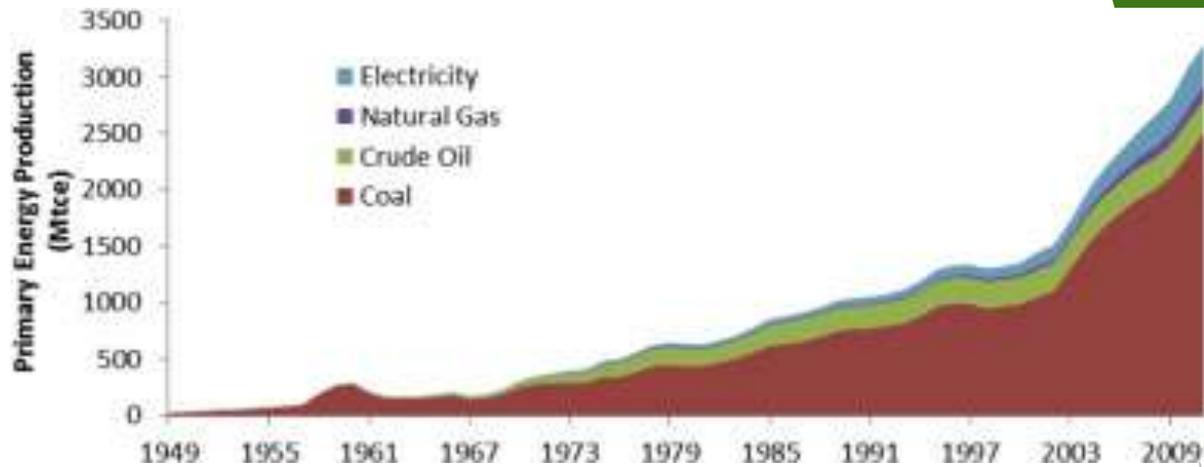


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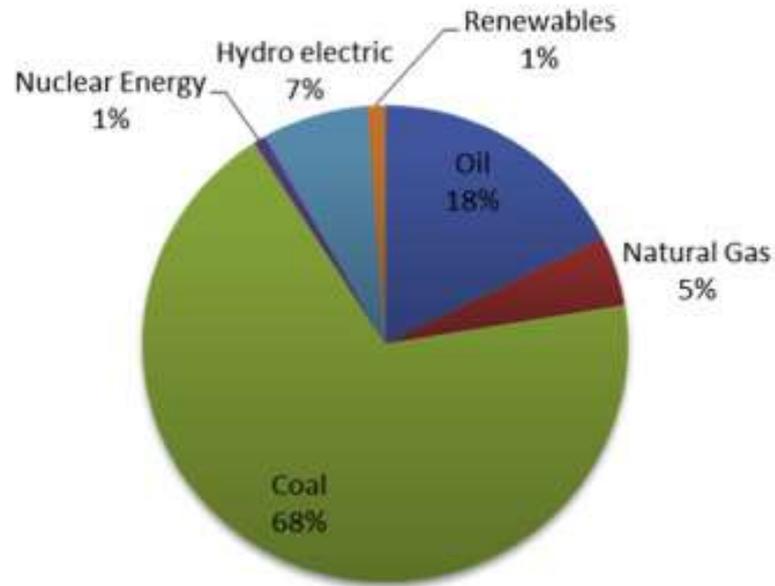
Solar Water Heating Systems and Performance Enhancement

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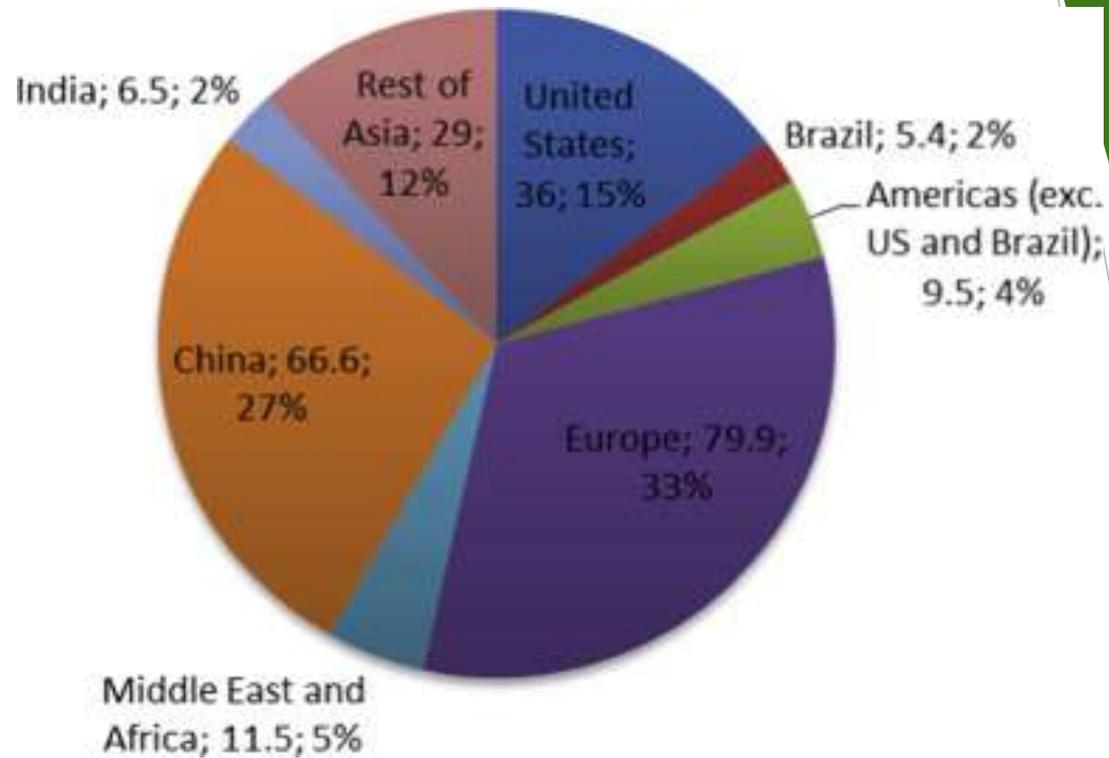


Primary Energy Production by Source, Megatonnes of CO₂ equivalent for 1949–2013. Source.

