Solar energy and power

Solar Basics

- Energy from the Sun
- The sun has produced energy for billions of years. Solar energy is the sun’s rays (solar radiation) that reach the Earth. This energy can be converted into other forms of energy, such as heat and electricity.
- Radiant energy from the sun has powered life on Earth for many millions of years.
- In the 1830s, the British astronomer John Herschel famously used a solar thermal collector box (a device that absorbs sunlight to collect heat) to cook food during an expedition to Africa. Today, people use the sun's energy for lots of things.

Solar Energy Can Be Used for Heat and Electricity

- When converted to **thermal (or heat) energy**, solar energy can be used to:
- Heat water — for use in homes, buildings, or swimming pools
- Heat spaces — inside homes, greenhouses, and other buildings
- Heat fluids — to high temperatures to operate a turbine to generate electricity

Solar energy can be converted to electricity in two ways:

- **Photovoltaic (PV devices) or "solar cells"**change sunlight directly into electricity. Individual PV cells are grouped into panels and arrays of panels that can be used in a wide range of applications ranging from single small cells that charge calculator and watch batteries, to systems that power single homes, to large power plants covering many acres.
- **Solar Thermal/Electric Power Plants** generate electricity by concentrating solar energy to heat a fluid and produce steam that is used to power a generator. In 2009, there were 13 solar thermal-power generating units operating in the United States, 11 in California, 1 in Arizona, and 1 in Nevada.

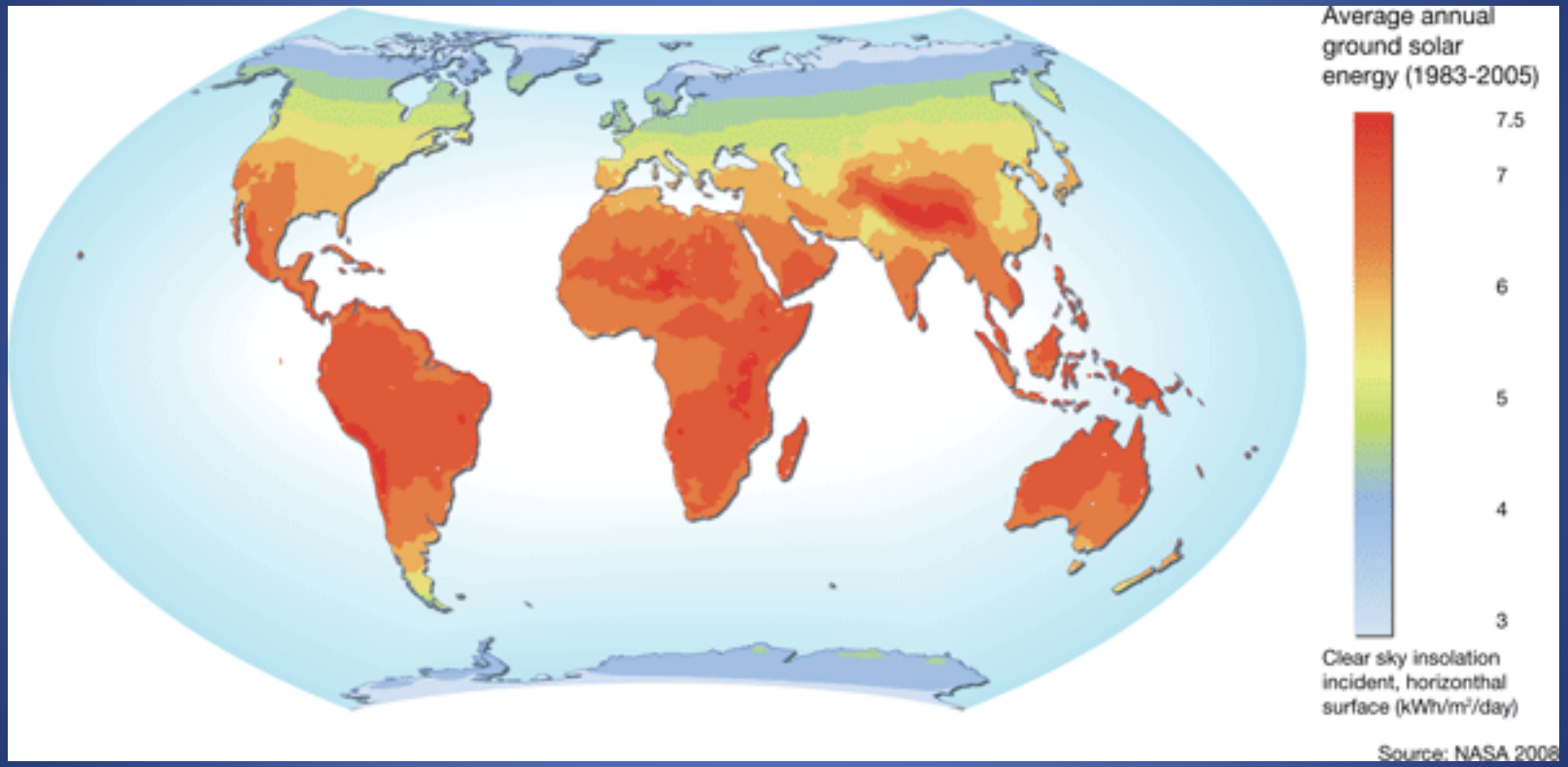
The main benefits of solar energy are:

