Driving Change: Alternative Fuel Vehicles

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Overview

The world consumed $3.1x10^{10}$ billion barrels of oil in 2007 (nation master) with the United States far surpassing all other oil consuming nations by using 20,680,000 bbl/day. That's 2.7 times more oil than China, our closest competitor. The primary point of concern regarding global petroleum consumption is the non-renewable status of this crucial energy source since each drop of that 3.1 $x10^{10}$ billion barrels is one that cannot be replaced. Aside from inevitably "peaking out", our accelerated usage of petroleum as a fuel and materials source over the past decade has contributed to a myriad of secondary problems including the warming of the troposphere via carbon dioxide emissions (and associated ecological consequences), and economic and political consequences of being dependent on foreign countries for such a vital resource. As such, development of alternative fuel sources is crucial to the construction of a sustainable society.

The primary use (2/3rds) of oil in the United States is transportation (eia.doe.gov) - so it makes sense focus efforts to develop technological alternatives to petroleum in the transportation sector. Conveniently, students are far more interested in alternative fuel vehicles than they are in alternative sources of electric energy (wind, solar, hydro.) since they can envision buying a car far more easily than buying a home and making decisions about mundane gas and electric bills. The rapidly growing alternative vehicle market is a perfect lens through which to examine the science and the affordances and constraints of emerging technologies. These technologies fit into the basic categories of a) relying on petroleum sources but improving fuel efficiency and b) exploiting a fuel source other than petroleum (natural gas, hydrogen, biofuels).

This unit is an elongated case study centered around the school's parking lot. Students will collect and analyze data regarding the current oil and carbon footprint of the lot as a snapshot of modern consumption and complete the necessary research on fuel alternatives to develop an alternate vision of a sustainable parking lot. As a result students will gain an understanding of the limitations of our current transportation technology, the mechanics of the greenhouse effect and climate change, and be able to comparatively analyze the various alternative fuel technologies currently on the U.S. vehicle market.

Rationale

Energy is the ability to do work
A unit on energy resources cannot begin without a discussion of what we require billions of barrels of liquid energy to accomplish- work. Especially in the usage of energy for transportation, the scientific meaning of work has great resonance. It is the application of force to cause a change in

the motion of an object. In 2008, vehicles in the United States were forced into motion for *3 trillion miles* along highways (bts.gov.) That distance required significant amounts of work (since **W**ork= **F**orce x **d**istance)

Power is the rate at which work is done (work/time). Newton first captured this measurement in the unit horsepower (how much weight a horse could move in a period of time.) We expect our vehicles to move large masses very quickly- and it is common to see sedans with over 190 horsepower. Oil is the primary transportation fuel because it can be fractionally distilled into various products used for transportation from jet fuel to gasoline (which accounts for about 17 percent of the energy consumed in the United States) to diesel. Additionally, petroleum is relatively easy to extract from the earth's crust and extremely easy to transport in barrels. But perhaps most importantly, oil contains enough energy density to provide the power we require to accelerate quickly while carry heavy loads (power.)

Despite oil's significant advantages discussed above that have kept it so cheap and ubiquitous. Significant constraints regarding oil usage are beginning to force us to explore alternative fuels and technologies.

Consequences of our reliance on petroleum for transportation

<u>Depletion:</u> Petroleum (crude oil) is made of combustible hydrocarbons- the molecular remains of dead organisms that rained down and became buried on seafloors over millions of years. Some organic material became buried under enough sediment to create the pressure and heat necessary for conversion into the appropriate length hydrocarbons for use and extraction. It's rare enough to encounter appropriate conditions for the production of crude oil, but known global reserves also had to have been created in geologic conditions that allowed for it to collect and avoid escape or contamination. While these events occurred in many locations around the globe (98 of 205 countries possess oil reserves- but that also means that 107 do not), the amount of oil in each varies widely. Saudi Arabia far exceeds the rest of the world with 2.7×10^{11} billion barrels of oil. The United States is 12th in the world with 2.1×10^{10} billion barrels (cia world factbook).

Extraction of crude oil is heavily limited by drilling and extraction technology. Currently producers only get 35-50% of the oil out of a deposit, though this efficiency is expected to increase with development of technology capable of recovering remaining heavy crude oil (steam flushes and otherwise.) Regardless of how efficient technology becomes, it is clear that the biological and geologic conditions responsible for creating crude oil were finite and that crude oil is non-renewable and cannot be exploited indefinitely.
In 1956 M.King Hubbert predicted that U.S. oil production would peak in the 1970s. He was correct- and the United States now imports about 60% of the oil it consumes. While the United States has already "peaked out" in terms of oil production, predictions for a global oil production peak still range from having already occurred to 2018 (science daily peak oil). Peak oil is difficult to predict because The Organization of Petroleum Exporting Countries (OPEC), who control 75% of the world's proven oil reserves, frequently change the amount of proven reserves. This fuzzy math makes it difficult to asses the true status of oil reserves.

