Student Fact Sheet
Levels 3-4

A Short History of Photovoltaic (PV) Cells

The photoelectric effect discovered

The first discovery of the photoelectric effect was in 1839 by Edmund Becquerel, a nineteen year old French physicist. He found that certain materials would produce small amounts of electric current when exposed to light.

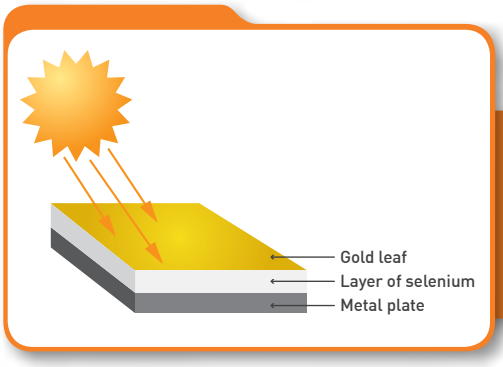
Sunlight + Selenium = Electricity

In the 1860s, an electrician called Willoughby Smith was testing underwater telegraph lines for faults using a material called **selenium**. By chance, he discovered that electricity travelled through selenium very well when it was in light, but it didn't if the selenium was in darkness.

In the late 1870s, two American scientists, William Adams and Richard Day, became interested in this. They soon discovered that the sun's energy creates a flow of electricity in selenium.

The First Photovoltaic Cell

Over the next ten years, scientists worked hard to understand more about selenium. Then in the early 1880s, Charles Fritts invented the first **PV** cell by putting a layer of selenium on a metal plate and coating it with gold leaf. Placed in the sunlight, this cell made even more electricity but not enough to be useful. One or two scientists became very excited about this invention, but most scientists paid no attention to it. Some thought it was just a worthless gimmick. Based on what they knew about black materials absorbing the sun's heat energy, they couldn't see how a cell that wasn't black could use the sun's light to make electricity.



The selenium PV cell produced a small amount of electricity when placed in direct sunlight.

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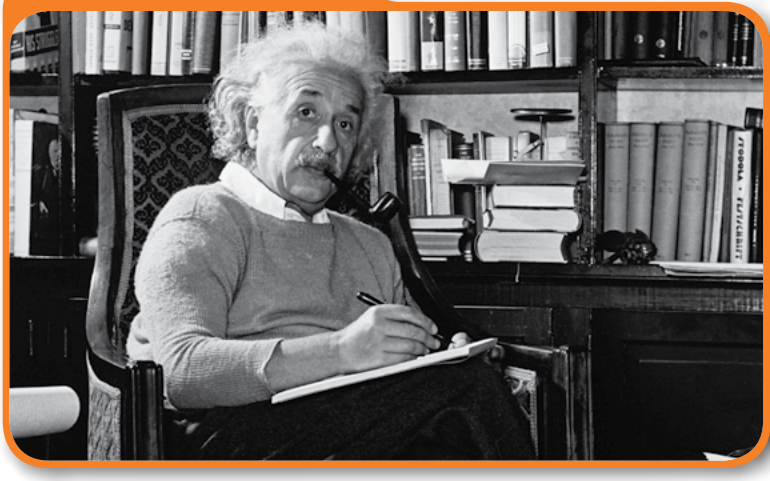
It didn't help that PV technology was competing with other better developed technologies that were generating electricity. Steam-driven electricity generators (or 'dynamos' as they were called at the time) had been around since Michael Faraday invented the first electromagnetic generator in 1831. By the end of the 19th Century, this technology had improved a lot. In 1882, Thomas Edison opened his first electric power station in New York. It used coal to create steam.

To find out more go to:
Pearl Street Station: The Dawn of Commercial Electric Power,
IEEE Virtual Museum
http://www.ieeeghn.org/wiki/index.php/Milestones:Pearl_Street_Station

Albert Einstein Sees the Light

Albert Einstein was one scientist who set his mind to understanding how light could create electricity when it hits a metal. In 1905, Albert Einstein surprised everyone. Einstein explained how light was made of tiny packets of energy that wiggled like waves as they sped along. He called the energy packets "lichtquant" meaning the "light quantum". This concept later came to be called **photons** (1927).

