

21st Century Energy Production & Resulting Impacts on Society

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Abstract

Our project examines current alternatives to fossil fuels and evaluates their drawbacks and benefits in relation to specific applications in 21st Century society. It provides information concerning future research and development for each respective technology. Due to the limitations of fossil fuels, the authors believe further research should be conducted in solar, wind, nuclear, and emerging energy sources as these have the most potential for improvement and utilization in a world with ever increasing demand for sustainable energy resources.

Executive Summary

In our modern world one of the most important concerns for the future is energy; specifically renewable energy, as the reserves of oil and gas are depleting and demand for affordable energy increases. With an increase in demand and a decrease in supply it is imperative that alternative sources of energy be explored. Without addressing the concerns associated with the continued production, distribution and use of fossil fuels – concerns such as global warming, acid rain, and disasters like oil spills – we will see this result in a negative impact on our society and environment. Raising public awareness as to the urgency of these issues is the only way that any changes will be made.

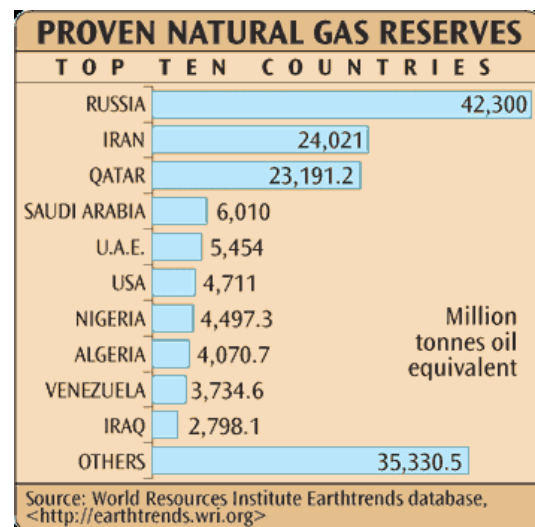
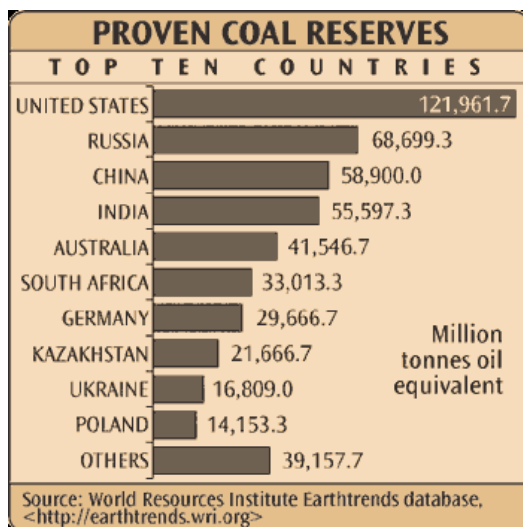
The objective of this project is not to explain the repercussions of using fossil fuels, but to explore and analyze sources of alternative energy, and the developments in recent technology; allowing them to be harnessed more efficiently and effectively. The energies discussed in our project range from the most common: (solar, wind, and nuclear) to those less prominent: (hydroelectric, hydrogen, biofuel, geothermal, and others). Along with a detailed analysis of each energy source, we provide social implications and a long term outlook with respect to their future utilization.

There are several current sources of alternative energy that we believe do not have much room for improvement or further utilization. These energy sources are namely hydroelectric, biofuels, and hydrogen. Their shortcomings do not lend themselves to large scale energy production for the next 100 years. The most promising sources we see for future use are wind and solar power. They have vast room for improvement and are widely applicable on a global scale. Nuclear energy has vast potential as well, providing the public can be properly educated about the risks and benefits. Not only will nuclear fission become much safer and more efficient within the next few decades, but the real possibility of nuclear fusion as an intrinsically safe and powerful source of energy must be taken into account. The combination of new research and development across all aspects of energy production will produce sufficient energy for global consumption without the environmental drawbacks of traditional fossil fuels. Due to the radically different nature of newer alternative fuels, the future applications of such technologies can only be guessed at. Imagine a world with an infinite source of cheap, reliable, and renewable energy; the possibilities reach into space and across the galaxy.

Introduction

In this day and age alternative energy has become a major topic among scientists, politicians, scholars, and others. With global warming looming over our heads and the Earth's natural resources starting to diminish we, as humans, need to change our ways. We can find solutions to these difficulties by looking for alternatives to meet our energy demands. Currently, our consumption of non-renewable energies is too high, and there are many contributors, as well as side effects, to these issues.

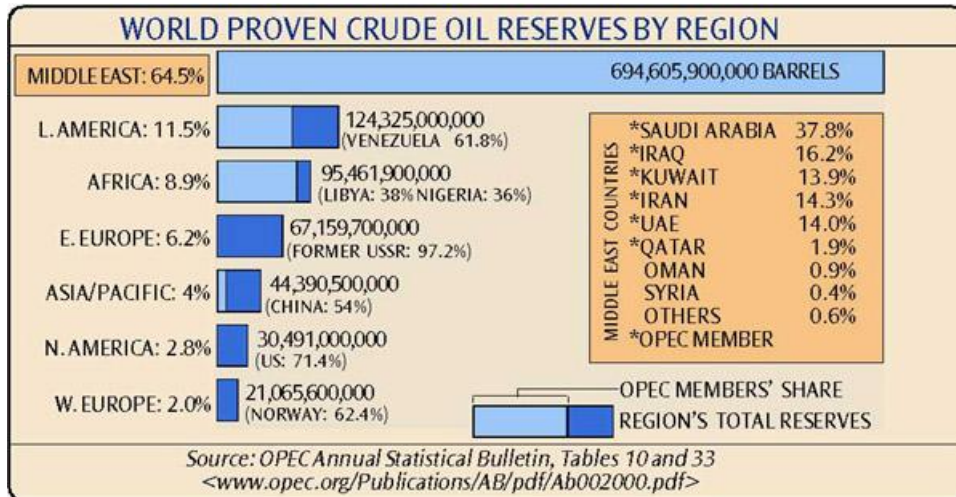
The first sign that the amount of non-renewable energies we use needs to decline is the fact that non-renewable energies are just that: non-renewable. Eventually, we will run out of these types of energy, and unless we focus our attention on alternative forms, we will have no means of future survival. A recent study has shown that at the current rate of production there is enough coal on Earth to last us for about the next 120 years (Where Is Coal Found?, 2011). Coal is considered the cheapest and most abundant form of non-renewable energy out there, so it is obvious that we use a lot of it. Looking at the related bar graph below, you can see that the US has the most coal reserves per country in the world:



(Oil, Coal, and Gas Reserves, Peak Oil, Global Energy Use Statistics)

120 years might seem like a short time, but this is long compared to how quickly we will run out of oil and gas. At the current rate of production, known gas reserves will last about 59 years (Where Is Coal Found?, 2011). The above graph to the right shows the amount of known gas reserves per country, with Russia almost doubling the country behind it (Oil, Coal, and Gas Reserves, Peak Oil, Global Energy Use Statistics). Oil reserves, however, will not last as long as the other two fossil fuels, and many of us

living today could potentially see the world run out of oil. This is because at the current rate of production, known oil reserves will only last a little over 40 years (Where Is Coal Found?, 2011). The graph below shows the amount of known oil reserves per region:



(Oil, Coal, and Gas Reserves, Peak Oil, Global Energy Use Statistics)

As shown in the graph, the Middle East towers above the other regions with how much oil it has. With these charts and data, one can see that running out of fossil fuels is indeed a reality. In order to combat this we need to rely less heavily on non-renewable energies, and focus more on alternative energies. Sixty years will pass sooner than the public may believe, and if realistic alternatives to oil and gas do not become available, the economy, the infrastructure, and the lifestyles that we possess today will cease to be sustainable.

To further stress these issues, the controversial issue of global warming is also becoming detrimental to current ways of living. People wonder whether or not it is a true occurrence, but statistics show that it is indeed a problem. When we burn fuels like coal and gas they create hazardous byproducts, including sulfur and carbon dioxide, which get released into the air and atmosphere. These byproducts trap in excess heat that would otherwise normally go back into space. As we use more and more of these fuels, heat is continually trapped in the Earth's atmosphere. This, in turn, causes a significant rise in the temperature of the Earth, thereby contributing towards global warming.

We believe that alternative energies are the future to our world, especially when considering the drawbacks as well as the timeline associated with fossil fuels. Taking a considerate look at past, present, and future alternatives to energy sources has provided us with a lot of awareness to the reality of our world. In order to combat the reality of a future with no energy, we are studying the

opportunities available to us through alternative fuels. Fossil fuels are depleting rapidly and cause many of our global issues today including global warming. The new direction of alternative fuels encompasses energy supplied through solar power, wind turbines, nuclear plants, and hydrogen storage along with a few others.

By discovering the applications of each of these alternative fuels, we can open new paths for growth and development in the future. The first step to reducing our reliance on fossil fuels is to define the availability and the possible uses associated with each alternative fuel. For example, solar energy, in its vast abundance could potentially supply villages, cities, countries, and whole continents with clean and renewable power. Likewise, wind turbines have the potential to supply power to the energy grid and power thousands of homes in a given area. Nuclear power is already being utilized by society today, however, the future of this power could be in nuclear fusion; with a higher efficiency and possibly stronger infrastructure. Energy storage in hydrogen can be utilized in applications that range from heat storage to storage of energy for vehicles and mass transit. We consider each of these for their projected availability and use for our future.

Even with these promises of high efficiency and clean and abundant power, our job is to find the viable and realistic applications of these technologies. It is unreasonable to simply state that these alternative technologies will function and that all of our energy dilemmas will be solved. We must consider the implications of implementation of each of these technologies as well. We will consider the social and economic issues as well as the unexpected issues associated with implementation of these new technological alternatives. Although these new alternative technologies supply a lot of promise for the future sustainability of our world, they still have downfalls and problems that must be faced and discussed. Solar energy, although abundant, is very difficult to store and transmit into power grids. Wind turbines create unwanted harmonic sounds, potential pressure and wind variations in a region, and can kill avian animals. Nuclear power, although clean and widely used, still has the potential for meltdown and creates radioactive byproducts. Hydrogen storage is still not perfected and not perfectly contained, with its only current use in buses due to their robust size. Just as fossil fuels have their drawbacks, each of these new alternatives has drawbacks that need to be worked out before full implementation and acceptance can be realized.

With this in mind, we must discover the potential of these new alternative fuels, define their uses, mark and solve their drawbacks, and inform society as to their potential, importance, growth, and future intent. Our future requires an informed society that realizes the importance of such dramatic revolutions and the ability to enact these revolutions in alternative fuels.

Every day, new power generating technologies are developed and improved. But, no matter how efficient these technologies become, they need to be put to the correct uses. Different power sources are suited to different applications. For example, using a nuclear reactor to power a car is a bad idea, for reasons that will be elaborated upon later, and using a wind turbine wouldn't work at all. So, there are impossibilities, and then there are things that work but are better suited for other applications. This project will take a look at where specific technologies are best applied, and give evidence to support those claims. Another example would be power sources that are not consistent, and do not generate constant power. These sources are fine when coupled with energy storage technologies, but only for small scale power generation. For large scale production, like powering a city, generators that produce large amounts of constant power are required. So, wind is not suited to power an entire city, while nuclear is. However, a nuclear reactor is too much for a single house; but a wind turbine would fill the role perfectly. These issues with application can arise from several things.

Issues associated with application of energy technology commonly concern the transportation as well as the storage of this energy to begin with. A solar panel outside the atmosphere would generate far more power than one inside, but getting the energy back to earth let alone utilizing it would be difficult. Two more issues with this are size and location, and both concern storage. A hydroelectric plant generates a large amount of power, but it takes up a huge amount of space. With the plant itself, and the reservoirs required to make them run, it needs to be placed near a large body of water. The last issue we believe is fuel source. On one hand, a hydrogen fuel cell is fueled by liquid hydrogen, which is easily stored. On the other hand a solar panel is powered by the sun's energy, which cannot be stored. All power generation technologies have advantages and disadvantages, but how those disadvantages can be dealt with lies within their specific applications. We will explore this later in more detail.

We start by providing our readers with specifics concerning each alternative fuel. The three major alternative fuels covered are solar (Chapter 1), followed by wind (Chapter 2), and nuclear (Chapter 3). In Chapter 4 we discuss several less widespread renewable technologies and their possibilities. These energy technologies are biofuel, hydrogen power, geothermal systems, hydroelectric energy, shale gas, and oil sands. In Chapter 5 we analyze different applications of some of the alternative energies. These topics include transportation, building integrated systems, and national power. The final chapter will be the conclusion of our project.

For clarity we give our readers a short background of the authors. Timothy DeGreenia is a Mechanical Engineering major seeking to work in the automotive field and work directly with energy

alternatives in the transportation industry. Kaj Peterson is a Mathematical Science major and German language minor with international employment interests in industry and applied differential equations. Lukas Aschbacher is a Mechanical Engineering major with a concentration in Design and a minor in German Language Studies. He is seeking to work internationally in the automotive field. Ben Sancetta is a Mechanical Engineering major looking to design new and better products that will decrease negative environmental impacts.

Chapter 1 - Solar Energy

The Sun is and always has been the most abundant source of energy for our planet. Solar radiation warms our atmosphere, provides the necessities for plant life, and is the basis of life on our planet. Until recently, harnessing this abundance of energy has been difficult and inefficient. New photovoltaic receptors as well as solar thermal power plants will allow for lighter, cheaper, and more efficient gathering and storing of the Sun's energy. The use of such solar applications will create a clean, green powered society, with a low carbon footprint and sustainable future.

1.1 Availability

According to Gerhard Knies, the implementer of Desertec™, by 2050, three Earth's will be required to sustain humankind. At the current time, all of humankind on Earth consumes a total of 15-18 Terawatts of power per year (Transportation and Energy) while the Sun transmits about 101,000 terawatts of power to the Earth every year (Solar Thermal Renewable Energy, 2001). A 2002 study stated that in one hour, more energy from the sun was absorbed by the Earth than was used by humankind in the whole year. This means that just one year of solar energy absorption provides twice as much energy as all of the current exhaustible resources combined.

Much of this solar energy provided to the Earth can be extracted and transported from the deserts around the world. About ninety percent of the human population lives within 3000km of a desert. This means that many societies have accessibility to available solar power. Just three thousandths of the world's desert area, about 90,000 square kilometers could supply the entire world with clean power. It would require less than 1% of the available land area in Africa and the Middle East to supply the entire world with clean power (Solar Thermal Renewable Energy, 2001). Each year, a single square kilometer in this area can produce more energy than 1.5 million barrels of crude oil. (Concept: Desertec)

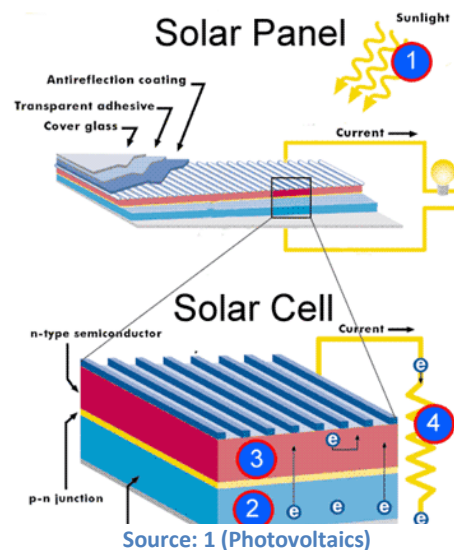
Currently, the average citizen of the world consumes 300-500 watt hours per year of energy. This includes all of the common daily activities including transportation. By utilizing the massive amount of space and solar radiation provided by deserts, just 20 square meters of a solar power plant could provide enough power for a person for an entire year. (Concept: Desertec)

1.2 Solar Modules

Solar modules are arrays of crystalline silicon photovoltaic cells. The cells gather and convert the sun's radiant light energy into useable electrical or thermal energy. Traditional solar modules are mildly efficient between 10% and 20% but are becoming better through advance design and use of mono crystalline thin film cells. Thin film cells are between 15% and 35% efficient with lower capital and installation costs. (Thin Film Solar Cell) They are more simply produced as well as installed, so total cost to power production efficiency is much higher than traditional modules and more competitive with other energy resources.

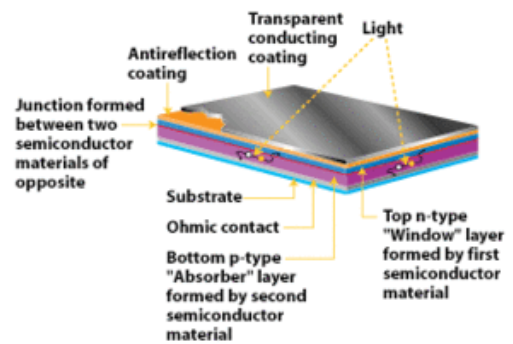
The solar cells that comprise the solar module are layers of N and P crystalline, semi conductive, silicon, separated by a conducting diode. The two chemically treated layers transmit electrons when the Sun's incident radiation adds electrons to the system. Electrons will detach from the Phosphorus doped, N silicon, layer and transfer across the diode to the Boron doped P silicon layer that has room for surplus electrons. This process results in a voltage difference between the N and P layers, usually around .5 volts per array. (Photovoltaics) When input and output leads are added to the solar module, the voltage difference between layers, and the electrical field of the array, cause a current to flow out of the module for electrical use. These two factors, current and voltage, together create the conditions for power generation and transmission.

Current silicon based PV cells are not pure silicon. They are purposely contaminated or "doped" with impurities such as phosphorus or boron that help to release extra electrons in the energy conversion process. During the conversion process, these impurities allow the silicon to become a better conductor of electricity by balancing the available electron clouds in the material structure. The N silicon layer is commonly doped with phosphorus that holds more electrons for the system while the P layer is tainted with boron that creates holes for extra electrons. When light energy strikes this electrical field, electrons detach from N and fill the holes in P creating a voltage difference and a current out. (Photovoltaics) Thin film cells are making this process more efficient through the use of thinner layers on the order of a few microns in thickness. Although the layers are thinner and may contain less



semi conductive silicon in thin film cells, they are enhanced with non reflective films that help to absorb and trap more of the sun's light energy. These enhancements along with the inherent light weight and simpler production allow the thin film solar modules to be more efficient, more widely applicable, and more promising as energy suppliers for our sustainable future.

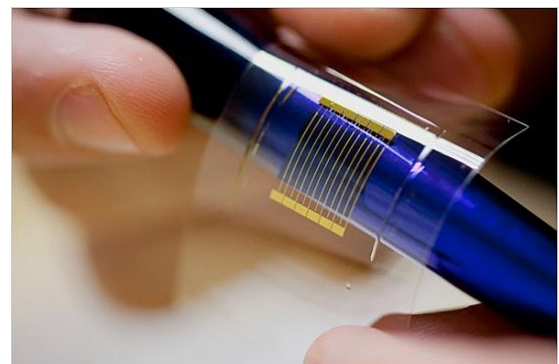
Beginning in March of 2011, Mitsubishi Chemical Corporation made advancements in the thin film PV solar cell design. Their solar cells operate in much the same way as other cells with silicon as the semi conductor. However, carbon compounds were introduced that activate and operate the semiconductor instead of the phosphorus and boron compounds mentioned earlier. (Spray On Solar Power Technology from Mitsubishi) This design resulted in thinner cells and has even created the opportunity for spray on cells that can be applied to virtually any surface. The thin films promise to replace the bulky, expensive, less efficient, less aesthetically pleasing, large modules as well as open the doors for further applications of cells. When thin film cells take heavily to the market after mass production, they will be applied not only to roofs, but also to walls, windows, vehicles, buildings, virtually any surface and transmit energy into an electrical system with extreme ease and peace of mind.



Source: 2 (Photovoltaics)

1.3 Local Applications of Solar Modules

With the introduction and growth of thin film solar technologies, the field of personal power applications is growing. Thin film, laminate solar panels as well as the carbon panels can be used for phones, laptops, and other small electronic devices. (Portable Solar Power: Convenient Battery Charging for All Your Devices) The lightweight and easily applicable modules could be applied to virtually any device, but practical use of most items is not dependent on being in the sunlight. Solar straps and



Source: 3 (Thin Film Solar Cell)

even belts can be worn on a daily basis in order to have a constant supply of useable energy on your person. Instead of having direct input into your power devices, you could capture and store energy with you so that there will no longer be a problem with charging your electronics. Constant portable power will be available to all and independence from current energy sources and infrastructures can be known. Although these new solar films are currently projected for use in small scale applications, innovations will allow them to be applied to more versatile and large applications such as buildings, transportation, and self sustained power plants.

Application of the thin film cells to building power systems will come soon. These thin film devices could be applied to almost any surface of a building and could transmit the energy to power the building (Building Integrated Photovoltaics). The films and paints will be applied to walls, roofs, and windows thereby creating an energy tower that absorbs energy at all times. Not only will energy be widely abundant but the cells themselves will also help to maintain the ambient temperature of the

Source: 4 (Building Integrated Photovoltaics)



building by insulating it from the sun's incident energy. In a sense, the buildings will become self sustaining thereby reducing the need for dirty power plants to generate and supply the power to the building. With advancement in building integrated photovoltaic technology as well as the application of highly efficient and easily applicable solar products, future buildings could act as power plants themselves, absorbing energy to support themselves, and then transmitting excess power to surrounding locations (The U.S. Department of Energy Awards Dow Solar \$12.8 Million to Develop Next Generation Breakthrough Building Integrated Photovoltaics, 2011).

The transportation industry could rapidly develop when these light weight and efficient devices are used on automobiles and the transportation infrastructure as well. Similar to the buildings, the vehicles could absorb energy through all visible surfaces including their paint, solar panels, and windows. This energy can be directly forwarded to electric motors for each wheel of a car eliminating the need for combustible fuel, electrical charging, or battery disposal. These advances will create near perfect electrical systems with little loss in the way of weight, capacity, and efficiency, but power output must increase first due to the increased consumption during propulsion. (Transportation and Energy) The key will be to continue increasing efficiency so as to provide excess power to the vehicle wheels. In

addition to vehicle performance and application, the cells could be used on stop lights, street lighting, and traffic cameras so as to make the entire transportation infrastructure that much less dependent upon non renewable resources.

The thin film advancements will be perfect for the easy applications to small devices as well as medium sized systems. Their light weight, durability, ease of installation, and moderate efficiency will allow them to replace the traditional bulky solar panels in their applications as well as span new territories in energy generation. Although these films will not be useful for large scale generation of power, mass production and demand for these products will make a noticeable difference in our cost and efficient use of energy. Still large scale applications of solar generation will be needed for sustainability and the replacement of fossil fuel use in our society.

1.4 Solar Power Plants

Solar thermal power plants function much like conventional power plants. In a conventional power plant cycle, heat is introduced into the system either through a boiler, combustion chamber, or exhaust heat source. From here, the moving fluid will be steam or gas and it will produce work through a turbine before heat is removed through a heat exchanger or condenser. The cycle is completed when the moving fluid returns through a compressor or pump to the combustion chamber. With these cycles, the compressor and the combustion chamber are the only locations where work is introduced into the system and efficiencies of 30-50% can be achieved (Verlag, 1991).

The key difference that sets solar thermal power plants apart is that heat is introduced to the system by the sun. Instead of conventional combustibles like coal and oil, parabolic solar panels capture the Sun's radiation and concentrate the heat for use in addition to the power system. Power production will be clean, efficient, and abundant enough to allow whole countries to be supplied with energy without the drawbacks of hazardous waste and the risk of meltdown.

Such initiatives are already in progress such as the Desertec™ project in Northern Africa and the Ivanpah and Blythe Solar Power Projects in California. The Desertec™ Project began ten years ago and plans to place solar thermal power plants in Northern Africa for the purpose of transporting generated electrical power to Europe. Through direct current (DC) transmission lines



Source: 5 (Siemens Expands Solar Thermal Portfolio with Solel Acquisition, 2009)

run underneath the Mediterranean Sea, this electrical power will supply 20% of Europe with clean power by 2030 (Concept). Similar projects are being started in the deserts and plains of Southwestern United States and Mexico. Both solar projects in California broke ground in 2010 as part of California's initiative to produce 33% of its energy through clean means by 2020 (Solar Energy Goals). Power plants of these types are gaining popularity and through positive feedback and power generation, investment in future projects will be more likely.

These power plants will range in size and complexity as well as in power production. Some plants will collect their solar energy by utilizing fields of solar panels, each panel collecting energy separately. Others will utilize collecting towers surrounded by solar panels that direct their energy at the tower for absorption. Even the shape and orientation of the solar panels will vary depending on region and concentration of the light energy. In any case, the efficiencies will be raised, the energy will be renewable and clean, and the power production will be on the order of hundreds of gigawatts.

1.5 Global Advancement

Within the next five to ten years, many nations across the globe intend to drastically increase their capacity for solar energy use. Dozens of solar thermal power plants are under construction and thousands of photovoltaic systems are being implemented. The intent is to shift the world's energy reliance to clean fuels while increasing efficiency and reducing cost to the consumer.

In his State of the Union speech, President Obama declared that he wanted the United States to be powered by 80% clean energy by 2035 (Solar Energy Goals). The United States is currently providing loans in order to help the startup of new solar plants across the country. A billion dollars was just approved to start two plants, one in Nevada and one in Arizona with the capacity to supply 75,000 homes with power (Nations). In addition, the Ivanpah and Blythe initiatives in California have implemented two projects with the capacity to supply between 750,000 and 900,000 homes with power. With this proposed growth, the United States is hoping to increase production, acceptance, as well as efficiency of these products (Actualizing Our Solar Energy Goals: It's All About the Money, 2010). Although Obama's declaration does include the use of other clean and alternative energy sources besides solar energy, it does set the precedence for the other nations to begin sustainable objectives in all energy fields.

The European Photovoltaic Industry Association (EPIA) intends to have at least 12% of European electricity supplied by clean energy by 2020. Further, the EPIA has plans to increase this amount to 20% by 2030 and up to 30% by 2050 (Technology and Science Innovation). China is also taking initiative with promises of 10GW of solar power by 2015 and 50GW of power by 2050 as well as 100GW of power provided by wind turbines by 2015 (REVE - Regulación Eólica con Vehículos Eléctricos -). India is also attempting to make itself prominent in the energy transition by approving the start of an Rs.43.37 billion (US \$950 million) project intended to supply 10GW of solar power by 2017 and 20GW of power by 2022 (India Approves Solar Implementation Plan, 2010). Massive investments and expenditures are being made to continue the growth of the energy field but large nations are not the only contributors.

Many smaller nations are transitioning as well with projects that could supply power to small and distant communities. For example, in Zimbabwe, some small communities are implementing miniature solar plants to provide electricity as well as the possibility for lighted teaching facilities and running water. The intent is to produce newly educated members that can operate not only their personal and community technology but also contribute to future projects in the field.

In order to hasten the acceptance and use of solar energy, many nations now provide tax

incentives and subsidies for solar power utilization. Germany is the leader in this respect with the highest incentives as well as bolstering a 40% cost difference between their solar implementation and the United States'. Last year, Germany gained a million solar powered homes while the United States has a mere total of 80,000 homes powered by solar energy (Energy: The Obstacles to Scaling Up Solar Power, 2011). By streamlining the approval and incentive process, more efficiency with respect to installation of systems can be experienced in the United States.

