

# WPI

Alternative Renewable Energy Resources:

A Glance at The Energy of The Future

An Interactive Qualifying Project submitted for completion of partial fulfillment at  
Worcester Polytechnic Institute for the Degree of Bachelor of Science

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**Abstract**

The threats of climate change and energy shortage are imminent, and ones that mankind will have to confront in order to ensure the survival of our species. This project examines alternative technologies that have the potential to aid in finding a solution to these issues. It provides an in depth look into lesser known technologies that are being developed into alternative energy resources, bringing to light how essential the completion of the development of these resources are to humanity's survival.

## Executive Summary

All over the world, people rely on energy in all aspects of everyday life. From waking up to the sound of an alarm clock, turning on the lights, and driving to work, life is truly powered by energy. The issue however, is that the demands of humanity's current lifestyle are too great for the resources powering it. All arguments about when aside, the world is going into an energy crisis, and something must be done to save the planet. If the planet is not saved, then humans will be the next ones who need saving.

Throughout this paper, different 'out of the box' energy resources are explored. More typically thought of reusable resources are mentioned, and the purpose of this paper is not to downplay the possibility of these current reusable resources, as they will play a big part in earth's journey to clean energy. These modern reusable resources, such as solar panels on earth and wind energy, have constraints that require more outside thinking in order to achieve complete world renewable energy usage. The purpose however, it to explore the potential of more futuristic solutions to the energy crisis.

The energy crisis may seem far off, as humans are making strides in other ways towards a greener earth, in such cases as electric cars. This paper however, analyzes the fact that these strides may not be going as far as what energy reports may be telling us. For example, the car may produce zero emissions, but to power the car behind the plug, is a power plant emitting tons of greenhouse gases through the burning of fossil fuels. These steps to a greener future are not large enough, and futuristic ideas must be brought to the forefront for the success of energy in generations to come.

Three main types of energy sources are expanded upon within the paper, and examined more closely in terms of their capabilities for a greener future. Tidal energy, installing solar mirrors in space, and fusion reactors are all viable and very possible resources for the future. Although they are not currently in high use, or in some cases, have the technology fully developed, they do have the potential to produce energy around the more modern renewable energy resource constraints. For example, although it may seem like a far fetched idea, tidal energy is already an energy source used in a few places around the world. Installing mirrors in the sky may seem beyond possibility, however millions of dollars are being invested into teams who have already made technical steps towards achievement. Fusion reactors and their immense capabilities have been explored upon for years, bringing attention to the fact they could be a large part of humanity's answer to a near approaching crisis. Superconductivity is also extrapolated upon, and although it may not be a resource itself, it is an important piece of the

green energy puzzle. These technological advances require open thinking to the fact that there is more to alternative energy solutions than what is currently in place.

## Table of Contents

Section	Page Number
Abstract.....	1
Executive Summary.....	2
Introduction.....	6
Chapter 1: Fossil Fuels & ExxonMobils Energy Outlook.....	7
Section 1.1: Summary ExxonMobil Energy Outlook.....	7
Section 1.2: Critiques of ExxonMobils Outlook.....	9
Section 1.3: Graphical Analysis & Summary.....	13
Chapter 2 : Tidal and Current Energy.....	15
Introduction To Tides and Ocean Currents.....	15
Tidal and Ocean Current Energy Harvesting Technology.....	16
Costs of Tidal and Ocean Current Energy Plants.....	17
Tidal and Ocean Current Plants Already in Place.....	18
Possible Places For Tidal Plants.....	20
Possible Ocean Current Energy Harvesting Locations.....	22
Chapter 3: Mirrors in The Sky, Space Energy.....	24
Hypotheses Behind ‘Mirrors in The Sky.....	24
Introduction to The Technology.....	25
Costs and Constraints of Space Solar Panels.....	26
Countries Involved.....	27
Space Solar Possibilities.....	29
Chapter 4 : Fusion Reactor.....	30
The Future of Energy.....	30
Plans For Technology.....	32
The Power of Helium-3 and The Moon.....	33
Constraints and The Future.....	34
Chapter 5 : Jet Stream Energy.....	36
Introduction to Jet Stream Energy.....	36
Jetstream Energy Technology.....	37
Potential in the Future.....	38
Chapter 6 : Superconductors.....	39
A New Solution to the Energy Crisis.....	39
The Potential of Superconductors.....	40

Types of Superconducting Materials.....	41
Timeline of the Technology.....	41
Superconducting Conclusion.....	42
Chapter 7 : Geothermal Energy.....	43
Introduction to Geothermal.....	43
Small Potential of Geothermal.....	44
Discussion & Critique of The Results.....	45
Problem & Solutions: Futuristic Ideas.....	47
Recommendations For Future IQPs.....	56
Conclusions.....	57
Bibliography.....	58

## Introduction

To some the energy crisis just means higher gas prices and a higher electric bill. This crisis however, would affect every single person on the earth, in more ways than just financially. Picture a world where every night is dark, with no lights to comfort people in their homes. Roads would be useless as there would be no gas to power any cars. Finally, picture no grocery stores as there would be no energy to support an ever growing populations need for agriculture. Although this future seems dark and scary, it is a possibility if alternative energy sources are not explored and implemented.

This paper explores the potential of alternative energy resources, as well as exploring the necessity of them. The reasoning behind all of this is that the energy crisis is quickly approaching, and something must be done. The world is running out of oil, and even if a solution is found here on earth to slow the process, future generations will still be left with the task to solve the energy crisis when the oil finally runs out. Humans' reliance on fossil fuel driven energy forces must, and will come to an end. There are alternative sources out there, it is humanity's job to think bigger and explore the possibilities these sources have to offer. This issue is the driving force behind the need to find other sources of energy, some being beyond the earth's atmosphere.

