**Generating Solutions to Electrical Energy Production**

**Curriculum Connections**:

The topics addressed in this workshop are relevant for **9 science** (E: electricity), **10 science** (D: climate change, E: light), **11U physics** (F: Electricity and Magnetism, D: Energy and Society) and **12C physics** (D: Electricity and Magnetism, E: Energy Transformations).

**The Problem: Climate Change**

* **Climate change is a fact.** <http://bgr.com/2014/01/29/global-warming-gif-video/>

Weather systems are chaotic and there is variation year by year, however, over the past 130 years, temperatures have risen.

The temperature change is not even. The average increase over the past 60 years is 1.1o C, but some regions have increased by as much as 4 o C. These small changes will have huge effects.

* **Climate change by human activity is a fact.** <http://climate.nasa.gov/scientific-consensus/>

Scientists are very careful about how they use terms like proof. A theory can only be disproved, it can never be proven. Sometimes climate change deniers (and evolution deniers) point out that climate change has not been proven and that not all scientists are in agreement.

“In science, 'fact' can only mean 'confirmed to such a degree that it would be perverse to withhold provisional assent.' I suppose that apples might start to rise tomorrow, but the possibility does not merit equal time in physics classrooms.” Stephen Jay Gould

“97% of actively publishing scientists agree: Climate-warming trends over the past century are **extremely likely** due to human activities. In addition, most of the leading scientific organizations worldwide have issued public statements endorsing this position.”

* **The solution will come from ...**

It is important that students realize how serious the problem is, but it is also really important to show them that this problem can be solved. Without hope, they will just give up.

1. **‘Alternative’ Energy Sources:** What do you see?
2. Noise, bird deaths, ugliness, loss of farmland

Wind turbines in US kill 300,000 birds annually. However, cell and radio towers kill 20 times that amount and cats kill 100 times as many. <http://www.usatoday.com/story/money/business/2014/09/15/wind-turbines-kill-fewer-birds-than-cell-towers-cats/15683843/>

Why are these solar panels on the ground? Why aren’t they on roof tops?

We must drastically reduce our use of fossil fuels. If it isn’t solar or wind – what is it?

1. Elegance, hope, progress

Aesthetics and attitudes can change with education.

1. Hippy pipe dreams, not economically feasible

Things are changing. Germany is getting 7% of its energy from solar. Denmark is over 40% wind.

**2) Things are changing fast!** <http://energyeducation.ca/encyclopedia/Electricity> (bottom of page)

Animated bar graphs are easier for students to understand than multiple line graphs. These ones provide solid, up-to-date information in a form that allows for an active, minds-on exploration.

1. Select bar graph. This shows world **electrical energy production** in 2013. Which regions have increased their output significantly since 1985? Push play.
2. Asia Pacific B) Europe and Eurasia C) North America D) all three

A: Asia’s consumption has grown five times bigger while the rest of the world has grown no more than 20%. Part of this is due to their greater population and consequent population growth; Asia 4 billion vs. Europe 2 billion, North America ½ billion. The world population is presently 7 billion and is expected to level off at10 billion.<http://www.ted.com/talks/hans_rosling_religions_and_babies?language=en>

However, Asia’s accelerated energy growth is also due to its increasing standard of living, which is still way below ours. Asia has 8 times the population of N. America but uses only twice the energy. Any solution to climate change must include helping the third world improve its conditions without increasing the carbon load. One way would be to provide financial and technical assistance to increase hydro generation which has room for lots of growth in the 3rd world.

1. Select **Wind Power**. When did wind power become viable?

A) 1970 B) 1980 C) 1990 D) 2000

D) 2000. The three most technologically advanced regions only started 15 years ago.

1. Select **Solar Power**. Europe is leading the way. When did solar power become viable?

A) 1970 B) 1980 C) 1990 D) 2000

It isn’t noticeable until after 2005! N. America is way behind Europe and Asia.

**3) Where are things changing most?** <http://energyeducation.ca/encyclopedia/Electrical_generation>

a) What percentage of the world’s electrical energy comes from solar/wind/other?

It is just 2.8 %. It is so small that you need to hover the cursor over the baby blue triangle. It looked more hopeful on the previous graphs because the scales were so different. Total was 10, 000 TWh, Wind was 250 TWh and solar 90 TWh.

1. What percentage of the world’s electrical energy causes carbon dioxide emissions?

A) 20% B) 45% C) 70% D) 85%

C) (40.4 + 22.5 + 4.3 + 0.7)% = 68%. That’s a lot that needs to be replaced.

1. What percentage of Canada’s electrical energy causes carbon dioxide emissions?

A) 20% B) 45% C) 70% D) 85%

A) (10.6% + 10% + 1.1) % = 22.6 %. We are fortunate to have many great hydro sites 60% and we have 15% from nuclear. no significant expansion is possible.

1. Which country has the largest percentage of each carbon-free source?

hydro (Norway 97%), thermal (Iceland 30%), wind (Denmark 34%, over 40% in 2016), solar (Germany 7%) biofuels/waste (Finland 16%), tidal (South Korea 0.005%?), nuclear (France 76%)

1. How did Denmark achieve their recent turnaround?

Denmark is a great example of the combined effects of science, politics etc. They chose to raise the cost of electricity (politics and an educated population) and put that extra money into large scale off-shore wind farms (science and technology). They are now selling this technology to the rest of the world (economics and hope!).

**4) Wind and Solar Energy Need Storage** <https://en.wikipedia.org/wiki/Solar_power_in_Germany>

1. How would a graph from Denmark look different? The solar would be smaller and the wind would be much larger and also less variable. Denmark is in a great position to use the strong and steady winds over the North Sea. The sea bed is shallow, so these can be put offshore where the wind is stronger and the turbines are not visible from the shore.
2. Why does nuclear change so little?