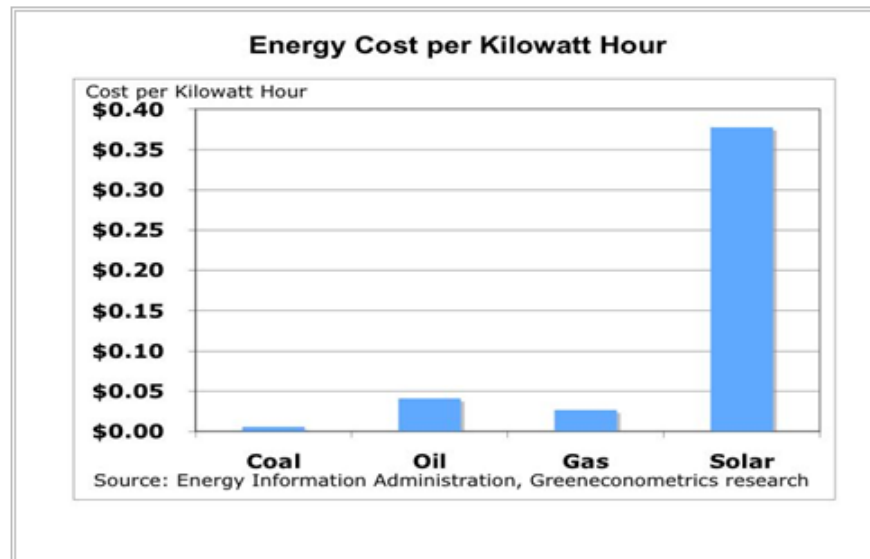
All of these advancements will occur over the next twenty years and possibly sooner as support for the growing field of alternative fuels increases. Our goals in the mean time are to lessen and hopefully extinguish our reliance as a society upon fossil fuels as well as reverse the impacts that these fossil fuels have had on our world. Preparation for future energy needs is of the highest importance and these projects take into account a two fold increase in energy demand within twenty years. If we install the system now and embrace a new energy supplement, we will be able to support this increase in demand while maintaining homeostasis with our environment.

In 2010, there was a sixty seven percent funding increase to over 41 billion dollars by the United States for sustainable energy changes (Crystalline Solar Photovoltaics PV Panel Systems Worldwide, 2011 to 2017, 2011). This is a good step in the right direction, but it could cost from one to five billion dollars for a single new solar project to be implemented. A single project could supply anywhere from one hundred thousand to one million homes with power but compared to the global population, this is miniscule. Every consumer must contribute to the shift to alternative fuels with future generations and the health of the world in mind. Only when there is high demand for this transition, will costs decline in the solar market and make it possible to begin implementing the new infrastructure.

1.6 Efficiency and Costs

At the current rates, solar power costs are not competitive with the fossil energies of coal, oil, natural gas, or wood. Power yielded from solar energies currently costs up to 38 cents per kilowatt hour of usage. Comparatively, the fossil energies noted above cost less than 5 cents per kilowatt hour of usage. Costs for the use of this renewable resource are high due to a newly developing infrastructure, expensive implementation costs, and developing efficiencies globally. These deficiencies lead to low economic demand and further price destabilization until advances are made to increase supply per total

cost of dispersal. Through support for a clean and renewable source of power, the costs associated with solar power usage will decrease to competitive rates through technological advances, infrastructure revolution, and increased available supply.



Source: 6 (Green Econometrics)

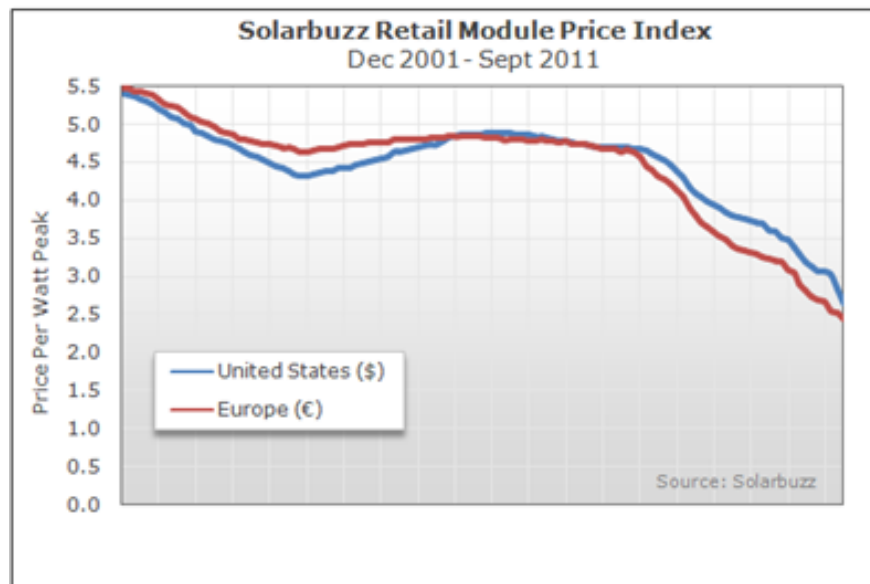
Efficiency analysis in the solar field does not end at the photovoltaic modules. In solar thermal plants, the mirrors, the panels, the heat sink, turbine, and even the transmission lines to the power grid must be considered.

When considering efficiency, the transmission of power through cables from the power plants to the power grids can be an important factor in calculation. Current power plants are considering high voltage direct current (HVDC) lines to supply the energy. These lines can be run either over or under ground for extreme distances with only a loss of 3-5 percent of the energy per 1000 kilometers (620 miles) of distance (Science Daily). There are such lines already utilized in Inga-Shaba, Democratic Republic of Congo as well as in Yunnan-Guangdong, China that have capacities of 5 gigawatts. Twenty similar transmission lines will be installed to provide Europe with power at a cost of 45 billion Euros just for the power lines (Transportation and Energy). This figure for implementation cost is rather high, but when considering the up to 45 percent power loss associated with alternating current (AC) power lines, they become more desirable.

Current photovoltaic solar production would only utilize 25 percent of the capacity of these lines. By 2020, through the utilization of solar power plants and the refinement of energy gathering techniques, power transmission through such lines will increase to 60 percent efficiency and up to 80 percent efficiency by 2050 (PV Solar Implementation Plan). Future HVDC lines promise to be even more

efficient with larger power switches and innovations to support the massive amounts of energy.

In the local sense, it is the installation that drives up costs due to the bulk size of the common solar panel and the low efficiency comparatively. A common household of four will require 1.5 to 3.5 kilowatt hour capacity to supply the home with power. Installation costs for this system with the common solar panels could range from \$15,000 to \$45,000 (Green Econometrics). This is highly undesirable because the return from the save in energy cost would take years to pay off the system, and then the house would lose aesthetic property value as well. The same trend is current in both the local and global initiatives for solar energy because it takes time and funding to start the shift toward effective use of alternative energies. In both cases, the troubles of lowering costs and making the systems more feasible and desirable to the common market start at the implementation of the system. It requires initial capital to install systems such as these but the only way to reduce cost is to invest now so as to start the trend. There are government issued tax incentives as well as an increase in home value when these systems are installed but competitive prices won't arise until support is given. With continued and added support for the solar energy initiative at the current trends, the Department of Energy expects solar energy costs to become competitive within 15 years. The question is whether or not 15 years will be soon enough to help reverse the damage done to our Earth due to our traditional fuel use and lifestyles.



Source: 7 (PV module pricing)

A revolution in photovoltaic practice, the gathering of the Sun's energy, for local use is here that could help to advance this energy progression. New photovoltaic solar panels support a 15 percent light to energy conversion efficiency and have promise of better performance. The older panels were developed enough to reach around 20 percent efficiency. With further research and development, these new cell panels will easily eclipse the efficiency set forth by their predecessors. Furthermore, although at the current time they are less efficient, these new cells are far less expensive for their value due to lower installation costs. Traditional home solar systems cost between 20,000 and 40,000 dollars with up to 40 percent of that cost associated with the installation and set up of the system (Energy: The Obstacles to Scaling Up Solar Power, 2011). These new panels are a thin film, photovoltaic cell, that is peel and stick with direct light to electricity conversion. With these systems, up to 70 percent of the traditional cost could be wiped out because these systems are easier to produce, install, handle, and use as opposed to their bulky, out of date counterparts (Green Econometrics).

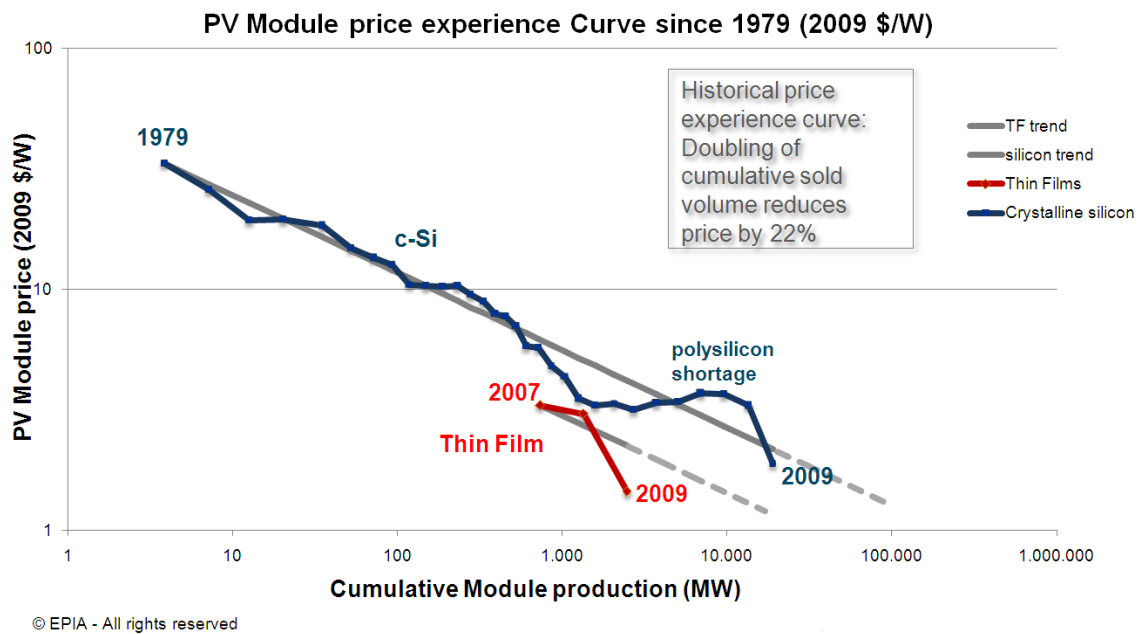
Although the new cells are more easily installed, they still suffer the same efficiency drawbacks as the traditional panels. Current photovoltaic technologies are limited to only gathering energy from the visible light of the Sun which accounts for 10 percent of the Sun's useful emitted energy. We are missing out on the use of infrared emission from the Sun which accounts for up to 50 percent of the emitted energy from the sun. When it becomes possible to harness this invisible energy, our energy intake will increase fivefold thus decreasing energy costs. Furthermore, collection of solar energy will not be limited to daytime, clear, and sunny weather nor will it be inhibited by our atmosphere. Energy for use in power will be abundantly available thus reducing costs and leading the way for building integrated photovoltaics as will be discussed further on.

As solar panels advance and energy collection and storage methods are refined, efficiency, ease of use, and energy yield will increase. This will lead to more possibilities in panel usage and placement, applications, new ideas such as solar absorbing paints, and more and more ways and places that can be used to capture and utilize the sun's useful energy.

1.7 Implementation and Limitations

Economic, political, and social constraints have been encountered during the switch from fossil to alternative and especially solar energy usage. As of now, solar energy is slightly expensive due to startup costs of its infrastructure. This cost and time required to start the infrastructure and mass production has been too much to conquer as of yet. Investors have had a hard time investing in such important change due to these extra costs and low social acceptance.

With fossil fuels so widely and easily accessible, the public has found it difficult to make the switch to the currently more expensive green energy resources. Through mass production, these high costs will be reversed and eventually fall to values that will greatly make up for their implementation. The problem is that any infrastructure including that of fossil fuels, takes fifty to seventy years to establish. Solar energy conversion is no different and the efficiency provided now by fossil fuels only slows the conversion further.



Source: 8 (PV Solar Implementation Plan)

Political relations are also a factor in the implementation of newly proposed solar grids such as those in Africa and the Middle East. Many of the nations in the area that would be ideal for solar harvesting have political tensions with one another or simply have no imposed policies governing the production and exportation of energy. Some of these nations also do not have an exchange rate for

energy exportation or the skilled labor for implementation. This is where, in time the operation will change this, providing jobs to the locals, peace and treaty to neighboring societies, and clean and renewable energy to the world.

The implementation and full realization of solar power is highly limited by social media and social norms. The biggest obstacles to overcome before solar power becomes a true global energy source are the social reliance on the current energy system as well as the economic startup required to get it going. Solar power cannot become globally utilized until these issues are dealt with and overcome. Unfortunately, only time and continued support for the solar movement will break down these barriers.

It took more than seventy five years for the current fossil fuel infrastructure to be implemented before it took off and changed the direction of our society. Now the reliance upon easily obtainable fossil fuels is so great that society is having a hard time accepting change. This transition was easier a century ago when technology and infrastructure was not so prominent. However, the current reliance upon non sustainable and “dirty” fuels is so great that a new transition is much more difficult. Political and economic barriers simply strain this reliance and further slow the move to alternative fuel sources.

The fact of the matter is that compliance with this energy transition is hard to devote to and invest in when many know that they will not reap the benefits of this new system. Still it must be shown and realized that the current energy system is not healthy, not sustainable, and is costly compared to the future price trends of solar energy. As more investments and innovations are made with respect to solar power as an energy source, production will increase and prices will decrease rapidly. Although the economy does not currently allow for such investment, time will change this and it could turn out that the transition to solar power could be the catalyst for the rebound of the global economy.

1.8 Social Implications

All of these advances will come in time and may appear quite rapidly. As solar energy takes over as the main power source for our world, the possibilities for what our technology will become and do will be endless. The global society as we know it will change forever and the Earth will become a healthier and sustainable place. Crops will grow better providing for world hunger, less natural

destruction will be needed for fossil fuels, global warming will cease due to fewer emissions, global health will increase, and all forms of life will explode in population. The only catch is that this massive and exponentially quick growth will essentially provide a new baby boom generation, of which we will have to be careful in order to avoid natural expansion and destruction. Overuse in any sense due to overcompensation will eradicate the benefits of the system. With this in mind, the solar revolution will prove to be the single most important revolution of the known world.

Without the demand for non renewable energy, the entire current infrastructure will collapse and lifestyles will be affected. Free energy will decrease the need for many common practices and jobs today. Luckily, establishing and maintaining the solar infrastructure will create thousands of jobs in response. People will be able to live sustainably with little impact on the Earth as well as little need for war or international disputes.

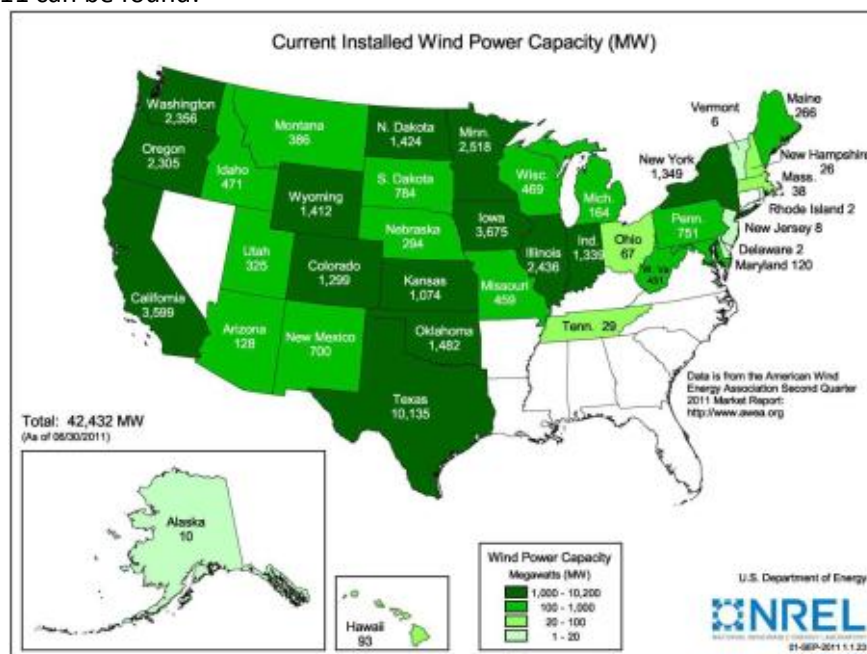
With decreased reliance on nonrenewable resources, cost of alternative sources will decrease and the world will become healthier. On the horizon, new technological advancements could be waiting for a new energy source to power them and a new technological renaissance could be realized. A change in this infrastructure will have rippling affects that will change the daily lifestyles and practices of all humans.

Chapter 2 - Wind Energy

2.1 Cost & Startup

When it comes to determining the cost of wind energy there are many factors that play a role in the calculation. First, there is the startup cost. Here is where most of the investment takes place. After the startup, money is then needed for maintenance too, though it is not as much as the initial startup costs. A big portion of the initial cost is used to buy land to house any wind turbines. Then, money is put in to buy the materials needed to set up a proper wind harvesting turbine. More money is then used for the installation of the turbine. Once it is all completed there is a big price tag placed on the whole startup and this is a reason why some people cannot benefit from wind energy; because initially it is too expensive.

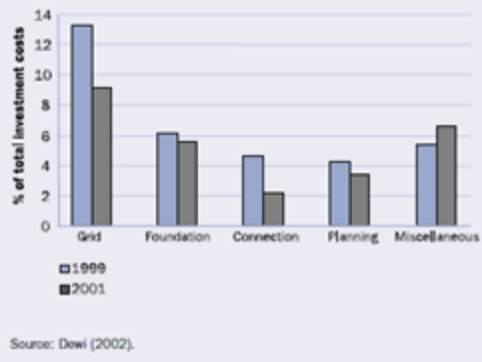
Now, it makes sense that the bigger the turbines and farms are, the higher the cost will be; since you would have to buy a lot of land, and a lot of material to build big wind turbines. However, all over the world there are different sized turbines used, so the overall cost of wind energy has a wide range. For a turbine to be economically efficient, it needs to be set in a good location so that it can harvest the maximum amount of energy possible. So, first, quality land must be selected as the designated home for the wind turbine. Below, a graphical representation of the current installed wind power capacity as of June 30th, 2011 can be found:



(Wind Powering America: U.S. Installed Wind Capacity)

As shown in the graph, most wind turbines are located along the west coast, in the Great Plains, and in Texas. The reason for this is because these locations are where the most wind is. Along the west coast wind from the ocean blows through and powers wind turbines. The Great Plains are a very flat region of America, and a lot of wind blows through here too. Texas borders the Gulf of Mexico, where much wind blows in from here and powers turbines. Once a good location has been established other

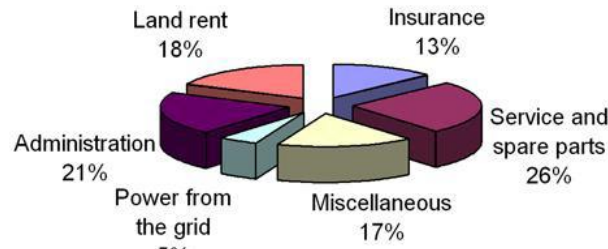
Figure 2.2: Development of Additional Costs (Grid-Connection, Foundation, etc.) as a Percentage of Total Investment Costs for German Turbines



investments are made. Some of these cost components include electrical installation and foundation, and construction labor to make access roads (Morthorst, 2011). The graph to the left shows the percentage of total investment costs from 1999 to 2001 for German Turbines. All the bars, except for “Miscellaneous,” seem to decrease with time; however, the areas that continually receive the most amount of investment stay the same from 1999 to 2001. Another graph, the pie chart below, breaks down the different categories of the operation and maintenance costs. This is also based on German turbines, though the years range from 1997 to 2001 instead. It is apparent that there are a lot of different areas that need investing in wind energy, but the question is: How much does it actually cost?

(Morthorst, 2011)

years range from 1997 to 2001 instead. It is apparent that there are a lot of different areas that need investing in wind energy, but the question is: How much does it actually cost?

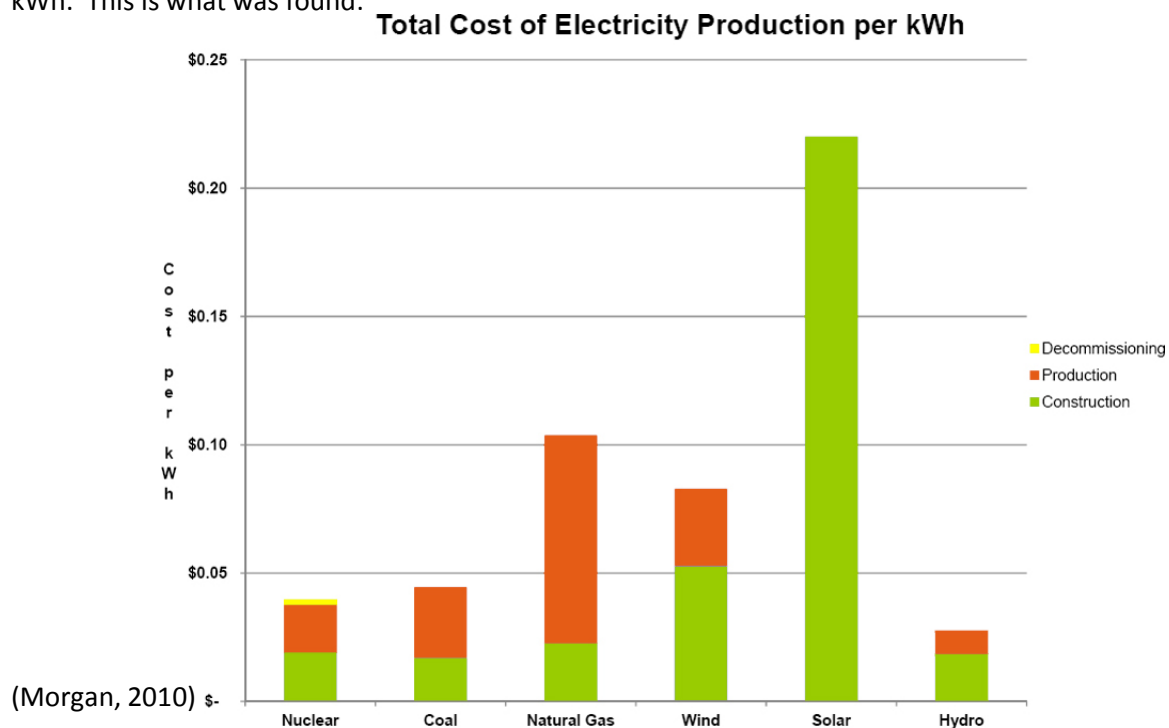


(Operation and Maintenance Costs of Wind Generated Power)

There isn't just one quantitative answer to this question, because there are so many factors involved in the costs. However, we were able to find certain areas of cost. Currently, more than half of the commercial-scale turbines installed today are 2MW in size (How Much Do Wind Turbines Cost? | Windustry). The cost to build and install a turbine of this size is about \$3.5 million (How Much Do Wind Turbines Cost? | Windustry). Multiply that by 4 or 5 to emulate the cost of a small wind farm, and you're staring down at about \$15 million. Once this initial fee is paid off, the maintenance and operation costs then take effect. So, it will take a couple of years to make the money back. As we said before, the bigger the turbines and farms are, the higher the cost will be. This applies in the opposite

direction as well. Smaller farms and smaller turbines cost less overall, but they are actually more expensive per kW of energy producing capacity (How Much Do Wind Turbines Cost? | Windustry). Turbines under 100kW cost between \$3,000 and \$5,000 per kW of capacity (Haluzan, 2011). To put this into perspective: The average household can be powered by a 10kW machine (Haluzan, 2011). A household wind turbine can be anywhere from \$5000 to \$2500 depending on size, efficiency, and labor costs (Haluzan, 2011). There is no exact number on how much a wind turbine can save over time, because this all depends on the efficiency of the turbine, the amount and frequency of wind, and of course, the current electrical bill. A few people may end up paying more for wind energy than what they were paying before (considering the price of electricity at the time and how their bill gets calculated), while most others will see the opposite happen. There is definitely a plus to having a wind turbine installed. On average, it will take anywhere from 8-15 years to make back what you put into a residential wind turbine (Haluzan, 2011). Since wind turbines are designed to last for more than 20 years, there is a minimum of 5 years of basically getting free electricity (Haluzan, 2011). This is a tremendous benefit in the long run.

Comparing the cost of electric production per kWh of wind to other energies really puts the costs of different energies into perspective. Coal is regarded as the cheapest form of energy; however, one study shows something different. This unique study took production, construction, and decommissioning costs per kWh into consideration, added them all up, and then found the total cost per kWh. This is what was found:



Hydroelectric was shown to be the most cost effective at \$0.03/kWh (Morgan, 2010). This would be good if more hydroelectric power were able to be harvested, because it has its limitations. This type of energy can only be harvested where there is a water reservoir or some sort of body of water. Without it, hydroelectricity cannot be harvested, and therefore it has a limited location range. Coal and nuclear power were tied at \$0.04/kWh, showing that in this study coal is not the least expensive form of energy (Morgan, 2010). Next on the list was wind at \$0.08/kWh, which beat out natural gas by \$0.02/kWh (Morgan, 2010). Solar power is by far the most expensive at over \$0.20/kWh and this is just taking construction into consideration. So, according to these numbers, the cost of wind energy isn't much more than what people are currently paying for coal, and it is even less than gas. The fact of the matter is that the initial cost is too high for wind energy, and until this goes down not many people will invest in this form of energy. We believe, it isn't too expensive to find a suitable household turbine (if you do have the room, money for the initial setup, and patience to wait 15 years), but large scale commercial wind turbines are still a big expense and need to be reduced.

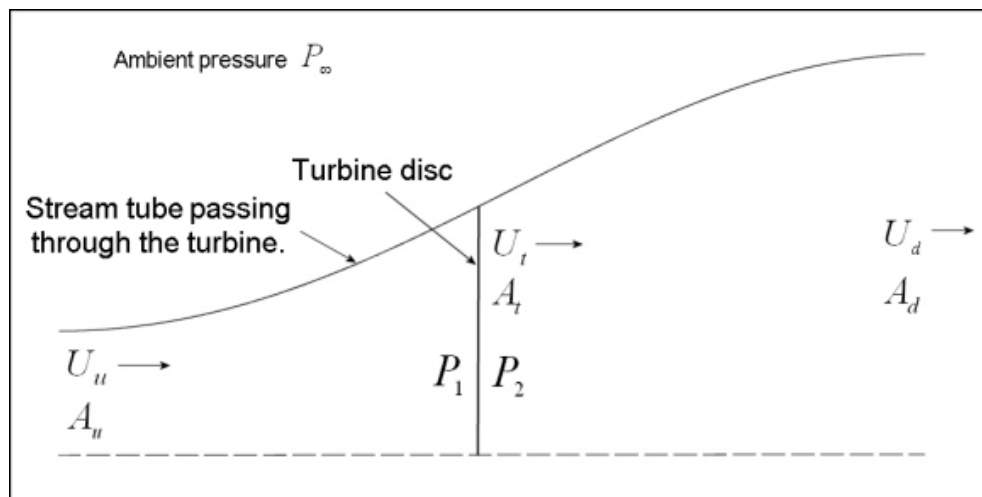
2.2 Efficiency & Limitations

Wind energy, as with many other alternative energies, has become a heavily looked at alternative energy in this day-and-age. These alternative energies are a much talked about topic, and there are many big questions that have been brought up in regards. One question that has been raised is the question about the efficiency of the method, and how much energy we can harvest from these alternatives. Another question asked has been the limitations or restrictions these alternative energy systems have. Each method of alternative energy clearly has its own individual characteristics, and we have focused on wind's characteristics.

