Solar Power

Basics

2 types:

active : convert sun's energy from heat to other useful form, such as electricity and hot water

passive : direct use of sun's heat energy for home heating, etc.

No R/P, solar is renewable

Potential is large, but we need to see how solar fits into use

How much is there

Average amount of energy received at the top of the atmosphere is 1,400 Joules per meter squared per second (1,400 J/(m^2 sec))

A joule is a unit of energy, like calories, Btu's etc.

How much is there?

About 50% of this energy makes it to the Earth's surface, the rest is reflected by clouds and aerosols, or is absorbed in the atmosphere.

This means 700 J/(m^2 sec) is available at the Earth's surface…

…this already takes in consideration average weather conditions and clouds.

How does this compare with needs?

1. Global calculation

Global energy consumption is about 3.5×10^{20} J/ year

Total surface area of the earth is 5.1×10^{14} m^2

Total amount of sun's energy per year over all earth is 1.1×10^{25} J/year… we need to reduce this in half as only half of the Earth gets sun at any time…

Global comparison

So we get about 16,000 times more solar energy than total energy used worldwide.

If we only use land area (1.5×10^{14} m^2) then we get about 5,000 times more solar energy than total energy used worldwide.

This is interesting, but it does not tell us about useful solar energy

US comparison

2. Energy use in United States

Compare US energy use with incoming solar in US

US energy consumption is about 0.8 $x10^{20}$ J/year

We have 9 x 10^{12} m^2 of land surface

This yields 1 x 10^{23} J/year from sun, or about 1,000 times more solar energy than energy used in US

This number is less (about 600) as US gets only an average of 8 hours of useful light per day (why?)

US comparison

View this another way; how much area of the US do we need to cover with photovoltaic cells (converts sun's energy to electricity) to meet US energy needs with solar?

Answer: about $1/600^{th}$ of land area, if photovoltaic cells are 100% efficient.

Photovoltaic cells are about 10% efficient, so we need about $1/60^{th}$ of US area, or 1.5×10^{11} m^2.

This is half of Colorado.

Another example

How much solar energy hits your roof compared with the amount of energy you use at home?

Numbers we need:

8×10^{19} J/year Total US energy use
$1/6^{th}$ of this is used in homes
75,000,000 homes

This gives about 2×10^{11} J/year per home

Another example… part 2

There is 6×10^9 J/(m^2 year) incoming sun (on average… 8 hour day)

If we have a useable roof area of 10m by 10m, or $100m^2$ of useable roof area,
then we have 6×10^{11} J/roof per year

So we have about 3 times more energy from the sun on the roof than we use in the house.

Caveats

Factors to consider…

- Efficiency with which solar energy is converted to useful energy in the home

- Passive and active use of solar in the home; passive is more efficient

Caveats

- How much energy is actually used in the home (we have used an average), more insulation, etc., less energy needed.

