IQP MH-1023

Alternative and Renewable Energy

Interactive Qualifying Project
Worcester Polytechnic Institute

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Abstract

As the demand for energy increases, the availability for traditional fossil fuels diminish. To combat this global problem, engineers and scientists have been designing alternate methods for energy generation. This project demonstrates the integration of such methods, in addition to the possible future outcomes of alternative energy research. The integration of alternative energy into society has been well underway over the past decades and will continue to expand in years to come as natural sources of fuel ultimately become depleted.

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Executive Summary

The National Energy Policy states that there will be an energy crisis in the next few centuries if alternative energy is ignored. Natural resources of fossil fuels are dwindling as the price of the remaining fuel increases dramatically. This cost increase has a large impact on society, forcing the implementation of high efficiency housing and transportation. Higher efficiency products will have a much smaller impact on society than continuing to pay for expensive fuel that will be wasted inefficiently. This project researches alternative methods for prolonging the extinction of the earth's natural resources.

Transportation accounts for a large amount of energy consumption through the form of gasoline and diesel. Biodiesel was investigated as a transportation fuel to explore the possibility of developing a cheap fuel from renewable sources such as corn or sugar. The price of production was determined to be too high, and the probability of biodiesel becoming a widespread fuel is unlikely, however if the production cost was lowered, it would make for a great alternative to diesel.

Electric and hybrid vehicles were also explored, although there are multiple automakers that have already been selling hybrid vehicles to the public. Electric vehicles would be determined to be the most efficient method of transportation. Electricity plant emissions were compared to the efficiency of gasoline vehicles, reviewing that electric vehicles were in fact more efficient than the common gasoline powered vehicle.

Efficient building modifications have the potential of saving thousands of dollars in utility bills, while at the same time conserving limited natural resources and protecting the environment by reducing greenhouse emissions. A LEED certified building on the WPI campus was compared to the one that was not certified, and proven that LEED certification does in fact lower energy consumption. In addition to LEED certification, there are multiple other energy saving modifications that can be made to a structure. One modification that was critiqued was a hot water heat exchanger that captures the heat from hot water entering the waste drainage system. This heat exchanger has the potential for saving four times its expense through utility bills.

A campus survey was conducted and exposed the serious faults with WPI's high energy usage. Turning off the computers on campus that are currently powered overnight would have

the potential of saving nearly $100,000 annually. If this high-tech, energy conservative campus has been wasting energy, how many other schools in this country are doing the same? How many other businesses are doing this?

These questions led us to compose a list of policies that should be enacted to reduce energy consumption. These policies focus on transportation reforms, building code updates, and public electricity and water usage. If these policies were to be enforced, the impact they would have on society would be negligible compared to the drastic reforms necessary once the earth's remaining energy resources have been depleted.

Introduction

It is common knowledge that one day the earth will be exhausted of its natural resources. In an effort to prolong this day, estimates of the earth's remaining fuels are to be analyzed. "Look back to where you have been, to have a clue of where you are going," is an old saying that is very applicable to this project. Before making any suggestions of how to alter fuel consumption or energy efficiency, traditional sources of energy must be examined first.

Using the National Energy Policy as a guide, a number of various other studies will be reviewed to determine an approximate date for when each type of traditional energy source will be exhausted. Once these estimations are complete, alternate ways of producing energy will be tested. Suggestions will be made on whether or not an energy producing or saving method is worth an investment. Areas of focus will be on transportation and building structures.

Finally, with all research complete, a list of policies will be created that will suggest ideas for the future with the potential of saving large amounts of energy. In addition, a small survey of the WPI campus will be made that will locate major flaws in energy consumption on campus.

Common Energy Sources

OIL

Courtesy of: http://3.bp.blogspot.com/_kApto83SZK4/TH_TMR-0cLI/AAAAAAAAKao/JAJbe1gZFts/s1600/oil_rig.jpg

Background

Oil accounts for 40% of the energy consumption in the U.S. It is projected that oil consumption will grow 30% by the year 2020. This increase is a major problem that U.S. will need to change in order to keep the cost of energy low, in addition to limiting air pollution (National Energy Policy[3]).

With an increase of 30% of oil consumption by 2020, the U.S. will consume 26 million barrels of oil per day. Although this number is extremely high, the U.S. is ranked the 23rd country for oil consumption per capita, consuming 68.7 barrels per day per 1,000 people. Perhaps the U.S. is not the most wasteful, spoiled country that it is claimed to be, however, Japan, with a much higher population concentration, is ranked 44th for oil consumption, using only 39.3 barrels per day per 1,000 people; nearly half of what the U.S. consumes (Nation Master[2]).

How is it that a congested country such as Japan can use significantly less oil than the U.S.? One reason may be that since Japan is a very clustered country, product transportation is limited, which significantly reduces oil consumption. For example, the U.S. uses oil for only 3% of the electrical power grid, while, as mentioned earlier, oil makes 40% of energy consumption. This means that oil is used almost exclusively for transportation fuel only. Another reason of how Japan can keep its oil consumption low is by creating a practical public transportation system. California created an underground subway system that was completely unsuccessful, leaving the state with the existing problem of excessive private personal transportation, not to mention costing the state millions of dollars of debt. In addition, large scale construction projects such as this use a significant amount of resources, including transportation fuels for all of the materials. Ideas such as the California subway system should not be attempted without reassurance of actual practicality.

The oil that is not used in electricity production or transportation is used for home heating. As the price of oil rises where low-income families cannot pay the increase, oil companies have no choice but to cut the energy supply to those customers. Oil prices constantly fluctuate, and cause unexpected spikes in costs. Currently there are programs that assist those who cannot afford to pay for heat, but this does not mean that the cost of heat (energy) production is lessened. There needs to be a lower costing alternative energy to replace oil.

Alternative Sources

As the Department of Energy claims, coal, oil, and natural gas are the resources used for 85% of America's energy consumption. In addition, oil makes up 99% of the fuel Americans use in cars and trucks (DOE[3]). Since such a large amount of oil is used in transportation, a primary objective should be to find more efficient ways to travel. General Motors answered this problem in the 1990s when they designed the EV1 electric car. And, as mentioned earlier, efficient, reliable, and practical public transportation should be in effect in large cities. To defer the cost of using oil for heating, geothermal technology should be analyzed. This source of energy is important in reserving oil because it uses all renewable energy; the plentiful supply of heat from the Earth's core.

Remaining Oil

It is very hard to predict the amount of oil left untapped. Educated guesses are around 2 to 3 trillion barrels. With the world consuming more than 80 million barrels per day (John Schoen[1]), and an estimation of 3 trillion barrels remaining, the world will be depleted of oil within a century. However, this is a very rough estimate because not all oil reserves have been discovered yet. In addition, with technology advancing, some oil wells that were classified as unreachable are now reachable, whether it is miles under the ocean floor, or buried under thick rock. There are two ways of offsetting the remaining oil estimation: either use more efficient oil-consuming machines, or use high rate oil-consuming machines less frequently.

Searching for Oil

The most current way of exploring for buried oil is by using seismic waves. The data is then analyzed to predict the best position to place a drill. These sound waves are very useful because of the accurate information they can provide about faults in the earth's crust, depth of earth layers, different types of shale, and of course, the location and presence of oil. On land, designated trucks generate sound waves into the ground, which are then reflected back to the surface and received by a geophone machine. By sea, ships are equipped with sound wave producing equipment. The downside of this oil exploration technology is that, since a lot of oil is located in deposits below the oceans, sound waves must be conducted in marine habitats. These sound waves can be harmful to some of the ocean wildlife that occupies certain areas of the ocean. Some months throughout the year prohibit oil exploration.

Satellites are the newest technological advance in oil exploration. Since most oil is encapsulated in lighter, less dense materials such as limestone or clay, there is a relative density difference between the encapsulating material and the oil within. This difference in gravitational pull forces the ocean to have a varied surface level, which can be detected using satellites. This surface variation indicates the presence of oil. The oil-searching satellite technology was publicized in 2009, headed by Ole Baltazar, the senior scientist at the National Space Institute, Technical University of Denmark (www.sciencedaily.com[4]).

With satellite and seismic technologies, the above estimates of oil remaining on earth can be found. Now that the remaining oil estimations are assumed to be accurate, there is a time window of when the oil will run out and implementation of new energy sources (especially for transportation) must be in effect.

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COAL

Courtesy of: http://gasprices-usa.com/coal-train330.jpg

Background

Coal is one of the most important energy producing fuels. For the most part, it is being used for electricity and for home heating. The reason for coal being used so much in the U.S. is because it is low in cost and there is a large supply of it. Most coal is located in the U.S., and therefore requires less transportation costs to refineries than oil. At the same time, burning coal causes the majority of the environmental pollution problems, especially sulfur dioxide, which is the main substance in acid rain. Carbon dioxide is also a product of burning coal, which is being recognized as the major pollutant for global warming. When the carbon atom (C) from the coal is matched with the oxygen atom from the air (O_2), the pollutant is produced. Also, when the sulfur atom (S) or nitrogen atom (N) is combined with oxygen, acid rain is produced. Below are the chemical equations that cause most of the current environmental problems:

$C + O_2 = CO_2$ Carbon Dioxide (Greenhouse gas)

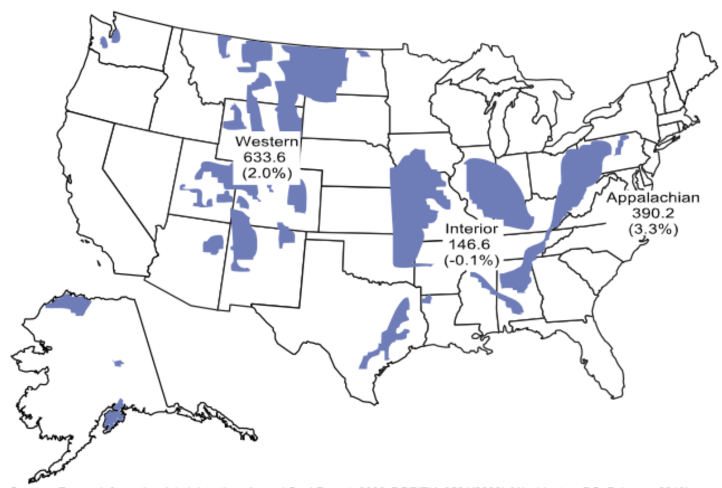
$2SO_2 + 2H_2O + O_2 = 2H_2SO_4$ Sulfuric Acid (Acid Rain)

$N + O = NO_x$ Nitrogen Oxide (Greenhouse Gas)

Coal is historically known for being the very first fossil fuel used by human beings. Archeologists have being looking for when coal was actually used during ancient history, and based on evidence discovered, they have figured out that between the second and third century in England, the Romans had been using it as an energy source. Even before that, the cave men also used burning coal for heat during cold nights. During the Industrial Revolution time period, all the new inventions that needed power to operate expanded the use of coal as an energy source. The steam energy was the most common system of energy production in those days, which used coal as the fuel. At the same time, mass metal production required power, and coal was the answer to the required energy for production. The first time that people thought about generating electricity with coal was in 1880.

Remaining Coal

Figure ES1. Coal Production by Coal-Producing Region, 2008
(Million Short Tons and Percent Change from 2007)
Regional totals do not include refuse recovery
U.S. Total: 1,171.8 Million Short Tons (2.2%)



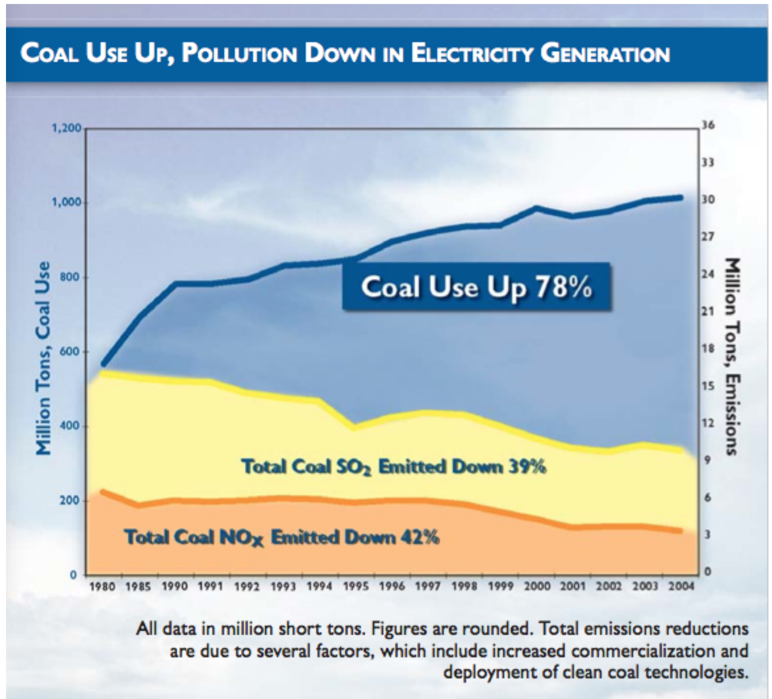
Source: Energy Information Administration, *Annual Coal Report, 2008*, DOE/EIA-0584(2008) (Washington, DC, February 2010).

As the most abundant fossil fuel on the planet, coal is widely used in different industries. In this case, the clean coal needs to be produced for saving the environment. "The United States has more coal than the rest of the world has oil. There is still enough coal underground in the country to provide energy for the next 200 to 300 years" (http://www.fossil.energy.gov[2]). Coal is formed from plants that decomposed thousands of years ago, at which point they were covered by water and mud. Under the high pressure and temperature, they started being carbonized. Over time, both the physical and chemical properties remained, but they were transferred into a solid form. Through these phase changes, the coal contains many different kinds of chemicals, which includes sulfur and nitrogen. Burning the coal can cause those compounds to react with the oxygen in the air to form sulfur dioxide and nitrogen oxides, which are two main elements that dissolve in rain. Coal is the largest electricity generating source worldwide, as well as the largest anthropogenic source of carbon dioxide emissions. Carbon dioxide is known as one of the most common greenhouse gases. There are other gasses and environmental problems produced by burning coal, such as the dirt and other minerals that will become ash. Ash can pollute the atmosphere since it is light in weight and becomes easily spread over large areas. All of the pollutants produced by burning coal show why coal is viewed as a very dirty fuel.

But things have changed in recent years. Scientists have now developed new ways to filter out most pollutants that are trapped in the coal, minimizing the damages caused by burning coal. "New clean coal technologies are showing that air pollution can be reduced, and energy efficiency [can be] increased, by using America's abundant supply of coal" (3-4, National Energy Policy[3]). All of these new technologies that are readily becoming available are generally concluded as the term "Clean Coal Technologies." Since the end of last century, the U.S. government has already invested more than $3 billion in improving and testing these operations in power plants around the country. Besides this, the state governments are also putting coal technology as a top priority, having already spent billions of dollars on the projects.

Clean Coal

More than 50% of the United States electricity supply comes from coal. According to the National Energy Policy Development Group (NEPDG), coal is going to continue playing a key role in securing a healthy U.S. economy in the next 20 years. "The federal government projected there would be 139 GW of new coal based generating capacity is projected to be added" (Source: U.S. Energy Information Administration, Annual Energy Outlook 2007). During the process of producing electricity, coal releases lots of pollutant gases, like sulfur dioxide, nitro oxide and the major one – carbon dioxide. In order to lower the damages that are caused by burning coal, clean coal technology was finally seen as one of the most important and necessary improvements. Since coal is America's largest domestic energy resource, it becomes much more necessary for us to find new ways of extracting power from coal while simultaneously expanding environmental protection and confronting the issue of global climate change.



(Sources: Energy Information Administration, Environmental Protection Agency)

The short-term goals for U.S. are to "maximize existing plants; provide advanced technologies for new, near-term plants; providing the technological bridge to transition to future plants". The long-term goals are "zero emissions, including carbon dioxide; increased reliability, cost competitive; technology for hydrogen economy" (Clean Coal Technology, from Research to Reality[2]). In order to achieve these targets, both the federal government and state governments have been putting billions of dollars into the clean coal technology. But why is the U.S. still using coal, even in the future, if it is such dirty energy source? The U.S. has to have energy secured, and it is America's largest domestic energy source that is large enough to last another 250 years at the current rate of use. Also, coal can be used in various forms: solid, liquid or even gaseous. It has traditionally been the largest single source in this country for energy generation, and we do not have enough technology to replace it with other renewable energy sources as of yet. At the same time, it can be used cleanly and affordably to drive our economic.

One thought about clean coal technology is that it is being recognized as an advanced coal power system. If the electricity generator is much more efficient, the same amount of coal used now could produce a much bigger capacity of electric power. This way, it will not only produce more energy, it will also cut down the usage of coal. The other way of improving coal efficiency is by collecting the pollutant wastes, which include carbon dioxide, sulfur dioxide, and nitrogen oxides

Technology	Impact
Low Nitrogen Oxide Burners	Now on 75 percent of existing U.S. coal power plants . . . one-half to one-tenth the cost of older systems . . . 25 million ton reduction in U.S. NO_x emissions through 2005, $25 billion national benefit.
Selective Catalytic Reduction	Achieves NO_x reductions of 80-to-90 percent or more . . . technology today costs half what it did in the 1980s, and is deployed on about 30 percent of U.S. coal plants.
Flue Gas Desulfurization (FGD)	Systems now cost one-third of what they did in the 1970s . . . more than 400 commercial units deployed . . . 7 million ton reduction in SO_2 (beyond what would have occurred without DOE R&D) through 2005, overall $50 billion savings from the lower FGD costs and environmental improvement.
Fluidized Bed Combustion (FBC)	170 units deployed in the U.S.; 400 units worldwide . . . highly commercialized, with more than $6 billion in domestic sales and nearly $3 billion in overseas sales . . . inherently low-NO_x emitting technology capable of using coal waste fuels not previously usable, providing an economic/environmental benefit of $2 billion through 2020.
Integrated Gasification Combined Cycle (IGCC)	In early stage, but 7.5 gigawatts (GW) projected (*EIA's Annual Energy Outlook 2007*) to be operating in U.S. by 2020 . . . estimated economic/environmental benefits of over $12 billion by then. Key component of *FutureGen.*

(Source: U.S. Department of Energy, Office of Fossil Energy)

One of the projects that ended May 31st 2010 is the Mercury Species and Multi-pollutant control. This project started on November 28th 2005, and cost $15.6 million. DOE paid $6 million to assist in the cost. "The intent of this proposal is to demonstrate plant wide advanced control and optimization systems on a coal fired steam electric power plant in order to minimize emissions while maximizing the efficiency, and byproducts of the plant as an electricity producer" (United States Department of Energy, Office of Fossil Energy[2]). A new power plant uses a tangentially-fired boiler that supplies steam to power a turbine generator, produced approximately 890MW. Besides this, the plant also has "a cold-side Electrostatic Precipitator (ESP) that is rated at approximately 99.8% particular removal efficiency and a wet limestone Flue Gas Desulfurization (FGD) system rated at approximately 90% sulfur dioxide removal efficiency" (United States Department of Energy, Office of Fossil Energy[2]).

A 275 MW power plant produces 1 million metric tons of carbon dioxide every year. FutureGen is a one billion dollar industry-government partnership to design, build, and operate a coal gasification-based, nearly emission-free, coal-fired electricity and hydrogen production plant. Scientists are trying to use a range of technologies for improved pollution control, higher efficiencies, and carbon capture and sequestration. There are three major factors for designing the plant. The first factor the plant must incorporate is the ability to use multiple coal types. Second, it must be able to pass multiple gasifying systems to meet operational requirement. The third factor is that the modularization of systems will allow for developing cost estimates without optimization of the integrated plant design (4.9 FutureGen[1]). The power plant's operating schedules allow two 25-day outages every year, meeting cold start requirements. An example of a great way for using this method is when 1 million tons of carbon dioxide are produced in the first 6 months of any year during full capacity operations. This would allow shutdowns and modifications to accommodate a different coal type, which allows constant operation for about 3-5 months after a shutdown.

DOE is supporting development of several new technologies for capturing carbon dioxide. One of the "step-out" technologies can improve economics of near-zero emission using a fuel cell, as long as it achieves its ideal performance. Fuel cell hybrids and integrating solid oxide fuel cells (SOFCs) with turbines are projected to result in very efficient power plant efficiencies (~50% HHV). The technology remains (although unproven) at the FutureGen scale, and durability of fuel cell systems need to be improved. The technology can result in substantial improvements in the cost of electricity if a high efficiency plant can be achieved with low fuel cell manufacturing costs (4.10 FutureGen[1]).

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3. National Energy Policy

NATURAL GAS

Courtesy of: http://www.sciencedaily.com/images/2007/10/071030120538-large.jpg

Background

Natural gas is the third largest source of fuel used for energy production in the U.S., accounting for 16%. Because it burns very clean, natural gas will account for 33% of the fuel used to generate electricity in the country by 2020. In addition to providing electricity, natural gas is also used as a heating fuel, a vehicle fuel, and an industrial fuel. Another benefit of using natural gas is that it is interchangeable with oil, meaning natural gas-fueled power plants can use oil if the natural gas supply becomes offline for a short amount of time. In the industries, natural gas is necessary to make products such as chemicals, clay, rubber, glass, apparel, furniture, paper, and more (National Energy Policy[6]).

Between 2000 and 2020, natural gas consumption in the U.S. is projected to increase by 50% to 34.7 trillion cubic feet per day. Although this projected increase is large, it is not as threatening as the oil increase because 85% of the natural gas consumed is produced domestically. The other 15% is imported from Canada via pipelines—a very efficient energy transportation method (National Energy Policy[6]).

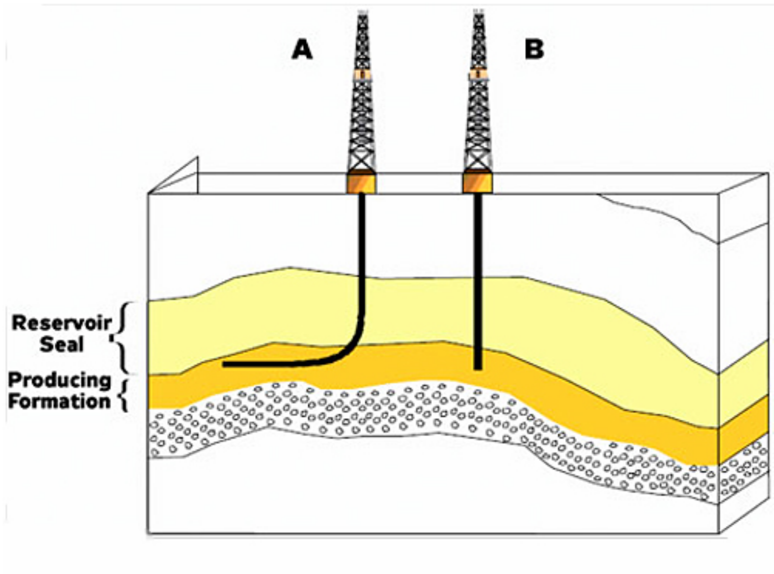
Natural Gas Drilling Sites

Natural gas in the U.S. is mainly located in or near Texas, as well as around the Gulf of Mexico. With the development of shale extracting, many more states are now suitable for drilling. In fact, as of 2010, there have been 22 basin discoveries in the U.S., mainly located between Texas and New York. These shale basins act similar to oil reserves, where the natural gas is trapped inside of the shale rock and can only be tapped by man-made equipment. It is said that the shale rock is so strong and impermeable that it makes marble rock seem spongy. These basins have just recently become drillable because of the development of drilling technology, such as the advances in horizontal drilling, and the advances in hydraulic fracturing (NaturalGas.org[5]).