Of course, many people are concerned with the efficiency of wind energy. With natural resources like coal, oil, and gas, the efficiency is fairly high. However, when it comes to alternative energies, their efficiency is not nearly as great. That is a reason why we don't rely as heavily on alternative energies. Nevertheless, engineers and scientists are working to create more efficient wind turbines, solar panels, and other means of harvesting energy. Alternative energy from wind is one of the most efficient alternative energy harvesting systems when set up at the right place. It makes sense

that the more wind blowing by a turbine, the more energy it will produce; so, for maximum efficiency a good location to set up a turbine is where there is a lot of wind. Ultimately, scientists would like to see wind turbines generate up to 20% of the U.S. electricity by 2030 (Kintisch). In order to do this, wind-generating capacity would have to increase from about 35 gigawatts today to more than 300 gigawatts (Kintisch). For this to happen, about 100,000 new turbines would have to be built (Kintisch). This requires a lot of money and land. To put it into perspective, one 1.8 megawatt wind turbine at a good location could produce over 4.7 million units of electricity each year; which is enough to power a computer for over 1,620 years or meet the annual needs of over 1,000 families (RenewableUK - Frequently Asked Questions, 2010).

So it seems like wind turbines are very efficient right? Well, let's take a look at the math and see. According to the Betz Law, or Betz Limit, the theoretical maximum energy which a wind turbine can extract from the wind is about 59.3% (Betz Limit - Wind, 2007). But where does this number come from? To get a better understanding of how the efficiency is calculated one must look at Fluid Mechanics to obtain the correct formulas. In order to start the calculations we first need to look at the simplest form of a wind turbine; an "actuator disc model" (Maximum Wind Turbine Efficiency - the Betz Limit). One must note that this model is important in calculating efficiencies of wind turbines; however, it does not play a part in the design of a wind turbine. In this model, the turbine is substituted by a circular disc where air flows through with a velocity, U_t , and there is a pressure drop from P_1 to P_2 (Maximum Wind Turbine Efficiency - the Betz Limit). This is shown in the diagram below:



(Maximum Wind Turbine Efficiency - the Betz Limit)

Here is where Fluid Mechanics comes into play in calculating the efficiency. We begin by first calculating the power, P , of the turbine. This is obtained from the following equation (Maximum Wind Turbine Efficiency - the Betz Limit):

$$Power = (P_1 - P_2) A_t U_t$$

Next we take a look at the Continuity Equation, which states that the flow (the flow, Q , at a point is equal to the product of the Area and the Velocity at that given point i.e. $Q=A*U$) in a control system is constant throughout the system. By this statement, we then get (Maximum Wind Turbine Efficiency - the Betz Limit):

$$A_u U_u = A_d U_d = A_t U_t$$

To calculate the force, F , across a system we must look at another equation (Maximum Wind Turbine Efficiency - the Betz Limit):

$$(P_1 - P_2) A_t = Mass\ flow \times Velocity\ difference = \rho A_u U_u (U_u - U_d)$$

This equation uses the variables from the above graph, and looks very complicated. However, a few of us have taken Fluid Mechanics and we can assure that it is quite the contrary. Simply put, force is calculated by the products of the density, ρ , the flow rate, Q , and the change in velocity, ΔU .

We must next look at Bernoulli's Equation to obtain the next few equations (Maximum Wind Turbine Efficiency - the Betz Limit). This equation is used at each point, and is equal to a constant at each point. We get these equations as a result:

$$P_\infty + \frac{1}{2} \rho U_d^2 = P_\infty + \frac{1}{2} \rho U_u^2 = P_1 + \frac{1}{2} \rho U_t^2$$

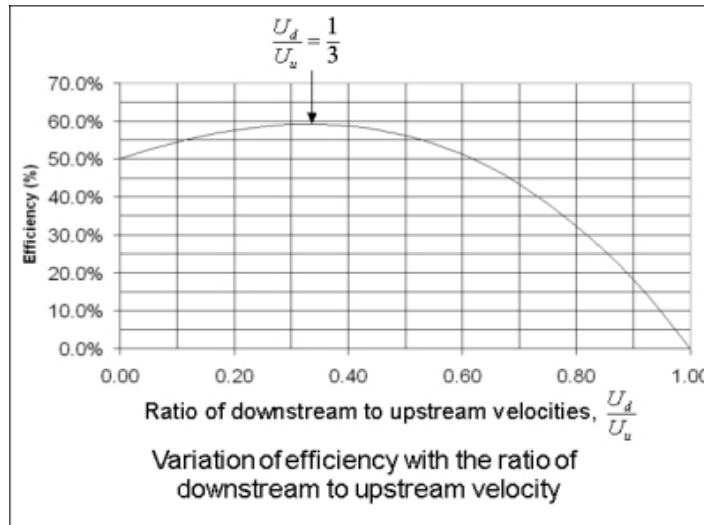
Combining the previous three equations together we then get this equation (Maximum Wind Turbine Efficiency - the Betz Limit):

$$(P_1 - P_2) = \frac{1}{2} \rho (U_u^2 - U_d^2) = \rho \frac{A_u}{A_t} U_u (U_u - U_d) = \rho U_t (U_u - U_d)$$

Going back to the first equation (calculating power), we use this in combination with previously calculated equation, and we are finally able to extract an equation for the efficiency (Maximum Wind Turbine Efficiency - the Betz Limit):

$$\eta = \frac{Power}{\frac{1}{2} \rho A_t U_u^3} = \frac{1}{2} \left(1 - \frac{U_d}{U_u} \right) \left(1 + \frac{U_d}{U_u} \right)^2$$

Below is a graphical representation of the efficiency plotted against the ratio of downstream to upstream velocities:



(Maximum Wind Turbine Efficiency - the Betz Limit)

As shown in the graph, the maximum efficiency (59.3%) is achieved when the ratio of downstream to upstream velocities is 1:3 (Maximum Wind Turbine Efficiency - the Betz Limit). For a turbine to be 100% efficient it would have to stop all of the wind. However, for this to happen the rotor would have to be a solid disk and then it would not turn, thus no kinetic energy would be converted (Betz Limit - Wind, 2007). So, it is impossible for a wind turbine to be 100% efficient. German physicist Albert Betz calculated the maximum mechanical energy produced of the kinetic energy of the wind to be 16/27, or about 59.3% (Betz Limit - Wind, 2007). The Betz Limit is named after him for his contributions and achievements.

On average, a wind turbine produces electricity 70-85% of the time; however, it generates different outputs depending on the speed of the wind (RenewableUK - Frequently Asked Questions, 2010). In a year a wind turbine will generate about 50% of the maximum energy, which is about 30% efficiency (RenewableUK - Frequently Asked Questions, 2010). Yet, efficiency is kind of a negligible term to apply to wind energy, since the “fuel” is free. It is not really a matter of efficiency, but a matter of how to improve the productivity to bring the cost of wind energy down.

Wind turbines have many advantages, though they do have their limitations and restrictions as well. One of the biggest limitations wind energy has is the fact that it doesn’t produce enough energy. This relates back to the efficiency of the system and with the Betz limit (RenewableUK - Frequently Asked Questions, 2010). Also, when there is no wind, no energy will be produced. So, you can’t harvest

a continuous amount of energy; it just comes as goes as the wind does. Although wind turbines do produce an average amount of energy, it is not nearly enough energy required to power towns in industrialized countries (Wind Farms Restrictions as Energy Platforms). You could theoretically produce enough energy to power an entire town; however, it would require a vast amount of land. This brings us to the next limitation: space. One wind turbine alone is, on average, 200 feet in height (RenewableUK - Frequently Asked Questions, 2010). A farm of 20 turbines would cover an average area of 1 square kilometer (about 247 acres), however, only 1% of this land is actually used to house the turbines and generators (RenewableUK - Frequently Asked Questions, 2010). The left over land can be used for farming or other things. Still though, a farm of wind turbines requires many acres of land, and land is expensive to buy. So, first you would have to invest money in land, and then invest money in the building and installation process. Naturally, this has been a limitation to many wind farm harvesters. Another restriction that has been brought up in association with wind turbines are their effects on the environment; namely killing birds and other flying animals (Naeem, 2007). Estimates have been made, claiming that about 45,000 birds have been killed over the past twenty years by the blades of the turbines (Naeem, 2007). As birds begin their annual migration many of them pass through wind turbines, and some are not fortunate enough to make it past. Safety measures, such as painting the tips of the blades and installing screens, have been put into place, yet the number of deaths has not seemed to decline (Naeem, 2007).

Other measures have also been taken to look for solutions to these limitations. Building wind turbines where there is a constant wind flow is ideal, because it helps increase the efficiency. These places could be along the shoreline where the sea breeze creates an almost constant wind flow. With an almost constant wind flow, the turbines would be able to produce much more energy and more often too. This would eliminate the need for many wind turbines, which would eliminate the need for a lot of land. With less money going into building turbines and acquiring land, more money can be put into research to make them even more efficient. Also, building near the shore helps to decrease the number of bird deaths resulting from the wind turbines. With fewer birds near the shore, it makes sense that not as many deaths will occur. These are only a few small solutions to help, and there are many more problems, and still other solutions. There is still a lot of research that needs to be put in to these alternative resources so that their limitations will diminish, and the efficiencies will rise. Until then, we must work with what we have, and continue to strive for the better, cleaner, healthier environment we wish to have.

2.3 Social Implications

Naturally, when introducing something new or unfamiliar to society there will be many different views, reactions, and opinions. These social implications generally arise because there is not enough information given to the people. The topic of wind energy is a much talked about subject considering all the parameters. Just like other alternative energies, wind energy has its own social implications. Whether it be size, cost, location, or noise, these implications cannot be neglected if we wish to move on from fossil fuels and look in the direction of alternative energy.

One of the biggest implications involving the harvesting of wind for energy is the noise factor of the turbines. When the big 100ft+ diameter rotors are spinning, there is a “whooshing” sound that emits from the turbine. Many residents near wind farms are complaining of headaches, nausea, and chest pains. People have coined this “Wind Turbine Syndrome”; however, this is not an actual scientifically proven term (Reviewing the Facts on Wind Turbine Sound Impacts | Renewable Northwest Project). For most people it is just mind-over-matter. Taking a look at the noise level of wind turbines and other activities shows that wind turbines aren’t actually that loud:

- | | |
|---------------------------------|--------------|
| • Jet engine at takeoff | 140 decibels |
| • Ambulance siren | 120 dB |
| • Chainsaw | 110 dB |
| • Power Hand Drill | 98 dB |
| • Tractor | 96 dB |
| • Hair Dryer / Power Lawn Mower | 90 dB |
| • Normal conversation | 60 dB |
| • Wind turbine | 50 dB |
| • Whisper in ear | 30 dB |

As shown, wind turbines are between a whisper and a normal conversation. Also, many researchers have said that most of the noise is lost in the wind anyway, before it reaches the ears of the complaining neighbors (Reviewing the Facts on Wind Turbine Sound Impacts | Renewable Northwest Project). Here is a quote from three scientists (Robert Dobie, M.D.; David M. Lipscomb, Ph.D.; and Robert J. McCunney, M.D.) who have delved further into this subject: “While opponents of wind energy have attempted to use self-published reports to block projects, the science is clear. Independent studies conducted around the world consistently find that wind farms have no direct impact on physical health. In fact, with no air or water pollution emissions, wind energy is essential to reducing public health

impacts from the energy sector.” (Reviewing the Facts on Wind Turbine Sound Impacts | Renewable Northwest Project).

To combat the complaints, one company by the name of Caithness Energy™ has given residents in eastern Oregon a \$5,000 check if they are willing to sign a waiver saying that they will not complain about the noise from nearby turbines (Yardley, 2010). Many people have happily accepted the check, with one man by the name of George Griffith saying: “It was about as easy as easy money can get” (Yardley, 2010). However, there are still some people in eastern Oregon who are opposed to wind turbines and this form of energy.

Residents aren’t just complaining about the noise from wind turbines; many are complaining because the wind turbines near houses are decreasing property value too, specifically in Ontario, Canada (Ontario Wind Power Bringing Down Property Values, 2011). However, the wind industry is not recognizing this, and this is making residents even madder. One particular example is that of Kay Armstrong from Clear Creek, Ontario (Ontario Wind Power Bringing Down Property Values, 2011). Before wind turbines even existed in her area she put her house up for sale for what real-estate agents said was a reasonable price of \$270,000 (Ontario Wind Power Bringing Down Property Values, 2011). However, two years later when the turbines arrived she was only able to muster \$175,000 for the house, and the only reason someone bought the house was because they just wanted a place to grow marijuana for legal use (Ontario Wind Power Bringing Down Property Values, 2011). Armstrong went on to say: “It was getting so, so bad. And I had to disclose the health issues I had. I was told by two prominent lawyers that I would be sued if the ensuing purchasers were to develop health problems” (Ontario Wind Power Bringing Down Property Values, 2011). Armstrong was not the only one who experienced this. In fact, on average, from 2007 to 2010, properties adjacent to turbines sold for between 20 and 40% less than properties that were out of sight from turbines (Ontario Wind Power Bringing Down Property Values, 2011). Still, the province of Ontario is not giving tax breaks to the residents or helping them out. Since this issue was just brought up in October not much has been done, but we will continue to see what happens to the residents.

2.4 A Look toward the Future

After finishing some of the background research on wind energy, we have now focused our attention on the next part: the future of wind energy. An interesting article was found on an alternative energy website, pertaining information that mentioned using wind turbines on airplanes. Much like hybrid cars, this invention by Dr. Josef Popf is trying to minimize and maybe even eliminate fossil fuels completely from flights (Bennett, 2008). This practice of putting wind turbines higher in the air to harvest energy more efficiently, has led to other areas of research and brought more designs and prototypes forward.

The idea of putting a wind turbine on an airplane came to Dr. Josef Popf while he was driving in Kentucky through a wind farm (Bennett, 2008). He says: "... I expected the wind turbine to slow down the airplane. But the deeper I delved into the problem, the more plausible it started to appear. Then, after about two solid months, I found the answers I needed and filed for a patent" (Bennett, 2008). The way this system works doesn't differ much from the way hybrid cars work. Basically, the entire time the airplane is moving the wind turbine is spinning, thus charging high capacity batteries located onboard the plane (Bennett, 2008). This energy can then be used for future take-offs and landings, eliminating the need for as much fuel as was previously required (Bennett, 2008). As one can probably presume, the wind turbine creates a drag force, and you would think that this would slow the plane down. However, there is an optimal point to use this wind turbine so that you do in fact gain something from it. Using the wind turbine at high altitudes limits the amount of drag, because the thin atmosphere at high altitudes puts less stress on the airplane (Bennett, 2008). This drag can also be used as an advantage; for instance when landing. At this time the wind turbine helps to slow the plane down, and in turn, helps the airplane to use even less fuel (Bennett, 2008). Dr. Popf estimates that by using wind turbines on airplanes, airlines could increase their fuel efficiency by 50-70% (Bennett, 2008). This is something to look forward to in the future.

In order to make wind turbines more efficient, companies have started to look towards the sky to find answers. Last year, NASA was given a \$100,000 grant from the federal government to research many types of airborne wind turbines (Webster, 2010). Mark Moore, an Aerospace Engineer for NASA, is currently undergoing the project, and he says that there is a lot of potential power in the sky that could be harvested (Webster, 2010). Moore says: "At 2,000 feet, there is two to three times the wind velocity compared to ground level. The power goes up with the cube of that wind velocity, so it's eight to 27 times the power production just by getting 2,000 feet up, and the wind velocity is more

consistent” (Webster, 2010). Taking a look at the following formula for calculating energy (in kilowatt-hours) from a wind turbine helps to prove this (Windpower Math):

$$E[kWh] = .5 * \rho * V^3 * A * Eff * H$$

In this equation, ρ is the density of air, V is the wind velocity, A is the area swept by the turbine rotors, Eff is the efficiency of capturing the kinetic energy that exists in the wind (as mentioned previously, this cannot exceed 59.3% according to the Betz Limit), and H is the number of hours for which the power was captured (Windpower Math). It is important to note that the wind velocity increases with height thus creating more energy; however, as height does increase the air density decreases. At 15,000 feet high the air density is about 57% of its density at sea level, and at 30,000 feet the air density is only about 31% of its density at sea level (Windpower Math). However, since the velocity in the equation is cubed, it offsets the decrease in air density, and, in the end, the cost per kilowatt-hour calculates out to be far less than from turbines on the ground.

When the fantasy of putting wind turbines in the air became a reality, many scientists and researchers jumped at the opportunity to do extensive research and begin making prototypes. Research shows that if we were to harvest just 1% of the energy from jet-stream winds it could produce enough power for everyone on the planet (Levesque, 2007). Companies such as Sky WindPower™ and Magenn Power™ are two such companies that have started researching and building prototypes for flying generators for high-altitude winds (Levesque, 2007). We chose to look at Sky WindPower™, since we thought their ideas were particularly interesting. This company is currently developing a 1,100lb “Flying Electric Generator” (or FEG) that incorporates the characteristics of a kite into its design (Levesque, 2007). This generator is designed to fly between 15 and 30,000 feet and is capable of producing power for as little as \$.02/kWh (Windpower Math). This process works by placing four rotors at each point of an H-shaped frame, giving the lift it needs to stay in the air like a kite. The electricity generated from the spinning rotors is then transferred to the ground through aluminum wires that are attached to the frame, keeping the generator in place (Levesque, 2007). For the future Sky WindPower™ has plans of building flying turbine farms and bigger flying turbines. Their plan calls for these FEGs to be bunched together in a 200 square mile restricted air zone (Windpower Math). To make the turbines bigger, Sky WindPower™ would like to construct the turbines out of aircraft materials; creating 130 foot diameter rotors that weigh about 45,000 pounds (Levesque, 2007). Once in the air, the FEGs would be able to tilt their rotors to optimize both wind speeds and harvesting energy (Levesque, 2007).

Another company, Makani Power™, is “developing Airborne Wind Turbines (AWT) to extract

energy from the powerful, consistent winds at high altitudes” (Makani Power). The set up is like this: First, there is a power grid and energy harvesting system on the ground. Attached to this by a tethering device sits a model airplane, about 13 feet across, that spins in a circular motion in the wind (using the principle of how a wind turbine spins to design specific wings for the plane). The optimal range for this is between the altitudes of 15 and 30,000 feet (Nguyen, 2011). This model is significantly smaller than the wind turbines currently used today, but it can harvest more energy and requires less cost (Nguyen, 2011). It can supply more energy, because at higher altitudes there is more wind, and the way this design works, it can harvest more energy using less wind (Nguyen, 2011). As we previously mentioned, the maximum efficiency of a wind turbine is about 60% according to the Betz Limit. The prototype that Makani Power™ has created can convert almost 100%, of this 60%, of the energy harvested into electricity (Nguyen, 2011). Wind turbines used currently can only yield about 50% of the maximum efficiency, so you can see the difference between the two. Also, this Airborne Wind Turbine can harvest energy at wind speeds starting at 20mph, whereas traditional wind turbines need more than 24mph winds to start producing power (Nguyen, 2011). The company has now received \$5 million in funding from Google™, and it hopes to scale up the technology and improve upon the aircraft’s aerodynamics (Nguyen, 2011).

With this breakthrough research, it is only a matter of time before more wind turbines and prototypes start heading further up in elevation to increase their maximum efficiency output, however we can see some drawbacks. The cables tethering the turbines would have to be strong enough to hold them to the ground (especially with the high velocity winds). Also, it could be a safety hazard for any small planes that might fly at a lower altitude. But, with the right precautions, these drawbacks can be eliminated and turbines can safely head to the sky. With companies like Makani Power™, Sky WindPower™, and Magenn Power™ all looking towards the sky, patents will soon start to be made, and hopefully, airplanes the way Dr. Josef Popf imagined, will start becoming more prominent.

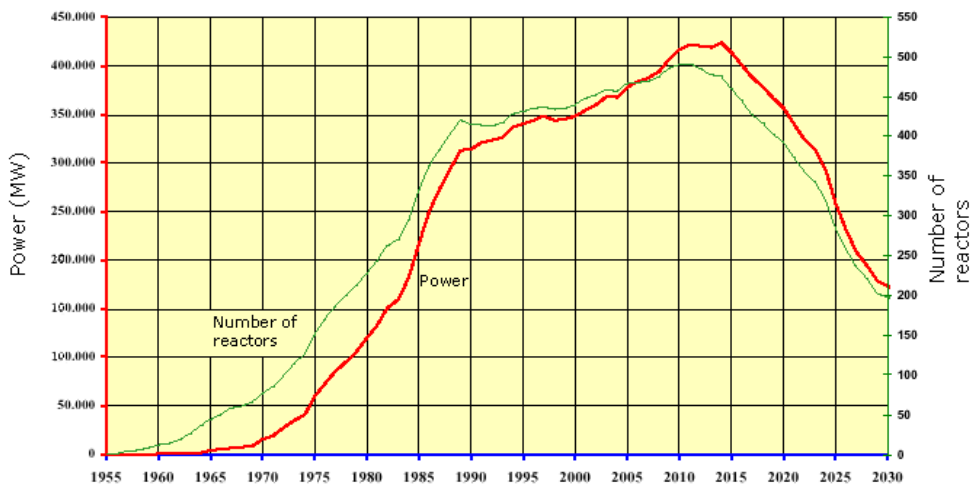
Chapter 3 - Nuclear Energy

We begin this chapter by looking at the nuclear reactors currently in operation. We will give a brief overview of their operation, their differences, and their drawbacks. We will then analyze their costs of operation and construction as well as their production capabilities. Finally we will touch on the future of fission reactors as well as the emerging technology of fusion reactions.

Current worldwide nuclear power production makes up 6% of global power generation and 13% of global electricity production. The majority of nuclear power is centered in 3 countries; the US, France, and Japan, which together constitute 50% of global production. There are currently 432 reactors in operation and 65 under construction as of August 2011. (World Nuclear Power Reactors & Uranium Requirements, 2012) The current 432 reactors generate 365,837 MW and the 65 reactors under construction are projected to generate 62,862 MW. (Nuclear Power Plants - Worldwide, 2012) The graph below shows the amount of power produced and the number of reactors. The projected reduction of nuclear power plants after 2015 assumes more decommissioning and termination of active reactors than construction of new ones. (World Nuclear Association, 2011)

Power and Number of Nuclear Reactors in the World

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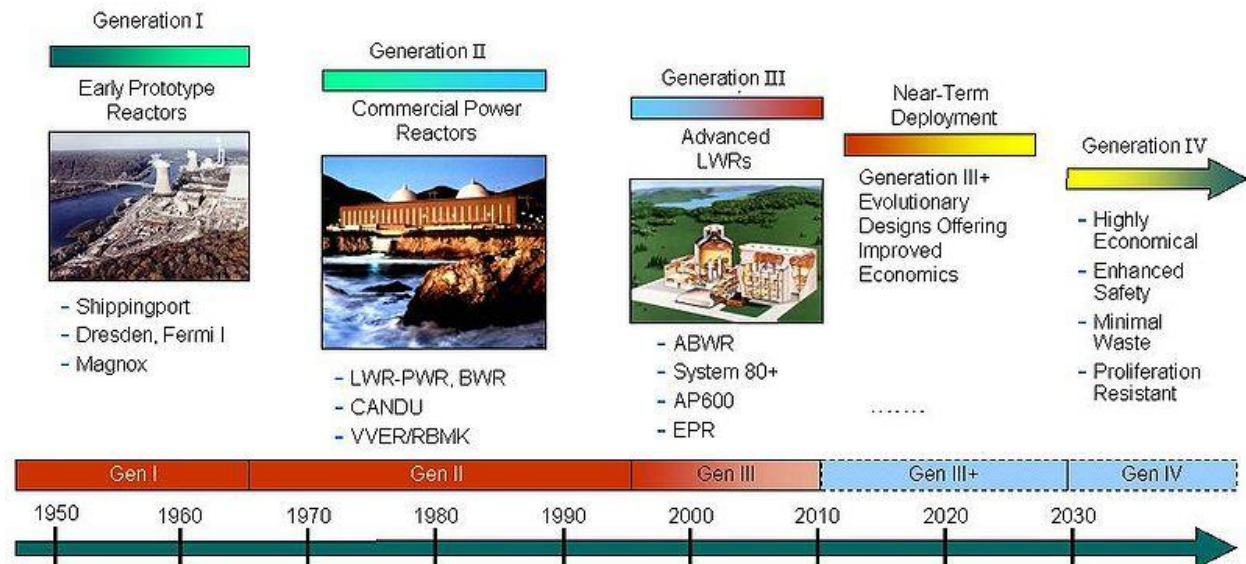
The diagram includes reactors that are currently used as well as all the reactors that are still under construction or seriously planned. It is very likely that in the next few years some new nuclear power plants will be constructed which means that the curve will continue growing even after the year 2015.

(Nuclear Power Plants in the World, 2001)

3.1 Types of Current Nuclear Reactors

Fission reactors have been characterized by their main characteristics into 4 “generations”, starting from the earliest models in the 1950s to the current reactors and future models. The diagram below shows the grouping of models by generation and their approximate dates of construction and operation. We will discuss reactors only in Generations II, III and finally IV with future models.

Generation IV: Nuclear Energy Systems Deployable no later than 2030 and offering significant advances in sustainability, safety and reliability, and economics



(Jan Leen Kloosterman, TU-Delft, 2012)

There are several different types of reactors, each using different control methods and different fuels. For example, most current reactors use U-235 which makes up about 0.7% of all known earth uranium deposits. Another uranium isotope, U-238 can also be used in nuclear fission and makes up the remaining 99.3% of known deposits. Light water reactors use U-235, but newer breeder reactors use the U-238, which has an expected usable lifetime of 5 billion years. Breeder reactors get their name because they produce more nuclear fuel during the reaction cycle than they consume to keep the reaction running, thus they “breed” fuel. There is current interest to configure conventional reactors to utilize U-238 and thorium due to the complexity of the breeder reactors.

Light water reactors (LWRs) are the most common type of reactor used for power generation. They utilize water as a coolant and neutron moderator. (Overview of Nuclear Energy, 2012) A neutron moderator is the substance used to slow the neutrons and lower their energy level to sustain a fission reaction. The primary substances used are light water (water), heavy water (deuterium) and graphite.

