A Study of Public Perceptions of Energy Issues and Technology for the Development of Engineering Education Activities

by
Nathan Hinkle

A PROJECT

submitted to

Oregon State University

University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Chemical Engineering (Honors Scholar)

Presented May 26, 2015
Commencement June 2015

AN ABSTRACT OF THE THESIS OF

Nathan Hinkle for the degree of Honors Baccalaureate of Science in Chemical Engineering presented on May 26, 2015. Title: A Study of Public Perceptions of Energy Issues and Technology for the Development of Engineering Education Activities.

Abstract approved: ____

Skip Rochefort

Human use of fossil fuels has caused a dramatic shift in the earth's environment, with global temperatures rising and ecosystem health declining. The need for the human species to reduce our reliance on fossil fuels is apparent. This will be achieved by replacing conventional energy resources with sustainable alternatives, and by reducing overall energy consumption on both a personal and global scale. Citizens must be engaged and informed on energy issues in order to achieve the drastic changes required. This project studied public perceptions and understandings of energy issues and technologies through survey research, and developed five new engineering education activities to address knowledge gaps identified in the survey. These activities have been conducted with groups of students at OSU, revised based on student feedback, and will be made available to educators online.

Key Words: sustainable energy, engineering education, energy efficiency, climate change

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APPROVED:

Skip Rochefort, Mentor, representing Chemical Engineering

Nick AuYeung, Committee Member, representing Chemical Engineering

Devlin Montfort, Committee Member, representing Chemical Engineering

Toni Doolen, Dean, University Honors College

I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Nathan Hinkle, Author

Acknowledgements

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Thank you to Dr. Skip Rochefort for mentoring this project, and continuing to encourage me through the several years of work and many piles of paperwork. To my other thesis committee members, Dr. Nick AuYeung and Dr. Devlin Montfort, thank you for your valuable insights and feedback on this thesis.

Finally, thank you to all of my friends and family for believing in and encouraging me throughout this process, and to my parents in particular for encouraging me from a young age to ask questions, be curious, and pursue my interests to the fullest.

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Chapter 1: Introduction

For most of human history, the energy powering our daily lives was derived from natural, renewable sources – primarily the use of biomass in small fires. Our never-ending thirst for more energy began with the exploitation of coal in the industrial revolution. Energy use per capita has more than quadrupled since the mid-1800s, and cumulative global energy consumption has risen exponentially (1). Meanwhile, global temperatures have risen dramatically due to unprecedented levels of greenhouse gas emissions from human combustion of fossil fuels (2). Advances in fossil fuel recovery – such as hydraulic fracturing and advanced oil recovery – continue to stave off long-foretold shortages of conventional fossil fuels, but the environmental impacts of continued fossil fuel development present immediate risks to the entire global community.

The US Department of Energy's Office of Energy Efficiency and Renewable Energy has launched an energy literacy initiative, stating that, "without a basic understanding of energy, energy sources, generation, use, and conservation strategies, individuals and communities cannot make informed decisions on topics ranging from smart energy use at home and consumer choices to national and international energy policy. Current national and global issues such as a declining fossil fuel supply and climate change highlight the need for energy education (3)."

The ultimate objective of this project was to develop new energy-related engineering outreach activities. Survey research was conducted to guide the development of new activities. An energy literacy survey was developed by the author and administered at outreach events presented by OSU Precollege Programs and the OSU Sustainable Energy Initiative during 2012 and 2013. Five outreach activities were produced based on the energy knowledge gaps identified by the survey results. These activities were tested with students, and will be published online for educators to use. Topics addressed include energy efficiency and conservation, emerging energy technologies, energy units and nomenclature, research and verification of energy data, and analysis of personal energy usage.

Personal Energy Philosophy

Garret Hardin's essay "The Tragedy of the Commons" was published in *Science* in 1968. The basic premise of the essay is that a limited resource of common ownership will eventually be depleted, given that each individual using the resource independently chooses the most rational and economical choice for their own self-interest. Even though the long-term effects of this unsustainable use are clear to all parties involved, to each individual this is the most logical choice. Although the essay was written about overpopulation, its message has been applied to many environmental issues. The essay starts with the following assertion:

> *"An implicit and almost universal assumption of discussions published in professional and semipopular scientific journals is that the problem under discussion has a technical solution. A technical solution may be defined as one that requires a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values or ideas of morality… It is fair to say that most people who anguish over the population problem are trying to find a way to avoid the evils of overpopulation without relinquishing any of the privileges they now enjoy… I try to show here that the solution they seek cannot be found. The population problem cannot be solved in a technical way, any more than can the problem of winning the game of tick-tack-toe." (4)*

Substitute the word "energy" for "population" into the above excerpt. The current status of the world's energy supply and usage is very similar in two ways to that described above. First, and perhaps most obviously, is to consider the world as one shared, common resource. Within that paradigm, our rate of consumption of resources – fossil fuels in particular – in the US is unsustainable, both for ourselves and for the common good. As predicted by the tragedy of the commons, we continue to exploit these resources for our own use, because that is the most economically sensible choice for each nation. The second implication is that there must be a single technological solution to the energy crisis. Even those deeply involved with energy research often exude a sentiment that the technology they are developing will singularly save the world, but there is no one perfect solution to the challenge of providing sufficient energy to all in a fair, affordable, accessible, and environmentally responsible manner. Technological advances are of course an integral part of the solution, but we cannot expect technology to save us alone.

One of the key phrases in the quote above is, "without relinquishing any of the privileges they now enjoy." This is a pervasive attitude in our culture when considering energy. The United States uses four times as much energy per-capita than the global average, and is responsible for more than one fifth of the total global energy consumption (5). Developed nations cannot force their citizens to decrease their quality of life; nor can they prevent developing nations from raising their quality of life to our level. However, as the largest consumer of energy in the world and as a leader in innovation, the United States has a responsibility to preserve the common resources of the world for the benefit of more than just ourselves. Western countries pioneered an energy intensive lifestyle; now it's time to pioneer an energy responsible future.

A holistic solution to the global energy problem will have to include more sustainable energy sources, improved efficiency and conservation, policy and market incentives, and education. Conservation and efficiency are drastically underrepresented in conversations about sustainable energy, relative to their potential to reduce fossil fuel consumption. Many efforts focus on replacing conventional energy sources with alternative sources to produce the same amount of usable energy, but eliminating unnecessary energy consumption is equally effective at reducing dependence on conventional energy sources. This ties into the importance of education as well. Many efficiency improvements and energy conservation actions can be implemented easily by individuals should they take the opportunity. Even privileged, relatively well-educated people often know far less about energy than they think they do though, and few people know – or care – where their energy comes from, so long as it is cheap and reliable. Framing energy education to highlight personal benefits and monetary incentives is therefore an effective method of promoting change. If people knew that replacing their refrigerator could save them hundreds of dollars per year; or that LED light bulbs are brighter than incandescent or CFL bulbs, last hundreds of times longer before burning out, and use a small fraction of the electricity (thus reducing bills); or that installing better insulation could reduce their winter heating bills by more than half; they might be motivated to make those changes.

Fully renewable energy sources may never be able to provide the amounts of energy we currently get from fossil fuels, even with significant improvements in efficiency and conservation. Nuclear energy is considered by many scientists to be one of the most available solutions here: estimates indicate that at current consumption rates, known uranium resources would last for at least 90 years (6). Nuclear power is also very clean in terms of greenhouse gas and particulate emissions and cheap compared to coal. The biggest problems facing nuclear power are public perception and disposal of waste. Nuclear supporters are quick to dismiss fears of catastrophic meltdowns, but in a society where safety is often sacrificed for profit, these are valid concerns. A worst-case nuclear disaster has the potential for devastating effects, and though nuclear advocates claim that newer designs are inherently safe, history has shown that systems which are designed to be fool-proof can indeed fail catastrophically. But is this the right perspective to take? Thousands of people are sickened and many die from complications due to air pollution every year. Waste from coal-fired power plants is extremely toxic and environmentally damaging. Fears over nuclear power are grounded in some truth, but put into perspective, nuclear is a surprisingly attractive option. That being said, a safe, long-term solution to dealing with nuclear waste is needed before significant nuclear development continues. While coal ash can be washed away or thrown in a landfill, radioactive waste remains hazardous for centuries, even millennia. It is irresponsible, both for ourselves and future generations, not to deal with the waste problem before pursuing more options. A significant problem is the US Government's irrational ban on reprocessing spent nuclear fuel, due to concerns of plutonium being obtained to create nuclear weapons. Nations the US is hardly on friendly terms with already have this capability, and the long-term consequences of poor energy decisions are more likely to harm us than nuclear weapons. Countries like France and Japan have successful waste reprocessing programs, which drastically reduce both the amount of new fissile material required to operate reactors and the amount of radioactive waste which must be stored long-term (7).

It is evident that in order to develop a sustainable energy future several things must happen. Individuals who care about the world they live in must take personal steps to use energy more sustainably. People who don't care or aren't aware of the issues must be educated in ways that will seem relevant to their lives. In the realm of technology, devices that use energy must be made more efficient, and systems that provide energy must be made more sustainable. This project seeks to contribute to that education component, so that more people might care to make energy decisions which will benefit themselves, their communities, and the earth.

Chapter 2: Background Information

What is sustainability?

In broad terms, sustainability refers to the ability of a system to continue functioning effectively and without degradation over generations. The World Commission on Environment and Development defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs (8)." Sustainability encompasses societal, economic, and environmental needs. "Sustainable energy" and "renewable energy" are phrases often used interchangeably in the media and in public discourse, but are in fact separate concepts. A renewable resource is one which either regenerates or is not depleted on a human timescale. Many renewable resources can be used sustainably, but renewability does not imply sustainability, and nor does sustainability demand renewability. The use of any resource – energy or otherwise – has some non-zero environmental, societal, and economic cost, even if it is renewable.

Take for instance solar energy. Sunlight is a renewable resource, because it is not depleted on a human timescale. The use of sunlight to produce useful work does not affect its future availability, so it can be sustainable as well. However, in order to make use of sunlight, we must capture and convert it to useful energy. That can be done by growing crops to make biofuels, but this comes at the environmental cost of clearing land. Solar panels can be used to convert sunlight to electricity, but the process of manufacturing solar cells has numerous environmental, economic, and societal impacts. Biomass is another renewable resource. Trees grow on a human timescale, and can be burned for heat. For thousands of years wood fires were humans' primary source of energy, and biomass was harvested at sustainable rates. Today, deforestation is occurring faster than forests can regrow. Despite biomass being a renewable resource, it isn't always used sustainably.

It is apparent then that sustainability is contextual. There is no single energy resource which is entirely sustainable, nor globally most sustainable. What mix of energy sources will be most sustainable for a given region depends greatly on what natural resources are available, how many people must be supported, and what the tradeoffs and impacts are between various energy sources. The ultimate goal of sustainable energy development is to achieve complete sustainability – producing sufficient energy to meet the needs of the entire population, in a way which can be continued indefinitely. In reality, this may never be possible at projected population levels, especially as the standard of living (and energy demands) rise in developing countries.

Climate change and the greenhouse effect

There is widespread scientific consensus that human activities are causing significant changes in the earth's climate (9). In the US, 63% of adults believe that global warming is occurring, but only 48% believe it is caused by humans (10). The primary human driver of climate change is the combustion of fossil fuels, which releases sequestered carbon dioxide and other greenhouse gases into the atmosphere. Increasing greenhouse gas concentrations enhances the greenhouse effect, shown in Figure 2-1. A portion of the solar radiation hitting the earth is absorbed and re-emitted in the infrared spectrum. Greenhouse gases absorb in the same infrared wavelengths, trapping some of the re-emitted heat in the atmosphere. Global carbon dioxide concentrations are now over 400 ppm, higher than any point in the past 400,000 years as shown in Figure 2-2. Average global temperatures have risen about 1 °C since the beginning of the 20th century (2), and climate change has already resulted in shrinking glaciers and ice caps, shifts in plant and wildlife habitat ranges, sea level rise, and more intense weather patterns. These effects are predicted to intensify as temperatures continue rising anywhere from 2 to 10 ° C over the next 100 years (11). Left unchecked, the effects of climate change will likely displace billions of people and cause resource shortages and other challenges for all of society.

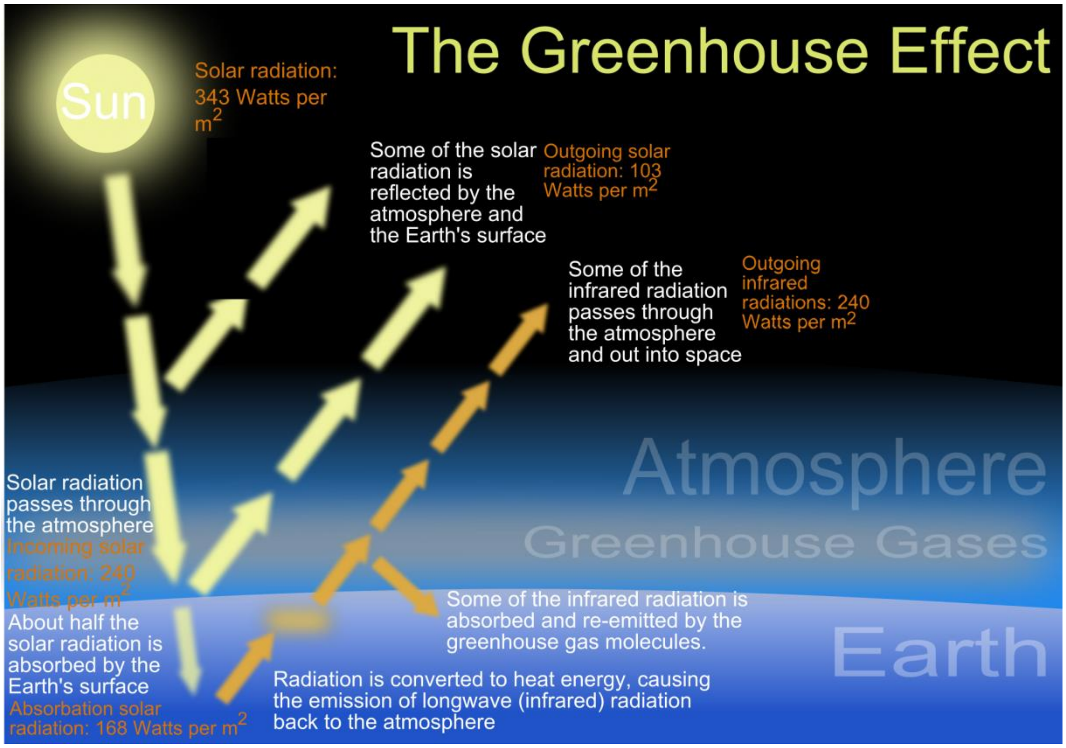


Figure 2-1: Simplified graphical explanation of the greenhouse effect. Various factors affect the amount of solar radiation returned to space by various means. As greenhouse gas concentrations increase, the amount of infrared radiation trapped in the atmosphere increases, resulting in increasing global temperatures. *Image from Wikimedia Commons (https://commons.wikimedia.org/wiki/File:The_green_house_effect.svg).*

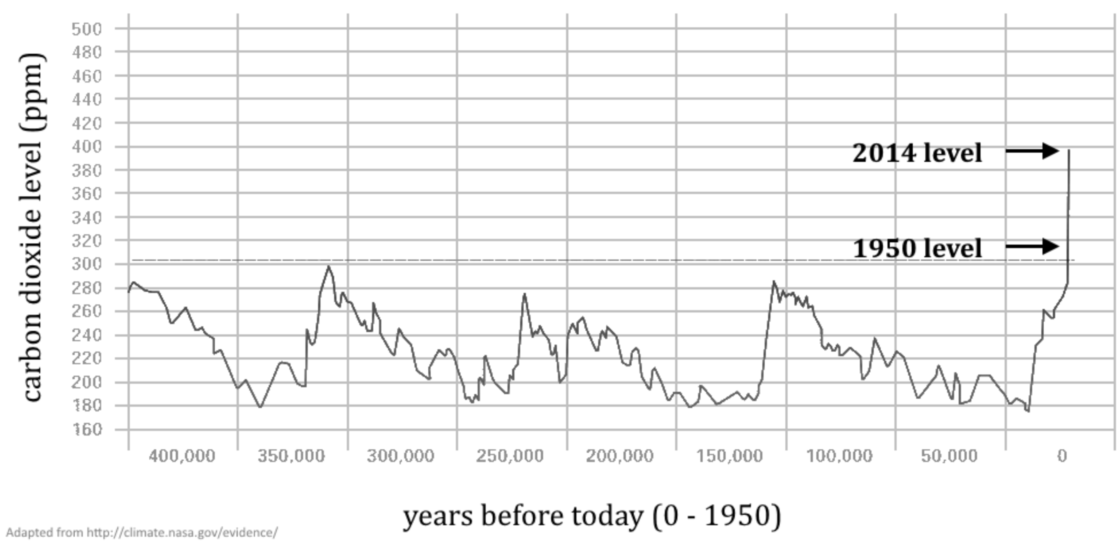
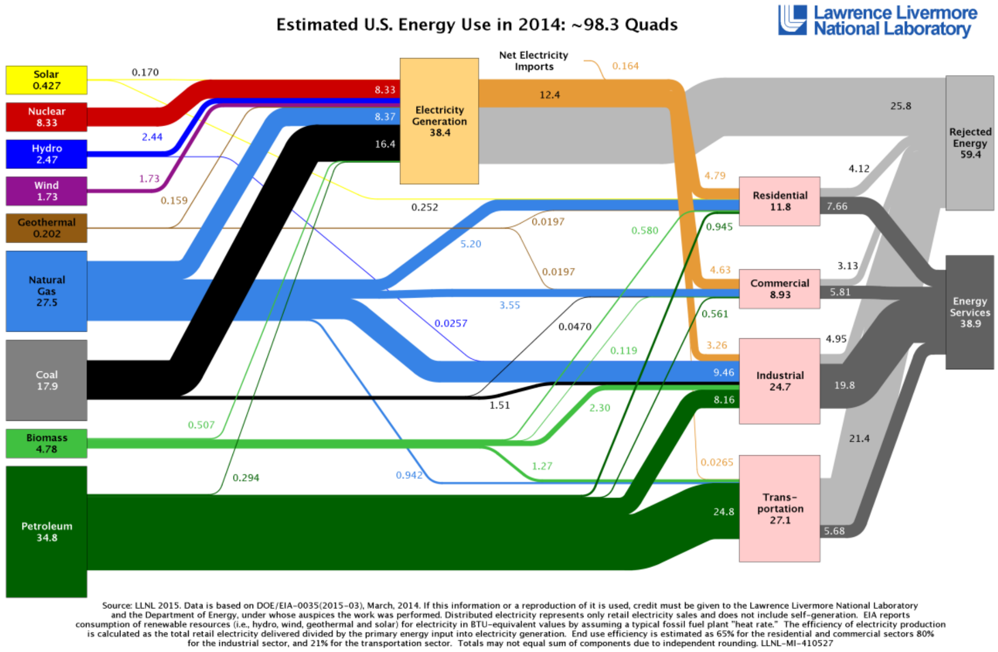


Figure 2-2: Historical atmospheric carbon dioxide levels have been estimated using ice core samples. Atmospheric CO_2 levels are currently at the highest point in the past 400,000 years. *Image adapted from NASA Climate Change website (http://climate.nasa.gov/evidence/).*

Energy efficiency and conservation

A significant portion of public discourse surrounding energy issues focuses on developing the means to provide usable energy in equal or even greater quantities than current technologies allow, while reducing the negative effects of these processes. Development of sustainable energy resources is required to achieve a significant reduction in carbon emissions, but modifying systems and processes to reduce energy consumption is often easier, cheaper, and faster than replacing conventional energy sources.