The recent availability of the buried natural gas in New York has caused a large battle among the gas companies, farmers, and environmentalists. Since New York has to import 95% of their natural gas consumed, this Marcellus Shale could potentially have a huge pay off for the state, as well as the farmers that own the land above the deposit. It is estimated that there are 489 trillion cubic feet of natural gas in the New York shale, enough to supply the entire country for 20 years. The EPA is currently investigating the effects of the drilling chemicals used while performing horizontal fracturing. Since this is such a new discovery, no information or data has been collected on chemical contaminants in local drinking water (EPA[1]).

Shale Fracturing

There are two ways of accessing the shale deposits: horizontal drilling or vertical drilling, and each method have their benefits. Vertical wells only cost about $800,000 per well, while a horizontal well can cost up to $2.5 million. However, 16 vertical wells are normally required to accomplish the same output of 4 horizontal wells. The reason for this is because shale deposits are structured horizontally. Since the gas inside of the highly impermeable shale (between .01 to .00001 millidarcies) is harder to evacuate in relation to the distance away from the well, more wells are required. However, if a horizontal well is placed, the shale gas that is deposited in the same horizontal direction is easier to be evacuated because there is less sand and gravel that the gas has to travel through. Although the horizontal wells disturb 6.9 acres of surface environment while the vertical wells only disturb 4.8 acres, there would be more vertical wells necessary to drain a shale deposit, and therefore it is more beneficial to use horizontal wells.



This image is an example of horizontal (A) and vertical (B) drilling.

Courtesy of:

http://www.popularmechanics.com/cm/popularmechanics/images/bh/ashalediagdrilling_500x375_0509-lg.jpg

Once the shale is reached, it needs to be fractured. A lot of engineering and field experience is used to accomplish this task. A cocktail of additives are used to assist the main abrasion force of the water and sand mix used to fracture the shale rock. These additives only account for about 0.5% of the total volume of fluid used to break the shale, but the Environmental Protection Agency (EPA[1]) still upholds their strict standards of water quality in the surrounding drinking water. These chemical additives consist of, but are not limited to: Hydraulic acid, potassium chloride, oxygen scavengers, and pH adjusting agents. There was an estimated 3.9 million gallons of water needed to drill into the Marcellus Shale (New York's large deposit). These environmental facts suggest that it may be just as problematic extracting clean natural gas as it is to continue burning coal and oil.

According to the Energy Information Administration, there is an estimated 2,587 trillion cubic feet of natural gas remaining on Earth. Since most natural gas resources are located in Northern America, the U.S. has an estimated 2,074 trillion cubic feet. With the country consuming 22 trillion cubic feet every year, there is enough natural gas to last about 100 years without importing or exporting any of these resources (Mina Kimes[3]).

Conclusion

With the natural gas remaining, significant improvements in transportation can be made. Similar to the idea of an electric car with a home fueling station, natural gas can be compressed and used as an automobile fuel. The most common reason that alternative energy is not more commonly used is due to the cost. However, the equivalent gallon of natural gas would cost as low as $1.25 for the same amount of gasoline that would cost $3.49 (California 2007). The initial investment in purchasing the in-home fueling system is only $900 after government refunds. Also, buying the clean burning natural gas car (a Honda Civic) is only about $20,000 compared to the traditional gasoline burning Civic at $17,000. Unfortunately, these natural gas vehicles are not common, mostly because the out-of-home refueling stations are scattered widely and mostly located only in the mid-west. If refueling stations were mandatory throughout the country, more natural gas vehicles would be sold, delaying the extinction of the remaining oil supply (Chris Woodyard[2]).

Our Opinion

Fossil fuels, in particular oil and coal, have been used as energy sources for over a century. Burning any kind of fuel will produce large amounts of carbon dioxide, the most common green house gas. Most machines and engines that run on fossil fuels have very low energy efficiency, where most of the energy spent is lost through the form of heat. In order to increase the efficiency, a system needs to be designed to capture and transform it to a different type of energy that is useful.

One of our ideas is adding a metal case outside of the engine, and filling it with some kind of liquid such as water, that will capture the heat. This process would produce steam, the driving force of moving vehicles for decades. This captured steam would spin a small turbine that would in turn charge onboard batteries. This battery system would be another way to alternate power between gasoline and electric (similar to a hybrid), where the batteries would power the necessary functions of the car in heavy traffic while the gasoline motor would power the vehicle during high speed travel.

Factories that are still using fossil fuels as an energy source are required by law to install a carbon dioxide reducer. The coal-fire power plants need to adopt the clean coal technologies to reduce green house gas emissions.

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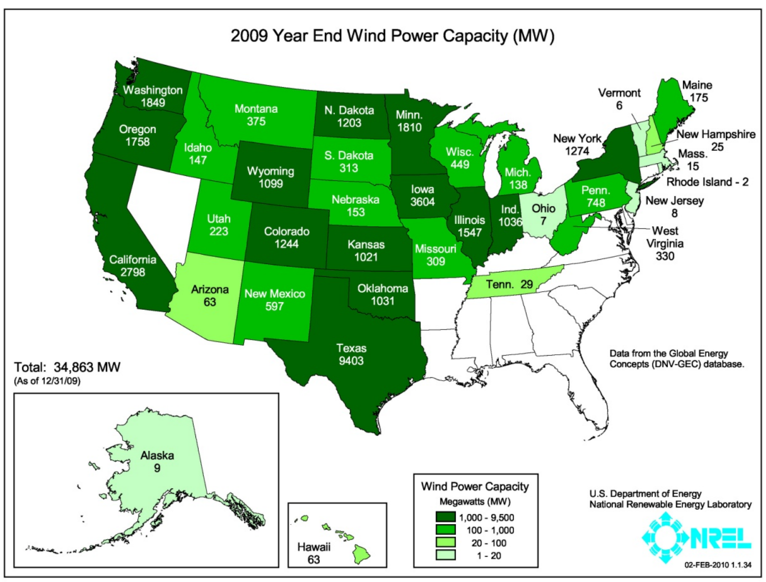
WIND ENERGY

Background

Wind energy has been around for at least 5,500 years. Wind energy was primarily used to propel boats along the Nile River as early as 5000 B.C. By 200 B.C., simple windmills were used as water pump in China. At the same time in Persia and the Middle East, people used vertical-axis windmills with reed sails to grind grain. New ways of using wind as an energy source started spreading around the world and became useful for different purposes. By the 11th century, people in the Middle East were using windmills extensively for producing food, and the merchants and crusaders carried this idea back to Europe. Holland, the country known for its large amount of windmills, used this technology to pump water for farms and ranches, and later, to generate electricity for homes and industries.



Courtesy: http://www.windpoweringamerica.gov/wind_installed_capacity.asp

Industrialization in Europe and America decreases the usage of windmills. The steam energy took over water-pumping windmills in Europe, and the Rural Electrification Administration's programs brought inexpensive electric power to the most rural areas in the U.S. in the 1940s. However, industrialization also pushed the development of using large windmill for electricity generation. Electricity generating turbines appeared in Denmark as early as 1890. The world's largest wind turbine of the time began operating on a Vermont hilltop known as Grandpa's Knob in 1940. This turbine fed electricity to the local utility network for several months during World War II, and rated at 1.25 megawatts in winds of 30mph.

The usage of the windmills was mostly dependant on the price of fossil fuels after World War II. When the price decreased, interest in wind turbines waned. But the 1970s fuel crisis allowed wind turbines to catch attention again. “The wind turbine technology research and development that followed the oil embargoes of the 1970s refined old ideas and introduced new ways of converting wind energy into useful power. Many of these approaches have been demonstrated in ‘wind farms’ or wind power plants — groups of turbines that feed electricity into the utility grid — in the United States and Europe” (U.S. Department of Energy[1]). Expanding the amount of wind farms and improving the efficiency of wind turbines will lower the cost of wind-generated electricity to the cost of power produced from conventional utility generation. As the world’s fastest-growing energy source, it will power industries, businesses and homes with clean, renewable electricity for many years.

Applicability

Wind is a type of renewable clean energy. Wind energy power plants are unlike fossil fuel plants, which rely on combustion of fossil fuels. Wind turbines do not produce any kind of waste gas such as sulfur dioxide, which is the compound responsible for acid rain, or carbon dioxide which is the main greenhouse gas. The U.S.’s wind supply is abundant; it is a kind of renewable energy source that can never be extinct.

“Wind is actually a form of solar energy; winds are caused by the heating of the atmosphere by the sun, the rotation of the earth, and the earth's surface irregularities” (U.S. Department of Energy[1]). Since wind energy will always exist as long as the sun shines, wind energy also becomes one of the lowest-costing renewable energy technologies that are available today, costing between 4 and 6 cents per kilowatt-hour. They can be built directly on farms or ranches, thus benefiting the rural area’s economy where many wind sites can be found.

Even though wind energy is a very clean resource and has a lot of advantages, it still has many other problems. Wind energy has to compete with other energy sources on a cost basis. Wind power plants are very expensive to build, although the building cost has been decreasing in the past 10 years. This technology still requires a much higher initial investment than fossil-fueled generators. Other than the cost, the location of wind farms is also a big concern, since good wind sites are often far away from the city it is supplying energy to. The land required for a wind farm may also have to compete with other uses that may have more of a property value than an electricity production plant.

Although wind energy is a clean energy with no polluting substance, it still has some environment impacts. Some wind farms are critiqued for the noise produced by the rotor blades, aesthetic impacts and claims of causing high bird mortalities. Most of these cases have already been resolved or greatly reduced through technological development and a proper location for wind plants.

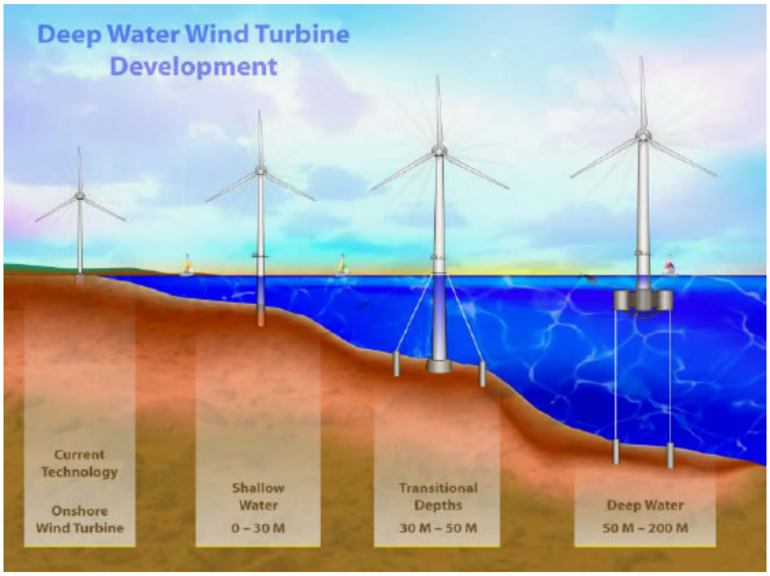
Turbine Design

There are two major types of turbines, the vertical-axis design and horizontal-axis design. "Horizontal-axis wind turbines typically have either two or three blades. Three-bladed wind turbines are operated "upwind," with the blades facing into the wind" (U.S. Department of Energy[1]). A normal utility-scale turbine ranges in size from 100 kilowatts to as large as several megawatts. These kinds of larger turbines are grouped together into wind farms to provide bulk power to the electrical grid. Smaller sized turbines are generally used for home or private usage, producing less than 100 kilowatts.

Cape Cod Wind Farm

On April 28th, 2010, the Cape Cod Wind Farm was approved for construction. The approval from Interior Secretary Ken Salazar came with requests to be completed prior to building. Salazar's requests consist of minimizing potential adverse impacts on the wildlife, and to conduct additional marine surveys to avoid any submerged archeological resources that may be buried. The location of the Cape Cod wind turbines is ideal for offshore turbines since it is shallow water and the waves are not large or varied.

The farther away from land that a wind turbine is built, the more difficult and more expensive it will cost. There are three traditional versions of offshore wind turbine foundations: mono pile, gravity foundation, and the tripod foundation. The mono pile is primarily used in shallow waters up to 30 meters. The turbine shaft is extended into the soil bed between 10 and 20 meters. The gravity foundation is most applicable in water up to 50 meters deep. The structure consists of a large concrete block, resting on the ocean seabed. This "anchor" is the weight that keeps the turbine in the upright position, as well as holding the turbine in place. The last traditional foundation is the tripod foundation, which is used in water up to 200 meters deep. This method relies on multiple mono piles connected to the base of the turbine. The tripod foundation is rarely used in offshore turbine construction. Below is a picture of the foundations.

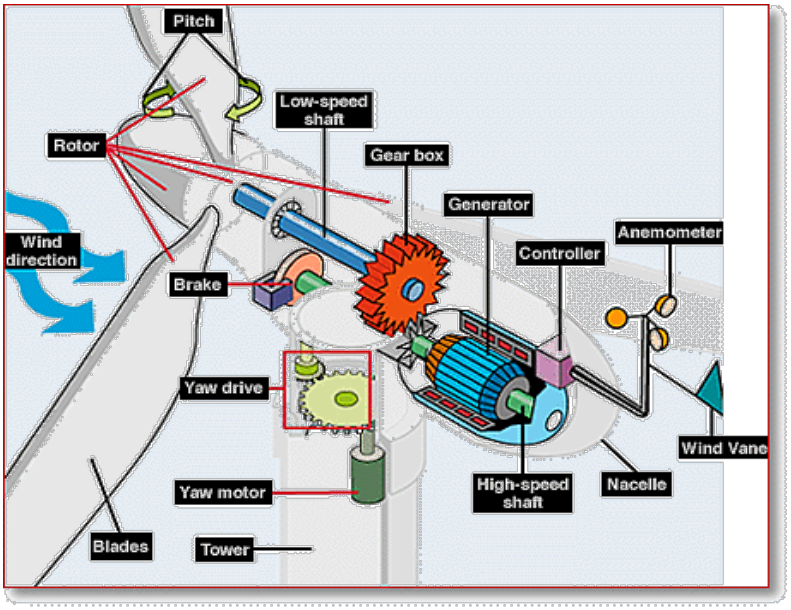


courtesy: http://offshorewind.net/Images/Foundations/Offshorewinddevelopment.jpg

The 130 turbines will provide clean energy to the cape and the islands, saving an estimated $800 million over the next 20 years. It is estimated that every house in Massachusetts uses 6.45 megawatt-hours annually. The Cape Cod wind farm is going to generate 1,491,384 megawatt-hours per year. That is enough energy to power over 230,000 homes. On average, one kWh produces 1.3 pounds of CO_2. At this rate, the Cape Cod wind farm is going to prevent 880,000 metric tons of CO_2 emissions. To this date, if the construction of these offshore turbines had been built immediately after designed without permitting hassles, 6 million tons of CO_2 emissions would have been prevented.

Wind Turbine Function

Wind turbines are simple machines that harness wind energy and convert it to electrical power. Present day, most turbines are self-regulated, meaning that there is a controller that monitors wind speed and direction, as well as positioning the turbine for highest efficiency. This part of the turbine system is called the anemometer (measures wind speed) and the wind vane (measures wind direction). Once the data is sent to the controller, the yaw motor is adjusted so that the blades will face directly into the wind. The yaw motor is located inside of the nacelle, which also houses the turbine's gear box and the generator. The yaw drive mechanically moves along the stationary gear ring, located on the top of the shaft, under the nacelle. The yaw drive is



courtesy: http://www1.eere.energy.gov/windandhydro/wind_how.html

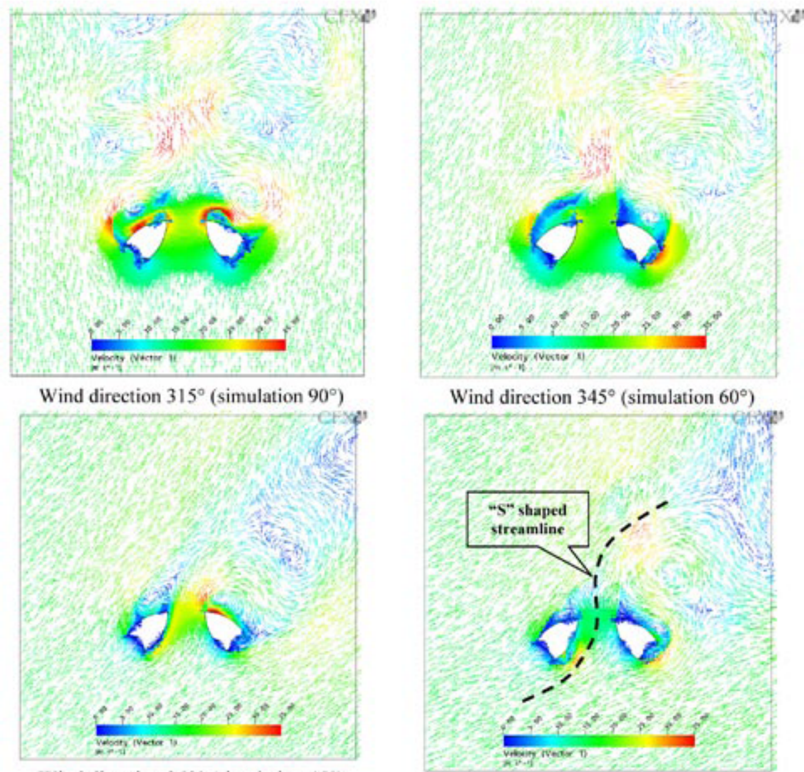
physically attached to the nacelle. Now that the turbine is facing the wind, the low speed shaft (the shaft connected to the blades) can now turn. The ideal speed of a turbine is 15 RPMs, but the generator needs to rotate faster than that to create energy. This is accomplished by using a gearbox, transmitting the slow, high-torque low-speed shaft into a fast, low-torque shaft called the high-speed shaft. The generator is the final step in converting wind energy into electricity. The electricity leaves the generator and presents the electrical grid with clean power. Above is a picture of a wind turbine and its components.

The Future of the Wind Turbine

The modern wind turbine is efficient, performing its job by catching the wind. Most turbines are vertical axis wind turbines (VAWT) rather than horizontal axis wind turbines (HAWT). Vertical turbines are more applicable and efficient at capturing wind, which is why they are more common than horizontal turbines. The placement and location of turbines is changing frequently in wind turbine technology.

Bahrain World Trade Center

The newest application of turbines is being incorporated in building structures. The Bahrain World Trade Center (BWTC) is an example of the integration of wind turbines and buildings. Three 225 kW turbines are placed in between the two “sail-like” buildings. The sail-like buildings allow wind to funnel into the center of the buildings, giving more wind to the turbines.



Wind direction 315° (simulation 90°) Wind direction 345° (simulation 60°) Wind direction 360° (simulation 45°) Wind direction 15° (simulation 30°)

This picture represents the forced wind direction into the turbines, between the buildings. The 29 meter rotor diameter allows enough room to be the common size of all three turbines, from the lowest turbine that fits between the thick-end tapered buildings, to the highest turbine that sits furthest away from the buildings, as the taper of the twin buildings shorten.

Courtesy: http://www.ctbuh.org/Portals/0/Repository/T3_KillaSmith.cfce5b62-fc35-4de7-ba53-90eeca647d94.pdf

Courtesy of: http://farm3.static.flickr.com/2359/2139274930_5c7be4866d_z.jpg

Mount Wachusett Community College

2009, Mount Wachusett Community College decided to install two 1.65MW wind turbines to supply electricity to campus. The whole project is estimated to be completed February 2011. This is a $9 million project, and can save 6,200,000 kWh per year, which saves about:

$0.13/kWh x 6,200,000 kWh/year = $806,000/year.

The two turbines will supply 97% of the college electricity needs and return 30 percent of its power back to the electricity grid. Based on all of this information, the whole project can be paid back in less than 5 years, and starts making profit after that.

Our Opinion

Wind energy is one of the cleanest ways to generate electricity. Central and western parts of the U.S. have a huge area with an abundant wind resource; the government should encourage residents in those areas to purchase a residential wind turbine. There are sections within central and western U.S. where it is unsuitable to live. To maximize the efficiency of these areas, wind farms should be constructed (without taking over commercial land). Mount Wachusett Community College as an example of integrating wind energy technology, and WPI should also investigate installing wind turbines. In Institute Park, for example, there is enough area to set up one or two wind turbines. Two turbines may not be suitable to supply the whole school, but will at least cut down half of the electricity bill every year. It requires a huge amount of funds at the beginning of construction, but just as Mount Wachusett Community College, WPI will start making a profit in the near future.

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3. "Wind and Water Power Program: How Wind Turbines Work." *Inside the Wind Turbine*. Department of Energy, 1 Sept. 2010. Web. 06 Oct. 2010. <http://www1.eere.energy.gov/windandhydro/wind_how.html>.

SOLAR ENERGY

All pictures in this section are from: http://www.eere.energy.gov/basics/renewable_energy/csp.html

Background

Photovoltaic (PV) cells, also known as solar cells, are devices widely used in generating electricity. They convert sunlight into electrical energy. The French physicist Edmond Becquerel first discovered this technology in 1839. He found the process using sunlight to produce electric current in a solid material, but it took nearly a century for people to understand the concept. Eventually, scientists learned that there were certain types of materials that can convert light energy into electric energy on an atomic level. PV systems already play a very important role in our daily lives. PV systems can provide power from small consumer items, such as calculators and wristwatches, to complex systems such as lights, appliances, machines, street signs and streetlights, and even communication satellites. In many cases, PV systems are the least expensive form of electricity for these tasks.

PV cells are the smallest units in the PV system, which are the actual devices that convert sunlight to electricity. When light shines on the PV cell, it may be reflected, absorbed, or pass through. Only the part of light that is absorbed will be used to generate electricity. “The energy of the absorbed light is transferred to electrons in the atoms of the PV cell semiconductor material. With their newfound energy, these electrons escape from their normal positions in the atoms and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell—which is called a "built-in electric field"—provides the force, or voltage, needed to drive the current through an external load, such as a light bulb” (Photovoltaic Cells). Solar systems are made up of PV cells, which can typically produce 1 or 2 watts of power, are shaped into different sizes and produce different amounts of power.

