Alternative Energy Solutions

An Interactive Qualifying Project Report submitted to the faculty of Worcester Polytechnic Institute, in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Abstract

Providing a self-sustaining, efficient, and cost-affordable source of energy is perhaps the greatest challenge posed in modern society. With supplies of common fossil fuels and many other non-renewable resources nearing depletion, humanity must soon find safe, dependable, and inexpensive fuel sources capable of adequately fulfilling our heat and electricity generation needs. In this report, unique solutions and regulatory policies are proposed after closely examining the advantages, disadvantages, and sociopolitical concerns of many different fuels in both qualitative and quantitative respects.

Contents

I. Executive Summary

Our current energy policies, particularly in regards to electricity generation for both residential and commercial use, are not adequate in sustaining our world in the generations to come. With standard fossil fuels such as coal, natural gas, and oil rapidly diminishing in supply, combined with the steep prices of common renewables like solar and wind power, there is no clear candidate that can provide us with an efficient, safe, and inexpensive form of energy in the near future. This report examines and proposes many alternative solutions by closely observing these mainstream resources with the intent of looking for ways to change how we capture and produce fossil fuels and renewables. In addition, the viability of implementing new forms of energy, such as atmospheric electricity and helium-3, are examined and considered as potential alternative fuels in order to lighten the energy burden in the years to come.

Coal dominates the electricity generation sector because it is abundant, cheap, and easy to process. However, it comes at the grave cost of excessive carbon emissions, despite the technological progress being made with "clean coal" techniques. Natural gas will soon take an important role as an energy source in the future because its cleaner and easier to extract via methods of horizontal drilling and hydraulic fracturing. Also, the demand for oil has steadily increased over the last 20 years. It seems developments in oil harvesting technology as well as the expansion of ocean drilling sites only slow our inevitable approach towards peak oil. The price of oil will continue to grow, and we will need to utilize alternative energy sources more than ever.

Advances in technology among the last few decades have attributed to the growing popularity of solar power given its limitless supply and negligible effects on the environment. To determine when solar power could be readily available, cost analysis was performed to predict the market price in the near future and estimate installation costs for residential homes for different buy/lease business models.

Helium-3 holds a potential to the future carbon-free energy, but only if fusion power plants prove to be feasible. The rush for helium-3 would could bring about the first base on the moon, including a robot assistant that holds the key to successful mining. This is an ambitious plan that some might deem impossible, but with the right knowledge, proper technology, and excellent execution, it can be done.

In addition to Helium-3, the feasibility of harnessing electrostatic particles from the air (also known as "hygroelectricity") was considered via a thorough investigation of the Pyramidal Electric Transducer, which utilizes the stunning mathematical relationship between three dimensional geometry and an AC voltage waveform for the purpose of converting atmospheric electricity to usable DC voltage. Pursuing a similar idea, the creation of lightning rods composed of conductive material capable of withstanding strike with a high impulse was studied.

To summarize the research and results found in this report in a meaningful and applicable way, the final section holds a list of policies that are believed to be important to the continued success of our world and its energy policies. These policies dictate how the world and its many governments ought to regulate its consumption of various fuels by calling upon the conclusions and results laid out in this report. Often times, the simplest of solutions to a problem is overlooked. The evidence gathered in this report may help those actively engaged alternative energy in finding a new solution to the energy crisis.

II. Introduction

We live in an age where our natural resources are being consumed faster than ever and the demand for further production continues to grow. The question that cannot be left unanswered is - how long will our resources hold out and what can we do to meet our population's ever growing thirst for energy? The motivation for this project includes a rising number of employers seeking to answer this question as well as a personal interest in one of the greatest challenges presently facing humanity. The following project considers several of our current energy sources along with several other potential energy alternatives. After taking social and political considerations, a list of policies is proposed that suggests ideas that may help curb the growing demand for energy in the future.

III. Current Energy Sources

Coal, oil, and natural gas are three of the most common fossil fuels used for energy generation on our planet. As this section explores, their efficiency, abundance, and low cost remains unparalleled, even with the very real dangers these fuels pose to our health and our environment. Despite the recent technological advancements and growth of the renewable industry, sources such as solar power - while not plagued with many of the drawbacks found in fossil fuels - are still far from ideal in many ways. Does the key to the energy crisis really just reside in the passing of time, or is there something we must do *now* to ensure the wellbeing and longevity of a world amidst troubling energy policies?

Coal

By: Chris Chaggaris

1. Introduction

Coal has been around since the beginning of man in order to generate heat for cooking and warmth. It is a very versatile fuel that has a wide variety of usages and can easily be found in large deposits all around the world[1]. Throughout recent history, coal has been mainly used for home heating and cooking, but today it is also one of the most important fuels used in electricity generation via centralized power plants[2]. Despite its widespread usage and continued demand as being a "cheap" and easy to process material, the continued usage of coal as a primary fuel source raises many safety and environmental concerns amidst the coming of new, cleaner processing technologies.

2. Production Process

There are two major types of coal mining - surface mining and underground mining. The first method, surface mining, is much more recent due to the development of higher power equipment, and makes up around 60% of coal producing in the United States today. To access

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[1] "A Brief History of Coal Use." *U.S. Department of Energy*. Fossil Energy Office of Communications, 24 Apr. 3012. Web. 02 Sept. 2012. <http://www.fossil.energy.gov/education/energylessons/coal/coal_history.html>.

[2] "Uses of Coal." *Ground Truth Trekking*. N.p., 16 Aug. 12. Web. 2 Sept. 12. <http://www.groundtruthtrekking.org/Issues/AlaskaCoal/CoalUses.html>.

the coal - which can be up to 100 feet deep - the layers of topsoil and subsoil are removed from the land and put aside to refill the space after mining. To remove the layer of large rock and other material (also known as overburden), large excavating machines are used to reveal the coal deposit. After the coal is extracted, the overburden is replaced first, then the soil in an effort to restore the land to its previous state. A more specific process of surface mining, known as mountaintop removal, has been pursued by some American coal companies without regard for the natural terrain. In this process, laborers strip down mountain summits by "peeling" the coal from the hard rocks.

When the coal is further down than 100 feet, or if the land is not ideal, then underground mining techniques are used. Mine shafts are constructed, which require miners and machines to systematically remove coal so that the mine shaft does not cave inwards. Specific machines that have large, sharp teeth break the coal seam and use mechanical arms to scoop up the loose coal and load it into shuttle carts. To further ensure the security of the mine, the roof is reinforced with roof bolts which are essentially long metal rods placed into the roof by machines to bind the weak layers to make them much more secure. Underground mining is very dangerous, as some coal reserves go as deep as 2000 feet underground, but this method still occupies 40% of the coal mining market[3].

The very aspect of coal mining is both dangerous to workers and destructive to the environment. Labor associated with underground mining is daunting and high risk, but despite safety precautions and newer reliable equipment, every year there are a number of mining related injuries. In many developing countries where the safety procedures and equipment are not as modern, mine shaft collapses and worker deaths happen frequently enough to appear on the frontlines of international news reports. Meanwhile, surface mining and mounting topping, which are fast and easy ways to mine coal that are not particularly dangerous, still come at high costs to many wildlife ecosystems and habitats. Not only is the topology of the terrain irreversible, but the extraction process disturbs and pollutes neighboring residential communities. These are the kind of malicious resource gathering techniques that our ancestors practiced regularly when biomass fuels were mainstream. In short, with our modern day culture and level

[3] "How Coal Is Produced." *Kentucky Educational Television*. American Coal Foundation, 15 Dec. 2005. Web. 10 Sept. 2012. <http://www.ket.org/trips/coal/agsmm/agsmmproduced.html>.

of sophistication, this kind of work seems to contradict the many green earth policies that have been popularized in the last few decades.

3. Reserves and Supply

Coal deposits and reserves exist in practically every region in the world, with the only exception being the pole regions. The United States has the largest proven coal reserve of around 243 gigatonnes, which is roughly 29% of the global total. Russia, China, Australia, and India have the next largest coal supplies, at approximately 157 (19%), 115 (14%), 77 (9%), and 57 (7%) gigatonnes, respectively[4]. While Europe has less coal overall then other regions, the small and scattered deposits that can be found there are generally more commercially exploitable and easier to obtain for a variety of reasons. This map roughly shows where substantial coal deposits can be found throughout the world (omitting lesser reserves):

Approximate locations of major coal reserves in the world

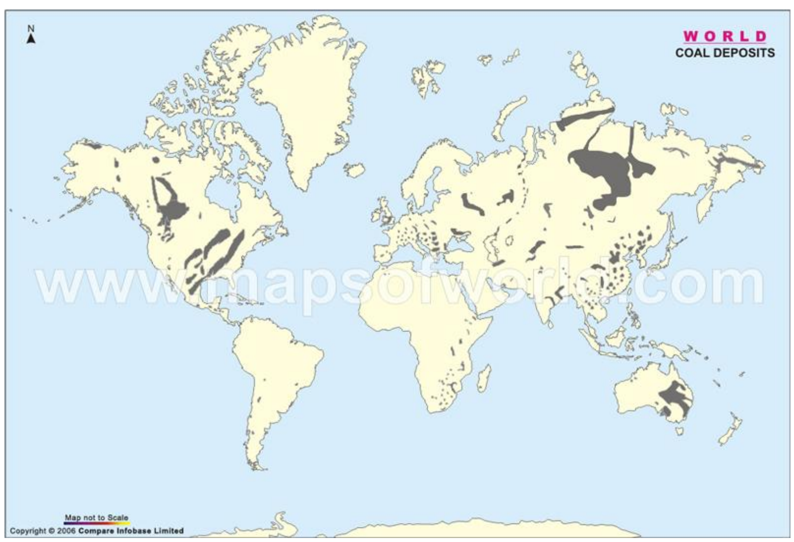

Figure 1[5].

In regards to supply, it is difficult to say exactly how long coal will last, given the possibility that supply and consumption rates can fluctuate in any amount of time. This rate corresponds directly to the coal market, and could change upon the discovery of new deposits or

[4] Ilnyckyj, Milan. "The World's Biggest Coal Reserves." *A Sibilant Intake of Breath*. N.p., 18 Nov. 2008. Web. 17 Sept. 2012. <http://www.sindark.com/2008/11/13/the-worlds-biggest-coal-reserves/>.

[5] "World Coal Deposits." *Maps of Worlds*. Compare Infobase Ltd., 2006. Web. 17 Sept. 2012. <http://www.mapsofworld.com/business/industries/coal-energy/world-coal-deposits.html>.

processing techniques designed to make coal burning more efficient (thus providing more energy). Some experts say that if consumption rates stay at where they are now, then we can roughly estimate a 100 year supply of bituminous coal (higher quality), a 457 year supply of sub-bituminous coal (medium quality), and a 171 year supply of lignite coal (lower quality)[6]. Other views claim that given current production levels, the world's coal supply will not last more than 155 years, with the annual global consumption rate increasing at around 2.5% every year through 2030[7].

These statistics should be thought of as a best-case scenario, due to a large amount of variables this data is merely a snapshot of the world's coal supply. Many consumers are under the notion that coal is abundant, and this is true relatively speaking. While obtaining coal is as easy as drilling a reserve, the undeniable fact remains that coal is non renewable and will disappear entirely in just a few centuries. Either way, these estimates indicate an obvious truth about using coal to generate heat and electricity in the near future.

4. Environmental Effects

It is a well known fact that the intensive heat required in the processing of coal creates many oxides and greenhouse gases that can have a negative effect on the environment. Sulfur and nitrogen oxides release toxic amounts of ozone, smog, haze, mercury, and also contribute to the formation of acid rain that collectively damage property, natural landscapes, and adversely affect human health[8]. The other major byproduct of coal burning, carbon dioxide (CO_2), is well known to have adverse effects on marine life by increasing the acidy of ocean water, and could contribute to the record-breaking trends in climate behavior[9]. In much smaller amounts, carbon dioxide is used by plants through photosynthesis to make food, but it is also used in the formation of dry ice for large scale refrigeration processes, fire extinguishers, and has numerous medical applications.

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6 "How Long Will Coal Last?" *River Basin Energy*. N.p., n.d. Web. 02 Sept. 2012. <http://riverbasinenergy.com/pages/the-future-of-coal/how-long-will-coal-last.php>.

7 Heinberg, Richard. "Peak Coal: Sooner than You Think." *Energy Bulletin*. Post Carbon Institute, 21 May 2007. Web. 10 Sept. 2012. <http://www.energybulletin.net/node/29919>.

8 Greb, Steven F., Cortland F. Eble, Douglas C. Peters, and Alexander R. Papp. "Coal and the Environment." *American Geological Institute*. AGI Environmental Awareness Series, June 2006. Web. 2 Sept. 2012. <http://www.agiweb.org/environment/publications/coal.pdf>.

9 http://www.keepbanderabeautiful.org/co2us.html

In order to get a better understanding of this impact, take a look at the emission quantities of a typical coal plant (estimates are based on a one year interval)[10]:

- 3,700,000 tons of carbon dioxide
- 10,200 tons of nitrogen dioxide
- 10,000 tons of sulfur dioxide
- 720 tons of carbon monoxide
- 500 tons of small airborne particles
- 220 tons of hydrocarbons and ozone
- 170 pounds of mercury
- 225 pounds of arsenic
- 114 pounds of lead

These numbers a grossly high, and it is clear that these plants *at the very least* are causing a proportional amount of harm for any benefits contributed to the energy sector. Measurements taken over a 50 year period in Mauna Loa, Hawaii, show that the amounts of carbon dioxide in the atmosphere are sharply increasing:

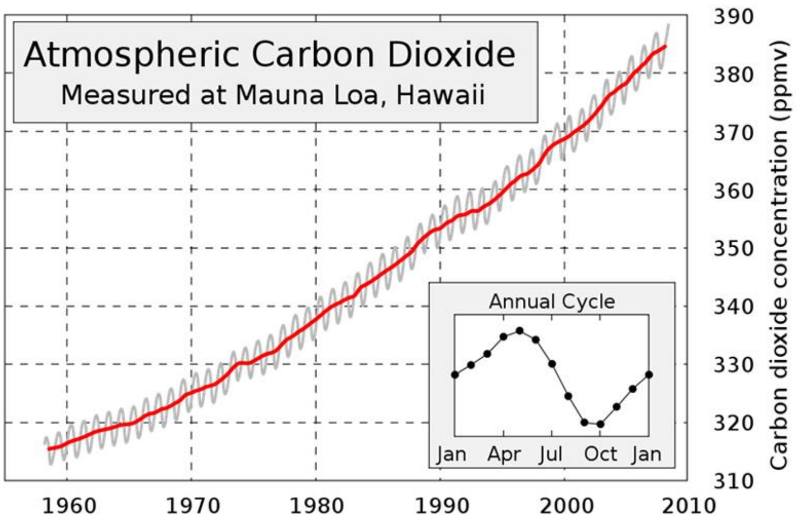

Figure 2: Changes in Mauna Loa, Hawaii's atmospheric readings of carbon dioxide from 1960 to 2010[11].

Every year coal plants operate, our air gets more and more dangerous to breathe and live in with a greater risk of falling ill. The environmental effects are just one of the many problems

[10] http://www.ucsusa.org/clean_energy/coalvswind/c02c.html
[11] http://earthguide.ucsd.edu/eoc/special_topics/teach/sp_climate_change/p_keeling_curve

associated with long term coal usage. In the next section, it is further demonstrated that new coal plants are just bad investments as these pollutants have an additional monetary cost that could be directly harming the economy.

5. Cost Analysis

Like most other fossil fuels, it is extremely difficult to accurately estimate the change in the price of coal. In the past, coal has often been cited as being one of the cheaper fuel sources, more recent studies and cost analyses indicate that coal may be much more expensive than the traditional belief. New trends and constraints, both in the transportation and manufacturing sectors, appear to be having adverse affects on the price of coal.

In the United States, rail lines and large commercial vehicles provide the majority of coal transportation from mines to power plants. As eastern coal mines near depletion, it is likely that more pressure will be placed on the Powder River Basin reserve in Wyoming, which provides some of the cheapest coal per pound, to continue supplying the United States' coal. This is a major factor of concern, since rail lines through the basin are limited and are already acting at or near capacity. The increase in demand for transportation throughout the Midwest will only increase transportation costs, which already stand at about two-thirds the cost of delivered coal[12].

In addition to rising production costs, many economists have recently come to terms with the possibility that the pollution from coal power is actually hurting the economy. Their studies found that coal power plants hold more than 25% of the United States' gross external damages (GED). This number represents the amount the government must allot to cover damages, deaths and sicknesses caused by the pollution, equipment malfunctions, and mining accidents associated with coal production. In the electricity generation sector, the market value for electricity is actually less than the value of air pollution damages, at about half the average coal-related GED expenditures. The origin of this cost-benefit problem could be a result of under-regulation or overproduction of coal as a fuel source.

6. Cleaner Alternatives

As mentioned briefly above, new advancements and years of research in chemical processing have led to some feasible solutions in drastically reducing emissions. New

[12] Glustrom, Leslie. "Coal: Cheap and Abundant... Or Is It?" *Clean Energy Action*. Clean Energy Action, n.d. Web. 10 Sept. 2012. <http://cleanenergyaction.files.wordpress.com/2011/10/coal_supply_constraints_cea_0212091.pdf>.

techniques such as clean coal technology are making it more plausible to continue using coal while still meeting today's environmental expectations and costs. The term "clean coal" describes the process in which raw coal is vigorously washed by chemicals using a variety of different reactions and processing techniques.

One example of clean coal is fluidized-bed combustion, in which limestone rocks and dolomite minerals are added during combustion to minimize sulfur and dioxide emissions. In another process known as integrated gasification combined cycle (IGCC), heat and pressure convert coal to gas or liquid that can be further processed and refined to produce cleaner fuel for transportation use. A process that is more common in the industry is carbon capture sequestration (CCS). CCS is the process of attempting to prevent carbon dioxide emissions from entering the atmosphere by capturing the gas, transporting it to a designated pumping station, and injecting the gas into deposits deep within the ground where it is out of the atmosphere.

The U.S. Department of Energy believes it can incorporate carbon capture sequestration (CCS) to IGCC power plants, with no more than a 10% cost increase for electricity generation[13]. Today, new coal power plants can emit up to 90% less pollutants and particulates than plants from forty years ago because of technological advances[14]. The following graph demonstrates this drastic change:

[13] *FutureGen Initial Conceptual Design Report*. Rep. no. PNWD-3760. 2nd ed. N.p.: n.p., n.d. Print.

[14] "Clean Coal Technology." *National Mining Association*. National Mining Association, n.d. Web. 17 Sept. 2012. <http://www.nma.org/pdf/fact_sheets/cct.pdf>.

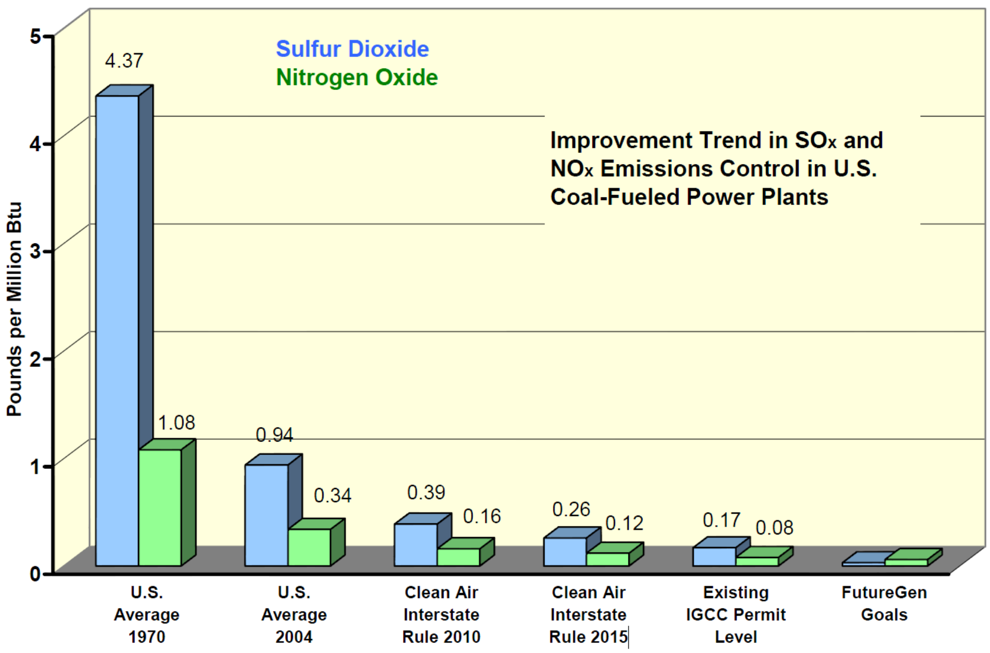

Figure 3: Reductions in air emissions of oxides from 1970-2015.

The prospect of clean coal is not a futuristic dream, and there are currently plans to establish one of the world's first coal plants capable of capturing 70% of CO_2 emissions in Odessa, Texas. According to Senator Kel Seliger, when this new plant is finished (in about three years) it "…will be the model for coal plants in the entire world… This will be the way plants will be built from now on[15]." The problem with these new technologies and clean coal is that they are emerging simultaneously to advances in renewable resource technology and the discovery of natural gas reserves. It seems more logical to spend resources and budget money on these sort of projects, based solely on the fact that coal is in limited supply and retains some of the highest environmental costs. While these new technologies certainly enhance coal quality and may very well meet most of our ideal expectations, most coal today burns without being "cleaned", and this figure is not projected to substantially increase in the coming years either:

[15]http://www.newswest9.com/Global/story.asp?S=10475512&nav=menu505_2

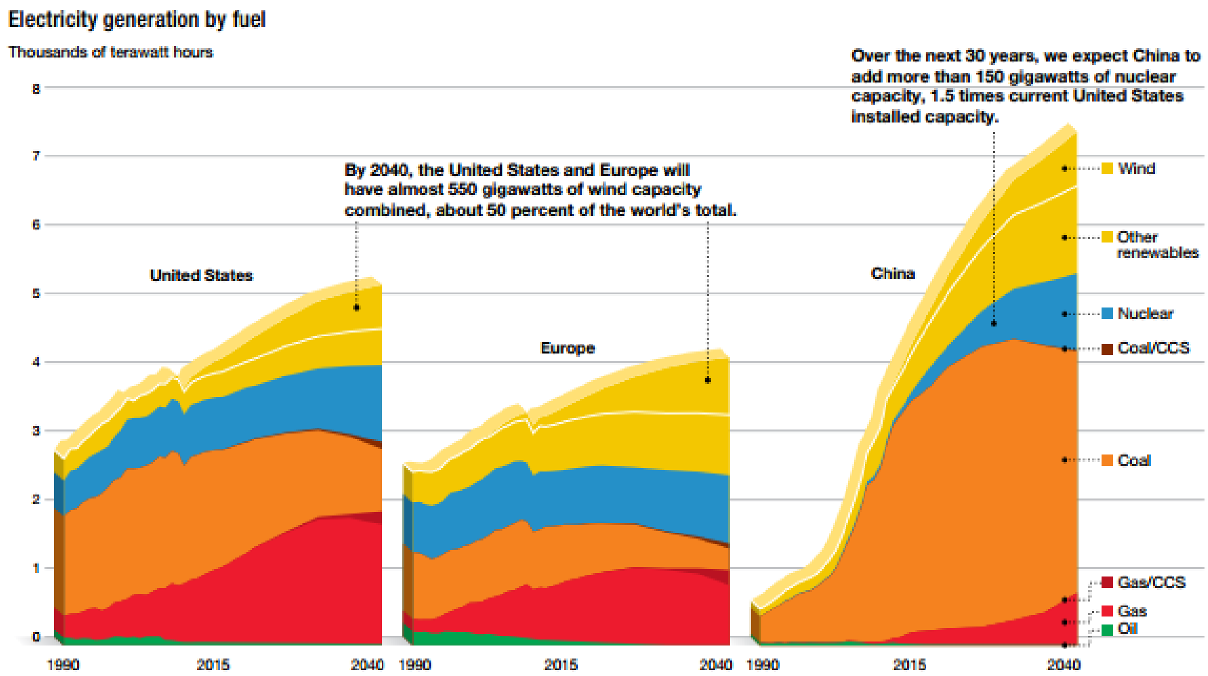

Figure 4: Electricity generation by fuel from 1990 to 2040 (projected) in three major countries[16].