Einstein went on to argue that these particles of energy are much more powerful in invisible light (such as ultraviolet light) than they are in light we can see. In fact they have enough energy to knock loose electrons off some materials like selenium and silicon. It is these **free electrons** that move through wires as electricity.



In 1905, Albert Einstein explained how light was made up of tiny packets of energy, that came to be called photons.

Soon after, other scientists tested these ideas and found that they seemed to be right. These ideas later won Einstein a Nobel Prize. Einstein's ideas also became very important as scientists tried to make PV cells more effective in using sunlight to generate electricity.

Cheap Oil and Gas

From the late 1800s until 1912, gas-powered lighting and heating became more affordable and more widely used. This meant that people developing technologies for heating or lighting began to focus more on improving gas burning technologies rather than spending money on investigating PV technology. By 1875, many European town houses were lit by gas.

In the early 20th century, most cities in the United States and Europe had gas-lit streets using lamps like this one.

By the end of the World War I (1918), oil and gas had replaced coal as the cheapest and most common fuels for engines. Because oil cost so little and because there was plenty of it, people became less interested in solar energy. But some scientists kept trying to find a way to use solar energy to heat water and to create electricity.

Problems with PV Cells

In 1931, Bruno Lange, a German scientist, built a solar cell panel out of selenium. But Lange had the same problem as Fritts. His panel generated such a tiny amount of electricity it wasn't very useful. Another problem was that the selenium cells didn't last long in strong sunlight. For these reasons, some experts thought PV cells would never be a good way to create electricity. It wasn't until the 1940s that people became interested in solar electricity generation again.

Accidental Discovery – Silicon

In the early 1950s, Calvin Fuller and Gerald Pearson, two scientists who worked at the Bell Laboratories in the USA, were trying to improve **silicon transistors** for electrical equipment. By accident they created a PV cell that also generated electricity when it was placed in light. It was made out of two different kinds of silicon that had different metals mixed in.

Bell Laboratories' Silicon Slices

In 1953, another Bell scientist called Daryl Chapin was trying to make selenium cells better at generating electricity. But he wasn't having much success. After Pearson told Chapin about his accidental silicon PV cell, Chapin started to look into it straight away. The Bell scientists were excited to find that silicon PV cells made nearly five times more electricity than selenium cells.

The Bell scientists spent a whole year experimenting with the silicon cells so they could make enough electricity to be useful. Finally, after many disappointments, they succeeded. They did this by mixing tiny amounts of different chemicals into slices of silicon crystals. The PV cells they invented were 50 times more efficient at generating electricity than the selenium cells had been 20 years earlier.

PV Cells in orbit

Solving Satellite Power Problems

Soon after this, US military scientists started to investigate if they could use PV cells to give power to satellites that were in orbit. These scientists thought that because PV cells could make electricity for years they would be better than the batteries that ran out of power after a few weeks.

Too risky to use?

But the people in charge of designing the US satellites did not want to try using PV cells to power the satellites. They thought it was too risky because no one had used PV cells in space before. Some scientists were angry about this and the debate was fierce. This was because many scientists felt that taking risks is an important part of improving technology. Other scientists believed that nuclear power would be a better way of giving satellites power.

Vanguard I

In 1958, the US Navy finally let a few small PV cell-powered radio **transmitters** go into orbit on a satellite called Vanguard I. The PV cells worked very well. They lasted much longer than the satellite's batteries. A few weeks later, Russia's new satellite radio equipment was in orbit. And it was powered by PV cells.

By 1972, approximately 1 000 satellites were running on solar power. This meant more money was spent on improving PV cells. So the cells became lighter, more **durable**, and better at generating electricity.

Vanguard I was the first satellite to orbit the Earth using PV cells.

The Cost of PV Power

But PV cells were still too expensive for use on Earth. In 1971, the price of PV power was 200 times the price of regular electricity in the USA. But a few power companies began to search for a way of making cheaper PV cells. They thought PV cells might be needed in the future if electricity became more costly.