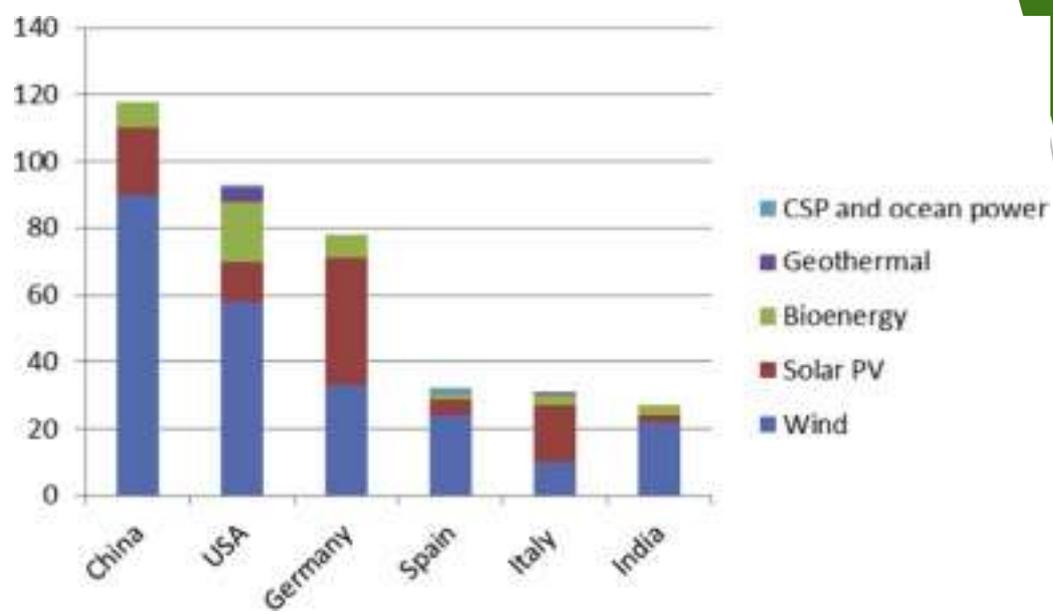
Primary Energy Consumption by Fuel



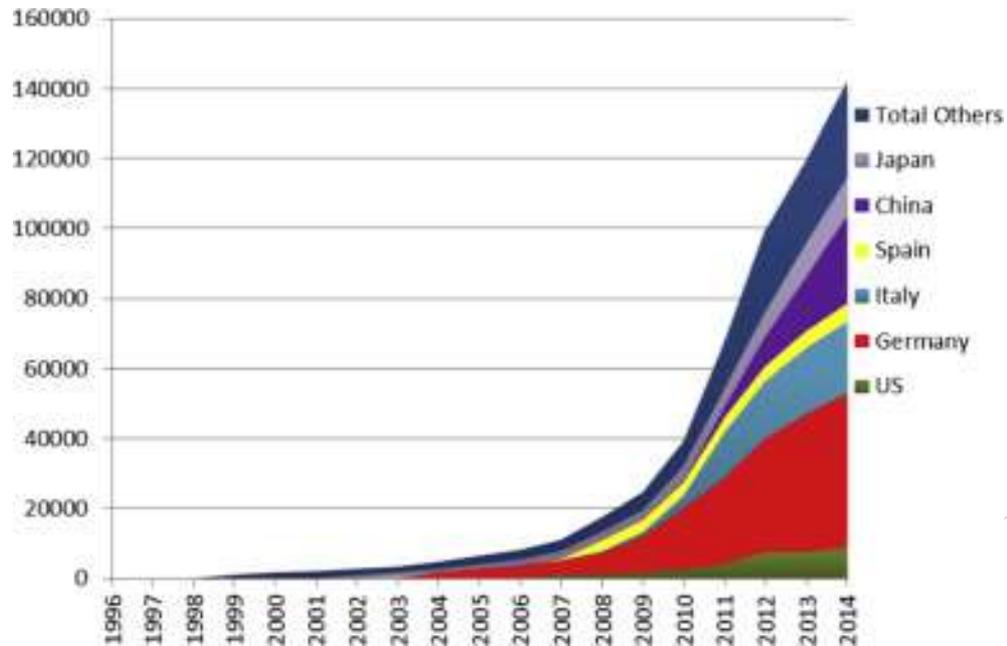
China's primary energy consumption by fuel, 2013. Data from BP Statistical Review of World Energy.



Global new investment in renewable energy by region, 2013, US\$ billion and percentage.



Installed renewable energy capacity, top world regions and countries, 2013, GW, excluding hydropower.



Global cumulative installed solar PV capacity, in megawatts, data for 1996–2014.

Latest solar thermal technology in China and its status. Based on [70].

Solar thermal technology	Status of technology
Evacuated tube SWH system	Commercialised for mass market, cost-effective prices
Flat-plate thermal SWH system	Not widely used or produced in China
Thermodynamic solar panels	Early stage R&D
Solar thermal air heaters	Early stage R&D
Solar cooling systems	Early stage R&D
Concentrated Solar Power (CSP), including parabolic, Fresnel, enclosed trough and solar tower	Early stage R&D
Solar desalination plants	Early stage R&D

Applications of solar energy

Solar water heating

Space heating

Solar desalination

Solar pumping

Solar furnace

Solar cooking

Solar LED lights

Solar energy: Solar Thermal Power Plant

Solar energy: Photovoltaic Electric Conversion

Types of Solar Water Heating System (SWHS)

Active System

Direct System

Indirect System

Passive System

Direct System

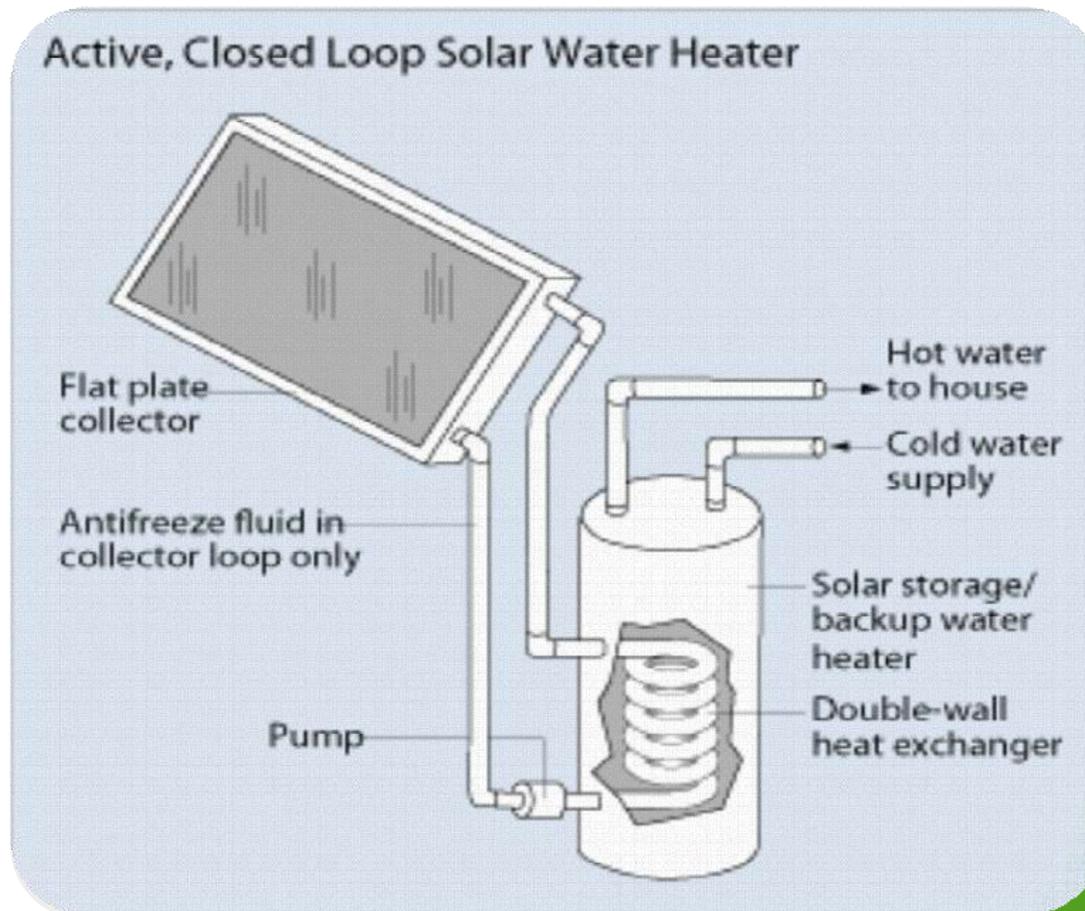
-ICS or Batch Heater

-Convection heat storage unit (CHS)

-Thermosiphon Systems

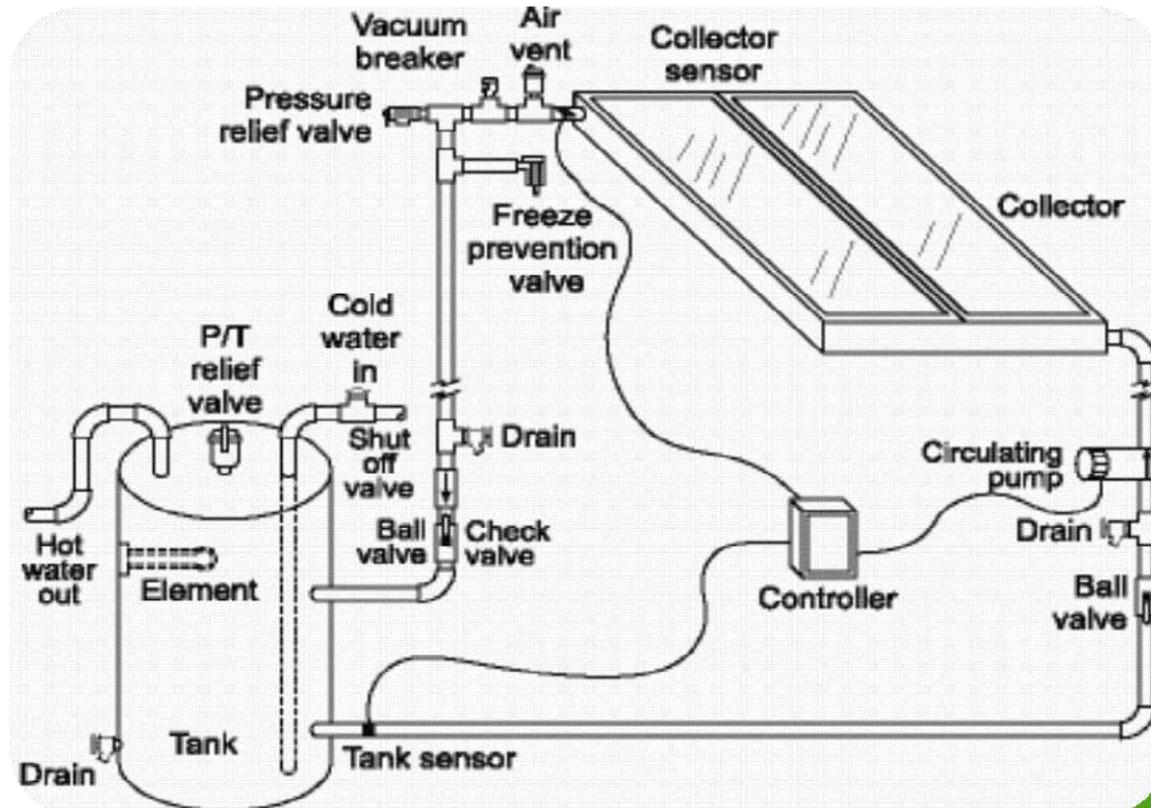
Active System

- ▶ Active systems use one or more pumps to circulate water and/or heating fluid in the system.



