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Renewable Energy in Connecticut – Softening Our Footprint through Sustainable Energy Use

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Rationale:

Currently, all 9 th graders enrolled in the New Haven Public Schools take a course called physic/chemistry (phy/chem), as their science requirement. Its curriculum is designed to tie together their last 5 years of science education, while preparing them for the Connecticut Academic Performance Test (CAPT). Phy/Chem stresses general knowledge of energy, energy flow, simple physics, and basic chemistry focusing on atomic structure, all the while stressing scientific inquiry and the application of the scientific method.

The last three units of phy/chem develop the ideas of how energy is used, how electricity is made, and the environmental impacts of our energy use. The students currently enrolled in New Haven Public Schools need to have a very vested interest in energy and its environmental impacts as they are seemingly inheriting the problems of previous generations' unsustainable use of nonrenewable energy sources.

The average 9 th grader in New Haven faces overcoming a large disconnection with this material. Up until this point in the curriculum, the concepts are mostly concrete, and hands on activities can at least model and demonstrate most concepts, while laboratory activities that solidify the scientific method, offer extensions of hypotheses made by students. When the curriculum lands on energy, however, it all becomes lost with concepts that are to big for the students to relate to or affect them in their daily lives.

Electricity, and its use, is of particular difficulty. There are endless demonstrations up to and including shocking students with a small converter to making small machines, but crucial to this unit is that students understand how electricity is created. Since, in the United States and other developed nations, electricity dominates as the most frequent form of usable energy, and most of our fossil fuel resources are devoted to electricity generation, this unit will focus on how our electricity generation can be moved away from fossil fuel or at least supplemented by renewable energy.

In order to make the content of this unit available to students in New Haven, it will be necessary to bridge the ideas of renewable energy to residents of Connecticut. The idea of a wind farm in Texas is not relevant to the average 15 year old in New Haven. But analyzing the energy use of a New Haven resident compared to the rest of the citizens of the world, or investigating the feasibility of a wind farm in Long Island Sound, brings this topic to a practical level. Currently, most of our energy use is in the form of electricity, and more than half of our electricity is generated by coal. This is an unsustainable practice. In this unit, students will investigate different forms of renewable energy, and their practicality in Southern New England.

Unit Objectives:

As a result of this Unit, students will be able to explain the consequences, both good and bad, of using fossil fuels to produce electricity, while learning to understand and being able to identify long-term effects of fossil fuel use as well as short-term impacts such as acid rain and its effects on the environment.

As part of a culminating lesson, students will describe various alternative energy sources and their consequences, as well as assess the reliability of the data that was generated in the investigation, using this information to communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic.

Overview:

Spin generator, spin!

Electricity is the flow of charged particles. Students can draw on prior knowledge of atomic structure, to understand that electricity is essentially electrons moving down a wire. Our energy consumption is tied to the simplification of Newton's law that "energy cannot be created or destroyed"; hence, we do not make electricity, we convert energy in one form (fuel) to energy in a usable form (electricity) (Trainer, 5).

All power plants, traditional fuel or nuclear, use their fuels to boil water to create steam. The steam is compressed and piped along the fans of a turbine, which is connected to a generator. As the generator spins, a series of magnets excites coils of wire to move electrons. In the case of a coal fired power plant, chemical energy is converted to heat, heat converted to mechanical energy, finally to electricity. Only photovoltaic systems do not require the use of a coil generator. All of our electricity needs are as simple as finding innovative, clean, sustainable ways of spinning the generator to create electricity.

Sustainable vs. Renewable vs. Green Energy

Whenever energy is a topic, alternative forms of energy to fossil fuels are often referred to as renewable, sustainable, or green. Though used so, these words are not interchangeable. Sustainability is a concept referring to the long-term viability of fuel option; it will not run out, and have minimal or zero environmental or ecological impact, and, thus, will be available to future generations. The most natural forms of energy, such as wind, tidal, and solar, will never run out as long as our planet receives solar energy (Elliot, pg xvii).

Use of the word renewable can cause some confusion. Energy sources can be renewable, such as from bio-fuels, but not sustainable or environmentally fiscal. It could be argued that fuels made from intensively farmed plants, such as corn to make ethanol, could be as environmentally harmful as burning coal it you take into consideration the water requirements, transportation needs, petrochemical fertilizer requirements, soil degradations, farmland that could be devoted to growing food, and subsequent emissions. Though the fuel itself won't run out, and for the most part can be grown indefinitely as long as it is replanted, it is not sustainable.

Green energy is often used to describe energy sources that are environmentally safe. In the current media, much attention has been paid to CO_2 emissions and their roll in global climate change, and the term green is often used to describe something that does not cause excess production of CO_2.

All sustainable energy forms are renewable and green. They will not cause long term or extensive environmental damage, their fuel source will not run out, and will be available to future generations.

Potential for Renewable Energy in Connecticut

When students are considering sustainable energy options, they will most likely apply the viability to their surroundings. Students having been raised in view of the Long Island Sound will no doubt be most curious about (and most anxious to exploit) tidal and wind energy. The reality is that with the appropriate leadership and infrastructure, all forms of sustainable energy are available to everyone in some capacity. It is important that students are familiar and comfortable with the concepts of electricity as the needs of society change. Below, background information for each form of sustainable energy will be discussed, followed by a brief description of its viability in Connecticut. In the teacher resources will be a list of websites and resources allowing this educational unit to be applied to other states.