Though related, conservation and efficiency are separate concepts. Energy conservation refers to eliminating unnecessary use of energy. Energy efficiency refers to producing the same amount of useful work with less energy, or using an equal amount of energy to produce more useful work than before. For example, energy efficiency is driving a hybrid vehicle which gets better mileage than a conventional vehicle, whereas energy conservation is eliminating unnecessary vehicle trips altogether. Over 50% of energy consumed in the US is wasted to inefficiencies, as shown in Figure 2-3. Domestic energy usage could be dramatically reduced by improving energy efficiency (reducing the "rejected services" category in the figure) and simultaneously implementing energy conservation measures (reducing the amount of energy services required).



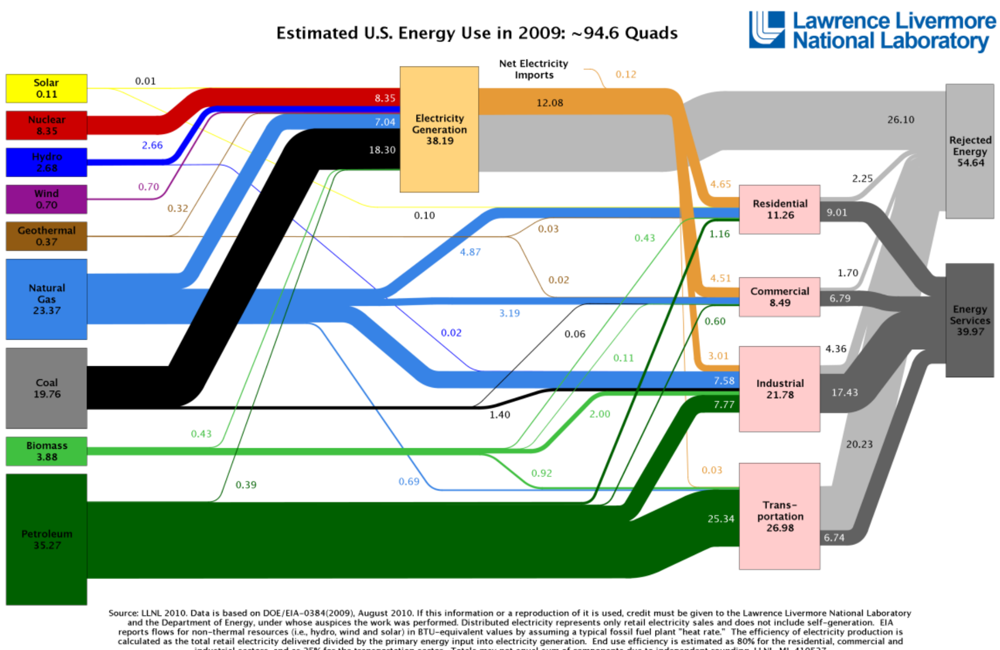


Figure 2-3: Total estimated energy flow in the US in 2014 (top) and 2009 (bottom). The thickness of each flow is relative to its quantity. "Energy services" refers to energy which actually provides useful work, while "rejected energy" encompasses losses in conversion, transmission, and use of energy. While energy services have decreased in the past 5 years, rejected energy and total consumption have increased. Wind and solar use is increasing, but natural gas consumption has increased far more. Transportation continues to account for the largest sector of energy usage in the US, and the vast majority of energy consumed in the US continues to come from fossil fuels – petroleum, natural gas, and coal.

Chapter 3: Energy Knowledge Survey

A survey was developed to assess the energy knowledge of participants. The survey included demographic information, factual questions, and subjective questions addressing personal beliefs and interests. Table 3-1 shows a summary of the survey questions. The full survey is included in in the appendices on page 32. The survey was reviewed by the OSU Institutional Review Board as study ID 5375, and was approved for up to 500 participants including children and adults. A total of 112 surveys were collected and analyzed.

Table 3-1: Summary of questions included in the energy knowledge survey. Question types include yes-or-no (YN), multiple choice (MC), and short answer (SA). Details about the context, motivation for, and answer to each survey question are discussed below.

#	Type	Question
1	YN	Have you taken this survey before?
2	YN	Have you been to a presentation or outreach event run by the OSU Sustainable Energy Initiative?
3	MC	Are you in school? If so, please circle your grade level.
4	MC	If you aren't in school, please circle your age range, and highest level of education.
5	SA	What is/was your favorite subject in school?
6	YN	Have you ever been to a science or engineering camp or class outside of school?
7	SA	How would you define renewable energy?
8	SA	What do you consider to be sustainable energy?
9	SA	Do you think there is a difference between "sustainable" and "renewable" energy?
10	YN	Can energy be created or destroyed?
11	MC	Are kWh a unit of power or energy? Are therms a unit of power or energy? Which is a larger amount of power or energy – 1 therm or 1 kWh?
12	MC	What is the difference between energy and power?
13	SA	Where do fossil fuels come from?
14	YN	Oil, coal, and natural gas: Are these fossil fuels? Are these renewable energy sources?
15	SA	List energy sources you know of. List as "renewable" or "non-renewable". Indicate which you think are sustainable.
16	MC	What fraction of energy used in the US comes from renewable sources?
17	MC	How much of the world's energy is used by the United States?
18	SA	What source is used to generate most of Oregon's electricity? Is it a renewable source?
19	MC	What do you perceive to be the biggest challenge to implementing sustainable energy?
20	MC	Which emerging energy technology do you find most promising or exciting?
21	MC	What is the greenhouse effect?
22	MC	Which of the following are greenhouse gases?
23	SA	What energy-related environmental impacts can you think of besides climate change?
24	MC	What uses the most energy in the average American home?
25	MC	Which sector accounts for the largest percentage of all energy consumed in the US?
26	MC	How much of the energy consumed in the US is wasted due to inefficiencies?
27	MC	What accounts for the largest amount of energy usage in the food sector?
28	SA	List three things you do in your daily life to reduce energy consumption.
29	SA	What do you want to learn more about?
30	SA	List any additional thoughts or feedback.

Survey Administration Details

Over 150 people in total participated in the survey. Of those, 112 surveys were "scored" and entered into a database. Survey participants included students at summer science and engineering camps hosted by the OSU Center for Outreach in Science and Engineering for Youth (COSEY), at public events like the Corvallis DaVinci Days Festival and the OSU Earth Day Festival, and in undergraduate engineering courses like the HC-407 Energy IQ honors colloquia. Due to the voluntary nature of the survey and the types of events it was offered at, most survey participants had a pre-existing interest in energy issues. The results therefore should not be extrapolated to make conclusions about the energy knowledge of the general public; however, the objective of the survey was to inform the development of activities which will also generally be offered to a similar audience.

Survey questions were either yes/no, multiple choice, or short answer. Yes/no and multiple choice questions were scored against a correct answer. Factual short answer questions with were evaluated by the author and categorized as "mostly correct" or "mostly incorrect", whereas opinion-based or open-ended short answer questions were placed into generic categories.

Survey Question Details

Demographic information

Questions 1-6 address basic demographic information. The information collected was limited to prevent possible identification of the anonymous survey participants. Grade level was recorded for students in school, and level of education and age range was recorded for people not in school. Age demographics were desired to determine if certain age groups had different knowledge gaps, and to determine whether a higher level of education corresponded to a more developed knowledge of energy issues.

At the time the survey was devised, the author was the president of the OSU Sustainable Energy Initiative (SEI), a student group sponsored by the School of Chemical, Biological, and Environmental Engineering. Many of the concepts contained in the survey have been addressed in presentations and outreach events delivered by SEI. Survey participants were asked whether they had attended an SEI event to evaluate whether these outreach events were increasing energy knowledge as measured by the survey. Participation in extracurricular science and engineering activities was also queried, as the types of activities developed in this project are often offered outside of regular classroom time.

Sustainable and renewable energy

Several questions in the survey focus on the definition and distinction between sustainable and renewable energy. Both terms are often used interchangeably, especially in general-audience media. Questions 7-9 ask participants for their own personal definitions of renewable and sustainable energy. Question 15 asks participants to list energy sources they are familiar with in either a “renewable” or “non-renewable” column and to circle those they consider sustainable.

Renewable energy resources are generally considered to be those which are replenished on a human timescale. Renewable resources include sunlight, wind, water, biomass, and geothermal heat. Most engineers agree on the definition of a renewable resource. Sustainable energy is more subjective, but is generally understood to include resources which can continue to be used into future generations with minimal harm to people, the environment, and society. The key point of understanding is that a resource which is renewable may not necessarily be sustainable, and some non-renewable resources can potentially be used in a sustainable manner. This topic is explored in detail in the background section on page 5.

Basic energy concepts

Several basic energy concepts are approached in the survey. Most people at a high school level or higher would be expected to readily understand most of these topics, although some of the specific statistics are not necessarily common knowledge.

Questions 11 and 12 address the differences between energy and power. These words are often used interchangeably when talking colloquially about energy issues, e.g. “wind power” or “solar energy”. To people working with energy systems it is important to understand the difference, and the various units which accompany energy and power. Energy is a quantity, and power is a rate of energy.

Questions 16 – 18 ask about "energy trivia", specifically the fraction of energy usage in the US which comes from renewable sources, what percentage of global energy is used by the US, and what the largest source of Oregon's electricity is. While knowing the exact numbers for these statistics is not particularly useful to an engineer, it's important for people to have a general understanding of where their energy comes from and how their usage compares to that of other people. As of 2014, 9.8% of US energy is supplied from renewable sources (12), and as of 2012 the US uses about 18% of the total energy consumed worldwide (13). Oregon's primary source of electricity is conventional hydroelectric, accounting for over 70% of state electricity usage (14).

Questions 24 – 27 contain additional "energy trivia" which are less commonly discussed than those above. Question 24 asks what uses the most energy in American homes. Understanding major uses of energy in a person's daily life is important for them to be able to effectively reduce their energy footprint. The largest use of energy in most homes is space heating, accounting for over 40% of total household energy usage (15). Question 25 asks which sector uses the most energy overall. Industrial use is the highest, followed closely by transportation (16). Question 26 asks what percentage of energy consumed in the US is wasted to inefficiencies. Energy conservation is often overlooked in public discourse about reducing the environmental footprint of energy consumption, but over 60% of energy consumed in the US is wasted (17).

Questions 21 and 22 address the greenhouse effect. Climate change is one of the foremost concerns driving adoption of alternative energy technologies, but many people don't fully understand how increased greenhouse gas emissions lead to climate change. These questions asked participants to select the correct definition of the greenhouse effect, and to select all the greenhouse gases out of a list of common gases. Sunlight is absorbed by the earth and re-radiated at infrared wavelengths. Greenhouse gases, which include water, carbon dioxide, methane, and nitrous oxide do not absorb visible light, but do absorb infrared radiation. As the concentration of these gases – particularly CO_2 – increases, more energy is trapped in the earth's atmosphere (9). The greenhouse effect is explained in greater detail in Figure 2-1.

Challenges, interests, and actions

Questions 19, 20, and 28 approach more subjective information about the individual energy-related beliefs of survey participants. Question 19 asks participants to choose what they think the biggest challenge to energy sustainability is from a prepared list of options. Question 20 asks the opposite: which energy technology the participant finds most promising. Finally, question 28 asks participants to list up to three actions or choices they make in their daily lives to reduce energy consumption.

Survey Results

The survey was primarily taken by students at outreach programs run by OSU Precollege Programs, including SESEY (Summer Experience in Science and Engineering for Youth) and the Saturday Academy Apprenticeships in Science & Engineering (ASE) summer symposium program. The age distribution of processed surveys is shown in Figure 3-1. The second largest survey group was participants at the Corvallis DaVinci Days Festival. This is a semi-annual science, art, and engineering festival held in Corvallis in July.

Given the limited number and narrow demographic of the participants, these results cannot be considered to be representative of the energy knowledge of the general population. Neither of the primary participant populations are representative of the "average person" – because nearly all participants were attending courses or events specifically intended for people interested in science, engineering, and the environment, there is certainly a bias in the results. As the objective of the survey is to inform the creation of educational activities to be delivered to a similar demographic, this bias actually better informs the creation of activities. Considering that the average participant got less than 50% of the questions correct – even among a relatively well-educated and environmentally conscious survey population – it is likely that the general population would have similar or lower scores, especially in regions with less focus on science education and environmental issues in K12 curriculum. Further research and a more diverse survey population would be required to draw statistically significant conclusions about the energy knowledge of the general population.

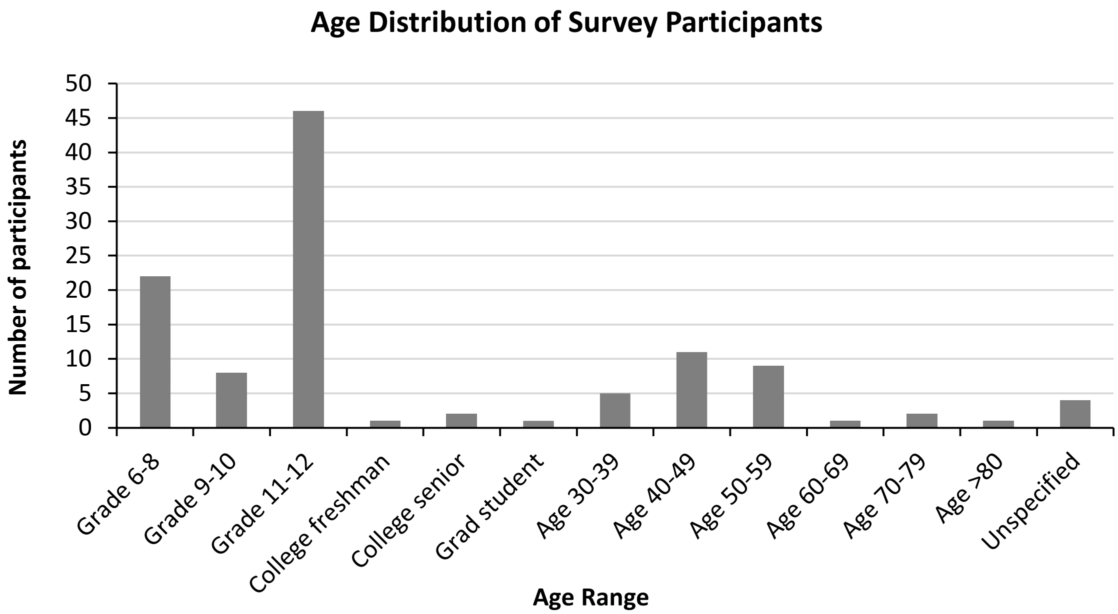


Figure 3-1: Number of survey participants in each age category as reported on the survey. Most survey participants were middle and high school students at OSU Precollege Programs camps and events, or adults at the OSU DaVinci Days festival.