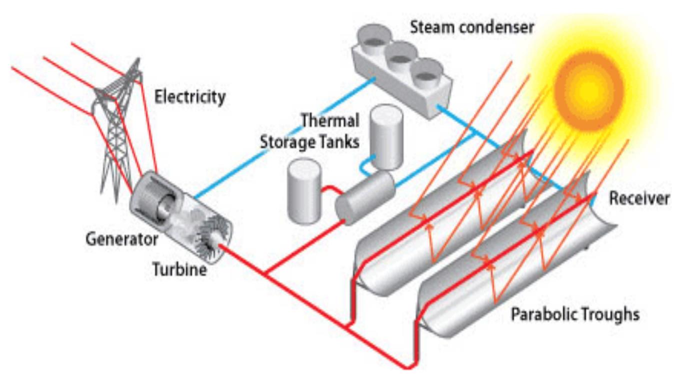
Concentrating Solar Power

Concentrating Solar Power (CSP) technologies use mirrors to reflect and concentrate sunlight onto receivers, which collect solar energy and convert it to heat, which is then used to produce electricity. The heat gathered from sunlight will heat up the steam, driving the generator. There are three major systems: Linear Concentrator, Dish/Engine, and Power Tower.

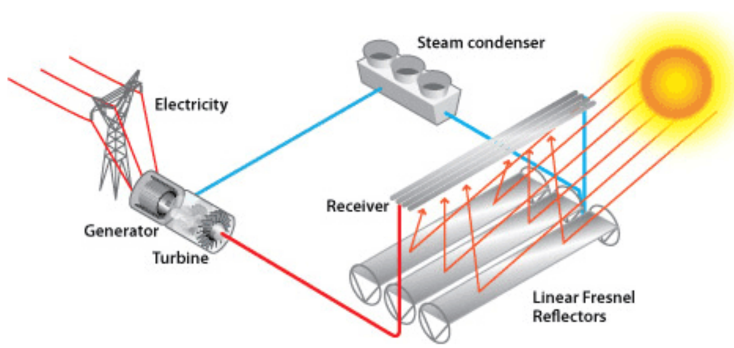
Linear Concentrator

Linear CSP collectors reflect and concentrated sunlight onto a linear receiver tube. "The receiver contains a fluid that is heated by the sunlight and then used to create superheated steam that spins a turbine. This turbine drives a generator to produce electricity. Alternatively, steam can be generated directly in the solar field, eliminating the need for costly heat exchangers" (linear concentrator systems for concentrating solar power). There are two types of linear CSP systems: parabolic trough systems, and linear fresnel reflector systems.

The parabolic trough system has its receiver tube positioned along the focal line of the parabola-shaped reflector. The largest individual trough system generates 80 MW of electricity. However, individual systems are being developed that will generate 250 MW.

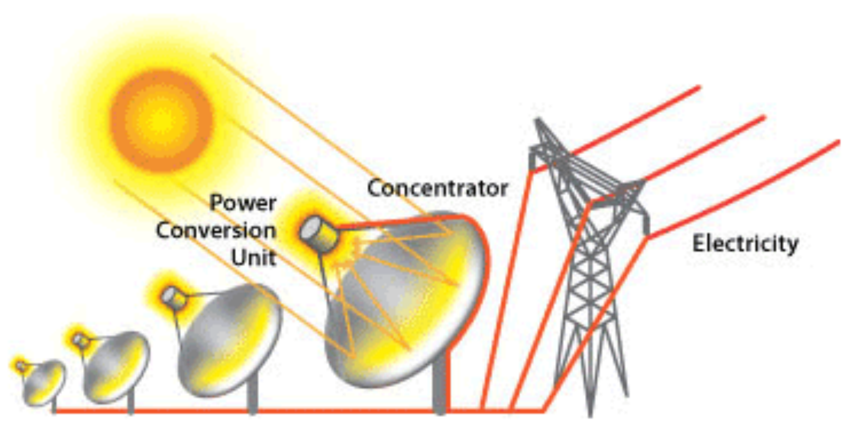


Linear Fresnel reflector systems use flat or curved mirrors mounted on ground trackers that configure to reflect sunlight onto a receiver tube fixed in the space above the mirrors.



Dish/Engine Systems

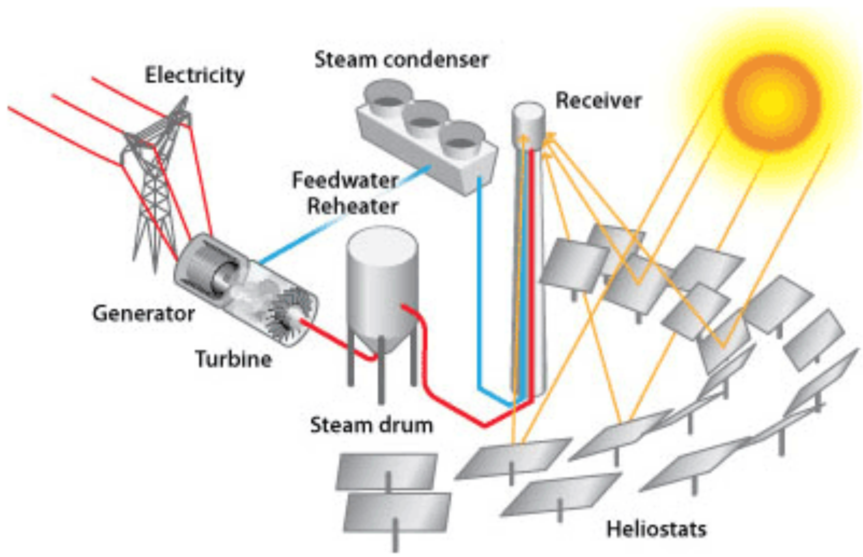
Dish/Engine systems use a parabolic dish of mirrors to direct and concentrate sunlight onto a central engine that will produce electricity. This system produces about 3 to 25 MW of electricity, which



is less than many other CSP technologies. The dish is mounted on a structure that tracks the sun continuously throughout the day to reflect the highest possible percentage of sunlight onto the thermal receiver.

Power Tower Systems

Power Tower CSP systems use numerous large, flat, sun-tracking mirrors, known as heliostats. These focus sunlight onto a receiver on the top of a tall tower. The receiver generates steam from the solar energy it gathers from the mirrors, which is then used in a conventional turbine generator to produce electricity. Commercial plants can be built to produce up to 200 MW of electricity.



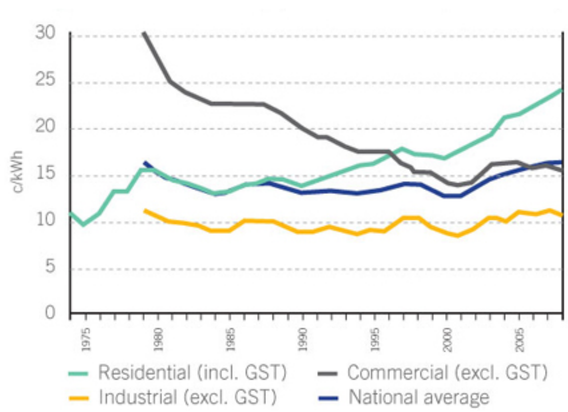
Solar Energy Power Plant-Calico (SES Solar One)

The Calico plant is one of biggest solar power plants in United States, manufactured by Stirling Energy System Inc., with Tessera Solar as the project developer. It is located on 8,230 acres of BLM land in Mojave Desert, 37 miles east of Barstow, CA. This is an 850 MW solar power project using about 20,000 – 34,000 dish-stirling systems. Calico has the lowest-water usage CSP technology, and has no need for water-cooling processes except for washing mirrors. It also uses comparatively low ground disturbance because it has no foundations and minimal grading and trenching as well.

Solar Energy Incentives

Photovoltaic panels are among the cleanest way of producing electricity. Once installed, they require no maintenance since there are no moving mechanical parts. Having no maintenance fees leaves only the cost of installation and parts, making solar panels an attractive option for an alternative energy resource. The life expectancy of a photovoltaic panel is about 20 years, so the cost of the solar panel installation should be divided accordingly to determine if paying upfront for photovoltaic panels is cheaper than paying the electricity bill from the grid.

A common critique about solar energy is that it is impossible to have a cost-effective system that the consumer will save money by installing solar panels on a residential home. If the average home requires 600 watts per hour, that would be equal to 14,400 watt-hours per day. Since a solar panel can produce 70 milliwatts per square inch, and can only be powered for 5 hours a day, the panel can produce 350 milliwatt-hours per day. For the system to adequately power the 14,400 watt-hours that the house requires, 285 square feet of solar panels are needed, a required area that could easily fit onto a roof, but would cost an estimated $15,000. To reduce the cost, electricity consumption in the house needs to be reduced by upgrading to high-efficiency appliances. Once upgraded, electricity consumption can be dropped to as little as 100 watts per hour, reducing the new price for required solar panels to around $2,600. Purchasing the same 100 watts per hour from the grid would cost about $100 a year (assuming 10 cents per kWh), while the cost of the panels would cost $130 a year assuming the 20 year lifespan of the panels, not to mention the cost of upgrading to high-efficiency appliances, or the cost of integrating a battery system. It may be hard to justify spending extra money to install solar panels, but the amount of CO_2 emissions can be considered priceless. Below is the cost of electricity per kWh over the last 30 years. If the graph continues the same pattern, the cost will remain linearly horizontal, staying between 10 and 15 cents per kWh for residential use.



In addition to saving the environment from CO_2 emissions, hefty tax credits are given out to those who chose to install photovoltaic panels. Tax breaks are given on solar systems installed for residential use of up to 30% of the total project cost. This is a large incentive for people who are looking to produce environmentally-friendly electricity for their house (Sherwood[1]).

Our Opinion

Solar energy is a very clean energy with the only disadvantage of requiring a huge area that has enough sun light during the day. The only area in America that can meet this requirement is southwest of the boarder. Instead of taking over commercial land to build a solar farm, we can use the rooftops of buildings in the city. The dish system is perfect for this situation.

Adding a solar dish to rooftops may require contractors to pay more money on the building material since the solar system adds an extra dead load on the structure. A larger size beam will be necessary on the roof level to prevent deflection that might cause beam failure. The regular design of a roof beam has to consider dead load from roofing material that includes the beam's own weight, insulation, joists, metal decking and utilities. Other than dead load, there is also a live load, which consists of a snow load that varies depending on the environmental area. Adding a solar system on the roof will produce a larger shear force and moment on the beams, and at the same time, the beams will have a larger deflection.

Cost-effective Design

For a 40ft long W24 x 84 steel beam, the moment of inertia along the x-axis (I) is 2370 in^4, and the modulus of elasticity of steel (E) is 29,000ksi. Assuming the average roof dead load without a solar system is 0.58 kip/ft, and roof live load due to the snow is 0.30 kip/ft:

ω (uniform load) = 1.2 dead load + 1.6 live load = 1.176 kip/ft

$$\Delta \text{ (deflection)} = \frac{5\omega L^4}{384EI}$$

$$= \frac{5 \times 1.176 kip/ft \times (40 ft.)^4 \times (12 in./ft.)^3}{384 \times 29{,}000 ksi \times 2370 in.^4}$$

= 0.9856 in < 1in requirement

If we add a 0.02 kip/ft dead load to the beam for the solar system

ω (uniform load) = 1.2 dead load + 1.6 live load = 1.20 kip/ft

Δ (deflection) = $\frac{5\omega L^4}{384EI}$

$= \frac{5 \times 1.20 kip/ft \times (40 ft.)^4 \times (12 in./ft.)^3}{384 \times 29{,}000 ksi \times 2370 in.^4}$

= 1.006in > 1in requirement

Since the deflection is larger than 1 inch, it might cause failure of the roof beams. We would have to use a larger beam to replace the estimated W24 x 84. In order to find a beam that meets these requirements, a beam with larger moment of inertia is required. There are two ways to do this: increase the height of the beam, which keeps the same loading but changes the inner building structure from original architect's design, or use a heavier beam, which changes the loading so the entire structure would need to be recalculated. Economically, a larger height beam would be considered in this case.

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Alternative Energy Source

BLOOM ENERGY

All pictures in this section are from: http://www.bloomenergy.com/products/solid-oxide-fuel-cell-animation/

Background

Bloom Energy, a company founded by K. R. Sridhar in 2002, produces fuel cell systems with the intention to deliver electricity for residential and commercial use. Sridhar was recruited by NASA to create a system that would provide astronauts with oxygen while on a mission to mars. Although this mission was never followed through with, Sridhar's invention was created, and then reversed into his new invention: the Bloom Box.

In 2001, Sridhar needed funding to pay for manufacturing and experiments. He approached John Doerr of Kleiner Perkins Investments looking for a $100 million start-up loan. Doerr approved this grant with hopes that the Bloom Box would become as big as some of his other investments such as Netscape, Amazon, and Google. In addition to this funding by Kleiner Perkins, Sridhar received at least another $300 million (private money) for research and development, yet by 2010, this "miracle box" is still not available to the public for a reasonable price. Michael Kanellos, chief editor of Green Tech Media, is very skeptical that this box will ever become successful since Bloom Energy is approaching the 10 year mark without an available product, but has already consumed $400 million.

Currently, each experimental Bloom Box is sold for between $700,000 and $800,000; a price that only extremely large corporations could own. This buyers list includes Walmart, Bank of America, Ebay, Google, and FedEx. With an outrageously high price per box, excellent results are expected. Of the 5 boxes purchased and placed on Ebay's San Jose campus, the boxes are producing nothing but great results.

John Donahoe, the CEO of Ebay, claims that in the 9 month time period that Ebay has owned the boxes, Ebay has saved 15% on electricity charges, amounting to $100,000. With the 20% California refund, and the 30% federal tax break, these boxes give Ebay a payback period between 17 and 20 years, not to mention the reduction of CO_2 released into the atmosphere. In fact, Ebay claims that these 5 boxes produce more electricity than the solar panels covering every inch of the 5 buildings on site. In addition to Ebay's praise, every other major company that bought a Bloom Box has nothing but good things to say about it. "Installing low-carbon technologies, like Bloom's Energy Servers, at our facilities is not only the right thing to do for our planet, but it's also a smart business decision. Bank of America is proud to be at the forefront as one of Bloom's foundation customers," says Mark Nicholis, Senior Vice President of Bank of America. The Bank of America phone-answering center installed Bloom Boxes to produce 500kW for the Southern California location (Bloom Facts). But with the current price, how could anyone privately own a Bloom Box?

Sridhar's goal is to be able to market the Bloom Box for $3,000 within the next five years; a timeframe that he believes everyone in the U.S. will have one. Since the box is not connected to the grid and is intending on replacing the high CO_2 producing, inefficient grid, some disbelievers think that the box will never be approved in order to keep the grid operational. When asked for his thoughts on this scenario, Doerr believes that the electric companies would gladly purchase these boxes in residential neighborhoods and sell the clean electricity to residents. This thought process is based off of the electric companies purchasing nuclear power plants and other electricity-producing plants to sell electricity via the grid. This is a valid point, however Doerr has had some experience in poor decisions, such as investing in the Segway; a horrendous fail in the inventor's world.

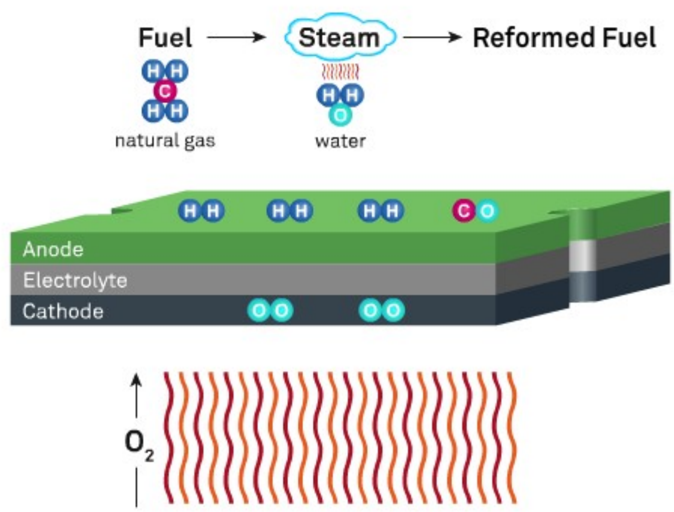
While Bloom Energy only has the manufacturing capacity to produce one box per day (despite the $400 million investment), former Secretary of State Colin Powell joined Bloom Energy's board of directors. Hopefully the publicity of this trustworthy politician can persuade critics that the Bloom Box is not a hoax. Forbes magazine congratulated Bloom Energy for capitalizing on the idea of clean, cheap energy, and making $400 million while producing nothing promising for the investors (60 Minutes[4]).

How the Bloom Box Works

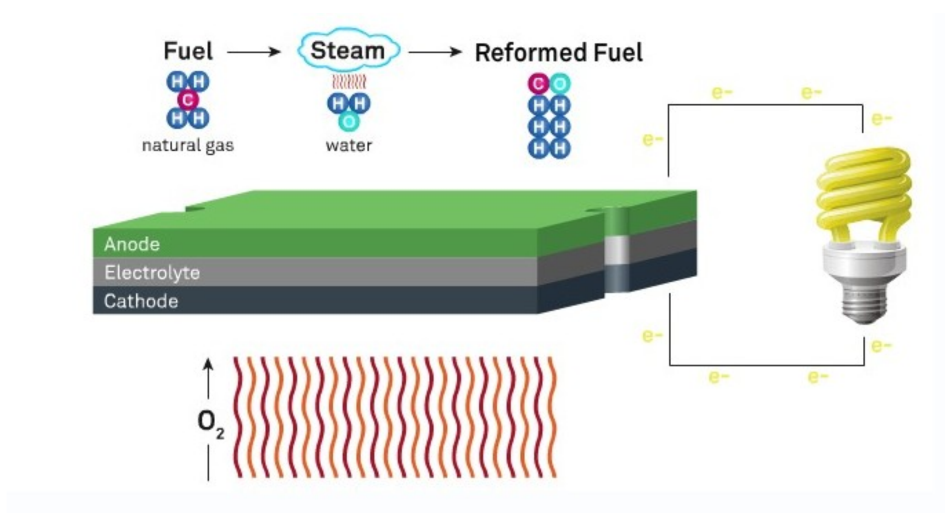
Solid Oxide Fuel Cell (SOFC) is the smallest unit in a Bloom Energy generator. However, fuel cells were invented over a century ago and have been used in practically every NASA mission since the 1960s. They have not been widely used as an energy source because of their inherently high costs.

The fuel cell contains three parts: anode, cathode, and electrolyte. The electrolyte layer is made by solid ceramic material. The anode and cathode are made from special inks that coat the electrolyte. There are no precious metals (in order to keep the cost low), or corrosive acid multi materials required in making the fuel cell. Below is the chemical equation that explains how energy is produced from the fuel cell.

CH_4+2O_2 --> $CO_2+2H_2O+e^-$+heat



Next, an electrochemical reaction converts fuel and air into electricity without combustion. It is a high temperature fuel cell, which means warmed air enters the cathode side of the fuel cell along with steam mixed with fuel, to produce reformed fuel, which enters on the anode side.



As the reformed fuel crosses the anode, it attracts oxygen ions from the cathode. Oxygen ions combine with the reformed fuel to produce electricity, water, and a small amount of CO_2. The water gets recycled to produce the steam needed to reform the fuel. As long as there is fuel, air, and heat, the process continues producing clean, affordable, reliable energy (How It Works[2]). The Bloom Box can generate energy by different types of fuels: gasoline, natural gas, and biodiesel.

The fuel cells are made of sand that is baked into diskette-size ceramic squares and painted with green and black ink (the anode and the cathode). Each fuel cell is able to power one light bulb, the equivalent of 25 watts. The Bloom Box is built by stacking many single cells into brick-sized towers, sandwiched with metal alloy plates (Haq[3]).

Our Opinion

The energy generated by Bloom Box is still relying on different fuels that produce a CO_2 footprint. In order to eliminate it, hydrogen could be a great candidate for fueling the box. Using hydrogen will only produce water and energy as products. Since the Bloom Box has to be placed outdoors, instead of just leaving them under the sun, they should be covered with solar panels. This way, the solar panels will contribute to the purpose of the Bloom Box: to make low emission energy. As of right now, the cost of the Bloom Box is too high, and due to the company's 10 year history, can be considered a scam. The price of the Bloom Box needs to drop significantly before any private companies or homeowners would consider buying it (with the potential risk of being scammed). The price of a single family use Bloom Box generates 1kW of electricity and will cost $3000, but is titled as "under investigation" since no information about the anode or cathode materials have been mentiond. Sridhar has been very secretive about his work and has only offered one quick factory tour by "60 Minutes". Any company that guards secrets this heavily seems to have something to hide. Sridhar should publish his work in technical reports that will develop him in the technical world of achievement.

We tried to contact the companies that have purchased Bloom Box, which includes Bank of America, WalMart, FedEx, Ebay and Google, but none of them have given us any information on savings of energy savings. Purchasing a new technology without getting any kind of background data beforehand is not a wise move for any company, unless they are only looking for a good reputation by using what they call a “green energy”. All the details of Bloom Box, except the green and high efficiency parts Sridhar himself claimed earlier, are still in veil. Below is the list of email addresses we sent our email to:

1. Bank of America: environment@bankofamerica.com
2. WalMart: customer service
3. Google: press@google.com
4. FedEx: fedexoffice.customerrelations@fedex.com
5. Ebay: customer support

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Alternative Transportation Methods

As noted earlier, oil is used for 40% of the energy demand today, but only 3% is used in electricity generation. The remaining 37% is used to power vehicles used for transportation. If this large number were somehow reduced or abolished, the current energy problem would be much less of a crisis. Alternative energy sources must be examined and tested for applicability in current energy consuming systems.

BIODIESEL

Biodiesel is an alternative fuel to fossil fuels. It can be applied in any diesel motor with virtually no modifications necessary. The production process of this fuel is easy and inexpensive. Most importantly to the environment, it burns clean; however there are some disadvantages to biodiesel that will be discussed.

