Solar Thermal Systems for Residential Homes

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THE OHIO STATE UNIVERSITY

Questions:

- What are solar thermal systems ?
- Why solar thermal?
- How effective and feasible that the solar thermal systems are?
- How much do they cost and what are the payback periods?
- How to select solar thermal systems?

What are Solar Thermal System?

- Systems to collect, storage, and transfer solar energy as heat energy for spacing conditioning and hot water.

Why Solar Thermal?

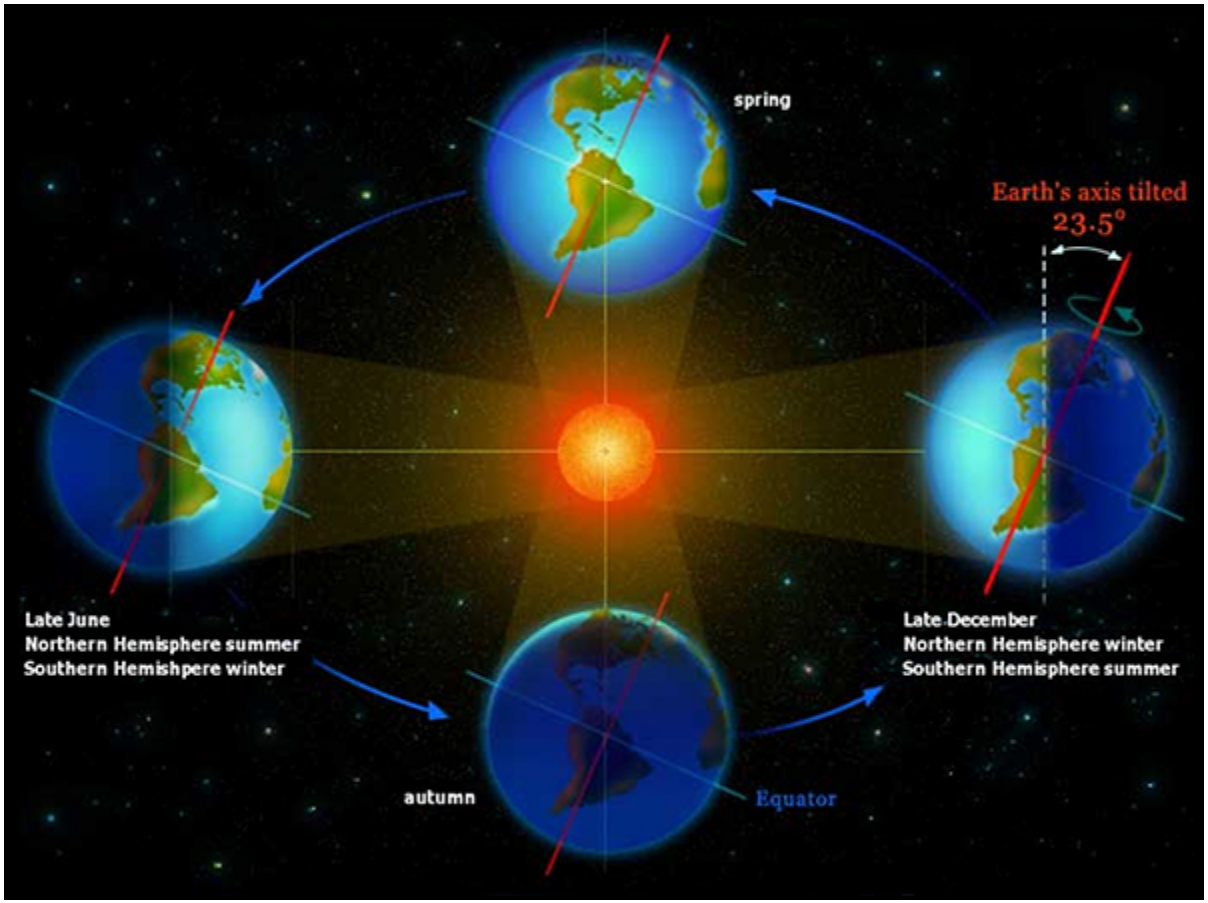
- High energy conversion efficiency
  - Solar Thermal: 70% - 90%
  - Solar Photovoltaics: 10% - 20%
- Shorter Payback
  - Solar Thermal: 3 - 6 years
  - Solar Photovoltaics: 5 – 15 years
- Reduces needs for other heating systems
  - Saves energy and money

Topics of the Day

- Solar thermal energy fundamentals
- Passive solar heating
- Active solar thermal systems:
  - Solar hot air system for pace heating and dehumidification
  - Solar hot water system
- Applications and products
- OSU research on solar heating and humidification systems.