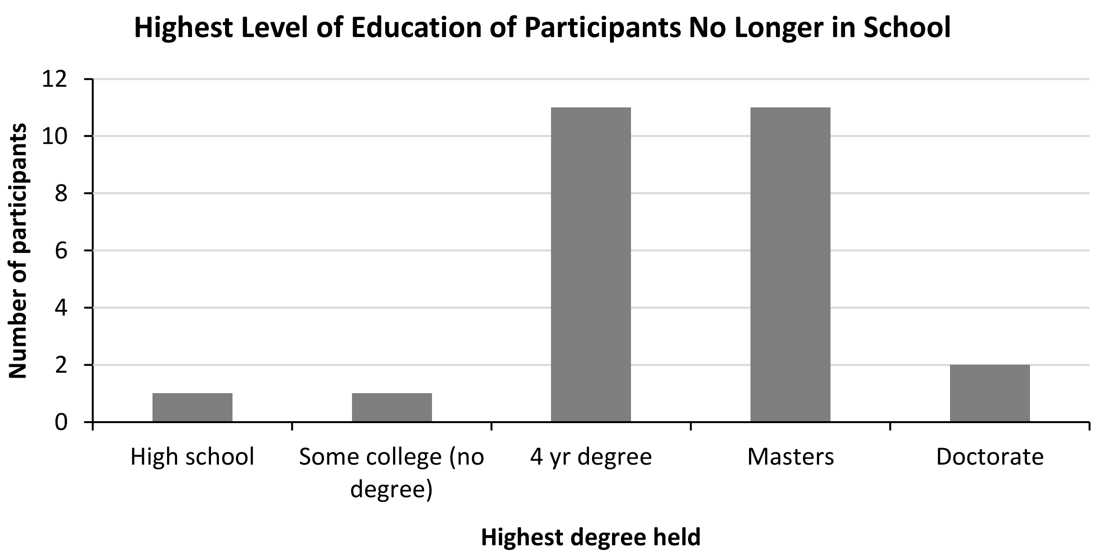


Figure 3-2: Almost all of the survey participants who were no longer in school had at least a bachelor's degree, and many had advanced degrees.

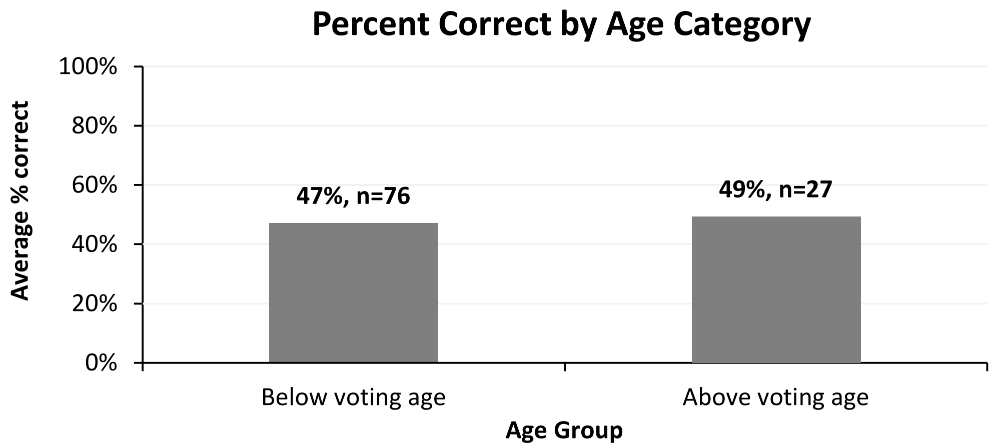


Figure 3-3: Survey participants who were over the age of 18– most of whom had at least a bachelor's degree – did not score significantly better on average than participants under the age of 18 who were still in middle or high school.

The overall percentage of correct answers to each quantitative question is shown in Figure 3-4. Most participants were able to correctly identify common fossil fuels and assert that they are non-renewable resources. The greenhouse effect was also well-understood by most participants. Only slightly more than half of participants identified the nuances between renewable and sustainable energy, or even agreed that there is a difference between renewable and sustainable.

About half of all participants identified the difference between energy and power, but fewer than 50% correctly identified kWh as units of energy. About 70% of adults failed to answer this question correctly, even though residential electricity bills are reported in kWh. Utility ratepayers must understand the units presented in their bills to reduce personal energy consumption, so this is clearly an opportunity for further education.

Fewer than 40% of participants correctly identified space heating as the largest use of energy in the average American home. Space heating alone accounts for about 40% of residential energy usage, and together with water heating and air conditioning accounts for two thirds of residential energy consumption (15). Heating, cooling, and water heating are easily controlled by residents. Fortunately, while most respondents underestimated the contribution of heating to home energy usage, "adjusting the thermostat" was the second most popular action described in question 28 regarding actions people take to reduce their energy impact, as seen in Figure 3-5.

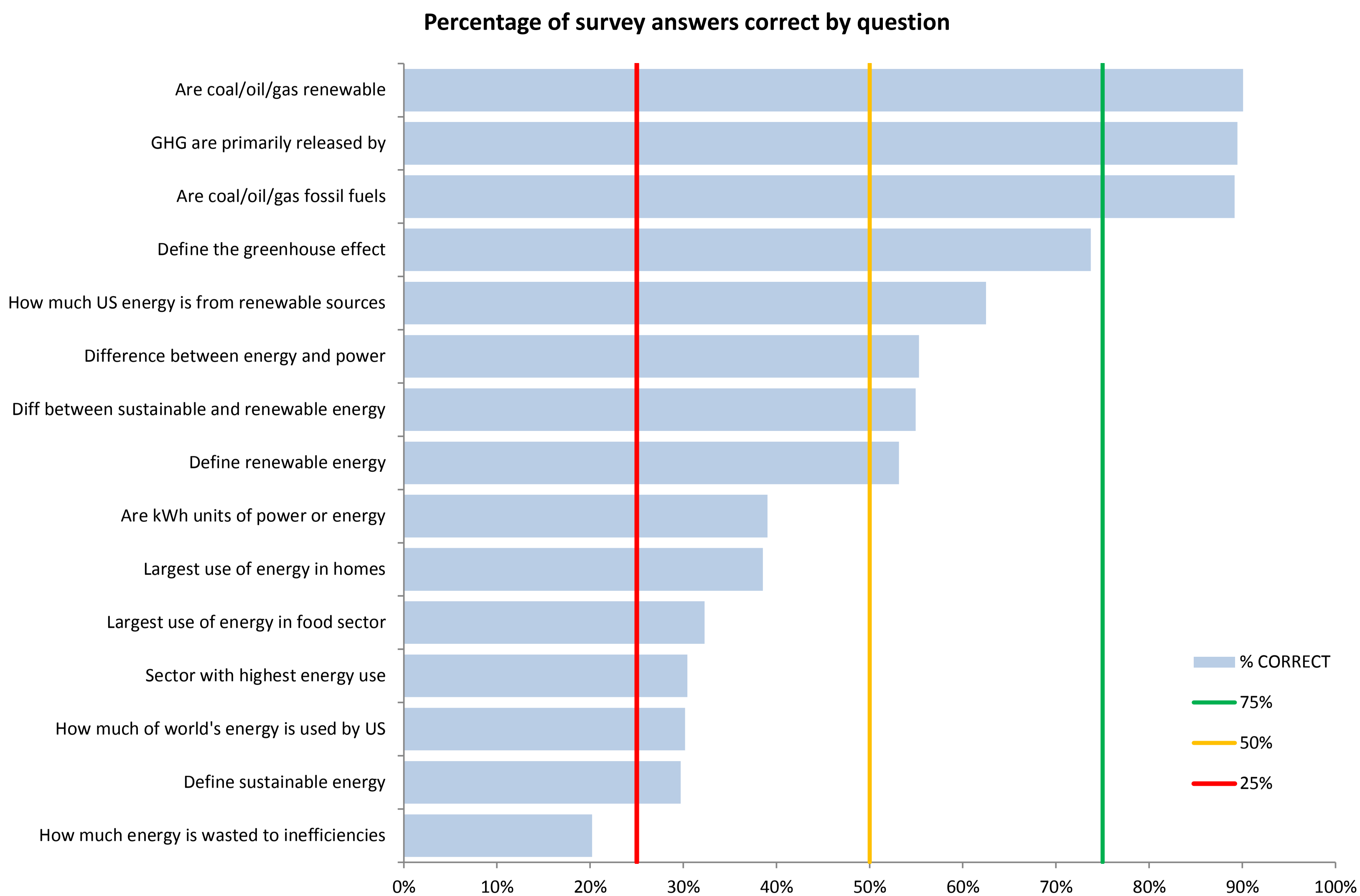


Figure 3-4: Correct answers to selected quantitative questions are shown here. Most participants are familiar with and can identify fossil fuel resources. Many participants have difficulty distinguishing energy and power, and very few are aware of which areas of their home and the energy economy in general use the most energy.

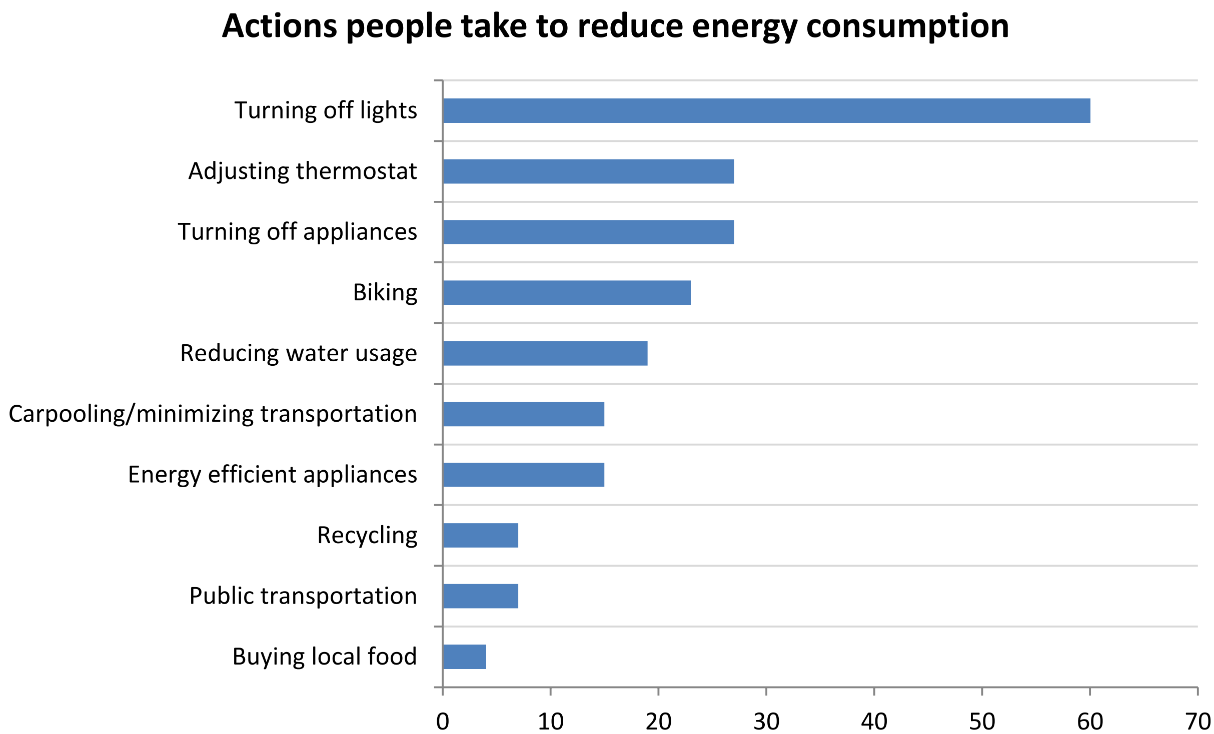


Figure 3-5: Question 28 asked survey participants to list actions they take in their daily lives to reduce their energy usage. Free-form answers were grouped by the author into related categories. The three most common actions take place in the home – reducing energy usage by turning off unused lights and devices, and adjusting thermostats to reduce heating and cooling loads.

About half of respondents wrote a description of sustainable energy which was mostly correct. Only 30% of respondents described a reasonably correct nuance between sustainable and renewable energy, even though about 50% agreed that they were not synonymous. Participants were asked in question 15 to list specific examples of renewable and non-renewable energy resources, and to indicate whether any were sustainable. These results are shown in Figure 3-6. Most participants identified the big 3 fossil fuels – coal, oil, and natural gas – while some lumped them together into a "fossil fuels" category. Most participants also identified solar and wind as being renewable, with hydroelectricity being a popular choice as well; likely due to Oregon's extensive hydroelectric resources. Participants were hesitant to describe resources as sustainable, again reinforcing the confusion surrounding these similar terms.

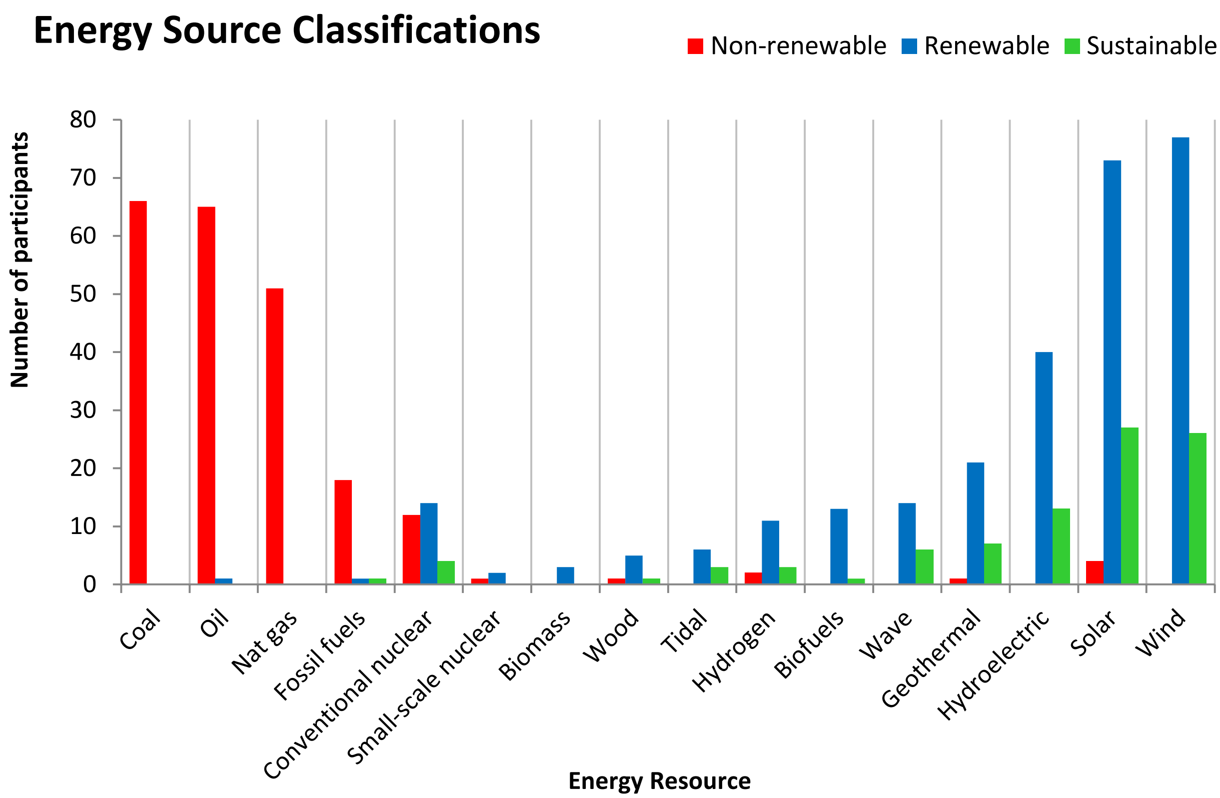


Figure 3-6: Energy resource categorization from question 15, a free-form list of renewable and non-renewable energy sources. Sustainable resources were marked with an asterisk, i.e. a renewable or non-renewable resource could be marked as sustainable.

Despite nearly 75% of survey participants correctly identifying the mechanism by which the greenhouse effect works from a multiple choice list in question 21, only 5 participants in total correctly identified the four major greenhouse gases without listing any gases which are not greenhouse gases. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O) are the major greenhouse gases and were all listed on the multiple choice. Ozone (O_3) and chlorofluorocarbons, along with some other longer and less-common hydrocarbons, are also greenhouse gases but were not included on the multiple choice list. Figure 3-7 shows the distribution of which gases were marked as greenhouse gases. More people (60) selected carbon monoxide (CO) as a greenhouse gas than carbon dioxide (CO_2), even though CO_2 is the most abundant greenhouse gas and CO absorbs only very weakly in the IR spectrum and is not considered a greenhouse gas. This result may be explained by colloquial reference to “carbon” in discussions regarding climate change.