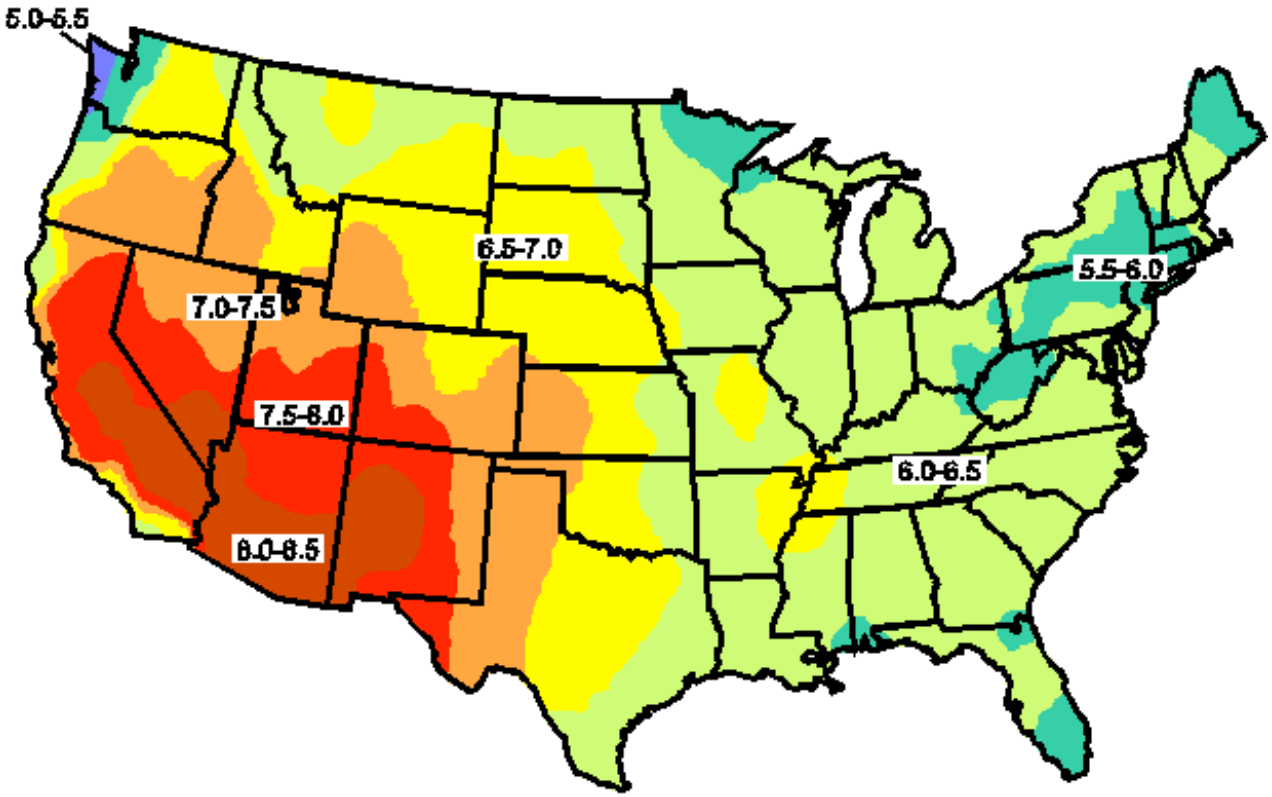
- How well we can store solar energy for night use and for use on cloudy days

- Seasonality of sun's energy

Caveats

Where you live: Southwestern US gets almost twice as much sun as Northeastern US