Even though this data only shows the fuel spread among the electricity generation sector, the point is still clear. In China, which has a much larger demand for electricity given its high population size and number of households, hardly utilizes CCS given the amount of coal it goes through. Now this trend could be for many reasons, but why then are time and money being spent developing ways to make cleaner coal if the vast majority of coal will not be processed in this manner anyway?

7. Future Usage

The many disadvantages associated with coal burning do not stack up well against its "cheapness" or immediate abundance, and given the government's stance on the issue, the expected use of coal is projected to start declining within the next 13-15 years. This is not only the case for the United States, but for Europe, China, and many other OECD countries as well. This means that at around 2025, coal usage will peak and then decline by more than 10% through 2040. Coal would move from the number two most consumed fuel type since the industrial revolution, to the number three position, behind natural gas and oil.

[16] "2012 The Outlook for Energy: A View to 2040." *ExxonMobil*. ExxonMobil, n.d. Web. 2 Sept. 2012. <http://www.exxonmobil.com/Corporate/files/news_pub_eo.pdf>.

It is my belief that the world must eventually substitute its coal usage in all sectors with one or more alternative fuel sources so that society's ever growing energy demands can be met. The first step in achieving this goal is the acknowledgment that the sooner the world's dependence on fossil fuels is eliminated, the better off we will be. Though there are certainly more practical solutions to make the effect of coal burning on the environment substantially lower (i.e. clean coal), it does not change the problem of emissions, cost, and supply that make future usage of coal implausible and unethical. To me, it seems pointless to spend money on carbon capture sequestration or other clean coal processing techniques that only provide us with short term benefits. Although there is no other source of fuel today that can meet the same needs as coal while being both accessible and economic, I still believe that the time and funding for alternative energy research is better spent on the technology of renewables, such as solar or wind, that are clean and dependable so that one day these resources can be efficient, cost competitive and capable of satisfying the world's growing energy demands.

Oil

By: Nick Muller

1. Worldwide Reserves

Oil's high carbon and hydrogen content as well as its flammability make it a versatile substance for fuel, heat transfer, lubrication, and other applications. Unfortunately oil is a non-renewable resource, and demand for it is higher than ever. So how can we meet this massive demand for oil? How long will our reserves last? According to the data on oil reserves in the BP Statistical Review of World Energy, the global amount of oil in reserves has increased steadily since 1980 as can be seen below in Figure 5.

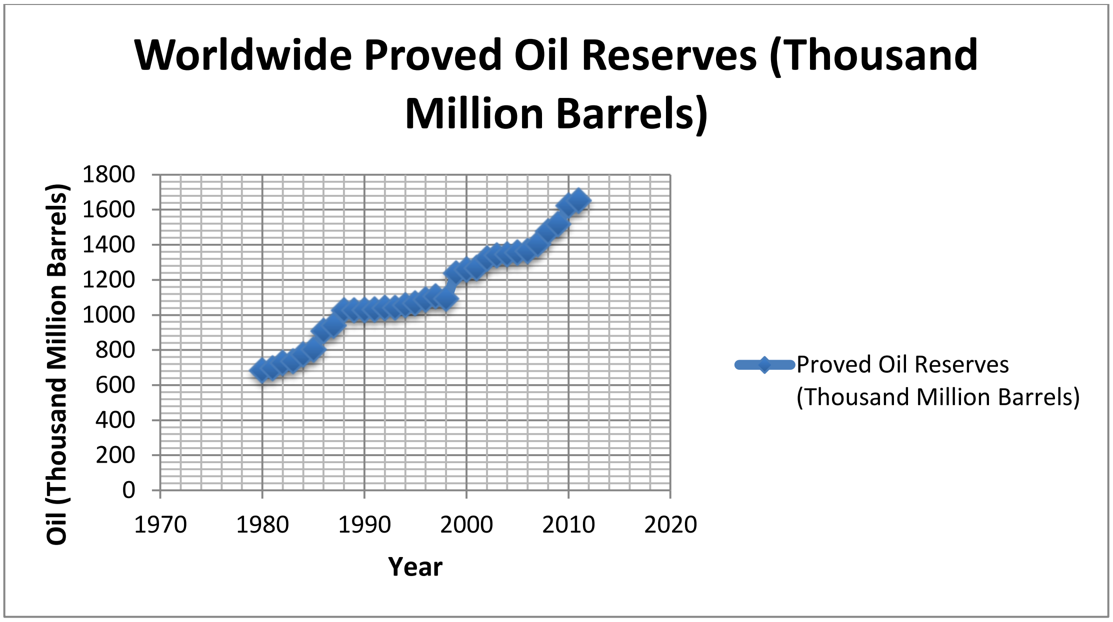

Figure 5[17].

Note that proven oil reserves are taken to be "those quantities that geological and engineering information indicate with reasonably certainty can be obtained in the future from known reservoirs under existing economic and operating conditions." Let's take a look at the worldwide oil consumption history.

[17] Based on data from http://www.bp.com/statisticalreview (Oil reserves data—Download Historical Data Workbook)

2. Worldwide Consumption and Peak Oil

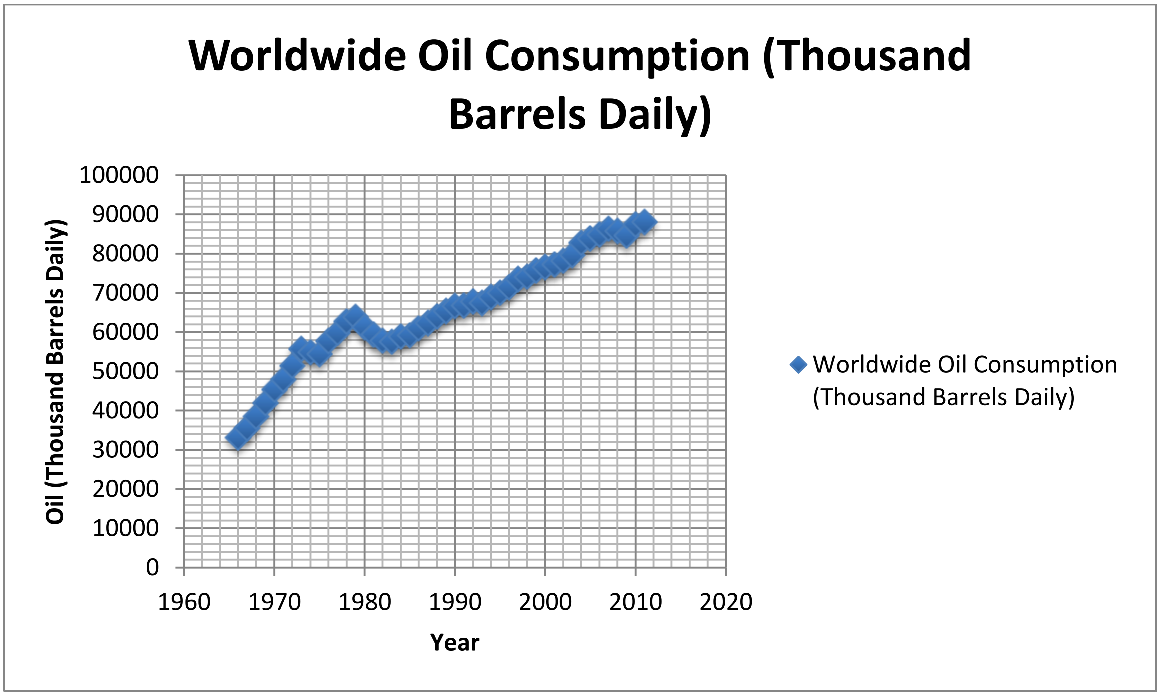

Figure 6[18].

In 2011, we consumed oil at a rate of about 88,000 thousand barrels of daily. Multiply this by 364 days and you get about 32 billion barrels yearly. Global oil reserves rose by about 31 billion barrels from 2010 to 2011. We are depleting our reserves faster than we are consuming them. At some point our planet is going to run out of reservoirs to harvest oil. It is difficult to predict exactly when this will occur due to factors such as production rates in individual oil wells, projected reserves, and advances in new technology. However, many sources predict that Peak oil will be reached sometime between 2020 and 2030[19]. Peak oil is the point in time when the maximum rate of petroleum extraction is reached, after which the rate of production is expected to enter terminal decline.

[18] Based on data from http://www.bp.com/statisticalreview (Oil reserves data—Download Historical Data Workbook)

[19]<http://www.bp.com/sectiongenericarticle800.do?categoryId=9037157&contentId=7068604> (Data on Oil Reserves from 2010 to 2011)

Marion King Hubbert's Oil Production Curve as Predicted in 1956

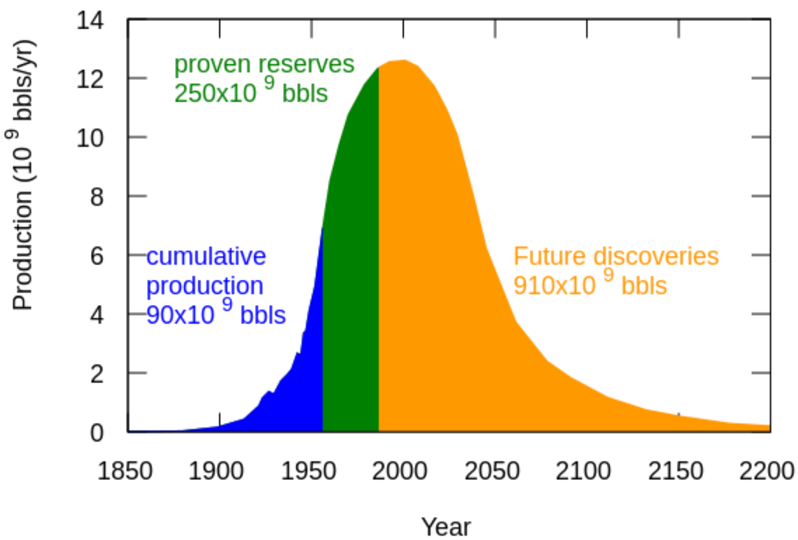

Figure 7[20].

Figure 7 shows American scientist Marion King Hubbert's prediction for peak oil made in 1956. This concept of rise and fall in production of oil depicts peak oil and is now known as the "Hubbert Curve".

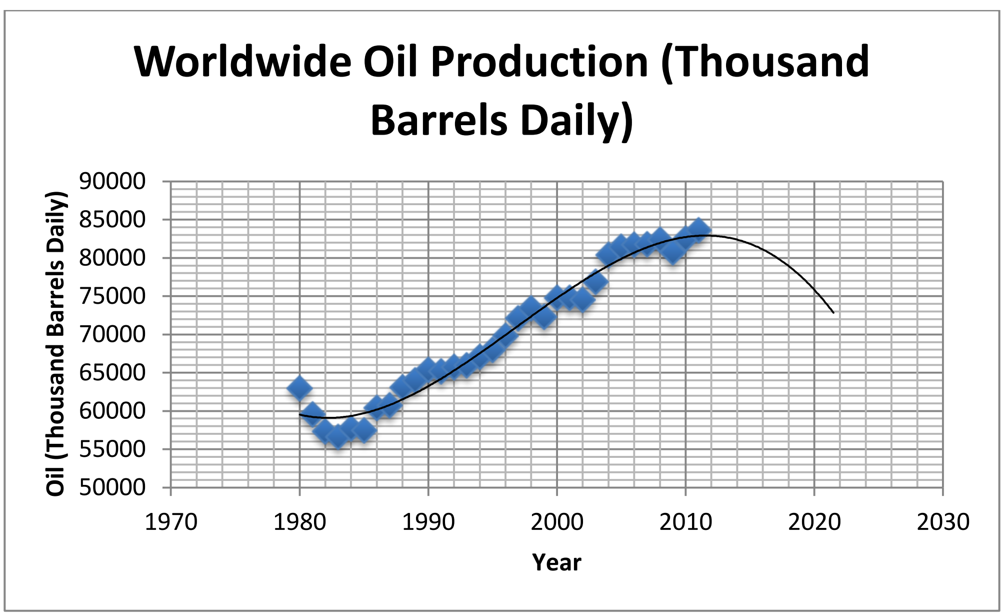

Figure 8[21].

[20] http://en.wikipedia.org/wiki/Peak_oil

Figure 8 shows a graph using data points from BP's 2012 Statistical Review of World Energy to display the growth of Oil production from 1980 to 2011. The curve looks very similar to the "Hubbert Curve" in the figure 7. In fact, the tread line predicts that we will hit peak oil within the next five years! Looking into the future, we will need to find new alternatives or implement new policies regarding the efficient use of oil.

3. Development in Oil Harvesting Technology

So, how are our oil reserves rising more rapidly all of a sudden? A large part of this increase in oil reserves is due to new technology that allow for more efficient oil harvesting. The first 5-15% of oil in a reservoir is extracted through primary recovery. This can be extracted through natural water displacing oil downward into the well while the underground pressure is still sufficient enough to force oil to the surface. After enough pressure has been released from the reservoir, another 40-60% of the reservoir's oil is harvested through secondary and tertiary methods. It's in these areas that technology has made leaps and bounds recently. One of the more commonly used secondary methods is injecting gas. By injecting gasses such as carbon dioxide, nitrogen, or natural gas, the pressure in the reservoir is increased while also reducing the viscosity of the crude oil by mixing gas with it. Chemical injection aims to help oil act more like a Non-Newtonian fluid and decrease surface tension by injecting long polymer chains. Another newer method of injection is microbial injection. Strains of microbes have been discovered which digest hydrocarbon chains, thus decreasing the oil's viscosity[22]. Liquids with less viscosity are easier to draw to the surface. Lastly, thermal methods like steam injection help build pressure in the reservoir while also increasing temperature which again decreases viscosity. These newer enhanced methods of extracting oil from reservoirs create large quantities of brine at the surface. The brine can contain toxic metals and must be taken care of properly and not let into our water supply. Another emerging method of extracting oil has been developed by researchers at UPI and can also be used to clean up oil spills on beaches. This method involves extracting oil from tar sands using recyclable ionic liquids to separate the oil from the sand[23].

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[21] http://www.bp.com/statisticalreview (Oil reserves data—Download Historical Data Workbook)
[22] <http://en.wikipedia.org/wiki/Enhanced_oil_recovery> (Enhanced Oil Harvesting Methods)
[23] <http://www.upi.com/Science_News/2011/03/16/New-method-extracts-oil-from-tar-sands/UPI-38861300307329/> (Article on New Tar Sands Harvesting Method)

This new separation method involves very little water and energy. It is also much cleaner due to the fact that it does not use contaminated wastewater in the separation process.

4. Oil Price History/Projections

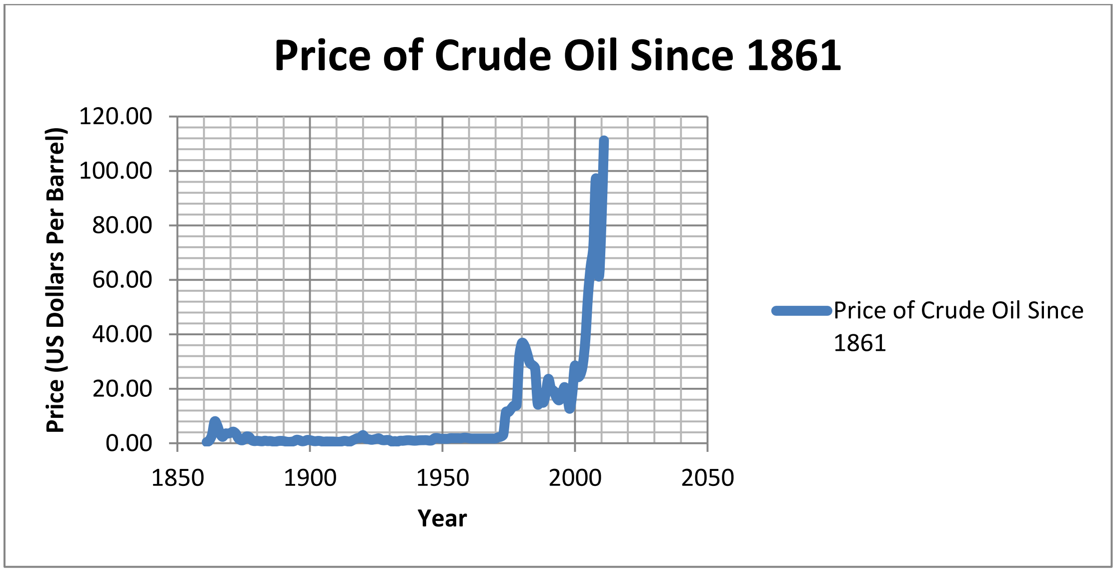

Figure 9[24].

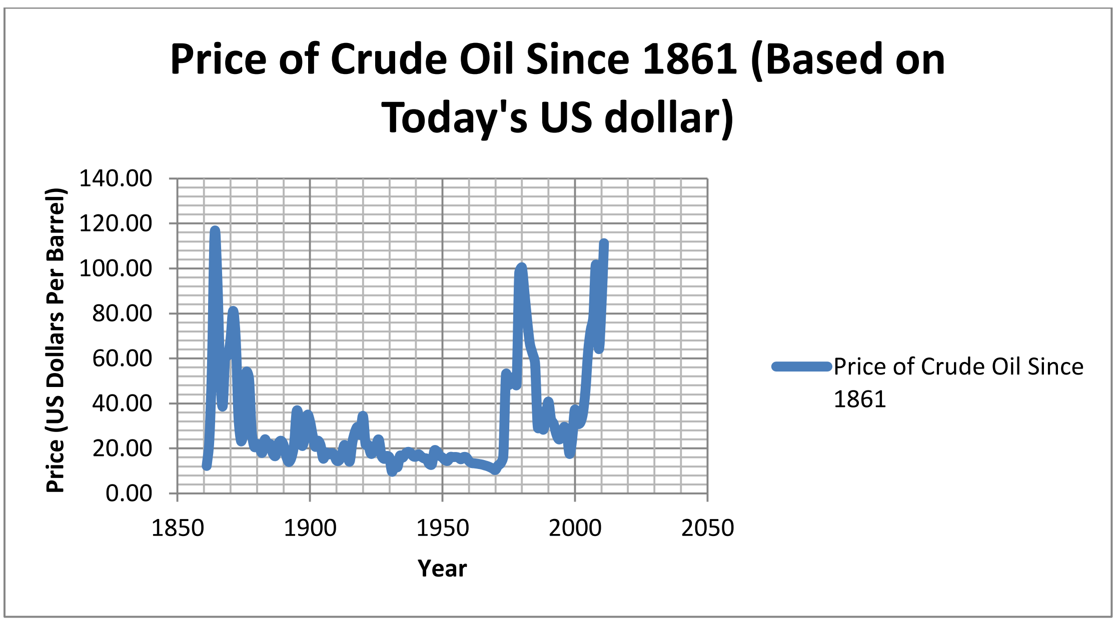

Figure 10[25].

[24] Based on data from http://www.bp.com/statisticalreview (Oil reserves data—Download Historical Data Workbook)

[25] http://www.bp.com/statisticalreview (Oil reserves data—Download Historical Data Workbook)

The price of crude oil has exponentially increased since 1861. However, it's interesting to note that based on the value of today's US dollar, oil prices are peaking at about the same point they have at two previous points in history, (1863 and 1979). The American Civil War occurred from 1861-1865 and the Iraq/Iran war peaked around 1979. This means the two previous peaks in oil price were most likely due to war-related inflation. Despite the recent climb in price, most sources project oil prices to begin to level off slowly over the next 20 years or so. The projections are based on global supply and demand as well as the rise of alternative sources such as natural gas and hybrid/electric vehicles. Figure 9 shows the price history of crude oil as is while figure 10 shows the price history of oil while taking inflation into account.

DECC Predictions for the Range of Oil Prices Over the Next 20 Years

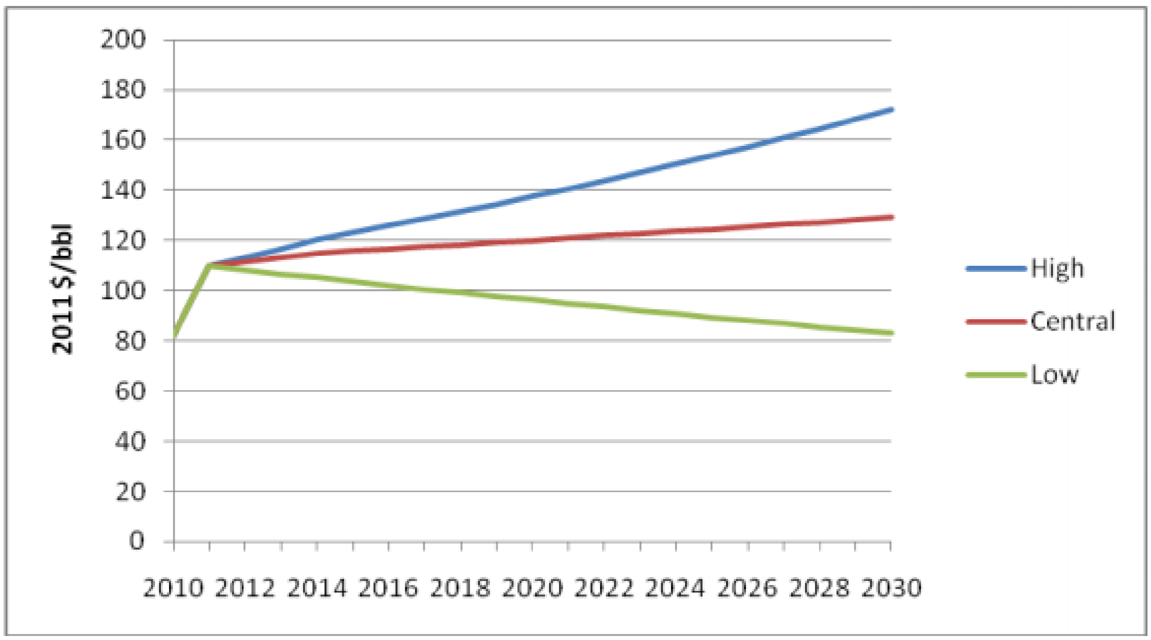

Figure 11[26].

In figure 11 above, The Department of Energy and Climate Change (DECC) show their range of predictions for oil prices over the next 20 years. In the high scenario, we see that the price of oil (in dollars per barrel) could rise to as much as $172 dollars per barrel. However, note that the price of oil had previously risen from about $20 per barrel to over $100 dollars per barrel

[26] <http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2934-decc-oil-price-projections.pdf> (Projected Oil Costs)

from 2000-2010. Even with the maximum predicted increase in the price of oil, we can see that the rate of increase in price is expected to slow down and eventually start to level off to the point where it is only increasing with the rate of inflation. The main way we can reduce the cost of our oil, is to decrease our demand. And in order to decrease demand for oil, we can use alternative sources of energy and/or implement energy saving technology and policies. But research for new technology that can decrease our dependence on oil costs money. Perhaps this is why countries that are part of the Organization for Economic Cooperation and Development (OECD) have a lower demand growth for oil — generally, they have more money. So which areas of the world would see the largest improvement while reducing their demand for oil growth? Probably the non-OECD countries. Introducing alternative energy sources, and energy efficient technology/policies to these countries can help curb the rising demand and price of oil in the future. Figure 12 compares the predictions for the future price of oil estimated by several major sources.