There are intentional omissions or brevity of certain possible sustainable energies. Hydrogen power is generally regarded as non-feasible and is an inappropriate topic of study for this grade level. Niche hydropower is unrealistic as a large energy source and is discussed in this unit for the teacher's discretion. Solar power is discussed in the background to bring the teacher up to speed for classroom discussion. Geothermal energy in most locations in the United States is sparse and unattainable besides small local projects and is omitted. Any of the sustainable energy forms may not be relevant to certain geographic, demographic and ability level competencies, and should be developed or omitted accordingly to facilitate learning and discussion. For 9th grade science national standards, an understanding of the overall function and use of renewable energies, especially wind and solar, is considered the goal of learning, and being able to forecast use, pros and cons, and realistic applications of them is advanced for the grade level (Trainer, 97).

How much is that? The watt, megawatt, terawatt, and the oil equivalent

Before embarking on comparisons of energy sources, developing units of measurement as part of the curricula language is imperative. It is up to the individual instructor to decide if actual comparisons in real terms are realistic for the student base. Simple ways to discuss power sources would be to consider them in their oil equivalent. But even this is difficult for most students to consider, and looking at global figures often distance students further. Looking at a household, however, may be more realistic and providing students with workable numbers and letting them extrapolate these to larger regions, states, and countries (even if the total figures don't quite work out correctly) makes the data more accessible.

A watt (W) is a unit of measurement for power, used internationally, to measure electricity use. Watts are a present tense unit, whereas watt hours are used to measure energy use over time. A 50 watt bulb is using 50 watts of electricity each instant and 50 watt hours each hour. Utility services bill in kilowatt hours (kWh), with each kilowatt hour being 1000 watt hours. Power plants generate electricity in megawatts (MW), or 1000 kilowatts. 1000 megawatts can be measured in gigawatts (GW), some large scale power plants produce several GW; a nation's output of power from a particular source may be several GW. 1000 GW is measured in terawatts (TW), the total power consumptions by humans in 2005 was roughly 16 TW, with the United States accounting for 1.6 TW of consumption alone. All of these can be put in terms of watt hours. Sustained generation of a gigawatt for one hour is a gigawatt hour. A home using 5 kilowatts continuously for one hour will be billed by the utility company for 5 kWh (Nersesian 16; Hoffman 63).

How much his ours?

As human society becomes more and more of a global society, it should be noted that there is still a strong distinction between the haves and have-nots. Human use of fossil fuels having an effect on global climate is no longer debated, and its results will certainly be a global issue, yet distribution and use of fossil fuels is not equal globally.

The developed nations of the world use the lion's share of fossil fuels, and besides petroleum which is used predominantly for transportation, these energy sources are used to make electricity. The United States in particular uses roughly 10% of the global energy output with only 4% of the world's population, while one third of the world's population does not have in-home electricity. Furthermore, our current fossil fuel based energy policy is by no means sustainable. Not only do we depend on depleting fossil fuel reserves, we must import much of the petroleum need for transportation. It is in our nation's best environmental and fiscal interest to lessen our dependency on unsustainable energy use, and be a global leader in environmental stewardship by converting as much of electricity generation as possible to renewable and sustainable energy sources (U.S. EIA).

For students to consider these facts and figures in terms of change of practice and conservation can be unreasonable. Adolescents do not often consider themselves a part of community let alone a national or planetary movement. But redesigning the practice at home, and looking at the state they live in, makes these ideas accessible. An examination of electricity use and its method of generation is the obvious point of change for a movement towards sustainability. Reduction in energy use through change of habit and consumption choices such as efficient appliances can result in obvious reduction in power use. Since electricity accounts for a large part of total energy consumption, focusing on electricity generation at the students' state level and how sustainable practices could be applied offers a realistic path to study energy and electricity generating resources.

The Non-Renewables

Fossil Fuels

Millions of years ago carbon in the form of plants and animals, often micro-organisms, was buried under layers of sediments. After being subjected to immense heat and pressure, the organic carbon in the organisms, trapped in layers of non-porous rock formed oil, coal, and natural gas, depending on the conditions and ingredients. The carbon atoms stored in the bodies of ancient organisms, can provide an energy rich fuel when burned. Currently, our society is almost entirely fossil fuel dependent. The amount of energy that can be obtained from burning fossil fuels is immense considering they are essentially free; they only need to found and removed from the ground. It could be said that life as we know it could not be maintained without the use of unsustainably harvested energy from fossil fuels. The human population has been growing nearly exponentially since coal became widely used.

Once fossil fuels became the main source for generating electricity, their use continues to grow. Remember that in order to make electricity, source energy must be used to spin in a generator. In the cases of oil, coal, and natural gas, all three are used as source energy to heat water to create steam. The compressed steam is used to spin the turbine attached to the generator. Most of the coal use in this country is for electricity generation, while natural gas is mostly used as a heat source for buildings, and oil is mostly refined for use as a motor vehicle fuel. All three are used for electricity, and all three emit carbon dioxide when burned contributing to the greenhouse effect.