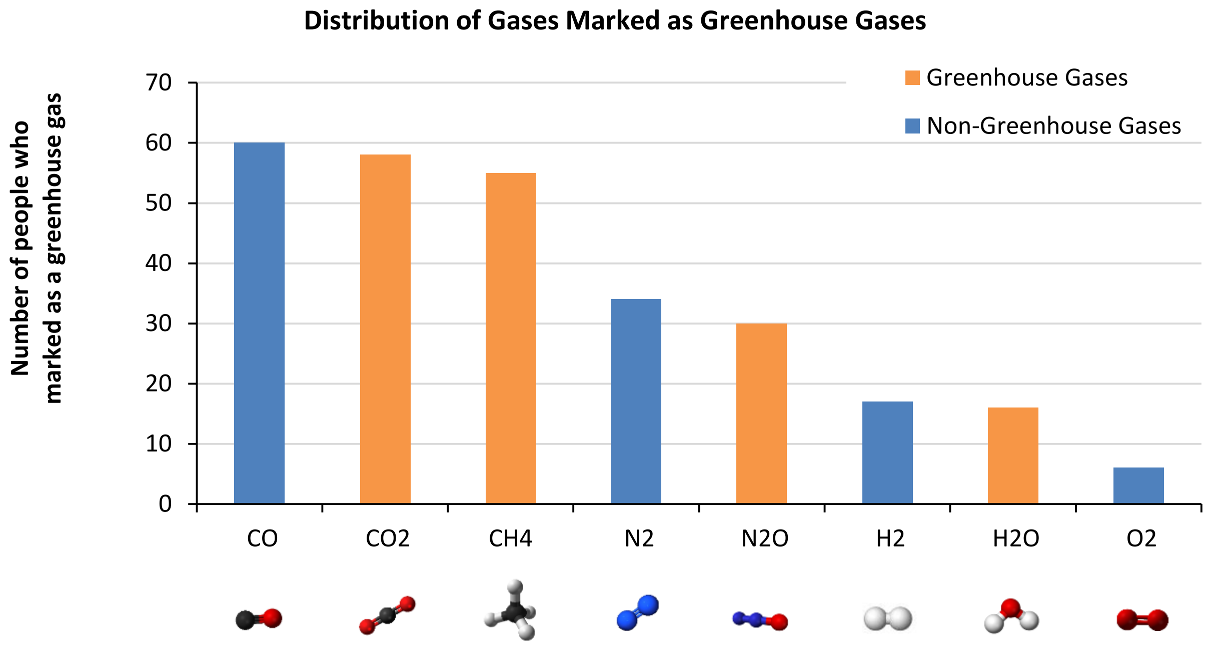


Figure 3-7: Question 21 asked participants to select *all* greenhouse gases on a list of gases found in the atmosphere. Of the gases listed, CO_2, CH_4, N_2O, and H_2O are actual greenhouse gases. The most-selected gas was carbon monoxide (CO), which is not considered a greenhouse gas because it absorbs extremely weakly in the IR. Only 5 participants correctly selected the 4 major greenhouse gases and *only* those gases; 10 participants selected all of the greenhouse gases but had some erroneous additions. The image below each column is a 3D representation of that gas molecule. *Molecule images adapted from public domain images hosted by Wikimedia Commons.*

Climate change is among most-discussed energy-related issues, and is often portrayed in the media as the most significant environmental risk associated with humans' immense use of fossil fuel energy resources. There are many other environmental impacts from energy usage which receive less attention, but are nevertheless important. Question 23 was an open-ended question asking about other environmental problems associated with energy usage. Figure 3-8 shows how many people mentioned various energy-related environmental problems. Most people's concerns focused on air and water pollution, global health, ocean acidification and pollution, and impacts on wildlife and natural habitats.

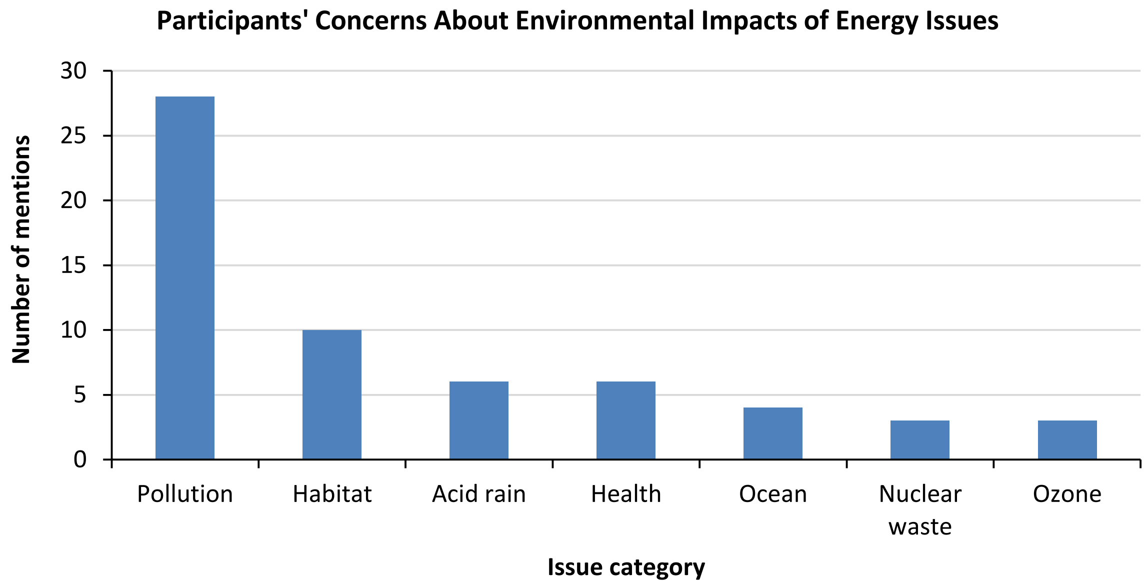


Figure 3-8: The most frequently mentioned environmental problems associated with energy issues, other than climate change. Many participants were concerned about pollution, habitat destruction, and various global health issues.

Finally, public perceptions of which energy technologies look promising and what challenges stand in the way of developing sustainable energy shape public policy decisions. The results of questions 19 and 20 are shown in Figure 3-9 and Figure 3-10. Most participants believe that costs and public policy challenges are the primary obstacles to implementing sustainable energy – not the availability of sustainable resources or technology to use them. Solar power, hydroelectricity, and wind power were considered by many participants to be the most promising or exciting energy resource for switching to a sustainable energy economy.

Overall, the results of this survey give interesting insights into what people think about energy issues. The survey participants see wind and solar energy as promising, but are concerned that a lack of political will and funding will prevent or delay the implementation of these resources. Many participants were very interested in hearing the "right answer" to these questions, and wanted to know more about what they could do to improve their understanding of energy issues. Getting people interested is half the battle, and it is always encouraging to see active engagement from the OSU community in building a sustainable energy future.

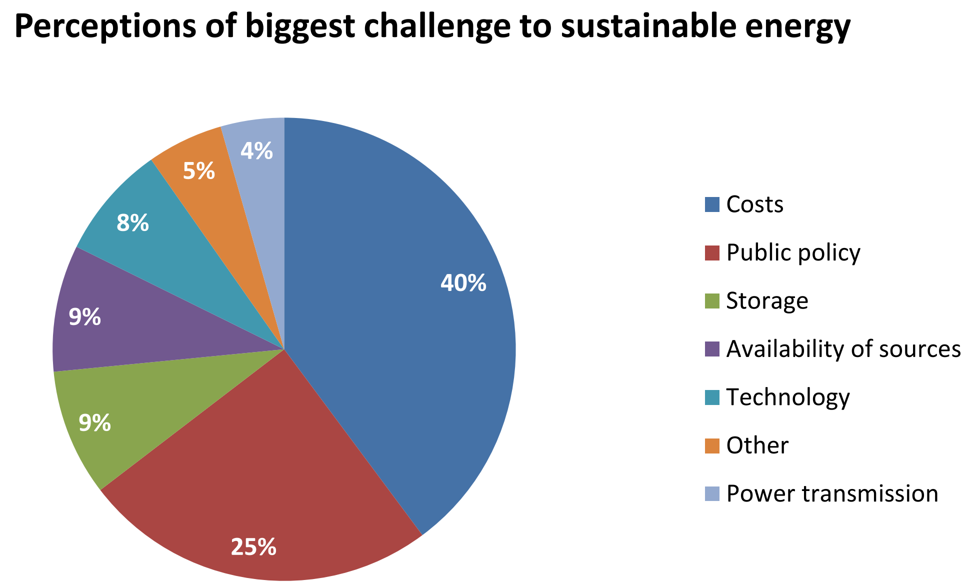


Figure 3-9: Participants chose what they perceived to be the biggest challenge to sustainable energy from a multiple choice list. Human factors such as costs and public policy were considered to be the most significant challenge by the majority of participants.

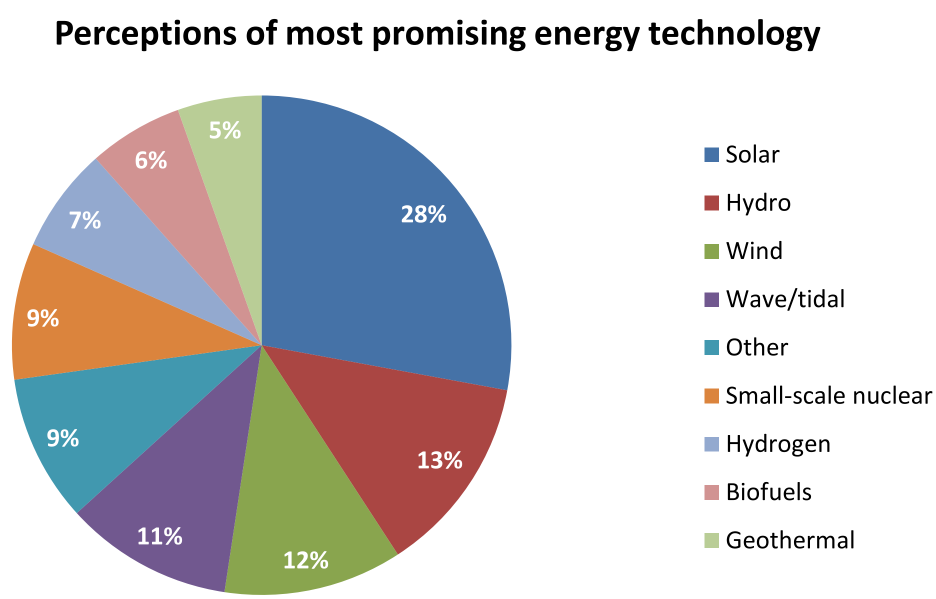


Figure 3-10: Participants were presented with a multiple choice list of energy technologies and asked to select which they believe is most promising for transitioning to sustainable energy. The three most-used and relatively mature renewable energy technologies – solar PV, hydroelectricity, and wind – were also the most-chosen.

Chapter 4: Educational Activity Development

The results of the energy knowledge survey, described in detail in the previous chapter, indicate several opportunities for new educational activities. Topics which stood out include energy efficiency and conservation, emerging energy technologies which many people are unfamiliar with, energy units and conversions, energy terminology, and understanding of energy statistics and trends. Multiple educational activities were developed based on these findings, and each activity was designed to address several of these topics. Most activities can be completed in one or two hours of classroom time, while some are based on take-home assignments. Teacher and student handouts for each activity, as well as any additional materials such as spreadsheets and accompanying presentations, will be published on the OSU COSEY website for educators to download. A copy of all materials produced for each activity is also provided in the appendix.

Efficiency of Water Heating

Reducing energy consumption and using energy more efficiently is widely regarded as one of the most cost effective and simple ways to reduce reliance on fossil fuel resources and decrease the overall environmental impact of energy usage. As shown in Figure 3-4, fewer than 30% of energy survey respondents knew that space heating is the largest consumer of energy in American homes, and fewer than 20% of respondents were aware that over 50% of energy consumed in the US is wasted to inefficiencies. This activity shows the impact of energy efficiency in a hands-on and relatable way by comparing the energy consumption to heat water via different means. We all use hot water in our daily lives, for everything from cooking to bathing. Water heating is the second largest source of energy consumption in homes, accounting for 17% of residential energy usage as shown in Figure 4-1.

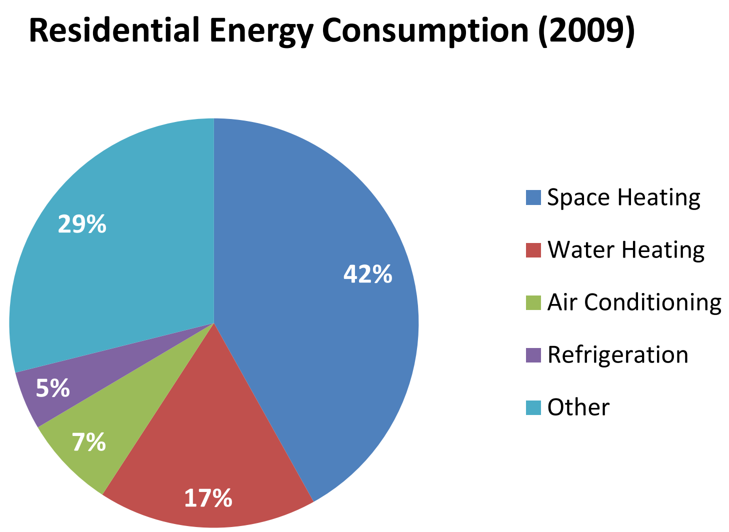


Figure 4-1: US residential energy consumption. Data summarized from the 2009 US Department of Energy Residential Energy Consumption Survey.

Students heat water using various different appliances, such as microwaves, hotplates, coffee machines, and hotpots. A power meter device like a Kill-A-Watt® (shown in Figure 4-2) is used to measure the power consumption of the device while heating, and the temperature of the water is measured before and after heating to calculate the amount of energy delivered to the water. Students can then calculate and compare the efficiency for each device. In addition to demonstrating efficiency concepts, this activity also reinforces the difference between energy and power, and requires students to use common energy and power units to complete calculations. The survey results indicated that many people do not understand the difference between energy, power, and the myriad units used to describe these values.

The experiments described in this activity were run by the author in a lab several times to establish the viability of the activity and to determine typical results. The water heating efficiencies of five devices were measured and calculated at least three times each. The average results are shown in Figure 4-3. The activity was also performed with two groups of middle school TAG students at an OSU Winter Wonderings class and achieved similar results. Activity handouts and instruction packets were edited based on student feedback.

Figure 4-2: A Kill-A-Watt meter (background) being used to measure the power consumption of an electric hot pot (foreground). The hot pot plugs into the Kill-A-Watt, which displays power consumption in W.

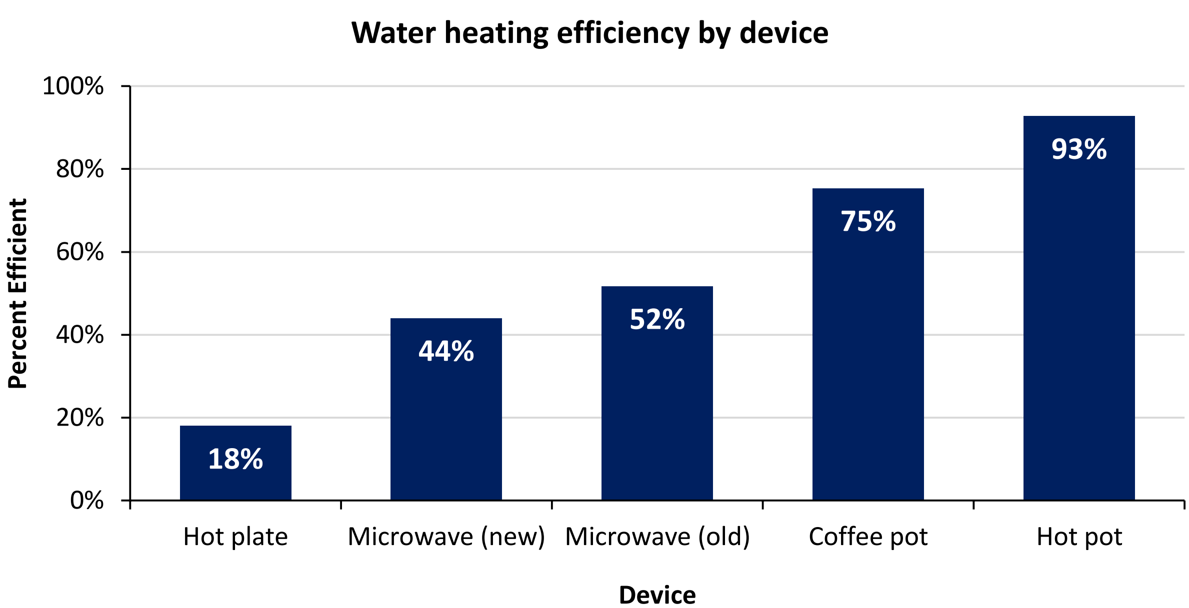


Figure 4-3: Efficiency of various residential water heating devices, as measured by the author in a lab. New microwave and coffee pot were borrowed from the OSU CBEE faculty lounge. Hot plate was used in the CBEE polymers lab. Old microwave was borrowed from the OSU CBEE student lounge. Electric hot pot was purchased for the experiment.

Home Energy Audit

Another efficiency-focused activity, the home energy audit is completed by students individually as a homework assignment. It consists of an appliance audit, a lighting audit, and savings calculations.

The appliance audit uses a Kill-A-Watt® meter – a simple measurement tool which goes between any A/C powered device and the wall outlet, shown in Figure 4-2. Its screen displays the power consumed by the device at any given moment. This can be used to determine the energy consumption of any device in the home, including energy consumption when the device is in use and when it is idle. For the appliance audits, students in a class check out Kill-A-Watt® or similar meters and bring them home to measure the standby and active power usage of devices in their home.