Light water is used in about 75% of all thermal reactors, graphite in about 20%, and deuterium in 5%. Of the LWRs there are three main subtypes: pressurized water reactors (PWRs), boiling water reactors (BWRs), and supercritical water reactors (SWRs). PWRs are the most common reactors (~240) and so this model will be explained in detail to provide the reader with a basic understanding of how modern nuclear reactors function.

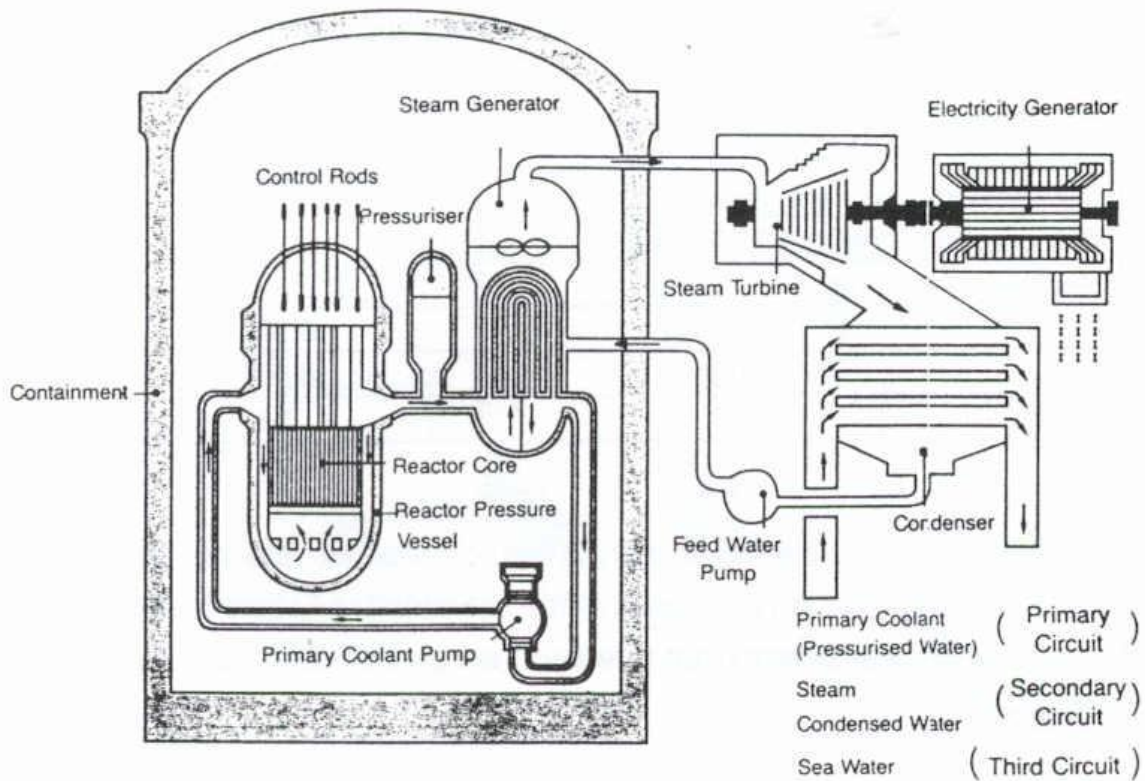


Figure 1. A schematic diagram of a pressurised water reactor

(Guangdong Nuclear Power Station ...Is It Safe Enough?, 1994)

A PWR functions by pumping water under high pressure to the reactor core where it is heated by the energy generated by the fission with the reactor core. The heated water is then pumped to a steam generator where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which in turn spins an electric generator. The pressurized water in coolant loop prevents the water from boiling within the reactor, unlike the BWRs. After passing through the turbine the secondary coolant (water-steam mixture) is cooled down and condensed in a condenser. The condenser converts the steam to a liquid so that it can be pumped back into the steam generator, and maintains a vacuum at the turbine outlet so the energy extracted from the steam can be maximized. The main difference between a BWR and a PWR is the pressure at which the water is kept at as it flows

through the core. The water in a BWR is pressurized to about 1100 psi and evaporates into steam directly to power a turbine whereas in a PWR the water is pressurized to about 2400 psi and so does not evaporate.

Another type of Generation II reactor is the CANDU reactor which stands for Canada deuterium-uranium reactor. As the name suggests these reactors were developed in Canada and utilize heavy water as a coolant and neutron moderator. The heavy water is pressurized and pumped through the core as the primary coolant. It is then run through a steam generator to transfer the thermal energy to a secondary coolant of light water which then evaporates and powers a steam turbine. Since CANDU reactors use uranium, heavy water is used as a neutron moderator because it works more efficiently to separate the uranium from the neutrons.

Generation III reactors are advanced LWRs with improved technology incorporated into Generation II reactor designs. They utilize better fuel technology, higher thermal efficiency, and more effective safety features. Examples of Generation III reactors are advanced boiling water reactors (ABWRs), AP600s, System 80+ and European Pressurized Reactors (EPRs). The main difference between generation II reactors and the EPR is the additional internal safety systems. They are equipped with four independent emergency cooling systems, additional containment, a secondary cooling area around the primary containment in case of core meltdown, and double concrete walls 2.6 meters thick, capable of withstanding unforeseen internal and external stresses. Their additional safety features are important when the current emphasis on nuclear safety is the main argument against its utilization.

The current Generation III and Generation III+ reactors, while more efficient and safer than earlier reactors, do not represent the future for nuclear technology. Generation IV reactors are currently being researched. There are 3 main types of thermal reactors being investigated, Very High Temperature Reactor (VHTR), Supercritical-Water-Cooled Reactor (SCWR), and the Molten-Salt Reactor (MSR). Along with these 3 designs there are 3 fast reactor designs: Gas-Cooled Fast Reactor (GFR), Sodium-Cooled Fast Reactor (SFR), and the Lead-Cooled Fast Reactor (LFR). Fusion reactors are not considered in this category due to their completely different specifications and technology. The listed reactors are currently being researched and expected to be viable within the next 10-20 years whereas fusion reactors require far more time and effort. Below is a brief overview of the benefits and downsides of each type of Generation IV reactor. (Generation IV Nuclear Reactor Comparisons, 2008) (Nuclear Reactor Technology, 2011) (IAEA, Nuclear Power Reactors in the World, 2006)

Reactors	Advantages	Disadvantages
VHTR	<ul style="list-style-type: none"> • Helium Coolant • Thorium/Uranium Fuel • Electrical power efficiency > 50% • Hydrogen Production 	<ul style="list-style-type: none"> • Low thermal conductivity of Helium • Limited research interest
SCWR	<ul style="list-style-type: none"> • 45% thermal efficiency • Compatible with PWR/BWR reactor components • Does not require jet pumps, pressurizers, or dryers • Improved version of PWR/BWR reactors 	<ul style="list-style-type: none"> • Research on supercritical water necessary • High water pressure increases risk of Loss of Coolant Accident • High temperatures/pressures require new research on materials
MSR	<ul style="list-style-type: none"> • Small reactor size • Technology is researched and ready for use • Higher operation temperatures • Chemical retention of fission products 	<ul style="list-style-type: none"> • High corrosion risk • Corrosion resistant material must be found
GFR	<ul style="list-style-type: none"> • Breeding capabilities • Higher power density • Uses new fuel design 	<ul style="list-style-type: none"> • Low thermal conductivity of Helium • Fast neutron damage • Research required
SFR	<ul style="list-style-type: none"> • Shares all advantages with fast reactors • 2 primary fuel cycle technologies • Recovers/recycles 99.9% of actinides • Low decontamination factor of product • No separation of plutonium • Thermal efficiency of 40% 	<ul style="list-style-type: none"> • Design is expensive • More research required for fuel system, passive safety and component design • Sodium explosive on contact with air/water
LFR	<ul style="list-style-type: none"> • Operates unpressurized, eliminates possibility of LOCA's • Can be assembled off-site • Can be modified to utilize H₂ • Long time between refueling (10-20 years) 	<ul style="list-style-type: none"> • Requires more research before viable (expected 22 years) • New fuel requires performance analysis • Off-site manufacture increases possibility of errors in fabrication

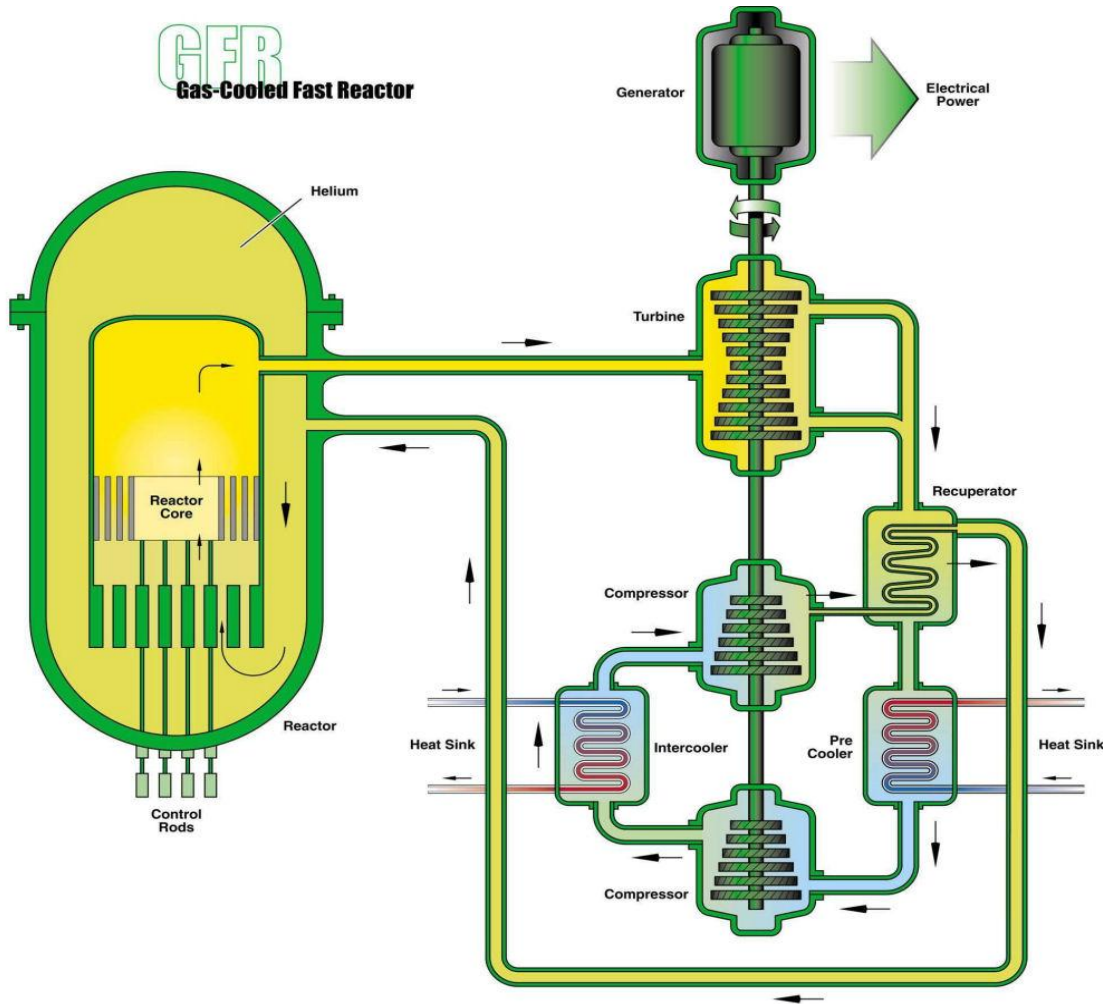
VHTR reactors use Helium coolant in place of traditional coolants, allowing for an average operation temperature greater than 1000°C. The core is comprised of Thorium-232 and Uranium-235,

surrounded by a graphite shell. This design allows easy access to the core, which makes core maintenance easier and recycling/refueling more efficient. This eliminates the majority of loss from maintenance shutdowns, characteristic of traditional reactors. The helium coolant can be used directly as a turbine propellant, in place of heated steam, or it can be used to produce hydrogen gas at higher efficiency levels than earlier reactor designs. An additional feature of the helium coolant is that if there is a fuel cladding failure, radioactive material will not be cycled through the cooling system. The major issue preventing the production of this reactor design is the limited interest in research.

SCWR reactors are essentially LWRs with higher operating temperatures and pressures. The reactor is one of the more popular designs because most of the technology required is already used in PWRs and BWRs, thus it is a cheaper option than other Generation IV reactors. Consequently the design is primarily for low-cost electricity production. The coolant water around the core is about 500°C and is under such high pressure it is incapable of boiling. Unlike its predecessors, the SCWR reactors do not require steam generators or evaporators. The fuel used in SCWRs is low-enriched Uranium and the overall simple reactor design allows for a much smaller reactor complex than current designs. The problem facing this reactor design is the supercritical water itself and the necessary materials required to safely contain it. This can be a serious drawback due to current safety concerns facing nuclear power generation after the Fukushima incident.

The final primary candidate for Generation IV thermal reactors is the Molten Salt Reactor. MSRs operate at lower pressures but higher core heating efficiencies. This makes them ideal for use in nuclear powered aircraft, submarines, and ships. MSRs are separated into two types, molten salt fueled reactors (MSFRs) and molten salt cooled reactors (MSCRs). MSFRs use Uranium and Thorium fuel dissolved in the salt, which reduces chemical reactivity and alleviates corrosion on the core and its containment. Its characteristic low-pressure operation allows for multiple smaller cores rather than a single large one, reducing risks and increasing mobility. The reactors are also capable of being used for breeding purposes, but if the fuel is removed from the coolant, the corrosion issue returns. At the current time, no material capable of the required corrosion resistance has been developed, however research is ongoing. The corrosion is caused by the fluoride salts reacting with the coolant water, which creates hydrofluoric acid. This means constant reprocessing and purification, which increases neutron economy of the reactor but also requires constant energy consumption. The overall design with low pressure operation, smaller reactor cores, and higher efficiency and operation temperatures makes it an ideal candidate for future utilization and improvement.

There are 3 major designs for Generation IV breeder reactors based upon the thermal reactors. The Gas-cooled Fast Reactor (GFR) uses a helium coolant similar to the VHTR. Instead of the standard steam-driven turbine to generate electricity it utilizes a Brayton Power Cycle. A Brayton Power Cycle occurs in a closed cycle gas turbine and follows a 4 step process within the reactor system. First the gas is compressed without heat transfer (system is insulated from surroundings) and heated; it is then transferred to a turbine where it is allowed to expand, thus driving the turbine; the gas is then allowed to return to its normal state before being returned to the compressor.

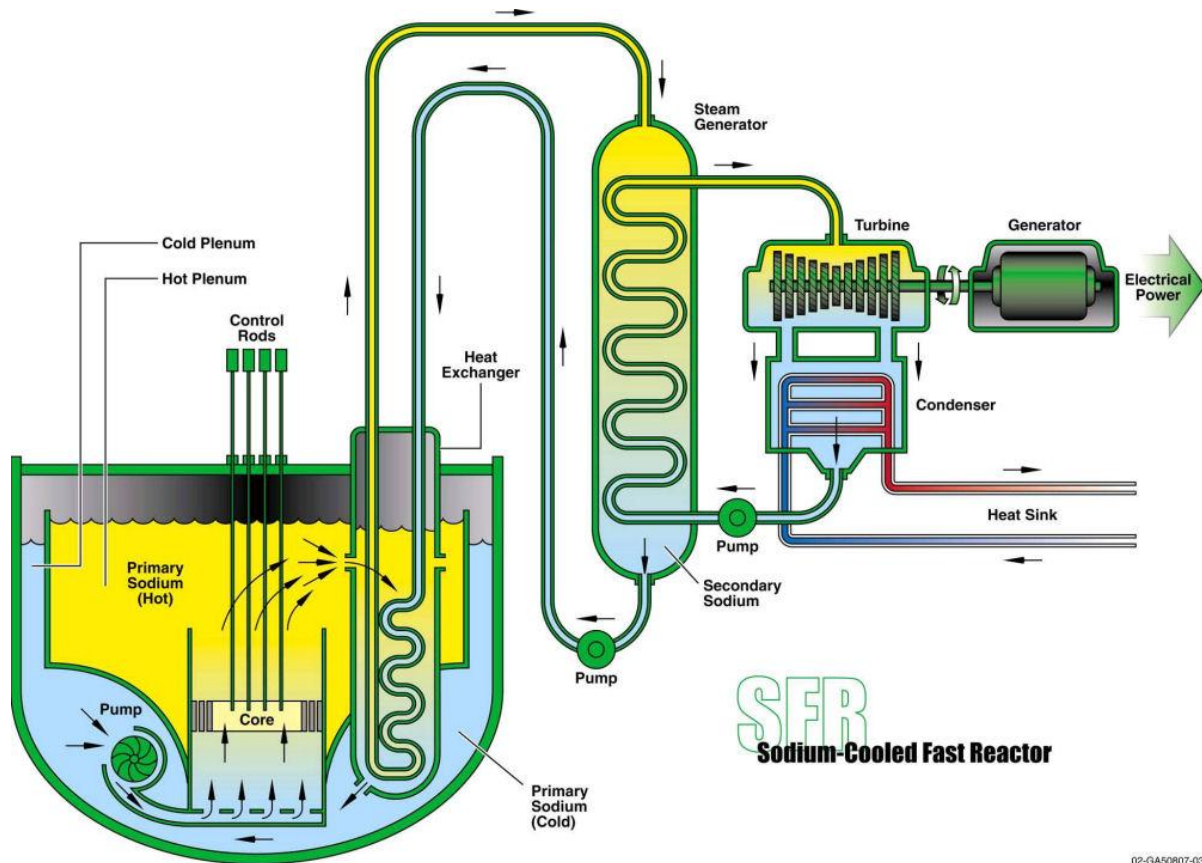


(Generation IV Nuclear Reactor Comparisons, 2008)

Unlike VHTRs the GFR utilizes fertile Uranium and other fissile fuels without neutron moderation, allowing for effective fissile fuel breeding over time. Due to the lack of neutron moderation and internal high temperatures, the core needs to be redesigned with a material capable of withstanding the stresses of the core. A suggested cladding is Zr_3Si_2 which has higher heat transfer and

fast neutron reflection characteristics. More testing has to be done in order to assure the safety and reliability of the new components before this type of reactor can be used commercially.

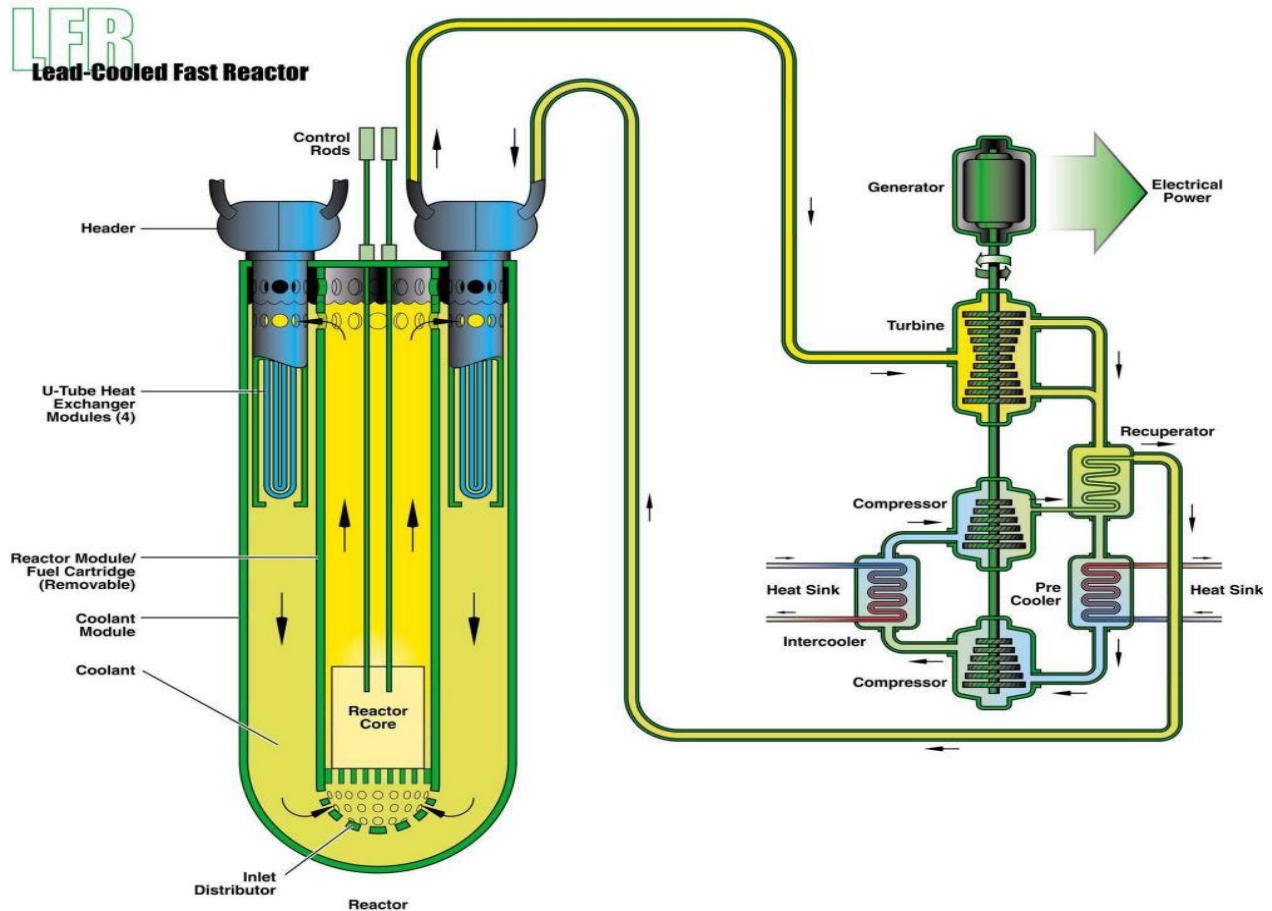
Sodium-cooled Fast Reactors (SFRs) utilize sodium as a neutron moderator instead of water or other liquid coolants. Sodium is heavier than other coolants and it has the beneficial property of absorbing less energy from colliding neutrons, making the reactor more efficient. The core fuel itself is a uranium-plutonium mix. There are 2 sizes of SFRs, an output of 150-600MWe (Megawatts of electricity), and an output of 600-1500MWe. The smaller size uses uranium-plutonium fuel mixed with metal alloys whereas the larger build uses uranium-plutonium oxide. The sodium coolant leaves the reactor unpressurized at 510-550°C and is sent to a heat exchanger where its thermal energy is transferred to a secondary system and finally the energy is transferred to a turbine and a generator. The benefit of this reactor design is its reliability. The technology is within a decade to usability in the United States for electricity generation and several of the reactors have been built and are in operation across Europe.



(Generation IV Nuclear Reactor Comparisons, 2008)

The third major design for Generation IV breeder reactors is the Lead-cooled Fast Reactor (LFR). As the name suggests lead is the primary coolant in this reactor, while the fuel is uranium. Another

difference between this reactor and other designs is its capability to utilize the Multi-TRU recycling process due to its closed fuel cycle. TRU (transuranic) wastes are man-made elements with higher atomic number than uranium. TRU waste refers not only to fuel waste itself but any other material impregnated with high energy radiation; in the case of the recycling process we refer only to the fuel waste. TRU recycling is only possible in a closed fuel cycle system, which means the fissile fuel is recycled or use.



(Generation IV Nuclear Reactor Comparisons, 2008)

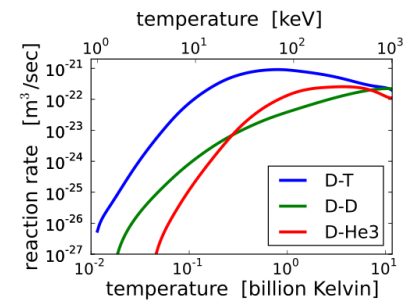
The technology required for a functional closed fuel cycle system will require about 20 years of research, but the benefits of little to no nuclear fuel waste could make nuclear technology viable as a renewable resource. The lead leaves the core at temperatures between 550-800°C and is unpressurized much like the SFR. The system operates much like the SFR system but lead facilitates natural circulation. This characteristic along with the unpressurized coolant act as passive safety measures within the reactor. The nuclear plants can be produced in modules, allowing for off-site fabrication and variable

size designs. The smaller version produces 50-150MWe, the medium design produces 300-400MWe, and the largest design generates 1200MWe.

3.2 Types of Fusion Reactors

The predicted future of nuclear power, providing its intrinsic safety concerns can be properly addressed, is fusion reactors. Nuclear fusion research receives € 750 million, compared with € 810 million for all non-nuclear energy research combined. Its lack of high-energy radiation and inability to be used for arms creation make it a prime possibility to answer the world’s energy crisis. Fusion reactors are categorized into two major design groups and their fuel cycle type. There are other designs however they are either not suitable for power generation or are not adequately researched. The two major types of fusion reactors are the magnetic containment reactors and the laser containment reactors. The different fuel cycles are detailed below along with reaction temperatures.

Symbol	Fuel Cycle	Reaction
D-T	Deuterium-Tritium	${}^2\text{D} + {}^3\text{T} \rightarrow {}^4\text{He} + {}^1\text{n}$
D-D	Deuterium-Deuterium	${}^2\text{D} + {}^2\text{D} \rightarrow {}^3\text{T} + {}^1\text{H}$ ${}^2\text{D} + {}^2\text{D} \rightarrow {}^3\text{He} + \text{n}$
D- ${}^3\text{He}$	Deuterium-Helium 3	${}^2\text{D} + {}^3\text{He} \rightarrow {}^4\text{He} + {}^2\text{n}$
p- ${}^{11}\text{B}$	Proton-Boron 11	${}^1\text{H} + {}^{11}\text{B} \rightarrow 3{}^4\text{He}$



(Dstrozzi, 2006 (Revision))

The deuterium-tritium cycle is the easiest fusion reaction due to the abundance of naturally occurring deuterium. (Nuclear Fusion) Tritium must be bred by bombarding lithium with neutrons. Since the fusion reaction itself creates the neutrons the reaction can be self sustaining with only the lithium requiring procurement from outside the reaction. Usually the reactor core itself is constructed containing various isotopes of lithium, however lithium is growing more difficult to use due to its widespread use in other applications such as lithium-ion batteries. The deuterium-deuterium reaction is slightly more difficult to operate than the deuterium-tritium reaction, but it has the advantages of requiring no lithium, producing tritium and emitting a lower energy neutron. The drawbacks to this fuel cycle are the greater required confinement (30X) and lower energy output (68X). The least used of any

of the fuel cycles is the deuterium-helium 3 fuel cycle. (Shuy, 1980) The major problem with this cycle is the requirement for helium 3, which does not occur naturally on Earth. The helium 3 must come either from a different nuclear reaction, the Moon's surface, or the atmosphere of a gas giant like Jupiter. The energy is primarily released as charged particles, which helps reduce activation of the reactor housing and potentially allowing more efficient energy harvesting. The proton-Boron cycle is most notable for its lack of neutron production. This characteristic is useful if the presence of neutrons is a problem however the required reaction temperature is close to 10X higher than a D-T cycle. Other problems with this fuel cycle include its low power density (2500X less than a D-T cycle) and its containment requirement (500X greater than D-T). These characteristics make this fuel cycle unsuitable for marginal laser or magnetic containment and consequently require radically different reactor designs, such as the Polywell and the Dense Plasma Focus.