Coal naturally has a high sulfur content; how much depends on the content, source location, and formation process. This sulfur contributes to acid rain and the particulate content in its emission is a heavy contributor to smog and particulate pollution. In Connecticut, coal represents around 5% of the total energy used, but nearly all of that is used to generate electricity. As this unit is focusing on alternative sources of electricity, coal should be targeted as not only a polluter but as an energy source that needs to be reduced. Coal's availability and its high energy content make it the ideal source for our society to wean onto long term sustainable projects, and the vast stores found in the United States make its intensive use practical in the short term. The idea that electricity must be readily available, and cannot be readily stored, lends itself to the likelihood that coal fired electricity power plants are a necessity in the immediate future.

The conservation minded student will quickly attribute oil as the fossil fuel we are most dependent on, and the one that will be hardest to reduce or eliminate from our society. While it does not play as major a role in electricity generation, it is hard to find anything that does not owe it existence to oil. Polymer based plastics are made from oil, and nearly all transportation is fueled by oil. Most personal vehicles run on gasoline refined from oil, and the chemicals we use to fertilize our crops are petroleum based. It is gasoline that represents the largest sink of oil use, especially in Connecticut. Diesel fuel is used by most commercial vehicles and public transportation, but the automobile and SUVs, are the vehicles that are using most of the fuel. Any practice in changing the way we think about the car, a mere 10% reduction in driving, would substantially impact the amount of petroleum used in our country.

The cost of oil, and gasoline, is hard to fathom and is not represented at the pump. We simply do not pay the true cost of oil. The environmental impact of the millions of barrels per day consumed is often ignored. The 2010 Gulf of Mexico oil spill is a glaring reminder that our reliance on oil is often blameless, with no particular entity to bill for the damages caused. Security for oil exploration in often hostile areas of the world is financed by the United States Government and not at the gas pump. Hugely increased asthma rates in our country, often attributed to pollution from combustion, and the increased medical cost is not included in price per gallon of unleaded gasoline. These factors, coupled with the fact that we use more each year of a finite resource, show that our reliance on oil can only be temporary. It is unreasonable to think that through change of habit we can curtail oil use any time soon, but not unreasonable to see that our reliance on oil will be forcibly reduced because of its scarcity in the coming years, certainly within the lifetime of current high school students.

Nuclear

The often misunderstood nuclear power is sometimes considered to be a sustainable energy source. It is often billed as a cheap and clean form of energy. It must be noted that nuclear power is capable of generating huge amounts of electricity that is carbon free. The benefit of nuclear power is its capability of generating massive amounts of electricity from a single plant. In 2004, the United States represented 24% of the world's electricity usage. That year the typical peak demand was about 800 gigawatts, with a base demand at any time of 500 gigawatts. A single nuclear power plant can handle the base-load needs of a 600,000 person city at any time. This means fewer plants are need in the long run, and only supplemental energy is need at time of peak use (Nersesian, 275).

Nuclear power has the drawback that, while it can produce large amounts of power, it is not fail safe. A single nuclear power accident, though rare and unlikely, can be devastating. The fuel needed to make the nuclear reaction, to boil water to make steam similar to a fossil fuel fired plant, is not easily obtained. Though not considered rare, uranium is not so voluminous that it could be considered sustainable. 25,000-100,000 tons of ore must be mined to produce the required 200 tons of uranium to run a typical 1 gigawatt nuclear reactor for one year. This will produce an annual waste of 25-30 tons of highly toxic, radioactive material. The immense cost and risk of transporting and storing nuclear waste, and the risks (albeit low but possibly costly ones) of a nuclear accident, make nuclear power far from sustainable. Reserves of uranium could last for over a century, but as with other forms of power, reserves empty faster as use and need increases with population. IF typical base-load electricity needs of the United States were satisfied with nuclear power alone, it would require more than 500 large-scale nuclear reactors producing 15,000 tons of nuclear waste each year. Waste and effluent from mining operations would be measured in millions of tons, and waste water pollution at non-point source locations is nearly immeasurable. Connecticut relies on nuclear power for almost 50% of its electricity power needs, with natural gas, coal, with fuel oil picking up the balance in order of most used. With only one small reactor operating in state, nearly all of the inherited risks and cost are outsourced to other locations for waste disposal, making this an irresponsible and in no way a sustainable source of energy (EIA, 2010; Nersesian, 277; Sweet, 181).

Solar

All sources of energy can be traced to the sun. Fossil fuels are derived from plants that stored solar energy and organisms that consumed plants. Wind, water and tides move because of weather and water cycles that are ultimately powered by the sun. As our needs grow for sustainable energy, it only makes sense that we should be looking for ways to exploit a nearly limitless supply of energy that enters our atmosphere daily. One of the most difficult aspects of providing electricity to millions of people is the fact that it must be produced instantly as it is needed, cannot be easily stored, and does not transport well. Using solar power can overcome some of these challenges, and certainly offset the costs of using fossil fuels in the immediate future.

Most student texts provide information on solar power being used either actively or passively by the individual homeowner. Passive solar designs have no mechanical parts, buildings can be designed to provide warmth and light from the sun by positioning the building to allow light to enter while reducing heating cost. Designs often account for shade during the summer months to aid in home cooling. Active solar power refers to a more extensive use of the energy, sometimes making electricity directly (Pahl, 34).