Biodiesel Ingredients

- Reactants

  Fat or oil (e.g. 100 kg soybean oil)

  Primary alcohol (e.g. 10 kg methanol)

- Catalyst

  Mineral base (e.g. 0.3 kg sodium hydroxide)

- Neutralizer

  Mineral acid (e.g. 0.25 kg sulfuric acid)

Weight Ratio among the Chemicals

Fat or oil: Primary alcohol: Mineral base: Mineral acid = 400 : 40 : 1.2 : 1

CH_2OCOR'''				CH_2OH		$R'''COOR$
|			Catalyst	|		
CH_2OCOR''	+	3 ROH	------>	CH_2OH	+	$R''COOR$
|				|		
CH_2OCOR'				CH_2OH		$R'COOR$
100 pounds Oil or Fat		10 pounds Alcohol (3)		10 pounds Glycerin		100 pounds Biodiesel (3)

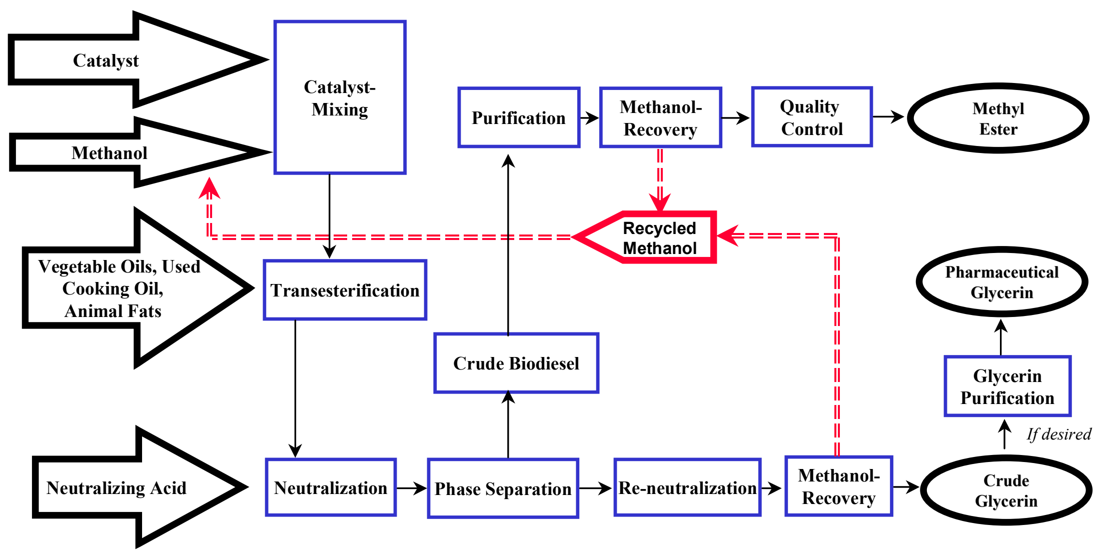
(Biodiesel Production and Quality[2])

Fats and Oils: Because of the chemical process and economic situation, fats and oils are used in producing biodiesel. Vegetable oils have a low percentage of associated free fatty acids. The phospholipids and free fatty acids in crude vegetable oils are removed in the "degumming" step, as well as the "refining" step. The sources for vegetable oil are soybean, canola, palm, and rapeseed. Animal tallows and recycled (yellow) grease have much higher levels of free fatty acids. Yellow grease is limited to 15% free fatty acids; trap greases come from traps under kitchen drains and these greases can contain 50% to 100% free fatty acids. Trap grease is not currently used for biodiesel production and may have some technical challenges that have not fully been resolved, such as the hard-to-break emulsifications (gels). Emulsification gels are fine silt that will cause equipment wear, high water contents, and very strong color and odor bodies that affect biodiesel and glycerin products. The sources from animal fat include beef tallow, lard, poultry fat, and fish oils. The free fatty acid content affects the type of biodiesel process used, and the yield of fuel from that process. The other contaminants present can affect the extent of feedstock preparation necessary to use a given reaction product (Van Gerpen[1]).

Alcohol: The most commonly used alcohol in biodiesel production is methanol, although other alcohols such as ethanol, isopropanol, and butyl, can be used. The water content is the key factor for the alcohol chosen; it interferes with transesterification reactions and can result in poor yield and high levels of soap, free fatty acids, and triglycerides in the final fuel. Since the reaction to form the esters is on a molar basis and we purchase alcohol on a volume basis, their properties make a significant difference in raw material price. It takes three moles of alcohol to react completely with one mole of triglyceride. Today, one gallon of methanol costs $0.61. That gallon contains 93.56 gram-moles of methanol; at a cost of $0.00652 per gram- mole. By contrast, a gallon of ethanol, at the current price of $1.45 per gallon for fuel-grade ethanol, costs $0.02237 per gram-mole, or 3.4 times more. In addition, a base catalyzed process typically uses an operating mole ratio of 6:1 moles of alcohol rather than the 3:1 ratio required by the reaction. The reason for using extra alcohol is that it "drives" the reaction closer to the 99.7% yield we need to meet the total glycerol standard for fuel grade biodiesel. Because of these reasons, methanol is used in the reaction (Van Gerpen[1]).

Catalysts and Neutralizers: Catalysts may either be base, acid or enzyme materials. Bases are the most commonly used, such as sodium hydroxide, potassium hydroxide, or sodium methoxide. They are highly hygroscopic and form water when dissolved in the reactant. Although acid catalysts can be used for transesterification they are generally considered to be too slow for industrial processing. Enzymatic catalysts are used for the production of alkyl fatty acid esters. Neutralizers are used to remove the base or acid catalyst from the product biodiesel glycerol. For base catalyst, acid is the typical catalyst used, and vice versa (Van Gerpen[1]).

General Biodiesel Production Process



(Biodiesel Production and Quality[2])

Reaction: The alcohol/catalyst mix is put into a closed reaction vessel and the oil or fat is added. The whole reaction system is completely closed to the atmosphere to prevent the evaporation of alcohol. The temperature is kept just above 160 °F, which is the boiling point of alcohol. The high temperature is to speed up the reaction. The reaction lasts from 1 to 8 hours, and care must be taken to monitor the amount of water and free fatty acids in the incoming oil and fat.

Separation: After the reaction is complete, the glycerin and biodiesel must be separated. Since the glycerin is much denser than biodiesel, and the two can be separated via gravity, glycerin is simply drawn off the bottom of the settling tank.

Alcohol removal: Alcohol is removed from the product by either a flash evaporation process or distillation.

Glycerin Neutralization: The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin.

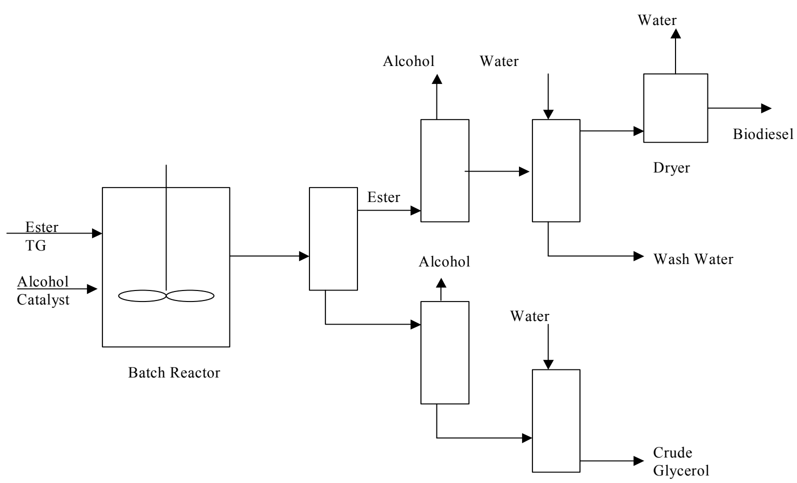
Methyl ester wash: As the last step of the whole process, the biodiesel is purified by introducing warm water to remove residual catalyst or soaps. The remaining biodiesel is then dried and sent to storage.

(Biodiesel Production and Quality[2])

Different Biodiesel Production Process Options

1. Batch processing

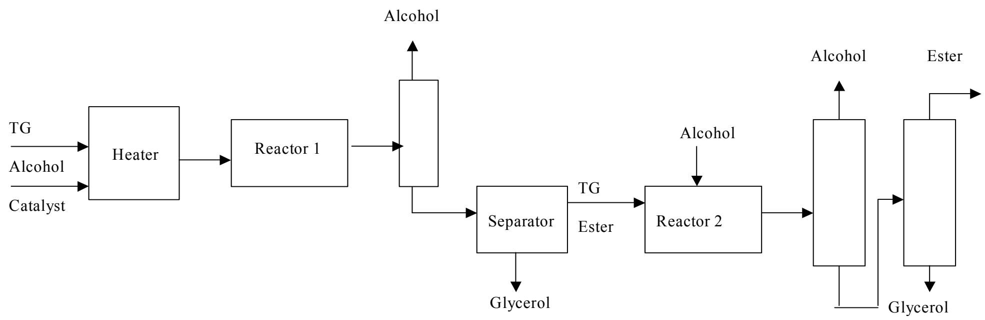
The simplest method for producing alcohol esters is to use a batch, stirred tank reactor.



(Van Gerpen[1])

2. Continuous process systems

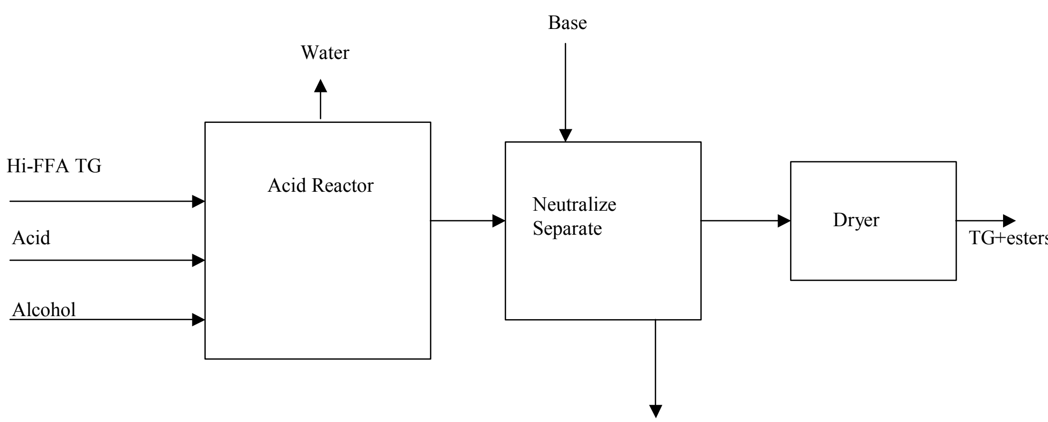
A popular variation of the batch process is used for applications that require a longer residence time in the reactor.



(Van Gerpen[1])

3. High free fatty acid systems

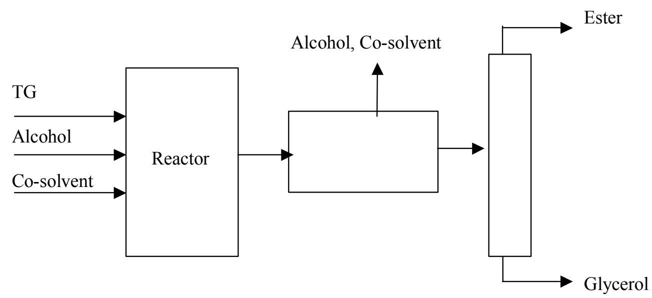
High free fatty acid feedstock will react with the catalyst and form soaps if they are fed to a base catalyzed system.



(Van Gerpen[1])

4. Non-Catalyzed systems – Biox process

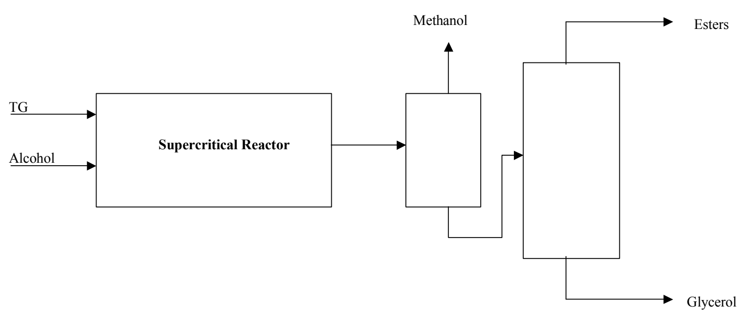
Slow reaction time caused by the extremely low solubility of the alcohol in the TG phase.



(Van Gerpen[1])

5. Non-Catalyzed systems – Supercritical process

   Use high alcohol to oil ratio under supercritical conditions, and the reaction is complete in about 4 minutes. Capital and operating costs can be more expensive, and energy consumption is higher.



(Van Gerpen[1])

Advantages and Disadvantages of Biodiesel

After manufacturing the biodiesel, it can be readily used in most diesel engines without any modifications. Biodiesel can be used as an additive to diesel or as a complete substitution in vehicles with diesel engines or diesel powered generators. When compared to traditional oil based fuels, biodiesel has many advantages. Currently, the most important trait of biodiesel seems to be the fact that it produces 78.5% less carbon dioxide as exhaust than a traditional diesel engine (Benefits of Biodiesel[4]). Carbon dioxide is a greenhouse gas, and is one of the six regulated air pollutants monitored by the Environmental Protection Agency (EPA) under the Clean Air Act of 1970. For every gallon of gasoline burned, 19 pounds of CO_2 are produced. A reduction of 78.5% would mean that biodiesel would only produce about four pounds of carbon dioxide per gallon of biodiesel. In industry, the EPA allows factories that do not meet a maximum emission limit to sell their unused emission credits to companies that exceed that limit. This is a large incentive to generate power with biodiesel. Another benefit of biodiesel is that it can be produced using existing industrial refineries. This would help curb start-up costs as it would eliminate the need for expensive new refinery buildings and equipment. It would also allow the production of biodiesel fuel to start immediately.

From a purely nationalistic standpoint, switching to biodiesel would create thousands of jobs for American citizens as well as decreasing our dependency on foreign oils. The current biodiesel industry has over 50,000 jobs, filled by American workers, and increasing dependence on biodiesel would correlate to an increase in jobs available. It is estimated that for every billion dollars spent on securing foreign oil, the U.S. loses between 10,000 and 25,000 jobs. For example, in 1996, more than $60 billion was spent to secure foreign oil, which translates to a conservative 600,000 jobs lost that year from the oil industry alone (Paulson[6]). The additional tax on the corn and soy farming industries would also lead to the creation of more jobs. Biodiesel is also much cleaner than traditional diesel. In fact, biodiesel will actually clean a diesel engine as it is being used (Biodiesel.org[2]). Some researchers believe that biodiesels burns better than regular diesel. Traditional diesel has a Cetane Number (CN) between 40 and 60, while biodiesel has a Cetane Number range around 100. A Cetane Number corresponds to the ignitability of a fluid; the higher the number, the more easily it ignites. However, after about a CN of 60, the ignitability stabilizes and an increased CN does not affect a fluid's efficiency.

Biodiesel also has a greater energy balance than all other fossil fuels. For every unit of fossil fuel needed to generate biodiesel, 4.5 units of biodiesel are generated. This ratio takes into account the entire process of producing biodiesel, including the production of corn, the creation of the vegetable oil, and the refinement of that oil into usable biodiesel. Although there are many benefits to using biodiesel over traditional fossil fuels, there are some disadvantages. Biodiesel turns out to be about 10% less efficient than traditional diesel. Practically, this means that larger storage tanks would be required to produce the same power as traditional diesel (Haugen[4]).

While there are many promoters of biodiesel that claim it to be a miracle solution to the use of fossil fuels, there are some environmental concerns regarding its production. There seems to be an increased propensity for farmers to grow corn specifically for the production of biodiesel due the lack of safety regulations and higher profits associated with biodiesel. This trend appears to be causing an increase in the price of corn and soy as a food product. Also, some environmental activists claim that a mass increase in the production of biodiesel will cause an encroachment on wildlife habitats ("The Green Car Website"[3]).

Although biodiesel is not the final solution to zero-emission power production, it would be an easy transition from fossil fuels to the transportation industry. As mentioned earlier, biodiesel does produce CO_2, but much less than traditional diesel. Also, this would decrease the nation's dependency on foreign oil, and increase productivity in the U.S., contributing to the success of the economy.

Biodiesel Applications

Biodiesel is most commonly used in the transportation industry. Since it is a direct substitute of diesel, it can be used in any diesel vehicle with only minor modifications. These modifications only include replacing engine components such as rubber hoses, since biodiesel is a solvent and will corrode the rubber.

Diesel motors operate differently than gasoline motors in that diesel engines do not require a heat source (spark plug) for cylinder ignition. The diesel motor relies on the ideal gas law, where as the piston compresses the cylinder, the volume decreases, increasing pressure, and therefore raising the temperature high enough to ignite the diesel. Biodiesel acts the same way, and lubricates the system better than traditional diesel.

As mentioned earlier, biodiesel is the direct replacement to diesel, and can be used in any application that diesel is used. This includes private vehicles, public buses, commuter trains, power generators (large and small), as well as heavy duty equipment such as dump trucks and other construction equipment. Some car enthusiasts claim that the diesel generation is on the downfall, however the facts show otherwise. Carmakers continue to offer diesel editions to the fleet, especially Volkswagon's traditional TDI lineup. But, new automakers are attempting their abilities at producing diesel powered vehicles, such as Jaguar's XF model, or BMW's new diesel

X5. Although these new vehicles are confirming the interest in diesel technology, traditional diesel vehicles are the most common vehicles used in the biodiesel world.

Biodiesel has been getting support from major celebrities such as Willie Nelson and Woody Harelson. *Dirty Jobs,* a show on the Discovery Channel, did a sequence on biodiesel production, which also stressed the point that biodiesel technology is simple, can be produced in a residential house, and is very efficient. Celebrity publicity is a great way to get attention where it is due, and biodiesel technology could be an excellent alternative fuel to diesel.

Our Opinion

Biodiesel is a very clean energy resource. It does not produce a lot of waste, however the cost of biodiesel is usually very high simply because of the production procedure. Rather than having a biodiesel farm cover a significant amount of land, a solar farm or wind farm can be simply built with less cost. Once people can find out a way to mass-produce biodiesel without such high cost, it will become the most efficient fuel of transportation.

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ELECTRIC VEHICLES

Background

Pressured by the California Air Resources Board (CARB), GM was forced to develop and market an electric car in order to remain selling cars in California. The mandate indicated that 2% of all vehicles sold by GM would have to be zero emission vehicles (ZEV), pure electrically driven cares. The mandate rules increased with time, as it required 5% by 2001, and 10% by 2003 to be ZEV. Although unhappy with the new law, GM complied and created the EV1.

GM was planning on fighting the mandate claiming that it would be impossible to sell 2% of its sales as ZEV, as if there was little demand for ZEVs. For this reason, the EV1 was marketed as small as possible with GM in control of all EV1s. All EV1s were sold through lease agreements, and GM refused to let any customers buy one. The EV1 was produced from 1997 through 1999, yielding about one thousand EV1s with a waiting list of four thousand customers. The waiting list was denied by GM, in addition to many other questionable acts that terminated the production of the EV1. There was a documentary video produced on the disappearance of the EV1 called "Who Killed the Electric Car," that explains the possible suspects in decommissioning the EV1. Regardless of the end of EV1, the car was an engineering masterpiece that used energy more efficiently than normal gasoline internal combustion engines.

The picture above shows an EV1 with a charging unit to the left.

Courtesy: http://www.adelman.com/cars/ev1.jpg

Cost Efficiency/Effectiveness

Despite the EV1 having terrible marketing advertisements and publicity, GM could not produce them fast enough to keep up with the demand. The cars were on lease agreements, between $250 and $500 per month, which is rather expensive for a lease payment. On the defense, the EV1 was only being produced at a rate of 4 cars per day; almost completely handmade. Had GM continued production of the EV1, a more efficient assembly line would have been created, lowering the cost of the car. At the time of production, the suggested retail price of the EV1 was estimated at $34,000, also on the expensive side, and also would have dropped with a more efficient assembly line.

In addition to the high cost of the car (yet not high enough to stop the alarmingly high demand for the car), the effectiveness of the car was heavily criticized. The first and most obvious problem with the EV1 is that it is a two-seater, which is very impractical for a family car. The second major problem with the EV1 was that it had a limited range of around 100 miles per charge. This range limitation is a debated topic in that the designer of the EV1 battery pack Stan Ovshinsky claims that he had developed a battery pack for the EV1 that would have a much further range than the original 100 miles. A major problem with the EV1 experiment was that the EV1 cars were sold primarily in California where long distance driving is more common, yet the average miles driven per day in California was only 29; easily met by one charge in an EV1.

So if the EV1 is claimed to be impractical for a typical Californian driver, will it at least save the driver money in the long run? For example, if an internal combustion engine (ICE) car costs half of what the EV1 costs ($17,000) and consumes fuel at a rate of 20 miles per gallon at $2.30 per gallon. The EV1 consumes fuel at a rate of 7.86 miles/ kWh, at $0.15 per kWh, equivalent to $0.38 cents per gallon for the same distance that gasoline gets in an ICE vehicle. Each car travels 29 miles per day, equaling 203 miles per week. Saving a difference of $1.92 per 20 miles, it would take 16.8 years to account for the $17,000 addition cost of purchasing the EV1. However, this estimate does not take into consideration the maintenance cost of either vehicle, which ICEs are known for expensive repairs while EV1 maintenance schedules are based on simply when the tires need to be rotated. In fact, many upset, prior EV1 owners suspect that one major reason for banning the EV1 from production was so that GM could continue to profit from the high cost of repairs required by gasoline fueled vehicles. If the consumer would break-even for owning a car after 20 years, whether it is an EV1 or an ICE, the EV1 would produce far less emissions than the ICE, and would therefore be beneficial (Karn).

Where is the Pollution?

Some disbelievers say that although the car does not generate pollution, the electricity used to power the vehicle is as polluting as any normal car. Using the numbers found earlier, the pollution produced from electricity can be determined. For a standard 20mpg car, 19 lbs of CO_2 are produced. An EV1 uses one kWh to travel 7.86 miles, and the electricity plant claims that 1.27kg (or 2.8 lbs) of CO_2 are produced per kWh. Travelling 20 miles at 7.86 miles per kWh requires 2.54 kWh.

2.54kWh x 2.8 lbs/kWh = 7.11 lbs CO_2 produced to travel 20 miles electrically

The EV1 would produce 64% less CO_2 pollution than a gasoline powered 20mpg car. In fact, an EV1 would have to travel 53.5 miles to emit the same amount of pollution of the 20mpg gasoline ICE car. Thinking more conservatively, if the EV1 were compared to a 25mpg car, the EV1 would be responsible for 8.89 lbs of CO_2 emitted at the power plant to the 25mpg ICE. The EV1 would still account for a decrease of pollutants by 53%.

Other ZEV or LEV

GM has released the EV1 successor, the Chevy Volt. The Volt is for sale starting in November 2010, and this time it is available for the public to buy (as opposed to EV1s lease only program) for a price of about $33,000. The Volt can be used as a ZEV or an LEV since it has an onboard fuel driven motor (gasoline, diesel, or bio-fuel). Some aspects were sharply improved from the EV1: it now sits 5 passengers, can have a range of 640 miles, and does not require any special charging unit (charges from a normal 120 volt outlet).

The Volt's battery pack holds enough energy to power the vehicle 40 miles before a recharge is necessary. If 40 miles is not adequate for a trip, the high efficient ICE can produce constant energy to recharge the battery pack. This electric/gasoline motor setup is referred to as a series hybrid because the gasoline motor has no contact with the actual drive train. Although the recharging motor uses gasoline to produce propulsion, it is more efficient because the motor operates at a constant speed, which is more efficient than the normal varying speed-ICEs.

The Toyota Prius is the primary hybrid vehicle sold in the U.S. with more than 2 million sales. A Nickel Metal Hydride battery was used for the first generation (01-03) Prius, and continued to be used in the second generation (04-09) Prius until 2006, when the Lithium ion battery became integrated into the hybrid design. Both generations were capable of achieving 60mpg, and in 2010, Toyota released the plug-in model that had a Lithium ion battery capacity ranging up to 15 miles on the battery alone before the gasoline motor needed to be activated. The only other car commercially sold in the U.S. that was capable of achieving a higher mile per gallon rate was the Honda Insight, however the Insight has been discontinued with the release of the Hybrid Honda Civic released in 2007. Many other car-manufacturing companies have a research and development team that is fully tasked with finding a way to make the hybrid car more profitable at a lower cost to the consumer.