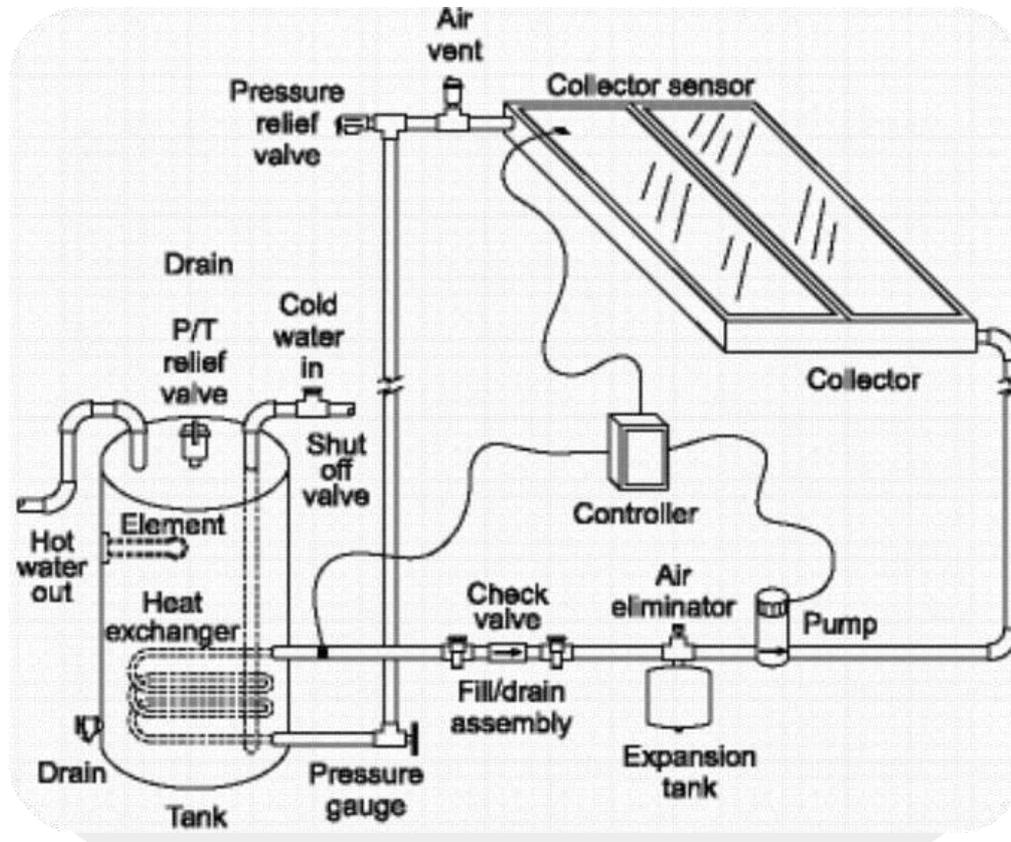
Active Direct System (Open loop active system)

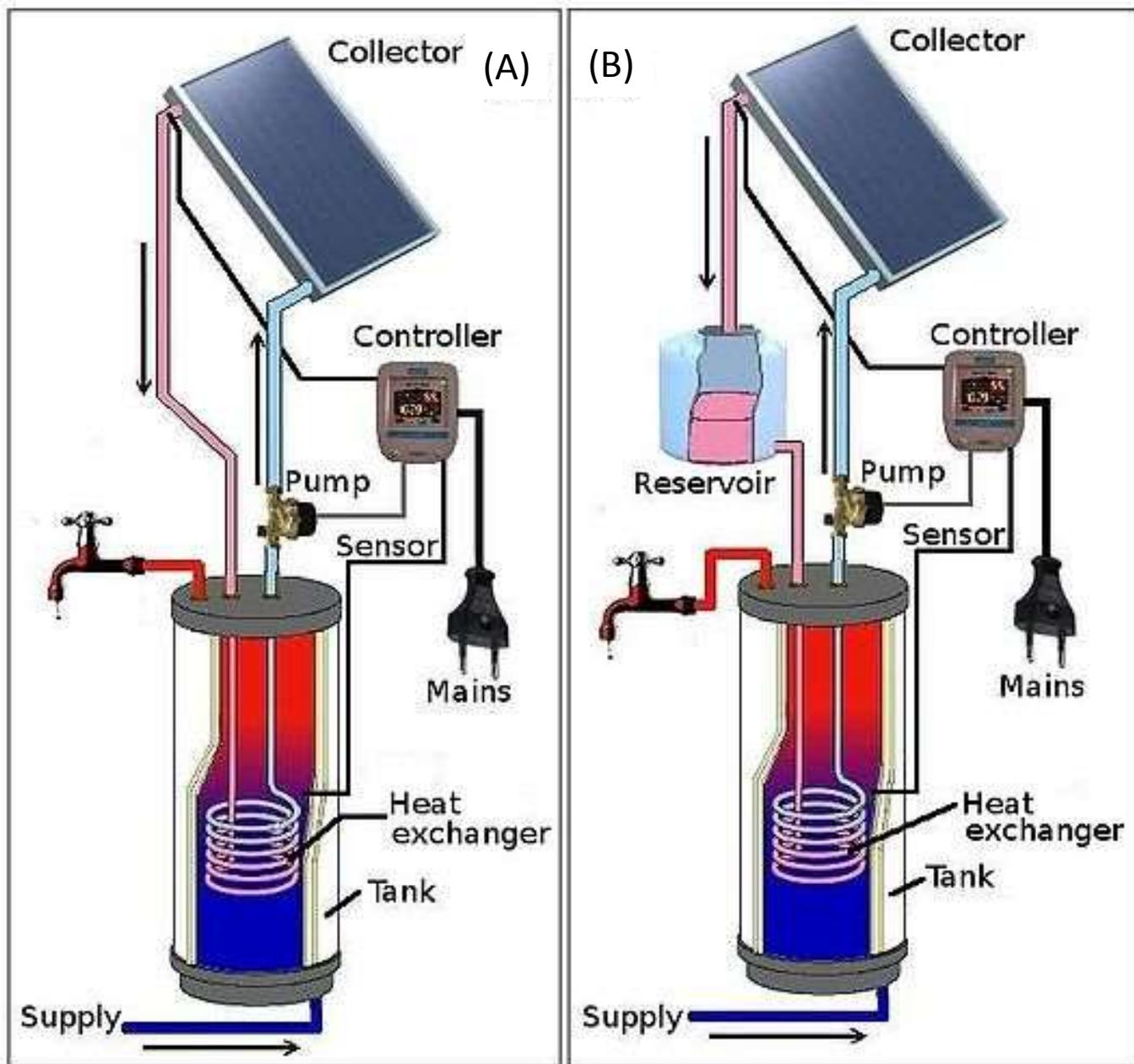
- ▶ Water circulates from the geyser/solar tank through the solar panels (which are absorbing infra-red radiation from the sun), and heats up as it passes through



Active Indirect System (Closed loop active system)

- ▶ Indirect or **closed loop** systems use a heat exchanger that separates the potable water from the fluid, known as the "heat-transfer fluid" (HTF), that circulates through the collector.