Active solar power is comes in two primary types, using solar energy to heat water for heating or to make steam to generate electricity, and the direct conversion to electricity. Using photovoltaic cells, panels of layers of semiconductor elements, often silicon, whose electrons excite when irradiated by the sun engaging the flow of electrons through a conductor, can convert solar energy directly to electricity. Currently, photovoltaic cells are expensive and not incredibly efficient, but once installed can generate significant amounts of electricity to a local user. Technological advancements in photovoltaic cells have allowed them to convert upwards of 15% of incoming solar radiation to electricity. Though unrealistic to think every home could become its own power plant, looking at data suggests that even small solar panels installed on rooftops could significantly reduce importation of electricity from large-scale power plants (Pahl, 38).

Solar power as a large scale industry is using several emerging technologies. Large mirrors that move to catch the sun and direct it to a receiver that heats water for steam can produce power in the 100 megawatt range. Solar power towers that direct sunlight to melt salts to "store" energy for late use are becoming more common in the western United States. Solar chimneys, large tubes that move are upwards dues to temperature differences, spin turbine-generator apparatus to conventionally make electricity. By using mirrors to direct and intensify solar power, Brayton and Stirling engines can turn generators and make electricity, only limited by space for mirrors and availability of sunlight. The idea of using solar power to assist the hydrogen fuel cell bring hope that solar efficacy can be increased by the ability to store usable energy (Trainer, 100).

The limitations of solar power are largely based on geographic location and climate. True solar power plants, or solar farms, can be constructed to make large amounts of power that rival conventional power plants. But even these are limited if cloud cover is significant. Covering the American desert in photovoltaic cells is not the answer to the questions of sustainable energy as the transportation of power and energy lost in the form of heat (some estimates put 1/3 of all electricity generated as losses in transmission) as it is transmitted. Again, large plants of photovoltaic panels will reduce the efficiency by location alone: places where they could be sensibly put where there is room and sunlight are often not where the power is most needed, and energy lost in transmission reduces the efficacy of large solar farms as a significant power source, especially in the northern climes and densely populated eastern United States (Elliot, 109).

Solar power in Connecticut is an under utilized source of power. Obviously, the climate in the northeastern United States is not conducive to large-scale solar power plants, but the population and housing of Connecticut gives it a serious advantage. Individual homes can be heated using solar power effectively, and photovoltaic cells on rooftops can provide power during peak daytime energy periods. Large scale solar farms are not necessary in the state for solar power to be utilized, and the space and climate needs do not make large scale solar a viable option. The Department of Energy reports that less than 1% of Connecticut's power comes from renewable resources and far less than 1% if biomass and hydropower are removed from that figure. When considering how Connecticut can move towards sustainability, solar power should be impressed upon to meet these needs.

Wind

Like any source of power that is considered sustainable, Wind power can make electricity from a source that is essentially free, has little or no chemical pollution, and is hampered only by a large initial investment that can be recouped through generation of electricity with next to no overhead costs besides routine maintenance. Wind turbines, both large and small, operate by harnessing the wind on the blades of a propeller and using the kinetic energy of moving air to spin a turbine and a generator to make electricity. Besides the low impact nature of this power source, it is simple and readily available. While being mostly benign environmentally, wind power has many opponents citing wind turbines as unsightly, noisy and dangerous to migrating populations of birds, not to mention as unreliable as the wind. This aside, used in conjunction with other renewable forms of energy, wind power can great reduce reliance on fossil fuels.

The largest problem with wind turbines is that the wind must be in the optimum range to reliably produce power. Too much or too little wind and efficiency can be reduced to zero, and variability minute by minute means all of the wind is not going to be converted to electricity. A single wind turbine can be at best an erratic source of power, but the erratic nature is reduced when several turbines are spaced in an area of high average wind-speed. Spacing of wind turbines near, but not to close to, developed areas make them ideal in that power is not lost significantly in transmission (Trainer, 21).

Large-scale wind power plants generally require Class 4 wind power density (13 mph sustained yearly average) to be considered viable, and any smaller project to be connected to the grid must be between Class 2 and Class 3 (greater than 11 mph sustained yearly average). Roughly one third of Connecticut sits in Class 3 Wind Power Density. Even if large-scale wind farms are impractical, small wind projects can offset electricity production (DOE, 2010).

Hydro

The concepts of potential and kinetic energy should be familiar to high school students. Hydroelectric power works by harnessing water and storing it in a dam (potential energy) to release it through a turbine to spin a generator (kinetic energy). This source of electricity is clean and renewable, producing no greenhouse pollution, though not without environmental opposition. It is unlikely that any new hydroelectric power projects will be attempted. Not only are dams obtrusive and potentially devastating to downstream ecology, they are expensive and most sites that have potential to provide large amounts of energy have already been tapped. In 2002, 7% of United States electricity generation came from hydroelectric power. This figure will not continue to grow due to no planned major projects, but hydroelectric power is not removed from being a major player in power production (Pahl, 7).

The reality with hydroelectric power is that what is developed is all that will be developed. As our energy needs grow, hydroelectric dams will represent a smaller and smaller portion of our power needs. There are ways to still tap the energy stored in water in less conventional ways.