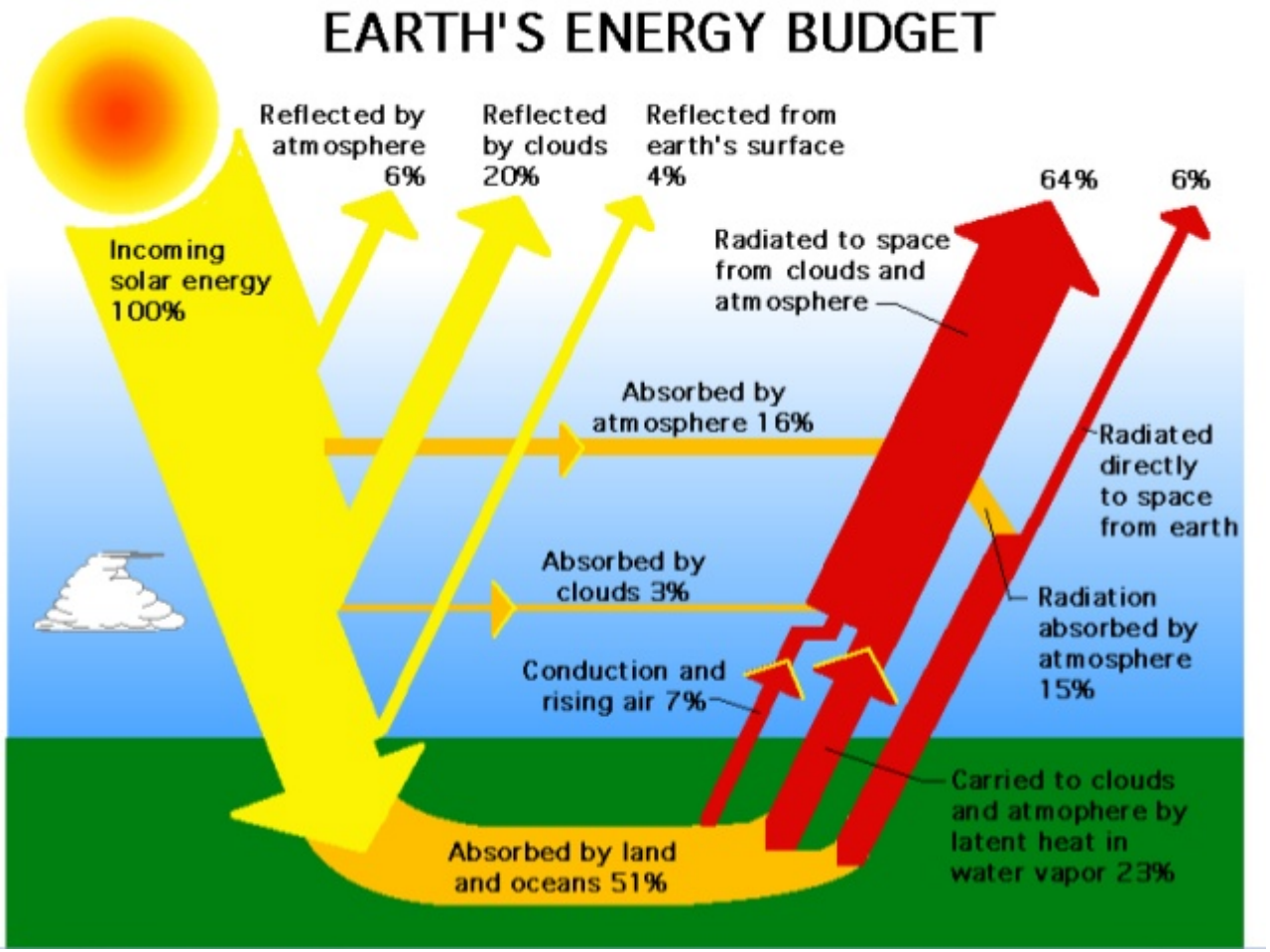
Sun and earth

Solar constant: average solar radiation energy reaching the outside of earth's atmosphere —433 Btu/hr.ft^2.



Source: http://songkle1.blogspot.com/2015/12/how-to-use-earth-rotation-around-sun-to.html

Atmospheric effects on solar radiation



Source: http://www.slideshare.net/NaginaNighat/atmosphere-amp-surface-energy-balance

Atmospheric effects on solar radiation

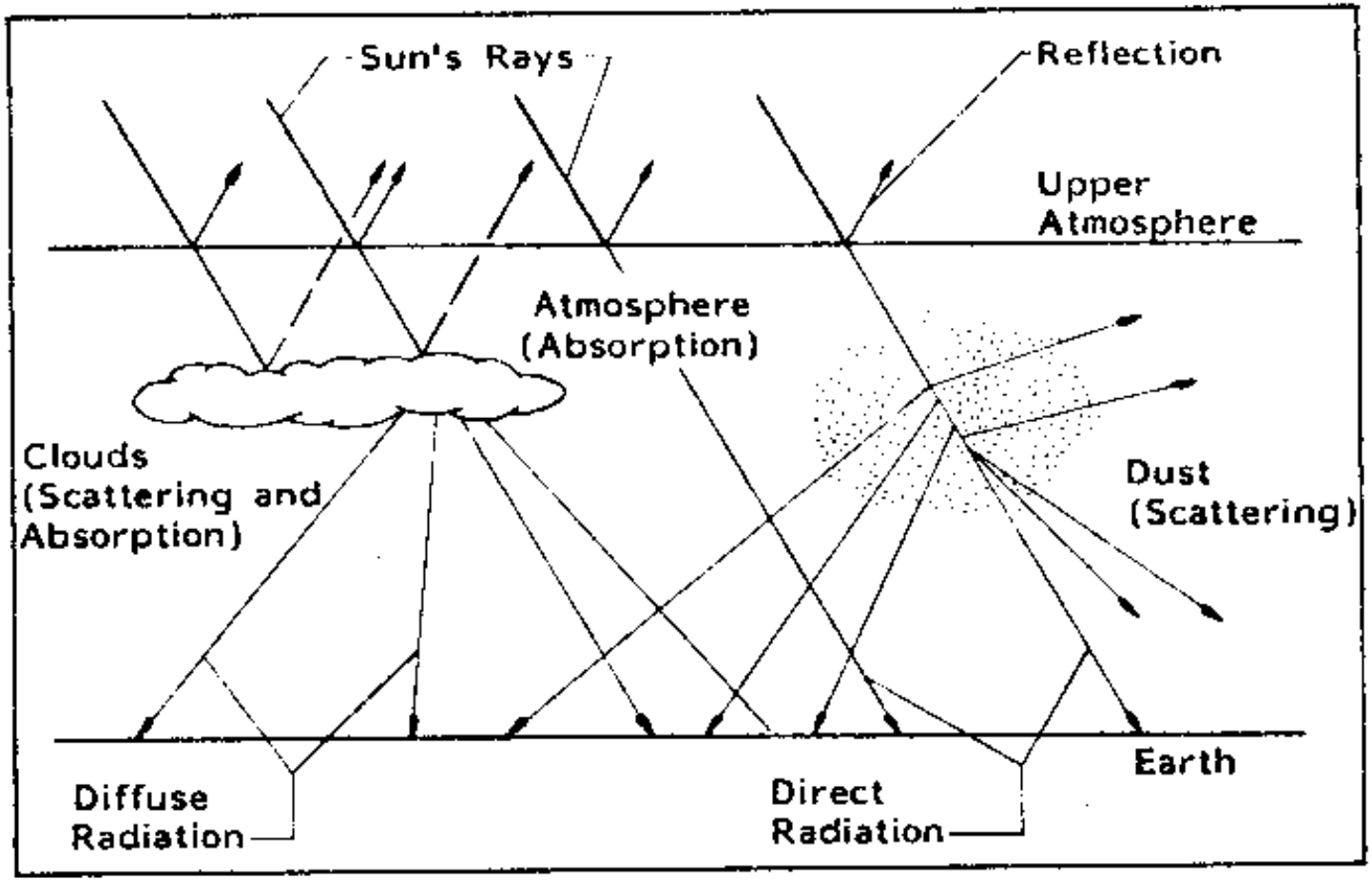
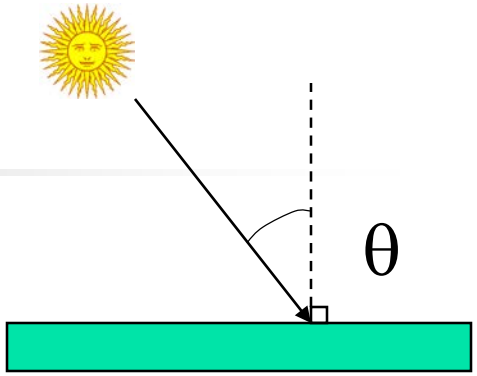


Fig 7. Atmospheric effects on solar radiation.