The lighting audit can be completed without any special device, simply by identifying and counting different types of lights in the home. Students are given a worksheet where they can fill in the estimated daily usage, lightbulb type, and location of each light in their home. Using the average power consumption for each light bulb type and the average hours of use each day, total energy consumption from each light can be estimated. Examples of each common type of lightbulb are shown in Figure 4-4.

Figure 4-4: Examples of common lightbulb types. From left to right, a 60W incandescent bulb, a 14W compact fluorescent lightbulb, and a 10W LED bulb. Each emits about the same amount of light, around 800 lumens. *Public domain images from Wikimedia Commons.*

After completing their energy audit, students perform several calculations to determine how much electricity their devices and lighting are using, and to estimate how much money they could save by changing their usage habits. The calculations reinforce the difference between energy and power, and require students to use common energy units. Students must also look up the cost of electricity in their area – either by checking a power bill, searching online, or using a value provided by the instructor.

This activity has been assigned to two years of the OSU Honors College Energy IQ colloquium, and underwent several modifications based on student feedback. The activity was particularly well received by students living in rental housing and paying their own utility bills for the first time. While some people attempt to reduce their energy consumption for environmentally altruistic reasons, money is a much stronger motivator for many people. This activity shows students directly how much money they can save by improving their own energy efficiency and conservation.

Wind and Tidal Energy

Ocean energy has immense potential to provide reliable, predictable, and clean energy. As of 2010, 39% of the US population lived in a county bordering the coast (18). Wave energy capture is an active area of research at OSU, which hosts the Northwest National Marine Renewable Energy Center (NNMREC). Despite significant local research on ocean energy generation, very few people listed wave or tidal energy when prompted by question 15 of the energy survey to list renewable and non-renewable energy resources. Wind power was the most commonly listed of all energy sources in question 15, and is widely recognized and understood. In-stream tidal energy systems work on the same principle as wind turbines – but they use water as the working fluid instead of wind.

The OSU Center for Outreach in Science and Engineering for Youth (COSEY) has an engineering outreach activity for elementary and middle school aged students which demonstrates wind energy concepts by having participants built their own turbine blades and compete to see whose generates the most power when placed in front of a fan. The new tidal activity was designed to be delivered in tandem with the wind turbine activity, and uses the same outreach kits with a few added materials. The standard wind turbine outreach kit uses 1" PVC pipe to build the turbine tower structure, and uses small DC motors as the generators. To add the tidal power components, an inflatable wading pool is filled with water, and a sump pump is used to recirculate the water. The PVC pipe segments are rearranged to create an underwater structure to hold the turbine. Several variations of this activity were run with 4th and 5th grade students at the OSU Spirited Kids in Engineering and Science (SKIES) summer program run by OSU Precollege Programs. This activity is most appropriate for older elementary school students and middle school students.

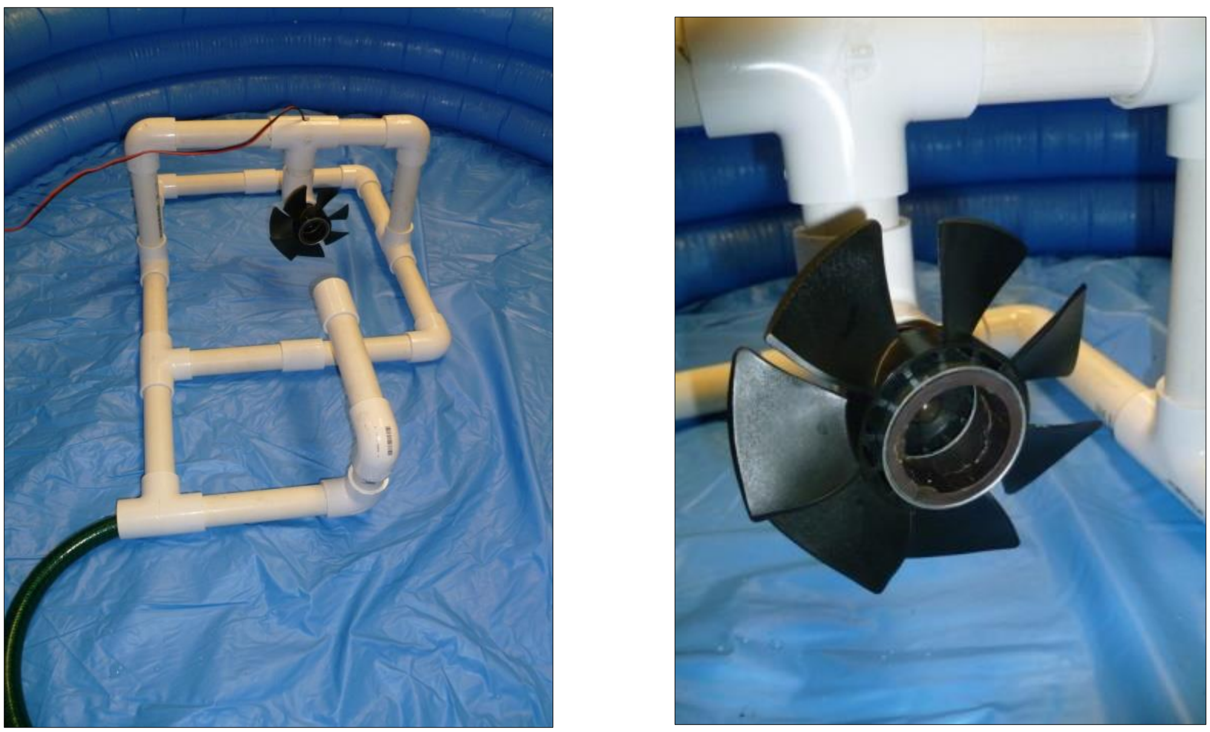


Figure 4-5: The tidal turbine demonstration setup in an inflatable wading pool. An electric sump pump is used to recirculate water, passing it over the turbine blades to simulate tidal flow. The generator is a small DC motor, and the power is calculated by measuring its output voltage and current using a handheld voltage meter.

Energy Definitions

As indicated in Figure 3-4, only about half of survey participants correctly defined renewable energy, and fewer than 30% had a distinct and valid definition of sustainable energy. This short energy definitions activity was created to establish a common understanding of renewable and sustainable energy to facilitate class discussions in the

OSU Honors College Energy IQ colloquium. The author was a student in this course in 2011 and a teaching assistant for this course for 3 years. The thesis mentor has been an instructor in the course since its introduction. For the definitions activity, students are simply asked to define "renewable" energy, "sustainable" energy, and state whether they believe there is a significant difference between the two. Students are also asked to list all of the energy sources they can think of, and list them as renewable or non-renewable, and to circle those they believe to be sustainable.

The assignment is completed before or at the beginning of a class, and then answers from all of the students are shared and discussed. Together the class agrees on a general definition for renewable and sustainable. The teacher handout for this activity includes general definitions of sustainable and renewable energy, and a list of common energy resources and notes regarding their sustainability. Iterations of this activity have been conducted with four years of the Energy IQ class, and have successfully clarified misconceptions and confusion regarding energy terminology and resulted in productive discussions about the concept of sustainability. This activity would be appropriate for almost any age group, and is often a good activity to perform at the beginning of an energy-related class or lesson unit.

Energy Data Detective

Since this project began in 2011, hydraulic fracturing and advanced oil recovery techniques have drastically changed the American energy landscape. Government grants and incentives have also led an increase in installation of solar photovoltaic systems and wind farms, while hydroelectricity production – which provides 70% of Oregon's electricity – is declining. Many of the energy facts spread throughout this thesis will likely be invalid within a few years of its publication. Energy technology and policy is constantly shifting, and it is therefore important for informed citizens to have the skills to verify claims and monitor changes. The energy data assignment guides students through the process of researching current energy data using the US Energy Information Administration's website. This activity was assigned to the OSU Honors College Energy IQ colloquium in 2015, and received positive student feedback.

Conclusions and Future Work

The ultimate objective of this project was to develop new engineering education activities to increase student interest and understanding of contemporary energy issues. A survey was conducted to guide the topic selection for new activities, and five new activities and assignments were written and tested with groups of students. The results of the survey indicated good awareness of many basic, high-level energy-related issues such as classifying resource types, understanding the greenhouse effect and its relation to climate change, and understanding what renewable resources are and the extent to which they are currently in use. Despite good understanding of the most basic concepts, many participants struggled with more nuanced questions such as the distinction between renewability and sustainability, energy-related units, and in what proportions energy is consumed by various end-use sectors.

Many of the energy concepts which survey participants struggled with are indirectly taught in the typical chemical engineering undergraduate curriculum, and they are typically taught as abstract concepts. For example, very few survey participants correctly selected all of the greenhouse gases from a list of common gases. Greenhouse gases are those which absorb in IR wavelengths, so with an understanding of molecular vibrations from physical chemistry it is easy to choose which gases these would be. Chemical engineering fundamentals like heat transfer, thermodynamics, and energy balances are instrumental to understanding many energy systems. Despite understanding these phenomena conceptually and being adept at the calculations to define them, students often lack the real world perspective to put them in context and consider the implications of the calculations they compute. Integration of real world examples is largely up to the discretion of each professor, and is lacking in many courses. The situation is likely similar at other universities and other levels of education. Activities like the water heating efficiency and the home energy audit make these concepts relatable to daily life, thereby reinforcing understanding of the material. A greater emphasis on hands-on, practical assignments which are relevant to contemporary engineering challenges would improve student engagement and understanding of materials in engineering education.

The activities and assignments developed for this project will initially be published through the OSU COSEY website for educators to download and adapt for their own classes. COSEY will also be using the wind and tidal energy activity and the water heating activity for precollege science and engineering camps at OSU, and the UHC Energy IQ course will be using the energy definitions, personal energy audit, and energy data exploration assignments in future classes.

Future work may include preparing the activities for submission to teachengineering.org, a nationally used resource for distributing engineering education activities. Submission to teachengineering.org will require specifying how each activity addresses specific state and national science and engineering curriculum standards. Further work is possible with survey analysis as well. At least 50 unprocessed surveys are available for analysis by future researchers.

Overall the project was successful in identifying opportunities for improving understanding of sustainable energy issues, and in developing new activities to address these opportunities.

Appendices

Energy Knowledge Survey

The primary survey administered to most participants is included below. Several shorter variations were also administered at events with time constraints.

This is a study being conducted by Nathan Hinkle and Dr. Skip Rochefort in the School of Chemical, Biological, and Environmental Engineering at Oregon State University. The results of this study will be used to guide the design of new energy education tools. If you have any questions or concerns about the study, please feel free to ask us.

You may choose to skip any question, and may withdraw from the study at any time.

1. Have you taken this survey before? ___ yes ___ no
2. Have you ever been to a **presentation or outreach event** run by the **OSU Sustainable Energy Initiative?** ___ yes ___ no
3. **Are you in school? If so, please circle which grade level you are in.**

   K12: K-5 6-8 9-10 11-12
   College: Frosh Soph Junior Senior 5th yr/+ Grad student Other _____________
4. **If you aren't in school, please circle your age range, and your highest level of education:**

   <18 18-23 24-29 30-39 40-49 50-59 60-69 70-79 >80

   N/A High school Some college (no degree) 2 yr degree 4 yr degree
   Masters Doctorate Professional degree
5. **What is/was your favorite subject in school?**
6. **Have you ever been to a science or engineering camp outside of school?** ___ yes ___ no
7. **How would you define renewable energy?**
8. **What do you consider to be sustainable energy?**
9. **Do you think there a difference between "sustainable" and "renewable" energy?**
10. **Can energy be created or destroyed?** ___ yes ___ no

11. Your bills arrive, and say that you used **1400 kWh of electricity** last month and **20 therms of natural gas**.

Are kWh a unit of **power** or **energy**? ___ power ___ energy

Are therms a unit of **power** or **energy**? ___ power ___ energy

Which of the following is a **larger amount** of power or energy? ___ 1 therm ___ 1 kWh

12. What is the difference between energy and power? (Choose one)

___ Energy and power are basically the same thing
___ Energy is a measure of the ability of a system to do work, power is an amount of energy transferred over a specific time interval
___ Power is a measure of the ability of a system to do work, energy is an amount of power transferred over a specific time interval
___ Energy is a measure of how much power there is, power is how strong the electricity is

13. Where do fossil fuels come from?

14. Oil, coal, and natural gas account for a large portion of the energy used in the US.

Are these **fossil fuels**? ___ yes ___ no

Are these **renewable** energy sources? ___ yes ___ no

15. List some energy sources that you know of – try to think of at least 2 in each category. Categorize them by "*renewable*" and "*non-renewable*," and put a * by the ones you think are *sustainable*.

Renewable	Non-renewable

16. **Approximately how much of all energy used in the US comes from renewable sources?**

___ Less than $^1/_{10}$th
___ About ¼
___ Almost ½
___ More than ½
___ Almost **100%**

17. **How much of the world's energy is used by the United States?**

___ less than $^1/_{10}{}^{th}$ ___ about $^1/_{10}{}^{th}$ ___ about $^1/_5{}^{th}$ ___ about$^1/_3{}^{rd}$ ___ about ½

18. **What source is used to generate most of *Oregon's electricity*? Is it a renewable resource?**

19. What do **you** perceive to be the **biggest challenge** to implementing sustainable energy?
(Choose one)

___ energy storage ___ availability of sustainable sources ___ financial costs

___ power transmission___ public policy ___ availability of technology

___ other - please describe: ____

20. **Which emerging energy technology do you find the most promising or exciting?**

___ solar ___ geothermal ___ wind ___ small-scale nuclear ___ hydroelectricity ___ wave/tidal
___ hydrogen fuel ___ biofuels ___ other (please specify) ___________________________

21. **What is the greenhouse effect?**

___ Sunlight that reflects off the surface of the earth can't escape
___ Heat absorbed from sunlight is re-radiated by the earth, and trapped in by gases
___ Clouds block sunlight from entering the atmosphere
___ Green vegetation absorbs heat, and releases it as carbon dioxide

22. **Which of the following are *greenhouse gases*?**

___ CO_2 (carbon dioxide) ___ O_2 (oxygen) ___ CH_4 (methane) ___ H_2O (water)
___ N_2 (nitrogen) ___ N_2O (Nitrous oxide) ___ H_2 (hydrogen) ___ CO (carbon monoxide)

Greenhouse gases are primarily released by using which of the following energy sources?

___ geothermal ___ fossil fuels ___ solar panels ___ nuclear reactors

23. **What other environmental impacts due to energy consumption and generation can you think of besides climate change?**

24. **Which of the following uses the most energy in the average American home?**

___ space heating   ___ lighting   ___ appliances   ___ electronics   ___ space cooling

25. **Which sector accounts for the largest percentage of all energy consumed in the US?**

___ residential   ___ commercial   ___ industrial   ___ transportation

26. **How much of the energy consumed in the US is *wasted due to inefficiencies* in moving, storing, and using energy?**

___ about $^{1}/_{10}{}^{th}$ ___ about $^{1}/_{5}{}^{th}$ ___ about $^{1}/_{3}{}^{rd}$ ___ almost half   ___ more than half

27. **Which of the following accounts for the largest amount of energy used in the *food sector*?**

___ transportation   ___ home refrigeration and preparation   ___ agricultural production
___ packaging and processing   ___ food retail

28. **List three things that you do in your daily life to reduce energy consumption:**

29. **What do you want to know more about? Is there any particular energy technology, environmental effect, or other subject you're curious about?**

30. **Please list any additional thoughts or feedback:**

Energy Activity Handouts Appendix

Energy Efficiency of Water Heating

The contents of this activity include:

- Teacher handout and activity description
- Student worksheet
- Student data collection sheets

Energy Efficiency: Heating Water

Summary

Heating water is part of our daily lives – from making coffee or oatmeal for breakfast, to taking a hot shower or washing our hands. There are many different ways to heat water, and the energy required for each method can be surprisingly different. This activity will teach you how to measure the energy change in a cup of water, and you will compare the energy delivered via different heating methods.

Engineering Connection

Hot water and steam are used in all types of engineering processes. Energy balances and thermodynamics are fundamental concepts in chemical engineering and other disciplines. This activity demonstrates basic energy balances and the thermodynamics associated with heating a substance, including the concept of heat capacity.

Materials List

Stations shall be created, with one electrical water heating appliance per station. Each station requires:

- Three 500 mL beakers. For high-temperature stations, additional beakers may be required to ensure an adequate cool-down period is available between tests.
- Oven mitt, tongs, or other appropriate handling equipment
- Thermocouple or thermometer
- Stopwatch
- Towels
- Safety goggles for each student at the station
- Kill-A-Watt power meter

Recommended Setup

This activity can be completed in a one hour lab period; however, at least an hour and a half is recommended if possible. Additional time allows for more discussion and comparison of results. Students with relatively little lab experience may also need additional time and supervision.

Electrical appliances suitable for heating water shall be selected and set up in stations. It is recommended to have students work in groups of 2-4, but larger groups may be necessary depending on the number of stations available and number of students. Ideally, each group will visit each type station once.

Recommended appliances include microwaves, electric kettles, hot plates, and coffee machines. Other appliances may be used as well – the instructions provided can be customized by the teacher.