<u>Climate Change etc.:</u> Vehicles that run on standard unleaded gasoline emit about 20lbs of carbon dioxide (170 cu. ft.) for every gallon of gasoline consumed (fueleconomy.gov). Despite the fact that other atmospheric gases have higher warming potentials, carbon dioxide is the most important

anthropogenic greenhouse gas because of its ubiquity. Annual CO_2 emissions have grown between 1970 and 2004 by about 80%, from 21 to 38 gigatonnes (Gt), and it represented 77% of total anthropogenic GHG emissions in 2004 (2007, IPCC). The result of such significant increases in carbon dioxide concentrations in the atmosphere is unequivocal warming of the climate system "as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (2007, IPCC). Despite the fact that carbon dioxide and temperature have both fluctuated throughout history on Earth, it is clear that current fluctuations are anthropogenic. The 2007 IPCC report clearly states that "global atmospheric concentrations of CO2, CH4 and N2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years, with a radiative forcing of +1.6 [+0.6 to +2.4]."

Large scale increases in tropospheric carbon dioxide result in global climate change via the greenhouse effect. Energy enters the earth as solar radiation is absorbed by the surfaces of the planet and converted eventually to outgoing infrared radiation (heat.) As the concentration of carbon dioxide (and other greenhouse gases) increase in the lowest layer of the atmosphere (the troposphere), they trap infrared radiation which leads to increased energy storage in the troposphere and the myriad secondary and tertiary consequences from droughts to floods to increased geographic range of infectious disease, and altered biological communities.

Alternatives

Due to the two reasons above as well as more immediate and compelling reasons put forth by the EPA/DOT to save money ($300-$2,000 per year) and strengthen national energy security by reducing American dependence on foreign oil, it is imperative to explore sustainable transportation technologies.

An interesting point of appreciation regarding all energy sources we'll consider in this unit is that they share a common origin; the sun. Petroleum and other fossil fuels are the decomposed and compressed remains of ancient plants whose biomass was converted from carbon dioxide using the *sun's power* for photosynthesis billions of years ago. It's no surprise that the burning of that modified biomass in the form of diesel, gasoline, and natural gas emits carbon (as carbon dioxide, monoxide, and methane) that was sequestered from the atmosphere so long ago. We now use modern plants such as corn, sugar cane, and jatropha for biofuels. These plant stocks have converted solar energy into biomass we can process into alcohols and oils for combustion engines. Assuming the electricity powering a plug-in electric vehicle is non-fossil fuel, it still ultimately depends on the sun. If the electricity was derived from hydroelectric power, the *sun's pull* manifest as evaporation and transpiration and the sun's influence in creating wind is responsible for replacing water at places along a watershed where it can flow and be captured to produce current. In the case of other electric sources, the sun's energy has been converted more parsimoniously from photons directly to current by photovoltaic cells. Perhaps the *sun's energy* was instead concentrated to single points where the tremendous heat vaporizes liquids that can then turn turbines to produce current. No matter what we choose at the fill station, we are ultimately plugging into the sun.

Significantly, choosing a vehicle that achieves an efficiency of just 5 more miles per gallon can prevent 17 tons of greenhouse gases from entering the atmosphere over the lifetime of the vehicle. Knowing the importance of fuel economy, the government set fuel economy standards Corporate Average Fuel Economy (CAFE) as part of the "Energy Policy Conservation Act," enacted into law by

Congress in 1975. The law authorizes the EPA to enforce a minimum standard for the sales weighted average fuel economy, expressed in miles per gallon (mpg), of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 lbs. or less, manufactured for sale in the United States, for any given model year. The standard set for 1985 was 27.5mpg where it has remained since. President Obama raised C.A.F.E. standards to 35.5mpg by 2016. Several technologies exist that respond to the fuel crisis simply by increasing a vehicle's fuel efficiency. While these technologies reduce the rate of global warming and petroleum depletion by combusting less carbon to accomplish the same amount of work, they cannot realistically be considered sustainable because they still rely on nonrenewable resources.

Hybrid electric vehicles

The most fuel efficient vehicles in some classes for the 2009 model year are hybrid-electric vehicles (HEVs). The Toyota Prius gets 48mpg in the city and 45mpg on the highway. Hybrid electric vehicle options exist in most vehicle classes including compact and midsize cars, pickup trucks and sports utility vehicles. Hybrids run on internal combustion engines (as do conventional vehicles) but have a secondary electric motor that can be used for low speeds off of a battery that charges using the kinetic energy typically lost when coasting and braking. HEVs do not need to be plugged into external sources of electricity or recharged. Hybrid vehicles rely upon 3 main technologies to conserve fuel, they are regenerative braking , electric motor/drive assist, and automatic start/shutoff**.** Regenerative Braking is a technology that allows the **"**electric motor to apply resistance to the drivetrain causing the wheels to slow down. In return, the energy from the wheels turns the motor, which functions as a generator, converting energy normally wasted during coasting and braking into electricity, which is stored in a battery until needed by the electric motor." (fuel economy.gov) The electric motor is useful in providing power to assist the engine in accelerating, passing, or hill climbing. Providing extra short-term power from electricity rather than increased fuel injection allows a smaller, more efficient engine to be used. The electric motor can also be used alone for low-speed driving (where internal combustion engines are least efficient). Lastly, automatic start/shutoff. prevents idling by automatically turning off the combustion engine when coming to a stop. Idle Free Philly reports that "thirty seconds of idling can use more fuel than can use more fuel than turning off the engine and restarting it. " Automatic start/shutoff prevents fuel wasting (and the air pollution issues) (CAC).

The federal government is offering a tax incentives for HEVs and some states offer additional incentives.