Total solar radiation



- Solar Constant = Solar flux density at edge of earth's atmosphere
  = 433 Btu/h-ft^2

- Total solar energy reaching earth's surface
  = E_t (Btu/hr-ft^2) = E_{DN} cos θ + E_d + E_r

Where: E_{DN} = Direct normal (perpendicular) radiation

θ = angle of incidence (angle between incoming rays and line normal to surface receptor)

E_d= Diffuse radiation from sky

E_r = Reflected radiation from adjacent surfaces

Solar collector position

Collector title angle:(β)

- Equal to the latitude-most consistent energy collection
- Latitude angle (~40° for Ohic
- +/- 15° for winter and summer

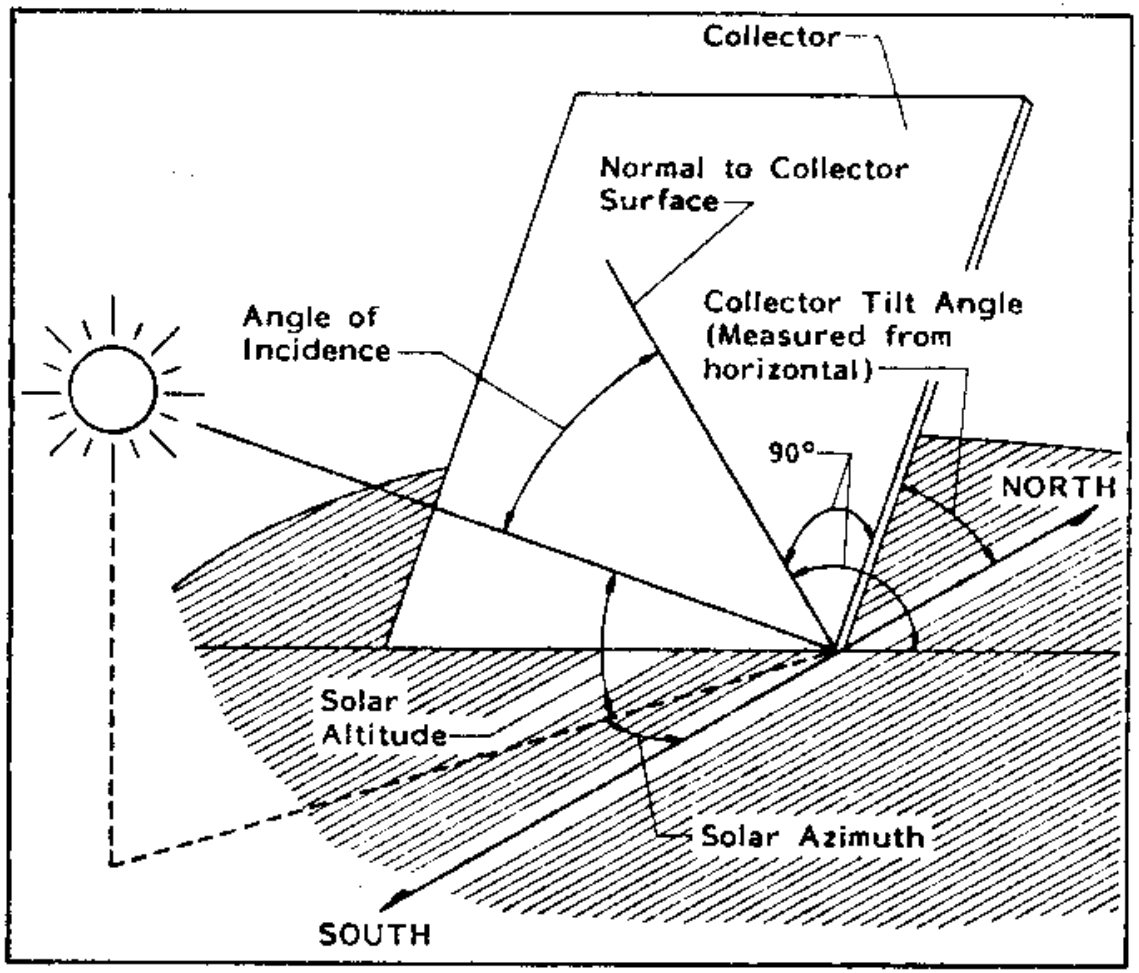
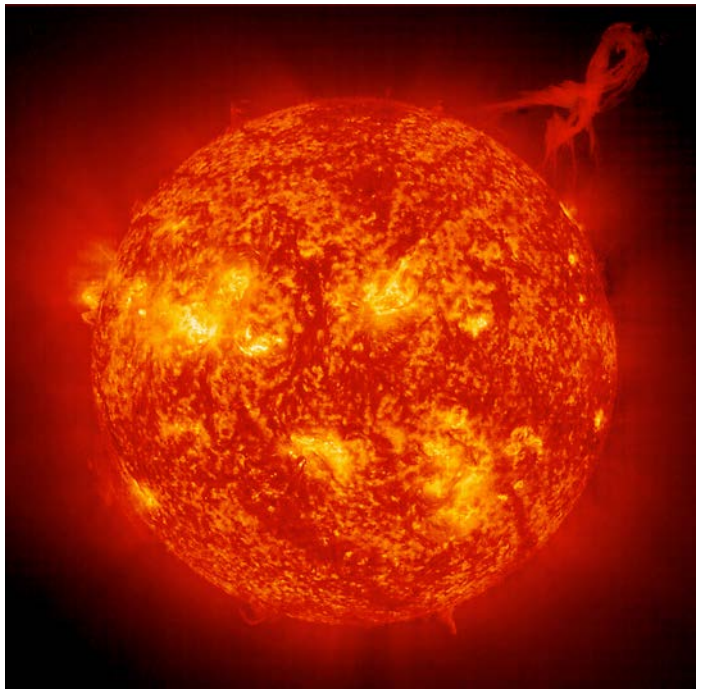


Fig 5. Solar angle of incidence on south-facing surface.

Typical Solar Thermal Systems

- Solar thermal systems
  - Passive solar systems
  - **Active solar systems**
    - Solar water heating
    - Solar space heating



Source: nssdc.gsfc.nasa.gov

Solar Heating Systems--Passive

- Heat is transferred by natural convection, conduction, and radiation without pump or fan power.

