Solar Energy Teaching Unit

Intro

https://www.youtube.com/watch?v=R62KjnKTtfc

0-4.08 mins explains that the sun emits rays of energy in the form of photons and we can convert into useable energy in four ways

- Passive solar
- Concentrated solar
- Solar thermal
- Photovoltaic solar

4.08-7.23mins gives an overview of how a solar cell is made, and how solar systems are fed either into the electrical grid or straight to users.

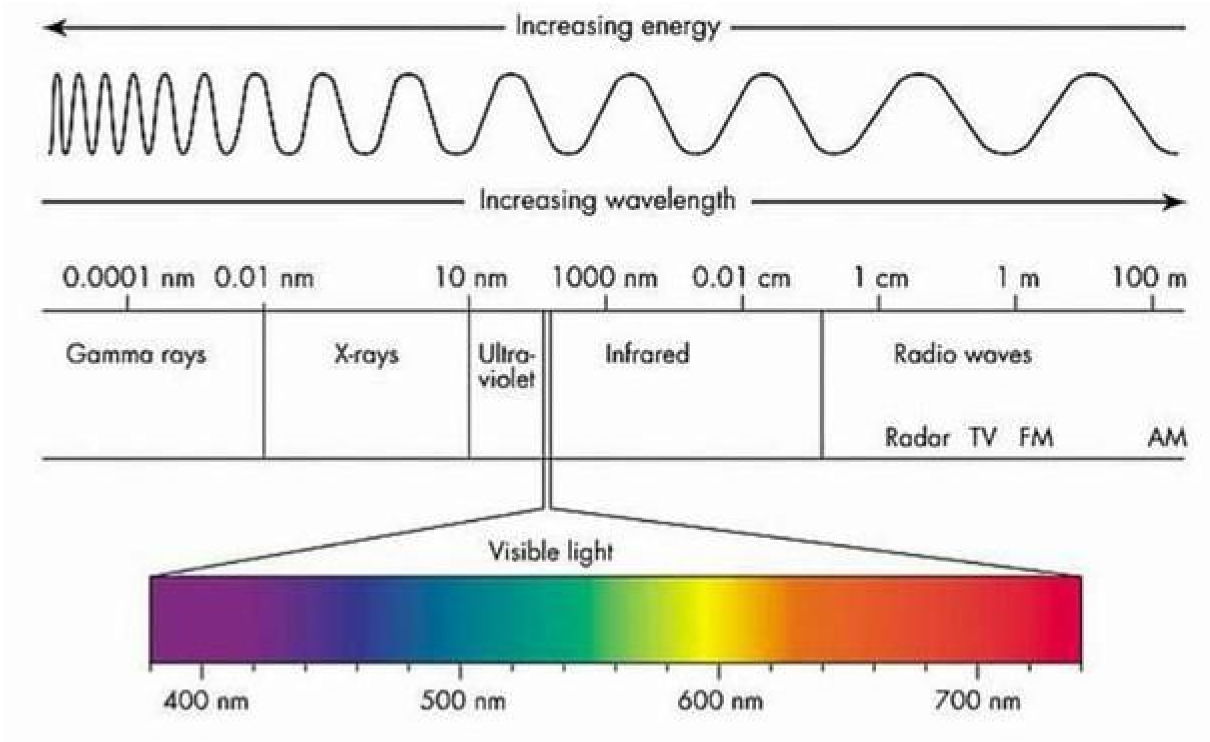
Sunlight[1]

Sunlight is the solar radiation that is visible at Earth's surface. The amount of sunlight received depends on cloud cover of the region receiving it, but varies between about 4,000 (in Sahara) and 2,000 (in stormy parts of Ireland) hours per year.

Sunlight is broken into three main components:

- visible light (light wavelengths of 400 (violet) and 700 (red) nanometres) constitutes about half of the radiation at Earth's surface
- ultraviolet light (wavelengths between 10 and 400 nanometres) is a very small proportion but important as it provides us with Vitamin D
- infrared light (wavelengths between 700 and 2500) is about half the radiation and produces most of the heat we feel at the Earth's surface.