Magnetic containment came about during the 1950s as scientists attempted to achieve a stable fusion reaction. The reactor functions by running an electric current through the plasma which generates a magnetic field. The entire process is based upon Lenz's Law which states:

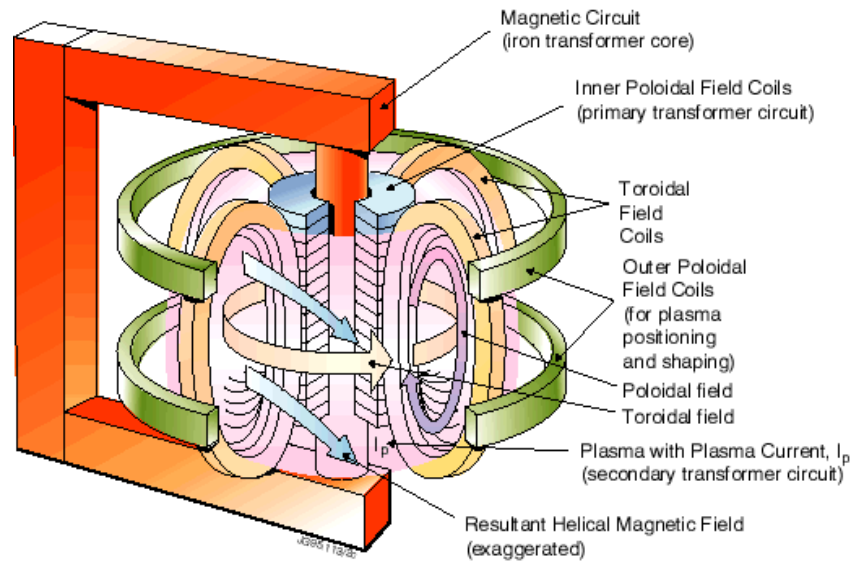
When an emf [electromotive force] is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such that it produces a current whose magnetic field opposes the change which produces it. (Faraday's Law)

$$\varepsilon = -N \frac{\Delta\Phi_B}{\Delta t}$$

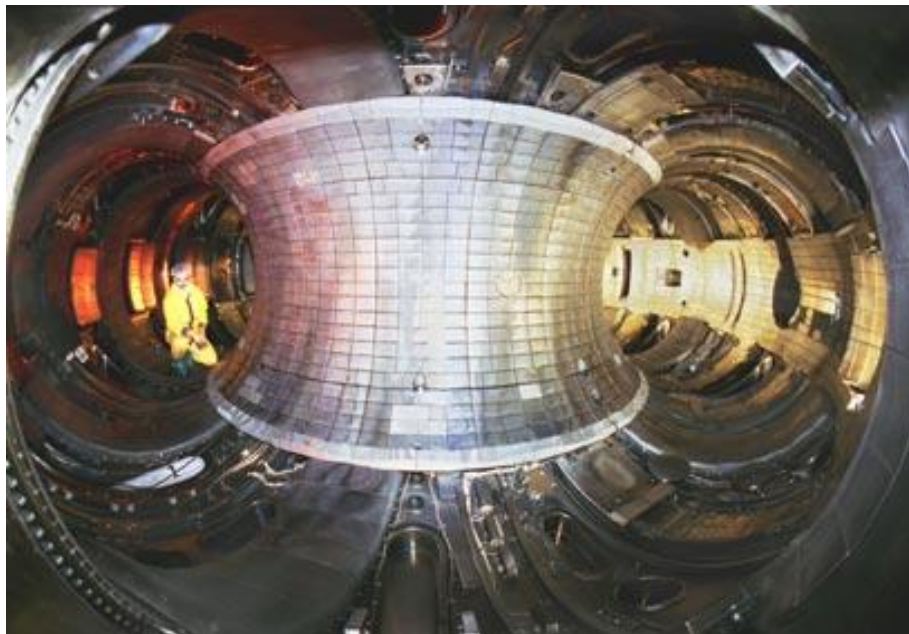
Lenz's Law is closely related to Faraday's Law of Induction, with ε the induced emf, $\Delta\Phi_B$ the change in flux over one loop, and N the number of identical loops in the wire. This field is inwardly directed and forces the plasma to collapse in upon itself, raising the density. As the plasma density increases so does the strength of the magnetic field it generates, thus creating a chain reaction. This can lead to plasma densities and temperatures needed for a fusion reaction. The electric current is introduced into the plasma from an external magnet, which also produces the external field the internal field acts against.

There are several designs utilizing magnetic containment, such as the aforementioned Polywell, however there is only one dominating design with possibilities for commercial energy production within the next few decades, the "tokamak" reactor. (F. Najmabadi, 1991) The tokamak was first experimented with in 1956 by Soviet scientists and was greatly improved during the 70s and 80s. They function by utilizing a flow of ionized particles to heat the plasma fuel and keep the fusion reaction running. This

requires a plasma temperature of about 100 million degrees Celsius. Methods for extracting energy from these reactors are still under research, as is the methods to maintain plasma temperature. Below are images, one a basic template for a tokamak reactor, the other a picture of the interior of the Tokamak Fusion Test Reactor located at the Princeton Plasma Physics Laboratory.



(Nuclear Fusion, Fusion Reactors, 2012)



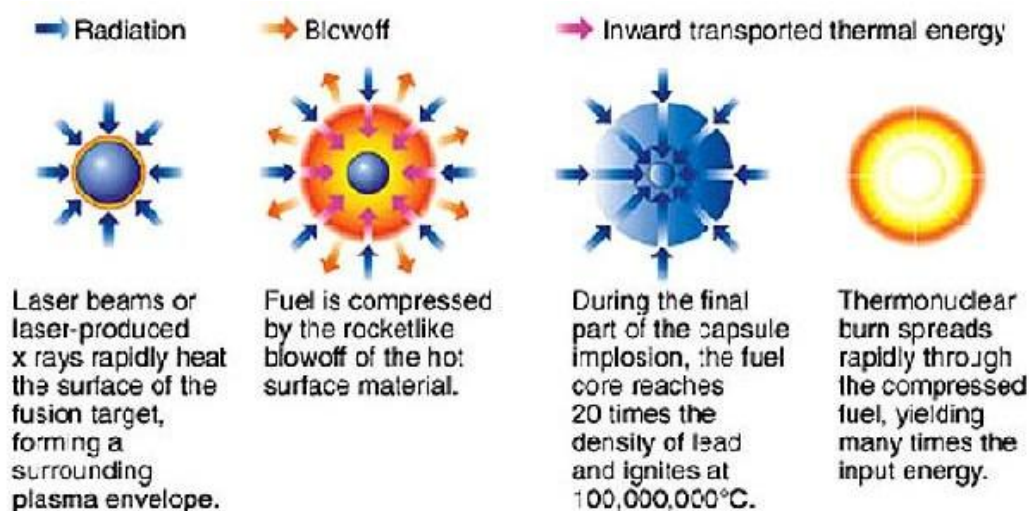
(Tokamak Fusion Test Reactor, 2002)

The modern designs utilize new geometries and materials to improve the containment density and stability, but a functional tokamak reactor is estimated to be decades away. Inertial (laser) containment is also a possibility, and does not require as much research because it is much easier to transfer the energy from the production. The lasers act on the semi-bare core as opposed to a core surrounded by a magnetic field and so core maintenance is much easier. Research is required in the areas of energy removal and tritium replacement before this technology can be implemented. Several small test tokamak reactors have been made, not to test for energy production capabilities, but rather the stability of the design and viability for future use. Nuclear fusion requires primarily deuterium, which is highly abundant in seawater (1 /6500 hydrogen atoms are deuterium) and thus there is enough fuel to generate enough power for the globe for millions of years.

Inertial Confinement Fusion (ICF) is one of the two major designs for future power-production fusion reactors. They were first developed alongside the magnetic confinement fusion reactors beginning in the 1970's. However due to imitations in laser technology during this time period and extremely lower efficiencies the design was largely abandoned until more recently. Within the past 5-10 years new advances in laser technology, particularly newer types of lasers, have allowed for much higher efficiencies, allowing the design to become a viable option for energy production. Estimates of between 35%-40% efficiency are within the competitive range of traditional coal power production.

The problems that held back laser technology can be grouped into two major categories. One problem was creating perfectly circular fuel pellets. The solution to this problem depends on the composition of the fuel pellets. One solution involves using cryogenic hydrogen ice to freeze a thin layer of deuterium to the inside of the plastic sphere and smoothing it with a low power IR laser. The aberrations on the fuel pellet can be no larger than a few micrometers on both the outer surface as well as the interior. The other problem is the accuracy, timing, and even energy distribution of the multiple laser beams. If the energy delivered to the pellet is uneven it may induce uneven compression, forming Rayleigh-Taylor instabilities, lowering the efficacy of the entire process. The problem dealing with timing and accuracy can be solved by using delay lines in the beam's optical path, causing all beams to strike the pellet within picoseconds of each other. Pellets filled with a mixture of deuterium and tritium are "self-smoothing" due to the small amount of heat caused by the radioactive decay of the tritium isotope; this is called "beta-layering". To solve the issue of even energy distribution various diagnostic regulators and beam smoothing techniques have been placed on the systems, but Rayleigh-Taylor instabilities are still a major issue.

The ICFs function by utilizing multiple lasers pointed at a fuel pellet to drive the fusion process. The fuel pellet is about the size of a pinhead and contains 10 milligrams of fuel, usually deuterium and tritium. The laser is directed at this fuel pellet and heats it until the outer layer explodes forcing the subsequent combustion of the inner layers inward through compression. This may cause shockwaves to travel inward and further compress the interior of the pellet, initiating the fusion reaction. The core is compressed to a density of about 1000g/cm^3 , 100 times the density of lead. While this density is not usually sufficient for fusion the presence of the shock waves amplifies this density to ranges capable of initiating fusion. Ideally this reaction will continue beyond the initial combustion, causing a chain reaction that consumes the majority of the fuel. This process is called “ignition” and is the primary goal of ICF. If the entire pellet is consumed the output energy is equivalent to that of a barrel of oil. Normally only one laser is used, called the driver, which is split into several beams and amplified a trillion times before being sent into the target chamber by means of mirrors, ensuring complete coverage on the pellet.



(Inertial Confinement Fusion, 2009)

The most recent research into the viability of ICFs is currently taking place at the National Ignition Facility (NIF) in the United States and the Laser Megajoule (LMJ) in Bordeaux, France. (Le Laser Megajoule, 2012) (National Ignition Facility & Photon Science, 2012) The NIF was recently completed in March 2009 and has conducted experiments utilizing all 192 laser beams. The LMJ uses 240 beams to deliver about 1.8MJ of energy to the target pellets, which is comparably powerful to the NIF. Both facilities currently utilize a technique known as “indirect drive” to achieve fusion. This process involves using the lasers to heat a cylinder of high-proton metal (usually gold). Once heated this cylinder, called a

“hohlraum”, emits x-rays which heat the pellet contained within the hohlraum. This method loses large amounts of energy in order to heat the hohlraum, however the emitted x-rays are much more efficient at rapidly heating the pellet than the lasers themselves.

Another method currently being researched is “fast ignition”. This process involves heating the high density fuel after compression, instead of concurrently. It begins with the standard compression via continuous laser bombardment however when maximum density is achieved a second ultra-short laser pulse delivers a single pulse on one side of the core, dramatically heating it and initiating a fusion reaction. This ultra-short laser pulse delivers power in the petawatt ($PW=10^{15}$ Watts) range.

Several newer facilities are under either the planning or construction phase, including a facility funded by the EU known as “HiPER”. The HiPER design utilizes the fast ignition to dramatically reduce the required input energy from 2MJ per beam in the NIF to about 200kJ for the main driver beam. Along with this reduction its output energy is expected to be greater than that of NIF. The NIF facility requires about 330MJ of electrical power to produce the main driver beams, yielding a total output of about 20-45MJ whereas HiPER requires about 3MJ assuming a first-generation laser driver (efficiency 10%), however it is expected to produce around 30MJ of fusion power.

The problems facing ICFs are largely the same as those confronting magnetic confinement reactors. Power extraction from the reaction chamber without affecting the target and driver beams along with excessive radiation caused by the large number of released neutrons remain the largest difficulties. Additionally fusion plants constructed from traditional materials such as steel would have a short expected lifetime and core containment vessels would require frequent replacement. At the current level of research ICF systems cannot compete economically with traditional fossil fuels such as coal due to their higher costs of construction and maintenance as well as the cost of the core elements themselves. Their only advantage is their lack of extensive pollution and contribution to global warming. Despite these large drawbacks newer generation facilities and upgrades to existing ones such as the NIF are within a few years of development. The NIF for instance is expected to begin its second stage experiments in 2012-2014 and the Laser Megajoule is also expected to begin further experiments around the same time.

3.3 By the Numbers Power Production

Nuclear Reactor Type	Construction Cost (Billion \$US/ 1000MW Capacity)	Construction Time (years)	Electricity Production (MW)	Typical Plant Turn Key Costs (Billion \$US)
LWR (PWR/BWR)	2.1-3.1	6-8	600-1750	1.5-4.2
CANDU	2.5-3.5	4-5	500-1300	2.5-5+
VHTR	NA	NA	600-1200	NA
SCWR	NA	~10	350-1650	NA
SFR	5.0-5.5	7-8	1000-1500	4.5-5
LFR	4-6	4-5	100-1000	4-5
Tokamak	~30	10	500 (research)	NA
ICF	NA	NA	NA	NA

(OECD, 2000) (China's construction moving ahead on CEFR "fast-neutron" nuclear reactor , pre-2010)

(Fast Neutron Reactors, 2011) (Technology Developments Russian Nuclear Power, 2010) (Power Plant

Design - Fast Reactors - The low-power SVBR-100 , 2011) (ITER Facts and Figures, 2012) (Guido

Baccaglioni, 2003) (IAEA, Status Report 68 enhanced CANDU-6 (EC-6), 2011)

3.4 Limitations of Nuclear Reactors

The major limitations of the current reactors is not with their energy production but rather with the safety of the reactors themselves, the disposal of the radioactive waste, and the byproduct of possible nuclear proliferation. Within the United States there is a large public resistance to nuclear technology, due to the infamous accidents of Chernobyl and Three Mile Island. This antipathy has halted all construction projects for future reactors since 1979. Due to this lack of new construction there has been little incentive to further research improvements to current fission technology within the United States. However globally there has been less resistance to nuclear utilization and advances have been made, mainly with the breeder reactor, but also with newer fusion reactors.

Current nuclear waste disposal within the United States is handled by the nuclear power facilities for short term storage. All waste produced is stored in steel-lined concrete pools filled with water or in airtight steel/concrete containers. The future plans for this hazardous waste is to store it in a

large geological repository such as the Yucca Mountain facility. The Yucca Mountain Nuclear Waste Repository was approved by Congress in 2002 despite protest from residents in Nevada but the project was scrapped in 2009 due to lack of funding in the 2011 government budget. For the foreseeable future all waste will continue to be stored at the nuclear power plants themselves until a proper plan for safe disposal is executed. (Nuclear Waste Disposal, 2012) In Europe the waste produced by each nation's reactors is either disposed of in repositories within each nation or shipped to repositories in other nations within Europe. International repositories haven been suggested to centralize nuclear waste but currently there are none operational.

The issue of nuclear proliferation has had an effect on construction of fission reactors, especially in places experiencing political and religious turmoil. Due to the production of uranium 235 and particularly plutonium 239, construction and operation of nuclear reactors has been strictly monitored internationally via the IAEA. The uranium 235 used in nuclear reactors is only between 3-5% pure when 90% purity is required for weaponization. Plutonium 239 can be used directly for nuclear weapons and is therefore under closer scrutiny.

While breeder reactors share largely the same limitations as traditional light water fission reactors they do not generate as much waste. Traditional reactors only consume 1% of the uranium used to start the reactions fuel cycle whereas breeder reactors completely use it up, with small losses during re-processing. Breeder reactors actually produce more fuel than they consume. As an example standard fission reactors have breeding ratios around 1 while breeder reactors have ratios between 1.2-1.8 depending upon time of construction and current research. The "breeding" is achieved by neutron irradiation of fertile material, particularly U-238 and Thorium-232. This irradiation causes the fertile material to become active fissile fuel such as plutonium as the fertile material decays. All reactors are designed to do this on a small scale, but breeder reactors are specialized for this. Current technology reactors cost between \$3-5 billion including operation costs and safety requirements. Breeder reactor costs are not significantly higher, between \$3-8 billion, but their reduced waste production makes them more environmentally friendly.

Limitations of fusion reactors are primarily technological and financial. As far as safety is concerned, the lack of high-level radiation and the construction and operation of a fusion reactor do not allow for any large scale accidents. The only safety concern is a leakage of tritium into the atmosphere but due to the small amounts present in a fusion reactor the dissipation of the tritium is such that it would be at a legally safe concentration by the time it left the reactors location. The same containment facilities in place for traditional reactors are sufficient for safe operation of a fusion reactor. There is no

waste from a fusion reactor until its shutdown when the materials in the facility must be disposed of. This disposal is nearly the same as that for fission reactors but with one important difference, fusion reactors do not require specialized materials in construction therefore radiation-absorbing materials can be replaced by those with less absorption properties. Effects of large scale emission of tritium in a fusion reactor based world are currently being researched. Currently there is no functional power-generating fusion reactor in existence but research into energy siphoning techniques is ongoing and small fusion reactors are being tested for viable future use. (Reed, 2011)

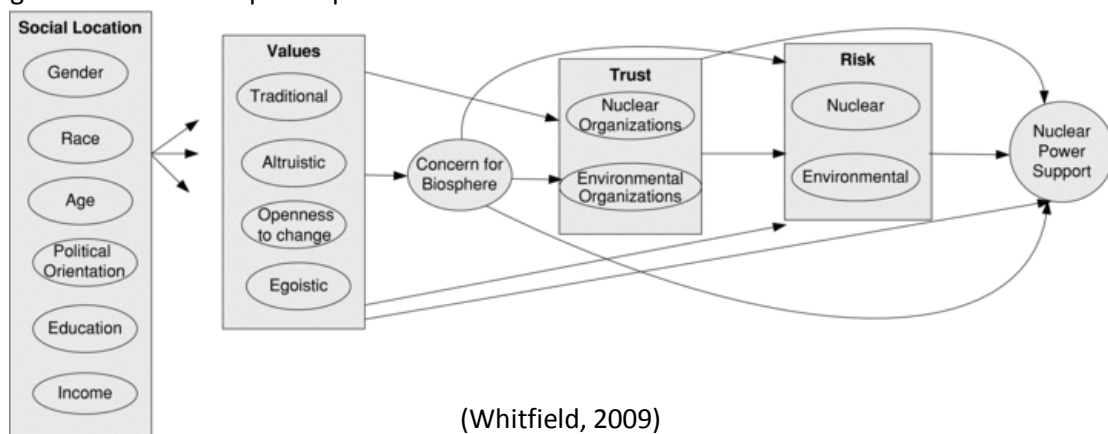
3.5 Social Implications of Nuclear Reactors

Only recently (within the last 25-30 years) has the social impact of nuclear facilities on the neighboring populations been considered beyond aesthetics. In 1973 26 utilities were surveyed by the Atomic Industrial Forum (AIF) to find out whether or not the utilities were considering social impacts of their operation. The results showed only 2 utilities attempted to address the social impacts, with only 8 considering social impacts beyond aesthetics. (Peelle, 1974) Further research in 1974 identified three major branches of impacts concerning only construction and operation of nuclear power plants. These branches are physical impacts upon the surrounding environment, effects of nuclear radiation and its dangers, and finally the impact on the social structure itself. (Peelle, 1974) The construction itself is not much different than the construction of any other major structure as far as investment, permission, and relocation of resources and manpower, with the process taking about 7-8 years.

Impacts upon the environment had been studied from the scientific viewpoint, including analysis of air, water, and land pollution as well as effects on the ecosystems surrounding the power plant. There was very little interest in exploring the effects of land usage for all the accessory buildings, new road construction or existing road congestion from plant operation, scenic destruction, and endangerment of aquatic resources. The problem faced when evaluating such impacts without quantitative methods is very difficult and social changes may only be observed after a longer term in some cases. The most prevalent social effect of the construction and maintenance of a nuclear plant is the growth of nearby towns to accommodate the influx of workers to build and operate the plant. This influx has economic impacts such as population growth, job creation and greater economic prosperity for the town along with the stresses of overtaxing such facilities. The distribution of the new wealth may not be in favor of the original inhabitants as they may not be technically trained and thus would not

benefit from the creation of the new jobs. Another effect of increased population is the required infrastructure to sustain a larger population including utilities such as water supply as well as social impacts such as poverty and greater crime rates. Land prices may also increase dramatically along with tax rates, forcing some original inhabitants from their communities and severely stressing others. For example in Waterford, Connecticut the social demographic altered from a balanced population of young families with children, middle-class and affluent families, elderly, and poor to primarily affluent and middle class families due to cost increases. (Peelle, 1974) The final branch of the study, dealing with perceived radiation danger, concluded the population was moderately concerned with possibility of radiation dangers. This is partly due to lack of knowledge concerning the safety measures of nuclear plants and the effects and properties of radiation itself. The accidents occurring at power plants such as Chernobyl, Three Mile Island, and Fukushima serve to alienate people from the possibility of future utilization of nuclear energy as a renewable resource. Without a complete understanding of the causes of these events and a basic understanding of the operation of a nuclear plant it is difficult to accurately assess the dangers of such plants.

In order to accurately assess the impacts to social structure we must first develop a method by which we can take as many factors into account as possible and evaluate each on its own merits. One cannot simply make a monetary analysis and in many cases the evaluation must take place on a site-by-site basis, as each site has its own issues. Below is an example of a Stern-Dietz environmental decision-making model for nuclear power plants:



As the reader can see there are a large amount of factors involved in how people prioritize risks and decide what is acceptable or not. A suggested criterion for analysis of social impacts put forward by E. Peelle consists of 11 factors. (Peelle, 1974) These types of criterion can help with decision-making and cost-benefit analysis for nuclear projects as well as identify social impacts before such projects are even started.

- Systematic identification of social costs and benefits
- Analysis of social costs and benefits through dimensioning
 - Dimensioning
- Quantification of social costs and benefits
- Identification and analysis of impact recipients
 - Mixed impact groups
 - Multiple impact groups
 - Separation of beneficial and adverse impact recipients
- Reducing problem to sets of identical beneficiary-payee groups
- Quantification of costs and benefits in terms of impact recipients
 - Number of recipients of each impact
 - Intensity of impacts
- Limiting/reducing unquantifiables
- Determining acceptable cost-risk levels
- Establishing equivalence among values
- Choosing an appropriate social discount rate
- Producing a final social cost-benefit balance

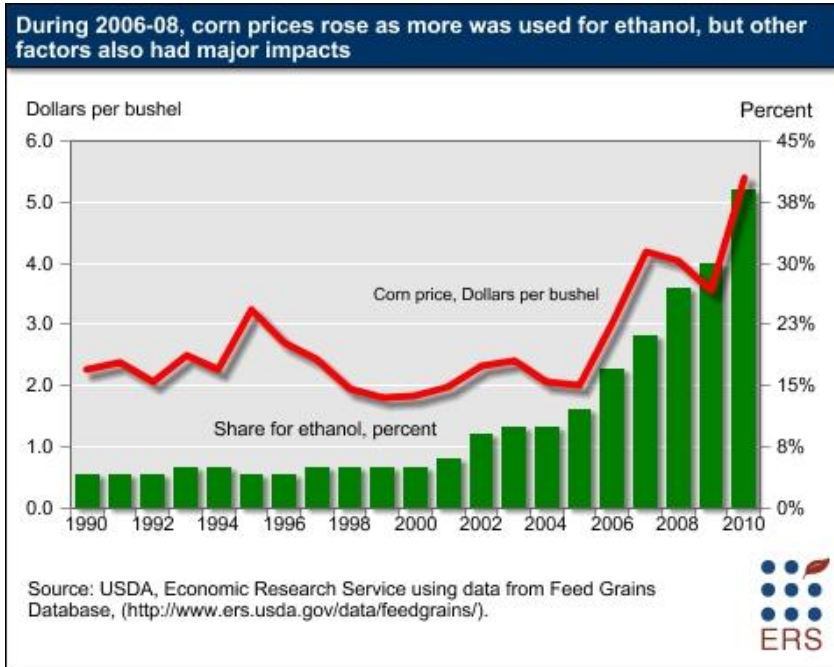
It is important to consider the future technologies involved with nuclear power production as the current generation reactors will be supplemented with newer types such as the generation IV and later possibly fusion reactors. The generation IV reactors will require similar operation facilities as current reactors but the fusion reactors have different requirements. One new aspect will be the space requirements for the newer reactors, as well as location. As an example, due to the utilization of lead, sodium or other coolants the traditionally large water requirement will not exist, allowing for construction and operation without close proximity to a water source. Also with less waste production (if any) the newer reactors will not require the space for waste lakes. Finally, the reactors are designed on a smaller scale, having less aesthetic and land use impact, they may also require less personnel to construct and maintain. All of the above factors will have an impact directly on the social structures in which these reactors will be placed. As awareness grows concerning nuclear power, its possibilities and impacts, it will be considered a candidate for sustainable energy production.

Chapter 4 - Other Energies

4.1 Biofuels

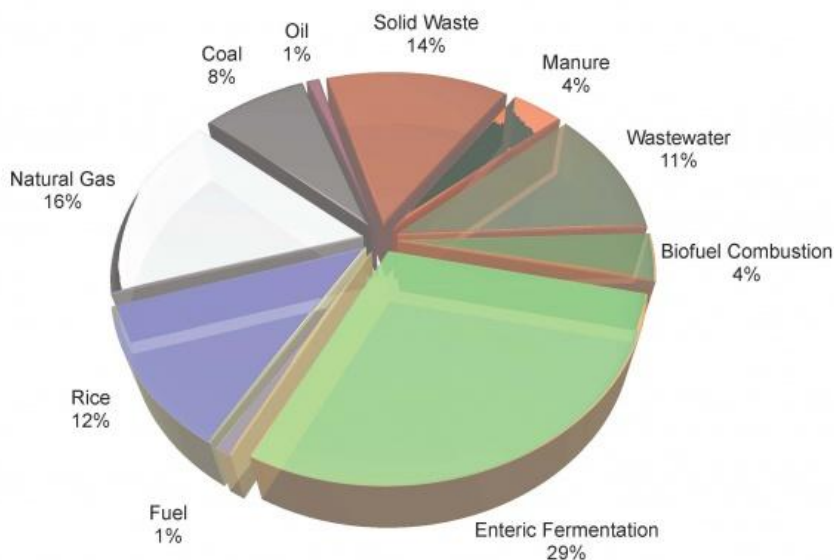
Biofuel is a general term to describe combustibles derived from natural processes that absorb carbon from the air. Solid Biofuels include wood, coal, dried manure, crops, etc, while liquids include alcohols, wood diesel, etc. Methane is an example of a gaseous biofuel. The main sources of biofuel used today are bioethanol, biodiesel, and charcoal.