The objective at each station is to determine the amount of electrical energy consumed by the device and the amount of energy transferred to the water in one minute. The energy loss and efficiency can then be calculated. Energy consumed by the device is measured using a Kill A Watt power meter. Energy transferred to the water is determined from the temperature change and calculated using the heat capacity.

At each station, the recommended process is:

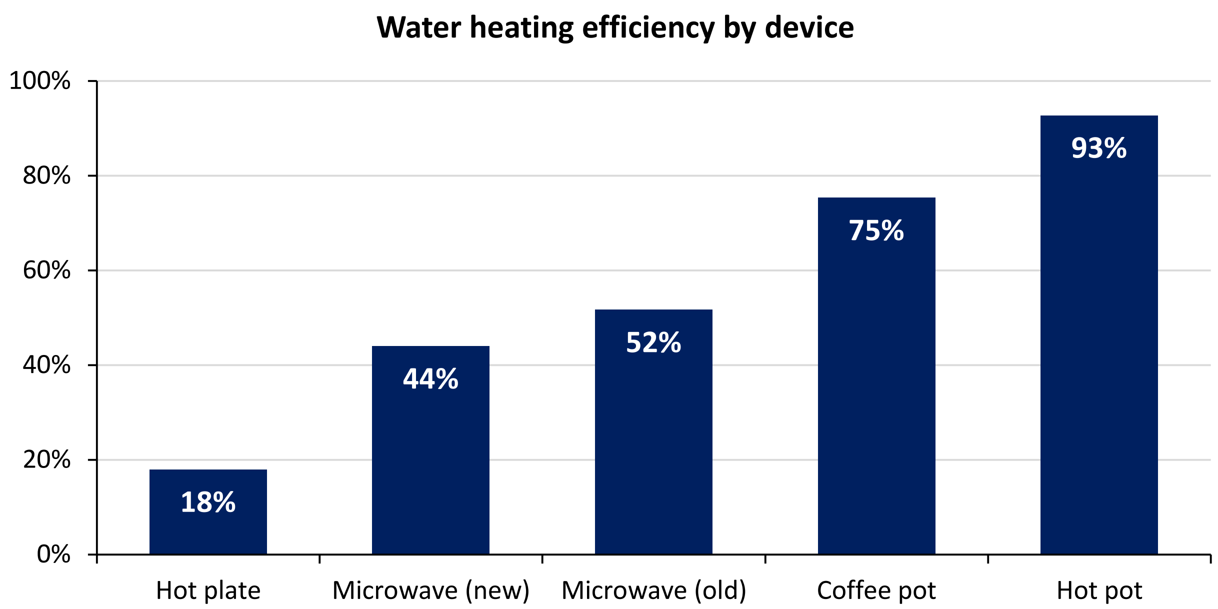
1. Measure out 500 mL of water from a sink using a scale. 500 mL = 500 g.
2. Take the water to your station.
3. Set the Kill-A-Watt to measure **watts**.
4. Put the water in the device, following the instructions for your station's device.
5. Measure the **temperature** of the water **before you start to heat it**.
6. One person in the group should **start the timer** while the other **turns on the device**.
7. While the water is heating, watch the temperature.
8. Write down how many watts the device is using while it's heating the water. If it changes, estimate the average.
9. After **1 minute** (60 seconds) has gone by, one person in the group **turn off the device** and stop the timer, while the other **writes down the final temperature**.
10. Carefully remove and dispose of the hot water.
11. If there is enough time left, run a **second trial** using the same procedure as above with a **new cold beaker and new cold water**. Do not use the same beaker as the first time.
12. Calculate the **energy used** to heat the water, and **how much energy the water absorbed**.
13. Calculate the **efficiency** of the heating device.

Temperature before	
Temperature after	
Change in temperature	
Heat capacity	4.18 J/gK
Mass of water	500 g
Efficiency (Energy captured ÷ energy used)	

Power (W)	
Time (seconds)	
Energy used (J) (power × time)	
Energy captured (Change in T × heat capacity × mass of water)	

Typical Results

Results will vary depending on the exact device used, and there will be significant variation between runs. Controlled tests conducted by experienced undergraduate researchers yielded the following results for various equipment.



Advanced Options

For advanced students or labs with more time, various extensions can be made to the activity. Detailed instructions and handouts are not provided for these extensions.

- **Heat loss and insulation:** Experiment with increasing the measured efficiency by reducing heat transfer out of the beakers. Discuss modes of heat transfer: conduction, convection, radiation, and evaporation. Discuss which modes of heat transfer have the greatest effect on this system, and design methods to reduce heat losses such as by adding insulation around the beaker, or adding a lid to prevent evaporation.
- **Non-electrical heating equipment:** Compare efficiency to non-electrical heating methods. For example, gas camping stoves can be used to heat water. To determine the energy consumed by the stove, measure the mass of the fuel bottle before and after heating. Discuss the enthalpy of reaction in a combustion reaction, and determine the energy content of the fuel.
- **Heat of vaporization:** Rather than merely heating water, bring it to a boil. Measure the amount of water vaporized by recording the mass of the beaker before and after. Discuss enthalpy of vaporization, phase transitions, and boiling points.

Energy Efficiency Activity

Student handout

In this activity, you will be measuring how much energy it takes to **heat water** using different devices. You will be using several different heating devices: a new microwave, an old microwave, a coffee pot, an electric kettle, and a hot plate.

You will have 10 minutes at each station to measure the energy usage with your group. Please read the instructions for each station carefully! We will be working with very hot water, and don't want you to get hurt!

These are the general instructions for each station. Some things may be different at some stations.

1. Measure out 500 mL of cold water from a faucet using a scale. 500 mL = 500 g.
2. Take the water to your station.
3. Plug the Kill-A-Watt into the wall and set it to measure **watts**.
4. Plug the heating device for the station into the Kill-A-Watt.
5. Put the water in the device, following the instructions for your station's device.
6. Place the thermometer or thermocouple in the water.
7. Measure the **temperature** of the water **before you start to heat it**.
8. One person in the group should **start the timer** while another **turns on the device**.
9. While the water is heating, watch the temperature.
10. Write down how many watts the device is using while it's heating the water. If it changes, estimate the average.
11. After **1 minute** (60 seconds) has gone by, one person in the group **turn off the device** and stop the timer, while another **writes down the final temperature**.
12. Ask your station helper to take away the hot water. **Do not touch the hot water yourself.**
13. If there is enough time left, run a **second trial** using the same procedure as above with a **new cold beaker and new cold water**. Do not use the same beaker as the first time.
14. Calculate the **energy used** to heat the water, and **how much energy the water absorbed**.
15. Calculate the **efficiency** of the heating device.

Station Data Sheet

Group name: ______________________________

Station: ______________________________

Temperature before	
Temperature after	
Change in temperature	
Heat capacity	4.18 J/gK
Mass of water	500 g
Efficiency (Energy captured ÷ energy used)	

Power (W)	
Time (seconds)	
Energy used (J) (power × time)	
Energy captured (Change in T × heat capacity × mass of water)	

Notes and observations:

Station Data Sheet

Group name: ______________________________

Station: ______________________________

Temperature before	
Temperature after	
Change in temperature	
Heat capacity	4.18 J/gK
Mass of water	500 g
Efficiency (Energy captured ÷ energy used)	

Power (W)	
Time (seconds)	
Energy used (J) (power × time)	
Energy captured (Change in T × heat capacity × mass of water)	

Notes and observations:

Home Energy Audit Activity

The contents of this activity include:

- Student assignment handout
- Student data collection worksheet
- Data collection worksheet example
- Excel lighting audit calculator
- Excel spreadsheet example

Activity: Personal energy audit

Objective

You will determine how much energy is used in your home and how much is being wasted to inefficiencies. You will also calculate the potential energy and money savings that could result from making changes to your energy usage habits.

Engineering Connection

Residential energy use accounted for about 15% of total US energy usage in 2013[1]. Almost 35% of energy used in homes is wasted energy – lost to various inefficiencies. Industrial energy use accounted for nearly 35% of total energy usage in 2013. Many engineers work in industrial settings, and reducing process and manufacturing energy usage is an increasingly important part of an engineer's job. Reducing energy consumption reduces utility bills for homeowners and industries alike, and reduces emissions of greenhouse gases and consumption of fossil fuels. Energy audits are a common method used to identify areas for improvement in both residential and industrial settings. This activity teaches you to use real engineering equipment and methods to identify energy savings potentials in your home – and maybe save you some money!

Activity Components:

- **Appliance audit:** Check the power consumption of at least 3 devices, both in-use and idle/"off"
- **Lighting audit:** Count how many light bulbs you have and what their power rating is, and estimate how long they are used each day
- **Audit review:** Determine how you could reduce your energy use based on the above checks, and calculate how much money that would save you annually

Materials List

This project requires a homework assignment and must be partially completed at home. Each student will need a Kill-A-Watt power meter (or similar device). These can be purchased from hardware stores, or online from vendors like Amazon and NewEgg. It is recommended to purchase several, and check them out to students over the course of a couple weeks, so that each student can use a meter for at least a couple days at home.

[1] LLNL Energy Flow Charts. US Department of Energy. Retrieved April 2015. <https://flowcharts.llnl.gov/>

Assignment Details:

Appliance audit:
For this portion of your energy audit, you will need to choose at least 3 devices or appliances in your home and measure their power consumption using the provided Kill-A-Watt. Measure the power consumption in the following states:

- "Off": whatever state you usually leave the device in when not in use. This might be standby mode, completely turned off, or just plugged in and not doing anything.
- In use: using the device under normal operation.

Please record these data in the table provided with this assignment.

Make sure the Kill-A-Watt is displaying Power (Watts) as the units.

Lighting audit:
For the lighting audit, you just need to count your lightbulbs and figure out the power rating for each. Most incandescent bulbs use 60W, and most CFLs use about 15W. If you aren't sure, the rating should be listed on the bulb. For each lightbulb, estimate how many hours it is on per week. Please record these in the provided table, then fill out the provided spreadsheet to calculate energy use and costs.

60W Incandescent

14W Compact Fluorescent

10W LED

Writeup:

It is difficult to calculate energy savings for heating without doing extensive measurements and calculations, so we will only be looking at lighting and appliances in this assignment.

For appliances, calculate the total annual energy usage in the “on” and “idle” states of the device. Multiply the estimated hours per week by 52 weeks to get the hours per year. Then, calculate the electricity costs of the in-use and idle power consumption. Determine the energy and money savings if instead of leaving the device in an idle state, you completely unplugged it instead.

For lightbulbs, use the provided spreadsheet to calculate the energy savings if each incandescent light were replaced with a compact fluorescent, and if all incandescent and CFL lights were replaced with more energy efficient LEDs. The spreadsheet will automatically tabulate the total energy savings and calculate the total monetary savings by month and year. Enter the cost of electricity, either from you or your parents’ electricity bill, your area’s average power cost, or assuming $0.10/kWh if you can’t find a local value.

After calculating the potential energy savings, write a paragraph about what changes you might make in your energy usage habits.

Name: ____________________________ **Personal energy audit**

Appliances and devices

Device	Power (active)	Power (idle)	Usage (hrs/week)	Active kWh/yr	Idle kWh/year

Total power usage			**kWh/yr**	**kWh/yr**
Your electricity costs			**$/year**	**$/year**
Rate:		¢/kWh		

Lighting audit*

Light location	Type	#	Power rating	Avg hrs/day

*Record your data here, then complete and turn in the Excel worksheet to calculate power usage from lights

Heating audit

Time	Temperature (°F)
Morning	
Day	
Evening	
Overnight	

Name: ___________________________ **Personal energy audit**

Appliances and devices

Device	Power (active)	Power (idle)	Usage (hrs/week)	Active kWh/yr	Idle kWh/year
Laptop	55	0.3	60	172	1.7
Phone charger	0.9	0.4	12	0.56	7.3
Desktop computer	260	5.2	20	270	40
Microwave	1600	2	1	83	903
Wireless router	4	N/A	168	35	0

			kWh/yr	kWh/yr
Total power usage			560	952
Your electricity costs			**$/year**	**$/year**
Rate:	12	¢/kWh	$67.20	$114.24

Lighting audit*

Light location	Type	#	Power rating	Avg hrs/day
Kitchen	CFL	4	15	3.5
Kitchen	Incandescent	1	70	0.1
Kitchen	Halogen flood	1	50	3.5
Dining room	CFL	3	15	5
Hallway	CFL	1	15	3
Living room lamp	Incandescent	1	60	4
Living room	Incandescent	1	60	10
Porch light	CFL	1	15	12
Bedroom 1	CFL	2	15	6
Bedroom 1 lamp	CFL	1	15	2
Bedroom 2	CFL	1	15	8
Lamp	Incandescent	1	60	4
Garage	Incandescent	1	60	0.5

*Record your data here, then complete and turn in the Excel worksheet to calculate power usage from lights

Heating audit

Time	Temperature (°F)
Morning	63
Day	62
Evening	68
Overnight	55

Location	Type	Hrs/day	Rating (W)	#	kWh/month	kWh/yr	$/month	$/year

	Total #	Hours/day	kWh/month	kWh/yr	$/month	$/yr
CFL						
Incandescent						
LED						
Other						

Electricity cost ($/kWh)		Potential savings	kWh/yr	$/yr
		Incandescent -> CFL:		
		Incandescent -> LED:		
		Incandescent + CFL -> LED:		

Location	Type	Hrs/day	Rating (W)	#	kWh/month	kWh/yr	$/month	$/year
Kitchen	Incandescent	3.5	15	4	6.3	75.6	$ 0.63	$ 7.56
Kitchen	Incandescent	0.1	70	1	0.21	2.52	$ 0.02	$ 0.25
Kitchen	Incandescent	3.5	50	1	5.25	63	$ 0.53	$ 6.30
Dining room	CFL	5	15	3	6.75	81	$ 0.68	$ 8.10
Hallway	CFL	3	15	1	1.35	16.2	$ 0.14	$ 1.62
Living room lamp	Incandescent	4	60	1	7.2	86.4	$ 0.72	$ 8.64
Living room	Incandescent	10	60	1	18	216	$ 1.80	$ 21.60
Porch light	CFL	12	15	1	5.4	64.8	$ 0.54	$ 6.48
Bedroom 1	CFL	6	15	2	5.4	64.8	$ 0.54	$ 6.48
Bedroom 1 lamp	CFL	2	15	1	0.9	10.8	$ 0.09	$ 1.08
Bedroom 2	CFL	8	15	1	3.6	43.2	$ 0.36	$ 4.32
Lamp	Incandescent	4	60	1	7.2	86.4	$ 0.72	$ 8.64
Garage	Incandescent	0.5	60	1	0.9	10.8	$ 0.09	$ 1.08

	Total #	Hours/day	kWh/month	kWh/yr	$/month	$/yr
CFL	6	36	23.4	280.8	$ 2.34	$ 28.08
Incandescent	7	25.6	45.06	540.72	$ 4.51	$ 54.07
LED	0	0	0	0	$ -	$ -
Other	0	0	0	0	$ -	$ -

Electricity cost ($/kWh)	$0.10	**Potential savings**	**kWh/yr**	**$/yr**
		Incandescent -> CFL:	406	$ 40.55
		Incandescent -> LED:	451	$ 45.06
		Incandescent + CFL -> LED:	544	$ 54.42

Wind and Tidal Activity

The contents of this activity include:

- Activity description teacher handout
- PowerPoint presentation (slide overview shown)

Activity: Wind and Tidal Energy

Summary
Many people are aware of wind power as a source of renewable and sustainable energy. This activity is an easy, hands-on demonstration of how wind power works. The concepts from wind energy are then transferred to understanding tidal energy – an emerging energy technology which operates on the same principles as wind energy in a different environment.

Engineering Connection
This activity addresses basic engineering concepts around energy, electricity, and mechanical design. Topics include electromagnetism and conversion of mechanical energy to electrical energy; relationship between voltage, current, and power; and how shape, material, and construction affect an engineering design.

Materials List
The base set for this activity is the wind power activity kit used by OSU COSEY. Additional supplies are required for the tidal power demonstration.

Windmill materials
- At least two PVC windmill kits. Components required (1” PVC pipe recommended):
  - Eight (8) straight pieces, 6” long
  - One (1) long straight piece (tower), 1-2 feet long
  - Five (5) elbow connectors (90°)
  - Three (3) T-connectors
    - One T-connector must have a ~0.25” hole drilled on the bottom
  - Windmill hub DC electric motor/generator with at least 3 feet of wire. Motor diameter must be small enough to fit into the PVC elbow connector.
  - Two (2) PVC straight joints
- One windmill hub for each group of students.
- Six wooden dowels for each group of students.
- One multimeter with alligator clips for each windmill.
- Blade materials, such as cardstock, cereal boxes, etc.
- Masking tape.

Tidal energy materials
- Two PVC windmill kits (described above).
- Recirculating pump with hose. A sump pump and garden hose work well.
- Inflatable or plastic kiddie pool. Recommended at least 1 foot deep.

- Turbines – many possible materials can be used here. Detaching the blades from recycled computer fans works well. A hole must be drilled in the center of the turbine for it to be attached to the generator.
- Water resistant generator. A standard DC generator/motor can be used if any holes on the side with the shaft are covered with electrical tape. Electrical tape should be wrapped around the circumference of the motor until it's just slightly thicker than the PVC elbow. The generator can then be carefully inserted to form a seal.