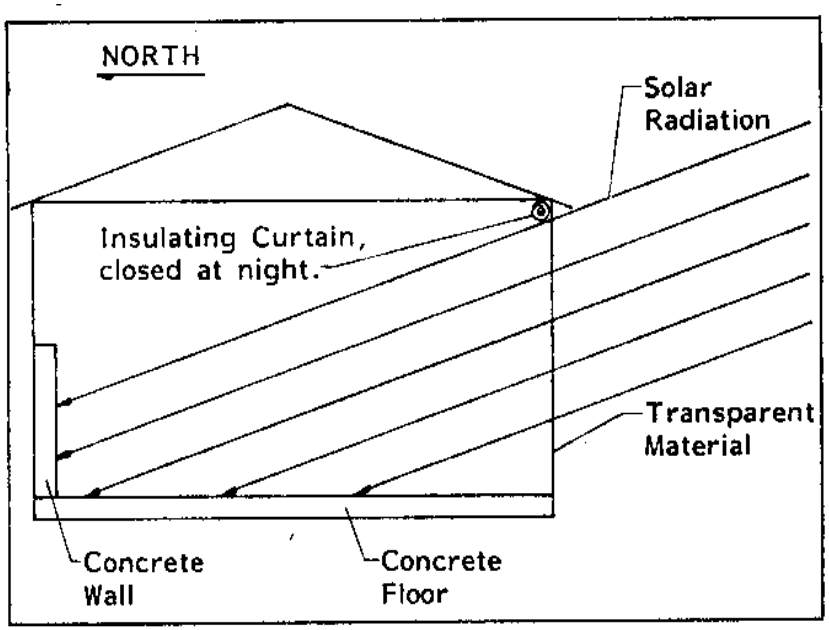
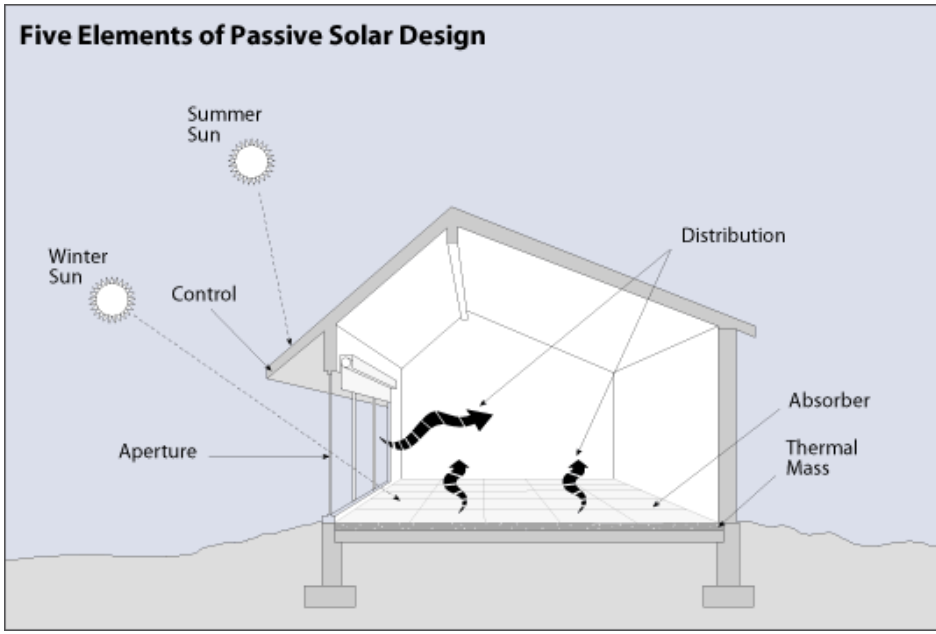


Fig 19. Passive solar heating by direct gain.



Passive Solar Heating Systems

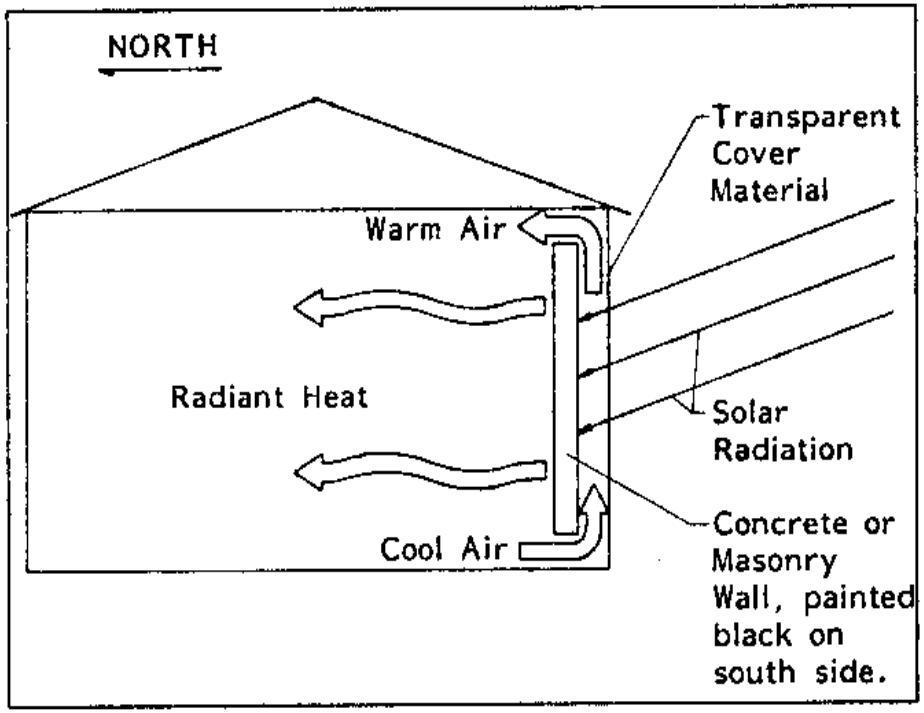
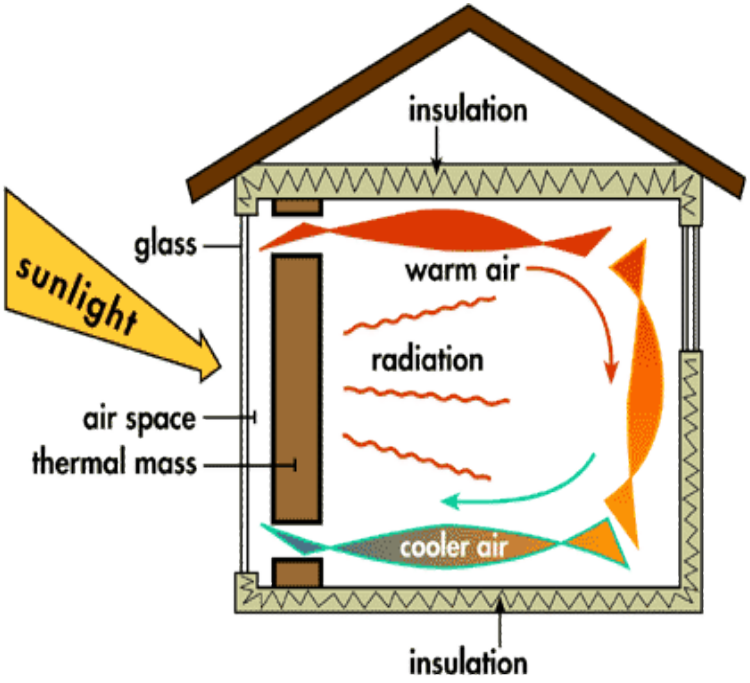