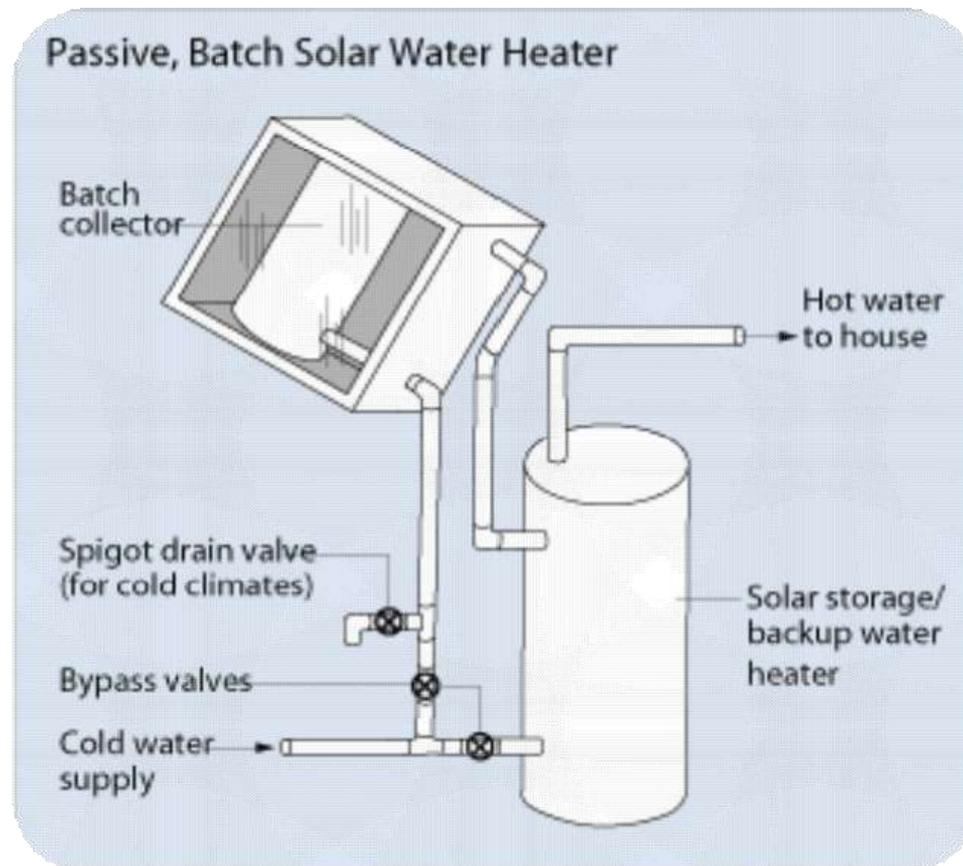




Indirect active system and indirect active drainback systems

Passive System

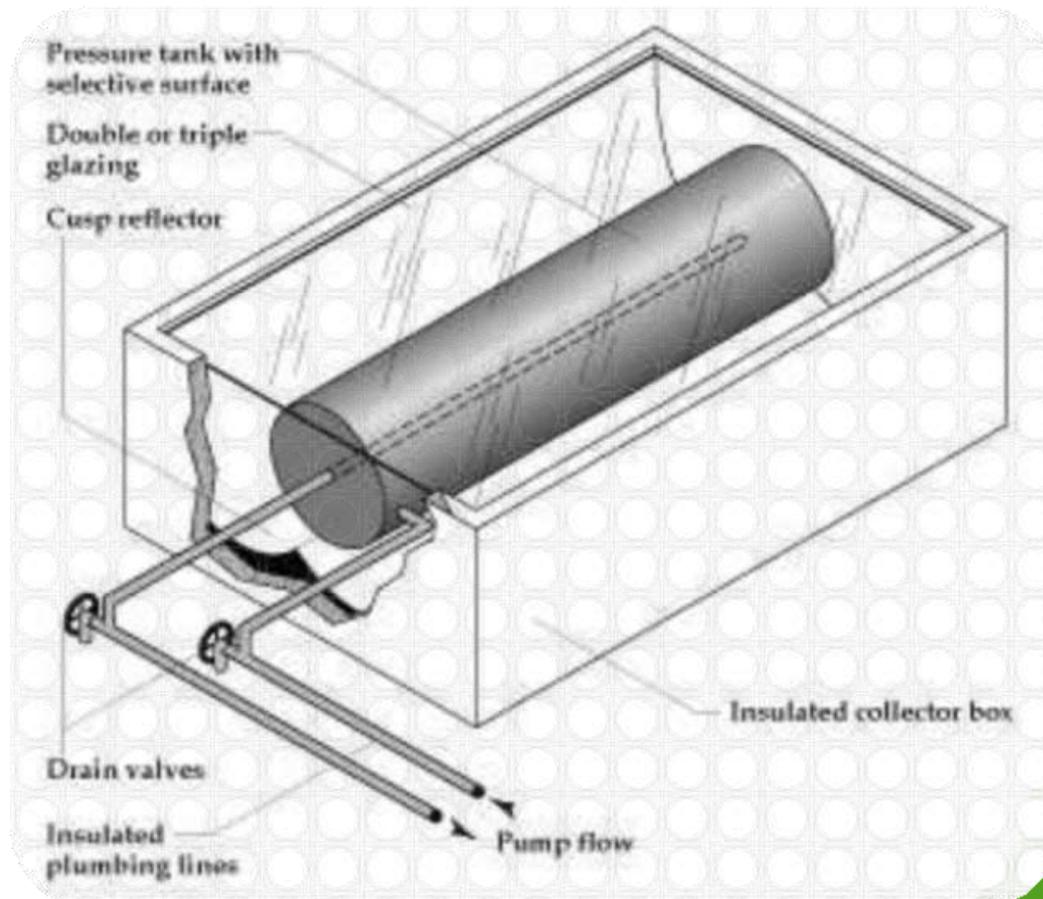
- ▶ Passive systems rely on heat-driven convection or heat pipes to circulate water or heating fluid in the system.



Passive Direct Systems

- ▶ ICS or Batch Heater:

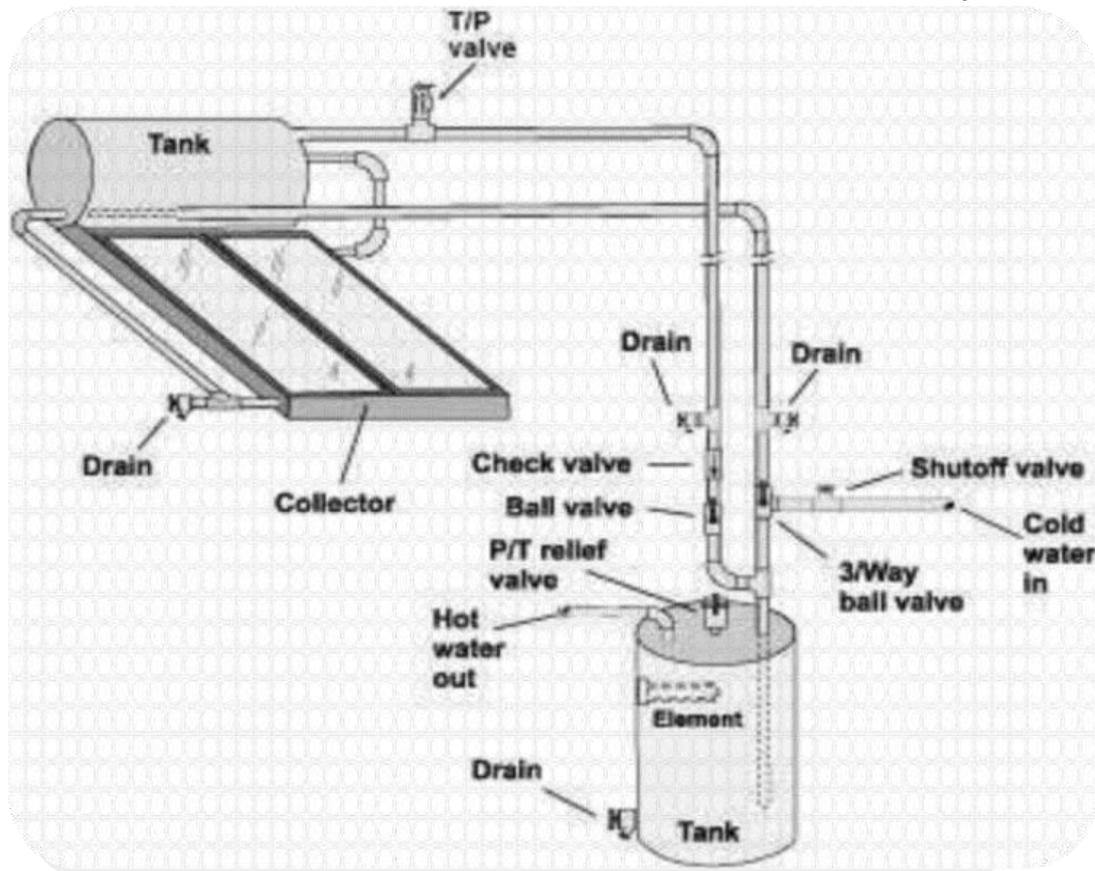
An integrated collector storage (ICS or Batch Heater) system uses a tank that acts as both storage and solar collector.