Oil Prices Go Up

Then in 1973, the price of oil doubled, then it doubled again. This was because some countries stopped selling oil. For the next few years oil prices kept rising. In 1980, the price of oil was 25 times more expensive than it had been in 1970. This gave governments and scientists even more reason to try to find ways to improve solar power technology like PV cells.

PV Cells in Remote Places

By the mid-1970s, PV cells were being used for power in remote places where it was too expensive to use electric cables. These were the kind of places where it was difficult or expensive to bring in new batteries or fuel for electricity generators.

Before long PV cells were used to give power to radio, satellite and telephone systems, and railway track warning lights in remote areas. Even school TV systems were powered with PV cells in places like Nigeria. This meant children in remote places could see education programmes on TV.

Photovoltaic systems are sometimes used in remote places where it is too expensive to use electricity cables.

PV Cells at Sea

Photovoltaic cells were also used at sea to give power to buoys, lighthouses and fog horns. Some of these began use as early as 1968. Photovoltaic systems were also useful for offshore oil rigs to provide lighting. The electricity from PV cells also helped to protect machinery and pipes from rust. In 1978, it became illegal to dump old batteries in the sea and this meant PV-powered systems were soon even more popular.

The electricity generated from PV cells helps to power this lighthouse.

Cheaper PV Cells

Over the years PV systems were improved. For many years PV cells were very expensive because they were made by shaving thin slices off pure silicon crystals. These crystals were expensive to make. So other new types of silicon were invented, such as thin ribbons of silicon and sheets of silicon.

In 1976, scientists began make silicon PV cells using silicon made from lots of small crystals joined together, called amorphous silicon. These types of PV cells are not as expensive to make as silicon cut from single crystals, but they create slightly lower amounts of electricity. PV systems soon were used to power water pumps, air conditioners and lights in countries where people lived in remote places, like Saudi Arabia.

Cheaper silicon PV cells are used to create low amounts of electricity.

In 1983, almost 20% of the world's solar cells ended up providing power to communities in French Polynesia. Today in some countries, like Kenya, more people use electricity from PV systems than electricity from the main power grid.

Organisations like The World Bank and many governments, such as the German Government, now provide cheap loans to help people with the cost of buying PV systems.

Better PV Cells

In the 1980s, PV cells were also being made from other materials apart from silicon, such as gallium arsenide, copper sulphide and cadmium sulphide. In the 1990s, PV cells were built into flexible plastic sheets.

In California the highways have over 10 000 PV-powered emergency phone booths. Photovoltaic systems are also used for speed limit signs and warning lights on roads. Scientists even use mini PV-powered radio transmitters to attach to wild animals, so they can learn more about their movements.

In New Zealand a PV array of 220m^2 has been installed on the roof of the Auckland Airport Arrivals Building. This is the longest single PV installation in New Zealand and generates approx 50 MWh / annum.

This road sign is powered with a PV system.

More and more houses have PV systems on their roofs to help power the home.

Since 1996, PV cells have been used to power remote controlled aircraft, such as the Icare and Pathfinder aeroplanes and now Solar Impulse. Photovoltaic cells are also used to recharge electric cars. Many buildings now have walls, windows and roofing covered in PV panels. And, as new technology is developed, PV cells continue to become cheaper, more durable and better at generating electricity.

In recent years new PV technology is now more efficient than ever at generating electricity from sunlight. Some super-thin PV cells are now over 300 times as efficient as the first selenium cells.

Solar Powered Aircraft

The world's first successful manned solar powered aircraft was the 'Solar Challenger'. It's wings were covered with solar cells to generate the electricity needed to power the propeller. The Solar Challenger successfully crossed the English Channel in 1981.

Solar Impulse is the latest, most advanced aircraft to be powered only by the sun. It has huge wings 63m across covered in 10,748 solar cells and light-weight lithium batteries to store energy and allow it to fly through the night. In 2013 it flew across America, and in 2015 plans to fly around the world.