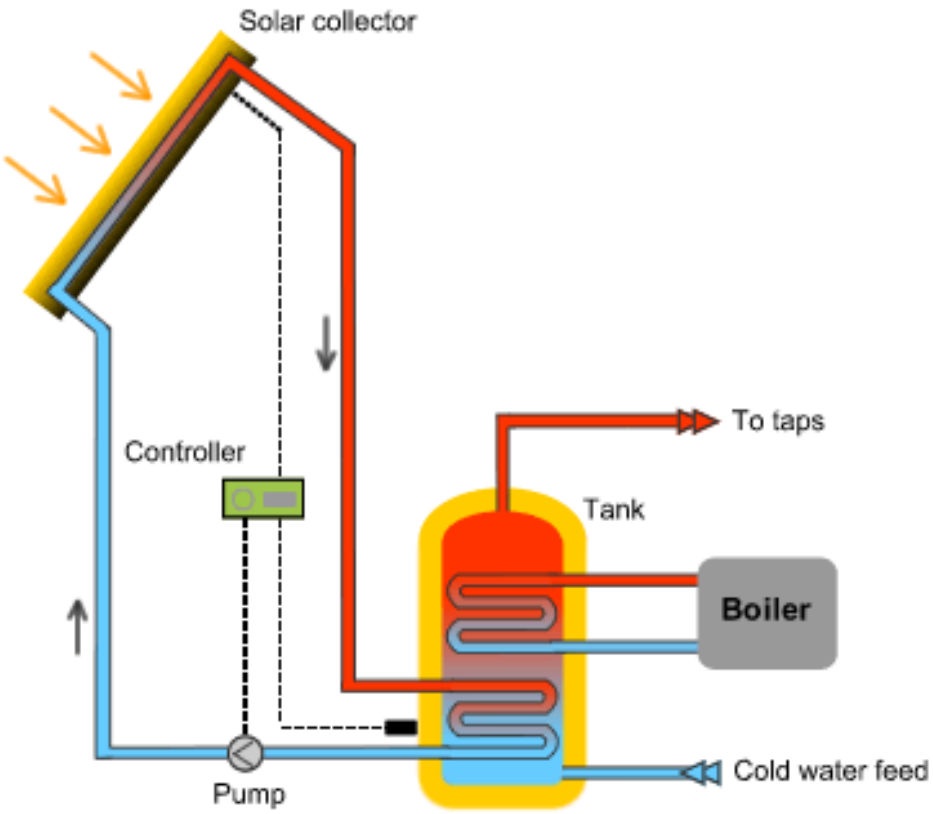
Fig 18. Passive solar heating with a Trombe wall.



Source: http://www.iklimnet.com/save/passive_solar_heating.html

Active Solar Heating Systems

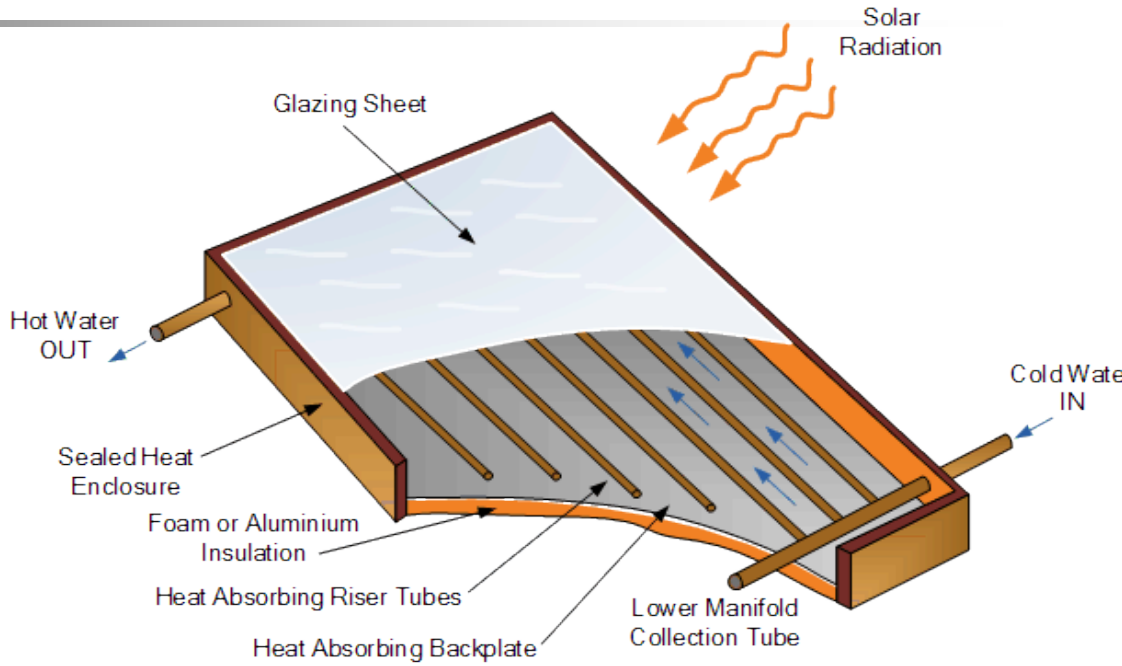
- Heat a fluid in order to provide hot water or space heating
- Uses mechanical systems
- Generally includes thermal mass to store heat



Source:
http://www.daviddarling.info/encyclopedia/A/AE_active_solar_energy_system.html

Active Solar - Flat Plate Collector

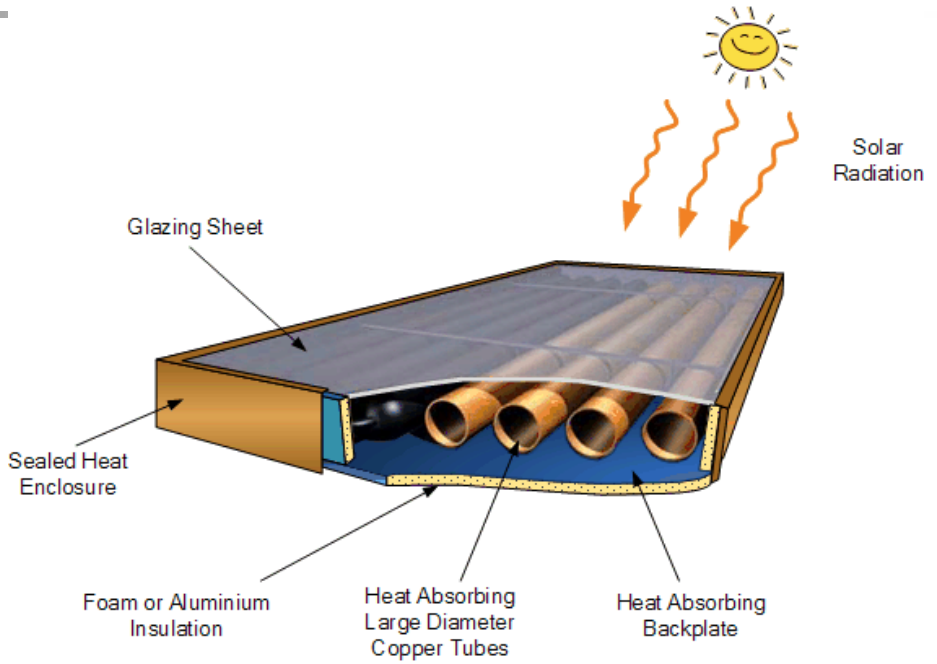
- A typical flat-plate collector is an insulated metal box with a glass or plastic cover, a dark-colored absorber plate, and flow tube for heat transfer fluid.
- heat liquid or air at temperatures less than 180°F.