Electric Vehicles

Vehicles that rely entirely on an electric motor are called electric vehicles. Because their engines are not powered by the residual energy from braking/motion as stored in a battery, electric vehicles offer a convenient entry into discussing all energy sources used to produce electricity These include hydroelectricity, solar energy, wind energy, and geothermal energy (to some extent) as alternatives to coal and nuclear power. Here are some brief points about each. Because electric vehicles do not combust any fuel, there are zero emissions from these vehicles. Although electric vehicles (EVs) are not direct pollution sources, they can still significantly contribute to global warming, acid rain, and other air pollution issues depending on how the electricity they plug into has been generated.

<u>Coal:</u> Coal is the primary source of U.S. electricity production (54%), followed by nuclear (21%), hydropower (11%), natural gas (9%), oil (2%), and non-hydro renewables (3%). A typical coal plant burns 1.4 million tons of coal each year. That adds up to 840 million tons of coal each year. Coal-fired power plants burn coal to heat water into steam. The steam turns turbines that produce electricity

through the movement of electromagnets. Coal is the world's most abundant fossil fuel (Miller, 2005) but accounts for over 1/3 of the world's annual carbon dioxide emissions and also releases sulfur dioxide, particulates, radioactive dust, and toxic metals like mercury, arsenic and lead into the atmosphere. The mining of coal (especially by removing mountaintops) creates incalculable damage to ecosystems by disrupting topography and hydrology and uses huge amounts of space and water in the process.

<u>Nuclear Energy:</u> Nuclear energy is the second most common source of electricity produced in the United States. In 2005 103 commercial nuclear power plants were operational in the United States and 14 were decommissioned with radioactive waste stored on site. Nuclear energy is still relatively new. The first nuclear reactor was built by Enrico Fermi in 1942, and the first commercial reactor became operational a little more than a decade later in 1957. One big advantage of nuclear power is that it does not emit any greenhouse gases. Fission reactors use controlled chain reactions in which fuel pellets made of Uranium (where the concentration of radioactive uranium-235 is enriched from the .7% occurring in nature to 3%.) Neutrons split the nuclei of radioactive isotopes, liberating large quantities of heat and more neutrons in the process that split more nuclei in a reaction that proceeds exponentially unless controlled very carefully by neutron absorbing control rods. Aside from the fancy science that occurs in the reactor's core, a nuclear power plant works simply and in much the same way as a coal-fired power plant. The heat generated in the core turns water to steam which turns a turbine to generate electricity. The challenges that nuclear power plants pose to the environment are very different from those of coal plants.

Some of the biggest concerns regarding nuclear power are how to keep reactors safe and reactions under control and what do do with spent highly radioactive waste. Two nuclear accidents are largely responsible for the dissolution of interest in nuclear energy that occurred in the United States during the 80's and 90's. A meltdown of a core at Three Mile Island in Pennsylvania due to a bungled reaction to a routine malfunction in 1979. The devastating explosion and dispersal of radioactive material that resulted from a core meltdown in Chernobyl, Ukraine in 1986 made the world think twice about the consequences of nuclear power. Nuclear accidents actually pose far less risk than the radioactive waste that is produced as a side product of the fission reactions. Many of the fission products are themselves radioactive and give off alpha and beta radiation as they reach nuclear stability. Isotopes with short half-lives give off radiation very quickly and pose immediate health risk while those with longer lives pose more of a distributed health risk, but must be contained and manage for geologic spans of time. The federal government had promised nuclear energy companies long-term waste management beginning in the 1980's, but never has succeeded in approving an acceptable site. Yucca Mountain, the most likely site was killed by the Obama administration in 2010 after concern over water infiltration. All high level radioactive waste is stored at the site of each reactor.

Despite initial optimism about nuclear power in the 1950's (Eisenhower administration), the United States lost interest in constructing new reactors after the Three Mile Island and Chernobyl safety scares. No new nuclear power plants were ordered between 1978 and 2009. But because of new safety and production technologies, increased electric demand, higher prices for oil and coal, and concerns about climate change, the Obama administration supports the expansion of nuclear power. They have offered $37 billion in new loan guarantees to support building new reactors (construction on one in Georgia has begun.)

Wind Power: One very promising alternative to coal and nuclear power plants for electricity generation is wind. It is one of the fastest growing energy sources around the world. Currently only 2% of U.S. electricity is wind generated, but this figure may rise to 20%. by 2030 (according to the DOE). Proposed projects for 2010-2016 in the wind sector far outstrip electricity generation (in GW) by coal (according to the National Energy Technology Laboratory.) 1-2% of the sun's energy is converted to wind on Earth as the planet heats unequally and gases in the atmosphere move in response to pressure differences. Geographic features can impact the use of turbines to convert wind into electricity. For example, buildings and uneven terrain can cause turbulence, but the windy side of mountains can compress air into a tunnel with higher wind speeds like those that exist at the tops of mountains, hills, and ridges. Placement of wind turbines is important for optimal electricity production. The main components of a wind turbine are the rotor (blades), hub, gear box, generator, and tower. Rotor blades are designed to make wind speed up as it moves over them and new turbines have the ability to respond to wind direction. Initial concerns about noise from turbines have been allayed as the produce less emissions than the average home or office environment.

