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Honors Physics Project H2
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The Future of Power Generation

The hunt for new sources of usable energy is one of the most pressing matters in today's world. The fossil fuels used to power our homes and vehicles are not only unhealthy, but also non-renewable. The fossil fuels being extracted today were formed from plants and animals that lived millions of years ago. The world is burning through the fuels much faster than they are being produced. The engines and other devices that use these fuels are also extremely inefficient. The average car's engine uses only 19% of the energy produced by its fuel. (Washington 2010)

While it's true that many are starting to implement cleaner, more renewable sources of energy, none have emerged as a good competitor against fossil fuels. Many areas now power homes with hydroelectricity, and many have switched to electric or solar powered cars, but fossil fuels remain dominant. However, many are still looking for a new way to generate power. They want a power source that yields even more energy while still being clean.

One idea, the fuel cell, is starting to find its place in today's energy market. In fact, President Bush started a program in 2003, with the goal to make cost-effective, fuel cell powered cars by 2020.(How 2008) The most common fuel cell uses hydrogen. The attraction comes from the fact that hydrogen is the most abundant chemical on Earth, and these fuel cells can be up to 85% efficient. These devices take hydrogen and oxygen and form water with electricity as a by-product. Since hydrogen and oxygen can be taken from the air, the fuel cell would theoretically never die, unlike batteries.

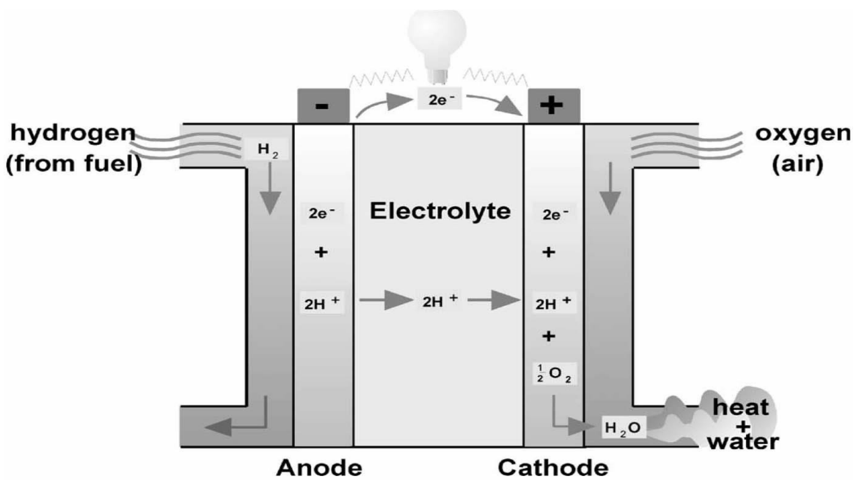
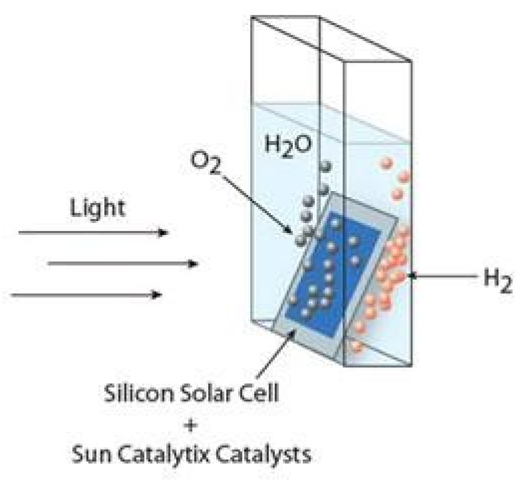


Fig. 2. Schematic of a PEM fuel cell operation. Source: World Fuel Cell Council.

A simple fuel cell is made of only a few parts. The anode, which has negative charge takes electrons released by hydrogen so they can be used in an external circuit. The cathode, which has positive charge, takes the electrons from the external circuit to be rejoined with hydrogen and oxygen to form water. The electrolyte, is a material that only conducts positively charged ions, meaning electrons can't move through. This setup allows for continual production of electricity from the formation of water. Of course, a single fuel cell such as this can only produce around .7 volts.(How 2008)To remedy this, fuel cells are often combined into “stacks”.

Fuel cells have been around since the 1800's, so why haven't they been the primary source of power from the start? The simple answer is that they aren't stable enough. They can't handle extremes in temperature or the constant changes from an engine.