Source: http://www.alternative-energy-tutorials.com/

Active Solar-Integral collector storage systems (ICS)

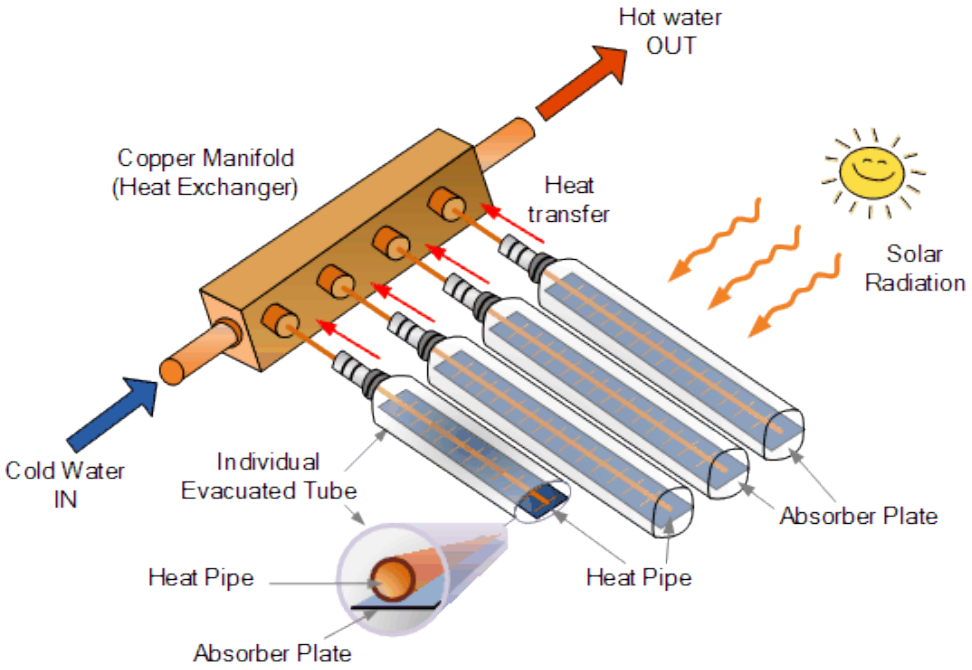
- "Batch" or "bread box" water heating systems
- Heat tubes are much larger
  - Collect and store
- No pumps or sensors
- Issues in colder climates



Source: http://www.alternative-energy-tutorials.com/

Active Solar—
Evacuated tube solar collectors

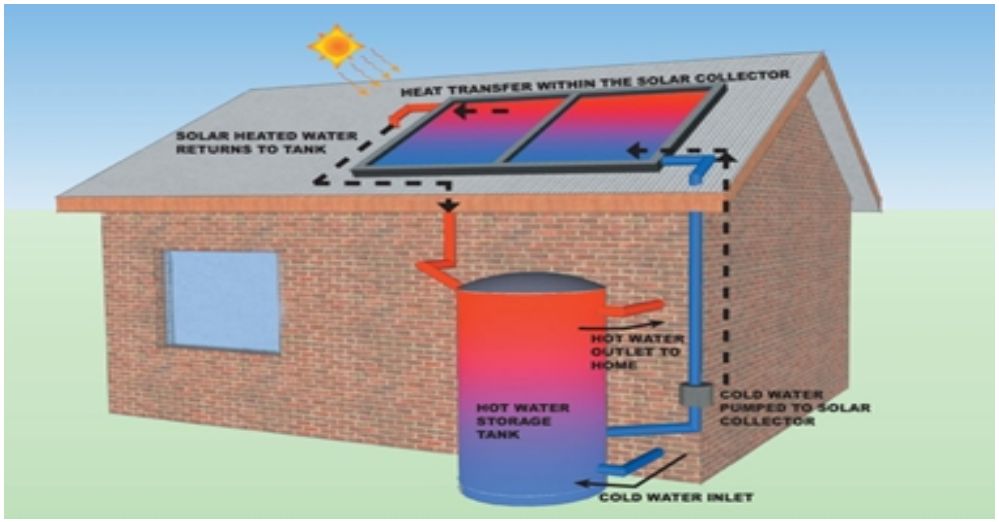
- Parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin is covered with a coating that absorbs solar energy well, but which inhibits radiative heat loss.
- Air is removed, or evacuated, from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss.
- Most efficient, more expensive, and low weight
- Vacuum space in external tubes
  - Decreased heat loss from tubes
- Rounded tubes increase efficiency