Oil Price Forecasts Estimated by Several Different Organizations

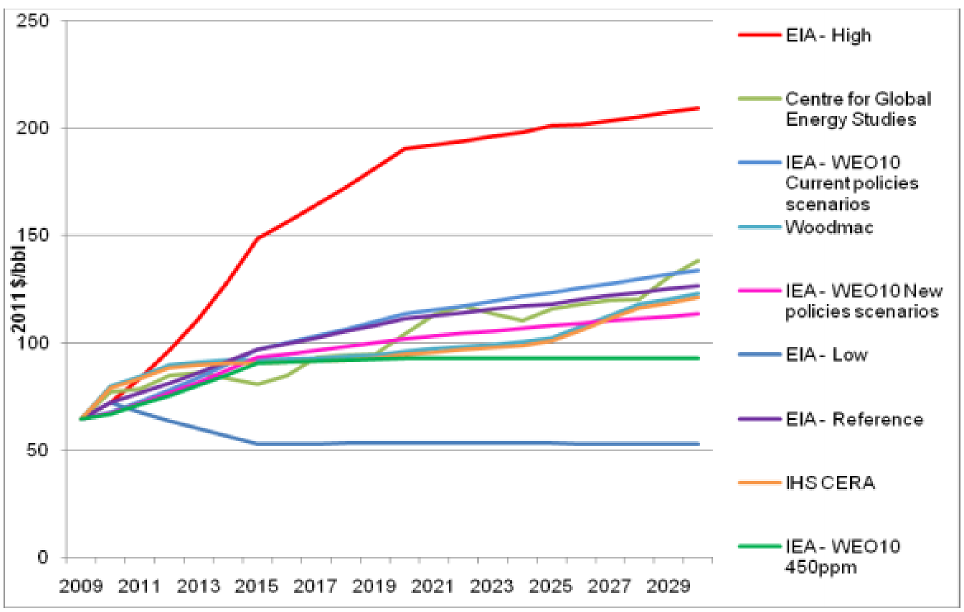

Figure 12[27].

[27] http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2934-decc-oil-price-projections.pdf

5. The Alaskan North Slopes

The question of whether or not to drill for oil on the North slopes of Alaska has been an ongoing controversy in the United States since the late 1970s. Currently, the federal government prohibits oil and natural gas development on the northern shore of Alaska, because on December 2nd 1980, president Jimmy Carter signed the Alaska National Interest Lands Conservation act. This act prohibits drilling and other commercial activity in the Arctic National Wildlife Refuge (ANWR). However, Surveys conducted by the U.S. Geological Survey (USGS) suggest that anywhere from 5.7 to 16 billion barrels of recoverable oil are located in the coastal plain area of the ANWR. The vast range of uncertainty is due to several uncertainties: the size of the underlying resource base, the oil field sizes, the oil quality, the characteristics of the oil reserves, and environmental considerations. According to the US Energy Information Association (EIA), the total production from ANWR would be between 0.4 and 1.2 percent of total world oil consumption in 2030. Figure 13 shows a projection of estimated oil production from the ANWR based on 3 cases: a maximum resource, mean resource, and minimum resource case.

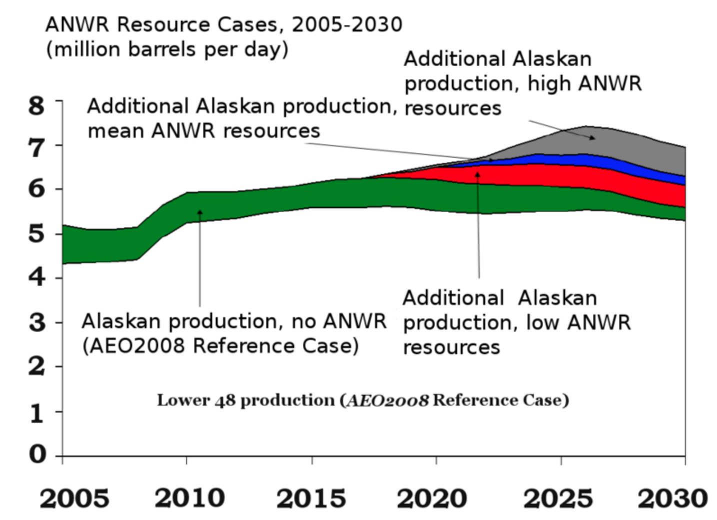

Figure 13[28].

With an average 10.4 billion barrels of oil divided among many fields in the protected Alaskan wilderness, politicians have used this as a subject for debates for the last 30 years.

[28] <http://www.eia.gov/oiaf/servicerpt/aong/anwr.html> (Alaskan North Shore Info/Data on Foreign Oil Dependence)

President Barack Obama opposes drilling in the Alaskan North slope because he believes it will have a permanent adverse effect on wildlife refuge and that the amount of oil harvested would negligibly affect the global oil price. If the ANWR were to be opened for natural gas and oil development, it would have the following positive impacts: slightly reduced world oil prices, reducing the US dependence on foreign oil, and the creation of US oil-related jobs. But the opening of the ANWR for gas and oil development also comes with negative environmental impacts. These include: Pollution of oil, and methane/nitrogen oxide gases that can cause smog and acid rain. In addition, drilling would disrupt the natural migratory patterns of animals, thus increasing their mortality rate. Figure 14 shows a map of the controversial North Slope of Alaska.

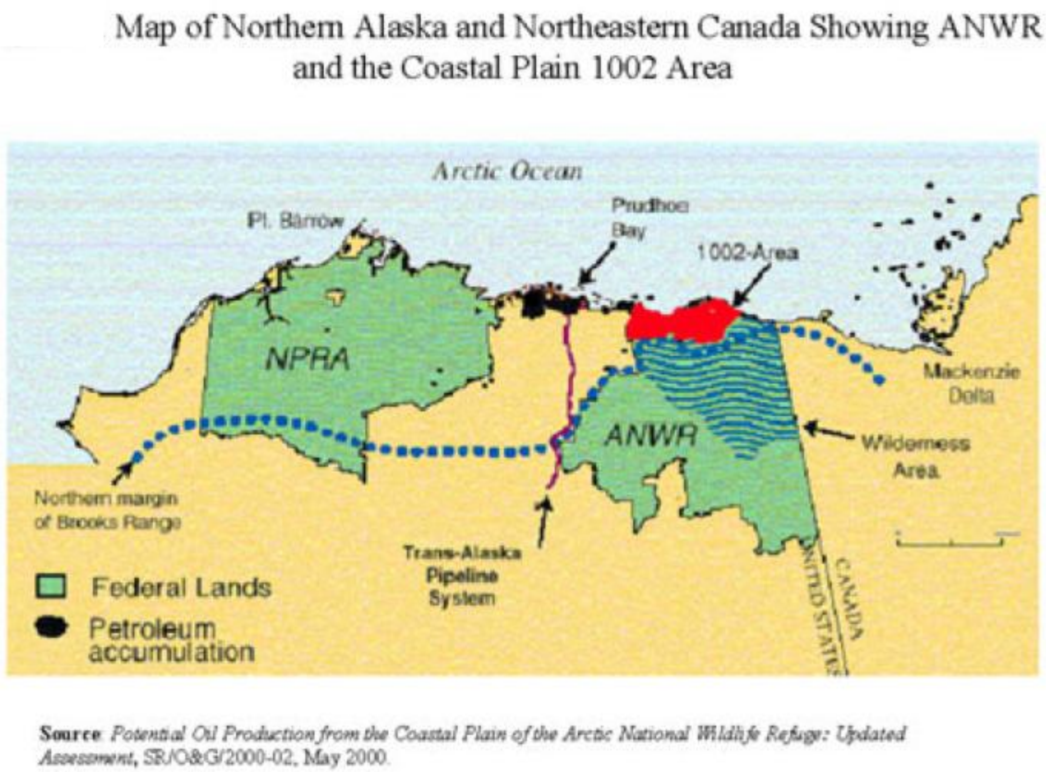

Figure 14[29].

Using the data mentioned earlier, the oil reserves on the North Slope of Alaska could contain anywhere from 5.6 to 16 billion recoverable barrels of oil. According to the US Energy

[29] http://www.eia.gov/oiaf/servicerpt/aong/anwr.html

Information Administration (EIA), the oil harvested from the Alaskan North Slopes would add approximately 800,000 barrels of oil daily to US crude oil production in 10 years. This mean approximation of 800,000 barrels daily would reduce the amount of imported oil we consume by 2% and increase domestic production by 14%. In the best case scenario of 16 billion recoverable barrels of oil, only 57% of the US consumed oil would be foreign, while a worst case scenario of 5.6 billion barrels would reduce US foreign oil consumption by 1% to 61%[30]. Overall, projected mean oil production from ANWR would only represent 0.7% of the world's total oil production by 2020. Personally, this seems fairly insignificant. I don't believe the mean 2% reduction in foreign oil dependency as well as the increase in employment is worth the negative environmental effects that drilling in ANWR would bring forth.

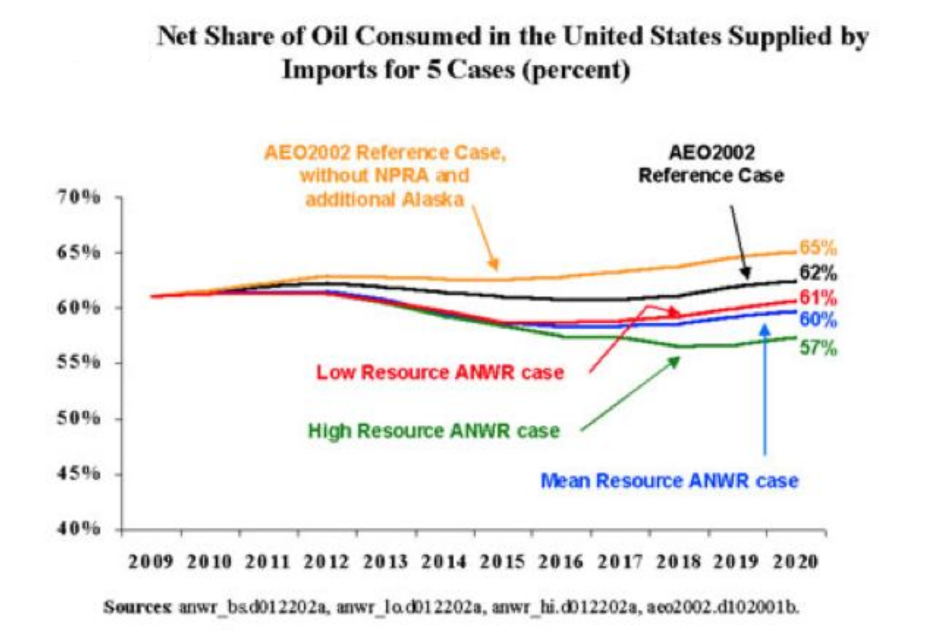

Figure 15[31].

6. Conclusion

Clearly the most desirable solution to our limited supply of oil is a clean, renewable, alternative source of energy. However, without this option immediately at hand, we must find the most effective plan to make our resources last as long as possible. One thing we can do is

[30] <http://www.eia.gov/oiaf/servicerpt/anwr/results.html> (Alaskan North Shore Info/Data on Foreign Oil Dependence)

[31] http://www.eia.gov/oiaf/servicerpt/aong/anwr.html

create programs that introduce technological advances in energy conservation to the areas that most need them: the non-OECD countries that have the least money and highest growth in oil consumption. These countries might include Belarus, Azerbaijan, Peru, and Vietnam with 22.8%, 11.9%, 9.0% and 8.9% increases in oil consumption over the last year respectively[17]. We can also utilize more alternative energy sources whether it be natural gas, wind energy, solar energy, geothermal energy or perhaps some new form, which is yet to be discovered. Continued research and development towards technological advances in oil efficiency is also important. Our recent improvements in tar sand and reservoir harvesting increase oil production efficiency, which helps "stem the bleeding" of our limited supply of oil. Finally, drilling for oil in the ANWR region of Alaska may not be the most effective solution. While drilling in the ANWR provides jobs and oil for the present, it's neither a clean nor renewable solution. The likelihood that drilling would cause permanent environmental harm coupled with the fact that the oil harvested would only decrease foreign oil dependence by 2% makes the decision to drill feel like a last resort option. In conclusion, there is no one specific answer to the issue of non-renewable oil. We must seek to reduce demand and improve efficiency through policies regarding oil usage, new technology, and the use of alternative energy sources.

Solar Power

By: Chris Chaggaris

1. Introduction

Humans, animals, and plants have a certain dependence on the sun's light. Historically, we have used solar energy in its simplest form to satisfy our basic heating needs, while plants and other fauna require sunlight to photosynthesize food. Solar energy can be defined as the electromagnetic radiation emitted from nuclear fusion processes on the sun that can be converted to thermal or electrical energy. Even with today's standards in technology, the amount of light and heat captured from the sun is only a small fraction of the total available solar energy[32]. While solar energy has certain obvious advantages, such as being a clean and abundant source of renewable energy, it is met with the challenges of steep production costs and unpredictability.

[32] "A Brief Description of Solar Energy." *SGN Solar Energy*. N.p., n.d. Web. 08 Oct. 2012. <http://www.sgnsolar.com/brifdiscription.html>.

2. Advantages

As previously stated, solar energy is a relatively green and unlimited source of energy. Unlike the burning of fossil fuels, which release heavy amounts of dangerous byproducts into the atmosphere, the actual process of harnessing sunlight via solar panels is a clean and non-polluting process. In addition, solar energy is extremely versatile and can be used for a variety of purposes, especially in the electricity generation sector. In areas throughout the world that are not close to a power grid, solar panels can be installed to supply a populated area with enough electrical energy to meet their daily needs. Today's solar panels are also efficient in the sense that the power rating of using photovoltaics (the current practice of converting solar radiation to direct current and then passing it through semiconductors to power a circuit) is very high, with the world's mean power density estimated to be around $170W/m^2$. So despite low yields, the amount that can be captured already provides more power than every other renewable resource, all while remaining mostly soundless[33].

Solar powered systems provide a unique set of benefits that are extremely desirable in an energy source. Ideally the energy of the future must be both smart and reliable, and most non renewables, especially fossil fuels, are hardly ideal. In the years to come, solar power will most likely dominate the residential/commercial sector as the primary source for electrical generation as long as technology expands exponentially to lower costs and improve efficiency. But the expected increase in energy demand among this sector in the next 30 years means more fuel is needed to create the electricity. As the next section will discuss, it seems much more logical - both economically and environmentally - to pursue and invest in solar capturing technology over coal burning.

3. Disadvantages

At the top of this list is without a doubt the cost required to produce these solar panels. Given the relative emergence of photovoltaics and the current political stinginess on the subject, it could take many years before the regular usage of solar energy is considered for long term applications. While solar panels can go without maintenance for decades - and therefore forego any repair costs - the cost of establishing a 3 to 7 kW solar power system in the residential sector

[33] "Solar Energy Pros and Cons." *Energy Informative*. Energy Informative, n.d. Web. 08 Oct. 2012. <http://energyinformative.org/solar-energy-pros-and-cons/>.

can range anywhere from $18,000 to $40,000 alone[34]. Expensive as they are, even at these prices a home solar powered system has the potential to lower monthly power bill costs in the long term, but these high installation costs are unattractive and to many homeowners, also unnecessary. Another important factor to consider is manufacturing pollution, since the production of every solar panel emits highly potent greenhouse gases, such as nitrogen trifluoride and sulfur hexafluoride. While these emissions cower in comparison to those emitted by fossil fuels, they are still problems that cannot be ignored. There is also the issue of geographic location, inclement weather, and the day/night cycle, which dictate exactly when and where sunlight can be extracted. Sunlight is scarce in the late evening/early morning hours, while peaks during the middle of the day. Also, certain areas of the world receive much less harvestable sunlight than other areas, as this map of the U.S. demonstrates:

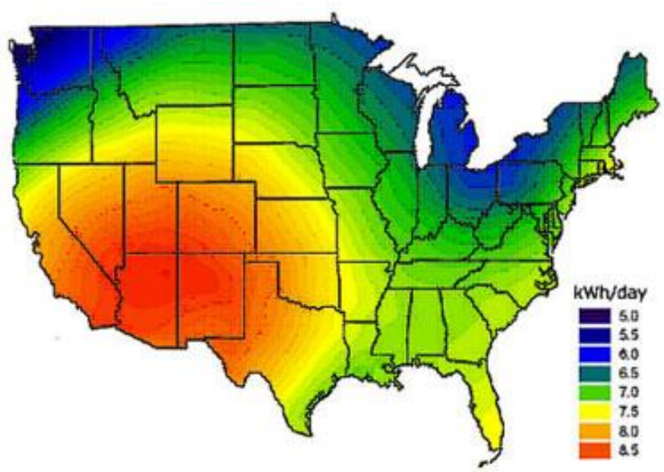

Figure 16: Kilowatt/hour per day ratings in different parts of the U.S[35].

In the future, through newer and more efficient technological changes, there are still hopes for the standardization of solar energy as an alternative energy to the world's swift depletion of fossil fuel reserves.

[34] "Cost of Solar Power." *Sunrun*. Sunrun Inc, n.d. Web. 08 Oct. 2012. <http://www.sunrunhome.com/solar-lease/cost-of-solar/>.

[35] "Solar Power Cost." *Solar Power Cost*. CoolerPlanet, 2007. Web. 07 Oct. 2012. <http://www.solarenergy.net/Articles/solar-power-cost.aspx>.

4. Future Solutions

As has been shown, there are many benefits to using and standardizing solar power. That being said, it is difficult to ignore the challenges that must be overcome if we are to make solar power practically efficient - in other words, cost competitive. Great changes are expected to become mainstream in the near future and can hopefully address and dissolve some of these problems. One example of this is the addition of solar tracking satellites, which rotate around the Earth at just the right speed so that light can be reflected from the sun to the panel where light would normally be out of reach. This is carefully calibrated to work as natural as possible, and is just one of many possible countermeasures to adapt solar panels for increased effectiveness. A second important addition is the introduction of the luminescent solar concentrator (LSC), which was created by researchers at MIT. Solar concentrators work as stationary devices that channel light wave particles so that less energy is lost in the transition. To do this, dye molecules are sprayed over a plastic film (or sometimes even glass) surrounded by solar cells. As light shines on the plastic, neutrons in the cells energize and this state causes them to release excess energy that would have otherwise been lost as heat. This energy bounces around inside the plastic and is concentrated until it eventually reaches the outer surface. Through these new innovations and more, solar panels are slowly but surely becoming more adaptable and cost-affordable.

5. Study: Quantum Dot Solar Cells

One of the newest and most promising emerging technologies in increasing solar cell efficiency in photovoltaics is quantum dots. These tiny charged particles are only a few nanometers long, and have very unique and desirable electric properties. Accidently discovered in 1980, these building blocks of transistors were originally dismissed as impractical for any commercial applications. Today, recent breakthroughs have led many specialists to believe that these beads could impact the future of solar panel manufacturing by providing an inexpensive and efficient way to create solar cells on thin film substrates - similar to the mass production of newspaper. Quantum dots are highly flexible particles synthesized from cadmium selenide solutions, and can be confined or altered into different shapes in all three spatial dimensions. Adjusting the size or shape of the array even slightly changes the color of light being reflected (i.e. fluorescence light). Since they are so small, quantum dots contain a unique set of properties that are sort of an intermediate between bulk semiconductors and molecules[36].

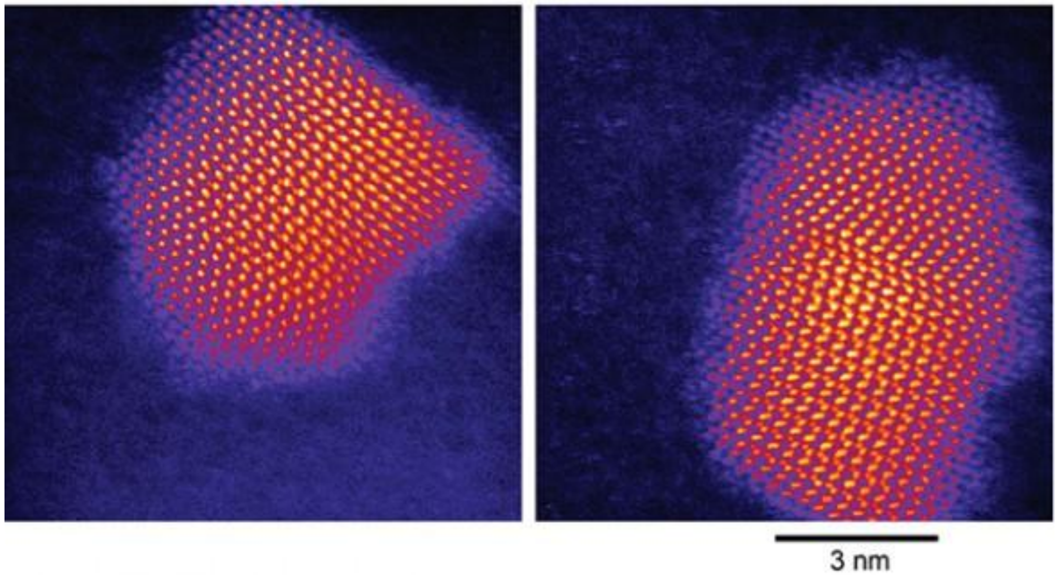

Figure 17: Close up of a bright red/orange quantum dot showing atoms under an electron microscope[37].

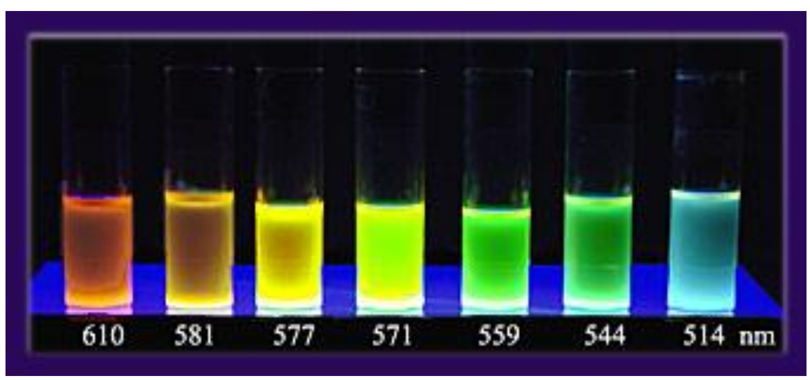

Figure 18: Relationship between solutions of different sizes to color emitted of quantum dots[38].

As mentioned previously, solar cells are inefficient because there is a significant amount of heat lost from the sun's energy due to escaping electrons that bounce off. While the LSC technique does improve cell efficiency, it is inadequate in capturing these hot electrons. A

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[36]Lee, Corissa. "Quantum Dots." *Mechanical Science and Engineering*. University of Illinois at Urbana-Champaign, 26 Apr. 2010. Web. 09 Oct. 2012. <http://mechse.illinois.edu/media/uploads/course_websites/lee_quantumdots.20100425.4bd4c1c5be8fe7.73485281.pdf>.

[37] Salisbury, David. "Quantum Dots Brighten the Future." *Vanderbilt University*. Vanderbilt University, 12 May 12. Web. 08 Oct. 2012.