[1] sunlight | Definition, Wavelengths, & Facts



2

As the solar radiation travels through the Earth's atmosphere some of it is absorbed or weakened by constituents of the atmosphere as well as scattered by air molecules and dust particles. Short wavelengths (like blue) scatter more easily and this is why the sky seems blue most of the time. The ozone layer filters out most of the radiation below 300 nanometers - or our UV light (less so in New Zealand and Australia because there is less ozone), and water vapour and carbon dioxide filter out long wavelengths greater than 1000 nanometers (our infrared light)

Too much light can cause damage such as fading in colours of dyed and natural materials, and UV light which has high energy is particularly damaging, including to our skin (it is the leading part of light that causes sunburn). Light damage is a function of light intensity (measured in lux - lumens per square meter) times length of exposure. So if measuring a light that is set at low levels but on 24 hours a day will cause the same amount of damage as higher light levels over a shorter period of time. IE: 50 lux X 24 hours = 1200….. Whereas 200 lux X 6 hours = 1200. This is a similar idea why in winter when the UV levels are lower we can spend longer outside without getting sunburnt, and in summer when UV levels are high we can't spend much time outside without getting sunburnt.[2]

We can reduce our light levels using a variety of methods such as:

- Window shades, films and filters
- Decreasing the number of light fixtures
- Decreasing the wattage of bulbs
- Using light dimmers, viewer activated switches or motion sensors
- Moving/putting things in the dark when not needed
- Shade, clothes and sunscreen to protect our skin when outside

[2] Light, Ultraviolet, and Infrared | AMNH

This is important especially for places like museums where they want their artifacts kept in good condition, but also why people tend to close curtains in beach houses when they aren't there for long periods of time.

Sunscreen experiments (activity option)

- Using a piece of coloured cheap construction paper. Fold in three, and open up. On one third put a solid object that will block the sun, on one third wipe some sunscreen on, leave the last third with nothing. Put in the sun for a few hours. The coloured paper will fade in the sunlight, sunscreen will withhold some colour, remove the object and paper should be the original colour underneath.
- Tonic water (with quinine) glows when UV light shines through it due to the quinine in the tonic water absorbing the UV light and then emitting it as visible blue light. Make the room dark and then light with UV lamps. Have glasses of tonic water and use different items between the UV light and the glass of tonic to see how much UV it blocks. Try
    - Glass (should remove most UV from light)
    - Clothing
    - Sunscreen

  Read more about this experiment at [Detecting Ultraviolet Light Using Tonic Water | UCAR Center for Science Education]

Passive Solar

Passive Solar is excluding or allowing sun radiation to enter a space in order to heat it up or keep it cool, without using any active measures (like heaters or fans). It is most commonly seen in housing designs as a way to heat and cool the house whilst lowering cost and need for human-made energy inputs. This was discussed in the housing unit also.

"The simplest method of passive solar heating is sunlight shining through windows. Since we know that the sun rises higher in the sky during the summer than in the winter, engineers and architects design buildings that allow sunlight through the windows during the winter months when the building needs heating, but block the sunlight during the summer to help keep the building cool."[3]

This simple method can be improved on by adding thermal mass (materials that absorb heat and then release slowly like concrete) and insulation (to stop heat escaping).