Source: http://www.alternative-energy-tutorials.com/

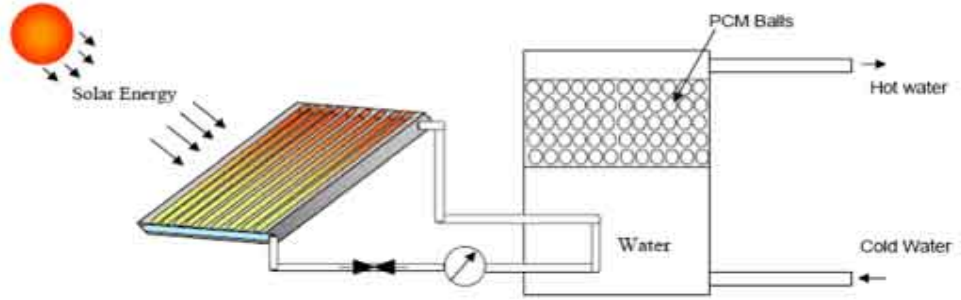
Active Solar Storage

- Water systems: transfer heat directly to water



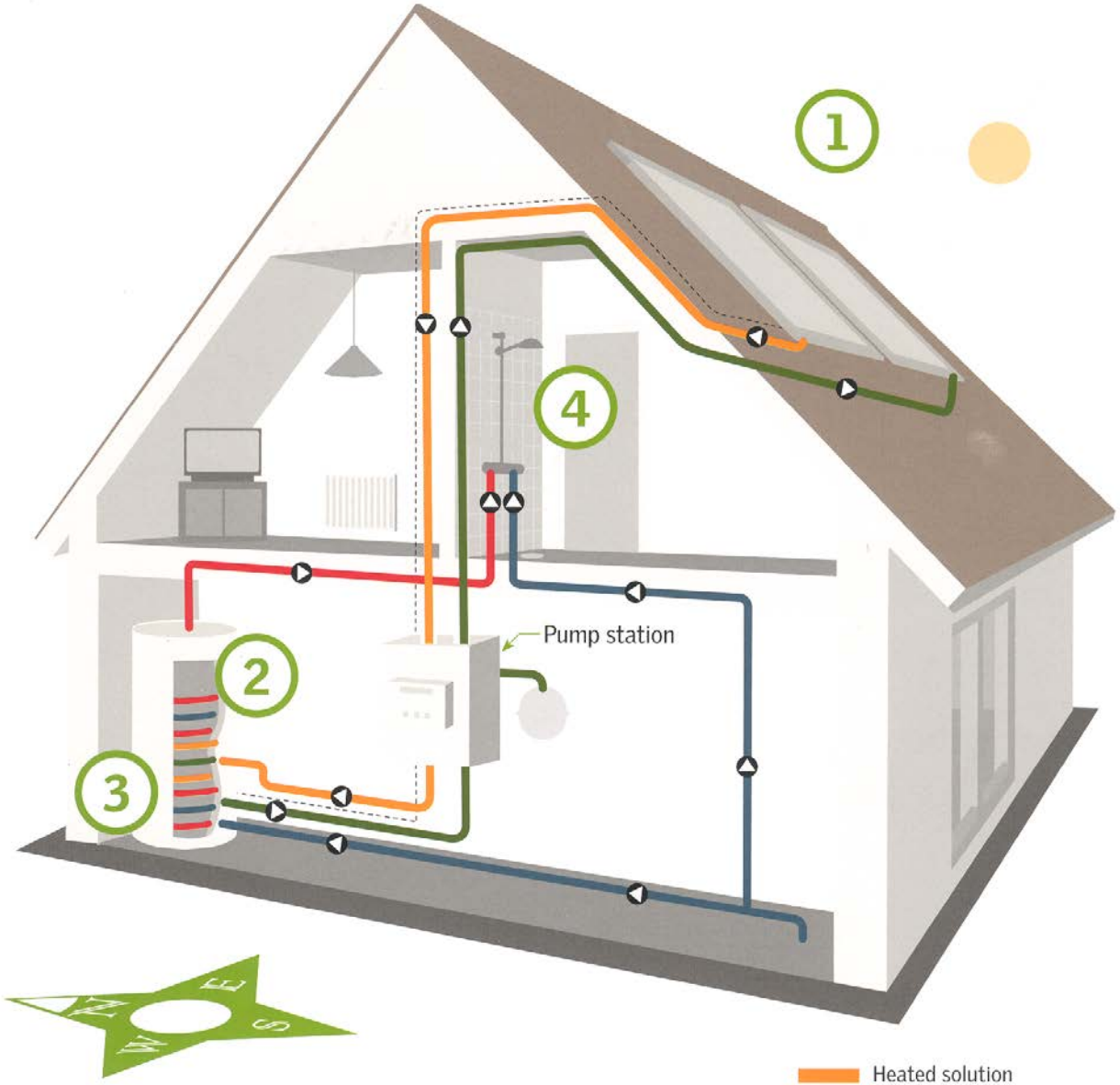
Source: Department of Climate Change and Energy Efficiency of Australia

- Store energy in phase changing materials



Source: www.rgees.com

How it works



For optimum performance, VELUX solar collectors should be placed on a shadow-free, south-facing roof with a pitch greater then 3/12.

Application - Costs

- Vary based on type of system and capacity
- 1 gallon of hot water = 1 ft^2 collector area
- Incentives - can reduce initial cost up to 75% depending on location
  - http://www.dsireusa.org/

Application - Costs

Breakdown of Costs and Benefits for Residential Solar Thermal System in NC		
Cost of System (eligible for tax incentives)	**$7,100**	**100%**
35% NC tax credit ($1,400 maximum)	- $1, 400	20%
30% Federal tax credit ($2,000 maximum)	- $2,000	28%
Impact of state credit on federal taxes	+ $392	6%
Estimated Net Cost of System	**$4,092**	**58%**

Source: NC Public Power

Application - Costs

Example: 2-collector system	Electric	Natural Gas
System cost	$7,100	$7,100
Utility rate	$.11/kWh	$1.48/therm
Efficiency of existing system:*	90%	60%
Solar energy produced:	3,664 kWh/yr	125 therms
Actual energy saved (solar energy / efficiency of system):	4,071 kWh/yr	208 therms
Total $ savings (year 1):	$448	$308
Net tax benefits:	$3,008	$3,008
Payback:**	Year 9	Year 10

* based on ACEEE data- http://www.aceee.org/consumerguide/waterheating.htm

**using a 4% utility escalation rate for electricity and a 9% rate for natural gas

Source: NC Public Power

Cost Examples:
Dovetail – Solar and Wind in Ohio

Solar Thermal Water Heating Systems			
Number of people	**One - Two**	**Three - Four**	**Five - Six**
OG-300 Clear Day C Performance Rating			
BTU/day	37,000	74,000	92,000
System Components			
Solar Collectors	1 GOBI 408	2 GOBI 408	2 GOBI 410
Water tank (gallons)	80	120	120
Balance of System	Rack kit, Valves, Pumps, Thermostats, Dyn-o-flo solar collector fluid		
Estimated Total Installed Cost			
Installed Price	$8,750	$9,850	$10,700

http://www.dovetailsolar.com/

Solar Thermal Air/Water Heating Systems			
Number of people	**One - Two**	**Three - Four**	**Five - Six**
OG-300 Clear Day C Performance Rating			
BTU/day	48,000	72,000	96,000
System Components			
Solar Collectors	Two Northern Comfort 4'x8'	Three Northern Comfort	Four Northern Comfort
Water tank	80	120	120
Balance of system	Heat exchangers, ductwork, pumps, controllers, valves, rack kit, etc.		
Estimated Total Installed Cost			
Installed Price	$9,800	$11,300	$12,500

Dovetail – Solar and Wind in Ohio

Alliance, OH

- Estimated cost: $10,000

Athens, OH

- 48 square foot system
- Estimated cost: $10,000

Image Source: http://www.dovetailsolar.com/

Example – Hot Air Collector

SolarSheat 1000GS Solar Fan Assembly — Heats Up To 400 Sq. Ft., 1,650 BTU Output/Hr., Model# 1251

Item# 41285

New — Write a Review | 1 Answered Question

Only $1299.99

1 Add to Cart

In Stock Online

View Shipping + Delivery Estimates

Not Available in Stores

Source: http://www.northerntool.com/

Example – Hot Air Collector

SolarSheat 1500GS Solar Space Heating Air Collector — 2-Pack, 1,500 Sq. Ft. Capacity

Item# 41850

New — Write a Review

Only $2699.99

1 Add to Cart

In Stock Online

View Shipping + Delivery Estimates

Not Available in Stores

Source: http://www.northerntool.com/

Example – Hot Water Collector

30 Tube Duda Solar Water Heater Collector 37° Frame Evacuated Vacuum Tubes SRCC Certified Hot

by Duda Solar

1 customer review | 17 answered questions

List Price: $2,275.50

Price: $1,230.00 & FREE Shipping

You Save: $1,045.50 (46%)

Item is eligible: **No interest if paid in full within 12 months** with the Amazon.com Store Card. Apply now

In Stock.