Passive Direct Systems

► CHS:

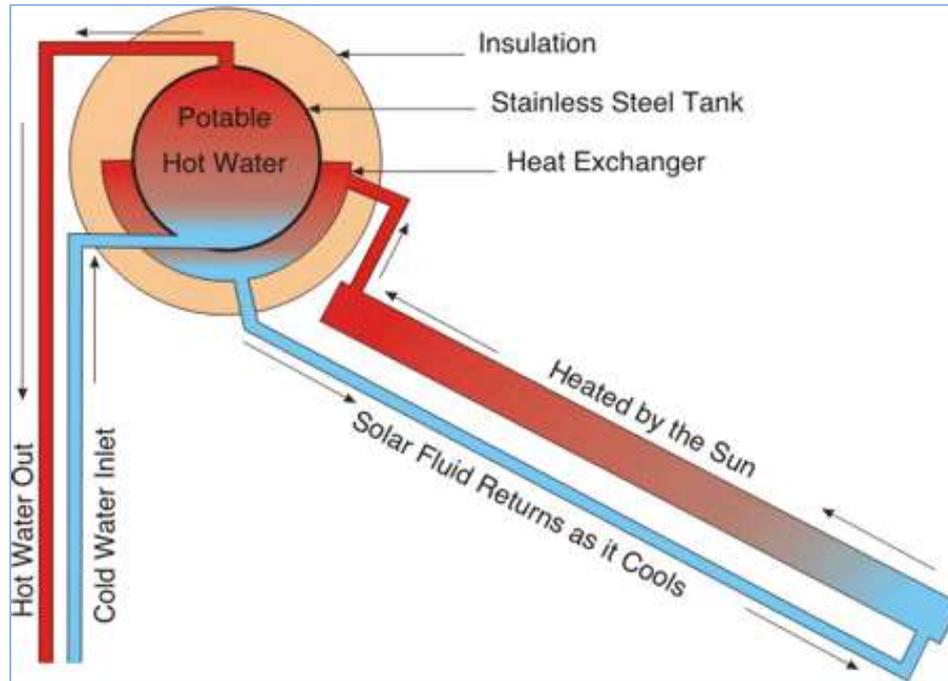
A **convection heat storage unit (CHS) system** is similar to an ICS system, except the storage tank and collector are physically separated and transfer between the two is driven by convection.



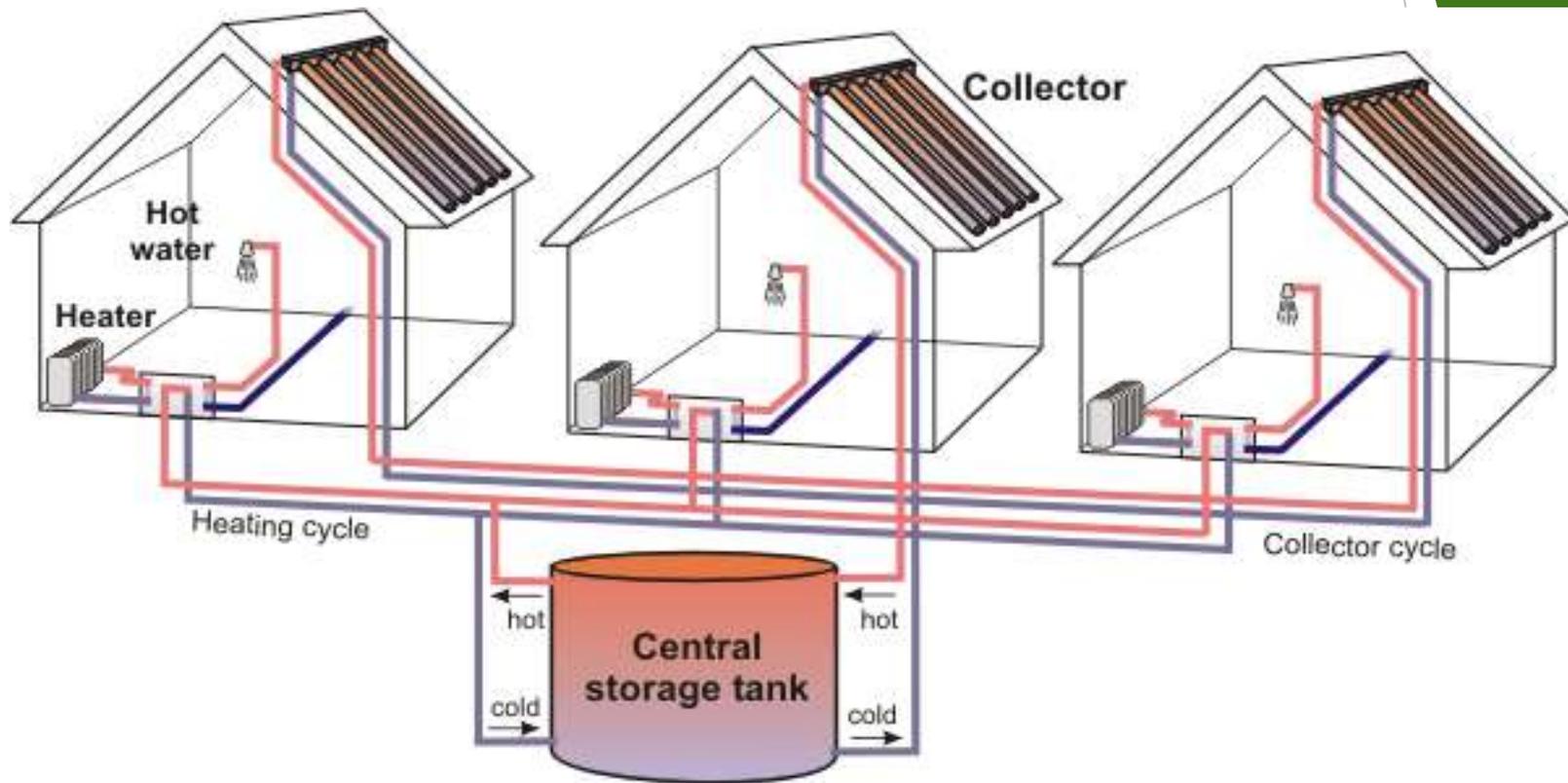
Thermosiphon Systems

Thermosiphon Systems (Passive Direct Systems) collect heat from the sun and transfer it to your water through a natural process. Independent of pumps, sensors, or any moving parts these systems rely on the simple principle that hot water rises and cold water sinks.

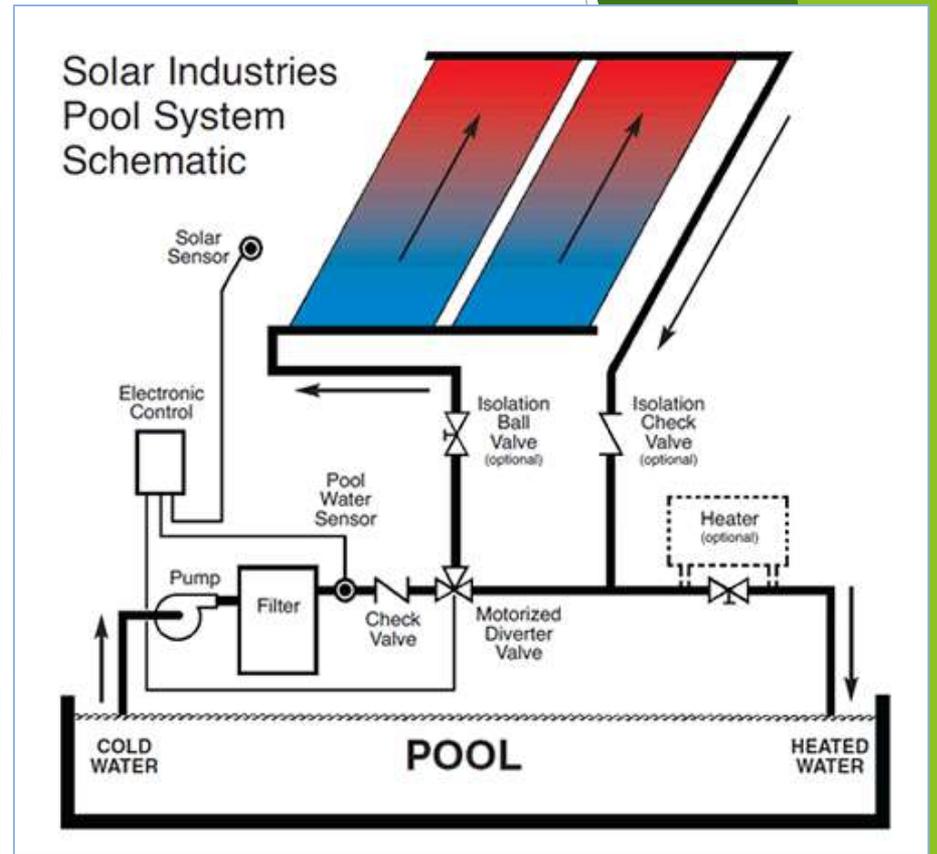
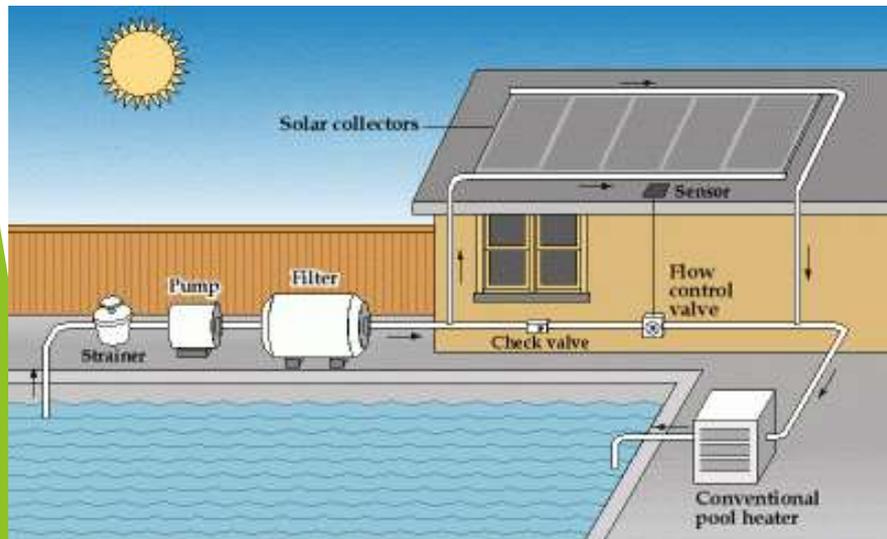
The collector absorbs the sun's rays and heats the cold fluid inside. As the fluid heats, it rises to the top of the collector and into the insulated, stainless steel tank. Here, it displaces cooler fluid which flows in to the bottom of the collector where the process is repeated.