Solar Power: Active harvesting of the sun's energy for conversion to electricity is accomplished by two primary means. The first is the use of photovoltaic cells to create electric current. Photovoltaic cells are silicon wafers that have been doped (intentionally introduced to impurities) with boron and phosphorus. When solar radiation strikes the doping atoms, electrons are released and pass through silicon crystal acting as a semiconductor. The circuit is constructed in such a way that electrons flow in one direction and create direct current that can be used to charge an electric vehicle. Silica, the raw material containing silicon is cheap to extract from the Earth's crust and abundant, PV cells offer the only direct conversion of solar energy to electrical energy, and the sun provides so much energy to the surface of the Earth that theoretically only a 100x100 mile area is required to supply all of the U.S. electricity needs. Currently, solar cells supply only about .05% of the world's electricity. The reason that we fall short is that PV panels do not yet have the efficiency necessary. Researchers are trying different layers of thin films to collect the optimum range of wavelengths, and changing the fill factor to balance the amount of space on the cell used to collect energy with the space needed to conduct it.

Another way to convert solar energy into electricity is solar thermal system. These system collect and transform radiant solar energy into heat which can be used to create electricity in the same way as coal and nuclear power plants. In solar thermal plants, sunlight is collected and focused on reservoirs of liquids that become superheated and boil water through heat exchange.

Batteries: Both HEV and EV are limited by their ability to store and efficiently use electric energy in batteries. The development of low-cost, long-life, and high-power energy storage systems is a crucial (and overlooked) part of alternative energy development. Most vehicles use lead-acid batteries, but these are proving to be too heavy and poor in terms of energy density (40Wh/kg) for the performance needed. Nickel-Cadmium batteries are slightly better, but are still considered low in terms of energy density and additionally contain toxic components (Cd) of concern during disposal. The ideal battery would weigh nothing, take up no space, provide infinite voltage over an infinite lifetime, but the closest we've come are Nickel-Metal Hydrides, and the more promising Lithium ion batteries use intercalation compounds to create huge surface area (sort of) where electrons can be stored and released. There are, however, safety concerns associated with the high voltage and the decomposition of the electrolyte.

Biofuels

Biofuels are fuels made from plants and have a lot in common with petroleum fuels that are the remains of ancient plants. Biofuels for transportation fall into two categories. Ethanol is an alcohol fermented from starch molecules. Vehicles can run on either 10% or 85% ethanol, but vehicles that run on 85:10 ethanol:gasoline blends are called flexible fuel vehicles (FFV) and have modified engines. Biodiesel a dried and processed fatty acid modified from plant oils and can be used in vehicles that are capable of running on diesel fuel. Biofuels are popular in the United States because they support the local farm economy and absorb carbon from the air as they grow so are part of a closed loop fuel cycle (in positive contrast to the open carbon cycle resulting from burning fossil fuels.)

Ethanol production in the United States has expanded from about 1.7 billion gallons in 2001 to approximately 8–9 billion gallons in 2008. This is largely due to the following advantages that ethanol fuels possess. First they are cleaner burning both in terms of greenhouse gas emissions (especially carbon dioxide) and in terms of carbon monoxide, particulate matter (which contributes to air quality and health problems), and sulfur dioxide (a major reactant in acid deposition.) Biofuels are especially advantageous relative to fossil fuels (gasoline, diesel) in terms of the greenhouse effect and climate change because they offset the carbon emitted during combustion with the sequestration that occurs during growth of the fuel material. Additionally biofuels can be produced (grown and processed) domestically whereas the majority of petroleum must be imported from other countries. Secondary benefits of domestic biofuel production include reduction of petroleum imports, decreased foreign conflict, increased self-sustainability, and creation of American jobs.

Concerns about biofuels still exist and include… market competition between the food and fuel industries leading to higher prices, performance concerns based on chemical differences between gasoline and ethanol (vapor pressure, octane rating), and perhaps most concerning is the lower energy density of ethanol which reduces torque, acceleration, and miles per gallon of ethanol vehicles. From a consumer perspective, the availability of biofuels at fueling stations limits the range of vehicles that cannot fall back on E10 gasoline.

Biodiesel is a liquid fuel made up of various fatty acid esters that has physical characteristics similar to petroleum diesel (flash point 100-170C, 77% C, 12%H, 11%O by weight, specific gravity .88). Biodiesel is synthesized from renewable sources such as new and used vegetable oils (soy) and animal fats. Biodiesel is made by reacting fats and oils with an alcohol (methanol) to produce fatty acid methyl esters. Glycerin is produced as a co-product and is usually salvaged and sold to cosmetic/pharmaceutical industries. The advantages of biodiesel are that it is less polluting than petroleum diesel, can be produced domestically, and is compatible with existing diesel engines. One limitation is that when biodiesel is made from fresh oil, it competes for raw material (soy) with food and other industries potentially driving up prices or encouraging monoculture. Diesel-powered vehicles get 30-35% better fuel efficiency than gasoline vehicles because of the energy efficiency of diesel engines and a 10% advantage in the energy density of diesel relative to gasoline. The federal government encourages the purchase of diesel vehicles (but not biodiesel vehicles specifically since there are no dedicated biodiesel vehicles on the market) by offering a tax incentive for qualifying vehicles. There were 6 diesel vehicles available in the 2009 market in the compact, midsize, small station wagon and SUV classes.

Ethanol vehicles that run on E85 (a mixture of 85% ethanol and 15% gasoline) make up the largest segment of alternative fuel vehicles in the 2009 market by far. There are well over 50 models available. Ethanol gasoline is cheaper than petroleum gasoline, but is less energy dense so the annual fuel costs are actually higher because a tank of E85 will not move a car as far as a tank of gasoline. There is a huge amount of innovation in the ethanol market. While ethanol was first made by fermenting crops high in sugar and starch like corn and sugar cane, competition for these crops drove up the price of all products containing them. Since that time, researchers have developed techniques for fermenting ethanol from waste components of crops like the stalk cellulose and have investigated ethanol production from plants that are not part of our food system such as switchgrass and jatropha. The availability of E85 fuel is severely restricted to the corn belt.