[38] "Quantum Dots." *Views From Science*. Views From Science, 2010. Web. 15===08 Oct. 2012. <http://www.viewsfromscience.com/documents/webpages/nanocrystals.html>.

phenomenon known as Multiple Exciton Generation (MEG), where incoming light photons can create multiple electrons, makes use of quantum dots as the absorbing material in solar panels. According to researchers, mastering this naturally occurring process with quantum dots allows the solar cells to absorb the high energy electrons that would otherwise be lost[39]. In the spring of 2012, scientists in Toronto and Saudi Arabia collaboratively created a colloidal quantum dot thin-film solar cell (CQD) using a modified process of MEG that achieved a record breaking efficiency of 7%. While this percent is lower than solar panel efficiencies with standard photovoltaics, most experts say solar panels with quantum dot cells could be more than 40% efficient in time[40]. Quantum dot technology, while very promising, is still in its working stages, so it could be at least five years before we see any sort of commercial debut. Needless to say, there has been no shortage of revolutionary advances in the way we capture, produce, and distribute solar energy.

Natural Gas

By: Sitthipat Preedawan

1. Introduction

Natural gas is a flammable gas, consisting mainly of methane, with other hydrocarbons, carbon dioxide, nitrogen, and hydrogen sulfide, occurring naturally underground over a period of time. Natural gas can be used as fuel and an energy source to provide heating and electricity. Natural gas is considered as a crucial element of the world's supply of energy because when it is burned it will only produce a few emissions in exchange of a great deal of energy. Natural gas differs than other fossil fuels because it is clean burning and only creates a minimum harmful side effect to the air[41].

Natural gas demand will increase greatly in the future due to the efforts to help keep emissions under control. Natural gas will eventually take over a second place in the world's fuel

[39] LaMonica, Martin. "Two for One: Quantum Dot Solar Cells Boost Power." *CNET News*. CBS Interactive, 17 Dec. 2011. Web. 07 Oct. 2012. <http://news.cnet.com/8301-11386_3-57344421-76/two-for-one-quantum-dot-solar-cells-boost-power/>.

[40] Henderson, Sandra. "Quantum Dot Solar Cell Achieves World-Record 7% Efficiency." *Solar Novus Today*. Novus Media Today, LLC, 13 Aug. 2012. Web. 15 Oct. 2012. <http://www.solarnovus.com/index.php?option=com_content>.

[41] "NaturalGas.org." NaturalGas.org. N.p., n.d. Web. 3 Sept. 2012. <http://www.naturalgas.org/overview/background.asp>.

sources from coal[42]. Unconventional gas production will expand all around the world, thanks to a combination of horizontal drilling and hydraulic fracturing that allows unconventional gas production to become more efficient and environmentally friendly.

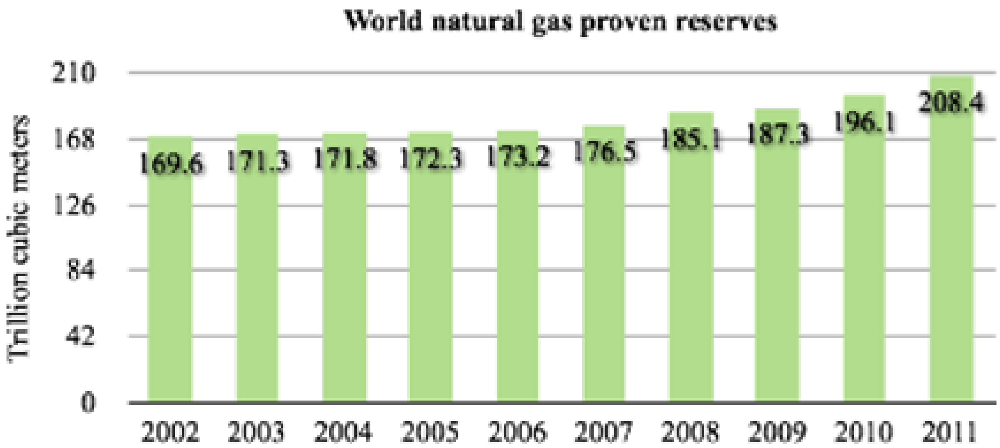

Figure 19: World's natural gas proven reserves[43].

Natural gas proven reserves proved to be increasing every year. In 2011, the world's natural gas proven reserve was 208.4 trillion cubic meters, increased about 6.3% from 2011 which has 196.1 trillion cubic meters[44]. The U.S had about 8.5 trillion cubic meters in natural gas in 2011. The top three countries that have the most natural gas proven serves in 2011 and in the past three years are Russian Federation with 44.6 trillion cubic meters, Iran with 33.1 trillion cubic meters and Qatar with 25 trillion cubic meters. These three countries are rich in natural gas especially Russian Federation, the record shows that they have an outstanding natural gas proven reserves than any other countries and they have been holding number one in natural gas proven reserves for more than ten years.

[42] "The Outlook for Energy." Exxon Mobil Corporation. N.p., n.d. Web. 2 Oct. 2012. <http://www.exxonmobil.com/Corporate/energy_outlook.aspx>.

[43] http://www.exxonmobil.com/Corporate/energy_outlook.aspx

[44] "Natural gas reserves." bp. N.p., n.d. Web. 3 Sept. 2012. <www.bp.com/sectiongenericarticle800.do?categoryId=9037178&contentId=7068624>.

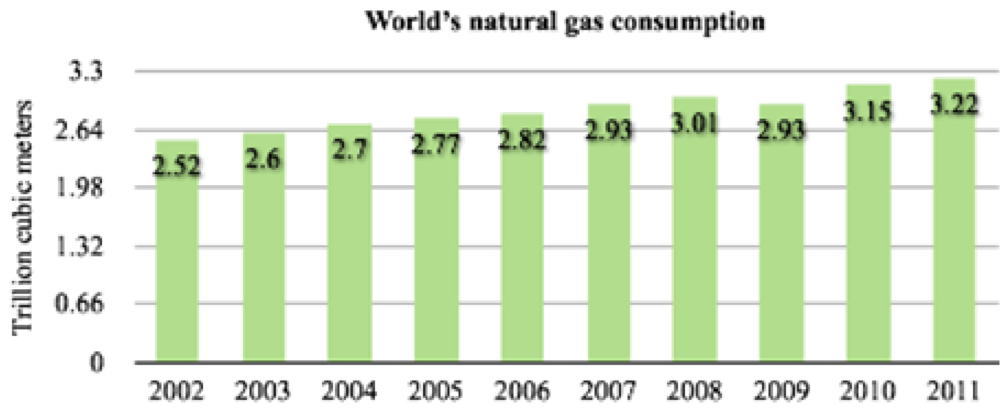

Figure 20: World natural gas consumption[45].

In 2011, the world's consumption of a natural gas was 3.22 trillion cubic meters which is 2.2% increasing from 2010 which was about 3.15 trillion cubic meters. The U.S. consumed about 0.69 trillion cubic meters in 2011 which is the highest rate compare to the rest of the world. If we use the information from 2011, the world's natural gas will last about 65 years and the U.S. natural gas will last about 12 years.

2. Natural Gas in the Mediterranean Sea

Leviathan gas field is a large natural gas field found roughly 81 miles west of Haifa, the largest city in northern Israel. It is 4,900 feet deep in the Levantine basin. Leviathan gas field is one of the world's largest offshore gas finds when it first discovered. Estimated natural gas in Leviathan gas field is approximately 470 billion cubic meters. There was a dispute between Israel and Lebanon over Leviathan gas field's ownership since Lebanon claimed that part of the gas field extended into Lebanese waters. Lebanon is unhappy with Israel because they felt that Israel was ignoring their rights over Leviathan gas field. However, this dispute was resolved later in August 2010 as the United Nations stated that Leviathan gas field doesn't fall within Lebanese water[46].

[45] http://www.exxonmobil.com/Corporate/energy_outlook.aspx

[46] "Leviathan Gas Field, Levantine Basin, Mediterranean Sea - Offshore Technology." Offshore Technology. N.p., n.d. Web. 2 Oct. 2012. <http://www.offshore-technology.com/ projects/leviathan-gas-field-levantine-israel/>.

3. Unconventional Gas in the United States

Production of natural gas in the U.S has been recline for many years and expected to decline by many in the future, but this did not happen. Thanks to unconventional gas production that significantly increase and help maintain level of natural gas production from declining[47]. Shale gas, tight gas, and coalbed methane are the major sources of unconventional gas that will take an important role in development of natural gas in the U.S. and help increase more job opportunities and rate of economic growth[48]. There is a large portion of unconventional gas in North America that waits to be extracted with the right technology and the right method. A combination of horizontal drilling and hydraulic fracturing plays a big role in unconventional gas production. Neither horizontal drilling nor hydraulic fracturing are new technologies, but by combining them together, unconventional gas can be extracted more efficiently and economically viable.

4. Harvesting and Processing Techniques

Horizontal drilling

Horizontal drilling is the process of drilling a well where the well bore changes it direction from vertical to horizon when reach the target gas reservoir and remain within the reservoir until reach the desired bottom hole location. Horizontal drilling is an important process to extract shale gas and tight gas because shale gas and tight gas are usually spread in a large area of rock where vertical drilling can only extract a small portion which considered inefficiently[49].

Hydraulic fracturing

Hydraulic fracturing is a technique that injects a very high-pressure mixture of water, sand, and chemical additives into the well to create the cracks and make it easier for the gas to release from the source rock and flow through the well[40].

[47] "US natural gas: the role of unconventional gas | Energy Bulletin."Energy Bulletin. N.p., n.d. Web. 14 Oct. 2012. <http://www.energybulletin.net/stories/2008-05-18/us-natural-gas-role-unconventional-gas>.

[48] "Unconventional Gas Report | IHS." IHS Home Page. N.p., n.d. Web. 14 Oct. 2012. <http://www.ihs.com/info/ecc/a/unconventional-gas-report-2012.aspx>.

[49] "Horizontal Drilling and Hydraulic Fracturing." Total. N.p., n.d. Web. 2 Oct. 2012. <www.total.com/en/special-reports/shale-gas/appropriate-production-techniques/horizontal-drilling-hydraulic-fracturing-201957.html>.

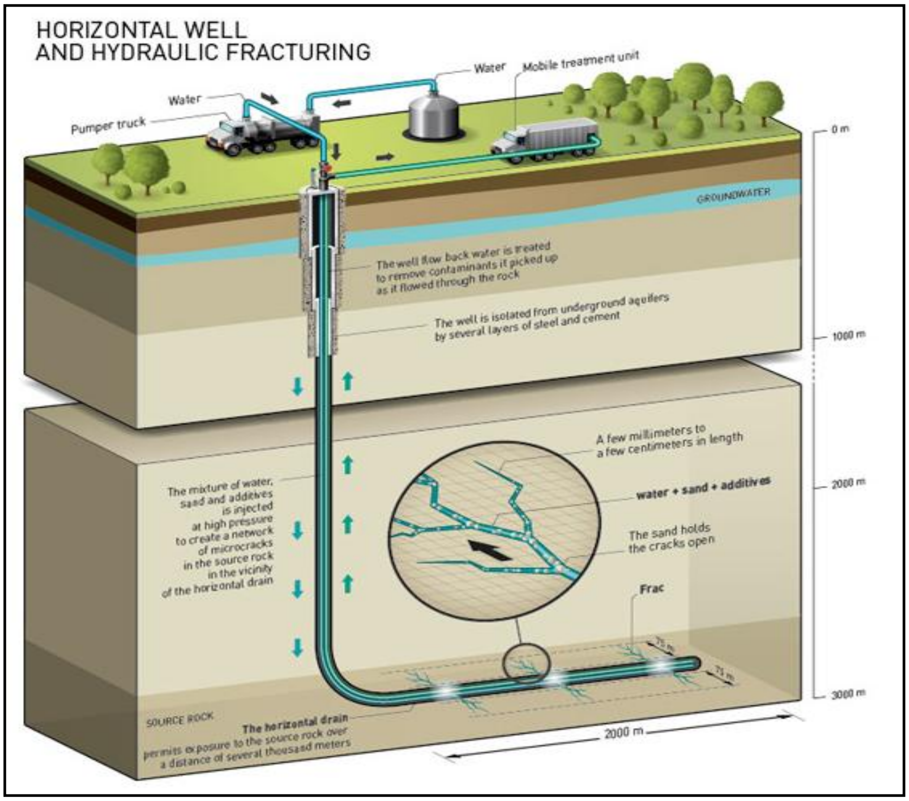

Figure 21: Horizontal well and hydraulic fracturing[50].

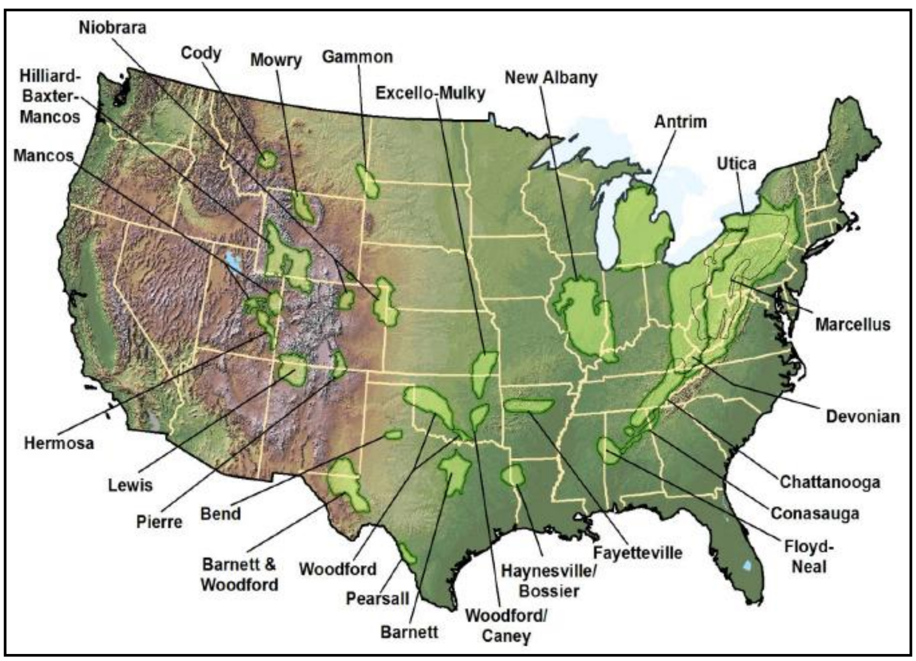

Figure 22: United States shale gas basins[51].

[50] http://www.total.com/en/special-reports/shale-gas/appropriate-production-techniques/horizontal-drilling-hydraulic-fracturing-201957.html

5. United State Shales

There are many shale gas basins all around the United State. Listed below are the major basins that hold a lot of potential in the future.

Barnett shale[52]

Location: Fort Worth Basin of north-central Texas

Estimated Basin Area (square miles): 5,000

Depth (feet): 6,500-8,500

Net Thickness (feet): 100-600

Gas Content (trillion cubic feet/ton): 300-350

Original Gas-In-Place (trillion cubic feet): 327

Technically Recoverable Resources (trillion cubic feet): 44

Barnett shale has the highest gas content among the other shales

*Fayetteville shale*52

Location: Arkoma Basin of northern Arkansas

Estimated Basin Area (square miles): 9,000

Depth (feet): 1,000-7,000

Net Thickness (feet): 20-200

Gas Content (trillion cubic feet/ton): 60-220

Original Gas-In-Place (trillion cubic feet): 52

Technically Recoverable Resources (trillion cubic feet): 41.6

Haynesville shale

Location: North Louisiana Salt Basin in Northern Louisiana

Estimated Basin Area (square miles): 9,000

Depth (feet): 10,500-13,500

Net Thickness (feet): 200-300

Gas Content (trillion cubic feet/ton): 100-330

Original Gas-In-Place (trillion cubic feet): 717

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[51] http://www.agiweb.org/environment/earthnotes/note.html?PublicID=4

[52] Modern Shale Gas Development in the United States: A Primer. Oklahoma: Ground Water Protection Council, 2009. Print

Technically Recoverable Resources (trillion cubic feet): 251

The Haynesville shale has a potential to become a significant resources of shale gas in the United States

Marcellus shale

Location: Spanning in six states in northeastern (Pennsylvania, New York, West Virginia, Ohio, Kentucky, and Tennessee)

Estimated Basin Area (square miles): 95,000

Depth (feet): 4,000-8,500

Net Thickness (feet): 50-200

Gas Conte t(trillion cubic feet/ton): 60-100

Original Gas-In-Place (trillion cubic feet): 1500

Technically Recoverable Resources (trillion cubic feet): 262

The Marcellus shale has the largest estimated basin area

Woodford shale

Location: south-central Oklahoma

Estimated Basin Area (square miles): 11,000

Depth (feet): 6,000-11,000

Net Thickness (feet): 120-220

Gas Content (trillion cubic feet/ton): 200-300

Original Gas-In-Place (trillion cubic feet): 23

Technically Recoverable Resources (trillion cubic feet): 11.4

The Woodford shale has the most gas content

Antrim shale

Location: upper portion of the lower peninsula of Michigan within the Michigan Basin

Estimated Basin Area (square miles): 12,000

Depth (feet): 600-2,200

Net Thickness (feet): 70-120

Gas Content (trillion cubic feet/ton): 40-100

Original Gas-In-Place (trillion cubic feet): 76

Technically Recoverable Resources (trillion cubic feet): 20

The Antrim shale is one of the most actively developed shale gas plays beside the Barnett shale

New Albany shale

Location: the Illinois Basin in portions of southeastern Illinois, southwestern Indiana, and northwestern Kentucky

Estimated Basin Area (square miles): 43,500

Depth (feet): 500-2,000

Net Thickness (feet): 50-100

Gas Content (trillion cubic feet/ton): 40-80

Original Gas-In-Place (trillion cubic feet): 160

Technically Recoverable Resources (trillion cubic feet): 19.2

United States has a large amount of unconventional gas reserves especially shale gas reserves and with the combination of technologies, it is now possible to extract unconventional gas more efficiently and productive. Increasing in shale gas production and shale gas reserves is tremendously good for the U.S. because this will result in less dependent on importing natural gas from outside the U.S. which will save the U.S. a lot of spending each year. It is even possible that the U.S. might be able to export its natural gas and make more incomes. The most importantly is that a price of natural will be cheaper in the U.S. which is good for everyone especially those who depend on natural gas. Increasing in unconventional gas production provided a lot of job opportunities in the U.S. in the past and will continue in the future. Many states such as Texas, Louisiana, Colorado, and Pennsylvania have a large amount of unconventional gas reserves and because of that an employment rate is increasing in these states. An employment rate is not only increase in those states that have a large amount of reserves, but it also affect to any other states.

Top 10 Unconventional Gas* Producing States: Employment** (Number of Workers)			
	2010	2015	2035
Texas	288,222	385,318	682,740
Louisiana	81,022	124,782	200,555
Colorado	77,466	126,525	127,843
Pennsylvania	56,884	111,024	270,058
Arkansas	36,698	53,919	79,723
Wyoming	34,787	45,763	78,792
Ohio	31,462	41,366	81,349
Utah	30,561	36,593	50,839
Oklahoma	28,315	41,763	69,261
Michigan	28,063	37,926	63,380
Top 10 Total	**693,481**	**1,004,979**	**1,704,541**
US Total	**1,008,658**	**1,463,450**	**2,438,877**

NOTES: *Unconventional gas includes gas from shale, tight sands, and coal bed methane.
**The rank for all years are based on the 2010 ranking.
Source: IHS Global Insight

Top 10 Unconventional Gas* Non-Producing States: Employment Contribution** (Number of Workers)			
	2010	2015	2035
California	22,773	33,265	49,494
Florida	15,758	27,402	30,903
Georgia	13,294	18,800	29,262
Missouri	12,031	17,427	30,105
North Carolina	11,377	16,570	28,271
Indiana	10,819	15,206	26,837
Wisconsin	9,608	14,285	24,871
Minnesota	9,271	14,499	22,638
Tennessee	8,519	12,323	21,487
Maryland	7,008	10,263	16,634
Top 10 Total	**120,459**	**180,042**	**280,503**
US Total	**1,008,658**	**1,463,450**	**2,438,877**

NOTES: *Unconventional gas includes gas from shale, tight sands, and coal bed methane.
**The rank for all years are based on the 2010 ranking.
Source: IHS Global Insight

Table 1: Top 10 unconventional gas, producing states and non-producing states[53].

[53] http://www.ihs.com/info/ecc/a/unconventional-gas-report-2012.aspx

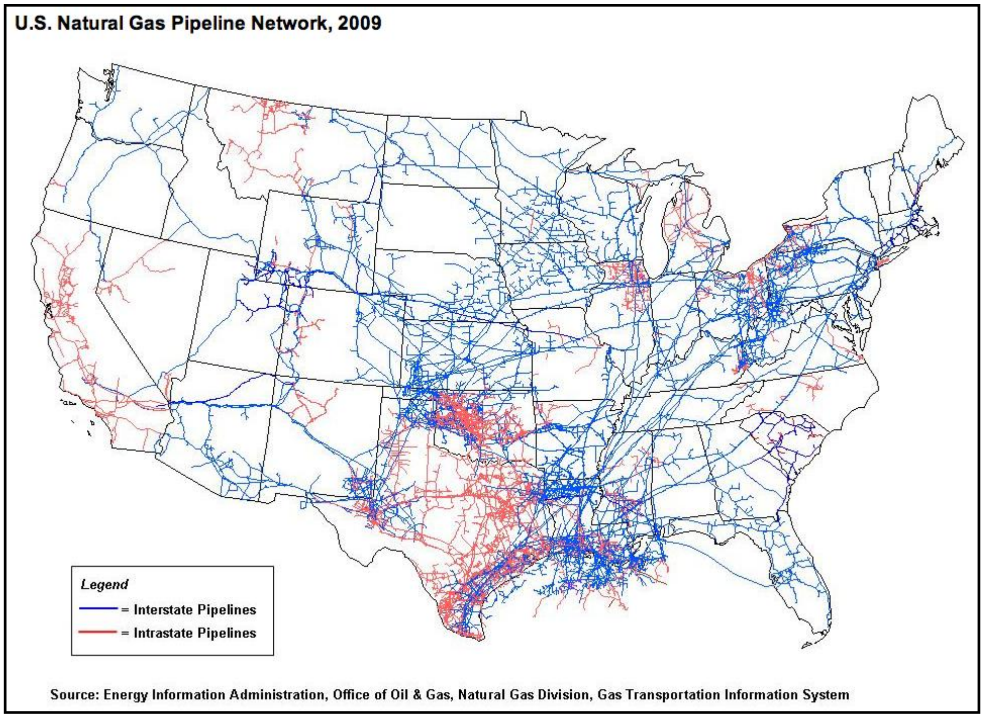


Figure 23: U.S. Natural Gas Pipeline Network, 2009[54].

6. Natural gas pipeline

The efficient and effective way to transport natural gas from producing regions to consuming regions is by pipelines. Pipelines can be characterized into two major groups, interstate and intrastate. There are more than 210 natural gas pipeline systems in the United States with a total of 305,000 miles long both interstate and intrastate. There are more than 1,400 compressor stations which its job is to maintain pressure to assure that supplies movements are continuous. There 11,000 delivery points, 5,000 receipt points, and 1,400 interconnection points which use to transfer a natural gas throughout the United States. There are 24 hubs which use to provide additional interconnections, 400 underground natural gas storage facilities, 49 locations where natural gas can be imported and/or exported via pipelines. 8 LNG (liquefied natural gas) import facilities and 100 LNG peaking facilities[55].

[54] http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/ngpipelines_map.html
[55] "How Natural Gas is Transported - Spectra Energy ." Home - Spectra Energy. N.p., n.d. Web. 15 Oct. 2012. <http://www.spectraenergy.com/Natural-Gas-101/Transporting-Natural-Gas/>.

