Teacher Resources

Nuclear Energy: A HOT Topic in a COLD War

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Information:
In this lesson, students will describe the functions of the parts of a nuclear reactor as well as make a model of the reactors. They will make calculations to determine how much fuel is needed to power a city as well as a submarine. Students will then used this information to evaluate the cost/benefit of using nuclear fuels as compared to fossil fuels in both the urban and submarine setting.

Standards:
*AP Environmental
- V. Energy Resources and Consumption
- D. Nuclear Energy (Nuclear fission process; nuclear fuel; electricity production; nuclear reactor types; environmental advantages/disadvantages; safety issues; radiation and human health; radioactive wastes; nuclear fusion)

*Earth/Environmental Science (NC Essential Standard)
- EEn.2.8 Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth.
- EEn.2.8.1 Evaluate alternative energy technologies for use in North Carolina.

Background:
Cold War: period of time (post WWII-Breakdown of the USSR) in which the United States and Soviet Union had strained relations due to different ideologies (Democracy v. Communism) as each raced to maintain the advantage in weapons capabilities and power. The two nations basically developed the technologies with the potential to cause mutual destruction (along with the ruin of the rest of the world). The reason this was considered a "cold" war, was that there was never actual fighting between the U.S. and USSR, just a combination of threats, posturing, paranoia, and uneasiness. Although there were regional wars, world peace was generally maintained.

Hook Activity: <u>Butter Battle</u> Book (This book gives students a good idea of the mindset of the power nations during the Cold war and can be purchased (easily/cheaply) from amazon.com or in most bookstores.)
Although war itself can never be considered a "good" thing, many good things resulted from the advancement of technology that occurred during this period of time. Satellites improved and applications of their data collection sparked the advent and continuous updating of cellular phones and other communication devices. Nuclear technologies also advanced. Not only were submarines already using nuclear energy as a power supply for the vessels, but also they carried weapons containing nuclear warheads. As scary as those warheads were (and still are), the application of nuclear energy as a reliable power supply looks to be promising in a world slowly running out of fossil fuels.

Video Links: 1. Reactor Operations.
2. Nuclear Propulsion "The Nuclear Navy"
http://usnavymuseum.org/Ex2_Power.asp

Activity #1: Parts of a Nuclear Reactor (Teacher Notes)

*Give students Activity 1 Worksheet.

*Divide students into pairs or small groups and have them:

Identify the Parts of a Nuclear Reactor and Hypothesize Why The Parts Are There:

reactor, fuel rods, control rods, pressurizer, steam generator, turbine generator, condenser, moderator.

Review the correct answers with students.

*Then, distribute cutouts of the parts and have the students (in groups) use the cut-outs of each part to build a nuclear reactor. Check the arrangements and ask questions of why students have placed things as they have.

*Discuss the advantages and disadvantages of using nuclear energy to power a city? A submarine?

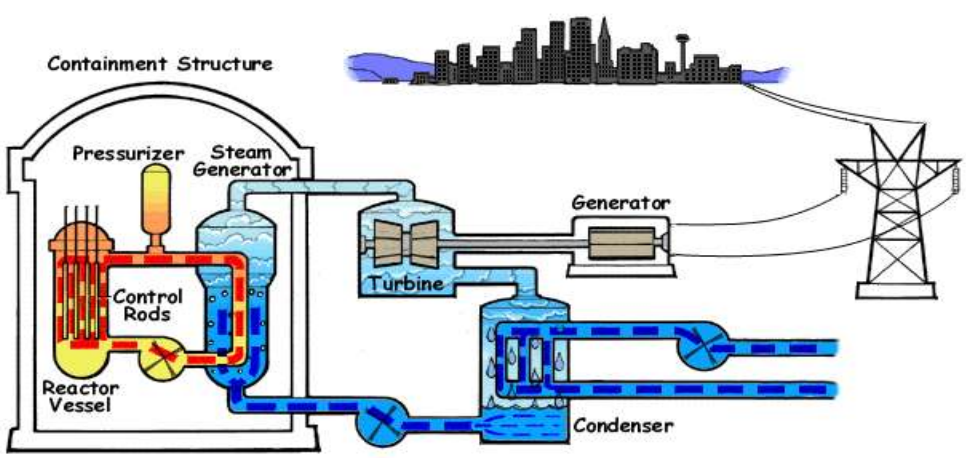
*Divide the class into four groups. Give one of each task to each of the four groups:

1. ADVANTAGES of Nuclear Energy—Cities/Towns
2. ADVANTAGES of Nuclear Energy—Submarines
3. DISADVANTAGES of Nuclear Energy—Cities/Towns
4. DISADVANTAGES of Nuclear Energy—Submarines

*Have students in the same group discuss their points with one another. Then, divide the class again making sure that each *new* group of four has a member from each of the previous groups.

*Students can then record evidence for each point in a 2x2 grid entitled Nuclear Energy.

Answer Key for Nuclear Reactor Construction:



http://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

Activity #2: Is Nuclear Power Better? (Nuclear v. Coal) (Teacher Notes)

Unlike power plants that rely on the burning coal for energy, nuclear reactors depend on controlled reactions involving the radioactive element, Uranium. Coal is produced from the decay and fossilization of living organisms over millions of years. Uranium is a natural element found within the Earth. Ores containing Uranium are mined and the majority of that Uranium is an isotope called U-238, which is relatively "nonreactive". Scientists have developed methods of enriching the Uranium in order to remove U-238 and concentrate the less plentiful, but "more reactive" isotope, U-235, within the fuel. This enriched Uranium is used to create fuel rods to provide energy and generate heat through controlled nuclear fission.