[3] Passive Solar Design - Lesson

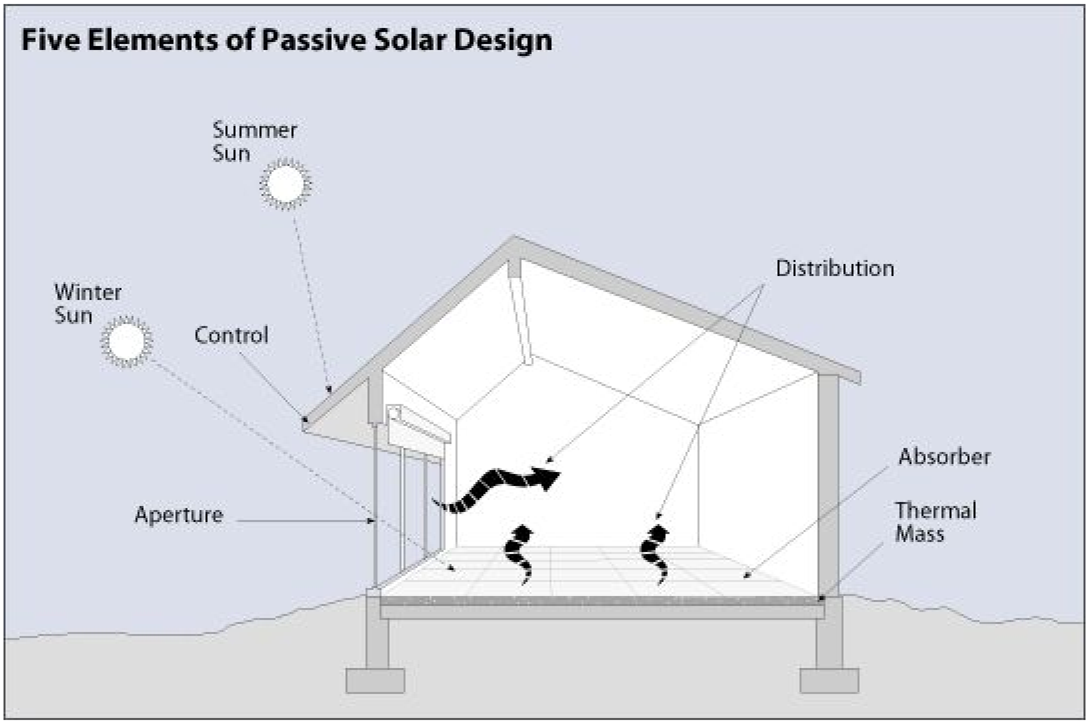


Figure 1. Working together, the five elements of passive solar design constitute a complete and successful passive solar home design: aperture/collector (north-facing windows - due to NZ being in Southern Hemisphere), absorber (hard and dark surface of wall or floor material), thermal mass (actual material that retains and stores heat), distribution (circulation of heat through natural conduction, convection and radiation) and control (roof overhangs, blinds, awnings, shade trees). Notice the differing angles of the sun between winter and summer.[4]

We can use 'passive solar' to heat things up a lot, by using them as a thermal collector. Solar ovens are a good example of this (activity option)

- Use cardboard boxes, painted black (to absorb more radiation) with tin foil on the underside of the lid and insulation if possible to construct a box solar oven. Measure the temperature over an hour in the sun, and try cooking in them (eg. Smores)
- More instructions here if needed [8 - Whats Cooking.xps]

Concentrated Solar[5]

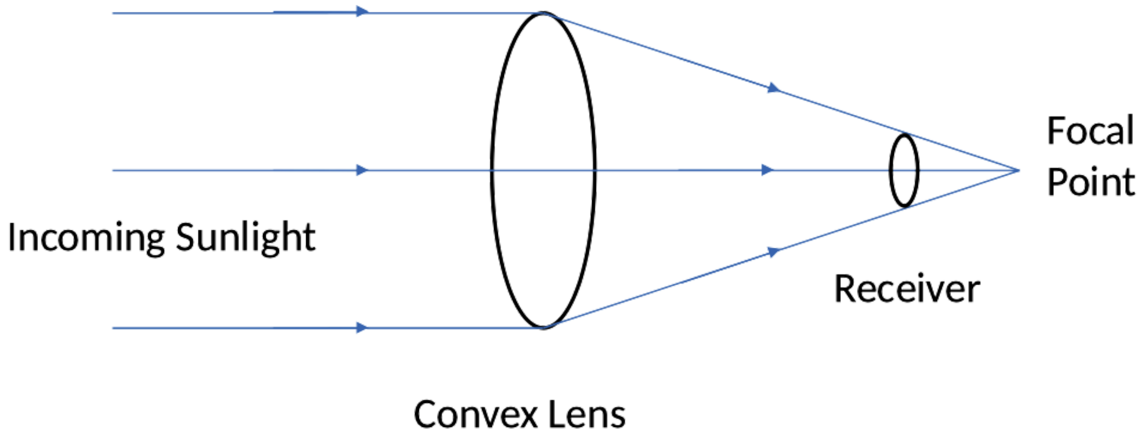
Concentrating solar means we can increase the efficiency of the system and/or build systems with less photovoltaic components. There are two methods to concentrate sunlight and they use two types of optical systems:

- Lenses – light is directed through a transparent material – glass or plastic
- Mirrors – a number of mirrors reflect the light onto a receiver

Using a Lens:

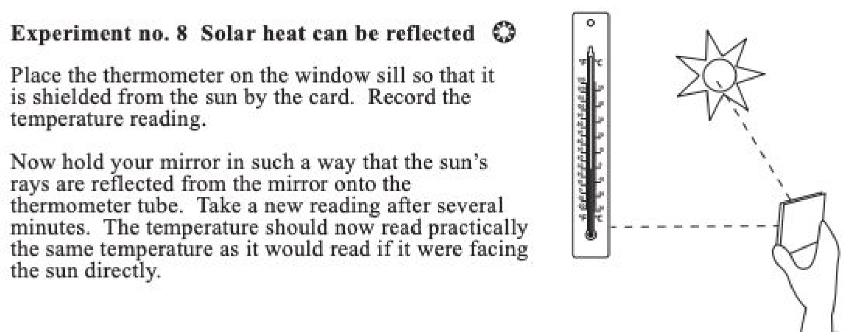
The sunlight is focused to a point and the receiver is positioned in front of the focal point.

[4] Passive Solar Design - Lesson
[5] Solar Energy.pptx



Using Mirrors:

Solar radiation can be reflected. This is most easily shown with a simple experiment (activity option)



Experiment no. 8 Solar heat can be reflected

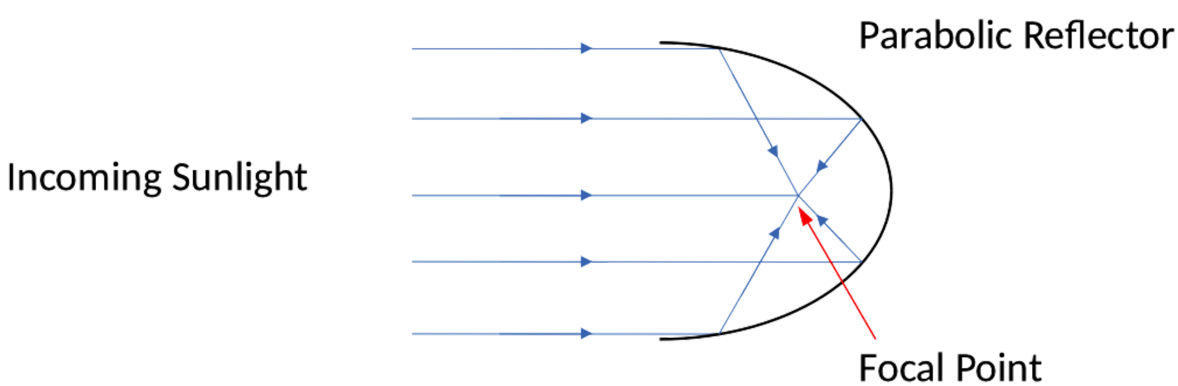
Place the thermometer on the window sill so that it is shielded from the sun by the card. Record the temperature reading.

Now hold your mirror in such a way that the sun's rays are reflected from the mirror onto the thermometer tube. Take a new reading after several minutes. The temperature should now read practically the same temperature as it would read if it were facing the sun directly.