Bioethanol is an alcohol derived by fermenting the sugar in crops. The most common crops used are corn and sugar cane. While it can be used as fuel on its own, it is most commonly used as an additive for gasoline. In 2009, the US used approximately 127 billion gallons of gasoline and 11 billion gallons of ethanol (EIA). Most gasoline that a person would buy at a pump is 10% ethanol. This is primarily made from corn. But, this is a pretty huge problem. According to the EPA, corn accounts for 26% of the crops grown in the United States (EPA). 58% of that corn becomes feed, and the USDA estimates that 30% will become ethanol in 2012 (USDA). This means that only 12% of the corn grown in the US becomes food, with a large percentage of that becoming high fructose corn syrup. This has caused a rise in corn prices. And, as demand for ethanol rises, the amount of corn used for food decreases. If all the corn produced in the United States was used for ethanol, it could only provide a third of the gasoline used in the US. Corn is already a poor food crop, and high fructose corn syrup causes a whole other host of issues, so the farm land taken up by corn could be used for other crops that feed people. In the long term, bioethanol is not a sustainable energy source. Biodiesel faces a similar problem in that it uses crops as energy. Photosynthesis is at maximum 6% efficient, which after the production of the fuel, drops to 1% efficiency, much less than a solar panel.



(ERS)

Methane is the most widely used biogas, and can be obtained from many places. The main source is a natural gas field, which is an underground deposit found most commonly off shore, much like oil fields. The other main source is coal bed methane. This methane, as the name suggests, is found absorbed in coal beds. While this is a wonderfully rich source of gas, and is becoming the best source for it, it has serious environmental impacts. The extraction relies heavily on pumping treated water in to cause the release of the gas. Not only does this use up large quantities of water, but the additives are also left in the ground. These pollutants often seep into aquifers and taint water supplies. Other, more environmentally friendly, ways exist to obtain methane. One interesting solution is to capture the waste methane from cows on meat and dairy farms by using an anaerobic digester to extract it from their manure. Landfills also release methane gas through the natural decomposition of the waste which can be captured to not only produce fuel, but also to prevent it from escaping into the atmosphere and adding to the greenhouse gas buildup.



(Global Methane Emissions, 2006)

Overall, Biofuels are a means to supplement oil usage, but not replace it. Ethanol is an interesting concept, but reduces biodiversity and food production too much for its low efficiency to be worth it. Methane is a good thing to focus on because a lot of the time it would be released into the atmosphere as a greenhouse gas if it were not collected, so collecting it and using it as fuel is almost like free energy. However, gas fields and coal gas have serious environmental repercussions that prevent them from being a sustainable means of producing biofuel. While it is an efficient end-product, most biofuel does not justify the means.

4.2 Oil Sands

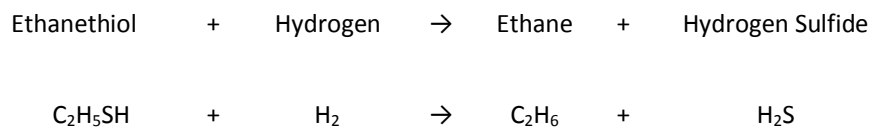
Oil sands (bituminous sands) are a less common type of petroleum deposit. Specifically, bituminous sands are a mixture of sand, clay, water and thick, viscous petroleum known as bitumen. Bitumen is sometimes called “tar”; however the word "tar" to describe these natural deposits is not accurate. Chemically, tar is an artificial substance produced by the distillation of organic material, usually coal. Bituminous sands are found all over the globe in varying quantities but the largest known

deposits are in Canada and Venezuela. Canada and Venezuela each have bituminous sand deposits equivalent to the current oil reserve estimates and overall there exists enough globally to fuel the world for centuries.

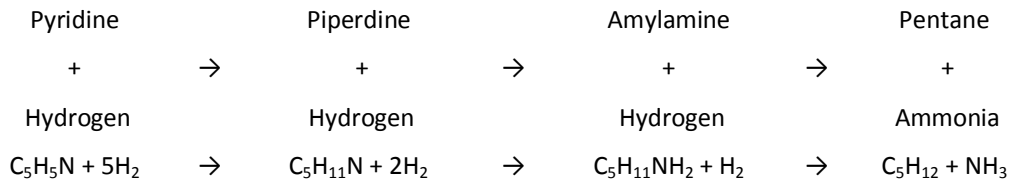
The bitumen requires different techniques for extraction than traditional oil wells due to its heavily viscous nature. The most common method for bitumen extraction is open pit strip mining. Other techniques utilized, particularly near the end of a deposits lifetime include injection of steam, solvents, or hot air into the sands to promote flow and ease extraction. The latter technique functions by injecting steam or hot air at around 300°C into the deposit and letting it pervade the deposit for a week or 2 until the bitumen is less viscous and can be extracted by conventional techniques. Extraction of the bitumen from the sand was about 75% efficient but with recent technological advances current extraction efficiency is about 90%. Once it is extracted it must be purified before it can be sent to the refineries for conversion into usable forms of oil. This purification process is called “upgrading” and can be outlined in the following manner:

- Removal of water, sand and other physical impurities
- Catalytic purification through the processes of hydrodemetallization (HDM), hydrodesulfurization (HDS), and hydrodenitrogenation (HDN)
- Hydrogenation through carbon rejection or catalytic hydrocracking (HCR)

HDM is the process by which metal is removed from the oil sands by using various hydrotreating methods. HDS is the name for a chemical process during which hydrogen is added to cleave the carbon-sulfur bond. The name for this class of processes is hydrogenolysis and it results in formation of carbon-hydrogen and hydrogen-sulfur bonds. Below is a simple example of such a process involving ethanethiol, a common sulfur compound found in petroleum deposits.



The same process can be used for hydrodenitrogenation. Below we provide an example of such a process for clarity. The nitrogen in this case is in the compound pyridine, another compound found in petroleum deposits.



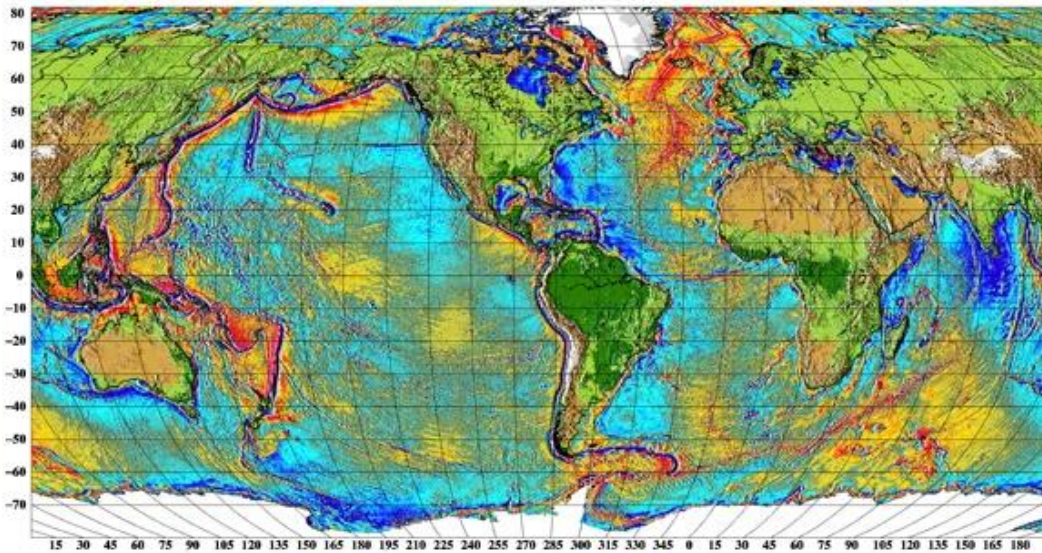
The final process is carbon rejection or hydrogen cracking. Carbon rejection is seldom used due to its inefficiency and large waste generation. Hydrogen cracking is the process of breaking down heavier organic molecules such as hydrocarbons into lighter hydrocarbons. The process involves utilizing hydrogen gas under elevated partial pressure to purify the hydrocarbon from sulfur and nitrogen bonds. The efficiency and purity depends on the chemical reaction conditions such as temperature, pressure, and catalyst presence. The problem with hydrocracking is that the impurities destroy the catalyst over time. There is currently a lot of effort in research to improve the longevity of catalysts. Approximately 1.0 – 1.25 gigajoules of energy are needed to extract a barrel of bitumen and upgrade it to synthetic crude, and a barrel of synthetic crude contains about 6.117 gigajoules of energy. The process is worthwhile from an energy standpoint since the net gain is 400-500%.

Originally oil, oil sands, and gas fields were surveyed by utilizing aerial photographs and analyzing them for telltale signatures of the presence of oil or gas by geologic formations. More commonly in the current industry satellites such as ERTS-1 are used to take images from space and also detect subterranean densities in surveyed areas to detect the presence of petroleum or gas. They function in a variety of ways:

- Overviews of the regional geology thought to contain oil and gas
- Aids in defining fold/fault structures
- Highlighting fractures along which hydrocarbons are known to rest
- Detecting presence of hydrocarbons by their geologic impact on surrounding rock
- Searching UV and IR signatures for anomalies
- Directly discovering oil and gas directly through leaks, spills, or other seepages into the environment

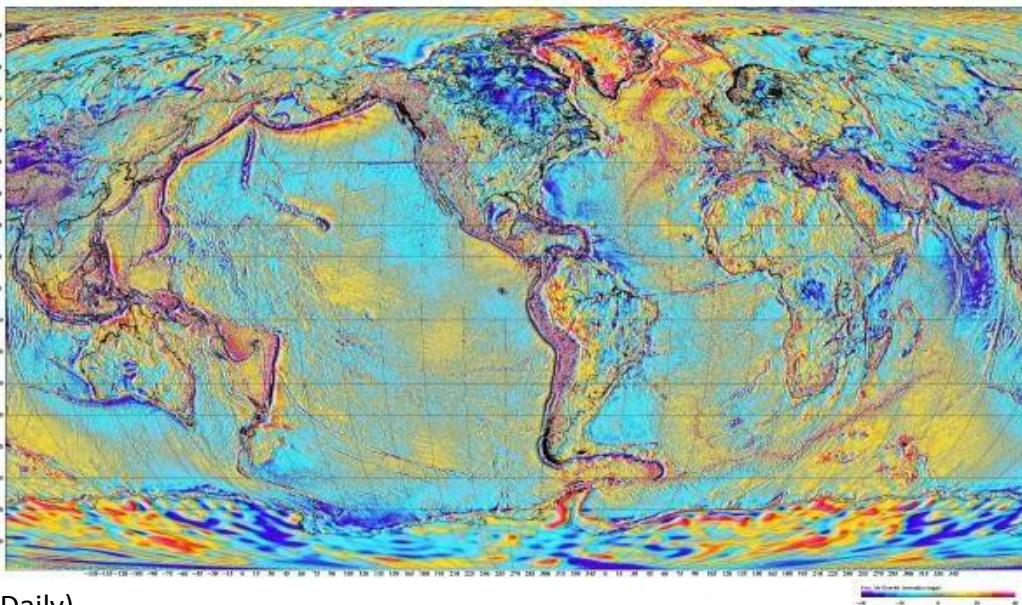
Below are examples of satellite images used for oil and gas detection:

Free Air Gravity Anomalies from Satellite Altimetry



(Global Gravity Field Model, 2010)

DNSC08 Global Free Air Gravity Anomalies

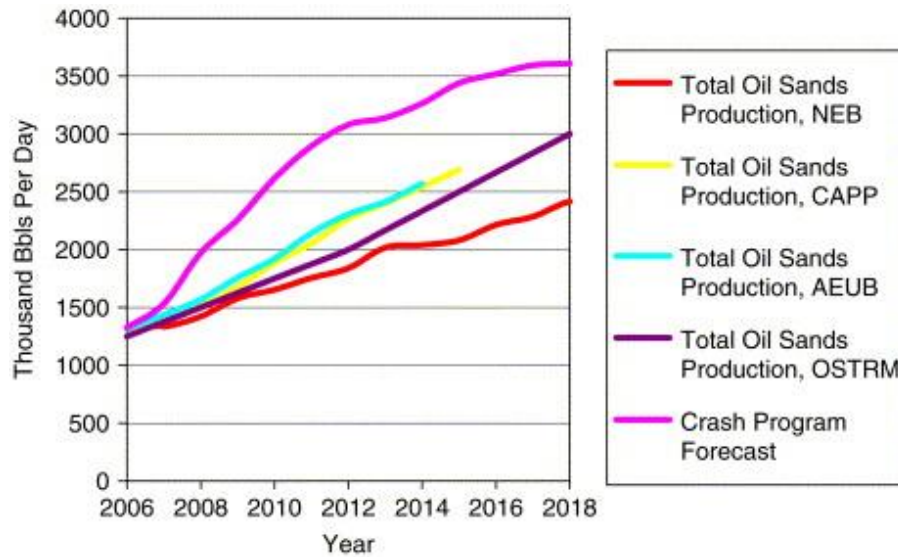


(Science Daily)

These images are combined with other detection methods to help pinpoint possible sites for further exploration and utilization, saving the companies time and money.

Total current production of oil sands within Canada is estimated to be around 1million barrels/day while total global production of oil sands is around 84m b/d. Below is the projected

production within Canada by different studies. It is clear the production will increase within the next 10-15 years, meaning oil sands are expected to become an energy staple for the foreseeable future, putting pressure on newer technologies to compete financially.



(Natural Gas and the Future of Tar Sands Production, 2006)

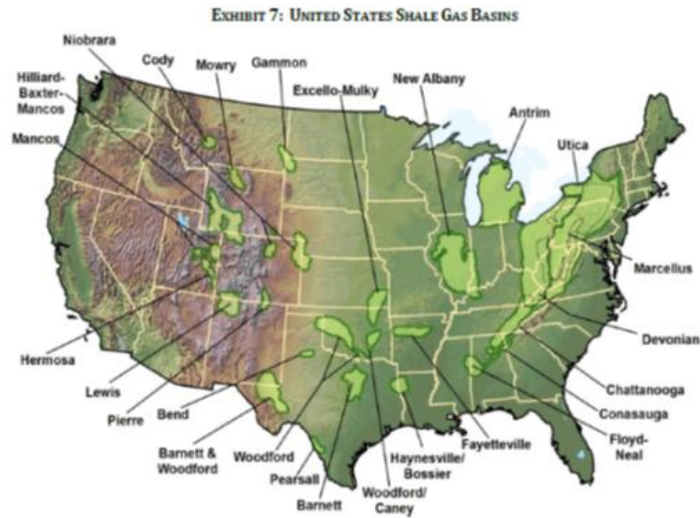
The costs of production of oil sands within Canada (2004) can be broken down by site as shown below. Due to Canada’s significant production it is an accurate example for the industry standard. The standard project investment ranges from \$8-24 billion from 1996-2007.

Site	Plant Gate (C\$/bbl)
Cold Lake CSS	14.5
Athabasca SAGD	15.5
Mining, extraction, upgrading	30.5
Standalone upgrading	12.7

Cyclic-steam stimulation (CSS) and Steam assisted gravity drainage (SAGD) are the two main methods for extraction of oil sands combined with open pit strip mining. There is current interest to construct newer nuclear reactors (CANDU) in proximity of the mining operations for power production to use in the processing to lower the cost. The approach is economically viable with a plant gate price of energy at \$50/MWh. With crude oil cost around US \$100/bbl it is clearly profitable for these companies to expand their operations and production, not just within Canada but sites around the globe.

4.3 Shale Gas

Shale gas is a natural form of gas produced from hydrocarbon-rich shale formations, and is a new form of energy that recently has brought forth much attention (Modern Shale Gas Development in the United States: A Primer). The reason for this is because, with the quantities we have, it can help support our energy demand. As shown in the graph below, across the United States lies many newly discovered shale basins (light green areas) that we can use to extract the gas:

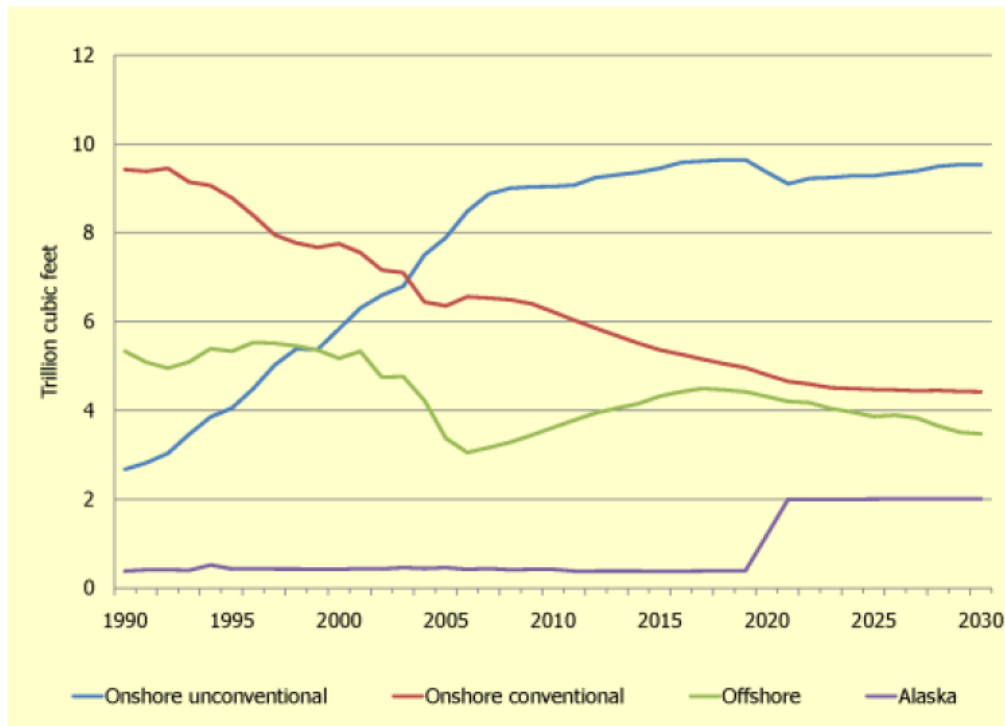


(Modern Shale Gas Development in the United States: A Primer)

With the use of shale gas, our reliability on other fossil fuels significantly decreases. Currently, natural gas supplies about 22% of the nation’s energy, since it is the cleanest burning fossil fuel and is also fairly inexpensive (Modern Shale Gas Development in the United States: A Primer). However, natural gas is being consumed faster than it can be produced, and this trend is continuing. It is estimated that about half of the natural gas currently consumed was produced from wells drilled within the last 3.5 years (Modern Shale Gas Development in the United States: A Primer). Gas reserves are now becoming harder to find, and the gap between demand and supply is growing. So, what can we do? We look to shale gas to help adjust the balance.

Many people wonder, what’s so good about natural gas and shale gas? Well, first off, natural gas is a very reliable source of energy. 84% of the natural gas consumed in our country is produced in the U.S., so it shows that we do not rely on foreign countries as we do for oil (Modern Shale Gas Development in the United States: A Primer). States, such as Texas and Wyoming, have seen additional proven gas reserves, coming from shale gas, tight sands, and coal bed methane which are all

unconventional gas (Modern Shale Gas Development in the United States: A Primer). Unconventional production now accounts for 46% of the total U.S. production, and it is anticipated to continue to rise (Modern Shale Gas Development in the United States: A Primer). As you can see by the graph below, the blue line (which is onshore unconventional) is currently rising, and is estimated to keep rising until 2030. On the contrary, the red line (onshore conventional) is declining and is estimated to continue to decline:

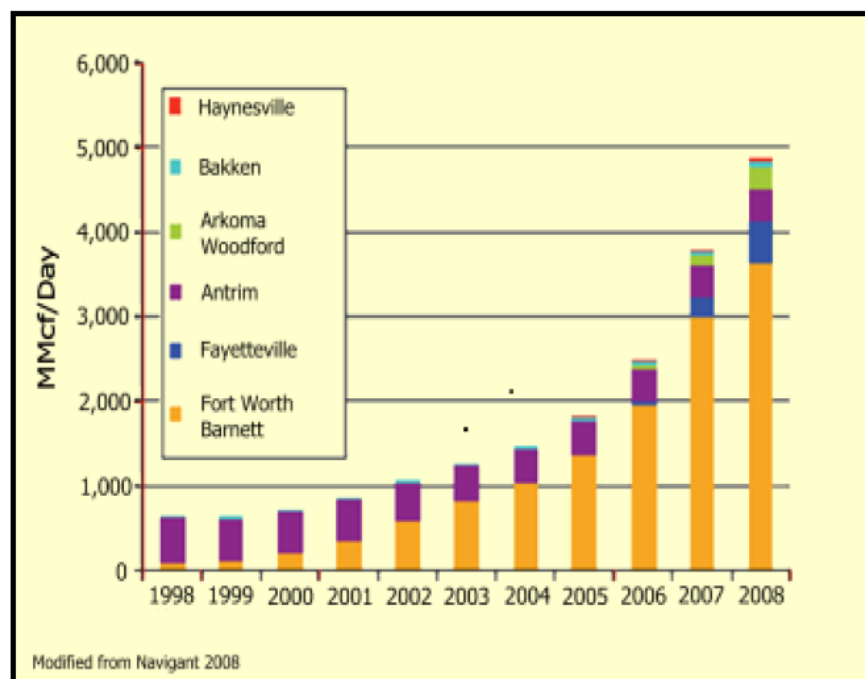


(Modern Shale Gas Development in the United States: A Primer)

There are currently some new factors that have helped to make the production of shale gas feasible. First, are the advances in drilling (Modern Shale Gas Development in the United States: A Primer). With the advances in horizontal drilling, we now have more access to energy that we didn't think was possible before. This has helped in the production of shale gas, since it can be very deep in the earth. Advances in hydraulic fracturing have also helped in the production of shale gas, since these advances can be used together with the drilling to produce shale gas (Modern Shale Gas Development in the United States: A Primer). One of the biggest reasons why the production of shale gas has seen an increase is because of the rising cost of natural gas prices (Modern Shale Gas Development in the United States: A Primer). Most forms of energy today have seen an increase in price, and natural gas is no exception. As the prices continue to rise, alternative solutions are sought, and shale gas is one of them.

With all the shale gas basins in the U.S. it will help to decrease the cost of natural gas since we will have more of a supply.

Looking forward to the future of shale gas shows an optimistic view on energy. Over time, more and more basins are being found, and more and more shale gas is being produced. Taking a look at the graph below shows the past trend of six different shale basins located in the U.S.. As you can see, the production over the 10 year period has significantly increased, and researches estimate that it will continue to increase for the next 20 years or so. As more information becomes available, more research is completed, and advances of technology continue, it is expected that shale gas resources will continue to rise. If we are looking to meet our energy demands, then we must continue to research shale gas.



(Modern Shale Gas Development in the United States: A Primer)

Shale gas looks to be a great alternative to other fossil fuels, in that many basins are located in the U.S., it is helping offset the cost of other fuels, and will help to meet our energy demands and decrease the gap between current energy demands and supply. As the production of shale gas continues to increase and more supply is available, it will soon become a much sought after fuel. However, shale gas is a fossil fuel just like the others, and has some environmental impacts. For now though, I believe it is a safe alternative. Taking a look further into the future, however, I believe that alternative forms of energy will be the keys to success and a healthier environment.

Modern shale gas development is proving to be a promising field for natural gas production.

Advancement in the process of shale production for natural gas combustion refineries has made production, cleaner, safer, and more efficient. Within just a few years, the production and sale of shale gas power will easily eclipse coal power as a cheap and efficient fuel source.

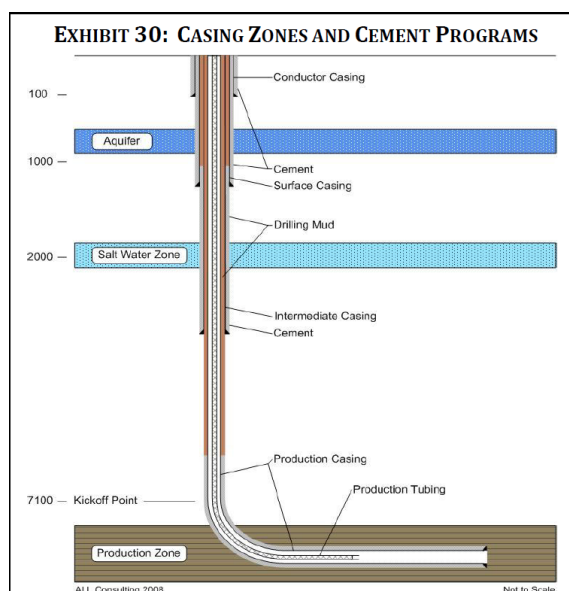
The shale gas production process involves drilling a hole and pumping large volumes (up to 4 million gallons) of water and sand mixtures thousands of feet below the Earth's surface. This mixture, under pressure breaks up the solid rock strata formations underground. It is under this formation that the shale gas resides. Once the water mixture is pumped down, it causes micro fissures and cracks in the rock which allow the gas to move to the surface. The sand in the water mixture helps hold the fissures open and allow time for the gas to move to areas of low pressure. When correctly functioning, the reinforced tube created by drilling, will be the only low pressure exit source for the gas thus allowing it to be collected. High pressure shale gas flows through the tube and is collected by permanent tanks or trucks for transport to refineries. After combustion in a plant, this gas can produce electricity at a lower cost and higher efficiency than traditional methods. Furthermore, shale gas may see use in more engines and even automobiles because of its efficiency and lower pollutant concentrations.

Traditional shale removal methods have involved vertical hydro fracturing methods. On average, complete development of a one square mile section of land will require 16 of these vertical well pads for production. Each individual pad will require its own infrastructure for production and will produce separately of the others. For this reason, the method is not quite efficient and also requires additional set up and land requirements. Each one of these vertical wells would require on average 5 acres of land each resulting in 70-90 acres of required land for a one square mile production. Unfortunately, this amount of land has a large environmental impact and increases the inefficiencies of the system. Luckily there is hope in shale gas production through a new technique referred to as horizontal hydro fracturing.

Horizontal hydro fracturing has many benefits over the use of vertical methods because of the total exploitation of the area of shale gas underground. Instead of a single straight pipe into the ground, horizontal fracturing drills deep down and then across entire gas fields to maximize total area of use. These horizontal sections can change 50 foot accessibility to between 2,000 and 6,000 feet of accessibility of a gas field. This greatly increases the efficiency of shale gas production. Instead of requiring 16 separate vertical pads for production, a single pad with as few as 4 horizontal wells stemming from it can produce the same amount of gas. Thus, the ecological footprint of horizontal hydro fracturing reduces from 70 acres in a 640 acre plot to just 7.4 acres. Horizontal production is effectively 10 times as efficient in surface area use. The long horizontal pipes also allow for reaching gas

reserves underneath existing structures such as buildings, airports and cities. An example of this availability would be the Barnett shale play around the Dallas Fort Worth international airport. On top of this, a single vertical well costs on average \$800,000 (not including infrastructure) to set up. Horizontal wells cost about three times as much, however only one is required in a single production as opposed to 16 of the vertical wells. Horizontal wells are the obvious superior choice in shale gas production. They reduce environmental, social, and community impact due to less required infrastructure, land use and repair, and maximization of a single well to access an entire field. So what are the issues? Most concerns with shale gas production are common with both methods and mainly concern environmental and public safety.