- Solar energy systems do not produce air pollutants or carbon-dioxide
- When located on buildings, they have minimal impact on the environment

Two limitations of solar energy are:

- The amount of sunlight that arrives at the Earth's surface is not constant. It varies depending on location, time of day, time of year, and weather conditions.
- Because the sun doesn't deliver that much energy to any one place at any one time, a large surface area is required to collect the energy at a useful rate.

Where Solar is Found



Solar Energy Is Everywhere the Sun Shines

- Solar energy is by far the Earth's most available energy source. Solar power is capable of providing many times the total current energy demand. But it is an intermittent energy source, meaning that it is not available at all times. However, it can be supplemented by thermal energy storage or another energy source, such as natural gas or hydropower.

California Has the World's Biggest Solar Thermal Power Plants

- Nine solar power plants, in three locations in California's Mojave Desert, comprise the Solar Energy Generating Systems (SEGS). SEGS VIII and IX (each 80 megawatts), located in Harper Lake, are, individually and collectively, the largest solar thermal power generating plants in the world. The SEGS plants are concentrating solar thermal plants.
- Concentrating solar power technologies use mirrors to reflect and concentrate sunlight onto receivers that collect the solar energy and convert it to heat. This thermal energy can then be used to produce electricity via a steam turbine or heat engine driving a generator.

Photovoltaic Systems Provide Small to Large Amounts of Power

- Another solar generating technology uses photovoltaic cells (PV) to convert sunlight directly into electricity. PV cells are made of semiconductors, such as crystalline silicon or various thin-film materials. Photovoltaics can provide tiny amounts of power for watches, large amounts for the electric grid, and everything in between.

Thousands of houses and buildings around the world have PV systems on their roofs. Many multi-megawatt (MW) PV power plants have also been built. The largest, at the end of 2010, was a 97 MW facility in Ontario, Canada, and the largest PV power plant in the U.S. was a 48 MW facility in Nevada. A 210 MW plant is planned for California.

Solar Power Can Be Used Almost Anywhere at a Variety of Scales

- Low-temperature solar collectors also absorb the sun's heat energy, but instead of making electricity, use the heat directly for hot water or space heating in homes, offices, and other buildings.
- Even larger plants than exist today are proposed for construction in the coming years. Covering 4% of the world's desert area with photovoltaics could supply the equivalent of all of the world's electricity. The Gobi Desert alone could supply almost all of the world's total electricity demand.

Solar Thermal Power Plants

Solar Thermal Power Uses Solar Energy Instead of Combustion

- Solar thermal power plants use the sun's rays to heat a fluid to very high temperatures. The fluid is then circulated through pipes so it can transfer its heat to water to produce steam. The steam, in turn, is converted into mechanical energy in a turbine and into electricity by a conventional generator coupled to the turbine.