A solar district heating system



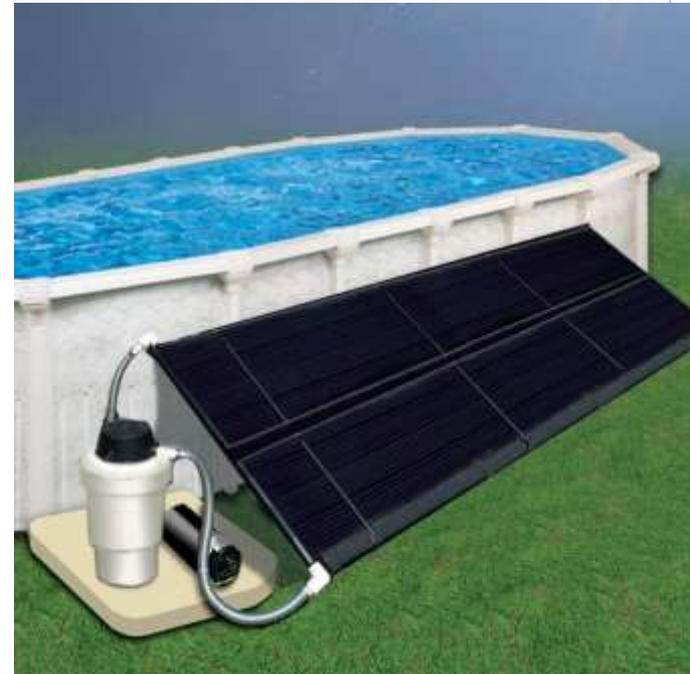
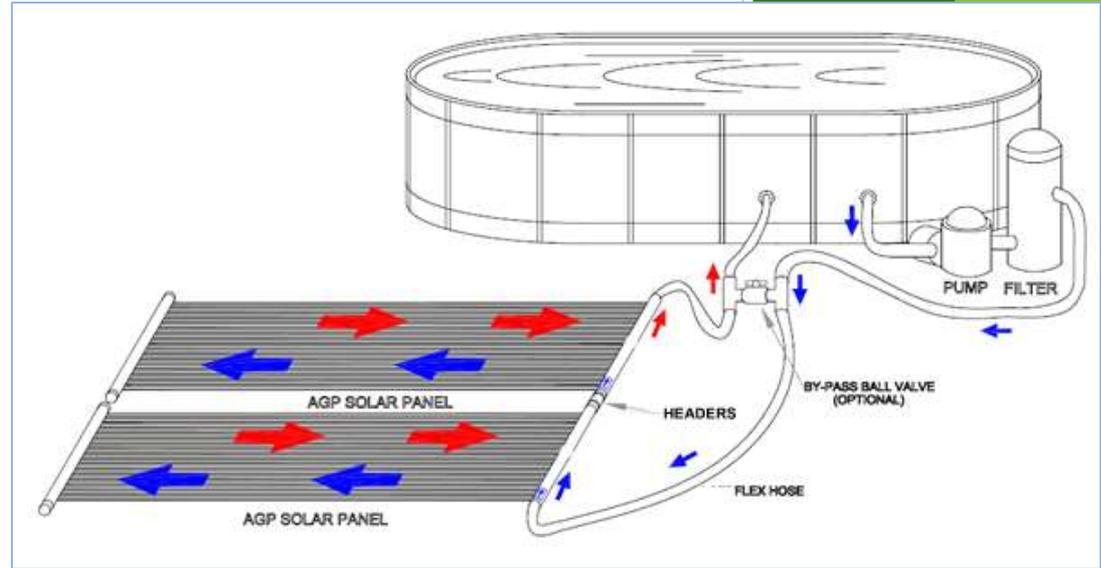
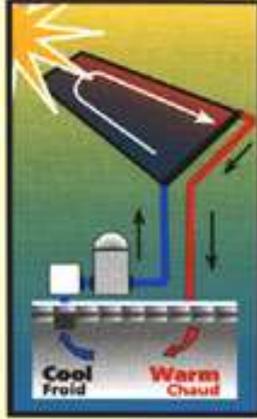
Solar pool heating/ Inground Pools



Solar pool heating / Above Ground Pools

How Solar Pool Heating Works

- Using the pool pump, water is automatically pumped through the solar collectors
- The water is then heated as it moves through the collectors.
- The heated water is returned back to the pool, through the return lines.



Collectors

- *The conventional collector is the core element of a solar system for DHW or space heating*
- *Solar collectors are heat exchangers that use solar radiation to heat a working fluid, usually liquid or air. They can be classified in three groups:*

1) Flat-plate collectors (FPC)

- Unglazed collectors (low-temp collectors)
- Glazed collectors (medium-temp collectors)

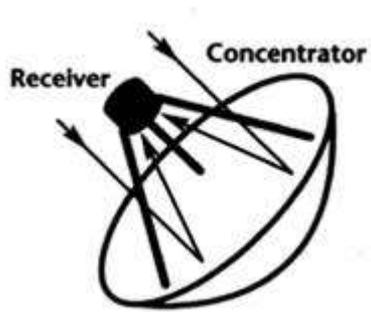
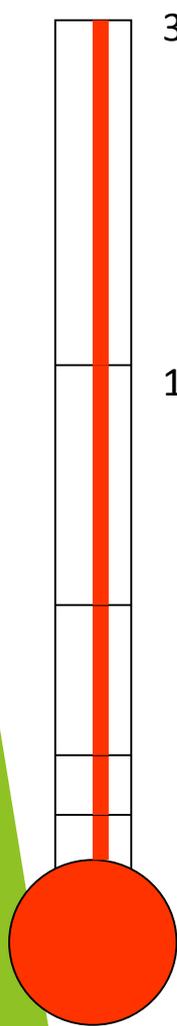
2) Evacuated-tube collectors (ETC), (medium-temp collectors)

- Single-glass tube collectors
- Twin-glass tube collectors
- U Pipe Evacuated Tubes

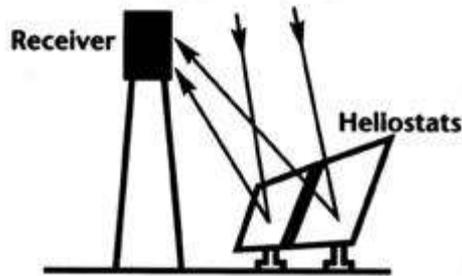
3) Focusing collectors

- High-temperature concentrating collectors

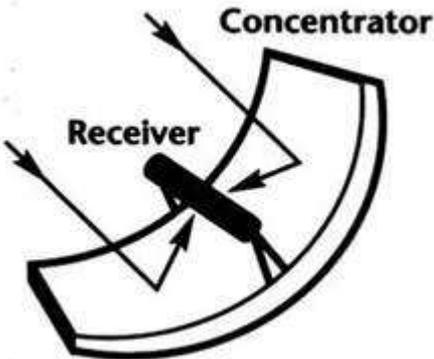
Temperature Levels of Collectors Technologies