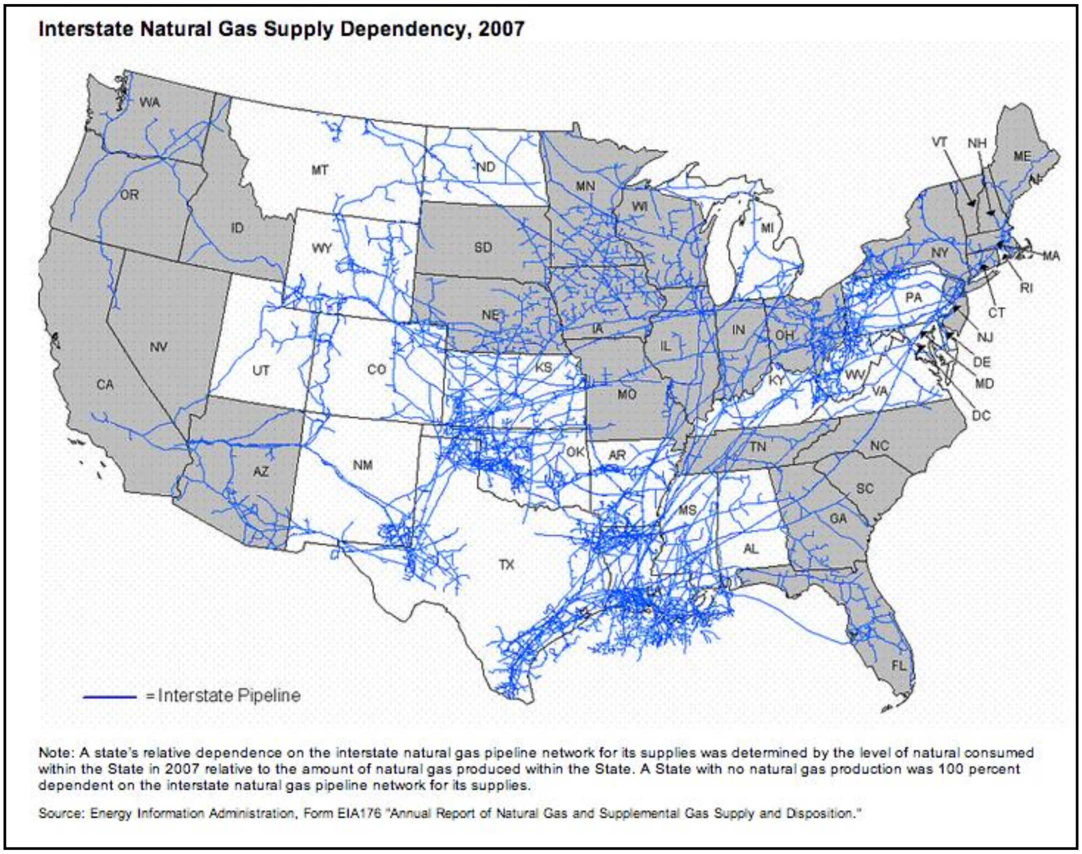


Figure 24: Interstate Natural Gas Supply Dependency, 2007[56].

States in grey are 85% or more dependent on the interstate pipeline network for their natural gas supply.

New England - Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.
Southeast - Florida, Georgia, North Carolina, Carolina, Tennessee.
Northeast - Delaware, Maryland, New Jersey, New York, District of Columbia.
Midwest - Illinois, Indiana, Minnesota, Ohio, Wisconsin.
Central - Iowa, Missouri, Nebraska, South Dakota.
West - Arizona, California, Idaho, Nevada Oregon, Washing ton.

[56] Source: http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/index.html

Pipeline components[55]

In order to make sure that a pipeline will work efficiency and safely, there are a certain number of components that a pipeline should have including compressor stations, metering stations, valves, control stations and SCADA systems. Normal transmission pipe's can be from somewhere between 6 to 48 inches in diameter. The main materials of pipeline is strong carbon steel that has been engineered to meet it standard. The pipeline also coated with a specialized coating to protect the pipeline from moisture underground that will damage the pipe and shorten the life of the pipeline.

Compressor stations

Compressor stations usually located at every 40 to 100 mile of the pipeline. Their main job is to make sure that natural gas will properly flow through the pipeline and travel to it final destination.

Metering stations

Metering station are located along the pipeline same as compressor stations to make sure that a natural gas is compressed, reduced it volume, and flow through the pipeline. Meter stations allow companies to check the amount of natural gas in their pipelines.

Valves

There are many valves along the pipelines. Valves control the flow of natural gas that flew through the pipelines. Valves may be closed in a specific section of the pipeline in case of a an emergency such as gas leak.

Control Stations and SCADA Systems

Control stations and SCADA systems control and monitor the gas that flow through all sections in the pipeline system. Control stations and SCADA systems receive the data from compressor stations and metering stations that help provide them fulfill their job which is to make sure that the customers will receive the gas in time.

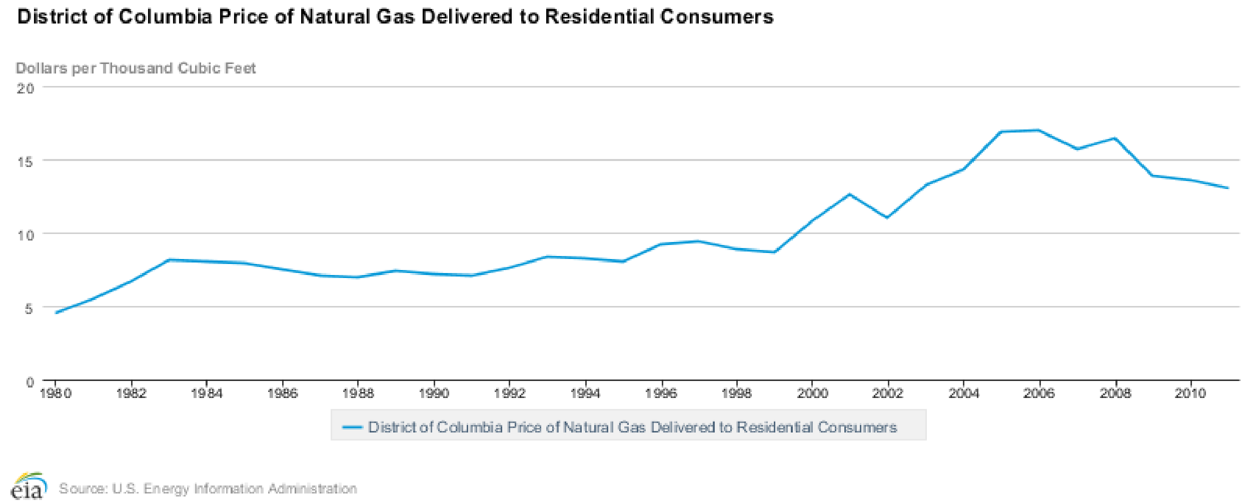


Figure 25: District of Columbia price of natural gas sold to residential consumers[57].

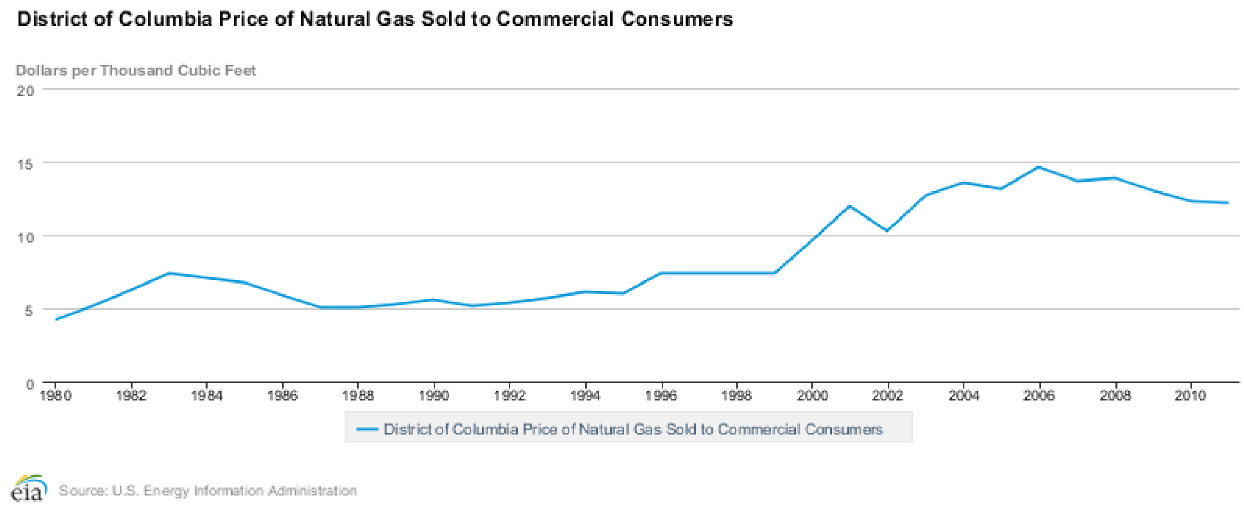


Figure 26: District of Columbia price of natural gas sold to commercial consumers[58].

7. Price of Natural Gas

Demand of natural gas never cease to increase and most likely to stay that way as long as natural gas is still a major source of energy production. Residential consumers always have to pay more for gas than commercial consumers. Natural gas price for residential consumers is 4.57 dollars per thousand cubic feet in 1980 and 13.06 dollars per thousand cubic feet in 2011. There is 8.49 dollars difference in price for residential consumers in the past 31 years. Natural gas price

[57] http://www.eia.gov/dnav/ng/hist/n3010dc3a.htm
[58] http://www.eia.gov/dnav/ng/hist/n3020dc3a.htm

for commercial consumers is 4.22 dollar per thousand cubic feet in 1980 and 12.24 dollars per cubic feet in 2011. There is 8.02 dollars difference in price for commercial consumers in the past 31 years. If you look closely at the record you will notice that after 2006 a natural gas price has go down and still keep going down until 2011. This is no doubt a good new for a consumer. Thanks to new technologies that help make it easier and more efficient to extract natural gas and hopefully this will help keep a natural gas price down in a foreseeable future.

8. Conclusion

Natural gas is playing a very important role today around the world as oil reserves are depleting in many parts all around the world and a combination of technologies such as horizontal drilling and hydraulic fracturing that allow us to be able to extract unconventional gas. As a result, we are able to extract more available natural gas with a higher efficiency which also leads to decreasing in a price of natural gas. Increasing in exploitation of natural gas will help reduce dependence on oil in which its price increasing everyday due to scarcity.

IV. Possible Energy Alternatives

As our world moves into the future, and our primary fuels slowly but surely deplete, we must race against time to develop an alternative yet equally sustainable source of energy that can provide power for an entire planet. The ideal source of energy or processing technology must be cost affordable, high in supply and conversion efficiencies, and environmentally safe. From analyzing current fossil fuels and renewable resources, there is no long term plan for sustaining our way of life beyond a few hundred years. While we diligently work to wean ourselves away from fossil fuel consumption in favor of renewable energy, many have a good reason to fear that the most substantial non-renewable fuels will deplete before current renewables become economically viable. For this reason, it may be necessary to look elsewhere - on places such as the moon, in the frozen depths of the Arctic, or even in the atmosphere we breathe - for more alternative solutions.

Methane

By: Chris Chaggaris

1. Methane Hydrates

Found deep within the seabed of the ocean floor in subzero regions, methane hydrate excavation is increasing in popularity rapidly. Methane is a hydrocarbon fuel source thought to be twice as large as all the petroleum deposits ever known. If we could somehow inexpensively harvest this gas, there would be enough energy to provide a first world country with approximately 3000 to 6000 years worth of electricity and heat. It is also the cleanest of the fossil fuels in terms of carbon dioxide pollution, but methane is still a greenhouse gas that is equally as toxic to the atmosphere in large quantities.

Methane hydrates are essentially natural gas compressed into blocks of ice. In conditions of extreme cold and immense pressure, the hydrates are stable. A sharp increase in heat or a decrease in pressure can result in an undesirable expansion of the methane block to about 164 times its volume. For this reason, it must be carefully extracted and consumed under specific conditions. The danger is well recognized in the industry as many suspect methane hydrate build up in oil drilling pipes, due to volumetric expansion, could have contributed to the pipe burst in the BP oil disaster[59].

In May 2012, integrated energy firm ConocoPhillips had the first successful trial off the coast of Alaska to inject CO_2 to free natural gas from methane hydrates. Their tests safely extracted the gas for 30 consecutive days, beating the previous record of six days. The progress made in this field could cut the price of natural gas, which is already low, by about one third within the next 10 years. This breakthrough, along with the natural gas combined cycle (NGCC) turbines that allow for efficient and clean production, explain how the same amount of energy is generated from natural gas as coal, at only half the cost of a typical coal plant:

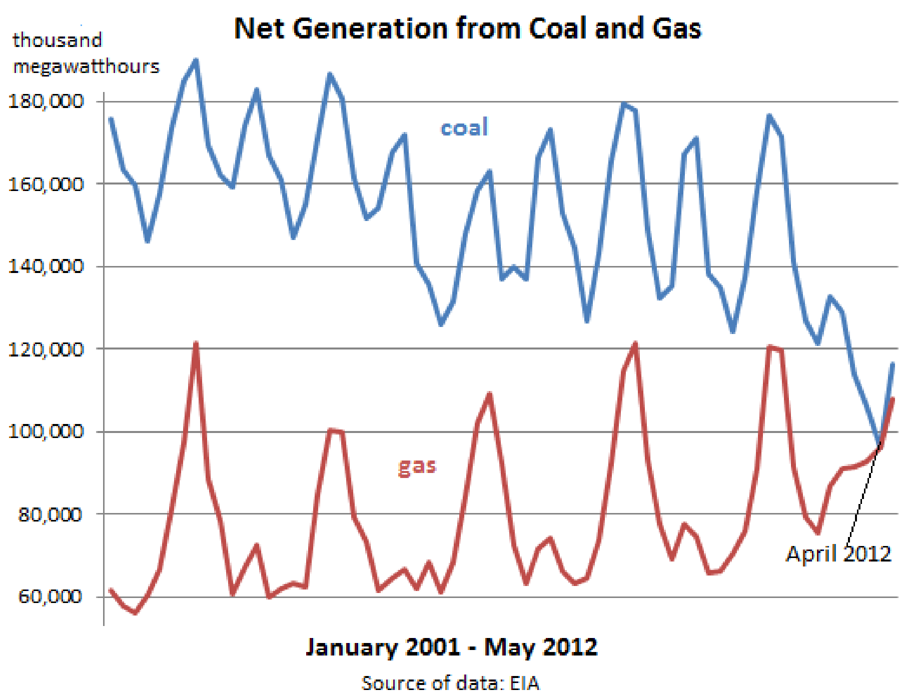


Figure 27[60].

For the first time in history, the net generation of electrical generation is shared almost equally between natural gas and coal. In addition, all indications seem to point towards a future where natural gas dominates the fossil fuel market.

[59] http://www.guardian.co.uk/environment/2010/may/20/deepwater-methane-hydrates-bp-gulf
[60] http://www.testosteronepit.com/home/2012/8/15/natural-gas-and-the-brutal-dethroning-of-king-coal.html

2. Coal Seam Methane

Methane gas is also created in the process of coal formation. Underground mining has proven more successful than surface mining, since the high pressure deep underground contributes to greater concentrations of methane. This can be shown in the following table:

Mean methane content as a function of depth interval

Depth Interval (metres)	Mean methane content (cubic metres per tonne of coal)
100	0.02
500	0.99
1000	3.73
1500	4.89
2000	7.09

Table 2[61].

The typical undisturbed coal seam can contains about 25m^3 of high purity methane, but standard extraction techniques can only capture around 50% of available methane. In a new process known as enhanced coal bed methane production, or ECBM, pressurized CO_2 is injected directly into the coal seam. As a tradeoff, the coal cannot be mined, but the recovery method is capable of capturing more than 90% of available methane. Given the benefit that carbon dioxide provides in the recovery of methane gas, ECBM gives an incentive to invest in CO_2 pumping stations that could capture more gas to use for methane extraction, thus removing it from the atmosphere. Also of importance is the cost of transporting CO_2, which is around $30 to $50 a ton - the variable being the fuel required for transport - per 300km (~187 mi) travelled. The availability of such pumping stations in locations close to major coal seam deposits could drastically reduce the costs from the transportation sector[62].

[61] http://www.worldcoal.org/coal/coal-seam-methane/
[62] http://www.ieaghg.org/docs/general_publications/8.pdf

Atmospheric Electricity

By: Chris Chaggaris

1. Hygroelectricity

Perhaps a solution to the global energy problem could lie within the charged particles that comprise Earth's atmosphere. The naturally occurring electric potential between the negatively charged Earth and the positively charged atmosphere could provide enough electricity to power our homes and businesses. This electromagnetic network includes thunderstorms (lightning/pressure), the humidity in air, and the polar Aurora effects (northern lights) that is a direct result of atmospheric electricity. Unlike other renewables such as solar cells or wind turbines, this is a source of energy that is available any time of day under most weather conditions. The word "hygroelectricity" is used to describe high potential electricity present in thin, humid air. It refers specifically to the process that uses tiny particles of silica aluminum phosphate (common in air), where the silica became more negatively charged while the aluminum phosphate became more positively charged as a result. These tests concluded that atmospheric electricity contained as low as the troposphere and as high as the ionosphere builds up a charge that can be transferred to any conducting material it comes in contact with. Identifying a feasible way to collect or store this humid electricity for use in the residential or commercial sectors could also reduce lightning strikes or other extreme weather by draining a region of its electric potential[63].

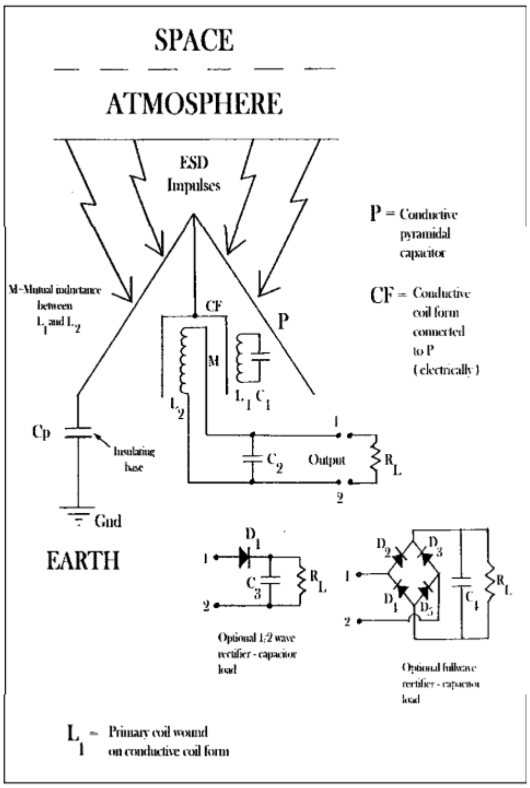
2. The Pyramidal Electric Transducer

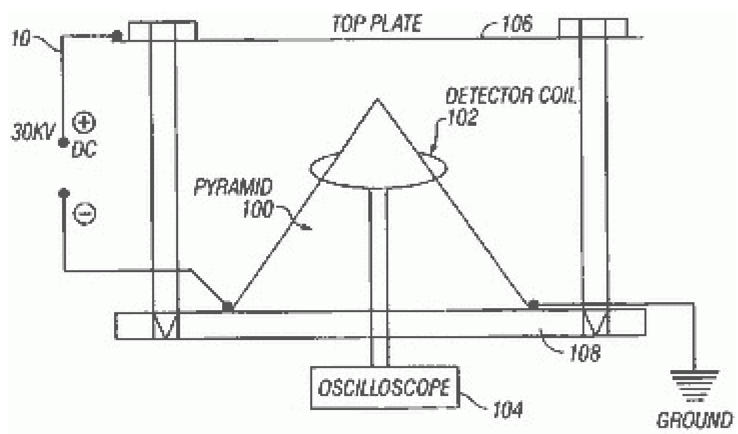
One such device, known as the Pyramidal Electric Transducer, is one of first attempts to capture electrostatics by converting low frequency waveforms to DC voltage. Thousands of terawatts of power could be generated in the troposphere by thunderstorms alone, and this device - which only spans six feet long - could produce a consistent voltage output a 100 times greater than the voltage required to run it. Researchers discovered that the dimensional ratios of the Great Pyramid of Giza express key ratios of a typical AC voltage sine wave, as well as ratios of the Fibonacci number sequence. The mathematical connection between microscopic electrostatics to geometric shapes is scientifically astounding, and evidence indicates that the ancient Egyptians could have been aware of this phenomenon, perhaps even more so than us.

[63] http://www.treehugger.com/renewable-energy/collecting-electricity-from-thin-air-might-one-day-become-reality.html

From here, it was hypothesized that the pyramidal prism shape could model a signal in the time domain. An external wideband antenna could be attached on an inductor coil near the apex of the pyramid to capture these electrostatic impulses. The impulses are transformed through a resonant circuit to produce DC voltage from an AC voltage sine waveform. The transducer can be modeled by the following schematic diagram:

Simplified circuit diagram representing the transducer (left) and connection of probes (right)





Figures 28 & 29[64].

[64] http://www.freeenergynews.com/Directory/Pyramid/GrandicsIE73.pdf

Power measurements taken inside primary and secondary coils

Primary							
Frequency (kHz)	83.00						
$V_{P\ RMS}$	3.97	9.86	20.3	26.7	33.8	39	40.8
$I_{P\ RMS}$ (mA)	87.6	300	792	1117	1389	1541	1838
$I_{P\ \text{angle with respect to}}\ V_P$	18°	14°	22°	23°	21°	20°	28°
Total power (VA)	0.35	2.95	16.02	29.70	46.77	59.95	74.75
True power (W)	0.33	2.87	14.85	27.35	43.66	56.34	66.01
Secondary							
$V_{S\ RMS}$	341	1150	3540	4670	6220	7140	7710
$I_{A\ RMS}$ (mA)	62.2	193	438	579	728	834	919
$I_{A\ \text{angle with respect to}}\ V_S$	42°	44°	52°	52°	54°	53°	52°
Total power (VA)	21.2	222.8	1552	2707.8	4530.2	5957.5	7087.3
True power (W)	15.7	160.3	956	1668.1	2664.5	3587.6	4366
Power sec/prim	61.1	75.4	96.9	91.2	96.9	99.4	94.8

Table 3[65].

As can be seen, the output voltage in the secondary coil (the coil being induced) read at levels over 7000 V_A when supplied with 70 V_A through the primary coil. Given that the size ratio between the constructed model and the pyramid was 1:125, the author went on to comment that a larger pyramid structure and coils - even as large as the GPG - could have an output in the range of hundreds of thousands of megawatts.

This ESD to DC generator sheds new light on the alternative energy debate, and given its self-sustainability, it could be mainstream in a matter of years. Generating atmospheric electricity is rapidly becoming the first "true energy" source, harnessing usable electricity from electricity as it's found in nature with little to no cost on the environment. While the authors of this device did not have cost projections in either of their reports, energy firm SEFE Inc. has recently undertaken a major investment in a project that harnesses electricity from the atmosphere. The firm projects electricity generation prices of just $0.03 per kWh, which is drastically lower that today's solar prices of $0.20 per kWh. According to the U.S. Department of Energy, the average price of residential electricity is $0.12 per kWh as of December 2011, with most homes running on either coal or natural gas[66]. Utilizing a system in which there are no emissions, no required maintenance work, and the cheapest cost out of any other renewable resource highlights the potential of large scale atmospheric energy generators.