Large-scale PV power stations

During the 1970s and 1980s, many governments started to build big solar power stations to generate electricity using PV systems. These power stations usually covered large areas and they were often called solar farms.

PV power stations usually cover large areas of land and are often called solar farms.

Pros and Cons of Solar Farms

There has always been debate about whether or not PV systems are more suitable on a smaller scale, providing power directly to users from on-site systems. Here are some of the arguments for small on-site PV systems being a better way to use PV technology:

- Each PV cell will still only produce the same amount of electricity. It makes no difference if it is part of a small system or a very large system.
- In comparison with small rooftop PV systems, big PV solar farms are expensive because they need large areas of land (which is expensive in many countries).
- For solar farms, there are additional costs to prepare the land, lay foundations and put up buildings for the extra-large machinery (such as inverters, switches and transformers).
- For solar farms, there is an increased cost of putting up long-distance power lines (the big farms are often located far away from the electricity users).
- Some electricity is lost when it travels long distances over power lines from a solar farm to electricity users.

- Many governments and organisations encourage people to install rooftop PV systems on their homes. Some governments give people money to refund them some of the cost of PV systems they buy. Sometimes people are given cheap loans or special deals.
- Many governments offer feed in tariffs which require electricity companies to buy back electricity (above market rates) that has been generated from renewable sources, such as by homeowners, schools, farms etc.

Because of climate change, many governments want to rely more on renewable energy and so they are spending more money on improving solar power technology. Many people believe that in the future the difference in price between electricity from PV systems and electricity generated from burning fossil fuels will level out. In some places, like Australia and California, the cost of buying large areas of land is not always such a problem. Photovoltaic systems are getting cheaper and more efficient at generating electricity. For these reasons many power companies and governments are still interested in large solar farms. Some of the largest solar farms can be found in Spain and Germany.

To find out more go to:

Top 50 photovoltaic power stations in the world
http://www.pvresources.com/PVPowerPlants/Top50.aspx

Agua Caliente Solar Project –the World's largest photovoltaic power stations in 2013
http://www.firstsolar.com/Projects/Agua-Caliente-Solar-Project

Flying around the World in a solar powered aeroplane
http://www.solarimpulse.com

Sailing around the World in a solar powered boat
http://www.planetsolar.org

Why Solar Electricity is Becoming More Important

Electricity is essential to every society and economy in our world. With growing populations and expanding economies the need for electricity is increasing worldwide. Unfortunately much of the world's electricity generation depends upon burning fossil fuels. In the 20th century the use of fossil fuels increased by ten times. Fossils fuels now provide about 90% of the world's commercial energy needs. Much of the world's transportation also depends on fossil fuels. These uses of fossil fuels have helped increase the worldwide emission of greenhouse gases.

There is a shift taking place around the world to reduce greenhouse gas emissions in the production of electricity. Some power companies and governments are beginning to introduce renewable energy sources to replace fossil fuels in the production of electricity. Electricity generated by PV systems is one of these renewable energies and it does not produce greenhouse gases.

In addition to this, oil and gas reserves that are easy to access are becoming harder to find. As these fuels become more expensive, other kinds of fuels will become increasingly important. Because solar energy is clean, safe and renewable, it is being used more than ever before. As more research into PV technology is done, new kinds of PV systems should become less expensive, more efficient, and used in new ways. These changes will mean PV technology becomes more widely used.

Glossary

durable	Tough, hard-wearing and long-lasting
free electrons	Electrons that are not bound to their parent atoms but are free to move around the crystal lattice. Can carry energy
gold leaf	Pieces of gold that have been beaten into very thin sheets
photons	The smallest units of light energy
PV (photovoltaic)	Able to produce electricity when light shines on it
selenium	A semi-metal chemical element that conducts electricity better in light than the dark when small chemical impurities are added. Used to make diodes, PV cells, transistors etc
silicon	A semi-metal chemical that can conduct electricity
transistor	A device used to control or increase the flow of electricity
transmitter	A device that transmits radio waves