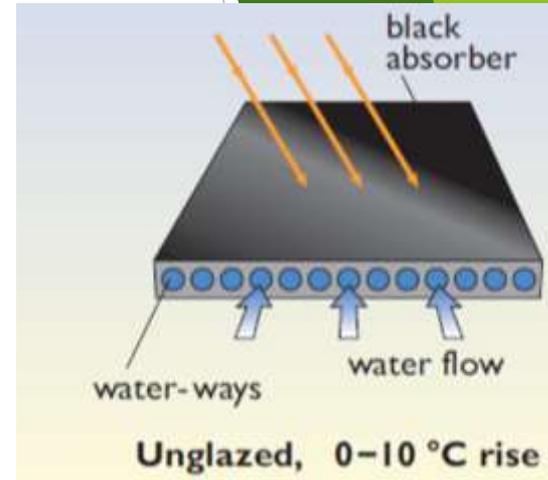
Paraboloid: "Dish"



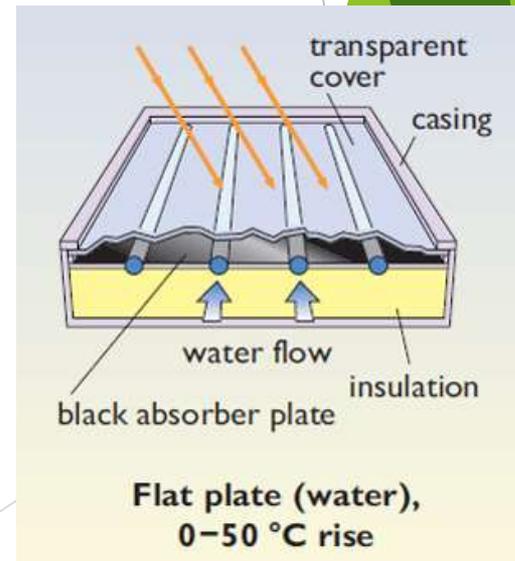
Solar Tower
(Central Receiver System)



Parabolic Trough /
Linear Fresnel



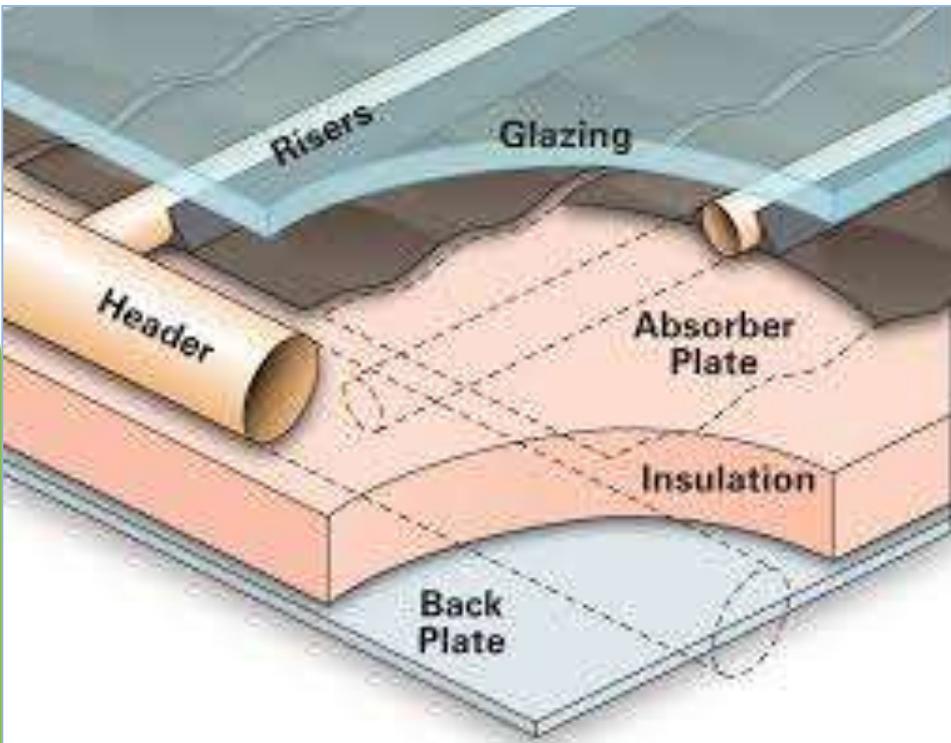
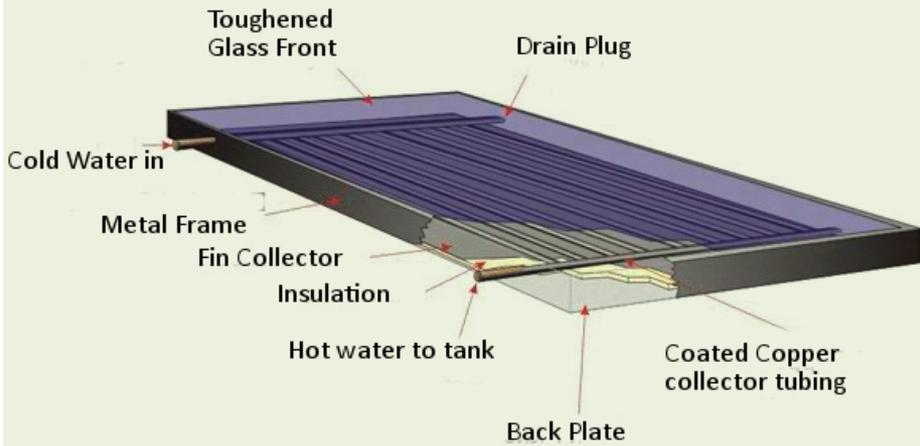
low temperature applications