Link: Fission Reactor. http://www.brightstorm.com/science/physics/nuclear-physics/fission-reactor

***Assume the average person uses 100 kwh of electricity per day (10 hr. day). (SSN 120, SSBN 160)**

>Conversion Factor: 1 kwh = 3.6 MegaJoules (MJ) or 3,600,000 Joules or (3.6×10^6) J

a) How much energy is used per person per day?

$$100 \text{ kwh} \times \frac{3.6 \times 10^6 \text{ J}}{1 \text{ kwh}} = 3.6 \times 10^8 \text{ J}$$

b) How much energy would be used by a small town containing 160 people per day?

$$3.6 \times 10^8 \text{ J} \times 160 \text{ people} = 5.76 \times 10^{10} \text{ J}$$

>Conversion Factor: 1kg U-235 can generate 80 TeraJoules (80,000,000,000,000 J) or (8.0×10^{13})

c) How much U-235 is needed in order to produce the amount of energy this city needs in one day?

$$\frac{1 \text{ kg U-235}}{8.0 \times 10^{13} \text{ J}} \times 5.76 \times 10^{10} \text{ J} = 0.00072 \text{ kg or } 0.72 \text{ g}$$

>Conversion Factor: 80 TeraJoules of Energy can be generated from 3000 metric tons of coal.

>Conversion Factor: 1 metric ton of coal has a mass of 1000 kg.

d) How much coal would be needed to run this same town for one day?

$$5.76 \times 10^{10} \text{ J} \times \frac{1 \text{ kg coal}}{2.6 \times 10^7 \text{ J}} = 2{,}160 \text{ kg coal}$$

Students will have to use the conversion factors to derive the needed data to figure out how much energy will yield from 1 kg coal.

$$\frac{3000 \text{ mton}}{8.0 \times 10^{13} \text{ J}} \times \frac{1000\text{kg}}{1 \text{ mton}} = \frac{3.0 \times 10^6}{8.0 \times 10^{13}} = \frac{1}{x} = \frac{1 \text{ kg coal}}{2.6 \times 10^7 \text{ J}}$$

e) Which energy source uses the least amount of raw materials for the fuel? What implication does this have for future energy needs?

From the results, students should see that far less nuclear fuel is needed than fossil fuels to generate the same amount of energy. This provides a feasible choice for moving to the use of nuclear power to satisfy cities' energy needs. It's not likely to be an energy source for transportation as wrecks/accidents could prove to be very dangerous if nuclear fuel was released during such mishaps.

Activity #3: Powering A City Vs. Powering A Submarine (Teacher Notes)

Many cities and submarines rely on nuclear energy to provide the power needed for normal operations.

An SSBN (Ballistic/Nuclear Submarine) carries 160 people on board. In essence, a nuclear submarine is a moving miniature city that needs power for a variety of reasons including those involving in ensuring the crew's survival (provide water, air, and clean the air of impurities), as well as constant propulsion, and generation of electricity for operation of equipment, light, and maintenance.

>The submarine generates 100 MW of power when at 100% power. However, normal submarine operations only use about 10% of the total potential power.

a) How many MWh are used by the submarines daily?

(100 MW x 10%) x 24 h = 240 MWh

b) Convert the MWh to kWh.

$$240 \text{ MWh} \times \frac{1.0 \times 10^{6} \text{ Wh}}{1 \text{ MWh}} \times \frac{1 \text{ kWh}}{1.0 \times 10^{3} \text{ Wh}} = 240{,}000 \text{ kWh}$$

c) How much energy (in Joules) is generated by the submarines daily?

$$240{,}000 \text{ kWh} \times \frac{3.6 \times 10^{6} \text{ J}}{1 \text{ kWh}} = 8.64 \times 10^{11} \text{ J}$$

>Conversion Factor: 1 kg U-235 = 80 TJ

d) What mass of U-235 is needed to power the submarines per day?

$$\frac{1 \text{ kg U-235}}{8.0 \times 10^{13} \text{ J}} \times 8.64 \times 10^{11} \text{ J} = 0.0108 \text{ kg}$$

e) How much U-235 is needed if submarines are typically patrolling for periods of 78 days?

0.0108 kg U-235 x 78 days = 0.8424 kg or 842.4 grams

>These submarines go on patrol for approximately 78 days and then are docked for maintenance and service for 30 days before going on another patrol.
>If the average SSBN reactor may have about 20 kilograms of U-235.

g) How long can the nuclear submarine continue to run without needing a new fuel supply?

Students must realize that 78 days (of using energy) + roughly 30 days (of not needing the energy while docked) basically gives them a period of 108 days. So, if subs use 0.8424 kg of energy in each patrol, and they go on 3+ patrols per year (I'd accept calculations with a range of 3-3.4 patrols), then they just have to multiply the amount of U-235 needed for 1 patrol by whatever factor (3-3.4) to get their annual use.

0.8424 kg U-235 x 3 = 2.5272 kg/year through 0.8424 kg U-235 x 3.4 = 2.8642 kg/year

Then, they just need to divide 20 kg U-235 (the given amount in the ships) by the rate:

$\frac{20 \text{ kg}}{2.5272 \text{ kg/yr}} = 7.9$ years $\qquad \frac{20 \text{ kg}}{2.8642 \text{ kg/yr}} = 7$ years

So, between 7-8 years should be acceptable.

If you completed, Activity #2, you should've calculated how much energy is needed for the operation of a city that has about the same population as a submarine.

a) How do the amounts of energy used to rub a submarine and a city differ?

The submarine uses much more energy (per person) than the city. (Many students will probably be surprised by this deduction.

b) Explain factors that could account for these differences in energy needs between the two systems.

Cities have *shut down* periods, in which there is little activity due to most of the population sleeping/resting. Submarines are constantly running all systems during their periods of operation because the many pumps, motors, and steam turbines are necessary to maintain life on the ships.