Incoming solar energy in watts/square meter



Bottom line…

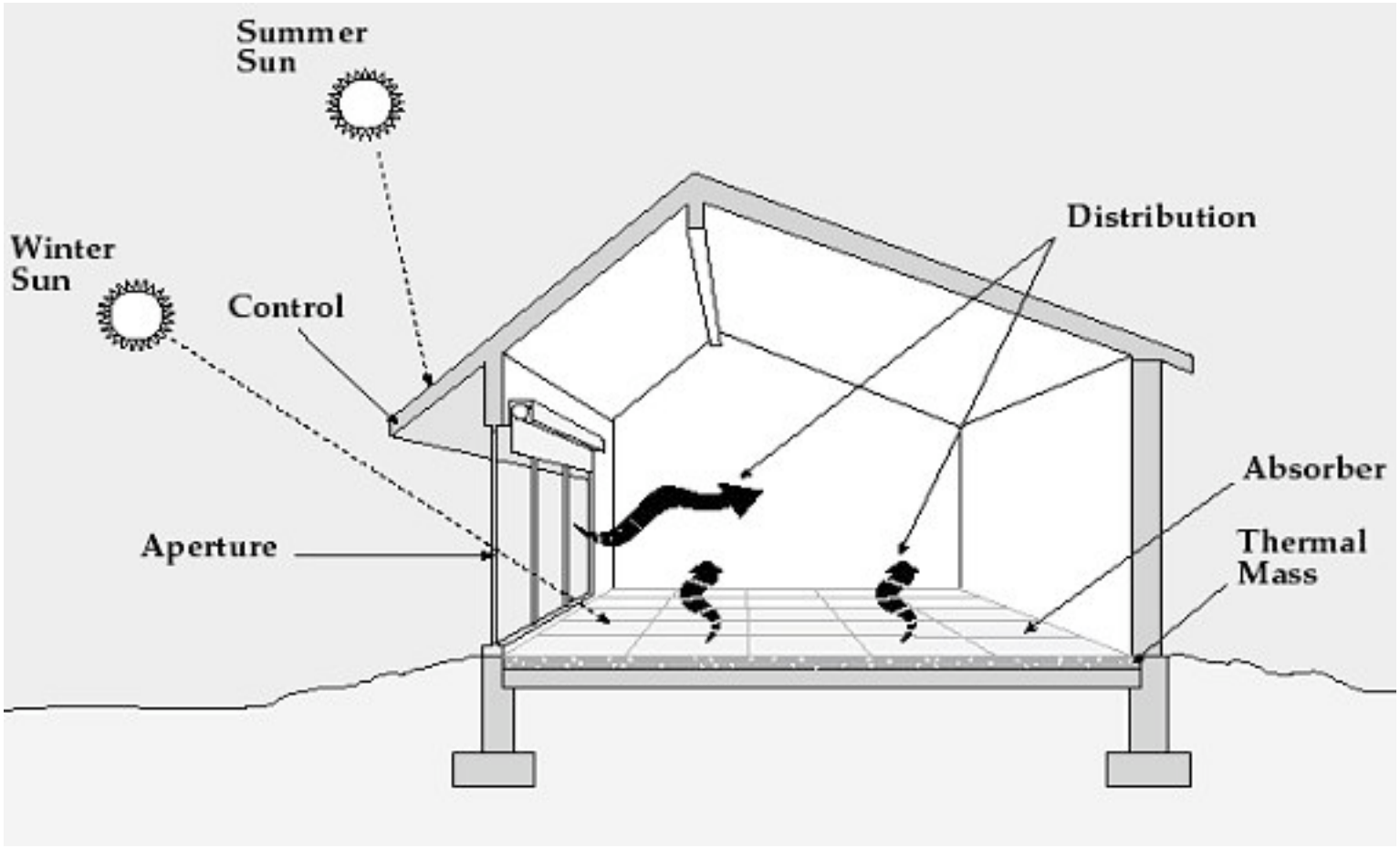
Overall Conclusion: solar energy is very abindant. It can meet much of home energy needs as well as other sectors via electricity (or other storage form)… *but we need a*