Batteries Used in Vehicles

There are two types of cars that are running on electric power, Electric Vehicle (EV) and Hybrid cars. An EV car operates solely on electricity from the grid, which holds an onboard rechargeable battery that supplies the power needs for vehicle movement and function. The Hybrid Car is another type of electricity-based vehicle that is powered by combining two types of technologies: an electric motor and an internal combustion (gasoline) engine. Having two engines work together makes the car extremely fuel-efficient. For example, the combustion engine will turn off when the car is at red lights and the electric motor will resume normal function of the car. There are three types of rechargeable batteries: Nickel-Cadmium Batteries, NiMH Hybrid Car Batteries (Nickel Metal-Hydride), and Lithium Hybrid Car Batteries.

Nickel-Cadmium Batteries-

Nickel-Cadmium Batteries are generally not used in Hybrid cars, since it contains lead and does not have an adequate capacity to operate a Hybrid car. It is normally used in cell phones or to start a gasoline-run vehicle (Hybrid Car Battery Technology[1]). Below are the equations that allow a Nickel-Cadmium battery to operate.

At the positive

$$NiOOH + H_20 + e^- \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} Ni(OH)_2 + OH^-$$

At the negative

$$Cd + 2OH \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} Cd(OH)_2 + 2e^-$$

Overall

$$2NiOOH + Cd + 2H2O \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} 2Ni(OH)_2 + Cd(OH)_2$$

Nickel Metal-Hydride Batteries-

NiMH batteries are currently used in hybrid cars. Similar to its Nickel-Cadmium counterpart, this battery uses the same chemical nickel oxyhydroxide (NiOOH) to help it hold a charge. But unlike the Nickel-Cadmium batteries, which use cadmium, this type of battery uses a Nickel alloy called Nickel Metal-Hydride for the negative electrode. Due to the absence of Cadmium, which is considered environmentally toxic, this type of battery is more "green." It is also safer to use and has a higher capacity than traditional Nickel-Cadmium batteries. The downside of this battery is that it still does not have the high capacity to run a hybrid's sophisticated electric motor without constantly being charged. It is also more expensive than most batteries due to the cost of Nickel. This is currently what keeps the cost of a hybrid car at a premium (Hybrid Car Battery Technology[1]). Below are the equations that allow a Nickel Metal-Hydride battery to operate.

At the positive

$$NiOOH + H_20 + e^- \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} Ni(OH)_2 + OH^-$$

At the negative

$$MH + OH^- \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} M + H_2O + e^-$$

Overall

$$NiOOH + MH \underset{Charge}{\overset{Discharge}{\rightleftharpoons}} Ni(OH)_2 + M$$

(M: Hydrogen absorbing alloy, MH: Metal Hydride

Lithium Hybrid Batteries-

Lithium Hybrid car batteries currently power small handheld devices such as laptops and cell phones. Lithium batteries have a higher capacity than other types of batteries, and they are also made more cheaply. Lithium batteries could enable hybrid cars to go much longer distances anywhere from 50-100 miles. Although most hybrids are not plug-in models, this would be required with the current technology if these types of batteries were to be used. Another problem with these batteries is that they use cobalt in their formulas, which has the potential of exploding. Automakers are seeking alternatives to cobalt that can provide the same amount of power. (Hybrid Car Battery Technology[1]) Below are the equations that allow a Lithium battery to operate.

At the negative

$$(Li\text{-}Al)\ \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}}\ Al + Li+ + e^-$$

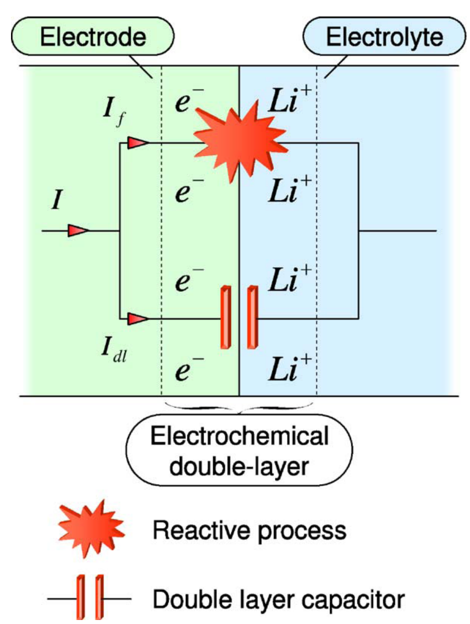
At the positive

$$MnO_2 + Li+ + e^-\ \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}}\ MnO_2\ (Li+)$$

Overall

$$MnO_2 + (Li\text{-}Al)\ \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}}\ MnO_2(Li^+) + Al$$

(Li-Al : lithium aluminum alloy)



The figure (courtesy of: Menard[7]) shows an electrochemical double layer capacitor, used in lithium-ion batteries. Two different conductive areas are in contact, which creates a Helmholtz layer, equivalent to an electric capacitor. The electrode–electrolyte interface divides the total current in two halves, *I*(f) and *I*(dl) that respectively play a part in activation and double-layer phase. This double layer capacitor stores energy and is responsible for the fast dynamics of the battery (Menard[7]).

Battery Comparisons

Nominal Voltage is the standard voltage used to express the capacity of a particular battery model. It is generally equal to its electromotive force or its approximate voltage during normal operation.

Typical Values:

- 1.2 volts per cell for NiCd and NiMH
- 3.6 or 3.7 volts per cell for Lithium Ion or Lithium Polymer
- 3 volts per cell for lithium primary
- 2 volts per cell for sealed lead acid
- 1.5 volts per cell for alkaline and carbon zinc

End-Voltage is the voltage that indicates the end limit of discharge. This voltage is almost equivalent to limitation of practical use.

Typical values:

- 1.0 volt per cell for NiCd and NiMH
- 1.75 volts per cell for sealed lead acid
- 2.75 volts per cell for lithium ion and lithium polymer
- 2.0 volts per cell for primary lithium
- 0.9 volts per cell for alkaline and carbon zinc

Self-Discharge is a decrease in battery capacity, which occurs without any current flow to an external circuit.

Typical values:

- 1% per day for NiCd
- 2% per day for NiMH
- ~0% per day for Lithium Ion and Lithium Polymer

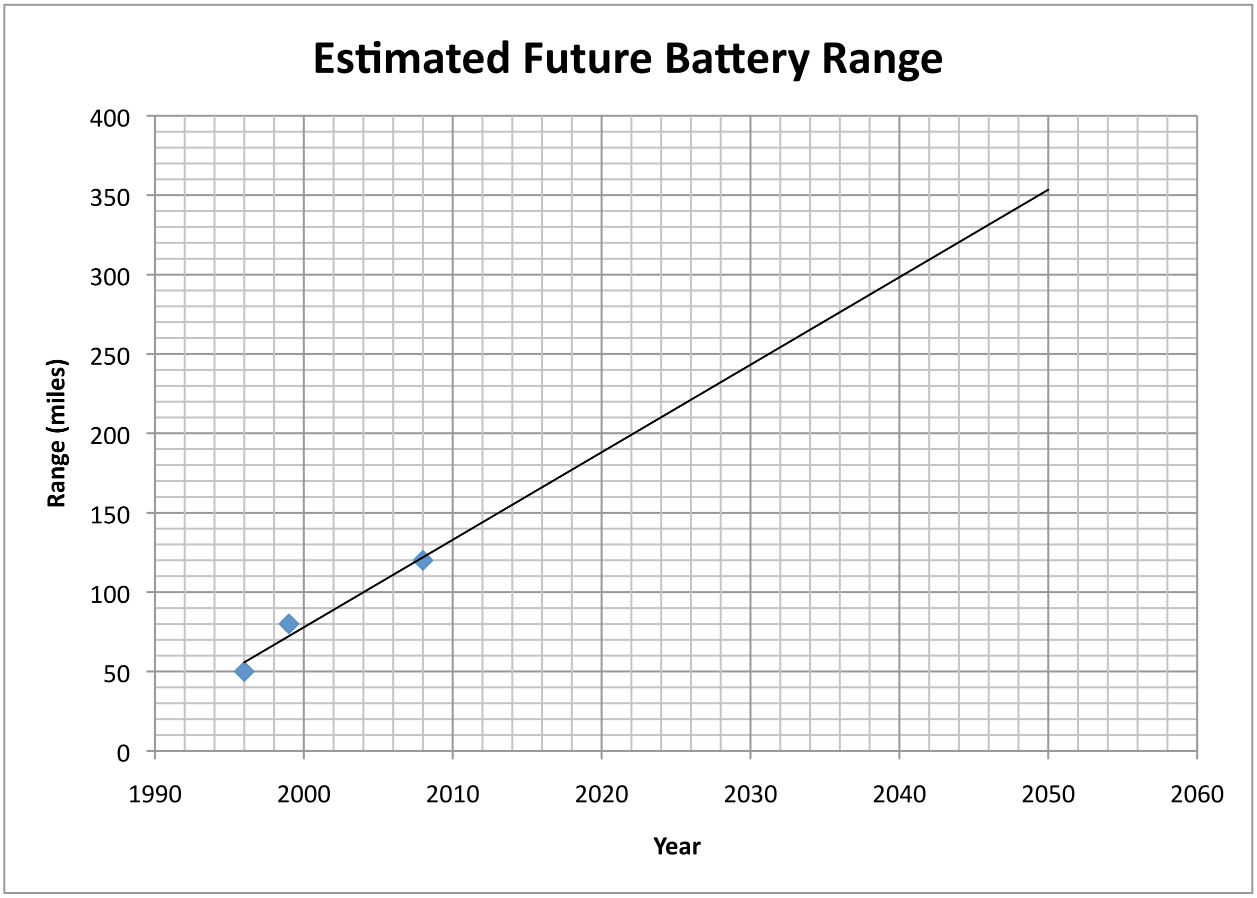
Lead-acid batteries generally have a range of 30 to 80 km (20 to 50 mi). Production EVs with lead-acid batteries are capable of up to 130 km (80 mi) per charge. NiMH batteries have higher energy density than lead-acid; prototype EVs deliver up to 200 km (120 mi) of range. New lithium-ion battery-equipped EVs provide 320–480 km (200–300 mi) of range per charge (Battery Knowledge[2]).

Future Technology

There are a lot of scientists working on the development of the next generation battery, setting a goal for a higher capacity and smaller size. Lithium-ion batteries are recent technology for powering electric vehicles. Unfortunately, the charge time for lithium battery takes far too long for them to be an acceptable battery used in EVs. Also, this kind battery is fairly expensive because of the Cobalt ingredient.

A new and highly promising battery design is now emerging from MIT – a new type of lithium battery that could possible become a cheaper alternative to the batteries that are now powering hybrid electric cars. Compared to the old Lithium-ion battery, its material is more stable and thus safer. This new battery contains Manganese and Nickel instead of Cobalt. Scientists have already known that Lithium Nickel Manganese Oxide batteries could store a lot of energy, but the materials in the battery took too long to charge for them to be used commercially. The MIT researchers set out to modify the material's structure to make it capable of charging and discharging more quickly. The major problem with the compound was that the crystalline structure was too disordered, meaning that the Nickel and Lithium were drawn to each other, interfering with the flow of Lithium ions and slowing down the charging rate. Lithium ions carry the battery's charge, so to maximize the speed at which the battery can charge and discharge. The researchers designed and synthesized a material with a precisely ordered crystalline structure, allowing lithium ions to freely flow between the metal layers. A battery made from the new material can charge or discharge in about 10 minutes -- about 10 times faster than the unmodified Lithium Nickel Manganese Oxide battery. This quick charging time brings the available battery technology much closer to the timeframe necessary for hybrid car batteries (Hanlon[3]).

Based on the steady improvements made with new battery technology, a new battery fifty years from now could be able to reach a driving range up to 1000-1200 km (620-750 mi) per charge. Below is a projected estimate of battery range in the future, based off of present and past battery ranges.



Our Opinion

After thorough research, it is determined that a hybrid car would be the most practical vehicle to incorporate electricity into vehicle propulsion. The reasoning behind this is because the most current technology is not advanced enough to drive a car far distances purely on battery charge, while hybrids can easily double the range that a gallon of gasoline provides to a non-hybrid vehicle. The batteries used in this hybrid should be Lithium Nickel Manganese Oxide. These are the most advanced batteries, and although expensive, have the largest capacity for batteries offered in hybrid or electric cars.

This car should also be very aerodynamic, similar to the Toyota Prius, in a way that will minimize the drag coefficient, therefore increasing fuel efficiency. Another concept that should be taken from the Prius is the electrically driven comfort components, such as the air conditioner and power steering. These optional accessories, in addition to a comfortable sedan type model, must be included in the vehicle in order to appeal to consumers. Unfortunately, a major appeal to consumers is the cost of the vehicle. The cost must be as low as possible, where profits on the vehicle will be minimal (at least for the first few years until the expensive battery components become cheaper). The car should also come with the option to have plug-in, using a 120v socket for home use.

Finally, using BMW's engineering designs, the car must be as light as possible (while maintaining all safety aspects), and will capture kinetic energy in the braking system. Capturing this energy will recharge the batteries while slowing the vehicle to a safe stop. If this were a perfect system, no energy would be lost. However, as the second law of thermal dynamics states, no system can be 100% efficient, and power will be lost in the braking system. If a car were to be designed with all of these aspects, car buyers would submit to hybrid vehicles, and the high pollution rate would decrease.

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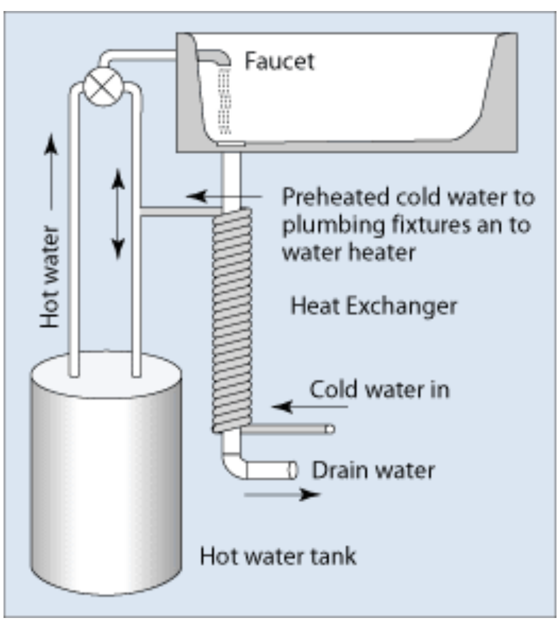
Existing Energy Saving Methods

DRAIN WATER HEAT RECOVERY

Everyday households use hot water for applications such as washing dishes, taking showers, or doing laundry. Once the water becomes dirty from a washing cycle or becomes "grey" water from showers, it goes down the drain and into the waste management system. This hot water has potential energy because it is warmer than the cold water entering the hot water heater. Devices have been created that will capture the heat from the hot drain water and use it to preheat the entering cold water.

Doubts may be raised about this energy saving method—how much energy could possibly be captured from wastewater? In fact, the hot water going down the drain obtains 80-90% of the original energy needed to heat the water. This means that of the energy used to get the water to the desired temperature (normally around 120ºF), only 10-20% of the energy spent is actually being used. The heat recovery system can capture the heat of the hot water and transfer it (technically half of it since the grey water cannot get colder than the entering cold water) to the cold water. Below is a diagram of how this system works using only gravity as a power source.



courtesy: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13040

The grey water flows down the faucet drain, but instead of going straight through the waste water pipe, the water passes through a heat exchanger. In this case, the heat exchanger is a copper pipe that is coiled around the drainpipe. The amount of heat exchanged is dependent on the area of contact, which in this case is the area that the coiled pipe touches the drainpipe. To maximize this area, the copper pipe is cut in half and welded to the drainpipe along the diameter axis.

A study was conducted by Energy Star, a joint EPA and DOE program, which assessed the performance of Gravity Film Heat Exchangers (GFX). Primary information was needed before analyzing the results of the GFX, such as home water usage and the water temperature of the water entering the house. The following data table was assumed for houses:

Volume of hot water use per day (proxy = number of bedrooms)

- 50 gallons of hot water use per day (2-bedrooms)
- 60 gallons of hot water use per day (3-bedrooms)
- 70 gallons of hot water use per day (4-bedrooms)
- 80 gallons of hot water use per day (5-bedrooms)

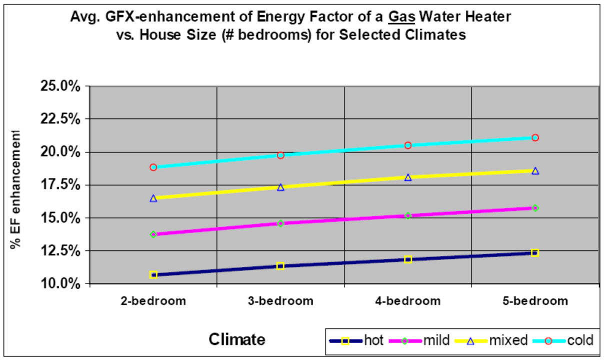
The equation used to calculate home water usage is 30gpd + 10gpd for every bedroom. The next necessary information is the entering water temperature. The water temperature is classified depending on the climate that the house is located in. The following data was assumed for this study:

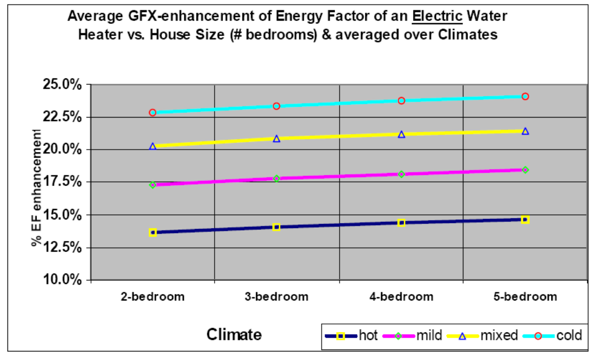
Water Main Inlet Temperature (proxy = average annual ambient air temperature)[5]

The following set of climatic conditions are correlated to **water main inlet temperature**

- 45 F average annual inlet water/avg.annual ambient temperature - "cold" climate
- 55 F average annual inlet water/avg.annual ambient temperature - "mixed" climate
- 65 F average annual inlet water/avg.annual ambient temperature - "mild" climate
- 75 F average annual inlet water/avg.annual ambient temperature - "hot" climate

Now that the initial data has been found, the GFX systems can be analyzed to find the energy factor enhancement. This enhancement will be dependent on housing climate, number of bedrooms in a house, and whether the water heating system is powered by natural gas or electricity. The final analysis is shown below:





Courtesy of:
http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf

Electric heaters show that they benefit more than gas heaters, and the colder climates play a large role in the amount of energy recaptured by a GFX. One interesting outcome of this data is that the efficiency factor was not heavily altered by the number of bedrooms per house. This is interesting because these heat exchangers are continuous, meaning that the warm water created from the waste water is perishable and will not stay warm unless used right away. This is why GFX systems are most beneficial in houses and buildings with many people that are constantly using hot water.

An example may illustrate this point best. If two people shower in the morning, the second shower will use less energy because it uses preheated water from the first. If five people shower in the morning, every shower after the first one will be efficient, increasing the percentage of efficiency. This theory was evident in the data tables, however a heavier increase in efficiency was expected.

Gravity Film Exchangers usually cost $500 to be installed in a residential house, and even less when installed during construction of the house. Depending on how much use this system gets (depending on how many people are using it and the entering water temperature), a GFX can save between 800kWh/year to 2300kWh/year for an electric heater. At $0.13/kWh, a GFX will save between $200 at $1500 depending on when it needs to be replaced during its 2 to 5 year lifespan. This GFX has the potential to save money with only a small amount of investment, in addition to saving the environment.

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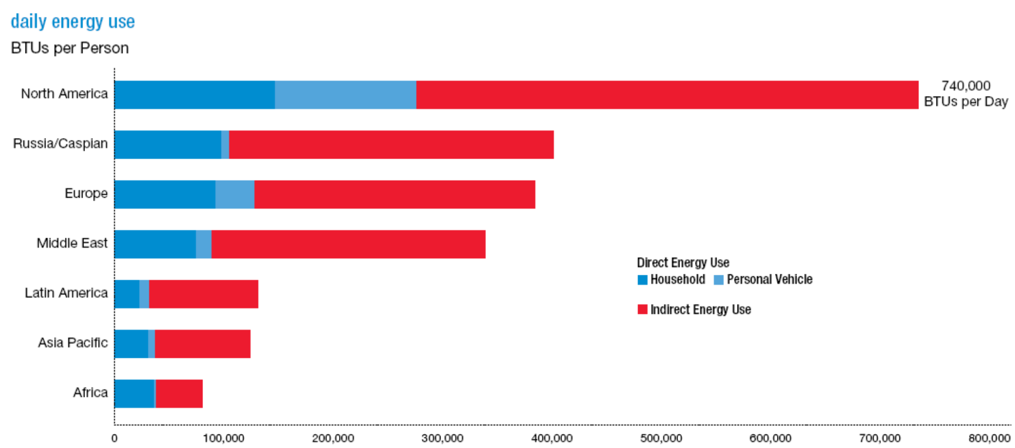
2. "Drain-Water Heat Recovery." *Energy Savers*. Department of Energy, 9 Feb. 2011. Web. 12 Feb. 2011. <http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13040>.

EXXONMOBILE'S OUTLOOK TO ENERGY 2030

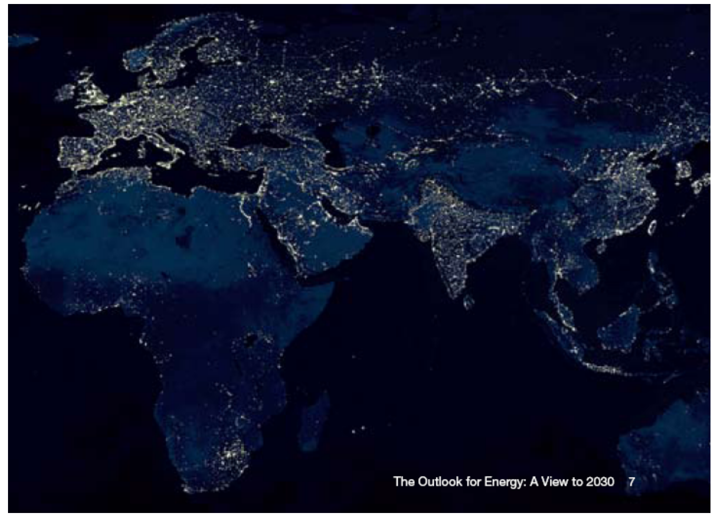
All graphs and images provided in this section are from ExxonMobile's outlook to Energy 2030

Every year, Exxon publishes an Outlook to Energy program that analyses energy data from over 100 countries. It is a comprehensive look at long-term trends in energy demand, supply, emissions and technology. This annual report is filled with very useful, interesting data; however a critical point of view must be used when reading. Exxon is primarily a fuel-selling company. Since the company is privately owned, there is no economical benefit to have any sort of fuel efficient ideas by this company. In fact, if the company were to support any sort of fuel-saving technology, they would be losing money by reducing the volume of fuel sold. With that taken into consideration, the data presented is useful for anticipating future energy consumption.