These methods of shale gas production are highly regulated mainly at the state level in order to reduce both environmental and social impact. Most of the concerns originate from the release of contaminants both into the atmosphere as well as local natural water supplies and fresh water sources. Contaminations are being combated with advanced drilling and sealing techniques. Each pad is created and reinforced with cement in order to contain the gas as it reaches the surface. The drilled holes themselves consist of a tube with various layers of cement and casings surrounding it to prevent any natural water contaminants from entering the tube as well as any from exiting the tube and polluting local ground water or soil. Depicted below, is a diagram of a common horizontal hydro fracturing production. As you can see, multiple sealing layers are implemented depending on depth of the hole. Since natural water reserves occur closer to the surface, more strict sealing measures are required.



Source: 9 (3 Studies Confirm Shale Gas Is Not Worse Than Coal)

If created correctly, these sealing measures reduce the possibility of contamination to just 1 in 2,000,000,000 wells. Common contaminants found through shale gas production include biocides, hydrochloric acid to break up the rock strata, and a stabilizer to reduce rust formation in the tube. Further, other contaminants such as hydrogen sulfide, methane, and benzene, toluene, ethylbenzene, and xylenes may also be present. However, through efficient sealing and transportation techniques, all of these contaminants are contained. Infrared technology is also being utilized to discover and repair leaks more effectively. On average the water mixture that is pumped into and released from the well is 98-99% water and the remaining is the diluted contaminants.

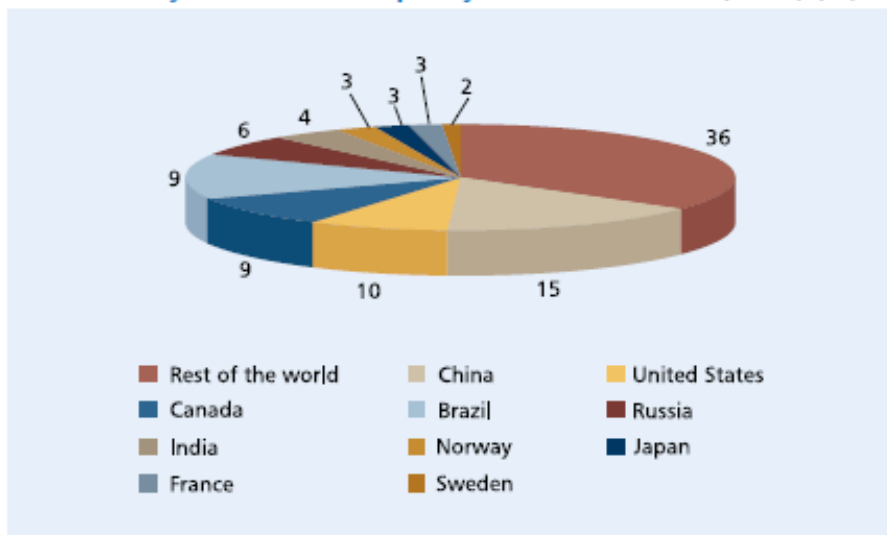
Further issues concerning these wells concern community fall out. By utilizing the best management practices, many of these are being corrected. Many initial community concerns have to do with environmental impact including tree deforestation and animal relocation. The visual obtrusion as well as the ecological footprint is being contained by the horizontal wells as well as landscaping and fencing of the well area. Sound and light pollution are being combated by sound barriers as well as directional lighting and the infrastructure itself helps to reduce the impact on the community. Through state regulations, all processes involved in shale gas production are highly regulated and maintained thus reducing all impacts. After production has stopped, the infrastructure is removed and the company responsible returns the used area to its original condition and in many cases to a better condition.

Changes are still being implemented in the shale gas production process in order to make it more streamlined and reduce its impact. Pipelines are being constructed to transport the gas so as to avoid implementation of roads as well as to reduce emissions from required vehicles. Compressed air is also being used in place of the water to cool, lubricate, and remove the debris, water, and gas from the production well. This reduces water contamination risks as well as the need for millions of gallons of water. As shale production practices are honed and efficiently maintained, their impact in any way on society or the environment will be reduced, thus making it more and more desirable as a fuel source. With efficiency 30% greater than coal as well as the potential to create thousands of new jobs and hundreds of millions of dollars in extra state income taxes, shale gas production will boom within the next couple of years. Soon it may eclipse coal and oil for clean and efficient uses.

4.4 Hydroelectric Energy

Water power is an idea that has existed for many years. It used to, however, be a purely mechanical process. Recently, hydroelectric power plants began popping up. Conventional plants take giant rivers and funnel them into giant turbines which spin and generate electricity, much like a wind turbine. And while the number of large rivers is limited, there are more ways to generate power using water. Energy can be stored by pumping water to greater heights, and the tides are another source of power.

Chart 1.3: Hydro Installed Capacity across the World (2006) (%)



Source: EIA, D&B Industry Research Service

There are eight conventional hydroelectric plants in the United States, accounting for 17 Gigawatts of power, or 7% of the total energy generated (EIA). Worldwide, however, it accounts for 20% of energy generated total, and 88% of that generated by renewable sources. China just completed the world's largest power station in the world, a giant hydroelectric generator spanning the Yangtze River, generating 20 Gigawatts of power on its own (REN21). This single generator has more capacity than the entire USA's hydroelectric plant system combined. This is due to two factors: how new it is, and how giant the Yangtze is. The United States has a dam in most of its major rivers generating power, meaning the only way to increase capacity would be to either upgrade our current dams, or build more on the current rivers. These plants, while renewable, are not without environmental consequences. Behind the dam, a giant reservoir must be constructed, destroying much lowland upstream. They also prevent salmon from swimming upstream to their natural breeding grounds, causing a dramatic

decrease in population. This damage is exacerbated when the spawn have to pass through the turbines on their way downstream, which often kills them. Then, the water temperature and oxygen density is also increased, causing problems to the wildlife downstream. Overall, these plants can generate huge amounts of power, but it is at the cost of aquatic life.

A less impactful, but similar source of power is using large height differences. Waterfalls and mountain lakes are tapped for power using turbines similar to those in conventional plants. This idea then, is not revolutionary. But, how it is used is brilliant. Rather than using the differing heights in large reservoirs of water as a source of power generation, they can be used for storage. The hydroelectric plants usually have to slow their energy production at night, but by using their nightly power generation to pump water up to a higher elevation, it can then be drained at peak hours to increase power generation when it is needed the most. Using existing reservoirs like giant batteries, power can be stored for little cost.

The most recent innovation in hydroelectric power generation has been harnessing the ocean's tides. Research into these plants began in 1924, but the first plant wasn't produced until 1966 (EERE). And while the tide is one of the most reliable power sources, the ability to capture it was severely limited. But, due to recent technological developments, tidal power output is on the rise. Dynamic tidal power is the name that researchers have given to a new tidal generation technique that would use large dams to exploit the large differences in high and low tide. A large T-shaped dam would be constructed so that when the tide comes in or goes out, one side stays higher than the other. This would then be used to generate power. These dams would obviously interfere with sea life as well as affecting the tide. Challenges include the sheer size of the dams, which would need to be upwards of 30km (MacKay). And small-scale demonstrations would do little to prove the point, as the power generation increases logarithmically with the dam length.

Fundamentally, all hydroelectric power is the same; exploiting elevation differences in large bodies of water to generate power. But, where a difference in height can be found and made use of, with the least impact to the environment is where the distinction lies.

4.5 Geothermal Energy

Global oil and gas prices have been rising as demand outstrips current supplies. This steady increase in prices and the predicted expiration of oil reserves has led to a renewed interest in alternate forms of energy such as geothermal energy. Geothermal energy not only refers to its use as a source of electric power generation but also as a source of heating and cooling of buildings using systems called Ground Source Heat Pumps (GSHPs). In this paper we will treat only GSHPs.

GSHPs have been developed in earnest within the last 20-25 years, but due to cheaper alternatives such as oil, there has been little improvement to the original designs. GSHPs function by circulating a fluid (currently water & antifreeze) through piping in the ground and a heat exchanger in the building. The fluid absorbs excess heat at the heat exchanger and circulates through the underground piping where through thermal diffusion the excess heat is transferred to the ground. Because of the relative constant ground temperature year-round, the system can be used as a heater in cold weather and as a cooling system in warmer weather. (Ground Source Heat Pumps (GSHPs), 2012) There are two main types of GSHPs; closed loop and open loop systems. Closed loop systems have two main configurations, vertical and horizontal. Horizontal closed loops systems require about 9000 sq. ft. as the piping for the system is laid between 1-2 meters under the ground. Because of space limitations vertical closed loop systems are more common, despite their higher installation cost (\$3-10,000 more than a horizontal system). Vertical systems are similar to horizontal ones, but instead of a field of piping near the surface, we have 10 or so boreholes drilled to a depth of 30-80 meters with piping arranged vertically. Open loop systems require a subterranean aquifer and thus are not widely applicable due to environmental concerns.

Horizontal closed loop systems are the cheapest type of GSHPs to install as the piping is not expensive and the shallow excavation does not require specialized equipment. Vertical closed loop systems on the other hand cost between \$7-14,000+, depending on the ground constitution and required drilling depth. A large part of the installation cost is drilling, which can cost between \$5-10,000. (Rafferty) This high cost of installation is the primary obstacle for GSHPs becoming widespread, despite their high efficiency and longevity. The primary objective of research is to reduce the cost-recoup time, currently about 10 years, which is higher than the average homeowner turnover rate. The recoup time of 10 years is based upon projected use and annual savings compared to traditional heat/cooling systems. The high installation cost compared to traditional heating methods creates a period of monetary loss that is offset by the very minimal operation cost over time. If the payoff time can be

lowered GSHPs will be more attractive to a larger section of population. Current efforts therefore are focused on reducing the initial cost and also maximizing efficiency to improve the returns on the systems. This can be accomplished in a variety of ways. (Lienau, 1995) First is to examine the structure itself and find the most efficient materials and structure for the system. Another area of research is hybridization possibilities. For example, a GSHP can be combined with what is called a “desuperheater” which takes the heat from the GSHP compressor and utilizes the vapor to heat the homes water. This can further save energy for the homeowner. More elaborate forms of hybridization are cooling towers suitable in cooling-oriented systems and solar-geothermal hybrid systems in heating-oriented systems. Hybrid systems are much more complex to optimize as they are more heavily reliant on external conditions such as air temperature and weather; as opposed to a simple GSHP. Once the proper hybridized system is optimally installed, if it is hybridized with photovoltaic cells or wind turbines it is possible to be completely self sufficient energy-wise. On the next page you will find an example of the cost difference between several hybrid GSHP systems.

Table 1. Summary of Hybrid GHP case study for 14,025 ft² office building in Houston, Texas (from Yavuzturk 2000)
Heating degree-days = 1434; Cooling degree-days = 2889 Annual heating load = 7.5 million Btus Annual cooling load = 181.6 million Btus*

	Base case—no cooling tower	Hybrid Case 1 ¹	Hybrid Case 2 ²	Hybrid Case 3 ³
Number of boreholes in ground heat exchanger	36 @ 250 ft	12 @ 250 ft	12 @ 250 ft	12 @ 250 ft
Cost of ground heat exchanger ⁴	\$54,000	\$18,000	\$18,000	\$18,000
Maximum fluid temperature entering heat pumps in 20-year period (°F)	96.6	96.3	80.5	96.0
Minimum fluid temperature entering heat pumps in 20-year period (°F)	71.3	67.3	40.5	54.1
Design capacity of cooling tower (tons)	22.5	11.5	8.5	
Cost of cooling tower and plate heat exchanger including controls and auxiliary equipment ⁵	-	\$8,662	\$4,427	\$3,272
Total cost of ground heat exchanger and cooling tower equipment	\$54,000	\$26,662	\$22,427	\$21,272
Present value of 20 years of electricity costs ⁶	\$19,611	\$19,413	\$16,011	\$20,573
Present value of total costs	\$73,611	\$46,075	\$38,438	\$41,845
Annual energy use (kWh)				
Heat pumps	24,425	23,877	17,792	24,453
Cooling tower fan	-	260	1,847	1,006
Cooling tower pump	-	42	302	164
Total system	24,425	24,179	19,941	25,623
<p>* From Air Force Manual AFM 88-29, "Engineering Weather Data," July 1978. ¹ Set point control to limit fluid temperature exiting heat pumps to 96.5°F or less. ² Differential temperature control activates tower when difference between heat pump exiting fluid temperature and air wet-bulb temperature exceeds 3.6°F and turns tower off when this difference falls below 2.7°F. ³ Tower operated between midnight and 6 a.m. year-round to cool ground heat exchanger field (attempt to balance heating and cooling loads on ground), secondary set point control to limit fluid temperature entering heat pumps to 96.5°F or less. ⁴ Estimated at \$6.00/ft of borehole, including horizontal runs and connections (Kavanaugh and Rafferty 1997). ⁵ Estimated at \$385/ton of tower design capacity based on data from Means (1999). ⁶ Assumes \$0.07 per kWh cost of electricity; no price escalation rate assumed. A 6% discount rate is used for present value computation.</p>				

(Energy, 2001)

These buildings are known as zero energy buildings (ZEBs). (Ahheng, 2011) With further improvements in the geothermal systems such as ecologically safe fluids that have higher heat capacity

and conductivity, and more efficient optimized systems; it can be financially possible for the majority of homeowners to install such systems. This can lead to dramatic drop in fuel usage for home heating and domestic electricity consumption. The GSHP systems reduce consumption of electricity by 50% annually in a normal household for heating and cooling purposes. Not only would this conserve exhaustible resources but with the green energy we can reduce our carbon imprint and improve our environmental impact. There is certainly a future for GSHPs, perhaps not alone, but combined with other technology the possibility of reducing fuel consumption and having long-term heating/cooling systems widespread can make a large difference in the future fuel concerns.

4.6 Hydrogen

Hydrogen is the most common element in the universe, and as the stars show, can be a potent fuel source. It can either be burned in a combustion engine or put through an electrochemical cell to produce power. There are several benefits to using hydrogen as a fuel over gasoline. Three of the large benefits are energy density, cleanliness, and renewability. Gasoline has an energy density of 47.2 MJ/Kg, while Hydrogen has a density of 123 MJ/Kg. But, even though hydrogen is lighter, it takes up 400% more space when compressed at 700bar. The other benefit to using hydrogen as fuel is that it does not have to be burned. Hydrogen fuel cells transmit chemical energy directly into electricity, without the aid of a mechanical system. The process is simple, but achieving it is hard. A catalyst, usually platinum powder, loosens the bonds between the hydrogen atom and its electrons. The hydrogen ion is then able to pass through the electrolyte, while the electrons are not. The electrons have to go the long way around, and pass through an electrical load before reuniting with their atom. But because of the energy drop, the hydrogen reacts, helped by another catalyst (most often nickel), with oxygen pumped into the system and it produces it's only byproduct water. The lack of moving parts and harmful byproducts makes hydrogen fuel cells an amazing and tantalizing technology for producing electrical power, but there are however limitations with the current technology. The catalysts are a vital part in the system, and get used up over time. This means that they need to be replaced. While this is a nuisance, it doesn't limit the technology too much. And, while nickel is easy to come by, platinum is not. It is rare and expensive, and therefore current fuel cells are not fit for mass production. There is research being done into other possible catalysts, but none have yet to yield the 60% efficiency that platinum boasts.

The renewability and abundance of hydrogen is another factor that is making many see hydrogen as the future. The two main means of hydrogen production are reforming and electrolysis. Electrolysis is by far the more mundane of the two. By sending electricity through water, the process that fuel cells use can be reversed, and separates the hydrogen into hydrogen and oxygen gas. Alone this process is fairly inefficient (25%), but when the hydrogen is heated it can reach efficiencies up to the 80% theoretical maximum. Current bests have reached 40%, which is a far cry from what could be produced with more research (FCHEA). What is exciting about the heating of the hydrogen to increase the efficiency of electrolysis is that most electricity generating processes produce waste heat, most notably nuclear, coal (and anything else that uses steam turbines), and even solar. This means the waste heat is no longer waste, and can do useful work. This exponentially increases the total efficiency of the system. And, since hydrogen is a fantastic means of energy storage, it makes a perfect fuel source. The other, more widely used method of hydrogen generation is called reforming. Fossil fuel reforming is the process of combining fossil fuels with high temperature steam to produce hydrogen. This happens in two steps. First, the hydrocarbons react with water to produce carbon monoxide and hydrogen. The carbon monoxide then reacts with the water to produce carbon dioxide and yet more hydrogen. The benefit of transforming existing fuels into hydrogen gas is the reduction of CO₂ production. This process is much more efficient than burning the hydrocarbons as fuel. And, while the fuel to carbon dioxide ratio remains the same, little to no carbon monoxide is produced, and the amount of energy produced per unit of CO₂ produced is greatly increased. The cost is also much less. A gallon of gasoline in the US is around \$4, and 1kg of hydrogen (which produces about the same amount of power) can be produced with current methods for about \$2, and it is not produced on the scale that gasoline is. All together, hydrogen is a promising fuel source, and a wonderful means of energy storage. Hydrogen has twice as much energy capacity as gasoline, but it is not easy to obtain and safely contain. 650,000,000 tons of hydrogen is converted to helium on the sun every second due to its thermonuclear process. Unfortunately, this kind of production is not possible on Earth. A kilogram of gasoline has the potential to produce 14 KWH of power due to its energy density as depicted below:

Energy Density of Some Materials (KWH/kg) (Wikipedia)

- Gasoline 14
- Lead Acid Batteries 0.04
- Hydrostorage 0.3 (per cubic meter)
- Flywheel, Steel 0.05

- Flywheel, Carbon Fiber 0.2
- Flywheel, Fused Silica 0.9
- Hydrogen 38
- Compress Air 2 (per cubic meter)

Hydrogen has twice as much energy density and thus twice as much storage capacity than gasoline. What is better is that the hydrogen is fairly easy to obtain through electrolysis and can release this stored energy with an efficiency of up to 85%. By using hydrogen as an energy storing and releasing device, it could be a more efficient propulsion method.

The most common method of producing hydrogen is through electrolysis. During this process two different material electrodes, zinc and copper; send electricity into a tank of water. The electricity separates the oxygen and hydrogen molecules in the water which are siphoned off and used to create electricity and water to propel the vehicle forward. This process of separating hydrogen is about 67% efficient. Solar energy's part in this process would be not to propel the vehicle, but instead to create the electricity required for electrolysis and basic vehicle functions. With the solar power creating the hydrogen for propulsion, this process is quite efficient and environmentally friendly.

4.6.1 Cost of Hydrogen

There are three major costs to look at when talking about hydrogen: generation, transportation and storage. To understand the cost of hydrogen to the consumer, these three things have to be taken into account.

Hydrogen can be produced in many ways. The two main processes used to produce hydrogen are steam reformation and electrolysis. According to the *IEEE* the cost of steam-methane reformation is two times that of the natural gas itself, taking into account an efficiency of 70% and production costs. And, according to the *EIA*, the cost of methane today is approximately \$3.75/MMBtu (million BTU). This means that it costs close to \$8.5/MMBtu to produce hydrogen from methane, and the cheapest recorded being 8.25. Through electrolysis it takes 360kwh of electricity to produce 1 million BTUs of hydrogen at the current best of 80% efficiency (Pillay). The *EIA* states that industrial electricity costs are

approximately 6.9 cents/KWh or \$.069/KWh (EIA). So, electrolysis can produce hydrogen at \$25/MMBtu using all electricity, but by only using renewable sources that number increases significantly. \$25/MMBtu correlates to about \$3.50/kg vs. the \$1.4/kg of steam reformation. Honda has demonstrated that a car can run three times as far on a kg of hydrogen then it can on 1 gal of gasoline. And, before tax, today's price for 1 gal of petroleum is \$2.68 (EIA). So, even the more expensive electrolysis can compete with the production costs of gasoline.

Transportation of hydrogen is another problem in itself. Liquid hydrogen takes up 3 times as much space as gasoline, and ironically contains less hydrogen per gallon. But, because of the increased efficiency from fuel cells, it is about the same distance/volume. Hydrogen can also be compressed to 200atm, as it is cheaper than producing a liquid. An 18 wheeler can hold 26 tons of gasoline, but only 400kg of hydrogen because of the tank needed to compress it to 200 atm. Liquefying the hydrogen increases that amount to 7600kg, or 19 times more. Liquid While that is still only 1/3 as much hydrogen as gasoline, because hydrogen cars run three times farther on the same amount of fuel, it comes out equally. While liquid hydrogen solves a lot of problems, it also causes as many. To store liquid hydrogen in a vehicle it needs to be compressed to 2000 atm and cooled to 20K. Because constant energy input for cooling in a car is unreasonable, the hydrogen would slowly expand. To keep the tank from exploding, the hydrogen would have to escape, meaning fuel would slowly leak from the tank. The tank developed by BMW became empty after sitting for 7 days (Wüst). This is barely acceptable. This has lead most companies to using compressed hydrogen. This creates serious range problems, as it is 19 times less dense than its liquid counterpart. So, this leaves a tradeoff: range or longevity.

The general consensus is that hydrogen is transported to a station as a liquid, and then decompressed during the pumping process. The current cost of liquid hydrogen is \$1.50/gal, which is much lower than the price of gas before tax, which as stated above is \$2.38/gal (FCHEA). So, to make hydrogen a viable fuel source for cars, larger tanks need to be used or better cryogenic storage needs to be developed. But for vehicles that have been developed to use gaseous fuel already, like busses that run on compressed natural gas, this may be a more viable option. While at 1 atm, hydrogen has 1/3 the energy density of CNG but runs more efficiently.

Chapter 5 – Applications in Transportation

5.1 Transportation

Solar energy use in ground transportation has only a few applications in conventional transportation, however; the future holds promise for new transportation infrastructure and applications for solar energy use in mass transportation.

A fully solar powered personal vehicle is a long way off for consumer transport. The efficiencies of the panels simply are not great enough to provide the power required to propel a large vehicle. Various solar panel styles could be implemented each with their own advantages however the only true variables are surface area and efficiency of the cell material. The power generated from a solar cell is represented below:

$$\text{Heat content (Q)} = (\text{Volume}) \cdot (\text{Specific Heat}) \cdot (\text{Temperature Difference})$$

$$Q = V \cdot c_p \cdot \Delta T$$

$$P = (\text{Power received per square meter}) \cdot (\text{Square Area}) \cdot (\text{efficiency per panel}) \cdot (\text{time})$$

$$P = Q * A * \eta * t$$

A large array of photovoltaic cells would be required to power a vehicle due to their moderate efficiency in propulsion of about 15% (Spray On Solar Power Technology from Mitsubishi). Common vehicles are simply too heavy to be powered by only solar produced energy. Batteries would contain this energy and supply it to the motor at a certain efficiency. Lead based batteries have an efficiency of about 40%. The efficiency of these batteries is directly related to their chemical composition and energy densities. Typical lead batteries have moderate efficiency and a high weight making their use less economic. One the next page is a table of viable battery compositions and their energy densities:

Material	Energy Density (W-hrs/kg)	Power Density (W/kg)	Comments
Lead Acid	40	70	Long Cycle Life
Nickel Iron	55	100	Very Long Cycle Life
Sodium Sulfur	90	100	300-350 C operating temp
Lithium-Iron sulfide	100	> 100	400-450 C
Nickel-Zinc	75	120	low cycle life

Sodium sulfur batteries are new, light, and highly efficient. The problem occurs at high temperatures and this applies to both the battery and the silicon photovoltaic cells. At high temperatures, the silicon's internal resistance increases thus decreasing its conductivity and making it less efficient. At 0 degrees Celsius the silicon is 24% efficient and only 12% efficient at room temperature. A typical vehicle requires 30KWH of power for a 100 mile journey. This cannot be obtained by only solar power storage and batteries so the hope for solar energy in personal vehicles is in its assistance for hydrogen power and storage.

Unfortunately, there are drawbacks to this method for personal transport. In order for the hydrogen capacity to be efficient, the hydrogen needs to be in liquid form at -253C which increases its efficiency by 1000%. Thus the hydrogen would need to be stored in a special containment vessel. The drawbacks are that both hydrogen and oxygen are very combustible if the containment vessel were to rupture. This makes fatal accidents more common and thus less desirable in the vehicles. The sheer weight and space required for the storage vessels and the dangers associated with them make personal ground transport more of a stretch, however public transport could provide the outlet for this energy method. This hydrogen system is being utilized on large buses, planes, and ships. These methods have the capacity to carry large amounts of hydrogen and oxygen and also provide a considerably lower safety risk.

5.2 Solar Powered Rail Transport Pods

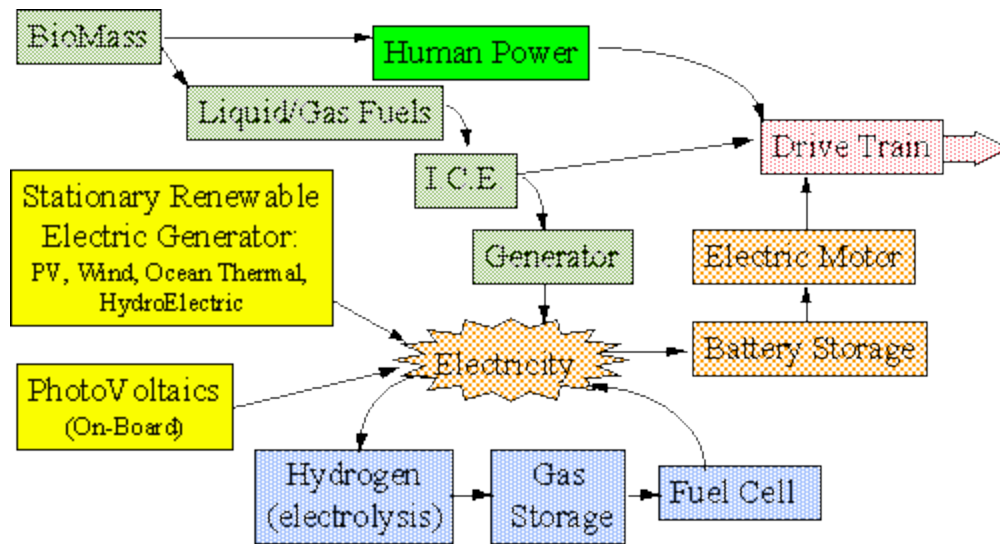
Perhaps the most exotic but also inherently most useful solar energy transportation system lies in the future of the elevated rail transport system. With this infrastructure, a raised monorail is

designed for both personal and public transport through the use of transportation pods. These pods will hang from the monorail and using electric power as well as magnetic fields in some cases, they will be propelled down the track. By covering the tops of these monorails as well as the pods with solar panels, enough energy could be produced to efficiently transport the pods. Inside of cities, where useable sunlight is less abundant, building integrated photovoltaic systems could transfer some of their excess energy to the monorail for transport.

A common pod would be large enough to support 20kw of solar power with about three horse power and carry from 10 to 20 passengers. With this system, mass transport that is quiet, clean, out of the way and convenient could be easily implemented at only \$100,000 per pod. These pods could also be made more affordable by only charging them at stations with large flywheels. These flywheels would remove energy collected by stationary solar panels and quickly transfer it to the pod with a relatively high efficiency. If these transportation pods and the elevated monorail system became active, large roads would become less needed, fewer pollutants would be released into the air, and convenient safe travel would be available through purely solar powered energy.