Fuel Cells

Fuels cells use electrochemical reactions to produce power. They are promising because there are zero carbon emissions, and environmentally clean, offer high efficiency, low noise. In fuel cells hydrogen combusts with oxygen to create water. Liberated ions respond to a semi permeable membrane to create current and come together at the anode to produce waste water. Fuel cells can be put into series to produce the voltage needed (car batteries use a 12V battery just to turn on.) Fuel cells do need to be supplied with fuel. Hydrogen does not occur in high enough concentration naturally to use air as a source, and even though oxygen does- all other components of the atmosphere (nitrogen, water vapor, carbon dioxide etc.) are essentially contaminants. Hydrogen is currently purified from either water (causing competition with other industries) or from hydrocarbons in fossil fuels (resulting in cancellation of the zero carbon emissions advantage.) There are various fuel cell cars on the market today including the Ford Focus, and Hyundai Santa Fe.

Objectives

This curriculum unit was developed for use in a senior year Environmental Science elective course. It follows a unit exploring global warming and climate change as well as non-renewable energy resources with a special focus on oil. The unit targets the following Pennsylvania Academic Standards for Science and Technology and advances student's content knowledge of earth systems, energy, and technology as well as their understanding of the nature of science. This unit further affords students opportunities to advance their scientific thinking about defining a problem and testing solutions according to a model.

More specifically:

Standard	Rationale
3.1.12. Unifying Themes A. Apply concepts of systems, subsystems - Compare and contrast several systems that could be applied to solve a single problem. - Evaluate the causes of a system's inefficiency. C. Assess and apply patterns in science and technology. - Assess and apply recurring patterns in natural and technological systems.	A) There are two main systems studied in this unit. The first is the Earth including cycling of matter (especially carbon in this case) and flow/loss of energy. These topics are important in understanding how use of fossil fuels and alternative fuel vehicles relate to natural systems and processes on Earth. The second set of systems are the vehicles themselves. Each system seeks to balance affordances with constraints in creating affordable vehicles that meet the needs of consumers. Increasingly, vehicles are being developed that more thoroughly consider the inefficiencies in energy usage. C) The carbon cycle as a natural pattern will be investigated in depth, as it is the key to understanding why global warming is occurring and how to slow it.
3.2.12. Inquiry and Design C) Apply the elements of scientific inquiry to solve multi-step problems.	Students will use scientific processes to answer the question "What should the school's vehicle fleet be composed of in order to meet future C.A.F.E. standards and solve

D) Analyze and use the technological design process to solve problems.	environmental problems associated with fossil fuel usage. Additionally students will propose changes in vehicle technology to address the limiting factors in existing fuel economy.
3.4.12.B Physical Science Apply and analyze energy sources and conversions and their relationship to heat and temperature	During this unit, students will analyze the efficacy of oil, natural gas, and electricity from various sources and their relationship
3.5.12.B Earth Science Analyze the availability, location and extraction of earth resources.	Students will assess the availability, location and extraction of both renewable and non-renewable energy resources as they make determinations about the future of transportation in the United States.
3.6.12.C Technology Education Analyze physical technologies of structural design, analysis and engineering, personnel relations, financial affairs, structural production, marketing, research and design to real world problems.	Students will analyze technologies that make fuel conservation possible as well as technologies that enable the use of hydrogen and electricity rather than petroleum products.
3.8.12. Science, Technology and Human Endeavors B. Apply the use of ingenuity and technological resources to solve specific societal needs and improve the quality of life. **C.** Evaluate the consequences and impacts of scientific and technological solutions.	In the last phase of this project, students will analyze the consequences of adopting green transportation technologies in the carbon and energy footprint of the school as well as broader societal impacts. Finally, students propose or predict a technological solution to the challenges that remain in American consumption of energy for transportation.

Classroom Activities
Overview:
Activity 1 (1-2days): Students will assess the existing fuel consumption and carbon emissions of vehicles used by the school community
Activity 2 (2 days): Students will explore nonrenewable energies as they relate to transportation via teacher-led interactive lecture and discussion.
Activity 3 (3 days): Students will identify major environmental problems that result from oil consumption as raised in the film A Crude Awakening.
Activity 4 (5 days): Students will research and present explanations of alternative fuel vehicles that either use petroleum more efficiently than traditional vehicles or that use an energy other than petroleum.
Activity 5 (2 days): Students will become familiar with the technologies and models available on the current vehicle market so as to navigate the fuel economy guide and make strong decisions in the final activity.
Activity 6 (5 days): Given upcoming C.A.F.E. standards, students will reimagine the school's parking lot that meets higher fuel efficiency expectations and present your schema in the form of a PowerPoint or Comic Life document.

Activity 1: What are our existing habits regarding petroleum consumption for transportation?

The hook for this activity is to ask students as homework the day before to decide on a dream car and to bring in a photo of it along with the make, model, and year. This information will be used for homework later. Students (male and female alike) are always excited to talk about cars.

During this activity students will establish a baseline of fuel efficiency and carbon footprint data for the remainder of the unit by conducting and analyzing a field assessment of average fuel efficiency of vehicles in school parking lot.