Micro-hydro

Mini generators placed in small streams, or small scale water diversions are becoming popular mechanisms for electrical generation in remote areas. Small systems that can generate 1 kW of power from a small stream head can be set up in almost any moving stream. Though this by no means will ever be a source of power that can wean an energy hungry society from fossil fuels, it can contribute to public energy systems, municipal and public power needs such as street or public space lighting or other application removing some drain from the grid. As students work on a culminating project, they should look at ways to get more and more power from renewable means. Micro-hydro represents an electricity generating system that they can relate to, and even build; and it should be presented to students. The small generating capacity of these projects helps in realizing how much power we need and how small scale renewable energy sources will not take the place of fossil fuel generated power plants on our energy budget (Pahl, 119, 122).

In Connecticut, many towns have old mill ponds that were used to operate machinery such as mills and grind stones. These dams hold a substantial amount of water head that could be retrofitted with electricity generators. If each town possessing a mill pond would invest in the retrofit process, upwards of one hundred 10 to 500 kilowatt generators could be functioning in Connecticut. Targeting dams that are in place but non-functioning would not add ecological stress to the environment, while delivering clean and reliable power to the states energy budget (U.S. EIA).

Tidal and Wave

The mere fact that the ocean covers roughly 70 seventy percent of the Earth's surface and is constantly absorbing solar radiation suggests that it must contain vast stores of usable energy. True, kinetic energy in tides, currents, and waves and thermal energy in temperature differentials are vast, but do not currently represent a significant form of attainable energy.

Tidal power can be used by damming incoming tides to create a head of water when tides recede. As the tide goes out, trapped water can be channeled through a hydroelectric dam and electricity can be generated. Technology using floats to catch the up and down motion of waves, propellers to harness the ebb and flow of tides at channels, and various forms of sluice gates to channel moving water have been developed (Pahl, 131).

The main drawback to all of these technologies is that they must be in areas of a large tidal differential to create a large enough flow to be significant, and in coastal areas that are otherwise likely to be developed. There is one significant source of tidal power in France currently in use producing 240 megawatts of power. Most other tidal sources are in the 0.5 megawatt range and indicative of the problems faced by tidal power. Though Connecticut has a little over 100 miles of coastline on the Long Island Sound, there is little if any undeveloped waterfront property with space suitable for tidal technology. The five main rivers in Connecticut could present the opportunity for small-scale hydro-tidal propeller generators with upwards of 10 megawatts peak production if technology were fully invested (Neirsesian, 324).

Biomass-Can it be sustainable and is it renewable?

Until the industrial revolution, and most specifically the introduction of coal as a fuel source, most of the world's energy came from biomass in the form of burning wood. Reliance of biomass on an energy source has been relegated mainly to niche communities and the less developed nations until recently, when interest in liquid bio-fuels has surged forward as a replacement for transportation fuel.

Energy from biomass, living or once living parts of plants, often lumped together with agricultural and municipal waste, presents itself as renewable form energy. If managed correctly fuels from biomass can be quite sustainable or tragically not so. For students this concept presents itself as an excellent topic for moral or ethical debate: If enough energy could be yielded from the land and any carbon emissions neutralized by the intake of the following years' crop, at what expense are you willing to sacrifice potential food sources to satisfy energy needs?

The idea of introduction of biomass to 9 th graders as a reliable energy source may be the most daunting aspect of this unit because of the variable nature from species to species and the different applications and processes. Yields per acre vary among species and clime. Currently, sugarcane and corn present the most likely candidates in ethanol production. Wastes from the fermentation/distillation process can be burned in biomass incinerators, and add to the energy yield per acre yet reduce the fertility of the soil. When considering biomass and bio-fuel production, one must consider the costs of fossil fuel expenditure in transportation, processing, harvesting, and petrochemical application. It is safe to assume that without some fossil fuel resource, production of enough energy per acre is not possible to make the expenditure viable; especially considering the volume of fossil fuel needed to support our transportation system would require a substantial portion of arable land to grow the equivalent crops necessary (Nersesian, 48).

Students in urban areas will relate directly to the idea of municipal solid waste as a fuel. People living in densely populated areas produce large volumes of waste that is highly visible. Burning municipal solid waste to produce electricity is not a new idea, but an emerging one as a sustainable practice. Even the most optimistic recyclers know that large amounts of energy are wasted by burying our garbage and incineration presents an opportunity for energy recovery. Ash waste after incineration is a reduction in volume, though more volatile and technology in scrubbers to prevent air pollution has improved to make this an important use of resources. Certainly waste is a renewable fuel.

Connecticut currently farms one half million acres of its 3.5 million acre area. Devoting this land to the production of biomass is unlikely, but properly managed cropland can add to the energy budget. Streamlining the waste flow and managing waste collectively, after building a statewide infrastructure for recycling and waste management while maintaining EPA protocol on waste incineration makes biomass a major aspect of the renewable energy slate.

What works for us, what won't, and how to digest it all…

The idea behind this unit is to make students aware of renewable energy, while considering global energy use. Students can understand straight facts of energy use easily and even the reluctant learner can grasp what millions of barrels of oil per day or tons of coal means. Gaining an enduring understanding that no one renewable energy source can sustain current practices is the ultimate goal, that adopting an all of the above strategy for energy while changing habits and practices is the only way to wean our society of non-renewable, unsustainable energy.