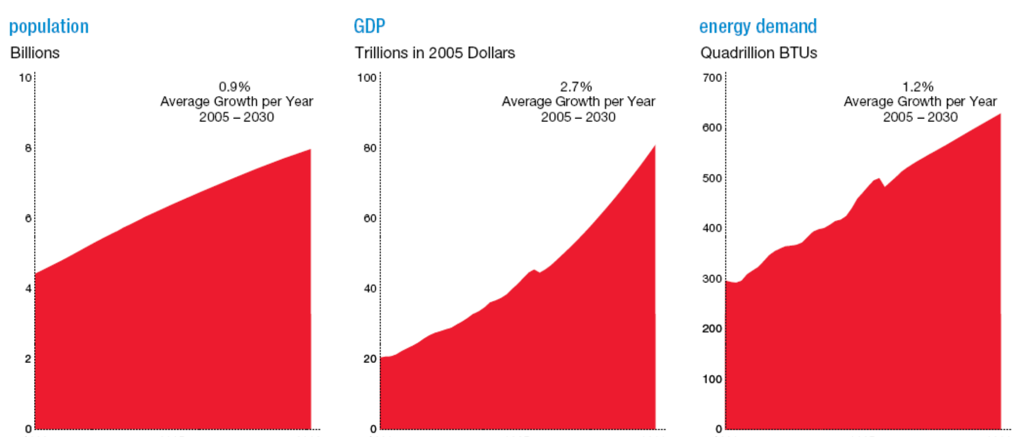


The graph above displays the average energy footprint by country. It should be noted that North America (primarily the U.S. by population) is by far the largest consumer nation of energy. This indicates the severe change necessary to preserve the remaining fuel supplies and reduce wasted energy. Unfortunately, energy projections of 2030 show that energy usage is going to increase. To compensate for this increase, while at the same time reducing the BTU's spent per person, more fuel efficient and energy efficient methods are going to be required.

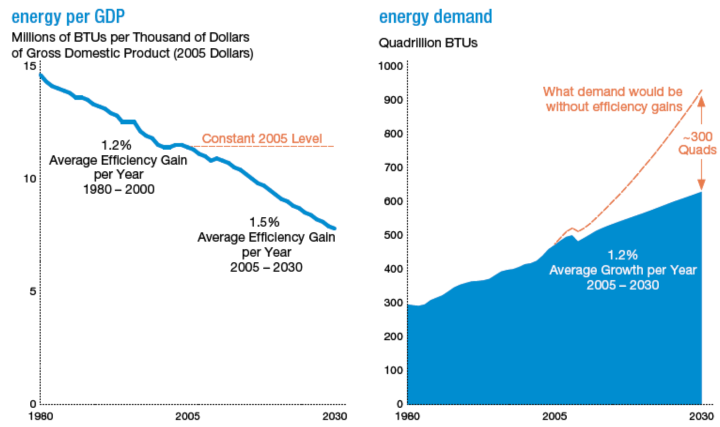
Globally, 2.5 billion people rely on traditional heating fuels such as wood or dung. This amount of people relying on this heating fuel type is too large to be ignored. The U.S. has not used wood as a primary heating source since 1880, yet nearly half of the world's population has not seen any technological advances in energy for well over 2000 years. Of these 2.5 billion people, 60 percent (1.5 billion people) do not have access to electricity. Electricity is another energy source taken for granted in the U.S., and three quarters of the rest of the world. The absence of electricity is most likely going to remain the same through 2030, as shown below in the light map of the eastern hemisphere. Notice the familiar blackouts in Africa and Asia.



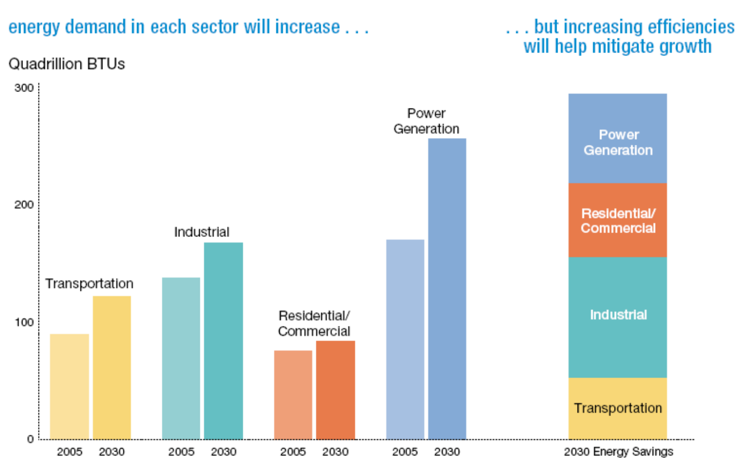
A city with a population of one million was examined and an analysis was done about the energy consumption of that city, such as Naples Italy. On average, the city will consume 1,000 gallons of oil per minute, as well as 150 tons of coal per hour. To account for this massive energy consumption, it would require 2 fully operating power plants for continuous energy flow. As mentioned earlier, this massive energy consumption is predicted to grow.



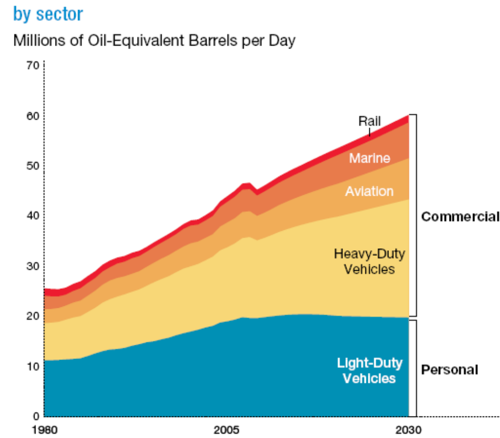
This energy demand is quantified by a rising rate of 1.2% per year. At this rate, energy demand will be 35% higher in 2030 than it was in 2005. Today, the world as a whole uses 15 billion BTUs every second. If the energy producing efficiency was to carry from 2005 through 2030, energy demand would be increased to more like 95% as opposed to 35%. The reason for this drop of 60% if from the advancements of technology, saving the outrageous increase of energy demand in accordance with the population and economic growth predicted to occur by 2030. This is visually explained in the graph to the right.



Transportation is believed to be the largest consumer of energy; however transportation is ranked third in energy consumption. Believe it or not, power generation is ranked first, and will account for 40% of all energy demand by 2030. This is an area that must be investigated for efficiency improvements, especially since power plants are static as opposed to vehicles that are always moving (meaning it is easier to design an efficient stationary power plant rather than a moving vehicle). It is also predicted that the main source of fuel used to produce this massive power generation is going to be coal, the largest producer of CO_2 emissions.



Although transportation is ranked third in energy demand, there still needs to be much more technological advances in this section. To the right is a graph of the breakdown of the kind of vehicles that are consuming the most amount of fuel.



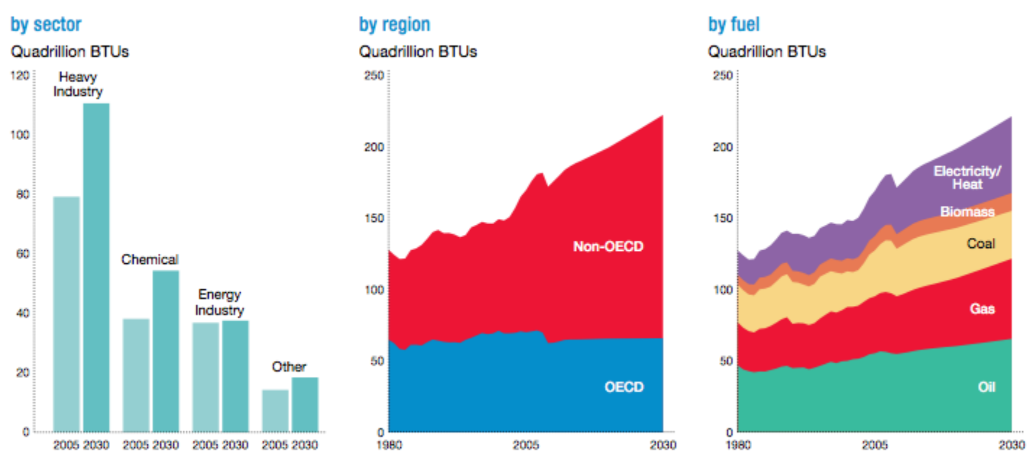
One method of improving this vehicle fuel efficiency is by using biofuels. Exxon claims to be developing a new algae biofuel research program. The goal of this program is to produce a commercially scalable, renewable algae based fuel that could potentially be used in all cars, trucks, and even aircraft. Using algae as a replacement to traditional gasoline or diesel would be extremely efficient; the first reason being that it is renewable. This would reduce the dependency on foreign countries for fuel, in addition to eliminating the need for inefficient fuel transportation. Algae biofuel would also reduce CO_2 emissions significantly.

Predicting the amount of registered vehicles in 2030 is difficult because there are many variables. Exxon predicts that there will be a noticeable rise in hybrid vehicles; from 1 percent today to 15 percent by 2030. It is also estimated that high population countries such as China and India will not have an increased ratio of cars per people that the U.S. will encounter. This rise in the U.S. will most likely be caused by the increase of wealth within the next 25 years. In addition to the much-needed increase of hybrid cars on the road in 2030, non-hybrid vehicles will become more efficient. As of today, automakers are continually improving auto parts to augment fuel efficiency. Engine technology exists such as cylinder shut-off options, camless valves, or turbocharging. These engine modifications will account for a 15 percent increase of efficiency. Transmissions with more gears will lower vehicle RPMs and will improve fuel economy as much as 5 to 10 percent. The other most commonly updated specification on a car is the drag coefficient, or the aerodynamics of the car. This will make the fuel last longer by up to 15 percent compared to a traditional vehicle. With this technology, a non-hybrid car can be efficient.

Fuel Saving Examples

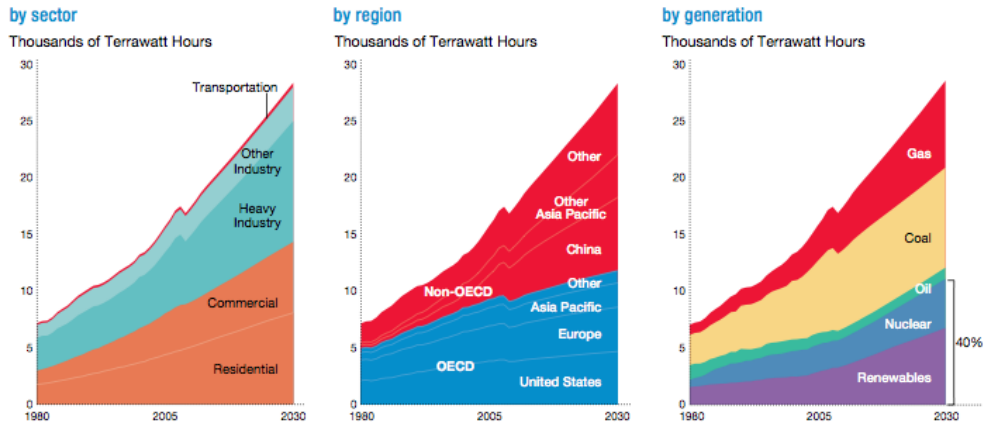
1. Developing a new tire-lining technology that uses up to 80 percent less material in the manufacturing process, making them lighter and keep them properly inflated.
2. Developed lightweight plastics for car parts.
3. Mobil 1 Advanced Fuel Economy, a lower-viscosity synthetic motor oil. Lower viscosity means less energy is required to circulate the oil in the engine.

Their technologies add up to significant fuel savings for the users, and emit less CO_2.



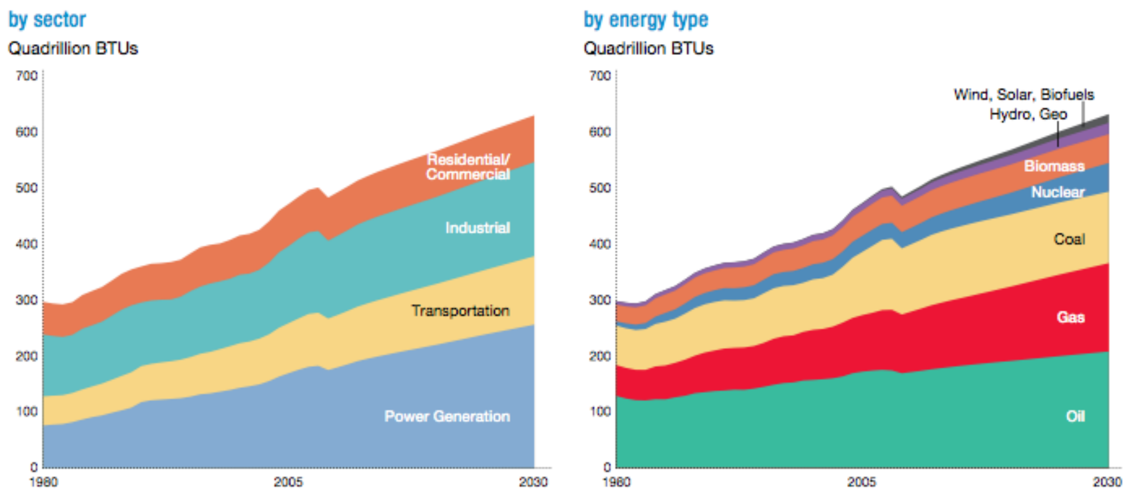
Heavy industry and chemicals account for the majority demand of fuel. Energy industry is the second-largest demand sector, following power generation. Industrial energy demand increases by nearly 60 percent in non-OECD countries from 2005 to 2030, with China making up about 35 percent of that increase. Meanwhile, OECD industrial energy demand is projected to be down slightly from 2005 to 2030, despite a near-term recovery in demand following the recession. Oil remains the largest industrial fuel through 2030 due to the growing of non-OECD demand. At the same time, coal consumption is decreasing with electricity as gas consumption increases.

ExxonMobil is successfully reducing emissions from its own operations. Since they launched the Global Energy Management System in 2000, the company has identified opportunities to improve efficiency by about 15 to 20 percent at the refineries and chemical plants. ExxonMobil continues on expanding its use of cogeneration – a process in which they produce electricity to power the operations while also capturing heat to make steam necessary in transforming raw materials into consumer products. Across the operation, they are also working on reduce flaring gas.

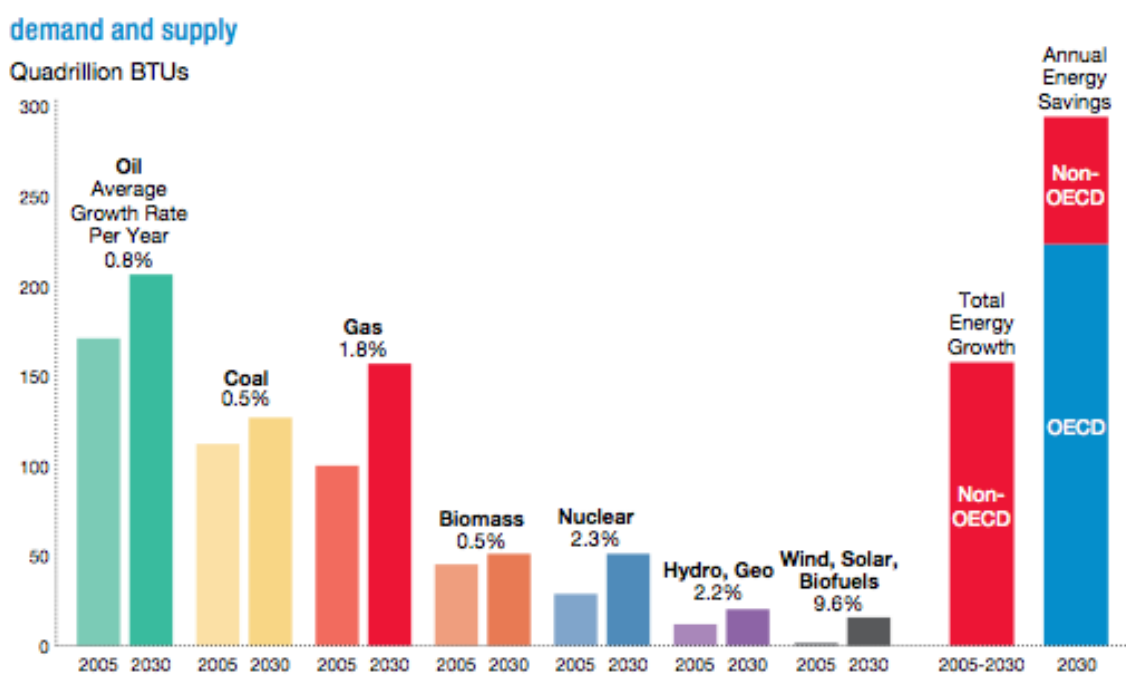


The consumption of energy is growing rapidly. Power generation is the largest energy-demand sector (aside from industry) and grows on average of approximately 1.7 percent per year. This will account for about 40 percent of all energy demand. By 2030, ExxonMobil predicts nuclear and renewable fuels will generate at least 40 percent of the world's electricity in 2030.

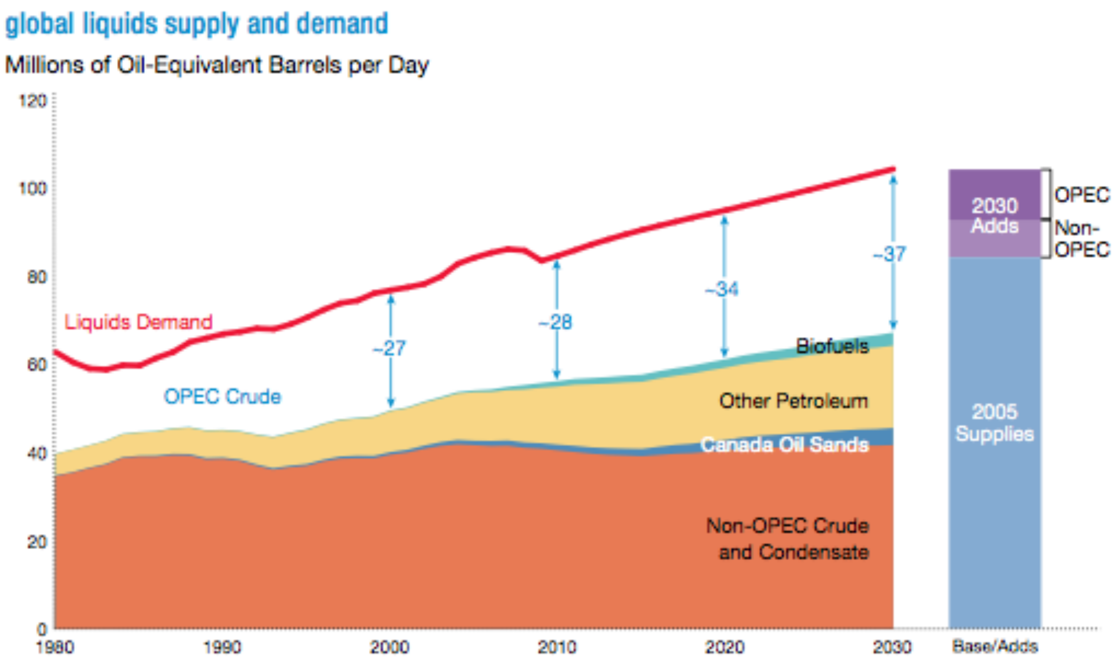
Currently, the U.S. has a policy that imposes a cost on CO_2 emissions. If the government starts charging more on CO_2, people will switch to use clean energy, such as nuclear, solar, wind and natural gas.



The picture above demonstrates energy usage from 1980 to 2030.

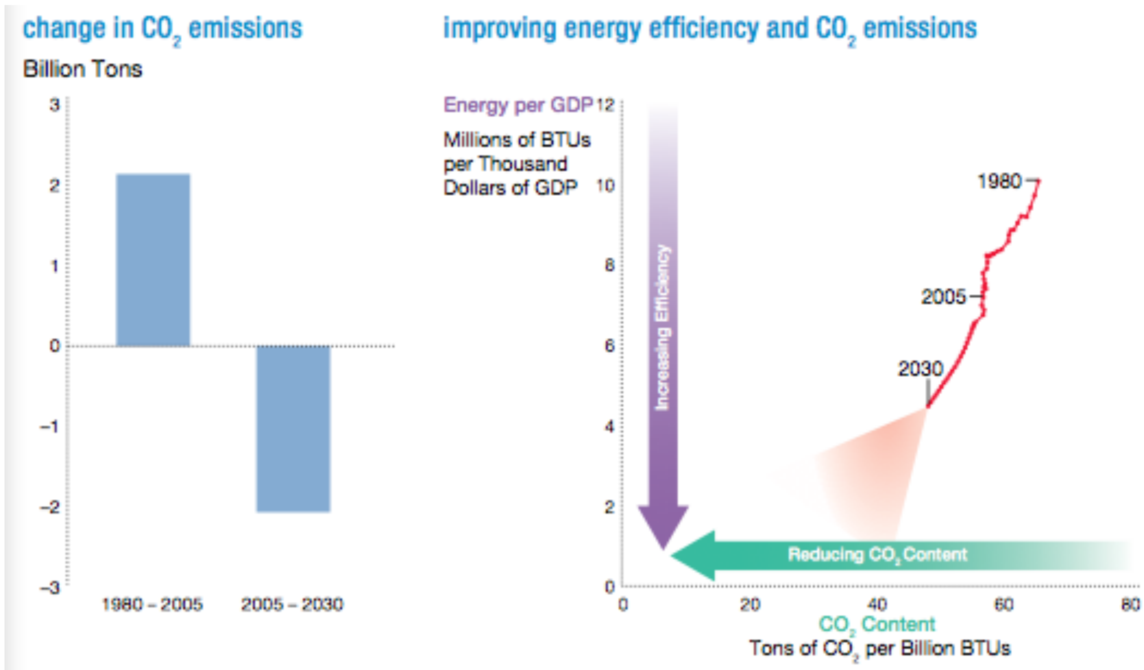


Since fossil fuels – oil, coal, natural gas – will still play a big role on generating energy in the coming years, a replacement should be found for them that has much less carbon emission. The fastest growing fossil fuel type is natural gas, which is a clean energy resource. Wind, solar and biofuels will also grow sharply through 2030, at nearly 10 percent per year on average. Technology is playing a key role in the energy industry.