- *backup,*
- *storage system and/or*
- *excess capacity*

for cloudy days, and for areas with less sun

Passive Solar

Primarily home heating but water heating is also sometimes considered a form of passive solar energy



Passive solar

Orientation of home is important (south and west)… this can be a problem in modern, planned neighborhoods

Maintenance free

Initial cost (if any) is usually recovered in a few years

Insulation

Amount of energy in winter coming in through a10ft by 10ft window is about 10 to 20% of the average home heating needs in winter.

For newer, highly insulated homes, amount of energy in winter from 10ft by 10ft window is 80% or more of the home heating needs in winter.

Homes and passive solar

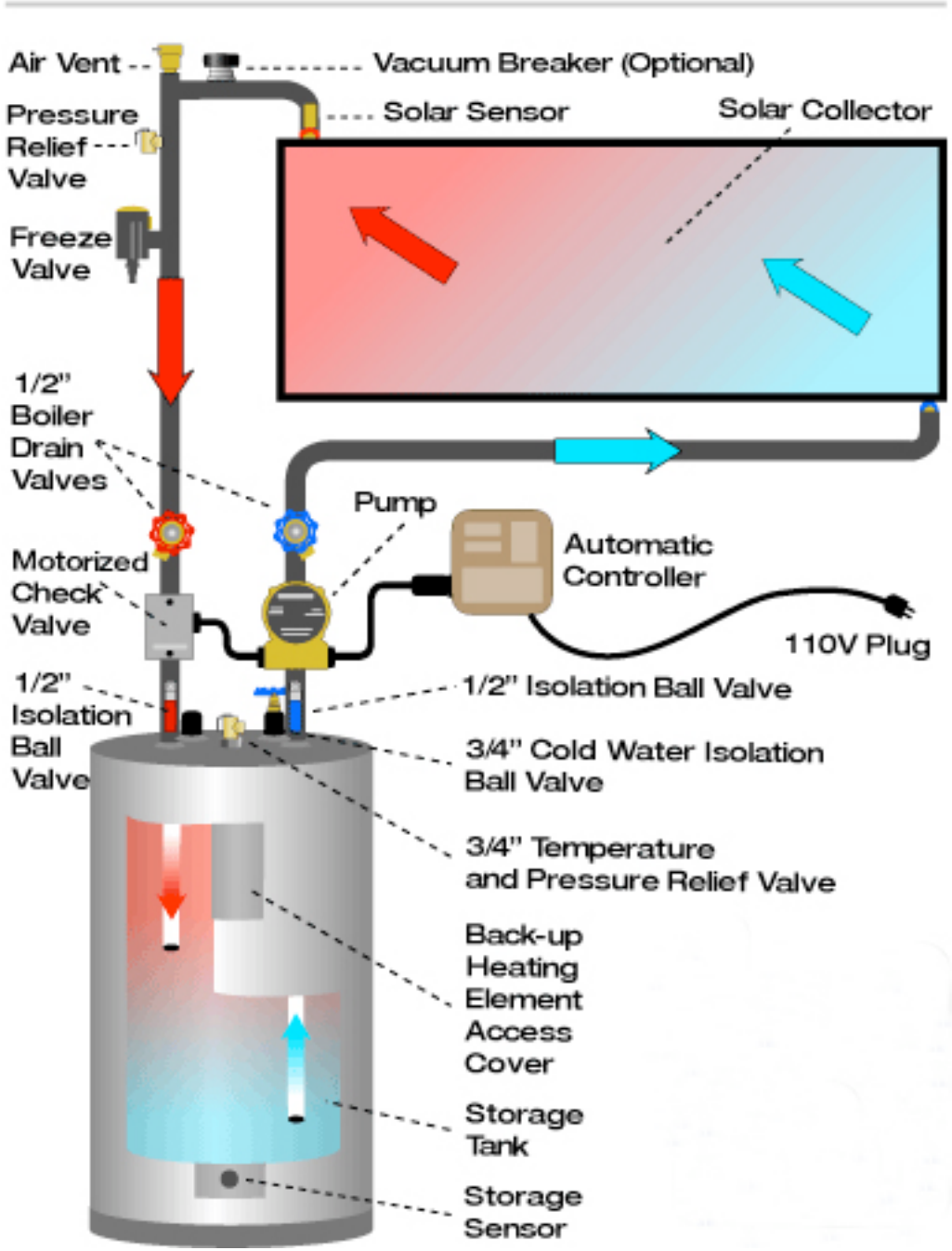
Keep in mind that homes last for 50 to 100 years (or more). Older, less energy efficient homes are going to be with us for a long time.