Estimated Delivery Date: April 29 - May 4 when you choose Standard at checkout.

Ships from and sold by Duda Energy.

- Hailstone Resistance: up to φmm (1"), Max Operating Pressure: 87psi, Max Flow Rate: 5.25 gpm
- 14mm TU1 Copper Heat Pipes, Manifold insulation: 45mm 93 Kg/m3 Rockwool, Rated Best Heat Retention
- φ58mm x 1800mm Three-Target Cu/SS-ALN(H)/SS-ALN(L)/ALN Vacuum Tubes, High Boron Silicon 3.3 Glass
- Sun Absorption Efficiency: 93-96%, Vacuum Rating: Less than 5.0 x 10-3Pa, Lifespan:70% @ 15 Years
- OG-100 SRCC Certificate Number: 10001880, Eligible for 30% Federal Tax Rebate, Winter Resistant

› See more product details

http://www.amazon.com/Duda-Solar-Collector-Evacuated-Certified/dp/B003SVNY88

Examples of Thermal Storage

80 Gal. Single Coil Heat Exchanger Solar Hot Water Tank

★★★★★ | Write the First Review + | Questions & Answers (2) +

$1,499.00 /each

Ship to Home FREE
Estimated Arrival: MAY 2 - MAY 6
See Shipping Options +

Ship to Store FREE
Available for Pick Up: MAY 4 - MAY 9

1 ADD TO CART

OR Buy now with PayPal

Item cannot be shipped to the following state(s): AK,GU

PRODUCT NOT SOLD IN STO

80 Gal. Single Coil Heat Exchanger Storage Tank with Electric Backup

★★★★★ | Write the First Review + | Ask the first question +

$1,849.00 /each

Ship to Home FREE
Estimated Arrival: MAY 2 - MAY 6
See Shipping Options +

Ship to Store FREE
Available for Pick Up: MAY 4 - MAY 9

1 ADD TO CART SAVE TO MY LIST

OR Buy now with PayPal

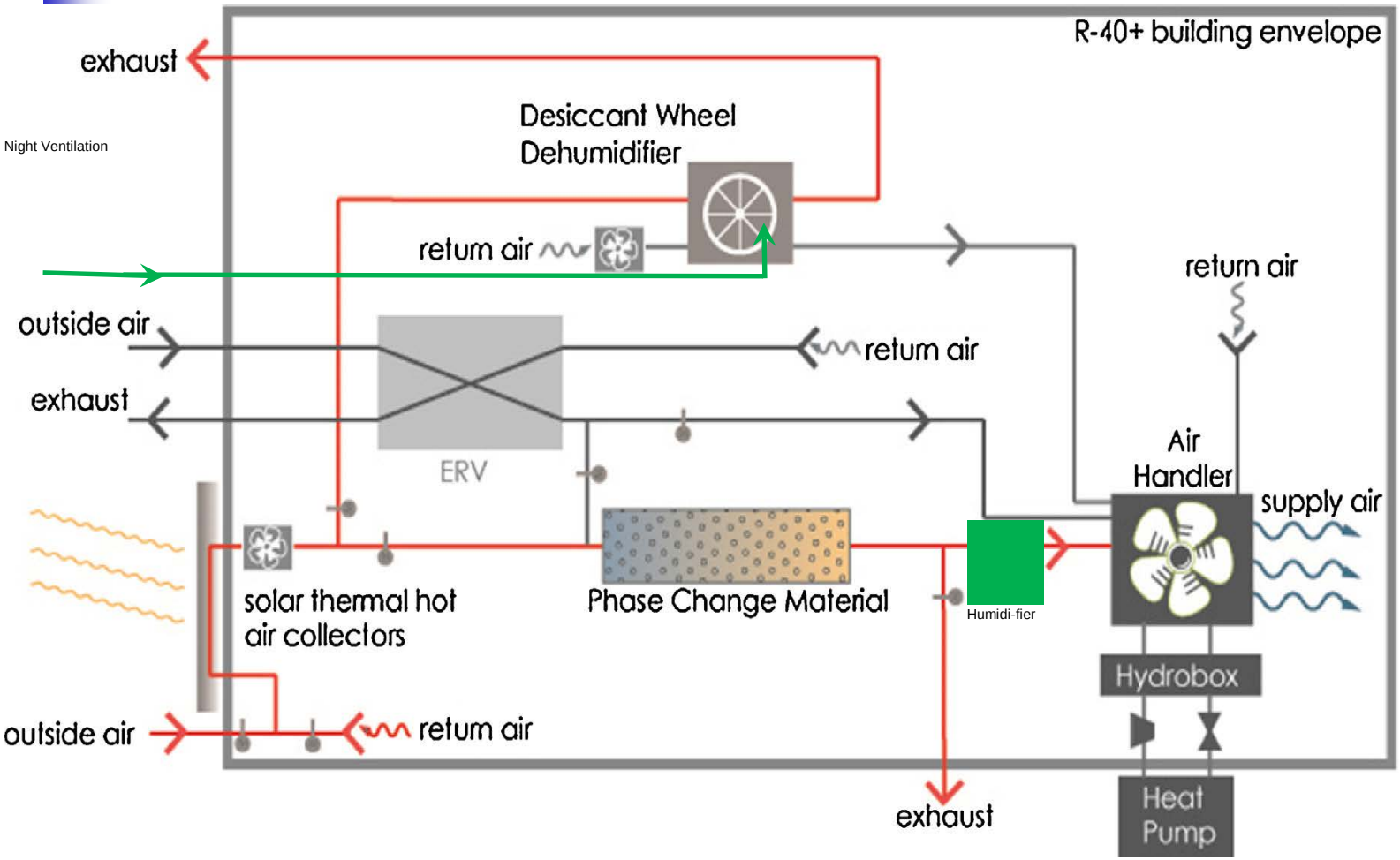
Item cannot be shipped to the following state(s): AK,GU,HI,PR,VI

PRODUCT NOT SOLD IN STORES

Source: http://www.homedepot.com/


2235 Fred Taylor Drive
enCORE House

OSU Research on Solar HVAC



Summary

- Solar energy collectors are advancing dramatically. Applications of solar energy system become feasible.
- Solar thermal systems efficiently using sun power.
- The payback period is short.
- Hybrid and innovative solar systems are needed for residential houses to meet various space conditioning and water heating needs.
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