[6]

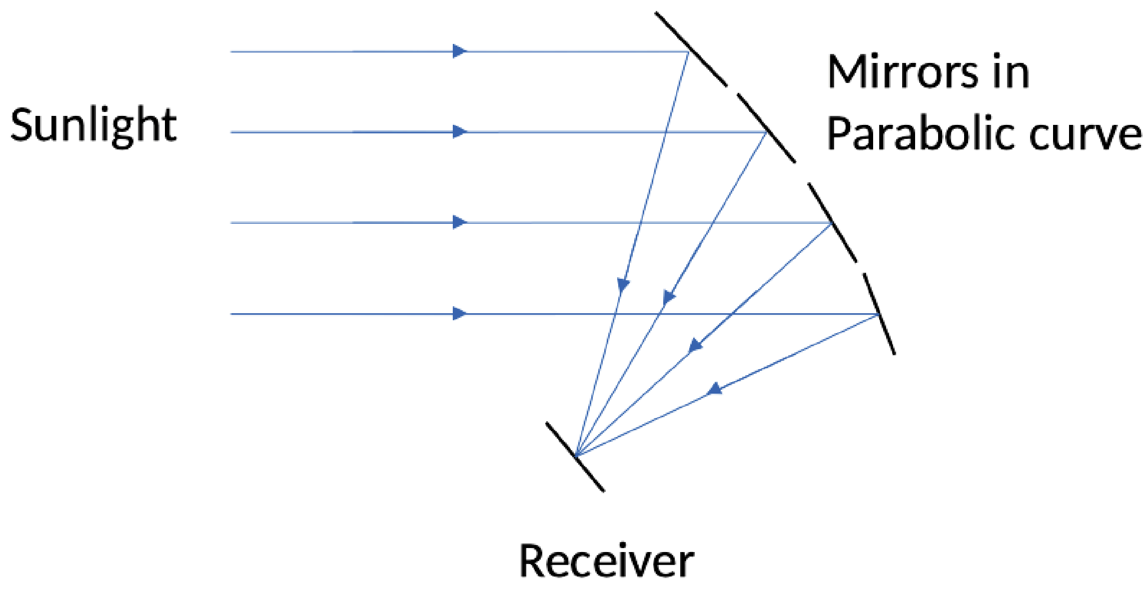
This means that we can direct more light or heat or energy onto a solar collector. Our solar oven also showed this, with the tin foil reflecting the light into the main black box of the oven. In more commercial set-ups mirrors are often used in a parabolic shape.

If the mirror is shaped like a parabola, it works like this:

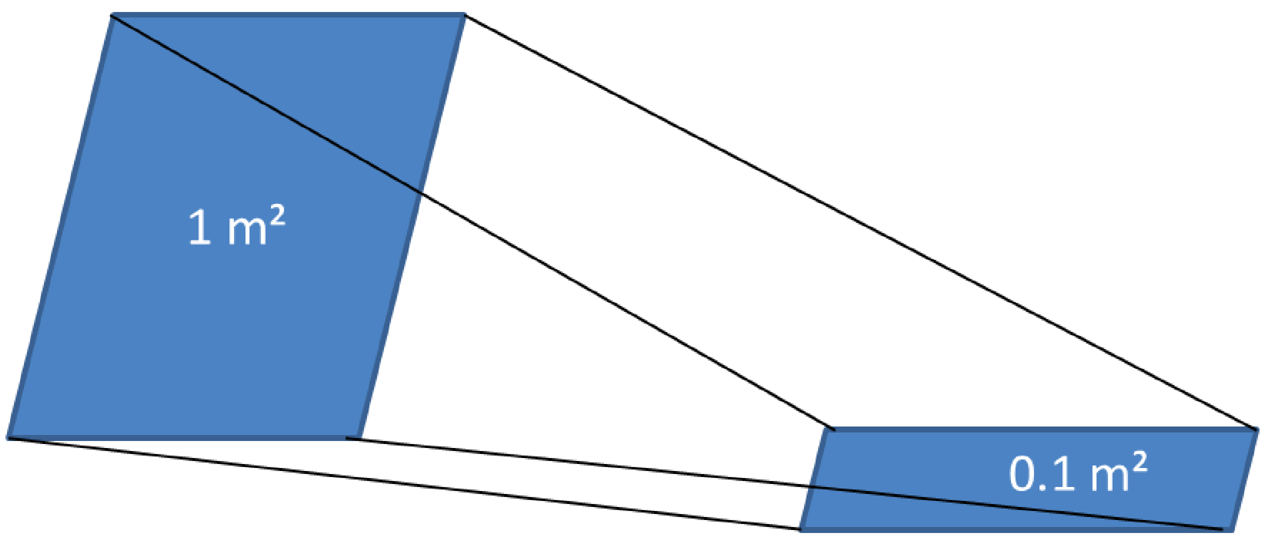


Flat mirrors can also be arranged in a parabolic shape - this is called multi-faceted:

[6] https://www.elenco.com/wp-content/uploads/2017/10/edu3050-3.pdf



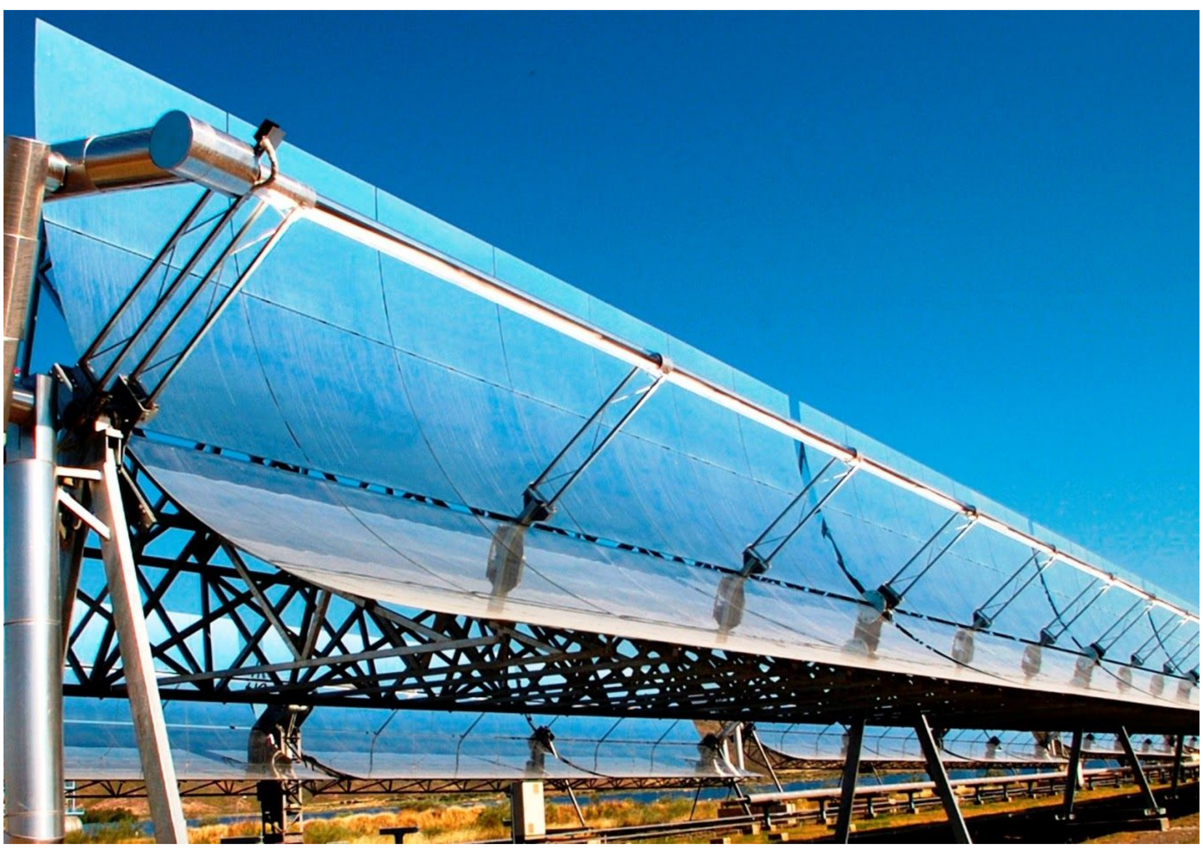
Concentrated sunlight:



If the area of the lens is 100 cm² and the area of the receiver is 10 cm², then the concentration would be 100 divided by 10 which equals 10, or 10 suns.