Source: 10 (Solar Power for Sustainable Transportation Systems)



Source: 11 (Transportation and Energy)

5.3 Transportation Infrastructure

Today's current transportation concerns are not only focused in the modes of transportation but instead in the infrastructure and integration of the national transportation system. Increased efficiency and safety are the main goals of the infrastructure changes in order to reduce waste and pollutants, decrease the number of accidents on the roads, as well as increase safety on the roads. These things are becoming available as the functioning of the road systems change, new forms of transportation are introduced, driver assist mechanisms become available, and as accountability and awareness increase.

The national road systems are over run with excess travelers and vehicles. This leads to high traffic concentrations, congestion, collisions, and the inefficient use of any roads. Many road efficiencies separate from specific traffic are caused by traffic intersections. Particularly, the left turn lane in an intersection greatly reduces the efficiency of any intersection due to wasted time to cross lanes of traffic. Some structural changes are being made in the types of intersections that are being designed to combat this problem; instead of a standard intersection as depicted on the next page to the left:



Source: 12 (MnDOT Construction Project: Diverging Diamond Interchange)



Source: 13 (MnDOT Construction Project: Diverging Diamond Interchange)

New intersections are utilizing more efficient designs that decrease signal light interval times and eliminate left turns that add so much inefficient time to travel as well as increased risk of accidents. These new intersections include the roundabout and the diverging diamond interchange displayed respectively above. Most new vehicles come equipped with a GPS device, and through this, each car will be linked and know where the other cars are on the roads. This same system also allows traffic signals to be informed of where the traffic concentrations are and to adjust their timing accordingly. With each car accounted for on the road, the cars will be able to use this information to avoid traffic and collisions thus maximizing the efficiency of the roads. Using this GPS system as well as driver assist

braking, maneuvering, and collision detection, the vehicles will be able to interactively provide for the safety of the drivers on the road. Increased detection and safety on the roads will lead to fewer collisions, thus less congestion will occur and road traffic will flow more smoothly and unimpeded.

In 2009 almost 2.5 million people were injured in car accidents in the United States alone and a million people were killed worldwide (Transportation- Conservation). This trend needs to change and it is through on board safety devices that it will happen. New systems that incorporate collision detection in the vehicle allow the vehicle through many mini cameras and sensing devices on the outside of the vehicle to detect as well as react to potential accidents. If the car senses an oncoming collision, it will automatically brake as well as steer out of the way. This technology doesn't allow for true autopilot vehicles, but it does provide extra assistance when navigating the roads. Other technologies that maintain a vehicle's position within the middle of a lane are also available and some systems even detect other vehicles and interpret their actions. Even when these technologies fail or if there is an unavoidable collision, new exterior airbags on the front and more commonly on the rear of vehicles will decrease the damage and risk of injury. All of this takes some of the weight off of the driver's shoulders and allow for more efficient travels that avoid human error.

Unimpeded travel through structural road changes as well as these safety devices will greatly increase the efficiency of our road systems. Increased efficiency in the travel will mean lighter traffic concentrations and decreased travel times for all vehicles. This reduces waste and fuel consumption lost in traffic. If all vehicles will be able to maintain constant speed due to decreased risk of accidents, and for the same reason they will travel more closely together, a higher traffic concentration will be handled thereby reducing the need for new larger roads. Further, new modes of transportation such as the Personal Rapid Transit on new elevated rails could decrease these issues as well. As new transportation modes are experimented with, traffic concentrations will be able to be brought under control and the functioning of the roads will be maximized. A realization of high efficiency and safety of all vehicles on the road will result in a more enjoyable driving experience as well as the maximization of the use of the roads. Issues concerning implementation as well as integration use will be confronted in a further article.

5.4 Fuels

To date, internal combustion gasoline engines have been the most desired and widely used motorized engines since their implementation in the 19th century. Unfortunately, simply expanding on and modifying an already low efficiency engine to meet the current standards may be unreasonable. Even current alternative fuel resources such as solar power and hydrogen power have major drawbacks. So where is the outlet that will make the difference?

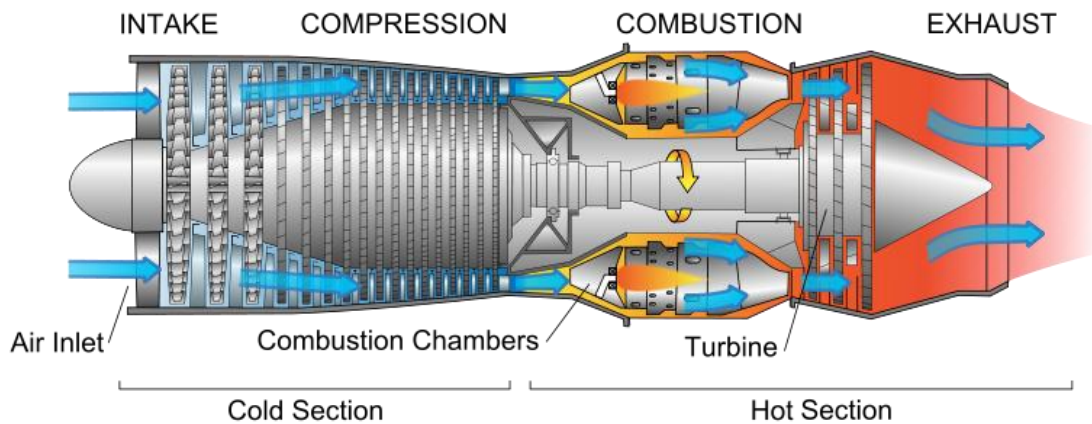
$$\eta = \text{work/heat absorbed} = \text{efficiency}$$

Current vehicles on the road are mainly propelled by either gasoline or diesel powered internal combustion engines. These engines are large, heavy, and the materials that comprise them make heat dissipation too rapid. Furthermore, the mechanical forces, the combustion method, and the need for a transmission continue to decrease their overall burning and propulsion efficiency. Other drawbacks of internal combustion engines include high weight, torque vibrations through the car, and air pollution as well as sound pollution. For these reasons, internal combustion engines are only 20%-30% efficient (Thurston, 1875). The other 70% of consumed energy by the engine is released as heat and is lost with no gain. These inefficient vehicles still operate on petrol requiring the use of oil and fossil fuels which adversely affect the environment (Thurston, 1875). Fuels such as gasoline and diesel contain about 2500 grams of carbon per gallon resulting in an average 9.5kg of carbon per kWh of energy production. On average, a new internal combustion vehicle will release between 150 and 300 grams of CO₂ per kilometer (Meyer, 2008). This figure alone is why the United States produces up to 40% of the world's greenhouse gases while utilizing 30% of the world's total number of vehicles (NewsWire, 2006). This needs to change and quickly, however alternatives are not working.

Both hydrogen and solar power for vehicles is unrealistic for either method alone. Solar power photovoltaics do not have the energy conversion efficiency to offset the weight of the vehicle and provide propulsion. Hydrogen on the other hand has great power output but is difficult to obtain and store for use. Both of these methods would also require heavy and currently inefficient battery packs to store their acquired energy. Even when combined in use through electrolysis, solar-hydrogen power would prove impractical. With solar energy providing the means for electrolysis, which is separating hydrogen from oxygen through an induced electric current, hydrogen could be produced and stored. Unfortunately, again the storage container adds weight and bulk to the package thus making it inefficient as well as dangerous with flammable materials stored within the vehicle. The only options

appear to be hybrid uses of either of these in combination with a more efficient alternative.

Instead of altering internal combustion engines, designing completely new engines, or dealing with inefficient power storage, new light has been shed on direct electric power. By using small electric motor hubs for each wheel of a car, more power can be obtained and weight and emissions can be reduced. Jaguar has done exactly this with their C-X75 due for production in 2013 (First Look: Jaguar C-X75 Concept). Their design consists of four separate 110lb electric motors that produce 200hp each and are supplied by a 400lb, 15kwh battery (Pollard). Each electric motor performs silently and transmits its power directly to the wheel without any CO2 emissions. Again however, this system relies on a battery so how is it different than the other alternative methods? To combat this power supply problem while not using a gasoline powered engine, Jaguar developed a twin microturbine system to recharge the battery as well as supply direct power to the electric motors.



Source: 14 (Jaguar Introduces C-X75 Gas Micro Turbine Extended Range Electric Vehicle, 2010)

The two turbines mounted behind the passenger cabin in a sound proof compartment effectively increase the efficiency and range of the vehicle. They operate by pulling in fresh air, compressing it, and then mixing it with any of a variety of fuels including biodiesel. This mix is ignited and the hot, expanding gases are directed past a turbine fan which powers the compressor and directs power to the battery pack. After this, the gases are expelled through a nozzle and can be used to help with the down force of the vehicle later. Due to the compression process of the turbines as well as their operating speeds of 80,000rpm, they are super-efficient and can run on little fuel producing fewer than 100grams of CO2 per kilometer (Jaguar to build C-X75 hybrid supercar with Williams F1, 2011). This total system with four motors, two turbines, and a 15kwh battery has a range of 559 miles and can be recharged easily with the turbines or by household power (Garrett, 2010). To make the package even

better, no performance or driving experience is lost by using this power system. The car produces 800hp, over 1100lbs of torque, accelerates from 0-60mph in 3.4s, and has a top speed of 205 mph (Pollard). Obviously being green does not take away from its exhilarating performance, so this vehicle can be used as a model for future hybrid cars.

In the future, this method of separate electric motors could see increased use. By using these electric motors, efficiency is increased, sound and pollutants are decreased, and overall weight is also reduced. Each of these is a step toward a green and efficient vehicle with room for growth. Since mini turbines are still a new coming idea, small gasoline engines can be substituted for the sole purpose of recharging the battery. Other ideas have included the use of future solar energy to help recharge the batteries as well as power the vehicle in combination with its electric motors. Even regenerative braking in which energy is recovered from braking and forwarded to the motors could be an option. All possible ideas that can reduce bulk, weight, energy loss, heat loss, sound and air pollutants will be required for future applications.

5.5 Social Implications

The implications of such ideas could have profound effects on our current transportation system. Imagine a quiet highway with clean air and fun travel. Mass transit vehicles such as buses could use this technology and even implement further uses in hydrogen power. With many vehicles operating electrically, CO2 emissions will plummet as will greenhouse gases and smoother travels could be realized. Although all of these benefits make the driving experience more efficient and enjoyable, certain social implications could occur. Farther travel distances could be maintained thus allowing for more isolated living conditions and decreases in social networking and communication. Even a healthier and happier social outlook could be realized. Each of these will be discussed later.

The innovations and headway being made in the alternative fuel and transportation aspects of society offer an exciting new environment and future for environmental and transportation enthusiasts. Even for those that just want to get to work and get home while saving money and feeling good about maintaining the environment, this can be an exciting and joyous time. As changes are made,

encouraged, and implemented in our alternative energy revolution, rapid changes in social structure, the economy, environment, and social views and norms will occur.

As multiple nations encourage and experience a shift in fuel dominance as well as more efficient power and transportation sources, many new social feelings will arise and create an exciting atmosphere for change. This exciting atmosphere will encourage the implementation and economic support of alternative fuel projects allowing for a new renaissance. As economies recover and support future alternatives, more people will become part of the revolution. Those who are simply conscious of their power expenses and of the environment will be happy to embrace healthier and eventually cheaper alternatives. New jobs will also be created in order to support the new infrastructure and directional growth. Further, international relations may be strengthened by global growth and change. Alternative energy projects will open up lines of communication and cooperation between neighboring countries and nations. Influence for nations to cooperate and work together in the energy renaissance could cause new alliances and super powers to occur. Cooperation and production will be reenergized and maximized resulting in more cultural growth and acceptance. Eventually efficiency and global health will increase leaving way for a new era in energy for modern society.

Fortunately, a new resurgence of interest in the transportation field will be realized as well. One of the fears for transportation enthusiasts is that the push toward alternative, more efficient, quiet, and possibly more restrained transportation methods will decrease the travel excitement experienced through personal travel. Luckily, these concerns are being kept in mind in order to maintain the interest in the push for new energy and transportation norms. Commuter experience will become less dredging and less stressful while supplementing occupant piece of mind and occupant enjoyment. By creating vast and quick change, although difficult, commuters will be excited to try new and cutting edge alternatives. Maintaining commuter interest will stimulate growth in the energy industry leading to faster innovation and new grounds for development. Stimulation of interest and cooperation in energy and transportation technologies is the key to gaining support for new alternatives and implementing a new infrastructure for power in today's society.

Chapter 6 - Conclusion

The future of alternative energy is very bright, due to the current interest and research. With ongoing research in the forthcoming years, scientists will be able to significantly advance alternative energy technology. We see these next few years as a turning point in alternative energy because of the declining availability of fossil fuels and global pressure for greater amounts of energy as the population increases. As a world, we will hopefully begin to rely less on fossil fuels, and more on alternative energies. With the right mix of energies used to their maximum efficiency this can be achievable. Many of the alternative fuels we have looked at have a lot of potential.

Power from the collection of solar energy is clean, renewable, vastly abundant, and it shows the most promise through revolutionary applications to replace our current fossil fuel infrastructure. With the increase in efficiencies, applications, and power supply; all that is required is an increase in demand to supplement the implementation of new infrastructure and lowering of the cost. Future growth in the solar power industry will be rapid, diverse, consistent, and could promise a shift in the energy market. Solar energy is the most widely applicable alternative energy resource. It harnesses the most abundant resource we have and if done correctly will pose little threat in the way of shortages. The sheer vastness of the field of applications for solar energy will make it desirable. Through some of the inventions discussed here, solar energy will effectively complement other existing energy resources. Through solar powered electronic devices, vehicles, homes, buildings, cities, and countries a new cultural revolution will take place. If we take steps now in the public and in the government to begin this energy shift, the world will change as we know it.

In these coming years look for wind energy to head towards the sky, as the efficiency of flying wind turbines is maximized and implemented. One of the big drawbacks currently associated with wind energy is the space it uses up. It takes a lot of land to house massive wind turbine farms, and many residents near the farms say they are an eyesore. So, in order to combat this, scientists are looking to put wind turbines in the air, just like kites. Another current downside of wind turbines is their lack of consistency and efficiency. The variation in wind speeds on land is what is causing this inconsistency in wind energy production, and thus hindering the overall efficiency. By putting wind turbines high up in the sky, we would be able to harvest wind from a steady source and maximize the efficiency of the turbines.

Compared to ground level, the wind velocity at 2,000 feet up is two to three times more

(Windpower Math). Wind velocity increases with height, and so, elevations between 15,000 and 30,000 feet would be ideal elevations for a wind turbine tethered to the ground. Research has been done that shows that if we were to harvest just 1% of the energy from jet-stream winds, we could produce enough energy for the entire earth (Levesque, 2007). Putting these wind turbines and turbine farms in the air will completely change our view of harvesting wind energy. With more research conducted and more resources put in, we will be able to make the most out of wind energy and ultimately reach our goal of only relying on alternative energies.

All of these measures would help to reduce efficiency, inconsistency, and space needed for harvesting; all current drawbacks related to wind energy. If we are able to eliminate the current drawbacks of wind energy, then we can expect a surge in wind energy technology. However we cannot focus on one energy in particular; we need to minimize the downsides of as many alternative energies as possible if we are to see them become more prominent. Finding the right mix of energies along with their most suitable application will help to maximize their efficiencies. With the future of alternative energy technologies looking promising, we are getting close to our goal of eliminating the need for fossil fuels and having a clean and healthy environment.

It is clear from the quantity of research into more advanced reactor designs, from higher efficiency and safety to greater compatibility with a wide range of fuels to quasi-portable designs, that there exists a healthy future for nuclear energy and its contribution to solving the myriad issues facing our society. With the wide range of choices within the next 20+ years, nuclear fission will continue to grow as a source of alternative energy. Not only are different fuels being explored but also solid coolants. This trend toward cleaner and safer fission and reduction in radioactive waste will allow reactors to be located nearer to metropolitan areas without large public resistance and thus increase their production and transmission efficiency.

Nuclear fusion is the ultimate ideal for the future of nuclear energy due to its generation capacity along with its safety characteristics and lack of waste or emissions. It is highly probable some form of commercial fusion reactor will be developed within the next 20-30 years capable of generating sufficient quantities of energy as to help alleviate the current energy concerns. The main issue, if this were to occur, will be fuel supply; tritium will either have to be synthesized in fission reactors or harvested from space. It is impossible to predict if the cost of procuring the necessary fuel will limit the scope of fusion, however, we believe this to be unlikely as alternatives to current fuels may become available with advances in other branches of science. The most widespread application of fusion technology will likely be simple electricity production, as its intrinsic limits prevent utilization for mobile

purposes or small scale applications. Small scale applications are unsuitable due to the required input energy, thus if you only desire a small output you drastically reduce the efficiency, and other renewable energy technologies become a much better choice.

Another possible application of these fusion reactors may well be space travel. If the reactors can be miniaturized and specialized for self contained long term operation it may be possible to explore further into space and with powered flight allowing for landings and ground exploration of chosen sites. They may also be used as a power source for lunar colonies as tritium can be found plentifully on the surface of the moon. Such technology could be key to maintaining such a colony without the necessity of refueling or regular shipments of traditional energy sources such as oil from earth which, without a much more efficient method to leave earth, would be very costly both monetarily and materially.

Along with the traditional fusion research there have been in the past attempts at “cold” fusion. Cold fusion is simply a low-energy nuclear reaction that generates more thermal energy than expected for the reaction. Over the past 25-30 years there have been many claims of such a device existing, however, the majority have been discredited or explained as a separate reaction entirely. Most recently a patent application (Rossi, 2008) for an Energy Catalyzer (ECAT Technology, 2012) appeared, registered to inventor Andrea Rossi and researcher Sergio Focardi based at the University of Bologna. The inventors claim to have successfully demonstrated commercially viable cold fusion with the device. It faced severe skepticism similar to any other prior device; however, the few scientists and others reported to have seen the device demonstrated claim it functions as described. The University of Bologna intends to launch its own investigation before any support can be given. The main reason for the strong resistance to the existence of such a device is that the operation of the device appears to break the laws of conventional physics, generating more energy than it consumes thus violating the law of conservation of energy. It is currently impossible to speculate on the validity of the claims but if such a device exists, functioning as claimed, it may usher in a new era of cheap, clean, and possibly even unlimited energy, providing the required materials are not extremely rare. Another factor to consider is the size and intrinsic safety of the device, making it viable as a portable energy resource, much more so than most traditional energy sources.

Of the many technologies that exist today, some have a limited future. Hydrogen, Biofuels, and to an extent, hydroelectric power are alternative fuels that have limited capacity for further improvement. Hydrogen, as energy storage, is inefficient as it requires low temperatures and high pressures to be space efficient, and is costly to produce. Bioethanol produced from corn is the most common biofuel; however current attempts at utilizing it as a source of fuel have shown it to be highly

inefficient, both to use and to produce. The required corn takes up huge amounts of farmland that could be used to combat the rising food prices and thus is a poor choice for an alternative fuel. Not only is photosynthesis a poor way of producing energy from the sun (6% maximum efficiency), but it also has to be farmed and processed which uses a large amount of energy itself. Hydroelectric power is a fantastic alternative resource that provides about 20% of the earth's energy. Its primary drawback is that it causes a large amount of environmental harm. It generates a lot of power, but there are dams placed almost everywhere possible, and the generators are already highly efficient. The existing dams should be maintained, but the focus of renewable energy should shift to newer, more abundant sources.

The amount of extractable oil left in the world is running low. Because of this, alternative energies are being pushed so that when there are no more fossil fuels left the earth will still have power. However, some want to keep using fossil fuels as long as possible because change is inconvenient. For this reason, new ways of extracting oil have been developed. These new sources include oil sands, or bitumen, and shale gas. Bitumen is a tar-like substance that lies close to the surface, and the most convenient method of extraction is strip mining. There are large deposits of oil sands in both Venezuela and Canada which are currently being mined. There has not been much research into the ill-effects of bitumen extraction done on the large scale operation in Venezuela, but the Canadian mining has been shown to cause many environmental problems. One of the main byproducts of the process is Sulfur Dioxide, one of the leading causes of acid rain. And because the process for cleaning requires large volumes of water, that water needs to be recycled. While the mining companies say that it is clean, they are not required to test the water before releasing it back into the rivers, and recent testing has shown clear signs of contamination.

Shale gas is similar to bitumen, except rather than being oil trapped in sand it is methane trapped in shale. It is extracted in a similar way too; water is pumped into the rocks, which causes the gas to bubble up through the gaps the water creates. However, these deposits often exist near drinking water supplies, and the micro-fissures caused by the mining will often allow the methane and other contaminants to leak out and not be collected. It has been shown that shale gas extraction can taint whole wells, and cause health problems for anyone drinking the water.

Another alternative energy source that has shown promise is geothermal energy. By running pipes into the ground, heat can be extracted from the earth with relative ease. Because the temperature difference between the earth's crust and the air is small, very little electricity could be extracted from this. Geothermal energy is still useful as a source of heat; to keep homes warm during the winter. On a small scale it has shown to be efficient and cost effective, but remains unproven on a

large scale. More research will help increase the efficiency, and help determine whether or not extracting large amounts of heat from the earth's crust would cause lasting environmental damage. With more money being put into research as eyes turn towards the future, alternative energy sources are beginning to shine. Other technologies that will improve the effectiveness of alternative fuels are also on the rise. Energy storage has come a long way in the last 20 years, and in the next it will go even further. There is no shortage of alternative energy, but being able to store it to be used when it is needed has always been an issue. Battery technology has evolved immensely, especially with the advent of lithium polymer, and now the safer lithium ion batteries. There is no doubt that this will evolve quickly, as better batteries also mean longer lasting and more powerful smart phones, something that consumers will pay for. Hybrid cars have also been more prominent lately. Currently they are not very effective, but because of the new hybrid class in formula one racing, that technology has been flourishing. Within the next five to ten years, expect the formula one hybrid experiments to bear fruit and spill over into the consumer car industry. If these examples can teach us anything, it's that for technology to develop there has to be a demand for it. This means that for alternative energy to succeed, consumers need to want it to succeed. This means making their lives cheaper and more convenient. If an electric car was cheaper to buy, fuel, and maintain people would buy it. At the moment most green technologies are expensive toys that are impractical. Tesla Motors has been pushing the boundaries of what is possible and are ready to release a second car. Their first was an electric sports car, another expensive toy. But the model-s, geared for a late 2012 release, will have a range of 160 miles and a more reasonable \$60,000 price tag. While still not appealing to the average person, it will get them closer to that goal. The hope is that within the next 5 years Tesla will be able to release a city car for under \$20,000 with the technology from these more expensive cars. A city is a very practical place for an electric car to be, as the distances are small and there are many places where one could park and charge a car at the same time. The model-s already can charge fully in one hour, and that is being released this year. So with battery and charging technology advancing at this rate, an electric car for the average person may be around the corner. Another step in the right direction was the halting of sales of incandescent light bulbs. People don't like change, and were resisting the move over to CFLs even though they are cheaper for the consumer, more energy efficient, and less resource intensive. But now that they are all that can be bought, people have no choice but to use these better bulbs. So even if something is clearly better in every way, the average person needs a large shove in the right direction. This means cleverly disguising newer energy efficient versions of products as the old ones. Marketing specialists found that people disliked the shape of the CFLs, and were much more likely

to purchase one if it were surrounded with a bulb the same shape as an incandescent. Many people couldn't even tell the difference. So it seems that the current future of alternative energy is learning how to camouflage itself as a cheaper version of current technologies, to make the change easier for those who resist it.

The shift from traditional fossil-based fuels to newer alternatives and the implications within the next 100 years are of great interest. Of particular interest will be how the centralization of resources, combined with the technological derivatives and applications of the research into new fuel sources, affects society as a whole. As the fossil fuel resources are finally exhausted and the remaining resources of our planet are gradually used up we must look to the universe for the continuation of our species, or even the vast oceans on our planet. Another approach to slow this overall decline in resources is to become much more efficient with their distribution and utilization. As an example, instead of powering cars with gasoline or hydrogen, we eliminate the need for personal transportation entirely, by investing our minds and resources into alternatives such as mass transit, powered more efficiently by any number of different renewable resources, or simply remove the necessity of regular travel by greater centralization and working from home.

These ideas will inevitably utilize newer energy alternatives and their partner technologies in other fields. Without the requirement of constant travel or trade based on material goods across borders we may be able to fully implement self sufficiency, or at least to a much higher level than is currently possible. With more efficient, self-sustaining, and even portable energy sources we can completely revolutionize how production and distribution of goods is accomplished. Instead of going to the supermarket for food we have biodomes capable of producing sufficient food for a family powered by a micro-nuclear reactor or geothermal heat. Another possibility is synthesis of fresh water through any number of chemical processes, providing unlimited water, made possible by abundant cheap renewable energy. Social aspects of such a world can only be guessed at. With greater centralization there may be more interaction with neighbors, offset by lack of direct work-related interaction. The other interesting social aspect to consider will be off-world living, such as the aforementioned lunar colony and space stations and so forth. The isolation we may think of may not exist if energy can provide the means for cheap intra-solar system travel and communication, and even beyond. Other possibly suitable worlds in other galaxies have been found, and attempts will be made to reach and colonize such places, as space and resources are exhausted on earth. Long-lasting self-sustaining energy sources may allow us to reach such places. There are truly unlimited possibilities, but the answers lie mostly in energy. If we are able to sustainably produce sufficient energy not only to survive but to prosper, we

may have a chance at true exploration of the galaxy.

Our group also provides some recommendations for future IQPs. In the chapter about nuclear energy we discussed tritium's lack of availability on the earth and its known existence on the moon and in Saturn's atmosphere. This brings up a topic of harvesting energy from space. With planets and our moon available to us, space exploration for the purpose of harvesting energy could be a foreseeable topic for a future IQP. This then leads to a whole different topic of space exploration in general. Scientists and many others are trying to find out if life can sustain in space and how it could be possible. Alternative energies could be used as a means of powering this space exploration, and it would be interesting to see the social implications that arise from this. We recommend this as another future IQP topic, considering the importance of space exploration.

An IQP devoted to the study of advancement in automotive propulsion and energy storage is recommended as well. The transportation industry is one that has the greatest impact upon our society as well as the environment but it is also a necessity in our society. Studying the relationship between travelers and their vehicles as well as the relationship between the vehicles and the environment could produce an interesting correlation between humans and our future environment depending on transportation advancement.

The project group focused a lot on the negatives of fossil fuels in our project (running out of fuels, not being clean, etc.), so we recommend future IQP groups to research the positives of fossil fuels. One idea, for example, could be to try and prolong the life of fossil fuels. There has also been research conducted in "cleaner" fossil fuels, such as cleaner coal, and this is vital in the prolongation of fossil fuels. With better means of production and harvesting, the cost of fossil fuels can be reduced. We recommend researching these positives as another interesting topic for a future IQP. Another project could focus on the future of space exploration and the viability of harvesting resources from space and the possibility of lunar colonies and astroculture.

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