So solar thermal power generation works essentially the same as generation from fossil fuels except that instead of using steam produced from the combustion of fossil fuels, the steam is produced by the heat collected from sunlight. Solar thermal technologies use concentrator systems to achieve the high temperatures needed to heat the fluid.

Types of Solar Thermal Power Plants

The three main types of solar thermal power systems are:

- Parabolic trough (the most common type of plant).
- Solar dish
- Solar power tower

Parabolic Troughs

- Parabolic troughs are used in the largest solar power facility in the world located in the Mojave Desert at Kramer Junction, California.
  A parabolic trough collector has a long parabolic-shaped reflector that focuses the sun's rays on a receiver pipe located at the focus of the parabola. The collector tilts with the sun as the sun moves from east to west during the day to ensure that the sun is continuously focused on the receiver.

- Because of its parabolic shape, a trough can focus the sun at 30 to 100 times its normal intensity (concentration ratio) on the receiver pipe located along the focal line of the trough, achieving operating temperatures over 750°F.
- The "solar field" has many parallel rows of solar parabolic trough collectors aligned on a north-south horizontal axis. A working (heat transfer) fluid is heated as it circulates through the receiver pipes and returns to a series of "heat exchangers" at a central location. Here, the fluid circulates through pipes so it can transfer its heat to water to generate high-pressure, superheated steam. The steam is then fed to a conventional steam turbine and generator to produce electricity. When the hot fluid passes through the heat exchangers, it cools down, and is then recirculated through the solar field to heat up again.
- The plant is usually designed to operate at full power using solar energy alone, given sufficient solar energy. However, all parabolic trough power plants can use fossil fuel combustion to supplement the solar output during periods of low solar energy, such as on cloudy days.
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Solar Dish

- A solar dish/engine system uses concentrating solar collectors that track the sun, so they always point straight at the sun and concentrate the solar energy at the focal point of the dish. A solar dish's concentration ratio is much higher than a solar trough's, typically over 2,000, with a working fluid temperature over 1380°F. The power-generating equipment used with a solar dish can be mounted at the focal point of the dish, making it well suited for remote operations or, as with the solar trough, the energy may be collected from a number of installations and converted to electricity at a central point.
- The engine in a solar dish/engine system converts heat to mechanical power by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding the fluid through a turbine or with a piston to produce work. The engine is coupled to an electric generator to convert the mechanical power to electric power.

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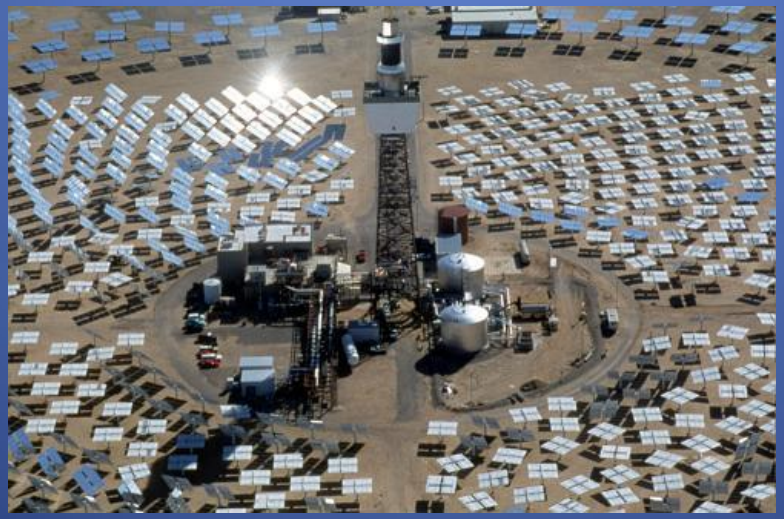
Solar Power Tower

- A solar power tower or central receiver generates electricity from sunlight by focusing concentrated solar energy on a tower-mounted heat exchanger (receiver). This system uses hundreds to thousands of flat sun-tracking mirrors called heliostats to reflect and concentrate the sun's energy onto a central receiver tower. The energy can be concentrated as much as 1,500 times that of the energy coming in from the sun.