This is a concentration of 10 suns. You still get only 1 kW. Concentration doesn't increase the power, but increases the intensity of that power. The same amount of power but in a smaller area. The increase in light intensity linearly affects the short circuit current produced.

Some commercial concentration based systems:



Concentrated solar can be used both for electricity and thermal set-ups.

Solar Thermal[7,8,9]

Heating water is the second biggest energy use in a residential home after a (fossil fuel powered) car. By placing solar collectors in a sunny spot (often the roof of a house or building) water can be heated by solar energy instead of needing electricity, wood burners or gas boilers.

Solar thermal systems for household hot water consist of two main parts – the thermal collector and a storage tank. The storage tank which looks similar to a traditional hot water heater, is well insulated to keep the water hot until it is used, these can store hot water for up to three days without sun. The thermal collector, which usually sits on the roof, is one of two types

- flat plate collectors
    - These have copper pipes running through a glass covered collector, often connecting to a water storage tank on the roof. The sun heats the copper pipes and the resulting hot water is **thermosiphoned** out of the storage tank.
- evacuated tubes
    - Consist of two glass tubes fused at the top and bottom. The space between the two tubes is evacuated to form a vacuum. A copper pipe runs through the centre of the tube. That then connects to a circulation pump that pumps water to a storage tank below.
    - These tend to be better as they still work without direct sunlight.

Shortwave, higher-frequency radiation from the sun travels through the glazing of the collector and is absorbed by the interior surfaces of the collector. The absorbed portion re-radiates lower frequency, long wave thermal radiation which becomes trapped by the glazing and insulation, thus increasing the interior temperatures within the collector, similar to the greenhouse effect. The heat travels through the copper pipes by **conduction** to the water flowing within them. On sunny days, the water that travels through the pipes reaches boiling temperature before leaving the collector. When the hot water circulates to the storage tank it increases the temperature of the water remaining in the tank by **convection**.

Thermosiphoning works as follows: as the sun shines on the collector, the water inside is heated. It expands slightly and becomes lighter than the cold water in the tank. Gravity then