It is hard and energy wasteful to change a nuclear or coal powered plant. It provides a base amount. Gas fired plants are more responsive.

1. Which has a greater need for storage – wind or solar? Consider the effects of the facts below.

Solar installations are more expensive (Storage of solar is more cost effective)

Solar power is more variable (Excess needs to be stored)

Solar power occurs in the daytime, when demand is highest. (No need to store solar.)

Large arrays of wind turbines linked together are less variable. (Less need for wind storage.)

**5) Storing Electrical Energy** <http://www.awea.org/Issues/Content.aspx?ItemNumber=5452>

What are the advantages and drawbacks of these different storage technologies?

a) Pumped Hydro:

Well-tested, provides over 90% of existing storage. Great for Canada, which has so much hydro.

1. Compressed Air Storage:

Only for countries with large limestone caves. New technology.

1. Capacitors:

These are presently used in race cars to replace flywheels and batteries. There has been a recent dramatic improvement in capacitors (supercapacitors, ultracapacitors) and they store ten to a hundred times the energy per volume or mass of regular capacitors. They charge and discharge faster and tolerate more charge-discharge cycles than rechargeable batteries, but are ten times larger.

1. Flywheels:

It would be great if someone developed a demo of this.

1. Batteries:

It is a proven but expensive technology. However, the technology and cost is being improved all the time. Flow batteries involve pumping chemicals into separate tanks.

1. **Exploring EM Generation and Storage**
2. **Generating Electricity:** Attach the generator to a voltmeter and then a variety of loads. What happens when you turn very slowly and moderately fast? What happens when you stop?

The voltage increases with the speed at which you turn. Don’t turn the Genecon really fast or you may cause the gears to slip out of place. Gears are needed to take a slow rotation and make it much faster. As soon as you stop, there is no electricity – that’s what storage is needed. LED’s require much less power than incandescent lights. That is why the government is encouraging you to switch.

1. **Storing Generated Electricity:** Use the generators to charge the capacitors. What happens when you top turning? After the capacitor is charged, see how well it can handle each of the loads.

These capacitors demonstrate clearly, the benefits of storing electrical energy.

1. **Small Consumer Product:** Does the flashlight use storage? How can you tell?

They must have storage and if you look inside you will see a capacitor. These flashlights showed up just a few years ago as a result of the abilities of the new ultracapacitors.

1. **Exploring Solar Cells:**
2. **Generating Solar Power**: Get the highest voltage with the solar cells. What did you have to do? Attach the cells to various loads. Which can they power?

The cells need to be connected in series and they need to be close to a bright light source inside or outside on a sunny day. Exploration of the solar cells can be frustrating if you have low power solar cells.

1. **Storing Solar Power**: Attach the solar cells to a capacitor and a voltmeter. How was this different from the EM generation?   
   **Charging is much slower. However, once charged, the capacitor will work just the same.**
2. **Small Consumer Product:** Does the garden light use storage? How can you tell?

They must have storage and extra circuitry to switch. When it is dark, the capacitor stops charging and starts discharging. If you look inside you will see a capacitor. These lights showed up just a few years ago as a result of the abilities of the new ultracapacitors.

**Demonstrating Energy Storage**

* Why use capacitors? They charge faster than rechargeable batteries, cost much less than fuel cells and are simpler to set up than mechanical systems. However, demos of these would be nice. Any ideas?
* <http://www.arborsci.com/1-farad-capacitor> #P6-8012 $25, 1 F, 5 V
* <https://www.sargentwelch.ca/store/catalog/product.jsp?catalog_number=CP32248-50> $69, 1 F

These 1 F capacitors may be the new type of capacitors. They have a high capacitance but low voltage.

**Demonstrating Solar Power**

* $16 Kidder (cheaper in bulk) 1.5 V, 200 mA, # 80-3568-35, The power cost is **53 $/W** and it comes with leads and alligator clips. It is a Canadian company. <http://kidder.ca/solar-cell.html>
* $19 Boreal 0.45 V, 200 mA (no leads) **211 $/W!!!!!** <https://www.boreal.com/store/catalog/product.jsp?catalog_number=160508>
* $8 Arbour 0.5 V, 400 mA, (no leads) **40 US $/W** <http://www.arborsci.com/solar-cell-photocell>
* $1.29 <http://www.canadiantire.ca/en/pdp/solar-rocket-light-0524789p.html#.VxI01qgrIdU>

**Demonstrating EM Generation**

* **Lego Motors**: The old Lego Mindstorm kits had great motors, product number #8735. I have seen these for sale on eBay for as little as $15 and for as much as $100. They used to cost $30 new and they last much better than the Genecon and can be connected to the other Lego parts to make devices.
* $61 <http://www.arborsci.com/hand-crank-generators> # P6-2631, buy Genecon not others
* $100 <https://www.boreal.com/store/catalog/product.jsp?catalog_number=162000> Genecon
* $6 <http://www.mec.ca/product/5027-913/coghlans-dynamo-flashlight/?f=10+50520>

**A Great Online Resource**

* **Visualizing and Understanding the Science of Climate Change**

<http://www.explainingclimatechange.ca/index.html> This is a complete course that would be excellent for senior high school students and their teachers. It is a well-organized combination of direct instruction interspersed with questions and interactive applets. Parts could be used for younger grades. **Lesson 9: What Now? Responding to Climate Change** is especially important and has a great applet that emphasizes the need for multiple strategies to solve the problem.