Consider: We probably use far more passive solar for home heating than is acknowledged. We just don't count it.

Active solar

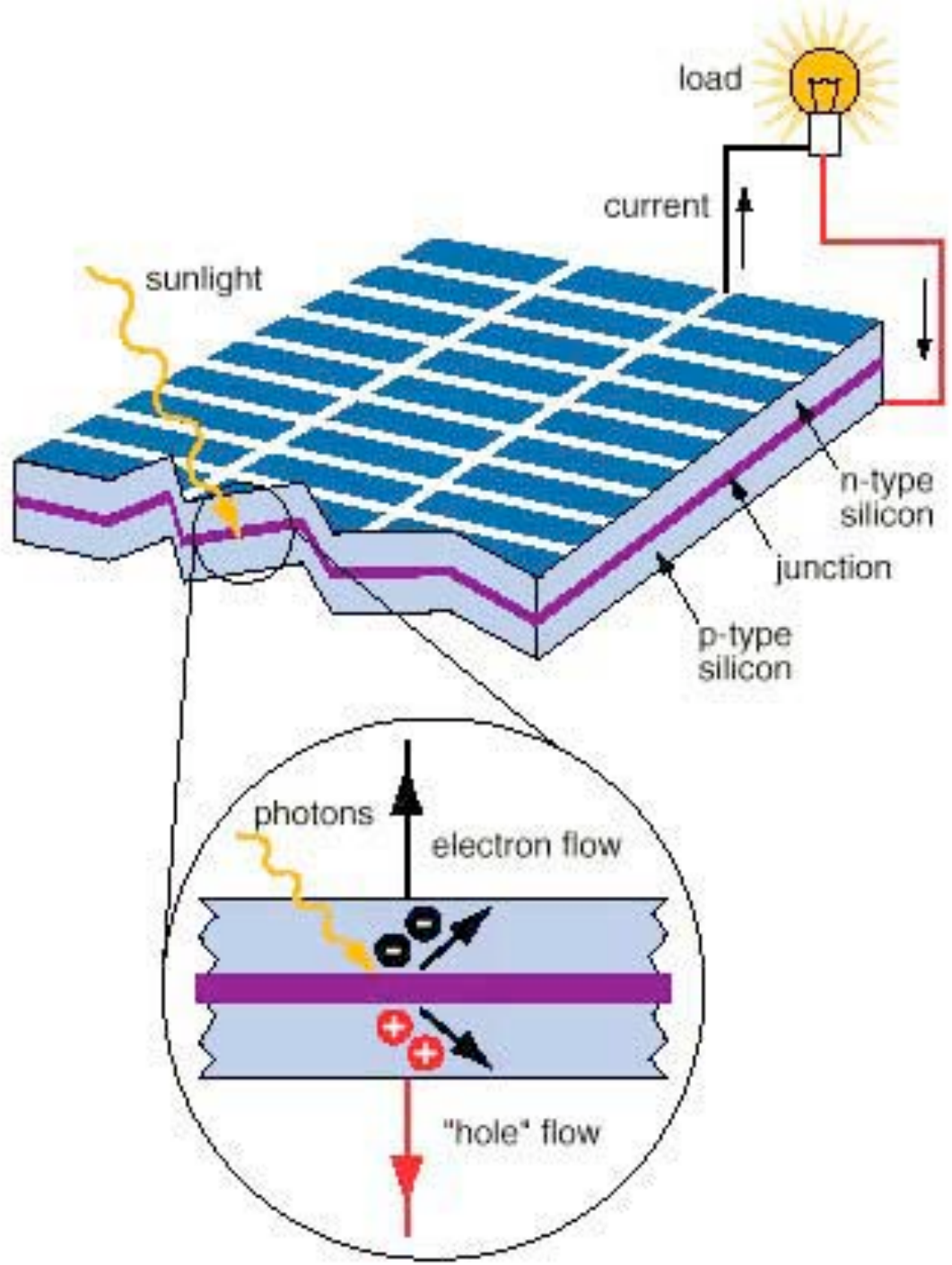
Hot water

100 gallons of water a day can be heated with a typical collector of 5 ft x 20ft



Solar hot water

Active solar: photovoltaics



These are devices that convert the sun's energy directly to electricity

Photovoltaics

Sandwiches of silicon, “doped” with an impurity to help electrons flow (electricity)

n-type doped with arsenic, antimony or phosphorous, these add an extra electron

p-type doped with boron, aluminum or iridium, these want to take up an electron

Photovoltaics

Sunlight provides the energy to make the current flow from the n-type side to the p-type side

Each sandwich produces only a small amount of electricity, about 0.5 volts. Group 40 or 50 sandwiches to make a solar cell of 20 to 25 volts

Types of Photovoltaics

Crystalline silicon: expensive to make as silicon must be very pure, but these are most efficient, about 10 to 15%. Maximum efficiency is about 25%.

Amorphous silicon: newer technology than crystalline silicone, lower efficiency, about 5%, but can be improved by stacking layers to get about 10% efficiency. Very durable. Can be made into roof shingles, for example.

Flexible, amorphous PVs

Rigid, crystalline PVs

Solar shingles

PVs don’t have to look bad!

Cost of solar electricity

Costs of PV electricity:
Commercial system:
Sunny day: 20 cents/KWhr, 50 cents on a cloudy day

Home systems:
Sunny day: 35 cents/KWhr, 80 cents on a cloudy day

Compare this with electricity from coal:

Peak cost: $0.15/kilowatt-hour

Off-peak cost: $0.10/kilowatt-hour or less

Solar and subsidies

Photovoltaics will not be able to compete given this cost differential without help (i.e. subsidies)

Subsidies are common in energy industry. President Carter gave tax breaks for passive and active solar use in the 1980's in response to the OPEC oil "shocks" at that time. Solar hot water added to White House…
Cost of solar cells drops by 100%

President Reagan takes office. Removes the solar hot water heaters…
Cost of solar cells does what??

How to improve cost competitiveness of solar

1. Concentrators: these are mirrors that concentrate the sun's energy to improve efficiency

How to improve…

2. Hybrid solar systems:
combine solar with other forms of energy production to make overall reliability higher and cost cheaper. For example, solar-wind:

How to…

3. Take cost of pollution into account. Cost of coal based electricity is cheaper in part because pollution is not factored into cost. Pollution from solar would add much less (some pollution in manufacturing).

CO_2 tax or carbon trading

Bottom line for solar

Solar is best used at home and possibly industry. Without electric cars, it cannot work for transportation needs.

Solar cannot meet all demands for domestic and industrial energy. Reliability is an issue in winter and in cloudy areas.

If we build new homes without considering solar, we are making a mistake that will last for decades to centuries.

Solar in our future: *optimistic estimate would be that solar can supply 30% of domestic energy needs within a decade and a lesser fraction of industrial energy needs… but it could be more…*