Students will be assigned to a section of the school's staff and student parking lot and will record the make, model, and an estimate of the year derived from information on the rear lights. When students return to the classroom, they will utilize data available at http://www.fueleconomy.gov/feg/findacar.htm to estimate the average fuel economy (mpg) and carbon footprint (tons/yr) of the vehicle sampling. It is important during this activity to engage students in a discussion of parameters included (average mileage) and excluded (topography, driving habits, city: highway ration) included in the case study especially in meeting standard 3.1.12.A that deals with the evaluation of models. The result of this phase of the unit is a) an estimate of the gallons of fuel utilized by the school community annually and b) an estimate of the tons of carbon emitted to the atmosphere by commuting to/from school.

Logistics: Students will form their own groups of 4 students each- and take a data table, clipboard, and map outdoors. Teachers may also want to provide groups with a piece of sidewalk chalk to demarcate their section from other sections. Once students have completed the basic information on their data sheets, they will enter that data into a collaborative Google document (http://docs.google.com). Between going outside and looking up cars, the students will determine what we will need to know to calculate the annual fuel consumption and carbon footprint for school transportation given the data collected from the parking lot. Students/teacher can decide whether to assume for the sake of the activity that all students and teachers drive independently to school or whether to include some amount of carpooling, public transportation, and bike transit. This can be accomplished by multiplying final results by a decimal factor agreed upon by the class. Rows for each group must be pre-assigned to avoid overlap and inadvertent deletion of data. The teacher will edit out any gaps or errors to the data table and groups will add data from fueleconomy.gov to the document for homework. In class, averages for the entire spreadsheet can be calculated.
Students will need these averages for comparison in their final unit project (activity 5.) The homework assignment following this project is for students to look up the fuel economy statistics for their dream car. The warm up activity on the following day would be to compare the current parking lot with the dream car scenario.
Questions to answer before continuing on are:

a) What was the average fuel efficiency of the CHS "fleet"
b) Does our "fleet" meet current C.A.F.E standards? (be careful to factor out any vehicles weighing over 8,500lbs.
c) If the current assemblage of vehicles at CHS do not meet C.A.F.E. standards- what are some explanations for that? (answers should include consumer preferences, car company funny business, personal habits, etc.)
d) What are the ratios of vehicle classes in the CHS parking lot?

Names ____ Period ____ Date __________

Car Survey: What cars does the Central HS population choose to drive?

Objective: Determine the cars that the CHS population drives based on current decision-making processes? Estimate the year by looking at the date on the rear lights. Once field data is collected, personalize your settings according to the parameters we decide on in class at http://www.fueleconomy.gov/feg/byfueltype.htm. Then look up each vehicle on your data sheet and record the associated use of fossil fuels and carbon footprint in each scenario using the resources available at fueleconomy.gov.

Based on Survey			To be filled in using fueleconomy.gov		
Make	Model	Year (guess)	Mpg (city)	Carbon Footprint (tons CO_2/yr)	Carbon Footprint Based on calculations

Mark the location of your section on this map

Activity 2: What nonrenewable resources do we rely upon for transportation (oil).
This activity is intended to give students the foundation of knowledge needed to later contrast alternative technologies with existing technologies. Through PowerPoint lecture and associated discussion students will discuss where oil comes from, who are current producers and consumers, and why oil is a non-renewable resource. Students will be able to defend the position that oil is a good choice for transportation fuel with supporting details.

Activity 3: Why do our vehicular choices matter?
During this teacher-centered phase of the unit, students will explore 3 compelling explanations for why fuel economy and carbon emissions matter. The first is that petroleum is a non-renewable resource and that every dropped used is one that will not be replaced. This concept is described very thoroughly in the "Precious and Nonrenewable" chapter of the film and can be reinforced with a PowerPoint presentation. The second is that U.S. consumption of oil is sated by more foreign than domestic sources- placing the country in often-trepidatious political and economic positions. The limited U.S. production of oil is made clear in chapter 3 "From Boom to Bust" and an interactive feature produced by the New York Times is excellent for an exploration of our current sources. Following a discussion of the modern geography of oil chapter 4 from ACA "Magnet for War" provides fodder for discussing the implications of unequal global resource distribution. The third content objective is understanding the contribution of gasoline/diesel combustion to the carbon cycle and the greenhouse effect. This concept is very well described by
Robert Krulwich's series on National Public Radio about carbon. He describes how the chemistry of the carbon atom results in our problems with global warming in 5 short animation episodes (Episode 5: What We Can Do About Global Warming , Episode 4: When Carbon Falls in Love, the World Heats Up,
Episode 3: Break a Carbon Bond and -- Presto! -- Civilization, Episode 2: Carbon's Special Knack for Bonding)

The above concepts will be introduced while viewing fragments from the film "A Crude Awakening" and must be reinforced with lecture, discussion, and additional resources. Students should complete a viewing guide while watching the film to help them focus on the major understandings.

Sample questions to check for understanding include:

1. Describe the greenhouse effect mechanism in paragraph form and a diagram.
2. What are 2 reasons to be concerned about use of petroleum for transportation?
3. What is peaking out? What are the causes and consequences?

Name ____ Period ____ Date _______________

A Crude Awakening

Before Viewing:

● List 5 products that are derived from petroleum

● Where and when do you think commercial petroleum extraction first occurred at modern industrial rates?