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[65] http://www.a-dresearch.net/ie_pyramid_paper_ii.pdf

[66] http://www.marketwire.com/press-release/could-atmospheric-energy-make-sefe-inc-sefe-clean-energy-play-nextera-energy-inc-nee-1650392.htm

Lightning Energy

By: Nick Muller

1. Introduction

With our current sources of energy dwindling, we will need to seek alternative sources as soon as possible. One innovative idea for an alternative energy source is lightning. Lightning strikes provide a massive amount of DC voltage then can be converted into electricity. Energy from lightning storms could be harvested through a lightning rod or an array of lightning rods and stored in a capacitive network. Lighting takes the path of least resistance from cloud to ground and the technology exists to ionize the air around the lightning rods to more easily attract strikes. We could also harvest energy through some sort of receiver balloon that would float inside the storm clouds themselves. This "receiver" balloon would be struck much more frequently while inside the thunderhead, however it would require an attached cable from the ground in order to transfer energy. While there is a large potential amount of energy to be captured from lightning strikes, there are also several shortcomings when capturing energy from lightning.

2. Associated Challenges with Lightning Energy

The first challenge associated with harvesting lightning energy is the infrequency of lightning strikes due to the fact that a storm must be present. To overcome this challenge we can locate the lightning harvesting system in an area of the world where storms are more often present. These areas might include central Africa, Florida, and Malaysia. Figure 30 shows NASA's data on worldwide lightning flashes per square kilometer per year from their space-based optical sensors.

Map of NASA's data on worldwide lightning flashes (per Km^2/year)

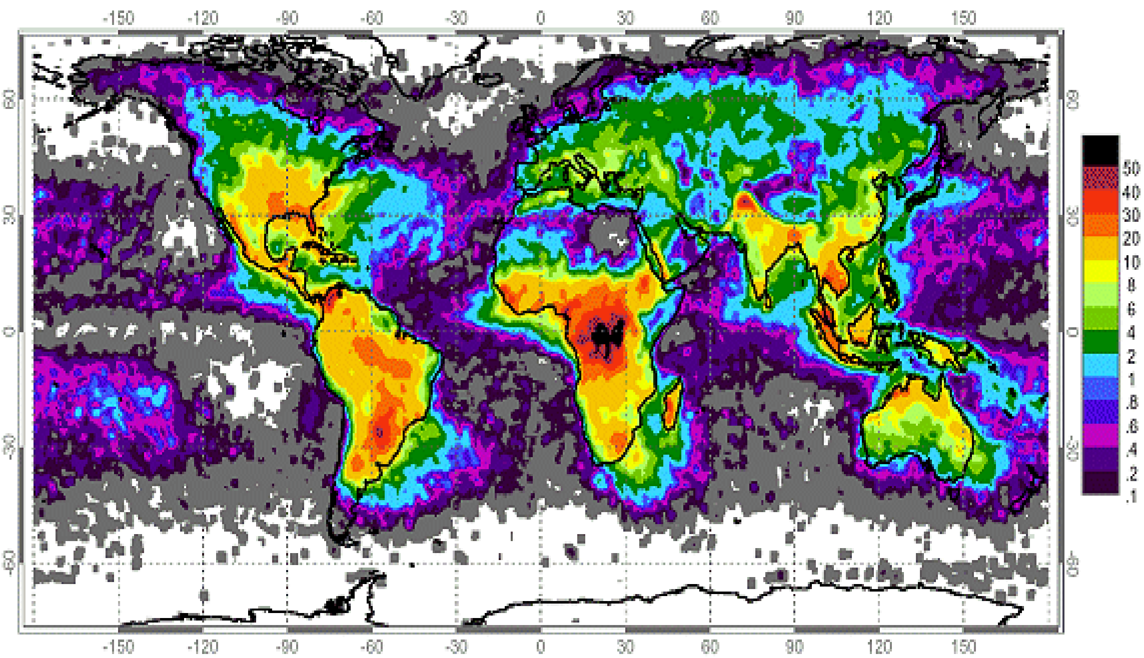

Figure 30[67]

One of the drawbacks of lightning infrequency is that harvesting energy from lightning would only be most efficient in the areas of highest flash frequency. This would mean that lightning energy systems would need to be localized around the areas where lightning flashes are most frequent and they would only be able to provide energy to the power grids in those areas.

A second challenge associated with the harvesting of lightning energy is the need to design materials to insulate and protect power plant technology, and workers from damage. The lightning parameters of engineering interest are: maximum current, maximum current steepness, and temperature. Figures 31-33 as well as Tables 3-4 below show maximum current steepness and current peak for a cumulative distribution of measurements taken at the Toronto CN Tower (474m), The Empire State Building (381m), the towers on Mount San Salvatore in Switzerland (70m), a tower on the Hoher Piessenberg mountain in Germany (160m), and two rocket triggered facilities in Florida and New Mexico.

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[67] http://science.nasa.gov/science-news/science-at-nasa/2001/ast05dec_1/ (NASA data on worldwide lightning frequency)

Summary of cumulative distribution of current steepness for CN Tower and data from other tall structures, and from rocket-triggered lightning in Florida

Maximum Steepness [kA/µs]						
	min.	max.	mean	95%	50%	5%
CNT	2.2	55.5	19.4	3.8	18.8	36.9
ESB	0.3	40	-	1.17	13.0	38.29
German Tower	1.55	162.2	36.96	2.65	25.94	120
Florida	44	260	111.4	62.78	100	219.7

Table 4[68].

Cumulative distribution of maximum steepness of lightning currents measured at the CN Tower, the ESB and the Peissenberg Tower

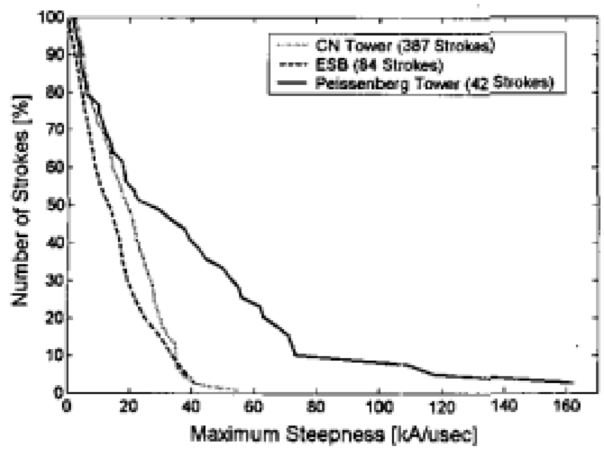

Figure 31[69].

Cumulative distribution of maximum steepness of lightning currents measured at the CN Tower and at the rocket-triggered lightning facility in Florida

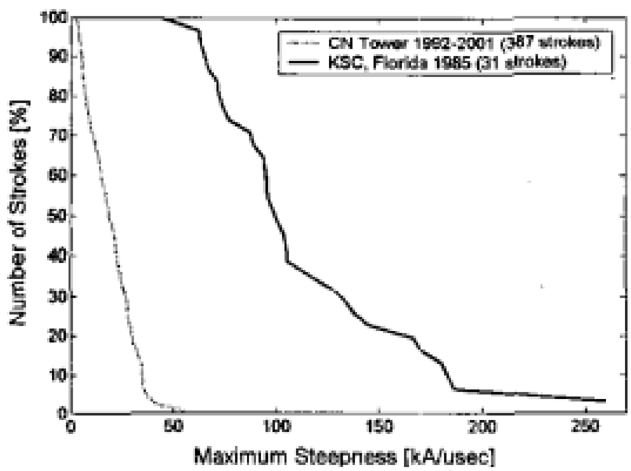

Figure 32[70].

[68] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703
[69] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703
[70] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703

Summary of cumulative distribution of absolute current peak for CN Tower and data from other tall structures as well as from rocket-triggered lightning in New Mexico and Florida

	Absolute Current Peak [kA]					
	min.	max.	mean	95%	50%	5%
CNT	1.01	59.2	9.0	2.2	7.2	23.3
ESB	2.5	60	-	4.17	9.99	33.91
Berger	1.9	101.6	-	3.5	12.1	63.8
German Tower	1.57	21.1	8.49	2.53	8.05	17.89
New Mexico	0.1	40.0	17.94	3.47	18.26	37.73
Florida	5	49	13.48	6.14	11.75	38.47

Table 5[71].

Cumulative distribution of maximum steepness of lightning currents measured at the CN Tower, the ESB, the Peissenberg Tower, and the two 70-m towers in Switzerland (Berger)

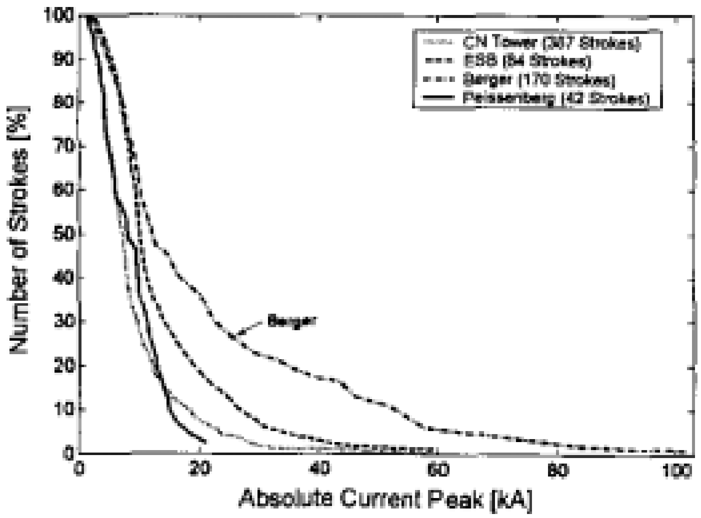

Figure 33[72].

As you can see from the data above, maximum current steepness can measure as much as 162.2 kA/µs on a tower strike and 260 kA/µs on a rocket-triggered strike. Absolute current peak measured as much as 101.6 kA on the tower measurements and 49 kA on the rocket guided measurements[73]. In addition, the rapid release of energy after the first return stroke of lightning

[71] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703

[72] http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703

[73] Hussein, A.M.; Janischewskyj, W.; Milewski, M.; Shostak, V.; Rachidi, F.; Chang, J.S.; , "Comparison of current characteristics of lightning strokes measured at the CN Tower and at other elevated objects," *Electromagnetic Compatibility, 2003 IEEE International Symposium on* , vol.2, no., pp. 495- 500 vol.2, 18-22 Aug. 2003 <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1236651&isnumber=27703> (Data on lighting current steepness/peak)

generates a temperature of more than 30000 °K or 29726 °C and a potential voltage difference of more than 10^7 volts[74]. The biggest hurdle for harvesting lightning energy right now is finding resilient materials that can both insulate and protect from lightning damage and conduct the flow of electricity without being destroyed by the intense heat and current of sustained lighting strikes.

3. Harvesting Energy from Vibration

Sound and vibration are waves–propagations of energy. An electric current can be generated through the use of piezoelectric materials in transducers located in areas of high vibration. Piezoelectric materials are doped with positive and negative charges on either pole. When pressure is applied, the area between the plates changes resulting in an electric field with a potential difference. In a capacitor, voltage causes a charge separation; in a piezoelectric material, applied stress or pressure causes a charge separation. Quartz is a good example of a piezoelectric material. These same concepts can be applied to sound as well as vibration. Using a microphone like device to pick up sound in noisy areas and run it through a piezoelectric transducer can also generate an electric current[75].

4. Drawbacks of Vibrational Energy

Piezoelectric generated energy provides a relatively small amount of energy and isn't cheap. Piezoelectric energy generating technology can also only be used in specific areas of semi-constant vibration. Areas like subways, concert halls, stadiums, busy cities, airplane takeoff ramps, or freeways might have semi-constant vibration and noise. However, he main issue with piezoelectric energy is that it is not a source of energy, but a way of making our existing technology more efficient.

5. Conclusion

Lighting energy is not a viable source of alternative energy right now, but it could become viable in the future with advances in materials science. Furthermore, we still need to understand more thoroughly: the total wave shapes associated with all kinds of natural lightning, the physical process by which lighting attaches to ground based structures as well as aircraft, and

[74] Uman, M.A.; , "Natural lightning," *Industry Applications, IEEE Transactions on* , vol.30, no.3, pp.785-790, May/Jun 1994 <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=293729&isnumber=7259> (Data on lighting parameters, namely temperature and potential voltage difference)

[75] <http://en.wikipedia.org/wiki/Piezoelectric> (Explanation of piezoelectricity)

material properties capable of withstanding the intense heat and current of lightning strikes. Other more minor complications include a DC to AC voltage loss upon conversion into usable energy, air traffic obstruction of lightning towers/balloons, and public disapproval of the building of lightning towers as they might be considered “eye sores”. However, lightning naturally generates an enormous amount of energy. A single bolt can contain over 500MJ of energy, enough to power a household for a month. Taking this all into account, I still believe that lightning energy will likely be viable in the future with research and funding in materials science. Vibrational energy on the other hand, does not have as hopeful a future. While, it has potential to improve efficiency in existing technology, currently the cost of producing piezoelectric energy outweighs the underwhelming amount of energy that can be generated.

Solar Orbiting Panels

By: Chris Chaggaris

1. Introduction

Some of the major issues that we run into with solar panels, namely the unpredictability to operate on a consistent basis, could be addressed if we consider the case that solar panels might not actually need to be on Earth to work. Solar power is the only renewable resource that has the potential to sustain the whopping 16 TW global energy demand and exceed it by a factor of over 5000. Therefore, if we consider a solar geocentric satellite, much like how any wireless communication satellite operates, some of these disadvantages can be eliminated without incurring significant trade-offs.

2. Orbital Panels and RF

In space, there are no space or size restrictions. The weightlessness and low temperature heat sink would significantly lower both structural and manufacturing costs. Placing an array of solar panels on a geocentric satellite that synchronously orbits around the Earth opens up options and new directions for the solar power industry. This could increase the solar panel's operating time since it is independent of Earth's day/night cycle. On the other hand, there is still the issue of positioning the satellite correctly in low-earth-orbit (LEO) to prevent times in which the Earth or the moon could block the sunlight's path[76].

By converting the sun's energy into microwaves, a working solar satellite can direct these high frequency waves to a receiving antenna on Earth. The RF signal from the rectenna is then processed to provide usable electricity, just like grounded solar panels. It is worth noting that these panels do not need to necessarily orbit in space, as the moon and other nearby planets could also prove useful for future solar panel housing. A labeled diagram depicting the transfer of energy is as follows:

Visualization solar orbital panel in geocentric orbit around Earth.

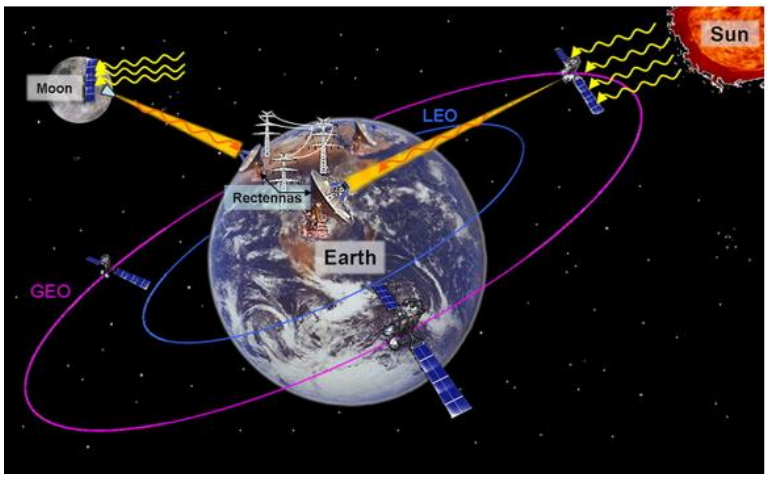

Figure 34[77].

Just like with the concepts behind hygroelectricity, we are just now starting to better understand how high frequency waves can see practical use as carriers of usable energy signals.

A space satellite also eliminates the potential for undesirable dust build up that has been shown to drastically reduce solar cell efficiency. In places such as the United Arab Emirates, or other hot and dry locations that typically receive more sunlight than other areas, there is also a considerable amount of sand, dust, and clay that regularly interferes with conversion efficiencies. Researchers at the Petroleum Institute in the UAE published their findings that there is a dependence between dust accumulation and efficiency loss:

Current-voltage (left) and power-resistance (right) trends amongst various weights of dust

[76] http://articles.businessinsider.com/2012-03-21/home/31218447_1_solar-power-nrel-axis/2
[77] http://www.sciencedirect.com.ezproxy.wpi.edu/science/article/pii/S0360544210005931

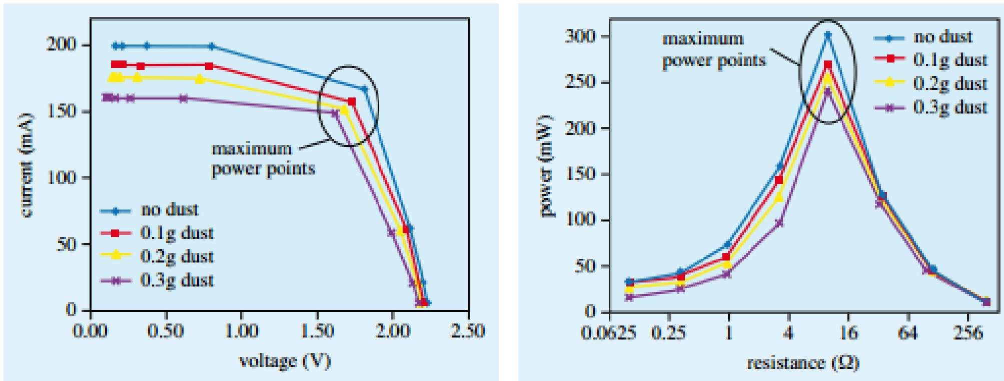

Figure 35 & 36[78].

As can be seen, up to 20% losses in current and power readings even when 0.3g of dust is present on the panels. At 4g of dust present, the panel is nearly inoperable with efficiency loses as high as 95%:

Average efficiency loss of a solar panel due to the presence of dust

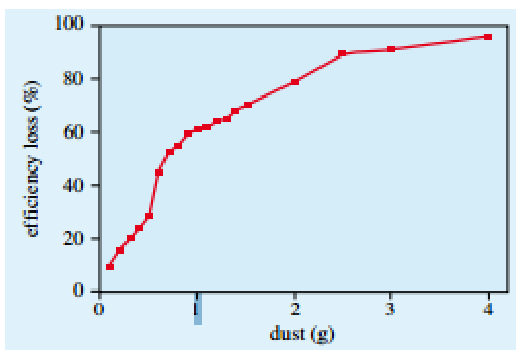

Figure 36[79].

This data shows us that orbital panels would not incur the same maintenance or production costs required to maintain panel efficiency. With the absence of dust or other polluting particles in space, the satellites can operate in steady conditions that would maximize usage while minimizing cost.

In order to position the satellites in orbit, the payload must first be propelled by rockets. Considering that there are multiple launch options, and that launching is the primary contributor to emissions and cost related expenses, it would be beneficial to consider how costly the options are. Examining the costs of two frequently used propulsions rockets - the Ariane 5 ECA and the

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[78] http://iopscience.iop.org.ezproxy.wpi.edu/0031-9120/45/5/F03/pdf/0031-9120_45_5_F03.pdf
[79] http://iopscience.iop.org.ezproxy.wpi.edu/0031-9120/45/5/F03/pdf/0031-9120_45_5_F03.pdf

SpaceX Falcon 9 Heavy - as they pertain to four different orbital patterns, the approach to future designs becomes much more clear. The following table demonstrates the cost effects for two different generated powers (estimates account for about 1/3 losses due to transitions, and are measured in dollar amount per one watt of electric power):

Estimated cost per 150W (a) and 1000W (b) for two launch rocket models

	Earth–LEO	Earth–GEO	Earth–Moon	Moon–GEO
a) Estimate for 150 W of generated power per 1 kg of the payload launch mass				
DOE/NASA concept [9]		Up to \$7/W[a]		
Ariane 5 ECA [11]	\$63/W	\$190/W	\$211/W[b]	\$21/W[c]
SpaceX Falcon 9 Heavy [12]	\$31/W	\$71/W	\$79/W[b]	\$8/W[c]
b) Estimate for 1000 W of generated power per 1 kg of the payload launch mass				
Ariane 5 ECA [11]	\$10/W	\$29/W	\$32/W[b]	\$3/W[c]
SpaceX Falcon 9 Heavy [12]	\$5/W	\$11/W	\$12/W[b]	\$1/W[c]

Table 6[80].

Clearly, the cost is significantly lower for both rockets when the launch to GEO takes place on the moon rather than the Earth. It makes sense that this number would be lower because it omits any CO_2 emissions from the rocket and satellite. In the future, if we were to establish a permanent base on the moon equipped with reliable robotics, we could mass produce rockets and all the necessary equipment at a fraction of the cost. Placing the satellites in GEO rather than LEO is also desirable because a GEO satellite almost gets the full 24 hours of sunlight. LEO, on the other hand, could only get around 10 hours in comparison - which is close to the same exposure time of panels on Earth. Low cost and zero emission projections may provide our leaders with more incentive to consider the moon as our next step in the race for affordable and sustainable energy sources.

[80] http://www.sciencedirect.com.ezproxy.wpi.edu/science/article/pii/S0360544210005931

Helium-3 and the Moon

By: Sitthipat Preedawan

1. Introduction

Helium-3 is a non-radioactive isotope of helium in which one neutron is missing. Helium-3 is a very rare element on earth since it can only be obtained by decaying Tritium over time. United States has 30 kilograms of Helium-3 reserves and a few hundred kilograms of Helium-3 reserves on earth. With 25 tons of Helium-3, it is capable of creating enough energy for a country the same size as United States for one year[81]. Helium-3 is very rare on earth because of the earth's atmosphere and magnetic field that block away Helium-3 from outer space. On the other hand, there are significant amount of Helium-3 on the moon because of the moon does not have an atmosphere. It has been reported that there are about 1,100,000 metric tons of helium-3 on the surface of the moon with only a few meters depth so there is no doubt that Helium-3 has a potential to be a future's energy source. Many countries such as United States, Russian Federation, and People's Republic of China showed an interest to going to the moon to mine for Helium-3.

2. Helium-3 and Nuclear Fission

Nuclear fusion holds the future of carbon-free energy. The world in the future needs a better and cleaner way to generate a power that never ceases to decrease in demand. Climate change and fossil fuels decreasing supply are also why we should consider nuclear fusion as an alternative way to generate energy. Fusion is common in the sun and any other stars because that is how heats are generate when atomic nuclei collide together[82]. There are many types of nuclear fusion reactor, Deuterium-Tritium fusion is a widely known type of fusion reactor, but the problem with Deuterium-Tritium fusion reactor is that it will create a significant amount of radioactive along with energy which requires a high level of care since a leakage of radioactive will do devastate damages not only to human, but to an environment. Deuterium-Helium-3 fusion reactor is very promising since it is safe, reliable, and clean. Nuclear fusion energy from Deuterium-Helium-3 fusion will not leave any radioactive behind so there is no need to worry

[81] "ExplainingTheFuture.com : Helium-3 Power." ExplainingTheFuture.com by Christopher Barnatt. N.p., n.d. Web. 17 Dec. 2012. <http://www.explainingthefuture.com/helium3.html>.

[82] "Fusion energy: Introduction to fusion." Fusion: Fusion - a clean future. N.p., n.d. Web. 17 Feb. 2013. <http://www.ccfe.ac.uk/introduction.aspx>.

about meltdown since Deuterium-Helium-3 fusion reactor operates at lower temperatures and even in the worst case scenario a damage will only expose as far as natural background radiation which is almost unlikely harmful. Deuterium-Helium-3 fusion reactor has the conversion efficiency of 60 percent which is better than Deuterium-Tritium fusion reactor that has 34-49 percent efficiency. Atomic nuclei collide together and release energy. Scientists and engineers are working really hard to use this process in commercial power stations. Unfortunately, we are going to have to wait up to 3 decades or more for nuclear fusion technology to become far advance enough for that to happen[83].