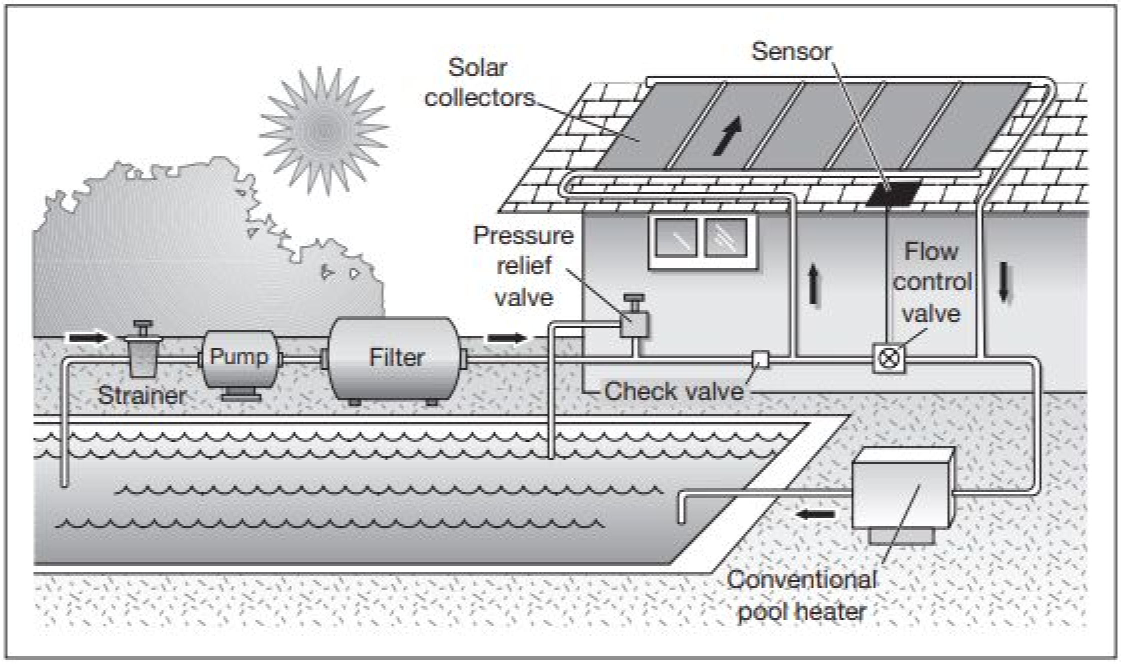
[7] Solar Matters III Teacher Page

[8] How a solar hot water system works

[9] https://www.infinitepower.org/pdf/No11%2096-825B.pdf

pulls the heavier, cold water down from the tank and into the collector inlet. The cold water pushes the heated water through the collector outlet and into the top of the tank. This continuous heating and flowing action provides a tank full of hot water.

In a school setting one option for solar thermal thermal panels could be to heat water for a school pool. A system for this could look something like this:



SOLAR WATER HEATER SYSTEM *Solar collectors become part of the existing system.*

Technology like flowmeters and temperature probes can be added to determine the energy gain by the thermal solar installation. This allows monitoring of how the system is working by calculating the energy gain and can help to optimise its efficiency.

Photovoltaic Solar

"Home and commercial photovoltaic systems are comprised of **photovoltaic cells**, devices that convert light energy directly into electricity, and **inverters** that convert the direct current from the photovoltaic into alternating current used in homes. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from "photo," meaning light, and "voltaic," which refers to producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight." Photovoltaics are often referred to as PV"[10]

Photovoltaic Cells

Here are two videos that explain how cells and panels are made

[10] https://www.infinitepower.org/pdf/No18%2096-815B.pdf

- This one shows the manufacturing in factories of the panels and explains how they are made - https://www.youtube.com/watch?v=qZgWC-Cxd44
- This video until 6:07 explains how the doping (injecting of extra minerals) of the panels (p and n) causes the electron flow that causes the current: https://www.youtube.com/watch?v=L_q6LRgKpTw

"Photovoltaic cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures. It is doped (coated/mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power whatever load is attached, in this case a motor. This flow of electrons is called electricity."[11]

Small solar kits (activity option)

You can find small solar kits such as https://www.creativeclassrooms.co.nz/solar-delux-educational-kit.html which can be useful to demonstrate solar power. Get the students to use them to power the various items (fan, light, music). Measure the electricity produced using a voltmeter and compare in full sun vs shade. There are extra instructions that come with them or here https://www.elenco.com/wp-content/uploads/2017/10/SK40-2.pdf

Local Solar Panels (activity option)

Research somewhere near to you that has solar panels.

Find out what their kWp is. kWp means Kilowatt Peak and is the peak electric power that can be produced by the system with optimal sunlight. See if they have a live power display on a website where you can see the power changing with weather and time of day/year.

Electrical grid (optional)

Most solar panel systems feed back into the electrical grid either always (most country or commercial sized solar farms), or when the building can't store or use the amount of energy generated (like the school panels). This is a great video discussing the electrical grid and how electricity goes from the source to a house https://www.youtube.com/watch?v=20Vb6hlLQSg

[11] http://www.fsec.ucf.edu/en/education/k-12/curricula/use/documents/USE_12_SolarPowerForSunTown.pdf