Knowing that elements as simple a process as forming water could generate electricity, it's not hard to see why scientists are looking to living organisms when it comes to producing energy. Plants and algae produce their own energy from sources like the sun. Scientists realized that they could use energy made in this way. Engineers are currently working on an “artificial



leaf"(Chandler 2011). This leaf would work just like any other leaf. Just add sunlight and water, and wait. The difference between this leaf and a solar panel is in the processing. A solar panel will take photons given off by the sun, and turn them into usable energy through the photovoltaic effect. In the photovoltaic effect, electrons captured from light rays are transferred between two points causing a buildup voltage between two electrodes. The leaf will actually break down the water forming hydrogen and oxygen bubbles that carry sizable amounts of energy, and can be used as sources of fuel. These bubbles can even be used in the fuel cells mentioned earlier.

Hydroelectricity is the most widely used form of renewable energy in the world. With water covering most of the Earth, hydroelectricity can be implemented anywhere there is a source of running water. In many cases hydro-plants have a reservoir of water that can be used to increase the output of power as it is needed. However, there is an even larger source of energy that comes from water in the oceans. Wave power is the use of energy from waves on the surface of the ocean. Waves are naturally occurring, and can be predicted, providing a steady flow of power.

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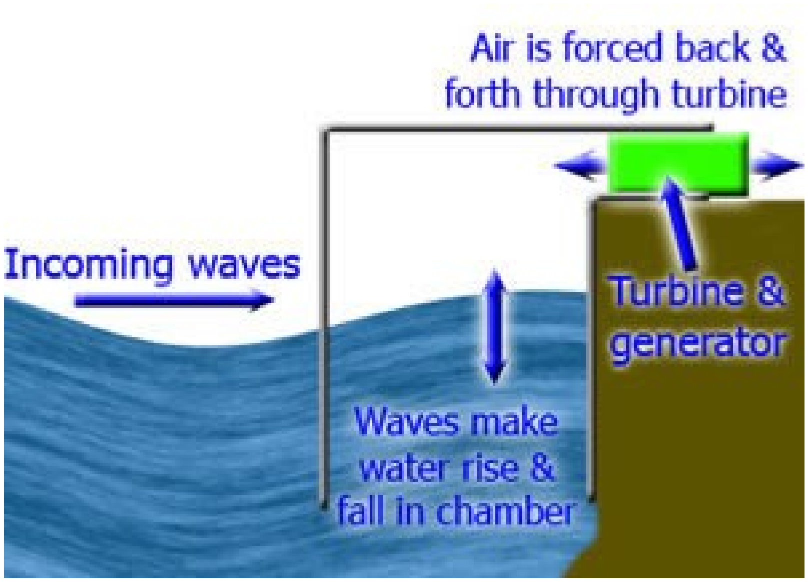
Waves on the ocean surface are caused by wind passing over. Energy is transferred into the waves from the wind. The waves then reach a chamber where air is compressed, pushing a turbine. When in deep water, the energy flux caused by a wave can be found with the equation,

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T \approx \left(0.5 \frac{\text{kW}}{\text{m}^3 \cdot \text{s}}\right) H_{m0}^2\; T,$$

(U.S. 2008)where P is the energy flux, H is the wave height, T is the period , and ρ is the water density. Using this equation, the average wave has the potential of 36kW of power per meter of wave crest. Large waves can produce upwards of 1.5 MW of power. A light bulb usually uses around 100 watts at any moment.(Spangler 2010)Since pretty much any wave produces 360 times this amount, its easy to see why wave power could be the way the Earth



powers its homes in the future.