Energy losses from thermal-energy transport are minimized as solar energy is being directly transferred by reflection from the heliostats to a single receiver, rather than being moved through a transfer medium to one central location, as with parabolic troughs

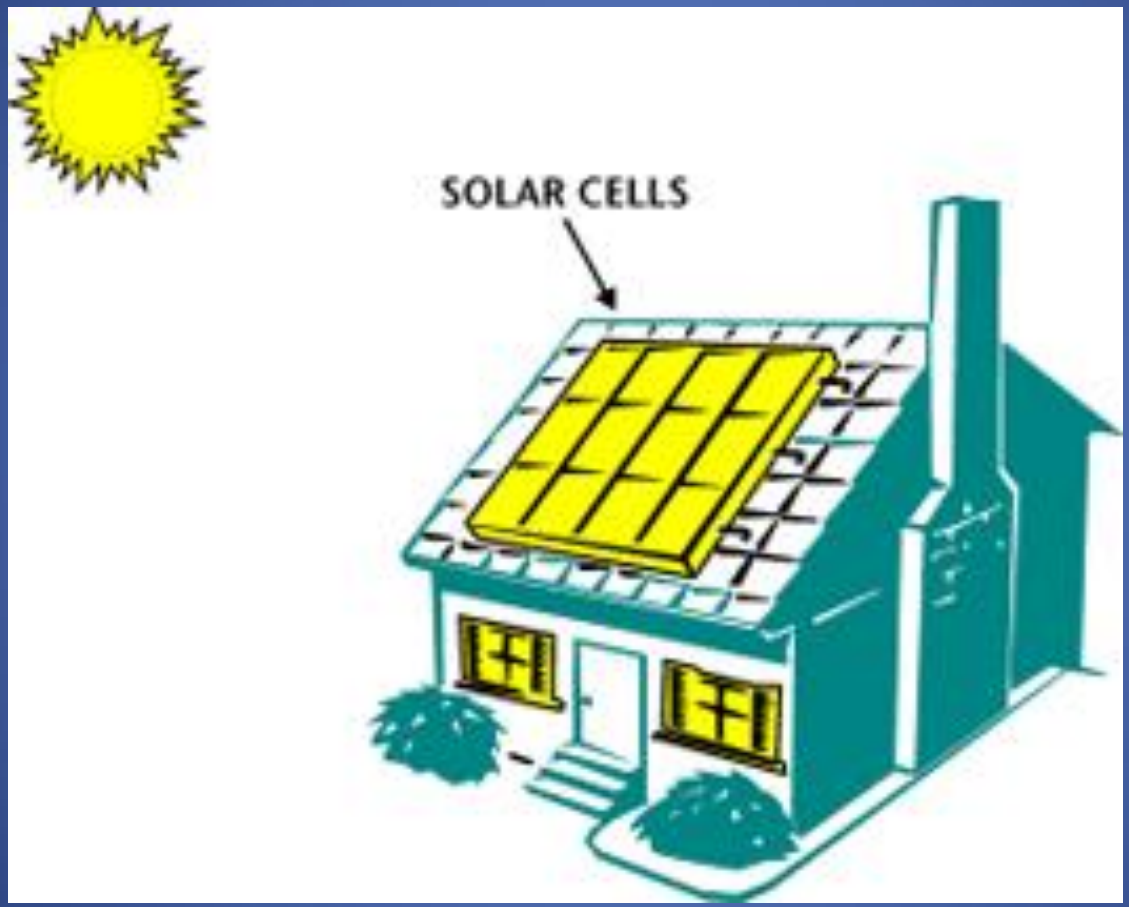
- Power towers must be large to be economical. This is a promising technology for large-scale grid-connected power plants. Though power towers are in the early stages of development compared with parabolic trough technology, a number of test facilities have been constructed around the world.
- The U.S. Department of Energy, along with a number of electric utilities, built and operated a demonstration solar power tower near Barstow, California, during the 1980s and 1990s. Learn more about the history of solar power in the Solar Timeline.