Advantages of fusion power

The world needs new, cleaner ways to supply our increasing energy demand, as concerns grow over climate change and declining supplies of fossil fuels. Power stations using fusion would have a number of advantages:

- *No carbon emissions*. The only by-products of fusion reactions are small amounts of helium, which is an inert gas that will not add to atmospheric pollution.
- *Abundant fuels*. Deuterium can be extracted from water and tritium is produced from lithium, which is found in the earth's crust. Fuel supplies will therefore last for millions of years.
- *Energy efficiency*. One kilogram of fusion fuel can provide the same amount of energy as 10 million kilograms of fossil fuel.
- *No long-lived radioactive waste*. Only plant components become radioactive and these will be safe to recycle or dispose of conventionally within 100 years.
- *Safety*. The small amounts of fuel used in fusion devices (about the weight of a postage stamp at any one time) means that a large-scale nuclear accident is not possible.
- *Reliable power*. Fusion power plants should provide a baseload supply of large amounts of electricity, at costs that are estimated to be broadly similar to other energy sources.

Figure 37: Advantage of fusion power[84].

3. Tokamak

Tokamak was first developed in 1960s by Soviet Union and later adopted by researchers from all around the world due to its potential for the future fusion reactor. Tokamak is a magnetic confinement system. The world largest, powerful, and developed Tokamak located in Culham Centre for Fusion Energy in Oxfordshire[85].

[83] "Fusion power: is it getting any closer? | Environment | The Guardian ." Latest US news, world news, sport and comment from the Guardian | guardiannews.com | The Guardian . N.p., n.d. Web. 17 Dec. 2012. <http://www.guardian.co.uk/environment/2011/aug/23/fusion-power-is-it-getting-closer>.

[84] http://www.ccfe.ac.uk/introduction.aspx

[85] "Fusion energy: The Tokamak." Fusion: Fusion - a clean future. N.p., n.d. Web. 17 Feb. 2013. <http://www.ccfe.ac.uk/Tokamak.aspx>.

The main tokamak components and functions are as follows:

- The plasma is contained in a *vacuum vessel*. The vacuum is maintained by external pumps. The plasma is created by letting in a small puff of gas, which is then heated by driving a current through it.
- The hot plasma is contained by a *magnetic field* which keeps it away from the machine walls. The combination of two sets of magnetic coils – known as toroidal and poloidal field coils – creates a field in both vertical and horizontal directions, acting as a magnetic 'cage' to hold and shape the plasma.
- Large *power supplies* are used to generate the magnetic fields and plasma currents.
- *Plasma current* is induced by a transformer, with the central magnetic coil acting as the primary winding and the plasma as the secondary winding. The heating provided by the plasma current (known as Ohmic heating) supplies up to a third of the 100 million degrees Celsius temperature required to make fusion occur.
- Additional plasma heating is provided by *neutral beam injection*. In this process, neutral hydrogen atoms are injected at high speed into the plasma, ionized and trapped by the magnetic field. As they are slowed down, they transfer their energy to the plasma and heat it.
- *Radiofrequency heating* is also used to heat the plasma. High-frequency oscillating currents are induced in the plasma by external coils or waveguides. The frequencies are chosen to match regions where the energy absorption is very high (resonances). In this way, large amounts of power may be transferred to the plasma.

Figure 38: The main Tokamak components and functions[86].

4. The Moon

The moon will become a famous mining place for Helium-3 when a fusion commercial power station proves to be beneficial. The moon is different from earth is many ways so it is very important to know and understand these differences before going there and start mining for Helium-3.

Temperature and phases

The temperature on the moon varies between day and night because there is no air temperature on the moon dues to the moon has no atmosphere. The temperature of the Moon can be as low as –243°F during the night and as high as 225° F during the day[87]. The phrase of the

[86] http://www.ccfe.ac.uk/Tokamak.aspx

[87] "Temperature of the Moon." Universe Today — Space and astronomy news. N.p., n.d. Web. 7 Dec. 2012. <http://www.universetoday.com/19623/temperature-of-the-moon/>.

moon is long. It takes up to 27 days for the moon to rotate once on its axis so the moon has about 13 days of sunlight and 13 days of darkness.

Human factors[88]

It is safer here on the earth surface than on the surface of the moon. There are three major hazards that humans have to be aware of when they are on the surface of the moon including radiation, lunar dust, and lunar gravity.

Radiation

The moon suffers from radiation due to lack of attenuating atmosphere. Radiation on the moon came from the sun and deep-space sources. Solar wind and cosmic radiation are the two major radiation on the moon. Exposure to radiation on the moon affects biological life spans, causes neurological problems, damages a genetic, and causes cancers. Exposure to radiation can be reduce by using a proper shielding and limiting the time of exposure.

Lunar dust

Lunar dust is common on the surface of the moon, but problematic for humans. Lunar dust is airborne and causes pneumoconiosis disease if enter the lungs. Pneumoconiosis disease interferes with respiratory function and causes cancers. Lunar dust can be found anywhere on the moon and it will cling to any objects that comes to contact with such as space suit. It is very important for humans to make sure to install monitoring and air-filtration system to prevent any hazards to human life.

Lunar gravity

Gravity on the moon is 1/6 less than gravity on earth which can cause health issues to humans such as loss of bone and muscle mass, increases a chance of kidney stones, and causes heart problem. These issues can be prevented by a proper exercise.

Physiological needs of humans[88]

There are three basic needs that are required by humans in order for them to be able to survive and work on the moon.

[88] Schrunk, David G.. The Moon resources, future development, and settlement. 2nd ed. Berlin: Springer ;, 2008. Print.

Oxygen

Oxygen is the most fundamental element yet very important to human on the moon. Oxygen can be found on the surface of the moon in lunar regolith which consist about 50 percent or more so oxygen can be obtain with a proper extraction on the moon.

Water

Humans need water to guarantee their survival. Water can be formed on the moon by combining oxygen with the hydrogen; both elements can be found on lunar regolith. There is enough hydrogen on lunar regolith to produce approximately 1.5 million liters of water for every square kilometer with only a depth of 1.8 meters.

Food

Food is not available anywhere on the moon they need to be transported from the earth or cropped on the moon, but humans have to make sure that their food production has a proper disease-screening procedure to prevent any diseases that may contaminate and cause any serious health issues. Fortunately, it is possible for food crops such as wheat, soybeans, potatoes, and lettuce to be cropped on lunar regolith, but artificial light will be required for some crops such as wheat since wheat cannot adapt to the moon day and night cycle which is a lot longer than the earth. Nitrogen, carbon, phosphorus, and sulfur are also important factors for planting crops on the moon.

Elements[88]

The moon has many major elements that are found on Earth including Oxygen, Silicon, Aluminum, Calcium, Magnesium, Iron, Sodium, and Titanium and trace elements including Sulfur, Phosphorus, Carbon, Hydrogen, Nitrogen, Helium, Neon, Argon, Krypton, and Xenon that can be mined on the moon and use in the process of constructing a moon base for helium-3 mining or living on the moon. Elements on the moon will help cut the cost of transportation from the earth which is as high as $20,000 for each kilogram and millions of dollars can be saved

Lava tubes[88]

Lava tubes are probably the most useful features of the moon to humans. Lava tubes are natural caverns result from underground lava rivers that have been drained. Lava tubes are 10 meters thick and can be sheltered to help protect from the moon's hazards such as radiation, meteorite impact, and temperature extremes. Lava tube should be considered as a moon base by humans with a proper building modification.

Lunar regolith

Scientists have been estimated that more than 250 metric tons of Helium-3 has bombarded the moon in the past 4 billion years, but the solar wind did not have enough energy to penetrate very deep below lunar regolith. In order to extract Helium-3 from lunar regolith, lunar regolith must be heated to about 600 degree Celsius[89]. After volatiles are extracted, they can be separated from Helium-3 by using an advantage of a low temperature of the moon during the night since everything else will be condensed and Helium-3 can be collected. Every parts of lunar regolith is valuable to humans, for every ton Helium-3 that has been extracted, there will be 3,300 tons of Helium-4, 500 tons of N, 400 tons of CO, and CO2. Helium-3 could be worth as much as $1 billion for every ton.

Sunlight[88]

There are benefits from constant, intense, and inexhaustible sunlight on the moon that can deliver up to 1.37 kW/m^2 on the surface when the Sun is orthogonal to the surface of the moon. Solar cells that produced from materials mined from the moon regolith can be planted on the surface of the moon to produce electricity for the moon base and the moon exploration. Agriculture applications to produce foods on the moon require sunlight. Sunlight can also be used with a combination with mirrors to generate the high temperature that may require during the process of material processing and manufacturing. One thing to keep in mind about sunlight on the moon is that the moon has a fairly long day and night so constructing a solar-powered electric grid around the circumference of the moon is a must if we need to have a constant amount of electricity.

Vacuum[88]

The surface of the moon is filled with the vacuum of space and there are many benefits the vacuum provides. First, vacuum allow trapped gas to escape from molten materials quickly than it escapes on earth with no worry about contamination of atmospheric gases during the refining process. Second, rusting is not occur on the external, aerodynamic concern is not require

[89] "Could Helium-3 really solve Earth's energy problems?." io9. We come from the future.. N.p., n.d. Web. 17 Dec. 2012. <http://io9.com/5908499/could-helium+3-really-solve-earths-energy-problems>.

when the building is built. Third, laser communication and power-beaming systems will operate without having to worry about any distortion and attenuation. Forth, particle smasher or atom smasher require vacuum to operate so the moon is a good candidate place to construct.

5. Moon Base Site Selection Criteria[88]

There are several criteria that scientists and engineers should keep in mind when they select the site of the very first moon base. First, will there be enough and reliable energy that is safe for an entire moon base? An area of the moon base should be energy generating friendly. Second, will there any problem with a communication between moon base and earth base? The best way to communicate between moon base and earth base should be by a communication link that does not rely heavily on satellite since the moon mass concentration create a non-uniform gravitational field that will interrupt satellite orbits and lead to problem in communication. Third, will a moon base locate close to a mining area? It is only make sense to build a moon base close to a mining area in order to save a traveling time. Forth, will there be any hazards from the harsh environment of the moon? Crater, rille, and lava tube are human's best bets. Crater, rille, and lava tube and combination of lunar regolith as a roof will help protect humans from harsh temperature and asteroid. Fifth, will there be any problem related transportation and logistics? We should be able to transport to and from a moon base easily and less problematic. Sixth, will there be any difficulty in case of evacuation? Humans should be able to evacuate easily and safely in case of an emergency.

Psychological needs of human habitation

Stress is a serious hazard to humans who have long-duration missions on the moon. Stress affects negatively to a performance of human which can lead to failure of the mission on the moon. Organization, cognition, physiology, and Human behavior are affected by stress. Stress can cause depression, irritability, insomnia, decreased intellectual and poor physical performance. It is very important that we are aware of factors such as isolation, lack of privacy, fear of equipment failure, monotony, forced confinement, noise and vibration, increased or decreased sensory input, and complexity of mission tasks. It is very important for the designer of a moon base to aware of these factors in order minimize any risks that may occur during the mission.

Crew selection is also very important. All crew members should be tested to see how they react in different situation and crew members who have the highest tolerances to stress will the best candidates. There should be psychological monitors for every crew members during their time on the moon to monitor and measure their conditions and these data will indicate whether or not they are capable of handling their stress levels.

6. Lunar electric power[88]

Electric power is important for humans if we want to have a moon base on the moon to mine Helium-3. There are two major methods to generate electric power including nuclear power and solar electric power.

Nuclear power

With enough resources and studies, nuclear reactor can be built on the moon to provide electric energy. Nuclear power will provides operation on the moon with continuous electrical power at levels of 100kW to 1MW range. The biggest problem of nuclear reactor on the moon seems to be political issues since every nation are fully aware of nuclear uses outside of the earth.

Solar electric power

Photovoltaic cells or solar cells can also produce electric power on the moon since the moon exposes to sunlight. One downside of photovoltaic cells on the moon is about the moon long day and night cycle.

Electric power for the earth

Electric power that is generated by solar power on the moon and exceed the needs of electric power on the moon can be transported back to earth and possibly other location in space. Solar power is a clean energy and if humans can transport it back to earth, this will lead to less dependent on fossil and fission power which are bad for humans and an environment.

7. The Robot Assistant[88]

There are many challenges that humans face on the surface of the moon. First, the weight from a spacesuit and additional life-support equipment will prevent humans from moving and performing tasks properly which leads to a longer time to complete a task. The weight from a spacesuit and additional life-support equipment also cause fatigue to occur sooner which will affect to efficiency of a task. Second, it is difficult for humans to change their orientations while they are inside spacesuits and maintaining their balances so it is difficult for humans to do a task such as bending up and down. Third, since the moon has less gravity than the earth, some problems may occur that would not be experienced in a terrestrial setting. Forth, human's exposure to solar wind, cosmic radiation, and lunar dust for a long period of time can be problematic since is can cause serious health issue.

There are many disadvantages that humans are going to face while working on the surface of the moon that can be minimized by using robot assistant. It is possible for humans to use robotic automation or tele-operation in which humans control robots to do certain tasks for them while they are staying on earth.

Difficulty aspects of the robot assistant

Technical heritage - How much new design and development of the robot assistant will be required for tasks on the moon. There are already existed space-proven technologies that can be used on the moon and there are some technologies that are not yet ready or still in the development.

Complexity of the task - It is easier for the robot assistant to operate on simple tasks than difficult tasks. This is also applying that it is easier to produce and program the robot assistant that operate on simple tasks.

Robotic compatibility - How well the robot assistant can perform a task. There are some tasks which are robot compatibility and there are some tasks which are too complex for the robot assistant.

Task criticality - This is a question of what would happen if a robot assistant fails to do its task? Would there be a serious consequence? Scientists and engineers must make sure that their designed robot assistants are well designed and will now cause any problem along the way.

Benefit aspects of the robot assistant

Task duration - How much time would the robot assistant will save humans from doing task on the surface of the moon? Humans need spacesuits to be able to stay on the surface of the moon and spacesuits have a limited amount of oxygen and battery power which are not easy to carry along so the robot assistant would be an ideal for task that require a lot time to complete.

Task frequency - It may not be good ideas to use the robot assistant on tasks which are not happen frequently. The robot assistant would be the best choice for long hours tasks

Task pervasiveness - The robot assistant would be beneficial for tasks that take place in many different places since humans are limited by spacesuits. On the other hand, tasks that take place in a single place can be done by humans.

Human factors - Some tasks are meant to be for humans such as challenging, interesting, and fun tasks while tedious, boring, and strenuous or dangerous tasks are meant to be for the robot assistant.

Distance from safety - It would not be a wise idea for humans to perform tasks that are too far away from a moon base since in case of an emergency humans might not be able to get back to a moon base in time. The robot assistant is an ideal for tasks that are too far away from the airlock.

8. Conclusion

Helium-3 is the key to future carbon-free energy, but this is only possible if fusion reactor is feasible in a commercial power plant. A combination of Helium-3 and Deuterium will generate massive amount of carbon-free energy without having to worry about radioactive by-product. Twenty-five tons of Helium-3 is enough to generate enough energy for a county with the size of the United States. The moon will become a mining place for Helium-3 since there is not enough Helium-3 on earth since earth's atmosphere block away all of Helium-3 from the sun and outer space. This does not apply for the moon since the moon does not have atmosphere. It is an ambitious plan to go to the moon and mine Helium-3, but it is not impossible to do so. If we really going to go to the moon, we have to come up with the finest plan not just, but to sustain on the moon.

V. Social and Political Considerations

Often times, we cannot proceed with a course of action because of political and social limitations. Most governments regulate energy in ways that provide the least financial risk to ensure national economic stability, but these careful steps might be inadvertently restricting potential found in some of the greater and lesser known fuels. Social attitudes, molded by these governmental policies and a lack of education, play an important role in the future of energy. This section explores in depth how sociopolitical attitudes are affecting the solar and oil industries.

Solar Power

By: Chris Chaggaris

1. Introduction

The previous section looked into the advantages and disadvantages of commercializing cost-competitive solar energy concluded that our electric energy needs can be better met by sunlight than any current fossil fuel or non renewable resource. Decades ago, what once seemed technologically and economically impossible is now readily available. But how come we don't find solar panels on every house and building in every city, or even the majority of them for that matter? The "hang-ups in the U.S. are strictly political," says representative Bill Powers from Solar Done Right[90]. This is indeed the case for countries in Western Europe, the Middle East, and Asia that also have this technology readily available. Governmental responses to energy issues are fueled by public opinion, but without the necessary support from politicians and the general populace, there can be only little change in how we consume energy.

2. Social Stigmas

The unfortunate reality of this situation is that the majority of homeowners and business owners do not have worthwhile incentives to switch from coal or natural gas to solar for their electricity generation. Many people, who decades ago dismissed solar power as impractical, are not properly educated in the current economics of solar panel technology. In fact, about 97% of American homeowners overestimate the cost of installing solar panels, according to an

[90] http://theenergycollective.com/energyrefuge/135736/politics-solar-power

interactive study by SunRun. About 80% of homeowners claim that they would have a solar system installed to supply their home if cost were not a factor. It is a valid reason for concern, especially since the up-front costs for buying panels can be over $20K[91].

With the competition amongst solar manufacturers being fiercer than ever before, new incentives are needed to alter the general public's perception. There are already a handful of solar manufactures and local governments that offer great alternatives to the financial concerns that drive many potential customers away fast. The New York State Energy Research and Development Authority (NYSERDA) presents buyers with one of the largest deductable subsidies on purchasing panels in the nation. Approved customers in New York City can receive up to $62,500 annually in tax credits, since the NYSERDA has provided select solar companies with millions of dollars of dispensable credit.

OnForce Solar, one the fastest growing solar power companies based in the Bronx, is leading the charge in the "solar revolution" for a more efficient incentive plan, and has already met with great success. They have received $6 million in allotment money from NYSERDA's $300 million cash subsidy fund. This astounding budget is clearly being put to good use and has gained more than just the attention of the city's public[92]. Despite the progress so far, New York and California practically stand alone in the attempts to promote residential solar power usage.

There is also the option to lease-solar panels so that the entire installation cost does not have to be paid in full up front. A leasing model can cost anywhere between $0 and $1K in upfront charges, and all maintenance and monitoring responsibilities are included at no additional costs. This solution would be practical for any homeowner with good credit willing to sign a long term contract (10-20 years). The customer still has to pay a monthly utility bill for the solar power, but at a lower cost than the conventional electricity bill. While the savings might not be anything exceptional, the leasing system provides a great alternative that is sure to reduce cost, and for those individuals that meet the basic requirements, there is almost no reason not to try it.

Thus far, the direct governmental cash subsidies and the leasing system adopted by a handful of solar companies are two great new incentives needed to sway public opinion in favor

[91] http://www.smartplanet.com/blog/intelligent-energy/97-of-americans-overestimate-cost-of-installing-solar/15388
[92] http://www.nydailynews.com/life-style/real-estate/bronx-solar-energy-company-article-1.1192464

of solar power. These are the sort of political measures that we ought to see in every city across the world that can develop solar power at marketable prices.

3. Return on Investment

While the lease system is appealing to many, most companies can still only afford to *sell* panels rather than lease them. A simple return on investment analysis shows us that what seems like a steep initial price can actually be paid off in full in a matter of ten years of less. So, if the installation price is reasonable (about $13,500 on average today), then any investment would turn profitable if savings (money that would have been spent on subsequent monthly electric bills) are considered to be normal profits. This is the benefit that renewable resources provide, and the return on investment can only increase as time goes on and the technology becomes cheaper and cheaper.

On average, a homeowner pays approximately $112 a month for conventional electricity[93]. If a homeowner decides to make the switch, pay the full installation price up front, it would take him approximately nine and a half years to pay off this cost, including inflation. After this amount of time, he would reach a point where he no longer needs to pay another electric bill again, having paid for a virtually limitless energy source that typically will not require significant maintenance (and thus no maintenance fees). This calculation is shown below (annual electricity inflation rate of 4.5% is included):

$$\frac{\$13500}{(\$112 + (1 + .045)t)\ \cdot 12 months} \rightarrow 12.54t^2 + \ 1344t - 13500 = \ 0$$

$$t = 9.25\ years$$

After this period of time, the homeowner can start to expect a positive return on investment (again, assuming that the cost of electric bills is forgone as money that *would* have been spent elsewhere). While this measure does account for an arbitrary estimate of the inflation rate, the unpredictability of the inflation rate varies significantly across the years and between nations. Regardless, on average the ROI would increase on a slight curve and take about 9.25 years for the ROI to equal 1, indicating that the investment has reached the break-even point:

[93] http://www.mass.gov/eea/pr-2012/120517-pr-electricity-prices-6-year-low.html

$$ROI = \frac{(Gain\ from\ investment - Cost\ of\ investment)}{Cost\ of\ investment} = \frac{x - \$13500}{\$13500}$$

$$x = \$13500 + (\$112 + (1 + .045)t) \cdot 12t\ months$$

Substituting in *x* would reduce the equation to:

$$ROI = \frac{\$12.54t^2 + 1344t}{\$13500}$$

Graphically represented, the above ROI equation is presented below:

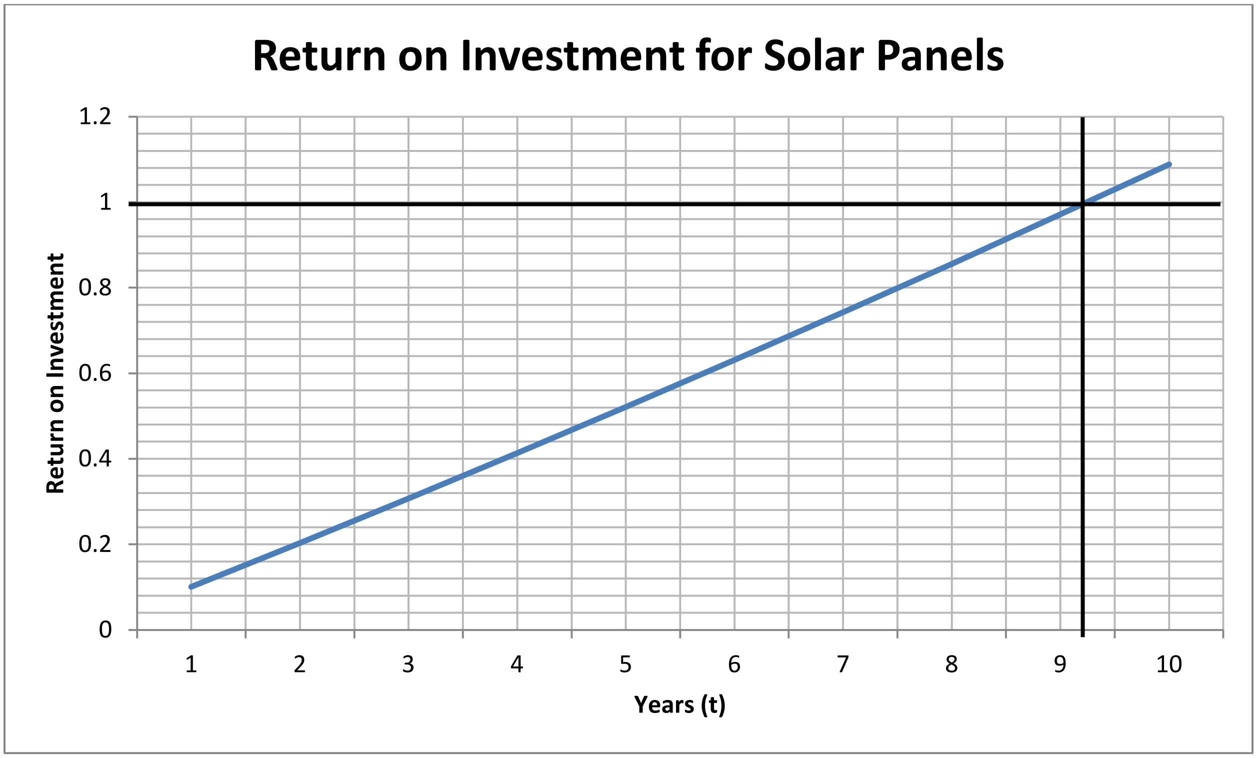


Figure 39.