● What is one reason you think petroleum consumption is problematic?

While Viewing:

Precious and Non-Renewable

● When was most of the world's oil formed?

● How is oil made (according to Don Clark)?

● How "potent" is oil in terms of manpower?

Magnet for War

● 17: 00 Outline the evidence the filmmakers present in support of their thesis "Oil fuels war and it also intensifies war and encourages war."

● 23:00 What do you think is meant by proven, probable, possible reserves-?

● What are the reasons a country would exaggerate how much oil is available?

● Who/what is OPEC?

Peaking Out

● What is peaking out?

● Draw the discovery and production curves. Label Hubbert's peak, the date when oil discovery peaked, and the U.S. production peak (barrels/day).

● What do the most recently discovered oil fields have in common?

● What kinds of technological tools exist to enhance production?

● What is the difference between producing oil from free flowing oil fields and tar sand (as in Canada)?

● 37:00 Where is the only remaining part of the world that has not yet peaked? Middle east

After Viewing:

● Which of the arguments in the film do you find most persuasive? Why?

Activity 4: In this student-centered activity, student groups will be assigned specific alternative fuel or efficiency-technologies to research and present to the rest of the classroom on the following points.

How does the technology work?

When was the technology developed?

What is the current status of the technology- what second generation improvements are being made?

What are the affordances of the technology?

What are the constraints of the technology?

What vehicles are available on the current market?

What do the reviews say about currently available vehicles?

How practical is this vehicle in the Philadelphia area? Why?

Students will break into groups of their own choosing and select a technology out of a bag (hybrid electric vehicles, electric vehicles, ethanol (FFV), biodiesel, fuel cell, compressed natural gas, hydrogen). The student group will create a PowerPoint presentation and interactive activity that provides the class with an understanding of that technology. The purpose is to present students with the information they need to make decisions in the final activity. Students will use laptops in class and continue research and preparation for homework.

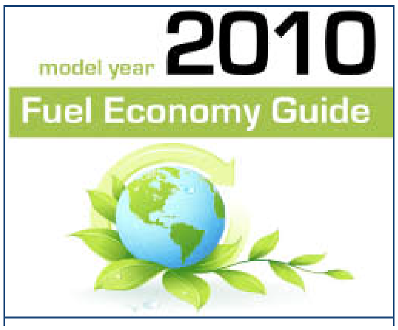
It is important to review with students how to select information from high quality resources and cite properly before beginning research. Success in these sorts of projects also revolves around giving students reasonable and firm deadlines to help structure their work. Day 1 - background research , days 2 & 3- half of the group works on the powerpoint while the other half works on the interactive activity. Days 4 & 5 presentations.

Rubric

TRANSPORTATION ALTERNATIVES	1	2	3	4	5
Research: The following questions were answered accurately, in detail, and cited How does the technology work? When was the technology developed? What is the current status of the technology- what second generation improvements are being made? What are the affordances of the technology? What are the constraints of the technology? What vehicles are available on the current market? What do the reviews say about currently available vehicles? How practical is this vehicle in the Philadelphia area? Why?	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___	___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Presentation/Activity: Communication of this information was clear, appropriate level, and engaging to the class					
Professionalism: The group worked well throughout the project. Workload and responsibility was shared equitably among students. The group was ready on time for the presentation and activity.					

Activity 5
It is important that in the final activity students are familiar enough with the technologies and vehicles on the market that they can spend the majority of their time discussing advantages and disadvantages of their proposed plans and creating their final product rather than learning content or how to navigate resources. This web-quest activity is intended to reinforce student's knowledge from the previous presentations while providing them with some time to become familiar with the actual vehicles available on the market. It is best to let students use the pdf online (avoid wasting paper) but if technology is limited, a hard copy is always available for printout.

Name ______________________________ Period _________ Date _____________



Fuel Economy Guide 2010
Published by U.S. Dept. of Energy, Office of Energy Efficiency and Renewable Energy, U.S. EPA

Go to **fueleconomy.gov** and click on the icon that looks like the one to the left in order to download it as a pdf file. Use the fuel economy guide to answer the following questions.

Introduction (p. i)

- What assumptions does the government make about how and how much the average American drives and current fuel costs?

- How do your (or your family's) driving habits compare to the federal government's assumptions? Be thoughtful and specific.

- What types of practices can lower a vehicle's fuel efficiency?

a)

b)

c)

d)

e)

Tax Incentives and Disincentives (p.4)

Incentives:

• What tax credits are available from the federal government to encourage new vehicles on the market?

$ 3,400 for ____

$ 4,000 for ____

• What type of AFVs are not eligible for alternative fuel credits?

• Why do you think the government offers stronger incentives for certain vehicles compared to other types? Be thoughtful and specific.

• Do you agree with the tax incentives as stated in the guide? Why or why not?

Disincentives:

•What is the Gas Guzzler Tax?

• How long has the Gas Guzzler Tax been in effect?

• Scroll through the part of the guide where vehicles are listed and find 3 vehicles that are subject to the Gas Guzzler tax. List them below.

Make	Model	Mpg (city/hwy)	Carbon footprint

• What are 3 reasons the federal government believes you should consider fuel economy?

1.

2.

3.

• Which of the above reason do you find most compelling? Why?