ExxonMobil is also working on developing new technologies for natural gas. The Multi-Zone Stimulation Technology allows creating fractures in reservoir rock at a more rapid rate than conventional technology so gas will flow more easily (previously discussed in the shale natural gas section). The company is also the leader in developing and delivering advanced Liquefied Natural Gas (LNG) technologies. This helped pioneer a new class of LNG carriers for transporting gas. It also opened the world's first offshore gravity-based structure for unloading storage and re-gasification of LGN in Italy. The company is producing almost 65 million tons in 2010, and targets 100 million tons per year by 2030. Growth of producing LNG will play a significant role in electricity production, and will also reduce CO_2 emissions. By 2030, global CO_2 emissions are likely to be about 25 percent higher than they were in 2005. With this significant growth, the positive development is the result of expected gains in efficiency, as well as a shift to clean energy resources, mainly natural gas, nuclear, wind and solar. Natural gas used for power generation can result in up to 60 percent less CO_2 emission than coal.

More policies should be created about carbon emissions to try to move people onto clean energy. A heavier carbon tax can create a clear and uniform cost for emissions, and instead of paying more money for using fossil fuels to generate energy, people will consider using low emission energy sources. Tax returns to consumers who are using clean energy would increase awareness and encourage more to join this group.



Beyond 2030, a decrease in CO_2 is likely as OECD countries continue to pursue efficiency and shift to less-carbon- intensive fuels to help mitigate risks associated with CO_2 emissions.

LEED CERTIFICATION

All graphs and images provided in this section are from LEED Project Case Study

Background

Leadership in Energy and Environment Design (LEED) is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies that improve performance across all the metrics that matter most: energy savings, water efficiency, CO_2 emission reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. This grading system takes place throughout the entire process from design to construction to operations of a building. LEED has nine different rating systems:

- New Construction
- Existing Buildings: Operations & Maintenance
- Commercial Interiors
- Core & Shell
- School
- Retail
- Healthcare
- Homes
- Neighborhood Development

Each of these systems rates a different type of certification. For example, New Construction is designed to guide and distinguish high-performance commercial and institutional projects, and Existing Buildings provides a benchmark for building owners and operators to measure operations, improvements and maintenance.

LEED gives credits for every efficient action taken in the building design. Some rules are required to be certified, while others are worth points ranging from 1 to 19. To be recognized by LEED and to have a basic LEED certificate, 40 points must be earned. Silver level status is given for 50 points or more, Gold status is given for 60 points or more, and Platinum status is given for 80 points of more.

The LEED certification program encourages global adoption of sustainable building practices through a rating system that recognizes projects for implementing strategies that improve environmental condition. Although this is a very positive tool for improving the environment, there are some areas of the document that need to be improved.

Some rules of the document seemed to carry too few points, while some other rules were weighted heavily. Following such weighted rules could technically qualify a building for certification, but would create wasted space within the building and therefore defeat the purpose of making an efficient building. For example, credit 4.2 of Sustainable Sites offers one point for constructing a building with a bicycle room. This point might as well be nonexistent for buildings constructed in rural areas. Credit 4.3 and 4.4 of Sustainable Sites gives five points for creating priority parking for hybrid vehicles and carpool vehicles. Parking closer to an entrance of a building does not seem to carry enough motivation to change from a normal gasoline operated vehicle to a hybrid, or from driving to work alone to carpooling with employees, yet a huge number is awarded for hanging these reserved parking signs. For a building to meet the certification level of 40 points, earning these 5 points is already 12.5% completed. These credits values should be reduced.

The Water Efficiency section also had similar problems with credits given for certain efficiency methods. Credit 6.1 only awarded one point for storm water design. Water runoff has recently become noticed as a major environmental problem, and more attention has been given to prevent water runoff from damaging the environment. Water runoff is the water that falls over a building, but since the building cannot absorb the water, the water then flows onto the street where it transports trash, oil, and other environmental hazards on the street into the sewer system. This runoff can be prevented by either constructing a green roof on the building that would absorb the water, or by using the captured water for non-drinkable applications such as toilet. The reason that this credit deserves more points is because laws are in the process that will heavily tax businesses for producing a certain amount of runoff. The only way to avoid this tax is to build a private filtering system for the runoff, which in many cases will cost more than a company can afford.

Our view on the certification process is that the LEED grading system should be circumstantial. The first credits for Site Selection should set the tone for what really matters when grading the building for certification. For example, up to 12 credits are given based on selecting a site that is in a highly populated area with nearby public transportation. If a building is to be constructed in a highly populated area, it would be conflicting to get other points such as credit SS 7.1, which requires a certain percentage of the building to be shaded by trees (to environmentally cool the building in the summer months). And this concept can be reversed, so if a building is going to be constructed in a lightly populated area, building a bicycle room would be a ridiculous concept, and perhaps hybrid and carpool parking would carry more points in this situation than in a building constructed in a highly populated area.

East Hall

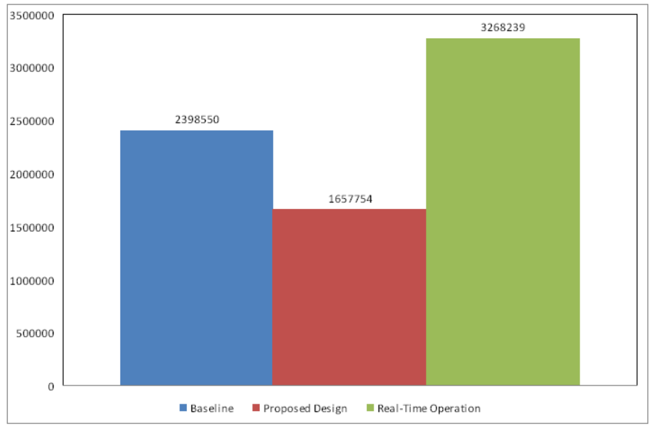
East Hall, the newest residential building at WPI, receives enough points to earn a Gold certification. This dorm has complete living facilities, which include eight tech suites, a laundry room, two piano rooms, and a fitness room. All of these facilities are open to the residents twenty-four hours a day with the idea that students will not have to drive other places for these services, saving fuel and protecting the environment at the same time. Besides these facilities, the utilities are also designed to save energy. The heating system of every apartment is only activated when all the windows are closed, preventing heat from leaking out.

Had improvements been made to the LEED certification guide, East Hall could have qualified for a higher rating, or could have offered students better living conditions without having to worry solely on attaining a LEED certification. For example, many students complain about the quality of interior walls and claim to be able to hear through them. Instead of designing the building to be focused on using minimal materials for interior wall construction, perhaps a small, useful school store would have been ideal for this building. Regardless of the complaints, East Hall is a very well designed building and every user-friendly application of the building is used, including the piano rooms.

East Hall qualified for 44 out of 69 possible points. Some points that the building received were not hard to accomplish, such as building on a site that is not a wetland. Other points that were given were more expensive to achieve, such as building the green roof, or designing areas for bicycle storage. And of course, there were credits given in categories that will save WPI money, such as low flow water fixtures and an integrated light management system. A LEED certified building would not be approved for construction if the cost was too high for certification, so what is the cost of building to these standards, and how much energy is the building actually saving? Interestingly enough, East Hall actually consumes more water than a regular building of that size.

This graph shows the actual water usage on the right (green), compared to the average water consumption of a conventional building on the left (blue), and the originally planned water usage of East Hall in the middle (red). The conclusion of these results is that East Hall consumes much more water than it should, but since it uses low-flow fixtures, the actual usage is still 30% below what it would be without LEED certification. This saves 1.4 million gallons per year.

Figure 5 Monthly water usage in East Hall (adjusted)

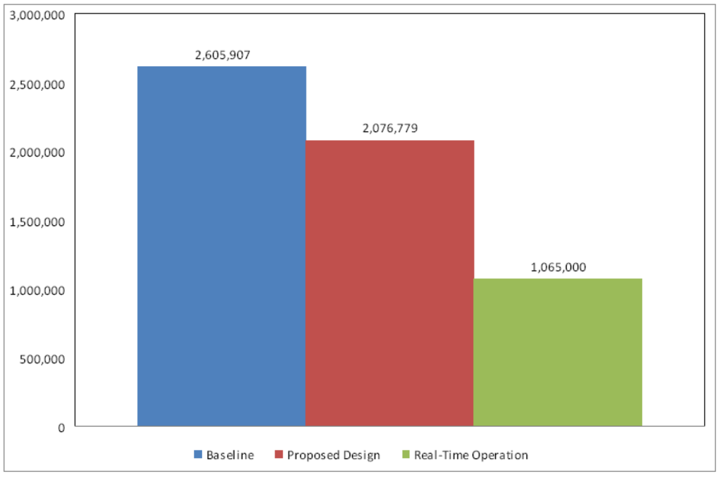


The total electricity savings is 31.4% compared to a conventional building. Below is a table that shows the electricity usage of the building. The electricity is broken into two parts: lighting and space cooling. Since space cooling consumes more electricity than lighting, it weighs more on the total electricity saved from the building.

Electricity Use Type		Annual proposed Energy Consumption	Percentage of Use Reduction	Techonology Used
Lighting	Interior Lighting	305,173.1 kwh/year	38.30%	decrease the lighting power from 1.0W/SF to 0.63W/SF; increase fenestration visual light transmittance to 70%
	Exterior Lighting	6,986.1 kwh/year	80.70%	decrease the lighting power from 30W/SF to5.79W/SF
	Parking Garage lighting	47,674.2 kwh/year	63.30%	decrease the lighting power from 0.3W/SF to 0.1W/SF
Space Cooling		313,005.6 kwh/year	30.10%	SHGC decrease to 0.38

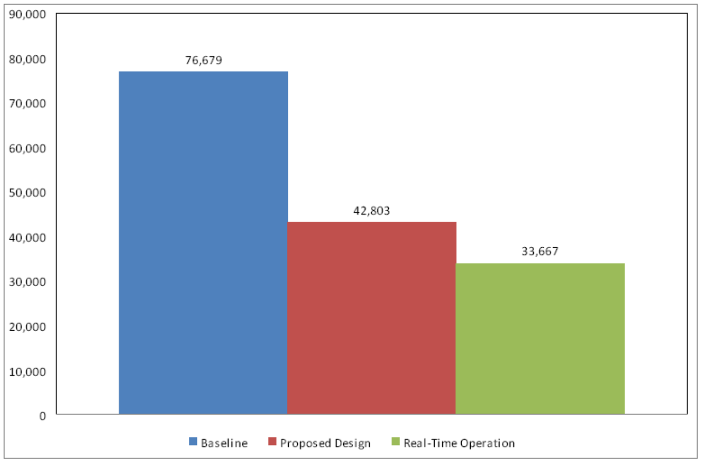
The electricity designated for lighting was reduced dramatically because less lighting was used over space. For example, interior lighting averaged from 1 watt per square foot to 0.63 watts per square foot. The significant savings are shown in the graph below in kWh. Similar to the above graph, the green bar is the actual consumption while the blue bar is the average consumption of a conventional building similar to East Hall.

In addition to consuming electricity, East Hall also used Natural Gas for heating. The annual natural gas consumption is shown in the table below. The unit has been converted to kWh so that it can be measured similarly to electricity.



Time	Electricity(kwh)	Natural Gas (therms)	Natural Gas (kwh)	Total monthly energy use(kwh)
07/2008	46600	2	59	46659
08/2008	101600	153	4484	106084
09/2008	98400	557	16325	114725
10/2008	98800	1070	31360	130160
11/2008	99000	2847	83441	182441
12/2008	86800	6024	176553	263353
01/2009	96000	6269	183734	279734
02/2009	95400	7786	228195	323595
03/2009	88800	4630	135698	224498
04/2009	95600	3132	91794	187394
05/2009	84600	1017	29807	114407
06/2009	73400	180	5275	78675

Notice the large savings in natural gas in East Hall in the table below.



Below is a table showing the annual cost of electricity and natural gas. The savings are found by subtracting the real-time operation cost from the baseline design cost.

Energy Type	Baseline Design		Proposed Design		Real-Time Operation		Proposed Percent Savings		Actual Percent saving	
	energy use	cost	energy use	cost	energy use	cost	energy use	cost	energy use	cost
Electricity	2,605,907kwh	$363,261	2,076,779kwh	$290,749	1,065,000kwh	$148,460	20.30%	20.30%	59.13%	59.13%
Natural Gas	76,679 therms	$99,683	42,803therms	$55,644	33,667therms	$43,767	44.20%	44.20%	56.09%	56.09%
Total	4,852,340kwh	$462,944	3,331,263kwh	$346,393	2,051,723kwh	$192,227	31.35%	25.18%	57.72%	58.48%

The final cost of the building was $34 million, in addition to $978,000 that was spent to certify East Hall in LEED. There is a $100,000 rebate for LEED certification on this building, and from the information in the table above, the building saves $270,717 annually. Disregarding inflation and the rising cost of energy, this will save $9,475,000 in the building's 35-year lifecycle. The initial investment was 2.6% of the total building cost, and the payback from saving electricity and natural gas is 27.9%, more than ten times the initial investment. Not only is this building promoting a healthy environment, it saves a large amount of money in energy bills.

WPI is not the only school that is constructing LEED certified buildings. The William Stanley Elementary School in Waltham was constructed in 2002 and has been LEED silver certified. This school was built with many energy efficient applications that allow the 90% of the building to be illuminated by sunlight (Carr[3]). Harvard University has also contributed to the sustainable energy buildings in Massachusetts with the renovation of the operations building. This building has been renovated to Platinum status, including the installation of solar panels that will save enough electricity to be completely paid off within 13 years of the renovation (Harvard[2]). LEED certification has become practical for schools to obtain. Certification will save the school money, while at the same time, promote sustainable living to the students.

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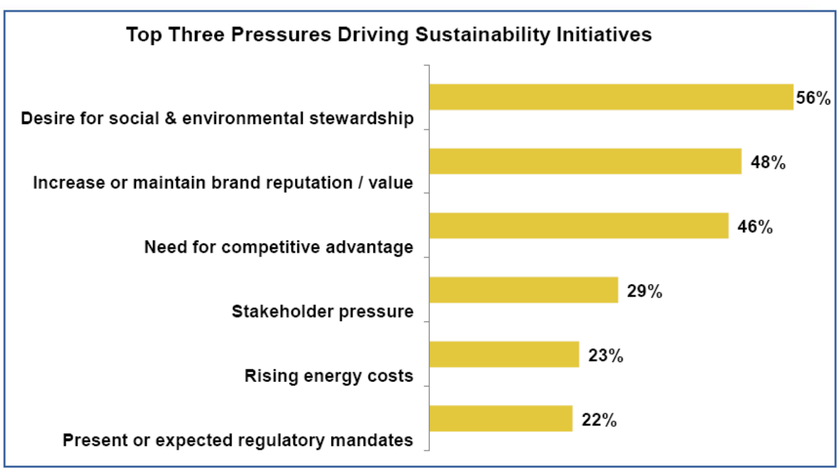
IMPLEMENTATION OF HIGH EFFICIENCY IN A CITY

Many people are afraid that the social impact of running out of fossil fuels will be tremendous, which it will. However, very minimal effort is being put into this thought of a future crisis simply because it is not a crisis at the moment. There is a common fear that the impact on society will be large if alterations are made to daily life, such as adding EV recharging stations, reforming public transportation on a large scale, or putting into place policies that would require buildings to meet certain efficiency levels.

In fact, this is not true at all. For years, cities around the world have been reforming to higher efficiency standards, in turn providing healthier environments. Some of the most prestigious cities known for their efforts in sustainability are Stockholm Sweden, Helsinki Finland, Portland and Chattanooga of the U.S., and the most innovative: Curitiba, Brazil. Integrating efficiency into society is a secondary goal of this project (where the primary is a set of policies made for society), so viewing a city that has already made this climate change would be a great example to lead other cities to do the same.

Before looking at how to force this on society, it would be best to determine what actually makes people want to care about efficiency. Below is a graph showing the results of a survey that presents the reasons of why people care about sustainability (Finpro[1]).



courtesy: http://www.tekes.fi/fi/gateway/PTARGS_0_201_403_994_2095_43/http;/tekes-ali1;7087/publishedcontent/publish/programmes/yhdyskunta/documents/michaellovejoy_finalreport.pdf

Interestingly enough, most people are not concerned with the rising cost of fuel. This data shows that people in general are more concerned about the status of the environment than anything else.

Now that "money is not an object," a city that has previously incorporated efficient designs into society will be analyzed: Curitiba.

Curitiba, Brazil has recently won the Global Sustainable City Award for achieving sustainable design in almost every aspect of the city. Much of the land was repurchased by the city and converted into parks. With the city now in control of how they operate, efficiency was at a maximum to upkeep these newly acquired areas. For instance, the grass is maintained at the parks by a herd of hungry sheep rather than a polluting lawnmower. While Curitiba's excellent initiative in parks is a highlight of many park users, nothing can compare to the city's public transportation system.

The system employed is rather simple yet so advanced and successful that many other countries have begun copying this transit system. This system works because of its riders; 60 percent of the city population use daily. A passenger demand of over one million per day is remarkable, especially since the system relies only on buses. When the transit system was coming to life, the possibility of constructing an underground subway system was far too expensive for this low-income city. This bus system has in fact flourished the city by allowing passengers to easily commute by color-coded buses. Passengers only pay only once per commute, regardless of the distance travelled. With a high demand, the buses come equipped to hold up to 270 people at once in the three car snake-like bus. The picture below shows the extremely long bus next to the tubular designed bus terminal.

Courtesy: http://nexus.umn.edu/Courses/Cases/CE5212/F2008/CS3/CS3_files/image001.jpg

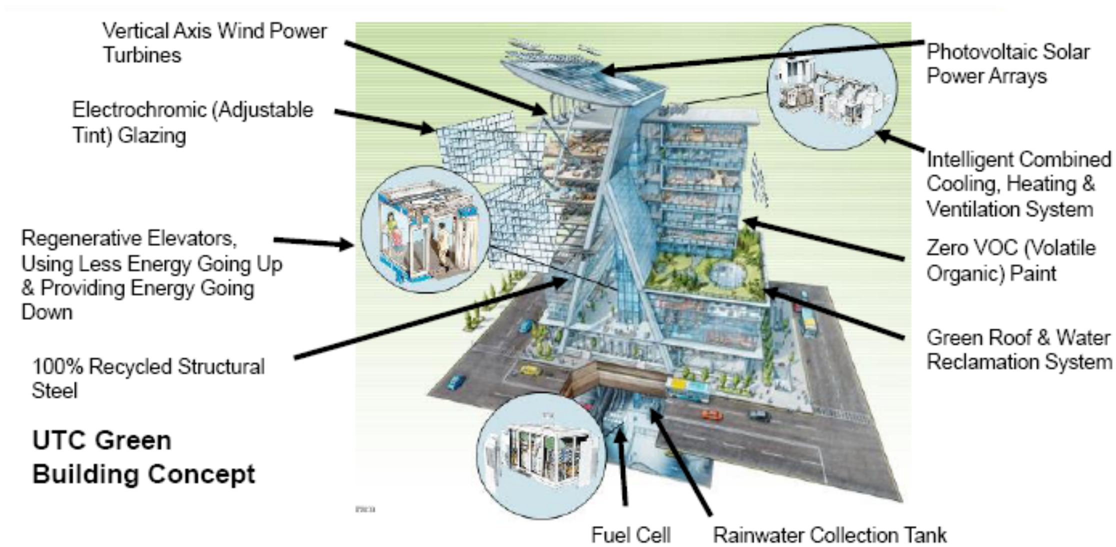
One interesting transportation fact is that the amount of cars per capita in Curitiba is bigger than most other cities in Brazil, yet the fuel consumption of this city is significantly less. As mentioned earlier, 60% of the city population on the bus keeps the gas-thirsty private vehicles off the road. The bus system now allows everyone to get to where their jobs are located, and gives more people the financial flexibility to purchase a car, whether or not they use it frequently. The table below compares Curitiba with Brasilia, another urban city in Brazil. Notice the greater vehicle per capita under Curitiba, as well as the lesser fuel consumption (Magalhaes[2]).

Variable	Year	Units	FD (BRASILIA)		CURITIBA CITY		METRO CURITIBA + 7	
Population	2008	inhabitants	2,557,158		1,828,092		2,861,750	
Total motor vehicle fleet	2008	vehicles	1,029,277		1,109,511		1,397,126	
Light vehicle fleet	2007	vehicles	832,637		850,760		1,079,101	
						Δ to FD		Δ to FD
Motorization index	2008	Vehicles per 1,000 inhabitants	**402.51**		**606.92**	51%	**488.21**	21%
				Market share		Market share		Market share
Yearly sales Gasoline C (E25)	2007	liters	731,690,263	64%	474,626,905	51%	630,916,650	40%
Yearly sales Ethanol (E100)	2007	liters	150,221,381	13%	169,231,359	18 %	290,679,523	18%
Yearly sales diesel fuel[(6)]	2007	liters	268,889,118	23%	290,416,975	31%	657,452,512	42%
Total consumption gasoline market	2007	liters	881,911,644		643,858,264		921,596,173	
						Δ to FD		Δ to FD
Average fuel Consumption gasoline market	2007	Liters per vehicles	**1,059.18**		**756.80**	40 %	**854.04**	24 %
Total CO_2 emissions from light vehicle fleet[(6)(7)(8)]	2007	Kg	5,122.322.409		3,385,879,088		4,558,649,533	
						Δ to FD		Δ to FD
Annual average CO_2 emissions from light vehicles	2007	Metric Ton CO_2 per vehicle	**6.15**		**3.98**	55 %	**4.22**	46 %

courtesy: http://www.isocarp.net/Data/case_studies/1492.pdf

What does this impressive bus system prove? This transit system is so effective that it may slip the mind of some people that it is actually a major step in progression to sustainable life with minimal impact to society. In this case, this improved bus system increased the quality of life to those who live in Curitiba, and many other energy efficient systems can do the same in other cities worldwide.

The integration of efficiency and society is a fragile combination. If applied too much or too forceful, society will reject the attempt. However, it would be irresponsible for humans to let the world fall into an energy crisis. Simple plans and smooth transitions are key to success. An example of a good idea but poor judgment is depicted in the image below (Finpro[1]).



courtesy: http://www.tekes.fi/fi/gateway/PTARGS_0_201_403_994_2095_43/http;/tekes-ali1;7087/publishedcontent/publish/programmes/yhdyskunta/documents/michaellovejoy_finalreport.pdf

As shown, this building is far too complicated and abstract to ask anyone from a normal society to believe. This structure was published in the Wall Street Journal back in 2007 to demonstrate this projects ultimate goal of completely integrating high-energy efficiency methods to be used citywide. The building concept produced missed the essential goal of integrating these methods in a discrete manner resulting in, well, have you ever seen one of these in person?

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Future Energy Saving Methods

As the world's energy supply rapidly decreases and the construction of renewable energy power sources plateaus, a reduction in energy consumption is necessary to prolong the remaining fuel supply. This can be accomplished on every scale level, whether it is university wide, state wide, national, or even global. A good place to start analyzing for energy reduction is the electrical grid: the highest energy consumer. The second stage of analysis should focus on fuel saving methods for transportation. Lastly, smaller individual categories can be examined for potential energy saving methods, although these prospective ideas do not contribute largely to energy reduction.

TRANSPORTATION VISION STATEMENT

Similar to most other modern advances in technology, independent transportation has only been present for about a century. Independent transportation is a major consumer of energy resources, and can be avoided using different methods. The most common methods are carpooling and the use of public transportation.