Connecticut can represent a microcosm of what is to come. Many people living in a small area make it obvious that all of the resources used cannot possibly come from the area occupied. Only from diligent use of resources, and a reduction of that use, can several million people hope to live sustainably in an area of several thousand square miles.

Vocabulary

Coal- plant based fossil fuel, burned for energy

Conservation of Energy- physics law, energy cannot be created or destroyed

Electricity- the current of electrons flowing through a conductor; usable form of energy

Energy- the ability to change or move matter

Fossil Fuels- any fuel formed from the remains of ancient plant or animal life

Generator- device using electromagnets to convert mechanical energy to potential

Gigawatt- one billion watts

Global Climate Change- an increase in temperature, due to increased greenhouse gases

Greenhouse Effect- process by which the atmosphere traps some of the energy from the sun in the troposphere

Heat- transfer of energy from particles of objects due to a temperature difference

Kilowatt- one thousand watts

Kinetic Energy- energy of a moving object due to its motion

Light- electromagnetic waves, carrying energy through empty space

Megawattt- one million watts

Natural gas- methane based gas, often found with coal and oil, burned for energy

Nonrenewable Energy- any energy source that is used faster than it can be replaced

Nuclear Fission- process that splits an atom in two or more pieces, releasing energy and neutrons

Nuclear Power- electricity derived from nuclear fission

Petroleum- oil, liquid predominately animal based fossil fuel, burned for energy

Photovoltaic- devices that convert sunlight into electricity

Potential Energy- stored energy resulting from the relative position of the object

Renewable Energy- any energy source that can be continually replaced

Sustainable energy- any energy source that can be continually replaced and has little or no effect on the environment or local ecosystem

Terawatt- one trillion watts

Turbine- motor producing torque, used to spin generators

Watt- unit of electric power

Lesson Plans

The following are three suggested interdisciplinary lessons/assessment tools that can accompany this unit. Each lists essential questions that are tied to district, state, and national learning objectives and descriptions of goals. Each of these should be assessed using a simple rubric.

Lesson one- What is Sustainable?

Essential Questions

What are the causes and effects of global climate change?

What is sustainable energy use?

How are population and energy use related?

Crucial to any forward discussion on energy use is a lesson on data and graph formation and interpretation. Students should be instructed to interpret data sets and learn to retrieve data and present it. Below are two example sets of data, one of national energy use for 2007, and another of historical energy use in Connecticut. Either can be used to show energy use over time or to make graphs presenting types of energy. Data sets of this type are available from the Energy Information Administration (link in teacher resources), state administrations, or local power companies. If historical population data are provided, students can make various graphs and look at the relationships of data. Teachers should be sure to provide additional information as needed, and be prepared to provide graphs with units and intervals prepared for special needs students or to account for limited class time.

After the student graphs are completed, direct discussion towards sustainable energy use. Have students discuss rates of resource use versus resource reserve; the effect of increasing population on unchanging reserves; and how energy policy reflects the amount of energy available. This activity provides an opportunity to look at what types of power are currently used, and the trends of their use.