The lines in black highlight the point at t = 9.25, ROI = 1. Notice the slight curve to the trend that represents the ROI as a second order polynomial, due to the volatile inflation rate.

It is worth pointing out that these ROI results will not apply for every homeowner, so the actual time required to pay off the installation costs and turn a normal profit will certainly vary. Variables such as geographic location, local government incentives and subsides, inflation, and much more will vary on an individual basis. Not to mention, it can be difficult to convince a customer to invest in a technology that is growing rapidly and becoming more economic. The point to be made here is still valid regardless of exact costs, because the ROI will still be positive (indicating gain as compared to loss which would be represented as a negative ROI). Committed homeowners will see reductions in their energy bills regardless of how much they paid up front, the main factor is the time it takes for the return on investment to become positive.

4. Future Economics

Predicting prices for solar panel production rotates around the basic economic principle of supply and demand. When solar panels first emerged, there was limited demand and limited supply, and thus a higher equilibrium (settling point) price per watt installed. The more recent breakthroughs in photovoltaics and thin film compounds has rapidly decreased the price per kilowatt-hour by about 2% a year.

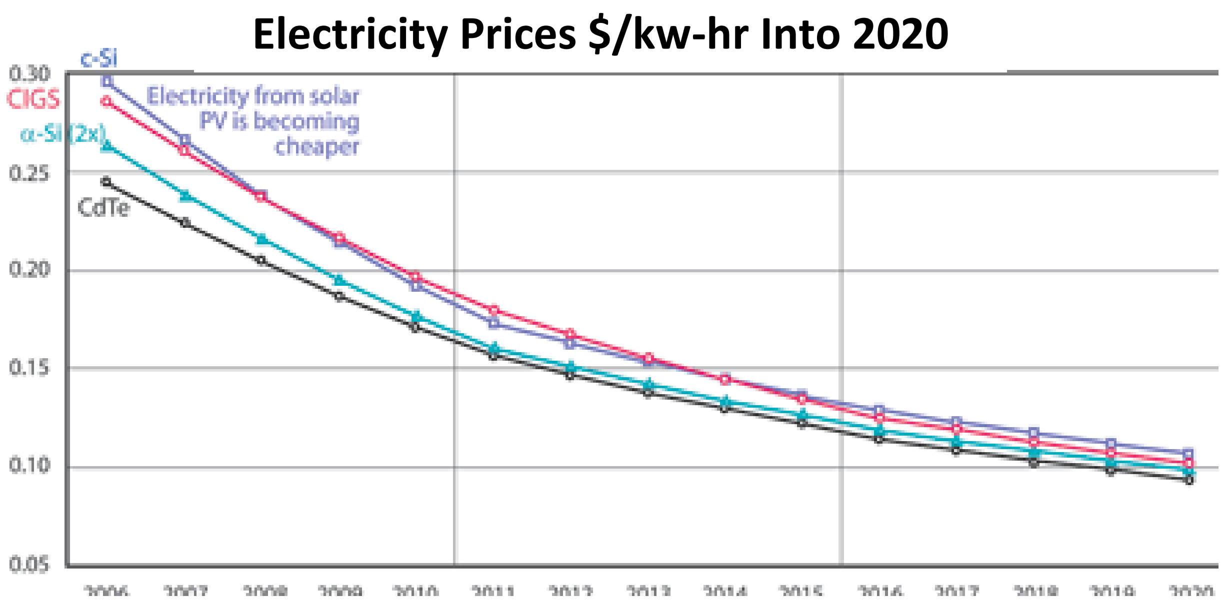


Figure 40[94].

The current price per kw-hr of solar power in 2013 is about 14¢, but could be as low as 10¢ in 2020 and 7¢ in 2030. In comparison, the average price of electricity from coal is about 5¢ to 6¢. It stands to reason that within 30 years, solar power could be mainstream worldwide, or at the very least economically desirable. With nowhere to go but down, the price of standard PV cells can only become more attractive to potentially buyers, and hopefully provide more incentives to considering switching to solar. Keep in mind that this graph only contains low-

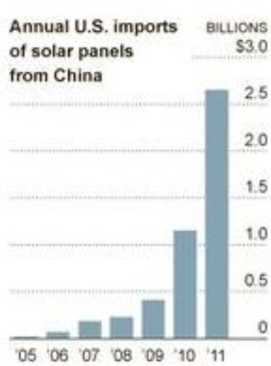
[94] http://www.dataweek.co.za/news.aspx?pklnewsid=40517

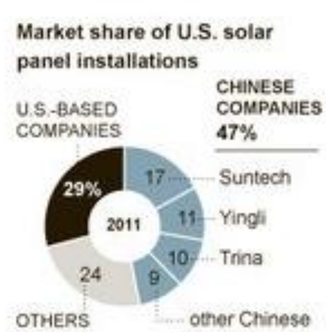
efficiency PV cells, and not those composed of higher efficiency dye materials and films, such as quantum dot cells. The real challenge is making the higher efficiency cells (over 40%) becoming economic, and while inevitable, could be as long as 50 years.

5. Manufacturer Competition

The competition amongst solar panel makers is fiercer in today's market than it ever was before. By the end of 2013, it is likely that solar cell and panel manufacturing could disappear entirely from the United States, as countries like China are highly committed to the success of solar panel installation and are determined to become the top manufacturer. It is predicted that within the next year, approximately 180 companies worldwide will either go out of business or be bought out by 2015[95]. The 70 gigawatts worth of global production capacity (supply) far exceeds the 30 gigawatts of global demand, which will effectively be responsible for the shutdown of about 88 companies as production costs become higher than sales.

To avoid bankruptcy, many of these companies are exiting the game - especially in the U.S. and Eastern Europe - as China uses questionable methods to secure their own financial means. Allegations of unfair business practices from China's companies, which includes using state owned banks and illegal government subsidies to fund manufacturing, has led the United States International Trade Commission to establish tariffs on solar imports from China earlier this November. The tariffs would range from about 24 to 36%, cover the majority of the exports, and effective for the next five years. Of primary concern is the restoration of panel manufacturing competition in the U.S. that "…was a growing industry just a couple year ago that has been basically decimated by the Chinese manufacturers," says Gordon Brinser, the chief executive of SolarWorld Industries America.





95 http://www.forbes.com/sites/uciliawang/2012/10/16/report-180-solar-panel-makers-will-disappear-by-2015/

Figures 41 & 42[96].

Trends in the solar panel manufacturing market demonstrate how far supply exceeds consumer demand, and explain why so many companies are forced to exit the industry. China's dominance in the market is greatly reducing the number of competitors, but also inadvertently guarantees some sort of product differentiation amongst the market's top sellers. This product differentiation comes in the form of new business tactics, namely cash subsidies or lease agreements, created in collaboration with local governments with the sole purpose of gaining public support and attention by providing more logical incentives for homeowners to switch to solar.

Oil

By: Nick Muller

1. Establishing Oil Exploration

When it comes to the political aspects of drilling for oil, the local government creates a politico-economic environment concerning the exploration of a particular national territory. Any company(s) interested in exploring the aforementioned area will judge the risks of operation against the likelihood of successful exploration and production. The company must also take into account taxation, production limits, and other policies within the nation's jurisdiction. Offshore drilling only further convolutes these issues. Since ancient times, control and ownership of the Earth's oceans has been a controversial topic. It remains so today with many regions of the ocean still under dispute, however most countries follow the maritime boundaries set up by the United Nations Convention on the Law of the Sea. Figure 43 shows a nation's exclusive economic zone (EEZ), a region determined by the United Nations Convention on the Law of the Sea, which took place from 1973 to 1982. A country's EEZ extends 200 nautical miles off its coastal baseline unless state coastal baselines are less than 400 nautical miles apart, in which case, it is up to the states to determine boundaries[97]. Figure 44 shows a world map of every country's EEZ boundaries. The regions in between the EEZ boundaries are considered international waters.

[96] http://www.nytimes.com/2012/11/08/business/energy-environment/us-affirms-tariffs-against-chinese-solar-companies.html?_r=0

[97] <http://en.wikipedia.org/wiki/EEZ> (Information and EEZ images)

Diagram of a Country's EEZ and Coastal Baseline

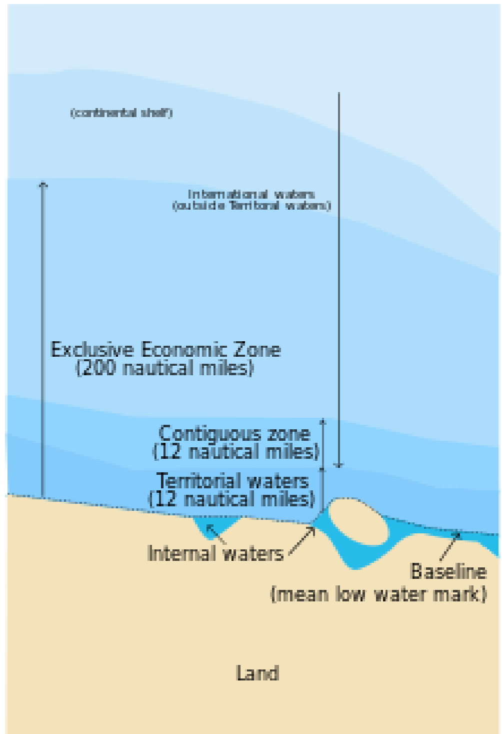


Figure 43[98].

World Map of Every Country's EEZ Boundaries

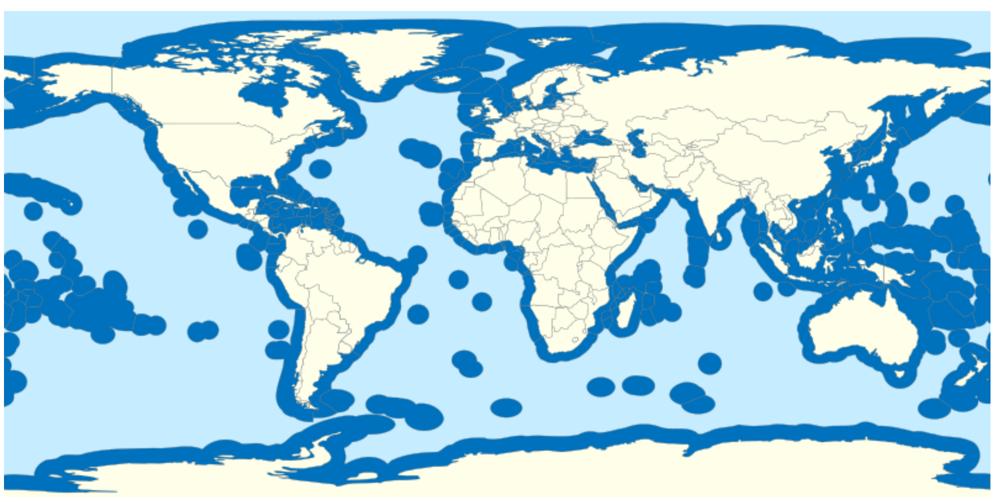


Figure 44[99].

[98] http://en/wikipedia.org/wiki/EEZ
[99] http://en/wikipedia.org/wiki/EEZ

2. Disputed Regions of the Ocean in East Asia

In the interest of maximizing underwater resource availability, I would like to minimize the amount of disputes over maritime boundaries. For the most part, the majority of complicated boundary disputes involve the numerous islands in East Asia. The major countries involved include: Japan, China, Taiwan, North Korea, South Korea, Vietnam, Malaysia, Brunei, and the Philippines. Islands produce many complications for the United Nations Convention on the Law of the Sea. Right now, an island is entitled to a radial EEZ of 200 nautical miles around its baseline. I believe that this is a major flaw in the ocean's law system because any miniscule island can control a proportionally massive region of the ocean. Islands also create a lot of EEZ overlapping, particularly in the case of groups of small islands. One possible solution to this issue would require no small political effort. I believe the United Nations should make a political push to reduce the EEZ of islands less than 300,000 square miles in area. 200 nautical miles is far too large an EEZ for islands smaller than this size. Their EEZ could be a set distance between 10nm-50nm or their EEZ could scale based with the size of the island to a more appropriate distance. If such laws are passed, most of the boundary disputes could be settled and free the previously contested underwater resources.

3. Climate Change and Uncertainty in Maritime Boundaries

The future brings a rising global temperature, and rising ocean levels with it. Since the coastal baselines are determined by the "low water mark", changes in ocean levels will alter coastal baselines, and undoubtedly create further dispute over ownership of resources under the ocean. The change in sea level will be felt around the world. Figure 45 shows the projected rise in sea level by the next century based on three different emissions scenarios that would each affect the global temperature differently. As you can see, the sea level is projected to rise at least two feet in the next 100 years alone.

Projected Rise in Sea Level Based on 3 Different Emissions Scenarios

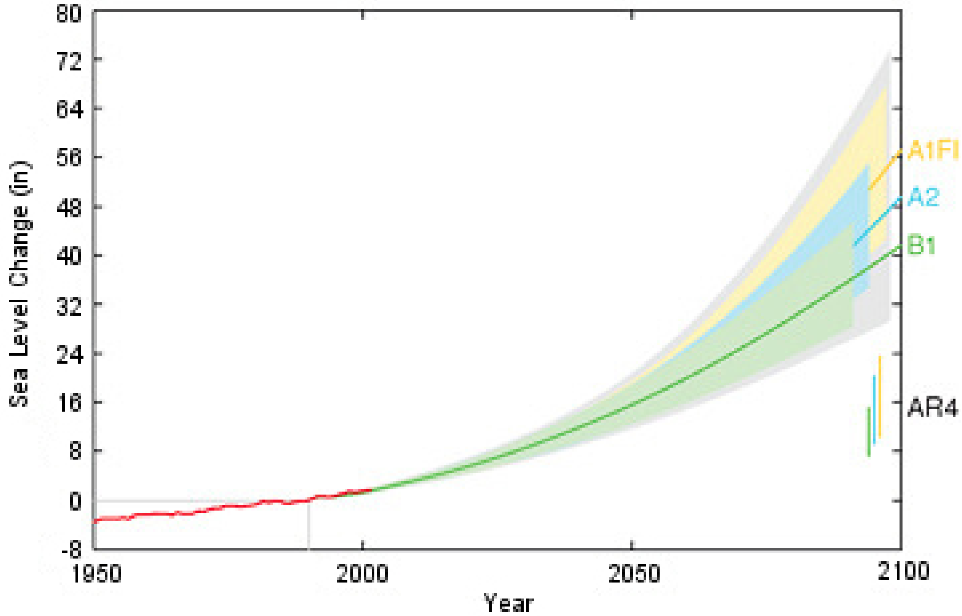


Figure 45[100].

So what's to stop countries and oil companies from taking advantages of the shift in future EEZ boundaries? At first glance, a sea level rise of a couple feet does not seem that daunting. However, the rise is sea level will be particularly apparent in the case of islands and regions where there is a gradual coastline. A possible solution to avoid the conflict of moving baselines is to make a political effort to "fix" the baselines. Even if this requires, extending baselines past where they are currently, "fixing" coastal baselines would provide stability to the currently unstable maritime boundaries.

[100] http://en/wikipedia.org/wiki/EEZ

VI. Group Designs and Policies

With so many different new fuels emerging in our world, each with their advantages and disadvantages, it is often difficult to decide how to proceed with our energy policies. Using the research and conclusions contained in this report, a brief list of designs and policies were suggested in response to the energy crisis. We believe that if followed as best as possible, these policies will dampen many drawbacks while providing additional insight as to how to handle our energy sources.

1. Common Fossil Fuels

Coal

1. Eliminate international dependence on coal as soon as possible—With supplies estimated to last at most another 200 years, it seems illogical to pursue a fuel that does not have the capability of sustaining our world in the coming generations. Not to mention, the toll on the environment is huge despite many attempts to reduce carbon emissions. While the next 15-20 years could see the first decline in coal usage, governments still ought to be the first to initiate rules and regulations that will limit coal usage more and more each year until we no longer need or want it. This will mean the end of many jobs in the coal industry, but the transition of a coal dependent planet to a clean energy harvester will not be perfect.

2. Enforce stricter safety policies at excavation sites—Hundreds of people die each year in coal mining related accidents. These problems are much more common in areas such as South America which don't have access to as many machines and materials to safely extract coal and reinforce mine shafts. If money cannot be allocated to this work either internally or externally, then surface mining procedures should be adopted to prevent further cost to human life. While environmentally unsound, surface mining is still our best bet for coal extraction purposes.

3. Stop investing in clean coal technologies—CCS and other clean coal techniques are new, expensive, and vastly underutilized in regions of high electricity demand, such as China.

Funds for these projects would be much better spent towards the progression of more promising renewables, such as solar power. In addition, given the inevitable end of coal in the coming years, these new processes and procedures would no longer have use and could not be justified as anything other than a waste of time, money, and effort.

Oil

1. Introduce new energy efficient technology to countries that otherwise couldn't afford it— In the interest of keeping global oil prices in check, companies could sponsor projects that develop oil harvesting technology like chemical injection, microbial injection, and tar sands extraction in non-OECD countries

2. Eliminate maritime boundary ambiguity—Establishing laws that reduce the EEZ of islands as well as establish fixed baselines for maritime boundaries will minimize boundary disputes and free resources below the ocean.

3. Create dedicated lanes for buses in populated regions—Buses would be able to travel between destinations quicker and more efficiently. This would in turn allow the bus company to lower fees and popularize public transport due to cheaper fees and quicker arrival time.

4. Mandate nighttime heating limits in non-essential public buildings—Whether through law, or furnace control systems, limit thermostat temperatures during nighttime hours when a public building is in minimal or no usage.

Natural Gas

1. Continue research and development of both conventional and unconventional gas in order to come up with the most efficient and new way to extract natural gas from both solutions.

2. Whenever there is a conflict over natural gas resource among countries, there should be a responsible organization that helps resolve the conflict from getting worse since natural gas will become more important in the future.

2. Solar Power

1. Continue research and development of solar technology—It really is only a matter of time until solar panels have extremely high efficiency rates, and once developed, will introduce some of the lowest costs of electricity per kw/hr the market has ever seen. Over the last 8 years, the price per kw/hr for the average solar photovoltaic cell has already dropped double from $0.30 to $0.15. Quantum dots and other techniques used to make solar cells have the potential to achieve record breaking efficiency rates higher than 40%. For many reasons, solar remains one of the most promising of all renewables, and being only in its youth stages, is certain to soon change our world.

2. Utilize solar orbiting panels—Many of the disadvantages associated with current solar technology can be solved if massive solar panels could be placed in geosynchronous orbit around the Earth. Orbiting panels eliminate dependency on the day/night cycle, and space provides a perfect heat sink free of dust particle accumulation. Ideally, if we were to colonize the moon in the near future with either humans or robots, we could use the moon to launch rockets containing orbital panels, thus reducing emissions here on Earth.

3. Provide cash subsidies in every major city to buy or lease solar panels—Governments need to provide more monetary incentives to homeowners and business owners to buy or lease solar panels. Despite higher efficiencies and lower costs each year, the vast majority of the general population already overestimates the cost of solar panels. With the competition in the solar industry as fierce as ever, companies are trying to set up new buy/lease models for customers to ensure savings. Every major city ought to have incentive programs, like those found in New York City, that cover many of the steep down-payments associated with the initial installation process. Homeowners and businesspeople who plan on staying at the same location for at least 10 years will still see long term reductions in their energy bills. For those not comfortable making a purchase

at these relatively low efficiency rates, leasing models make it even more appealing to try the switch with little to no risk.

3. Atmospheric Electricity

Lightning Rod

1. Implement energy harvesting lightning rods on tall buildings and radio towers—With development in lightning harvesting technology, lightning strikes will be able to help provide power to the building and radio towers they strike.

2. Establish energy harvesting lightning rods in the power grids of regions with high lightning density—Electric companies in regions of frequent lightning strikes will be able to directly augment their store of energy through the addition of energy harvesting lightning rod arrays.

Hygroelectricity

1. Reconstruct the Pyramidal Electric Transducer for further field test—This astounding capable of converting electrostatic discharge pulses into useable electricity is the first development of its. The results are conclusive, proving how the geometry of such a device can cause high power gains and some of the lowest cost per kw/hr ($0.03) for a renewable energy source. But could this machine be improved? Our recent recognition between naturally occurring charged particles in the atmosphere and three dimensional geometry could not possibly be complete just yet. There must be more we could gather from further testing.

2. Return to Egypt and use the Great Pyramid as a power station—The only prototype was about 1/125 the size of the Great Pyramid, so by constructing a full scale model we can confirm the creator's prediction of a massive power gain. Given its location and perfectly constructed geometry, it would quite interesting to test the pyramid as a giant power station capable of creating electricity in the same manner as conventional fuels - and see for ourselves if the ancient Egyptians were the first to make this discovery.

4. Helium-3

1. Continue research and development of fusion power. If fusion power proves to be feasible in commercial power plant then Helium-3 role will become more important all around the world.

2. If humans are going to go to the moon to mine Helium-3, the robot assistant will hold a key to success of an entire operation since they are more flexible on the moon than humans.

3. The mining operation on the moon must be planned out carefully. Every factors must be considered in order to cut cost and secure the safety of a human and an entire operation.

4. There should be a ground rule of governance of the moon. The moon should be split evenly to every nation that show interests in mining the moon.

VII. Conclusion and Future Recommendations

Global demand for energy has risen unrelentingly with the growth in industrial development and population. Hunger for energy is particularly apparent in countries that seek to fuel their rapid economic and industrial growth. Currently, he majority of the Earth's energy demand is met by the fossil fuels: oil, coal, and natural gas. These energy sources date back millions of years from the carbon-rich remains of dead plants and animals. They are also dated in the sense that they are behind the times. These non-renewable fossil fuels release harmful emissions and their supply is dwindling. We rely too heavily on fossil fuels for our energy needs. We must work toward replacing fossil fuels with newer, cleaner, and more efficient means of alternative energy.

The pressure to replace fossil fuels is no small task. Growing concerns are rising regarding irreversible damages to our planet's climate and environment. Renewable alternative energy sources such as solar power, methane hydrates, lightning energy, and helium-3 are emerging. However, viable technology is still under development, and start up costs can be high. The main challenge presented to our society is the implementation of a global energy infrastructure that can provide enough energy to meet or exceed the demand while minimizing costs and pollution.

There is no single alternative energy source that will solve the energy crisis facing us in the near future. It is imperative that we utilize the rising energy alternatives while continuing to develop existing technology to improve the production and efficient use of our energy. In order to allow time to establish more permanent energy solutions, we can administer energy related policies and regulations which will extend the lifetime of fossil fuels.

The topic of alternative energy will only become more relevant in the coming years. If this IQP is repeated 20 years from now, our conclusions may shift due to events that occur which we cannot predict. As more data becomes available, our vision of future energy will only become more evident.

Some recommendations for future IQP groups would be to examine alternative energy sources not covered in this report, namely: wind, nuclear, geothermal, and tidal energy. It is also important to note that our report covered a great range of topics, and any of these could be researched in greater depth. As far as our report's topics are concerned, I believe a significant amount more research could be done regarding current and future advancements in technology. In addition, I would have liked to look further into non-energy related changes that society could make in order to adapt to an impending energy crisis. For instance, differing methods of travel and changes in living conditions or work habits. I also recommend that future IQPs envision several likely scenarios or outcomes in the future and balance them against each other, highlighting potential differences and similarities. This would allow for a more accurate conclusion of what an "ideal" scenario would be for a future society dealing with a shortage of the energy sources we take for granted today.