Activity Procedure

The two activity components – wind power and tidal power – each take about an hour to complete. It's often easiest to do the two activities on separate day to allow more setup time and to avoid overwhelming students. The wind activity should be performed first, because wind energy is typically more familiar to students than tidal energy.

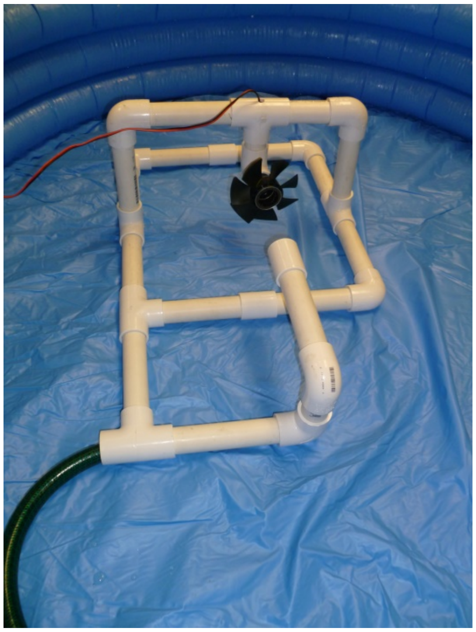
Wind Energy Setup

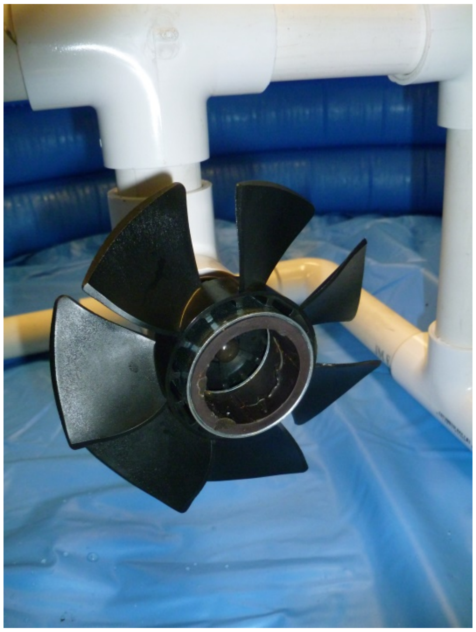
The wind activity instructions have been developed by OSU COSEY and are provided as an appendix to this activity.

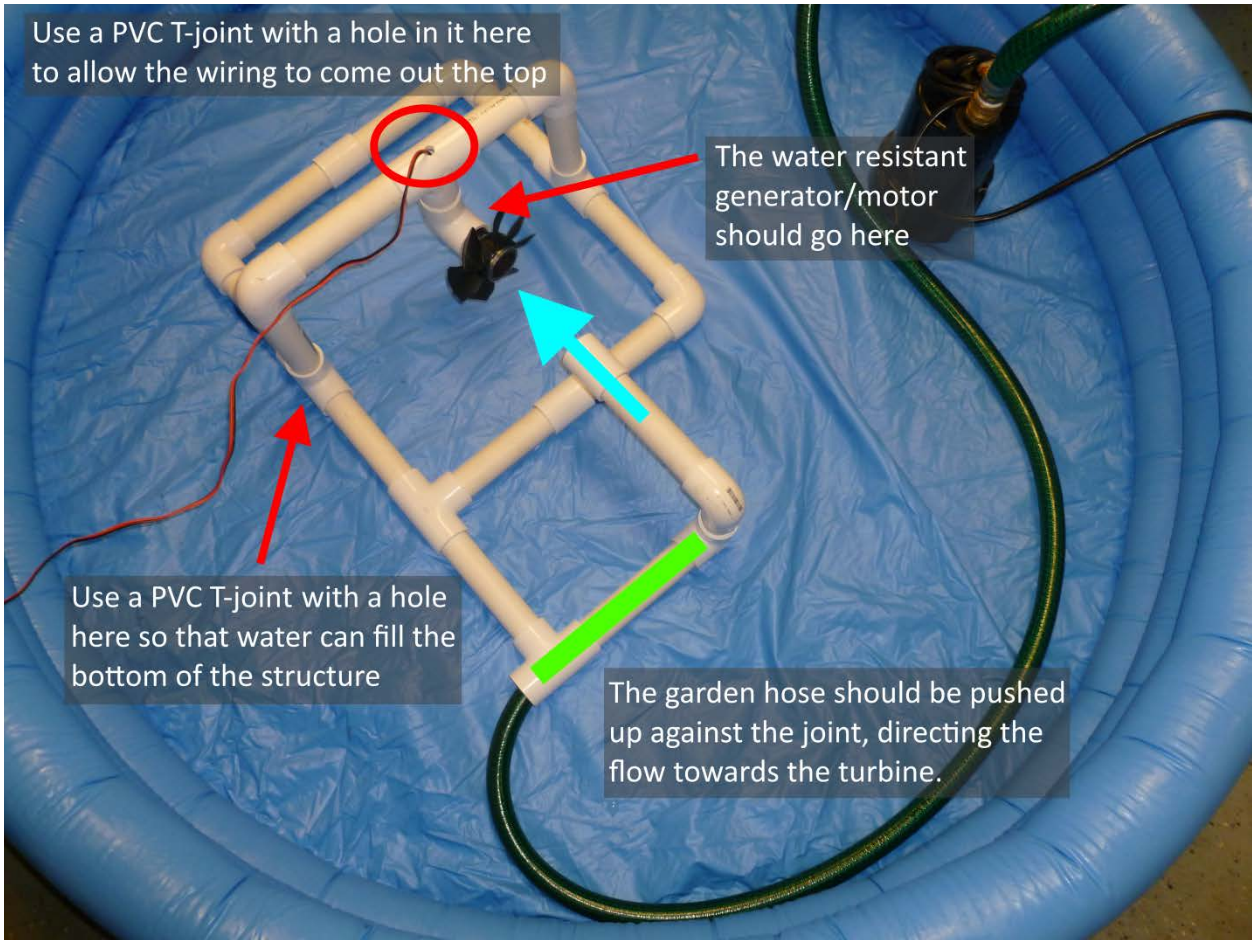
Tidal Energy Setup

Set up the kiddie pool in an appropriate area. This activity is best done outside if possible, or else on a paved indoor area with adequate drainage. The selected location must be near a water source to fill the pool, and near an electricity outlet to run the pump.

Using the PVC pipes from two wind turbine kits, construct the tidal turbine support structure as shown in the photos below:







After setting up the turbine structure, fill the pool such that the turbine is covered by the waterline. Start the recirculating pump, and adjust the angle of the pipes as necessary.

Tidal Energy Procedure

After completing the wind power activity, show the included PowerPoint presentation on tidal energy. Discussion points should include the similarities between tidal and wind energy, specifically the principle of using a moving fluid (water or wind) to turn a turbine (similar shapes) which turns a generator to produce electricity. Also discuss geographic limitations of wind and tidal energy, and differences in how predictable and reliable the power generation is.

Depending on the amount of time and supplies available, students may work in teams to design their own turbine blades, or may select pre-made blades using the suggested materials provided in the materials section.

After teams have designed or selected turbines, have each team explain their choice and what features of the design they think will result in the highest energy production. If the pump supports different flow rates, discuss which designs will work better at high or low flowrates. Teams can then test their designs. Attach a turbine to the shaft of the generator, and turn on the pump. Measure the voltage and current with the multimeter to determine power output. Adjust the angle of the turbine relative to the water flow to achieve the maximum power output. Record the maximum power output for each team's design. If the pump supports multiple flow rates, measure the maximum output at both a high and a low flow rate. After all teams have finished testing, collect and compare the results to determine which design is optimal.

Possible Extensions

This activity can be extended in many ways depending on the subject matter of the course, time available, and experience level of the students. Some possible extensions include:

- 3D printed turbines. Students learning CAD software can design a turbine and 3D print it. This allows for much more advanced turbine designs, and exploration of factors such as blade shape, number of blades, angle of blades, diameter of turbine, and weight distribution.
- Experimentation with different flow patterns. Tidal basins can have very complicated fluid dynamics. Adjusting the angles of the water outlet, or building diffusers to create different flow patterns can demonstrate how different flows affect different turbine designs.


Recall: How Wind Power Works

- Wind blows, turning the turbine blades
- The turbine turns a generator
- The generator converts mechanical energy to electricity

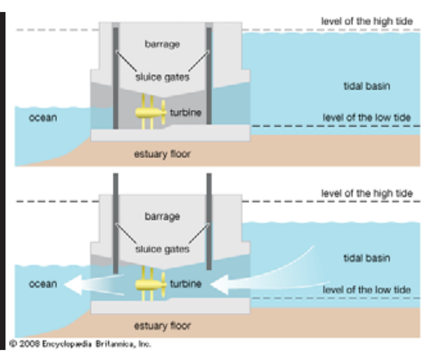
Tidal Power

Tidal power is almost exactly the same:

- The incoming or outgoing tide turns a turbine
- The turbine turns a generator
- The generator converts mechanical energy to electricity

Two Main Types of Tidal Energy

- Tidal Stream Generator:
  - Very similar to a wind turbine, but underwater
  - Small impact on surface conditions
  - Can generate power when tide is coming in or out
- Tidal Barrage:
  - Very similar to a hydroelectric dam
  - Blocks the mouth of an estuary
  - Captures water behind the barrage at high tide, and releases water at low tide to generate power




Energy Data Exploration Activity

The contents of this activity include:

- Assignment overview teacher handout
- Student assignment handout

Energy Data Assignment Overview

Objective:

As policies shift and technologies evolve, how we use energy and where we get it from can change completely in a matter of years. An important component of being an informed citizen is being aware of what's happening in the world, and being able to verify claims. Factoids in a lecture can be interesting, but may not even be true a few years later. In this assignment students will use the US Energy Information Administration's website to find current and historical data about energy-related issues. In exploring the website and data sources, students will learn where to find information to educate themselves in the future when they have questions or doubts about energy issues.

Engineering Connection

Data analysis is a necessary skill for any type of engineer, and the challenges of transitioning to sustainable energy resources require engineers of all disciplines. This activity introduces students to an important and comprehensive online resource for energy-related data.

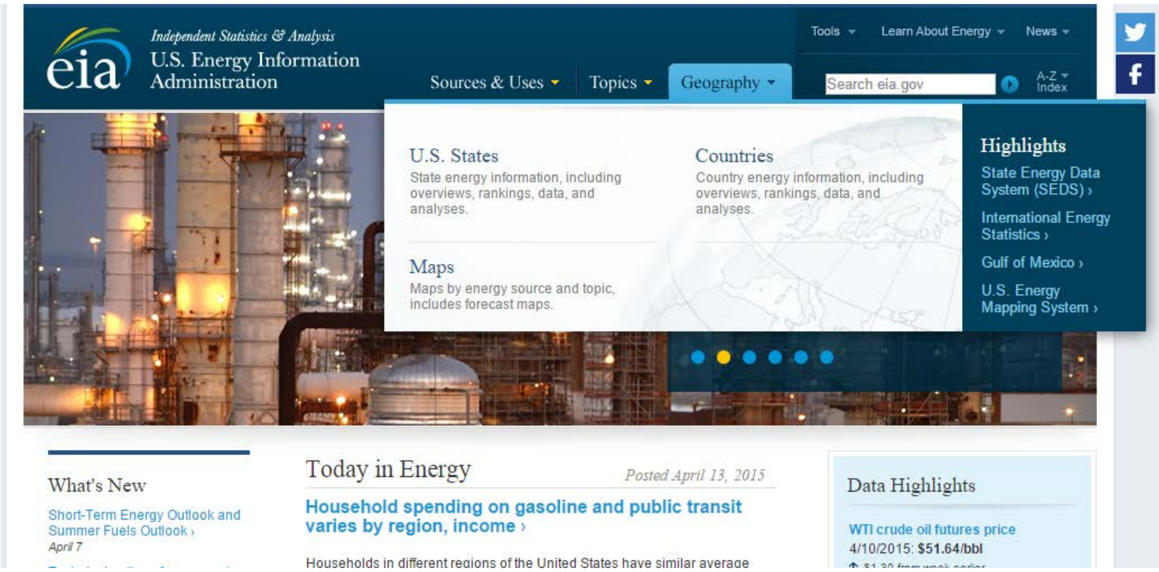
Assignment Overview

The instructor shall edit the assignment file to specify the state which the students reside in. All students will be asked to locate and report certain data about the state they live in, and a second state of their choosing. The answers for the home state should be the same for all students, and can thus be easily graded and discussed as a group. Comparisons can then be made between the home state and the second state of the students' choice. The national energy statistics has a more open-ended component, where each student locates a data table of interest and brings a printed graph of the data.

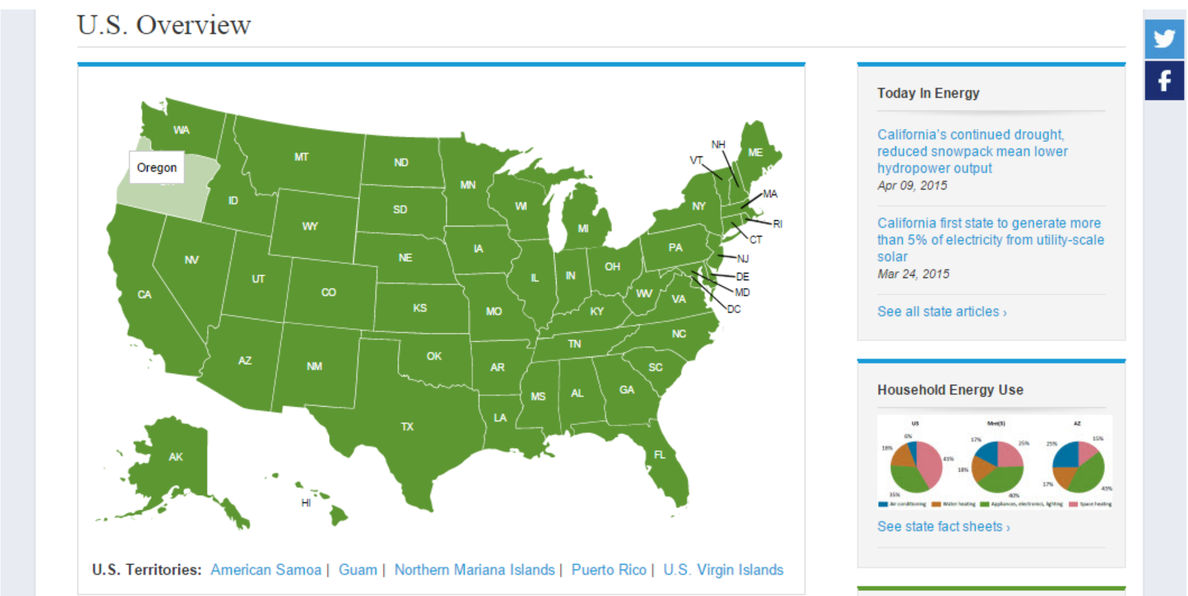
Data Source Reference

The location of all data required for this assignment should be easy to find on the EIA website. As a reference, here are instructions to locate the data as of April 2015:

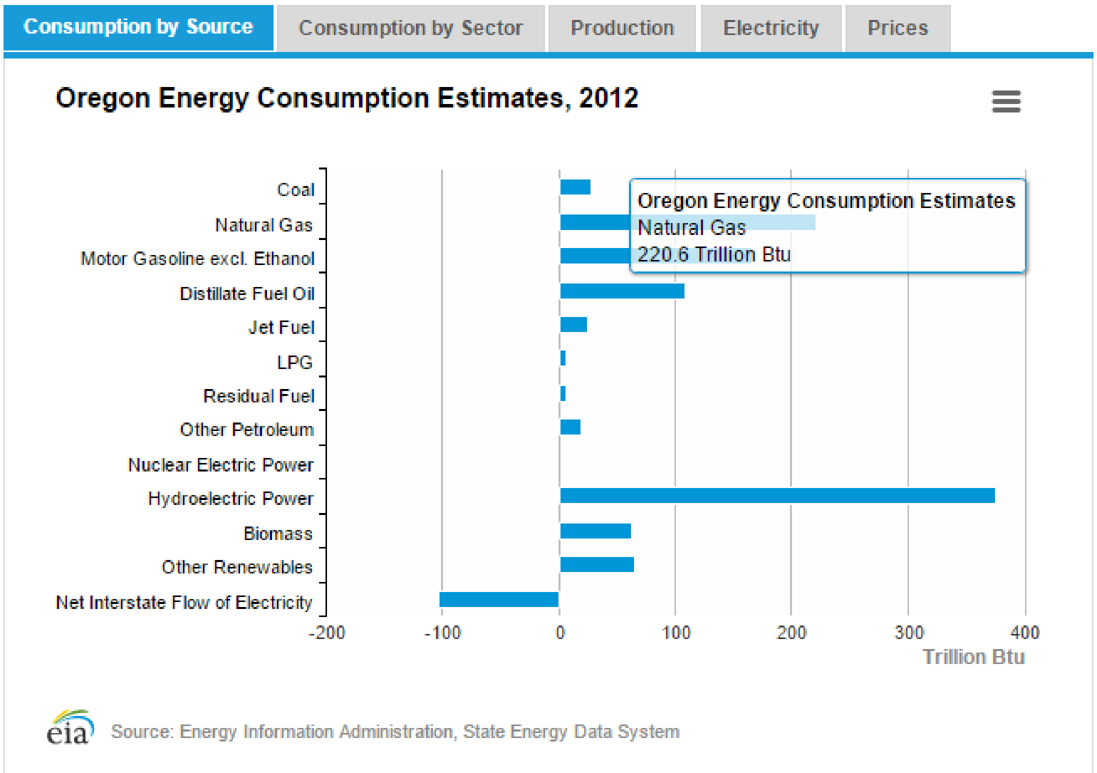
To get all state statistics, go to the eia.gov homepage, and click Geography > US States