Energy Information Administration updated 12/15/04

Energy Consumption Estimates by Source, 1960-2001, Connecticut

Units in trillion Btu

Year	Coal	Natural Gas	Jet fuel	Motor Gas	Home fuel	Total Petrol	Nucl. Electric	Hydro	Wood/ waste
1960	101.7	29.4	6.4	101.6	91.9	362.4	0	4.6	12.8
1961	107.5	31.4	6.2	103.9	93.5	365.8	0	3.9	13.2
1962	112.1	33.4	6.7	108.4	100.6	379	0	3.1	12.8
1963	117.4	35.6	6.8	112.3	102.3	382.5	0	2.9	13.3
1964	120.8	38.6	6.6	115.6	123.7	392.5	0	2.8	13.9
1965	128.6	41.7	8	120.5	107.9	389.4	0	2	13.5
1966	136.2	48.7	8.7	126	130.8	433.1	0	2.6	13.6
1967	109.5	50.8	9.6	128.8	159.6	469.7	6.1	4.1	14
1968	82.4	54.1	13.2	137.4	176.1	512.5	33.9	3.7	14.9
1969	59.2	584	14.9	142.8	203.9	553.6	40.2	4.4	15.3
1970	48.6	61.5	16.4	150.4	223.8	587.4	39.6	3.5	15.8
1971	36.4	62.4	12.4	155.2	212.6	546.4	84.2	4.1	16.1
1972	4.2	65	15.9	161.8	255.9	607.4	83.9	5.6	17.1
1973	2.6	63.5	14.2	166	272.2	629.8	46.9	4.6	17.2
1974	6.5	67.1	13.8	165.5	236.6	576.8	89	4.5	18
1975	1.3	64.3	12	167.2	204.4	535.7	89.6	5.1	17.1
1976	1.2	66.4	11	171.4	206.2	559.8	136.2	4	19.9
1977	1.2	64.7	12.3	174	202.2	556.2	141.9	4.5	19.6
1978	0.8	66	12	174.5	215.2	569.6	151.7	3.7	22.7
1979	1.1	68.8	13.5	165.4	169.2	541.2	138.2	4.8	24.6
1980	0.4	74.2	11.2	158.7	184.4	510.9	129.1	2.7	35.3
1981	0.9	78.7	8.9	158.9	135.4	447.5	139.8	2.7	36.5
1982	0.8	80.4	6.1	157.9	133.9	443.1	150.9	3.9	37.2
1983	0.7	76.6	5.4	160.4	146.6	434.8	126.4	4	39.4
1984	1.5	83.5	5.7	162.1	157.7	471.2	155	3.9	36.4
1985	21.3	80.6	6.1	162.8	132.3	457.2	135.1	2.8	36
1986	21.2	81.3	7.1	167.4	140.1	475.8	197.5	3.9	31.1
1987	21.4	94.7	10.1	170.3	119.1	470	214.5	3.6	27.1
1988	23.1	90.9	12.2	172.5	137.4	502.4	235.9	3.4	30.6
1989	23.8	102	12.7	169.5	139.3	513.4	207	4.6	30.7
1990	38.5	109	13.3	163.6	104.1	444.9	209.3	6	28.3
1991	38.6	115.8	12.7	167.4	91.3	432.8	128.4	4.5	29.9
1992	39.2	126.2	13	171.2	68.3	429.1	175.6	4.4	34.1
1993	37.3	125.9	13.1	173.9	55.5	406.6	229	4.2	34.2
1994	38.6	134.4	13.9	170.9	47.6	390.3	210.7	5	35.2
1995	40.8	144.9	14.1	159.5	42.8	371.1	197	3.6	43.2
1996	41.1	139.2	15.4	170.4	65.4	422.1	65.4	6.5	48.3
1997	45	148.6	13.4	171.7	92.3	449.2	-1.3	4.5	43.7
1998	32.6	134.9	12.5	175.1	94.2	438.5	34	4.6	42.8
1999	15.2	155.9	13.9	189.1	90.7	463.7	132.5	4.3	43.4
2000	36.2	163.7	14.7	182	74.4	450.1	170.7	5.3	43.4
2001	40	149.4	13.4	184.6	56.8	438.7	161.2	2.9	38.7

Energy Consumption Estimates by Source and End-Use Sector, 2007 (Trillion Btu)

Energy Information Administration

State Energy Data 2007: Consumption (Excerpt, New England States, Sources only)

State	Total Energy	Coal	Nat. Gas	Petro.	Nucl. Elec.	Hydro Elec.	Bio/ Wood / Waste	Geo-therm / Solar/ Wind	Net Inter-state Flow +/-	OTHER
CT	870.7	39.9	184.1	396.8	171.9	3.6	22.7	1.0	45.4	5.1
MA	1514.6	120.1	417.3	684.6	53.7	7.9	35.1	0.8	192.5	2.5
ME	455.6	6.6	47.9	235.6	0.0	36.9	115.5	1.2	0.4	11.5
NH	314.2	44.9	64.6	169.6	112.9	12.5	20.5	0.1	-113	2.1
RI	217.6	(s)	90.8	91.5	0.0	(s)	3.7	(s)	30.0	1.4
VT	162.1	(s)	8.9	87.5	49.3	6.4	8.6	0.2	-7.2	8.5

Where shown, (s) = Value less than +0.05 and greater than -0.05.

Lesson two- The Carbon Footprint

Essential Questions

How do human populations use resources in the environment in order to maintain and improve their existence?

What natural resources have been and will continue to be used to maintain human populations?

What are the causes and effects of global climate change?

This lesson connects individual behavior to resource use and depletion. It could be an introduction to the unit, or used as a before and after tool to make predictions about how different behaviors and choices affect energy use.

Several websites have energy use and carbon use calculators and are listed in teacher and student resources. Have students calculate their energy use, and give them simple data sets converting this amount of energy to renewable energy. Students can easily relate their energy use to how many windmills or photovoltaic cells it would take to maintain their current lifestyle, and how much renewable energy it would take to live a carbon neutral existence. This activity will facilitate further research and discussion.

For example, students may complete an energy use calculator and determine their monthly use is 950 kWh. If a local wind turbine produces 1 megawatt of power, discussions may lead to the number of wind turbines needed to provide for the class. Keys to feasibility of sustainable energy, such as availability of power will be introduced, leading to research on the cost benefits in pursuing various renewable energies. When students conduct further research, keeping in mind their own energy use, it will help them keep figures and reasonable avenues of power generation in perspective.

Lesson three- Choose a Power: a look a current and future energy sources

Essential Questions

What are the commonly used forms of renewable energy?

What forms of renewable energy are used or could be used in your home state?

What are the pros and cons of various renewable energy forms?

What makes a website reliable?

As a mini-research project, renewable and sustainable energy offers many media for student research. Many reliable websites exist for students, often specific to state and region, that can be used to look at many forms of renewable and fossil fuel energy sources. In the student resource section is a short list of current websites that have ability level information on fossil fuel and renewable energy resources.

Students can work in groups to prepare small presentations about renewable energy sources and create graphic organizers to present to class. Group work and group presentations are an effective assessment tool to share learning and groups can be directed to investigate one specific energy source to focus on to present in a roundtable discussion. The benefit of this strategy is that different ability levels can be expected to complete the same assignment and assessed using a similar rubric. Since students can base the strength of their argument on their preferred energy source and make a case for why they chose it, it allows for variation of ability, interest, and varied sources of information. This is an effective strategy to teach about reliability of information of websites, as well as bias within information. Assessment of completed work can be assessed using a rubric that addresses reliability of information, thoroughness of research, presentation quality and teamwork.