Solar Thermal Collectors

Heating With the Sun's Energy

Solar thermal (heat) energy is often used for heating water used in homes and swimming pools and for heating the insides of buildings ("space heating"). Solar space heating systems can be classified as **passive** or**active**.

- **Passive** space heating is what happens to your car on a hot summer day. The sun's rays heat up the inside of your car. In buildings, the air is circulated past a solar heat surface and through the building by convection (meaning that less dense warm air tends to rise while denser cool air moves downward). No mechanical equipment is needed for passive solar heating.
- **Active** heating systems require a **collector** to absorb and collect solar radiation. Fans or pumps are used to circulate the heated air or heat absorbing fluid. Active systems often include some type of energy storage system.



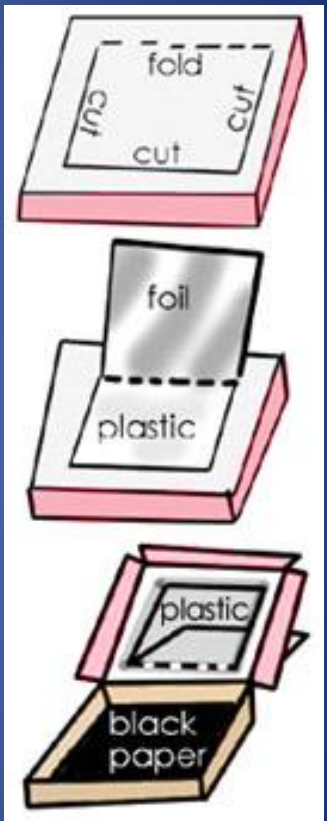
Source: National Energy Education Development Project (Public Domain)

Solar Collectors Are Either Nonconcentrating or Concentrating

- **Nonconcentrating collectors** — The collector area (the area that intercepts the solar radiation) is the same as the absorber area (the area absorbing the radiation). **Flat-plate collectors** are the most common type of nonconcentrating collector and are used when temperatures below about 200°F are sufficient. They are often used for heating buildings.
- There are many flat-plate collector designs but generally all consist of:
- A flat-plate absorber that intercepts and absorbs the solar energy
- A transparent cover(s) that allows solar energy to pass through but reduces heat loss from the absorber
- A heat-transport fluid (air or water) flowing through tubes to remove heat from the absorber, and a heat insulating backing
- **Concentrating collectors** — The area intercepting the solar radiation is greater, sometimes hundreds of times greater, than the absorber area.

Solar Projects

Building a Solar Cooker



- **Gather your materials:**
- A sunny day
  1 empty pizza box
  Black construction paper
  Aluminum foil
  Sheet of clear plastic laminate
  Non-toxic glue
  Tape and scissors
  Ruler and magic marker
  One wood dowel rod
- Draw and cut a window in the top of the pizza box leaving one side for folding.
- Cut two pieces of foil to fit on the inside of the lid and to line the inside of the box. Smooth out wrinkles and glue in place.
- Tape a piece of plastic to the underside of the opening you cut. Make sure the plastic is tightly sealed around all the edges. This makes your oven window.
- Glue corners of a piece of black construction paper to the bottom of the inside of the box on top of the foil.

Your Solar Oven is now ready!

- Just place your food to be cooked on the inside the box. Close the box and prop open the window lid using the dowel rod. Position your oven in the sun so that the foil lid reflects the maximum amount of sunlight through the window. Try heating up s'mores, hot dogs, melt some cheese on nachos, or even try baking a cookie!
- Make a chart with different time intervals and use an oven thermometer to test your oven temperature. Write down how long it takes to reach different temperatures and how long each item takes to cook.
- **Use an Empty Pringles Can**
- You can also substitute an empty pringles can for the pizza box and foil. The inside of the pringles can already has an aluminum foil finish inside. Just cut the can to make a door, tape the clear plastic on the inside to make a window and you're ready to cook!

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