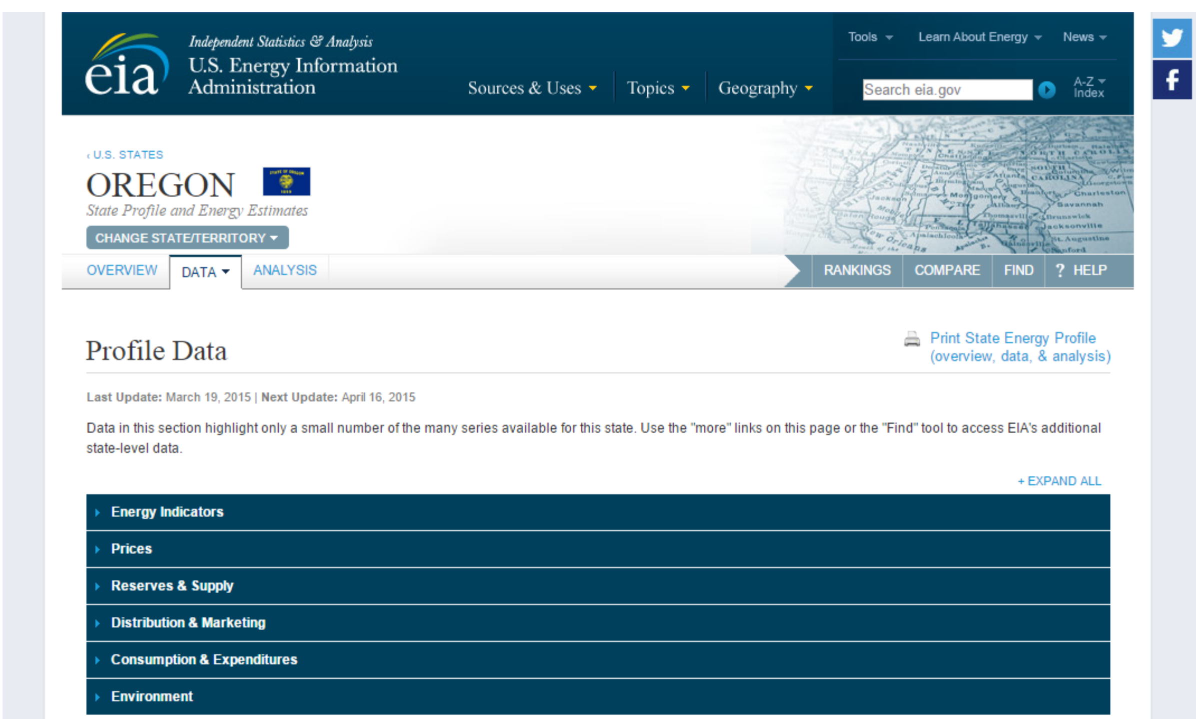
Click on the state of interest on the US map:



Much of the necessary data is available in charts on the state's data overview page:

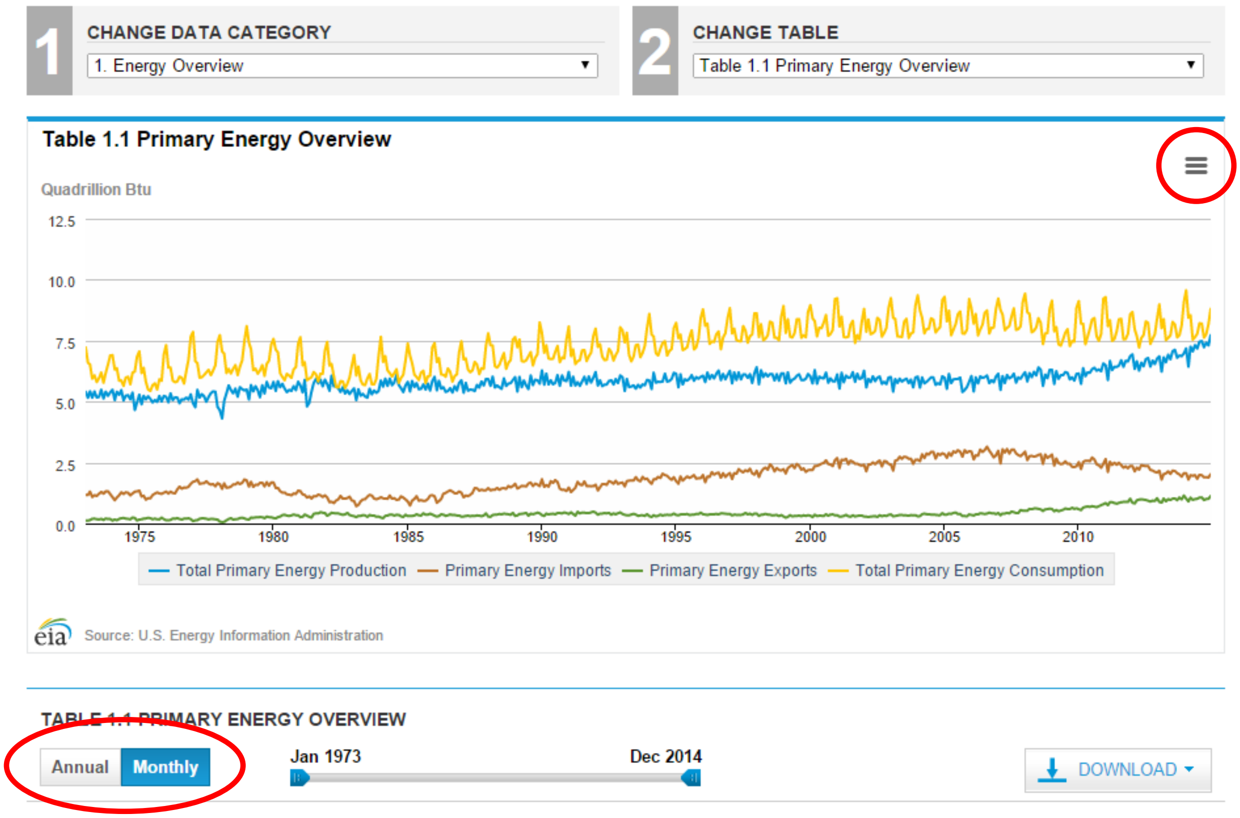


Additional detailed data can be found by clicking on the Data tab for the state:



For national statistics, go to the following URL: http://www.eia.gov/beta/MER/index.cfm

Here the data category can be selected, and the specific data table of interest can be selected.



Switching the date rang from “monthly” to “annual” is recommended, as annual data is available back to 1949, while monthly data is only available to 1973.

The menu icon on the upper right can be used to download images of the graph. Alternatively, students can report the URL to their selected graph, which can then be clicked on to view the interactive version of the chart.

Activity Extensions

This activity can be adapted to include specific topics relevant to the course’s area of study. EIA data encompasses almost every form of energy produced and consumed in the United States, and has significant amounts of international energy data as well. Students practicing plotting skills can download Excel worksheets with raw data, and produce their own graphs. Students researching a particular energy source can find information about where and how much it’s used. Courses focused on environmental impacts can find data on CO_2 emissions and other pollutants by energy source or usage sector.

Energy Data Assignment

You will use the Energy Information Administration (EIA) website at eia.gov to complete this assignment.

State Energy Stats

Find the following information for [Oregon] and for the state you were born in. If you were born in [Oregon] or outside of the US, select a different US state of your choice – perhaps somewhere you hope to live in the future, or somewhere your family is from. From the EIA homepage, click Geography > US States, then select the state from the map. Most of the information should be on the state overview but you will have to dig into the Data tab for some information.

	[Oregon]	**2nd state: ________________**
Find and report in order (largest to smallest) the top 3 *energy* sources (not just electricity).	1) ________________ 2) ________________ 3) ________________	1) ________________ 2) ________________ 3) ________________
Rank the state's energy consumption by sector (residential, commercial, industrial, transportation).	1) ________________ 2) ________________ 3) ________________ 4) ________________	1) ________________ 2) ________________ 3) ________________ 4) ________________
List the top 3 electricity sources	1) ________________ 2) ________________ 3) ________________	1) ________________ 2) ________________ 3) ________________
How many major pipelines are in the state? (Look under "Distribution & Marketing" on Data tab)		
How much CO_2 is released by energy consumption annually?		
What is the most recent residential electricity price? What is the US average?		
	US Average: ________________	

National Energy Stats

Go to eia.gov/beta/MER/index.cfm and use the graph data explorer. Click the "annual" button to get data going back to 1949.

- Select Category 3 (Petroleum) and Table 3.1 (Petroleum Overview). Compare petroleum field production (oil and natural gas produced in the US) to net imports (oil and natural gas imported from other countries). Comment on the recent trends, and answer the following questions:
    - Has domestic production increased or decreased in recent years?
    - Do you predict that domestic production will continue its current trend?
- Now, explore the different tables and graphs. Find one that's interesting to you – try to find one you don't think anybody else in the class will choose. Click the menu icon on the top right of the graph to print it out and bring it to class to share and discuss. Write 1-3 sentences describing the data in the graph you chose, and why you chose it.

Energy Definitions Activity

The contents of this activity include:

- Assignment overview and teacher handout
- Student assignment handout

Defining Sustainable Energy

Objective

Talking about energy can be confusing, and a common vocabulary is required to have meaningful discussions about energy-related issues. The technical aspects of energy definitions, such as the myriad units used to describe quantities and rates of energy, are covered in many engineering and science textbooks. The phrase “sustainable” is often thrown around, but many people disagree about what sustainability means. This activity asks students to consider their personal definition of sustainability, and provides some common definitions of related terms.

Activity Instructions

This activity is best conducted as an interactive discussion with groups of students. For very large classes it may be advantageous to break into smaller groups to ensure that each student has the opportunity to contribute. Each student should fill out the provided student handout individually or in groups. The handout asks students for their definitions of renewable and sustainable energy, asks whether they perceive a difference between the two, and asks them to list the energy sources they can think of and categorize them.

After students or groups have completed the handout, a group discussion should be held to share the definitions. With larger classes, this discussion can take place in two levels, with each group comparing their answers and sharing ideas and then reporting their collective definitions to the class. The teacher should keep a list on the blackboard of general definitions or words used to describe renewable and sustainable energy. Use a show of hands to evaluate how many people consider there to be a difference. A class list of renewable and non-renewable sources should also be created on the blackboard or document projector. For each source suggested, ask the class to vote by show of hands whether it goes in the renewable or non-renewable category, and whether or not it’s sustainable.

The ultimate goal is for the class to develop its own agreed-upon definitions of renewable and sustainable. They should be distinct definitions. Included below are some generally agreed upon definitions, but your class’s definition may be different, and that is OK.

Renewable energy is generally considered to be energy produced from resources which are naturally renewed on human timescales. Renewable energy sources may include sun, wind, water (in the form of rivers or wave/tidal energy), and biomass or biofuels. Geothermal energy is also generally considered to be a renewable energy source – although the earth’s geothermal heat is not regenerated, the amount of heat removed by human use of geothermal resources is easily replenished by the heat of the earth’s core in very short timespans.

Sustainable energy is generally considered to be energy produced by means which do not significantly compromise the ability of future generations to continue using that resource at the same capacity, and which minimize harm to the environment and society. While this definition is generally agreed upon, there is much debate over whether particular sources and methods of energy production are in fact sustainable. An energy resource may be renewable, and yet be collected in an unsustainable manner – for example, the production of biofuels from corn crops is renewable because the corn can be regrown, but may be unsustainable because of the high water consumption required and the destruction of natural wetlands to grow crops. The same energy source may even be sustainable in some places and not in others. Another important point to discuss is that the use of any energy resources has some impact on people and the environment. Sustainability is about minimizing, not eliminating, harmful side-effects.

Below is an inclusive but exhaustive list of energy resources, categorized as renewable/non-renewable, and with notes regarding their sustainability:

Resource	Renewable	Sustainability
Coal	No	Unsustainable
Oil	No	Unsustainable
Natural gas (conventional)	No	Unsustainable
Natural gas (biogas)	Yes	Natural gas (methane) can be produced from biological sources, such as decaying plant matter, landfill off-gas, or by capturing emissions from livestock. Research is also underway to produce methane from microorganisms in bioreactors. The sustainability of these methods depends on the details of the particular method, but biologically produces methane can be considered a sustainable source.
Conventional nuclear	No	The sustainability of nuclear power is very contentious. Nuclear is more sustainable than other mature grid-scale energy sources such as coal and natural gas, because it has no direct greenhouse gas emissions and no particulate pollution from combustion. It also doesn't have the ecological impact on rivers that hydroelectric dams do. Nuclear waste can be recycled to recover and use about 95% of the radioactive content to generate more power, but advanced waste recycling is not currently legal in the US. In some countries like Japan and France, nuclear waste recycling programs have made it a relatively sustainable choice. Next-generation small-scale nuclear reactors have significantly safer and more reliable designs, and keep less fuel in any one place, further reducing concerns with the safety of nuclear fuel. Depending on who you ask, nuclear could be considered to be a sustainable or non-sustainable resource.
Small-scale nuclear	No	
Biomass (e.g. wood)	Yes	Sustainability of biomass depends on the source. Logging old-growth timber to burn for fuel is not sustainable; however, emerging technologies for drying biomass and burning it similarly to a coal-fired power plant provides the possibility for relatively low-impact base-load power generation. If environmentally sound harvesting practices are used in appropriate areas, biomass can be sustainable.
Biofuels (e.g. biodiesel)	Yes	Biofuels from corn ethanol are generally considered to be unsustainable due to the significant amounts of fossil fuel derived fertilizer required to achieve adequate crop yields, and the significant destruction of natural wetlands associated with growing these crops. Emerging technologies to convert cellulosic biomass to fuel have potential to provide a more sustainable biofuel solution, but are currently not commercially viable.
Tidal	Yes	In-stream tidal energy has very low environmental impacts and is considered to be sustainable, although it is currently very expensive and not deployed at a large scale. Tidal barrages (which are essentially a hydroelectric dam across a tidal estuary) have significant environmental concerns due to the effects they have on estuary ecology. Tidal barrages can alter the salinity and cycling of water in an estuary, and can trap aquatic species behind the dam structure.

Wave	Yes	No large-scale wave energy deployments currently exist, and many different wave energy designs have been proposed with significantly different environmental impacts. Wave energy is considered to be relatively sustainable, but there are concerns regarding effects of moorings, cables, and light pollution on marine life.
Hydrogen	Sometimes	Hydrogen is not a primary energy source; it must be generated from another energy source. The sustainability of hydrogen is therefore directly tied to the sustainability of the energy source and method used to produce it. Hydrogen produced by electrolysis of water is considered sustainable if the electricity source to power the reaction is sustainable. Most hydrogen used industrially is produced by reacting fossil fuel derived natural gas though, which is not considered sustainable. Hydrogen fuel cells used to generate electricity from hydrogen use heavy metals like platinum, which have significant environmental effects associated with the mining and refining process.
Wind	Yes	Wind power is widely considered to be one of the most sustainable energy sources. It typically takes less than one year for a wind turbine to generate the same amount of energy used to create it, and a typical turbine can run for at least 20 years.
Solar photovoltaic	Yes	Photovoltaic cells are a semiconductor device (similar to a computer chip) which converts sunlight directly to electricity. Though widely considered to be sustainable, the production of PV cells requires rare metals which can be very toxic and environmentally damaging to extract. Next generation solar panels using organic materials reduce this reliance on potentially harmful elements. Overall solar PV is more sustainable than fossil fuel energy sources, but is not free of detrimental effects.
Solar thermal	Yes	Solar thermal energy uses concentrated direct sunlight to heat up water or molten salt. It can be used to drive a thermodynamic cycle to produce electricity, or can heat water to be used directly in residences or industrial processes. Solar thermal energy is considered to be a very sustainable process as it has few negative side-effects.
Geothermal	Yes	Geothermal energy is considered to be a relatively sustainable resource.
Hydroelectric (dams)	Yes	Dams have significant environmental concerns for river ecosystems, such as preventing the migration of fish, increasing water temperatures, and altering stream flows. Dams can be engineered to mitigate some of these problems, but will always have some environmental impact. Overall hydroelectric dams are a very sustainable resource from a human perspective, but the sustainability in a broader perspective depends greatly on the location of the dam, the health of the surrounding ecosystem, and the other energy resources available.

Energy Definitions

In this activity you will be asked to define and discuss the following concepts with your group.

What is *renewable* energy?

What is *sustainable* energy?

Do you think there's a difference between sustainable and renewable energy? If so, what is the difference? If not, why not?

List all the energy sources you can think of, and categorize them as "renewable" or "non-renewable". Circle the sources you think are *sustainable*.

Renewable	Non-Renewable

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