• What kinds of fuel alternatives or special information does the report include? Examine the abbreviations box on p. 5 and write what each stands form

CNG	E85	FFV	Gas
HEV	P	Tax	Li-Ion

Fueling Options: read the sections indicated and take your own notes in the space below (if there is not enough room, feel free to use an additional sheet)

<u>Ethanol Blends (E85, E10) p. 3 & p.18</u>

• Also- choose one vehicle that comes in FFV and non-FFV varieties. What do you notice about mpg between the two versions and the cost of fuel?

• Given what you noticed above, why do you think there are so many FFV vehicles on the market?

<u>Biodiesel p. 3</u>

<u>Compressed Natural Gas p. 22</u>

<u>Diesel p. 23</u>

Hybrid Electric Vehicles p.17

Fuel Cell p. 22

- Scroll through pages 5-16 to get a sense of all the cars on the market. Look for AFVs (they are highlighted in green to make your life easier) hybrids are not highlighted, so you will have to search for them
- Roughly how many new cars can American's choose from in 2010? ___________________

- Roughly what percentage of the American car market can be considered "green"? (Show calculations)

- Pages 17-22 sort out each AFV by type. Use those pages to organize information in the following table.

	# models on the market	Avg mpg (city/hwy)	Biggest advantage	Biggest disadvantage
Ethanol Blend (FFV)				
Diesel/Biodiesel				
CNG				
Hybrid Electric Vehicle				
Fuel Cell				
Electric Vehicle				

Pick a New Car

• Research other vehicle options using the guide. Select a car you would buy if you had unlimited financial resources, then pick the car you would choose if fuel economy was a top priority. Calculate the improvement in city/hwy mpg, and the annual fuel savings you would get by buying the second car.

	Make / model	City/Hwy mpg	Annual Fuel $
Dream Car		/	
New (Environmental) Choice		/	
Difference (calcs)	--		

• Why did you choose your particular dream car?

Activity 6

This is the culminating activity for the unit. It is really important that students know from the beginning of the unit that the purpose of every activity throughout is to gain the knowledge and skills needed to complete this challenge. Students will have 3 days to create a project that explores and communicates the current state of Central's parking lot to the best case scenario that meets or exceeds current C.A.F.E. standards. Students should be able to make their decisions on the first day and spend the next two class periods constructing their poster or document to communicate their findings. During the last day (day 4) students will present their work to the class and critique each other's decisions. The work created during this unit will additionally be saved and displayed during the school's Earth Day celebration.

Directions:
Imagine a world in which our parking lot met or exceeded current C.A.F.E. standards. What would it look like? What vehicles would it contain? And most importantly, what difference would it make in terms of the environment and possibly our lifestyles? Help the school community envision this alternate reality by creating a poster that communicates the following information.

1. Compare the raw data for the current parking lot and the alternate parking lot in terms of # of vehicles representing each category (this must be kept constant), average fuel economy, annual fuel cost, carbon footprint. Compare the # of vehicles representing the available technologies (conventional combustion engine, diesel, hybrid, electric vehicle etc.)
2. What is the environmental and economic impact of our current parking lot in terms of a) fuel consumption and associated issues b) carbon emissions and associated issues.
3. A discussion of the vehicles or technologies you chose for your future scenario and their specific affordances.
4. A discussion of the vehicles or technologies you left out and a discussion of why.
5. A conclusion that makes clear the meaning of your modeling experiment (that's what this is) and what people can do in lieu of purchasing your suggested vehicles.

Be sure to back up all information and opinions presented on your poster with solid research and citation. I recommend the use of comic life because of the flexibility, creativity, and professional products it makes possible. If you prefer to use another medium make sure you get it approved by me prior to beginning.

Annotated Bibliography

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"Energy Statistics by Country" Retrieved June 2010 from http://www.nationmaster.com/cat/ene-energy
provides oil production/consumption data by country and totals

http://www.fueleconomy.gov/
This site is absolutely incomparable. The unit is basically built around it. It provides information about all cars available in the United States, explanation and links that explain how vehicle technologies work, and an emphasis on the environmental impacts of driving. In many cases there are also links to refer to about each vehicle.

http://www.pbs.org/wgbh/nova/car/effi-flash.html
Nova Fuel Inefficiency- interactive feature (especially propulsion section)

http://www.afdc.energy.gov/afdc/
Alternative Fuels and advanced vehicles data center

http://rpm.nrel.gov/transatlas/launch
interactive atlas of alternative fuel stations

http://www.eia.doe.gov/kids/index.cfm
Very simple website the explains the basics of energy including what it is, sources, history, using/saving energy, and a conversion calculator/

"A Map of the Oil World" Retrieved June, 2010 from http://www.nytimes.com/interactive/2007/11/06/business/20071107_WINNERSLOSERS_GRAPHIC.html
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This is a great resource for current data about peopulation, oil resources, etc.

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A good website for understanding the environmental impact of coal for electricity production

New York Times. Nuclear Energy. Retrieved June 2010 from **http://www.nytimes.com/info/nuclear-energy/?scp=1-spot&sq=nuclear%20energy&st=cse**
I could write an entire paper on how great the New York Times is as reference. The Times Topics sections not only include proofread and fact checked background information but also contain links to the most recent developments in the topic and really approachable multimedia supplements.

EIA Energy Kids- Energy Timelines. Retrieved June 2010 from **http://www.eia.doe.gov/kids/energy.cfm?page=timelines**
Provides the historical context of coal, electricity, ethanol, nuclear, oil, photovoltaic, geothermal, municipal solid waste, wind, wood, natural gas, and transportation energies.