moderate temperature applications

Temperature Levels of CSP Technologies

Flat Plate Collector Diagram

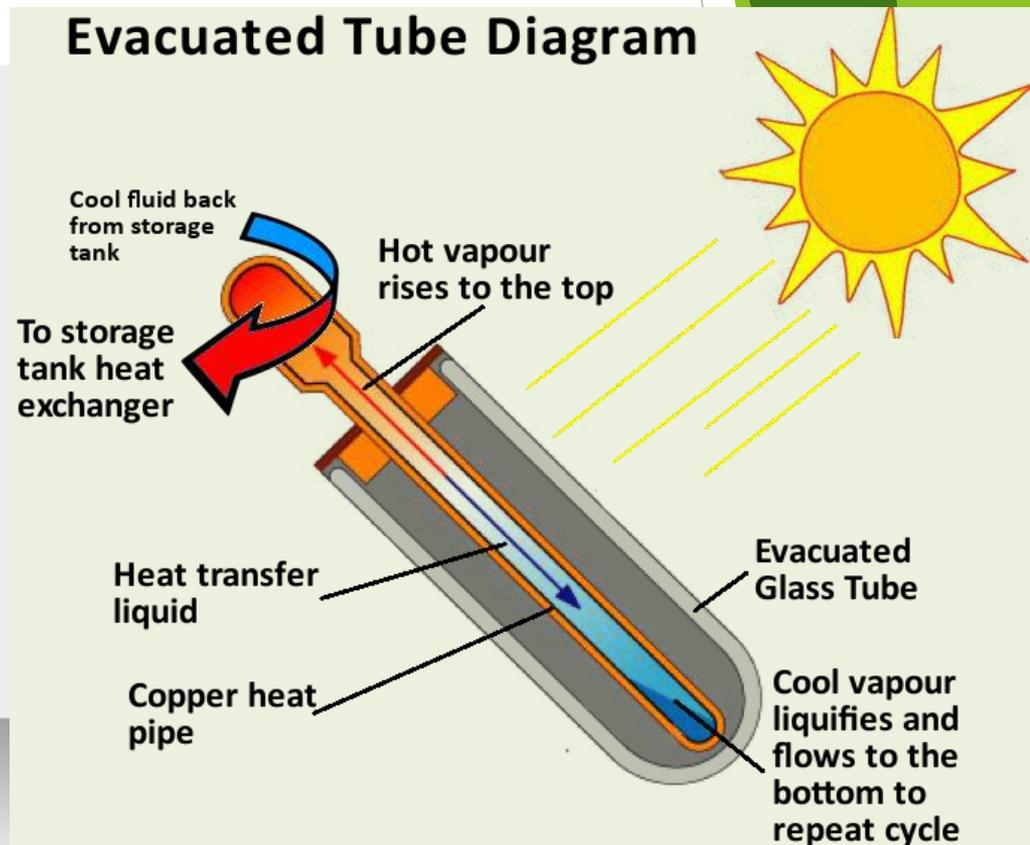


Evacuated-Tube Solar Collectors

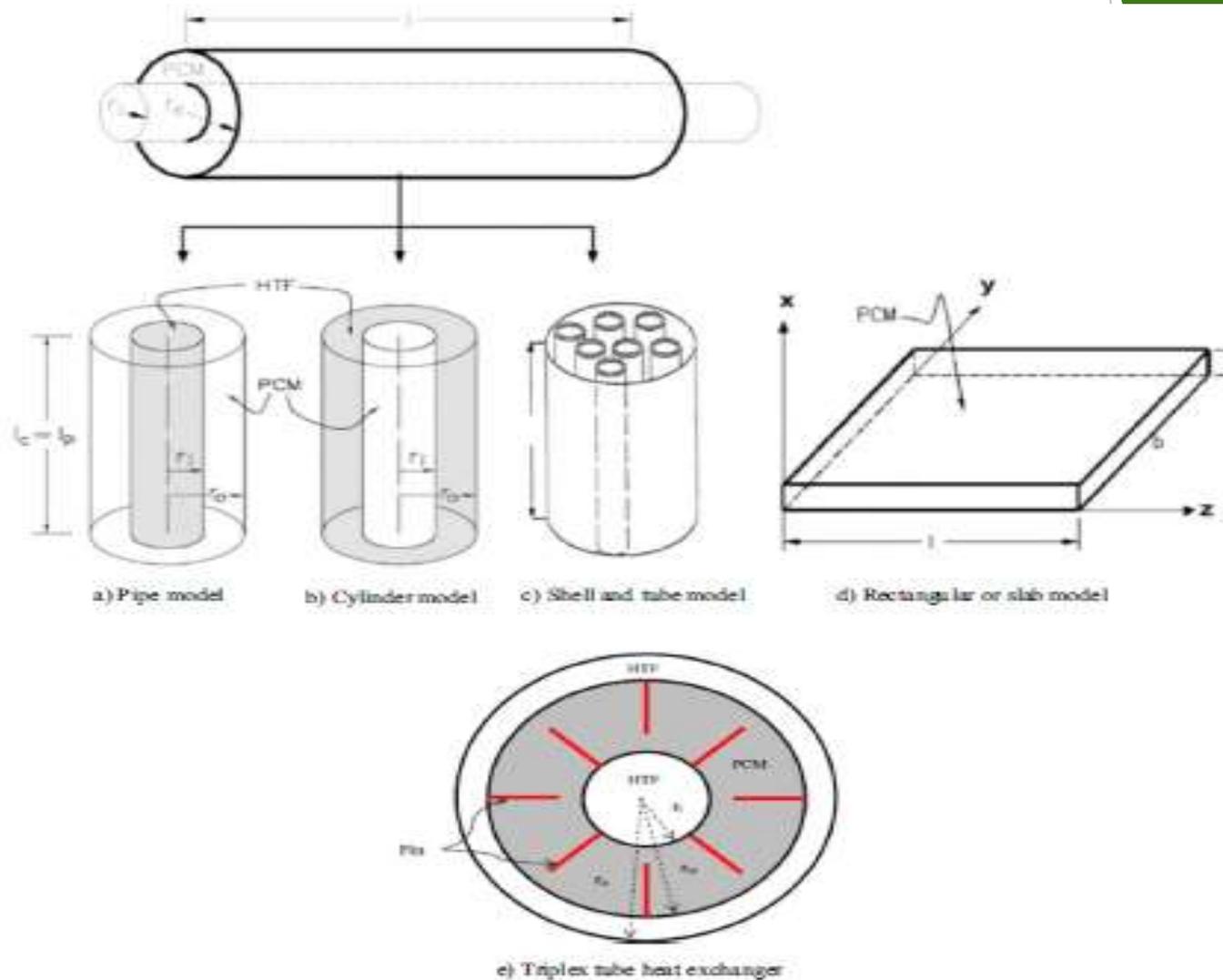
- ▶ An evacuated-tube collector contains several rows of glass tubes connected to a header pipe. Each tube has the air removed from it (evacuated) to eliminate heat loss through convection and radiation.



Evacuated Tube Diagram



Performance Enhancement of SWHS Fins-NanoPCM technique

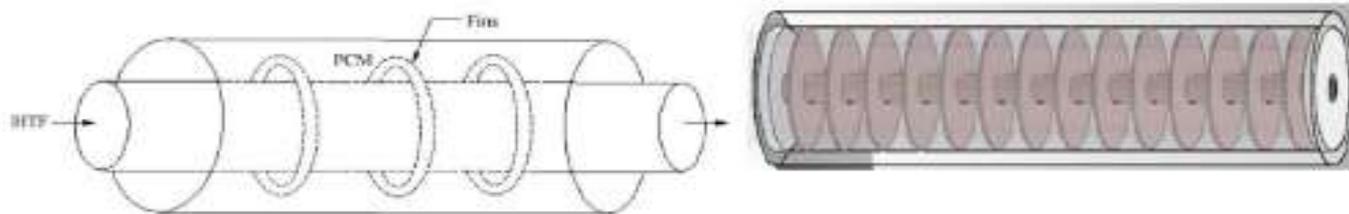


Classification of commonly used PCM containers terms of the geometry and configuration.

Performance Enhancement of SWHS Fins-NanoPCM technique

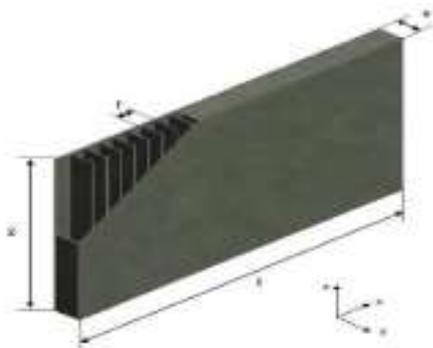


a) Longitudinal fins

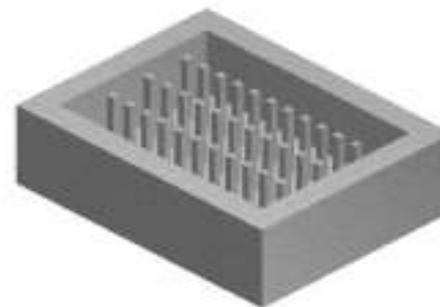


b) Annular fins

c) Circular fins



d) Plates fins



e) Pins fins



f) Tree shape fins

Different configurations of fins technique used in PCM-LHTES systems.

PCM Options

Compound	Melting temp. (°C)	Heat of fusion (kJ/kg)	Thermal conductivity (W/m K)	Density (kg/m ³)
<i>Inorganics</i>				
MgCl ₂ · 6H ₂ O	117	168.6	0.570 (liquid, 120 °C) 0.694 (solid, 90 °C)	1450 (liquid, 120 °C) 1569 (solid, 20 °C)
Mg(NO ₃) ₂ · 6H ₂ O	89	162.8	0.490 (liquid, 95 °C) 0.611 (solid, 37 °C)	1550 (liquid, 94 °C) 1636 (solid, 25 °C)
Ba(OH) ₂ · 8H ₂ O	48	265.7	0.653 (liquid, 85.7 °C) 1.225 (solid, 23 °C)	1937 (liquid, 84 °C) 2070 (solid, 24 °C)
CaCl ₂ · 6H ₂ O	29	190.8	0.540 (liquid, 38.7 °C) 0.1.088 (solid, 23 °C)	1562 (liquid, 32 °C) 1802(solid, 24 °C)
<i>Organics</i>				
Paraffin wax	64	173.6	0.167 (liquid, 63.5 °C) 0.346 (solid, 33.6 °C)	790 (liquid, 65 °C) 916 (solid, 24 °C)
Polyglycol E600	22	127.2	0.189 (liquid, 38.6 °C) –	1126 (liquid, 25 °C) 1232 (solid, 4 °C)
<i>Fatty acids</i>				
Palmitic acid	64	185.4	0.162 (liquid, 68.4 °C) –	850 (liquid, 65 °C) 989 (solid, 24 °C)
Capric acid	32	152.7	0.153 (liquid, 38.5 °C) –	878 (liquid, 45 °C) 1004 (solid, 24 °C)
Caprylic acid	16	148.5	0.149 (liquid, 38.6 °C) –	901 (liquid, 30 °C) 981(solid, 13 °C)
<i>Aromatics</i>				
Naphthalene	80	147.7	0.132 (liquid, 83.8 °C) 0.341 (solid, 49.9°C)	976 (liquid, 84 °C) 1145 (solid, 20 °C)



TEAP Polyolefine spherical capsule



TEAP Polypropylene flat panel



EPS Ltd stainless ball capsule



EPS Ltd module beam

Thank you for attention