Notes

Teacher Resources

Books

Green. Hoffman, J. & Hoffman, M. Palgrave Macmillan 2008. This book is a highly readable novelization of the global availability of, and conversion to, renewable energy. Loaded with stats, factoids, and anecdotes, it can be read in a weekend to prepare the teacher for this unit. Selections can be taken from it for readings for some high school students.

Holt Science Spectrum. Teacher's Edition. Dobson, K., et al. Holt, Rinehart & Winston. 2006. A broad text, common nationally that focuses on physical and earth sciences. It carries a strong environmental science unit with a large portion focused on energy use. Teacher's edition offers excellent activities and hands-on demonstrations.

Teaching Secondary School Science. Bybee, R., Powell, J. & Trowbridge, L. Prentice Hall. 2004. This resource offers teachers insight on inquire based questioning and teaching strategies to facilitate data analysis, as well as assessments, rubrics in particular.

Websites

http://rubistar.4teachers.org/index.php?screen=NewRubric&section_id=9#04

Rubristar.org offers prepared and up to date rubrics for all disciplines and including a free rubric generator that allows the teachers to add their own suitable categories.

http://www.eia.doe.gov/state/index.cfm Accessed July 1, 2010. An index listing of recent energy use profiles of all states.

http://www.cl-p.com/energycalculator/home.aspx Accessed July 1, 2010. This site directs to a Connecticut specific energy use calculator provided by Connecticut Light and Power. This calculator provides current information, changeable parameters, selectable rooms using current energy prices and availability.

http://www.carbonfootprint.com/calculator.aspx Accessed July 1, 2010. This site offers a carbon footprint calculator, streamlined for adults and high school students.

Student Resources

Books

Holt Science Spectrum. Teacher's Edition. Dobson, K., et al. Holt, Rinehart & Winston. 2006. A broad text, common nationally that focuses on physical and earth sciences.

Websites with readings, information, and research material

http://www.eia.doe.gov/kids/energy.cfm?page=about_energy_conversion_calculator-basics Accessed July 1, 2010. An energy use calculator designed for use by students. This calculator includes factors for lifestyle of the individual.

http://www.zerofootprintkids.com/kids_home.aspx Accessed July, 1 2010. This site provides a very basic calculator designed for school aged children. It may be appropriate for special needs or challenged learners.

http://www.ctcleanenergy.com Accessed July 2, 2010. A 3-D tutorial on nearly all renewable energy sources, with breakdowns on how they all work. Easy to navigate, great animated/flash images, and interesting sound effects.

http://www.eia.doe.gov/kids/energy.cfm?page=renewable_home-basics Accessed July 1, 2010. An all in one website that is readings based. Breaks down renewable and nonrenewable energies, in readings designed for students.

http://www.infinitepower.org/factsheets.htm Accessed July 1, 2010. A website from the Texas State Energy Conservation Office has fact sheets and information about renewable energy, and activities for students. Appropriate for research.

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Pahl, G. 2007. The Citizen Powered Energy Handbook. Chelsea Green Press (Pages 7, 34, 38, 119, 122, 131)

Trainer,T. 2007. Renewable Energy Cannot Sustain a Consumer Society. Springer (Pages 5, 27, 97, 100)

Sweet, W. 2006. Kicking the Carbon Habit: Global warming and the case for renewable and nuclear energy. Columbia University Press (Page 181)

U.S. Energy Information Administration, Independent Statistics and Analysis. http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=CT Accessed 6/4/10

CT Clean Energy Fund http://www.ctcleanenergy.com/innoflash/#/home Accessed 6/4/10

Appendix

Implementing District and National Standards

The following are district and national science standards that are addressed in this unit. It is the intention of this unit for students to use inquiry based questioning to investigate renewable and sustainable energy, and the impact they have on the local and global environment.

Logic and inquiry are the underlying goals of this unit. It is not crucial for a ninth grade student to have rote memory of the logistical requirements of a wind turbine. The goal of this unit is for students to look at the logistics of a wind turbine, and ask why it would or would not work in that location, is it feasible, and if not, why isn't it? As the student investigates these topics, developing a broad understanding, it should be the teacher's mission to develop the student as a thoughtful, questioning member of society. Most students in this age group understand that the current energy policy is not a successful long term plan. It is the intention of this unit for them to learn why this is so, and to start asking the questions that will lead them to an alternative plan that is necessary for a sustainable future.

District Standards Addressed

D8 - Describe the availability, current uses and environmental issues related to the use of fossil and nuclear fuels to produce electricity.

D23 - Explain how the accumulation of carbon dioxide (CO_2) in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes.

D9 - Describe the availability, current uses and environmental issues related to the use of wind and solar energy to produce electricity.

National Standards Addressed

Content Standard A- Scientific Inquiry

Students should formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding a hypothesis and the design of the experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations.

Content Standard C- Natural Resources

Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations.

Content Standard C- Natural Resources

The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and depletes those resources that cannot be renewed.