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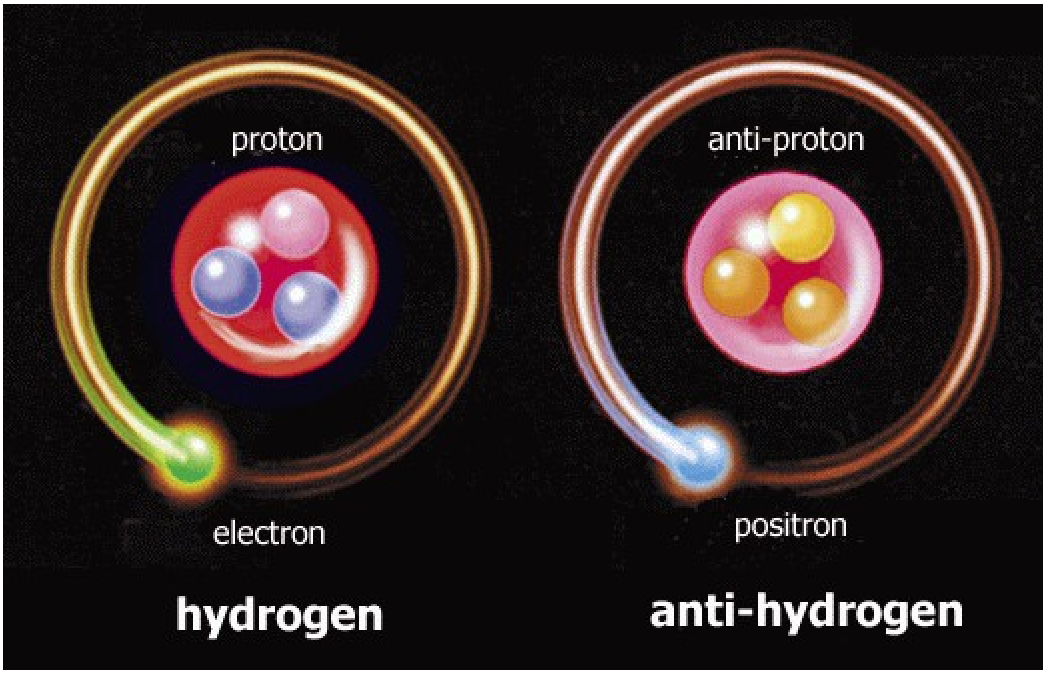
But, what if the solution to Earth's energy problem isn't actually harvested on Earth? Scientists now know that solar power and wind power are both viable sources of energy. However, researchers are now looking into a way to combine the methods. The solution is known as the “solar sail”.(AEN 2012) The idea is that a satellite could be placed relatively close to sun in order to tap into the massive amounts of energy being given off. Although called a “sail”, the device wouldn't work like the wind turbines found on Earth. The “sail” would actually be a copper wire or something similar. The copper wire would be charged in order to capture electrons being given off by the sun. According to researchers at Washington State University, 1000 homes could be lit by 300 meters of copper wire on a satellite only 10 meters tall. The energy collected from the “sail” would be transmitted back to Earth via laser. The practical applications of this method have yet to be realized. One issue is the transfer of energy back to Earth. Even with the tightest laser scientists have today, the laser would spread out over the distance and lose most of the energy. That being said, the amount returned would still be a substantial amount due to the sheer magnitude of energy given off by the sun. Also, in order to make the cost be worth the amount of energy returned would require huge satellites. The biggest issue is that scientists have yet to figure out how to utilize the energy once it reaches satellites orbiting Earth. The energy would be there, but they have yet to find a way to tap into it.(AEN 2012)

So, what if, instead of having to transfer energy over such a large distance, there was a massive source of energy, comparable to the sun, here on Earth? Scientists are actually working on a project dubbed the "artificial sun". It may sound unlikely, and in fact there are way to many unknowns for it to be accomplished anytime soon, but the idea is there. Through a process called nuclear fusion, two or more nuclei form together to form one dense molecule. This process creates a huge amount of energy. Using Einstein's equation E=MC^2, physicists came to the conclusion that 1 gram of matter had enough energy stored inside of it to power over 25,000 100 watt light bulbs for a year.(AEN 2012) So far, the only theory for actually creating a small star on Earth involves a complex series of lasers and mirrors, effectively producing energy greater than the energy put into the system.

A sun on Earth would produce so much energy that it may never be possible to contain one. Some physicists think that the answer to the Earth's energy problem, is much smaller, although not necessarily easier to contain. Antimatter is a physical mass made of antiparticles, just as normal matter is made of normal particles. When one of these antiparticles meets its counterpart particle(such as a positron colliding with an electron) they annihilate each other, subsequently releasing energy based off of E=MC^2. The problem with antimatter is that it is hard to find. Positrons are a natural by-product of beta decay, in which an unstable isotope



becomes more stable. (Figure Cern 2009) However a positron acting as an electron in matter is unusual. Other naturally occurring antiparticles have only been found in high energy processes involving cosmic rays.

The people of Earth will likely continue to have problems with power for years. However, physicists have shown that huge sources of clean, renewable energy are easily found. The only thing left to do is figure out how to use this energy.

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