Public transportation, such as an underground subway system, reduces traffic in hectic cities, which in turn, reduces energy waste. However, public transportation usually prolongs the daily commute to work. Working from home is another option that would save energy, and would not waste a person's time while commuting. This may seem like an obvious solution, but is it really efficient? Are the distractions at home worse than the distractions at the office?

"That information is very difficult to quantify," claims Karen Kroll, writer for FacilitiesNet[1]. Since many office jobs do not have specific outputs to accomplish work, it is hard to measure an employee's productivity. As a necessity in life, workers need to remain employed in order to live in a normal society. Therefore, workers will not be overly inefficient when work needs to be done for fear of being fired. At the office, workers can become distracted by coworkers or online activities. But working from home allows the same person to become distracted by their spouse, children, house phone, friends, television, or any other kind of distraction. In addition, working from home does not provide a working environment, especially without a supervisor present.

Although there are no studies of worker productivity, it is a known fact that employees work better when they are happy. To accomplish this, there must be more efficient ways to get employees to work, keep them happy while commuting (therefore productive at work), and especially cut down on wasted fuel during transportation.

Working in a Community Office

Working in an area where employees reside will cut down energy consumption. WPI's East Hall dormitory is a great example of this style of "working from home" scenario. The tech suits are open for students living in the building, and are available whenever needed. When the library is closed, students can keep working in these suites instead of driving to another study room. All of these suites also come fully equipped with electronic devices that are needed for meetings and projects. They function as well as any other high-tech room on campus.

New Working Hours

One alternative way of reducing transportation is by increasing the number of hours spent at work over four days, so that working the fifth day is not necessary. Working four, ten hour days would result in the same 40 hours per week that a full time position requires by working the traditional five, eight hour work days. This new schedule would reduce transportation by 20%. It would also require a commuting time different to the regular "rush hour" commute that would avoid rush hour traffic.

Using a Transportation Shuttle

Using a transportation shuttle is in many ways, bringing transportation back to the elementary level. But thinking back on it, how simple was it in those days to get on a bus and arrive at school without ever having to think about it? A transportation shuttle can be the same idea, but for employees. For this concept to be successful, all the company must do is encourage employees to live in a certain district of town. This shuttle will save fuel, reduce emissions, and reduce the stress of employees that is typically gained while commuting to work. By using this system, the company will also have employees start the work day at the same time every day, which provides positive accountability for employee attendance. The shuttle will also replace the necessity for employee parking, which in a large city would reduce the property cost significantly.

A large amount of transportation is for the sole purpose of going to and from work. If these needs are reduced, then pollution and resource consumption are reduced as well. Currently, there are some methods in practice, and benefits are given to those who chose to use them, such as a High Occupancy Vehicle lane. If these incentives are combined with new ideas, the amount of fuel saved would be tremendous, and employee productivity would increase from reducing transportation stress.

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WPI

The Computer Problem

Worcester Polytechnic Institute must have operating computer and equipment labs to function as an engineering school. These labs are in full use during working hours and are used for every kind of major degree from physics to aerospace engineering. However, after working hours and even after the buildings have been locked and secured for the night, the computers and monitors are still powered on. Below is a table showing computer totals in each building on campus.

Building	Computers
Higgins	60
Olin	30
Salisbury	30
Washburn	35
Stratton	25
Atwater Kent	62
Library	102
Fuller	30
Kaven	54
Total	428

Each computer requires 115 volts at 4 amps yielding 460 watts. Each monitor requires 125 volts at 10 amps yielding 1250 watts. The monitors do not have a sleep timer on them, so when the computers are idle, the screen remains powered on displaying the login screen. Assuming that WPI pays $0.13 per kWh, below are the calculations for operating the computer systems from 8pm to 8am.

$$\frac{428 computers \times 460W \times 12 hours \times 3600 \sec onds / hour}{3600000W / kWh} = 2363\text{kWh}$$

This number is only for the night hours that the labs are not in use. From the previous EV1 study, it was found that 2.8 pounds of CO_2 are produced for every kWh, amounting to 6615 lbs CO_2 per night, costing (at $0.13/kWh) $307.

$$\frac{428 computers \times 1250W \times 12 hours \times 3600 \sec onds / hour}{3600000W / kWh} = 6420\text{ kWh}$$

Again, this large number only accounts for powering the monitors for the unused 12 hours during the night. At 2.8 pounds of CO_2 per kWh, 17976 lbs CO_2 are produced every night, costing $834. Computer and monitor combined, WPI annually creates an unnecessary 4488 tons of CO_2, and pays $416,753 for it. Paying a work study student to turn off all unused computers every night could not possible cost this much money, and it would save tons of CO_2 emissions.

Our Recommendations

After speaking with the Senior Windows Systems Manager at WPI, there is a policy in place that requires all computers on campus to go into sleep mode after 45 minutes of inactivity. The Computing and Communications Center conducted a campus wide survey of what the students and faculty wanted from computer lab equipment. The conclusion of the survey was that the computers should be left on during the entire day and into the evening as long as they are being used without 45 minutes of inactivity. The reason for this is that the faculty do not want to wait for the computers to start up every time they have a class. In addition, every time the computers are turned on, there is a spike in the required energy, so it would be impractical for the computers to be shut off and powered on multiple cycles per day. Agreeing with this policy, we decided to check up on a few computer labs around campus during the night. The lab in Stratton Hall, Olin Hall, and multiple labs in Atwater Kent had illuminated screens indicating that the computers were not in sleep mode. We recommend that WPI conduct an audit of these computers to correct any computers that do not go into sleep mode during inactivity.

Solar Panel on WPI Campus

According to the data from the U.S. Department of Energy, the average energy usage per square foot is 10 watts (W)/square foot (ft^2), and the average retail cost of a typical solar system (installed) is \$8/W. The installation cost per square foot of solar panel will be:

Cost = \$8/W x 10 Watts/square foot = \$80 / square foot.

For the Massachusetts area, the photovoltaic solar resource is about $4kWh/m^2/day$, which is also equal to $0.372kWh/ft^2/day$. This value is extremely high when compared to other sources. The reason for this high value could be because it is from the DOE whose goal is to persuade people into investing in renewable energy.

$4kWh/m^2/day \times 1m^2/10.76ft^2 = 0.372kWh/ft^2/day$.

The cost of electricity in Worcester is about \$0.17/kWh, which means WPI will save \$0.06 for every square foot of installed solar panel. This will take the school 3.47 years to pay back the money spent on installing the panels. As noted earlier, due to the fact of a high efficiency rating, the payback time is extremely short compared to other estimated payback periods.

Since New England has four seasons, the solar panels will be covered by snow 25% of the year, prolonging the payback period. In addition, installing these panels of WPI buildings would be inefficient because of building modifications necessary for holding the heavy panels. If all of these problems were added into the cost, it would take more than 3.47 years to recapture the money spent on this system. By the time that the cost is repaid, new solar panels might need to replace the old ones, meaning that it would never be worth installing a solar system on WPI campus.

Below are the calculations to determine the payback period:

$\$0.17/kWh \times 0.372kWh/ft^2/day = \$0.06/ft^2/day$

$$\frac{\$80/ft^2}{\$0.06/ft^2/day} = 1265 days = 3.47 \text{years}$$

The Lighting Problem

Most academic buildings on the WPI campus have their lights and heat on during the night when the buildings are not occupied. There is lot of energy wasted through this process during nights, in addition to costing the school a lot of money. To demonstrate the amount of energy and cost that can be saved by turning off lights consistently, we will use the following information: each light bulb has an average power of 40W, there are 50 unnecessary lights powered in one building every night for 6 hours, and there are approximately 20 buildings on campus:

$40W \times 50$ lights $\times 6$ hour $\times 3600$ seconds/hour $\times 20$ buildings $= 8.64 \times 10^8$ W = 240kWh

Every night, WPI wastes 240kWh of electricity by leaving lights powered. If each kWh of electricity costs approximately $0.13,

0.13 x 240 = $ 31.2 / day

31.2 x 365 = $ 11,388 / year

WPI annually pays $ 11,388 for unnecessary electricity.

One way to improve this would be by installing motion sensors in all buildings. Once all the faculty members and students left the building, the lights and heating system would power down.

A lot of universities in China have a “lights out” policy. Schools cut the electricity supply at a certain time every day, including lights, power outlets, and anything else that requires electricity to operate. This is a very extreme way to approach energy saving, but it makes a big difference. WPI can learn from this, but rather than shutting down the whole school’s power, WPI can close most of the buildings on campus where students will not occupy late at night. For instance, leaving one or two buildings open during the night for those students who still need laboratory equipment will allow them to study with light while the other buildings are completely powered off. Through this process, WPI can save at least fifty percent of energy that is wasted, which is a very significant improvement.

In most metropolises, all sorts of commercial lights are kept on all night long. These lights are not only consuming a huge amount of energy, but also cause light pollution in these cities. The stars on the sky cannot be seen in the city anymore because of all the lights that are on and shining into the sky. Aside from that, these lights are also affecting human health. Night hours are supposed to be dark, but with lights consistently powered every night, some people are affected subconsciously and due to the brightness, insomnia and frustration results. The government needs to come up with a policy to limit the amount of commercial light usage at night.

In most family houses, there are always some electronics plugging into the wall even when they are not in use. A lot of people think there is no electricity running though them as long as they are off, but in reality, there is a term called “vampire power”, also known as standby power. Most electronics nowadays, even though they are off, still consume electric power and some can be up to 15 watts; equal to a small light bulb. If there are several devices like this in each family household, the quantity of energy lost can be enormous. One of the best solutions for this is using a power strip that has a switch. Whenever the electronics are not needed, these power strips can simply switch it off without having to unplug anything. This will save each family money, and in the long run, has potential of saving a percentage of this country’s energy consumption.

The Insulation Problem

WPI was founded in 1865, and many buildings on campus are very old without any major renovations. The older buildings such as Olin hall and Stratton Hall have all single pane windows. Single pane windows are the worst possible window type available because they have no internal insulation. Insulation is measure by “R-value” and an improvement in R-value can save huge amounts of energy. Replacing the single pane windows with double pane windows doubles the R-value, but unfortunately the payback on replacing windows for these old buildings would not be reached and therefore would not be practical for WPI. When choosing insulating materials for a room, local climate must be taken into consideration. Walls and floors usually have a lower R-value while the ceilings have a higher value due to the fact that heat rises. When adding windows into the room, the amount of area that the window occupies on the wall is changed to the window’s R-value and in almost every case, reduces the overall R-value of the room. Since large windows allow sunlight to enter for heating, large windows should usually be used. When large windows are used, it is important to get windows with high R-values. Besides getting better-insulated windows, better-insulated walls are also necessary. Replacing wall insulation would be more expensive than replacing the windows and should only be applied when designing a new building.

The other half of the insulating problem at WPI is that the buildings are overheated during the winter. Heating a building is one of the largest utility bills anywhere, whether it is a commercial building or a resident building. WPI students constantly complain of buildings being overheated and are forced to open windows. Opening windows lowers the temperature reading on the thermostat and makes the heating system work harder, which consumes massive amounts of soon-to-be-wasted energy. Further analysis of heat consumption in WPI buildings should be conducted, and the implementation of heat loss prevention techniques should be used such as vestibules and light shelves.

Our Opinion

WPI can save a significant amount of energy by powering-down unnecessary electronics. Computer labs on campus would be the best place to start saving since computers take up a lot of energy. Computers should go into sleep mode or shut down when idle, or there should be someone that walks through each building at night to turn off all unused computers. Students should turn off and unplug their electronics that are not in use. As an incentive for students to unplug their electronics, WPI can make a competition out of it (similar to recyclemania). Lighting on campus should also be reduced. A solution to this would be to integrate motion sensors in all buildings that will turn off lights when the building is vacant. Heating buildings should be set on a timer that will reduce heating demand during the nighttime hours, but will resume normal demand during the daytime hours. Current building insulation cannot effectively be changed or updated, but new buildings should be constructed with the goal of achieving LEED certification. As a technical school, it is important that we set the example for energy efficiency and technology.

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Group Designs

IMPACT ON SOCIETY

This project began with a background on all general energy sources used around the world. After researching these traditional fuel sources, two repeating problems consistently appeared in every source: the negative impact on the environment and society, and the fast approaching extinction of the source.

As our research concluded, there is an estimated 100-200 years of oil left, and between 200-300 years of coal left—the most commonly used energy sources. These estimates are based on the current usage, assuming that there will not be an outrageous discovery of fuel in the future. There are two ways to extend the life of our natural energy remains: reduce the consumption or find more of it. Some new technology has become available that will find more fuel, such as shale drilling for natural gas. However finding an amount of the oil that would prolong its existence for a meaningful amount of time would be unrealistic. Therefore, the only way to make our energy sources last longer is to reduce the consumption rate. This can be done by a set of policies enforced on company, city, state, federal, and international levels.

There will be an impact on society whether there is a reduction in fuel usage or not. With no current policy, the price per barrel of oil has fluctuated dramatically over the past few years. At $4 per gallon of gasoline, many people began finding cheaper methods of transportation such as carpooling or using public transportation. In this case, it was not a policy that changed the actions of consumers but rather the price of energy that changed the daily habits of people. With the rising of cost of coal, people became more energy conscious and started turning off unused lighting or idle electronics. This impact on society has been a passive result of energy extinction where a more active impact is necessary.

Although not directly specified in our research, there have been discrete alterations to daily life around the world. For example, the construction of the Bahrain World Trade Center is a massive 800-foot tall building with three integrated wind turbines providing electricity to the building. The miniscule automaker competition between building the best electric vehicle has been an even more discrete way of altering daily lives. These advancements in society are excellent icons for energy saving methods, but it is prevalent that a list of policies is necessary to force everyone into the habit of saving nonrenewable energy sources.

To start this very large task, an examination of current and prospective renewable energy sources was conducted to determine which techniques worked well and which didn't. This list included mostly large-scale methods such as LEED certification, photovoltaic farms, and hybrid vehicles, but also included some small-scale ideas such as Bloom Energy and the controversy of GM's EV1 car. From these analyses, a list of policies was created that would largely benefit the world population as a whole with a focus of those who live in areas of high-energy consumption (usually areas of high population). This list has been categorized by its area of impact, regardless if it should be used nationwide or companywide etc.

POLICIES

Transportation

1. Discount parking for electric or hybrid vehicles—LEED certification gives incentives to hybrid and electric vehicle (EV) owners by offering points to buildings with close parking designated only for hybrid and electric vehicles. However, if buildings or parking garages gave a discounted price to these vehicles, then maybe more people would be tempted to buy one. This policy could be established through LEED certification by offering a point to buildings that participate in this policy.
2. Construction of EV charging stations—The lack of EV charging stations where EV1 cars were present was a major complaint among users. EVs should be sold in highly populated areas where charging stations would be common. The government will need to employ this policy by purchasing gas stations, or by forcing gas stations to add EV charging ports at existing gas stations.
3. Reward for high electric or hybrid vehicle production—While the EV1 was in production, there was a policy that forced American fleet sales to have a certain percentage of car sales as EVs. As pointed out earlier, this policy did not last long, and in fact, the automakers sued the government to abandon it. The government should give incentives to automakers instead of making rules, making them want to make electric cars. A major way of enforcing this idea is to lure companies that have gone bankrupt and are in need of bailouts.
4. Low fuel efficient vehicles for commercial use only—Some vehicles that are sold today have terrible fuel efficiency ratings. Cars and trucks with low fuel efficiencies should only be sold to commercial businesses. This policy would cut down the amount of low efficient vehicles by eliminating them from private use. Privately used vehicles are often used in a wasteful manner, for instance a two ton truck may be used as personal transportation, or for family grocery shopping when a much smaller, more fuel efficient vehicle would be more suitable for these uses.
5. Public transportation corrections—Public transportation is an excellent way to reduce waste by combining many people going to similar destinations. This greatly reduces the amount of vehicles traveling through a city where more cars present create exponentially

worse traffic conditions. The California subway system was briefly analyzed in this report for being an underused public transportation system because the demand for this transportation was not necessary. Highly populated cities should reexamine their public transportation systems to maximize efficiency. This policy requires that highly populated cities submit a report to the EPA regarding the status of emissions, daily use of the system, and potential for growth in other areas of the city that would reduce the necessity of private transportation. The EPA would then make corrections to the system, making it as efficient as possible.

6. Taxi reformation—The majority of taxis in the U.S. are recycled police cruisers. These Crown Victorias get a combined highway/city fuel economy of 19 mpg. Since most taxis are located in the city, it is more likely that the fuel economy will be closer to 16 mpg. With this poor fuel efficiency, any policy that would increase the mpg is necessary. One thought at solving this problem would be to implement a modification to the engine control unit (ECU) that would turn off four of the eight cylinders. Automakers have been integrating this technology to their new vehicles to preserve fuel, and a policy that would make this technology mandatory on taxis would be extremely beneficial in reducing carbon emissions.
7. Maximize flights—On occasion, some airliners are not able to sell seats on a flight. This will cost the company money since the customer income does not cover the company overhead of that flight. Some airliners have a companywide policy that will not allow the plane to fly unless a certain number of seats are sold, however a policy set and enforced by the FAA would make certain that flights are heavily filled, making a high fuel efficiency per customer. Some strategies that airliners are using to combat the issue of not selling out a flight is by overbooking the flight. If an aircraft can hold 100 people, the company may sell 105 tickets, betting that 5 people do not show up for the trip. This strategy is more of a moneymaking method than an energy saving method, but between the thousands of daily flights in the U.S., some fuel efficiency methods should be adopted.

Water Usage

1. Convert high water usage buildings to low flow water fixtures—Also a section from LEED certification, low flow water fixtures should be used in high water usage buildings. These buildings include hotels, gyms, government buildings, and even residential buildings. This conversion could save up to half of the water consumption, and therefore reduce the waste production by half as well.
2. New buildings use rainwater—New buildings should be required to use a certain percentage of rainwater (predominantly in high precipitation areas) for building functions. These functions include toilet water and water for outside gardening. LEED certification also gives points for this, but having this policy as a building requirement would be much more forceful.
3. Hot water heat exchangers—Heat exchangers have been proven to be very inexpensive devices that have the potential to save energy by capturing the heat from the hot wastewater before it is deposited in the waste tank. Although there is no doubt that a heat exchanger will save a large family a lot of money on their heating bills, there is no way to enforce a policy that would require all residential homes to install one. What a policy can do is require that all large buildings with constant hot water usage require installing them. These buildings include hospitals, large apartment buildings, and Laundromats.

Air Quality

1. Fossil fuel power plants pay a higher tax—The EPA taxes companies for over pollution. Similarly, this policy would tax energy production plants that consume the remaining natural energy sources. This policy would encourage the investment in alternative energy production such as wind farms, solar farms, or nuclear power.
2. Government funding for clean energy—The U.S. government has spent over one billion dollars in research that would reduce emissions from coal-burning power plants. This policy should be spread across the board to all kinds of energy producing power plants including natural gas and oil plants, as well as car emissions. This policy would be very expensive but would have the potential for reducing many health problems of Americans caused by poor air quality.

Building Construction

1. Solar panels or green roofs on city buildings—Green roofs are an excellent way to divert runoff water from entering the wastewater drainage system. This runoff water has the potential of picking up oil and trash from the street and carrying it to the depositing water system. Green roofs also provide a good recreational area for buildings of residents and offices. A roof of solar panels would provide the building with clean electricity and would reduce the electricity bill. Because the transmission loss of electricity is approximately 30% over the distance it travels, a roof of solar panels would not have any transmission losses. This policy would have to be executed by the city, and would be highly encouraged by LEED certification.
2. All new buildings constructed with high efficiency windows—High R-value windows are very expensive. The value of these windows should not be as expensive as they are, but regardless, windows are a major point of weakness for heat to escape from a building. LEED certification offers points to buildings that have efficient windows, however older buildings that are not LEED certified should have to replace old windows with more efficient ones.
3. All new buildings are required to meet LEED certification—As this report verified, LEED certification is a very good program that guides buildings to become very efficient. Buildings that are LEED certified have been proven to save much more money than the amount invested in making them LEED certified.
4. Building assessments—Most buildings are constructed with a life expectancy around 30 to 50 years. However, there are plenty of older buildings still intact that are commonly used, for instance WPI's Stratton Hall, built in 1894. Building construction and efficiency has come a long way over the past century and is a fast growing technology. These old buildings, although sentimental landmarks to some, are in fact very inefficient. This policy would require an assessment to buildings every 5 years after the building is 30 years old, and would check for major inefficiencies such as poor insulation and poor electricity usage. If the building has been assessed as too inefficient it would be required to be torn down or remodeled to improve efficiency.

Electricity

1. Install motion sensors in all government buildings—Motion sensors are also used to LEED certify a building. Motion sensors will turn off unnecessary lights and electronics and will save electricity. Some buildings have already integrated these systems and have proven that they pay for themselves. This should be installed in all companies and should be enforced by the government.
2. Non-essential commercial buildings cut electricity—Phantom electricity was discussed in the "Energy Saving Methods" section and was described as electricity being consumed by appliances that are powered off. With this policy in place, non-essential companies would be required to completely power off the building during non-working hours. This would make for great publicity of a company if they were to publically advertise their efforts to conserving energy.
3. Citywide electricity control—Large cities ticket anyone who violate city laws, whether it be ticketing a car illegally parked, or ticketing a restaurant for not following health safety procedures. This policy would require city officials to give warnings to buildings that are using an unnecessary amount of electricity when it is unneeded. For instance, an above ground parking garage does not need interior lighting during daylight hours. The electricity monitor would warn this facility about it, and ticket the facility if they did not comply within a given period of time.

Conclusion / Future Recommendations

The research from this project resulted in a list of policies, if enacted, which would save energy and fuel while simultaneously saving the environment. It was found that LEED certification is an excellent guide to building design and construction and contributes to this project's ideals of preserving energy and the environment. In addition, LEED certification also results in reducing utility bill expenses. Electric Vehicles were proven to be more efficient than high efficiency gasoline operated vehicles, despite the emissions produced at the electric power plant. Bloom Energy was explored and determined to give inconclusive data, forcing the company to be labeled as unreliable and extremely overpriced.

Smaller energy saving techniques were examined that led to the policies recommended. These techniques include the heat exchanger, changing working hours, as well as surveying WPI's energy consumption. The results to this research serve as a basis to our policies, suggesting that all universities and major businesses analyze their energy consumption. Implementation of energy saving technology should be utilized, such as heat exchangers, working hours, and cutting electricity during nighttime hours.

Future recommendations and possible IQP ideas involve a deeper exploration of the topics discussed in this project. For instance, a detailed analysis of old buildings could be a great project that would highlight the building's deficiencies, as well as reducing energy consumptions. Another possible project could be explored is the actual carbon footprint difference between a traditional American home and a self-sustained home. A self-sustainable house would have to be designed for this project and would incorporate many items that were mentioned in this project. These items may be a green roof, an in home charging unit for an electric vehicle, a hot water heat exchanger, low flow water fixtures, or any other section described in LEED certification.