The main goal of this project is very similar to the goal I have for myself through my career. Although the goal is to explore other resources and hopefully take people a step further in understanding the need for environmental change, the main point and mission is to encourage outside of the box thinking. This sort of thinking is what drives change in whatever problem, circumstance, or part of life that one may encounter. Just like the issue of the energy crisis, there is no single one straightforward solution to any real world problem, which is precisely what this paper is about. The issue of the energy crisis and the need for multiple alternative energy sources is the main force behind this paper, but the main takeaway is that no way of thinking may be too far, 'outside of this world'.

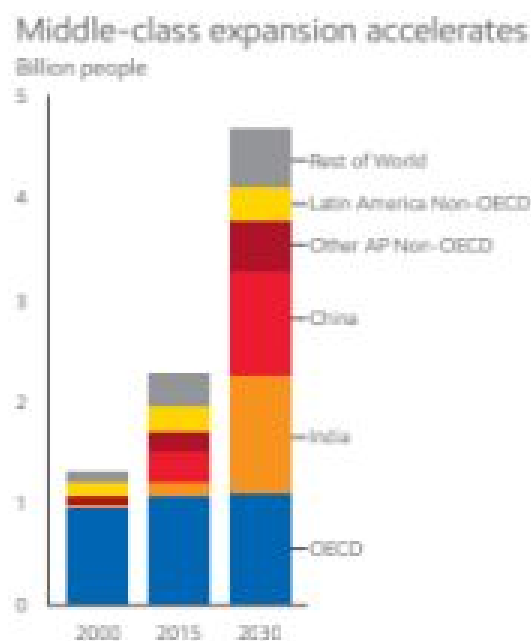
As an aspiring engineer, my entire career will basically be a lifetime of problems that all have no one straightforward answer. These engineering problems through my life will all require the same way of thinking that the solution of the energy crisis, and this paper, have. There are no ideas too crazy, or too strange to ever consider. Sometimes the craziest one, may result in the best solution. This lesson learned from this paper and the approach to solving the energy crisis, is the same lesson that will bring success to my career.

## Chapter 1: Fossil Fuels & ExxonMobils Energy Outlook

### Summary of ExxonMobil Energy Outlook

In the ExxonMobil Energy outlook report, predictions about future energy supply and demand are made based on past and current trends. The energy outlook is broken down into four categories: Fundamentals, Demand, Emissions, and Supply. These four categories are then expanded further into subcategories based on types of energy as well as countries. All predictions are made out to the year 2040, and include evidence from past trends in addition to future policies based on current standards.

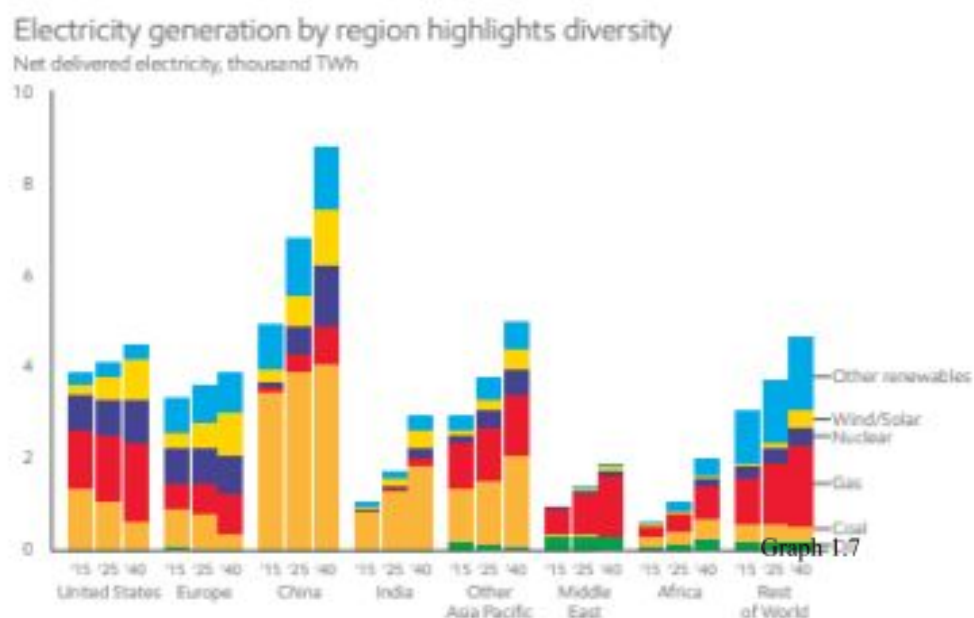
Throughout the entire report, the main theme is that energy supply and demand will increase due to the predicted expansion of the middle class. Based on current trends, the world population by 2040 will be upward of 9.1 billion. This includes a growing middle class that includes a whopping 5 billion people, which is a 1.2 billion increase from the current 3.8 billion in the middle class [2] (Kharas et Hamel, 2018). The accelerated growth of the middle class is explained in the report by a global increase in living conditions and economic growth in current countries where the middle class is currently much smaller but has large populations, such as India. This accelerated growth within the middle class is represented by Graph 1.4, showing that China and India will lead the globe with the largest increase. With a much larger middle class than present day totals, energy demand will increase in multiple ways. The first way being a larger need for transportation, especially with economic advancement allowing more people to own cars. According to the Energy Outlook, the need for transportation is predicted to increase by twenty five percent. In addition, the global miles traveled will increase sixty percent to 14 trillion miles. Marine and aviation travel will also increase, in addition to the increase in commercial travel. This will cause an increase in the demand for oil, however the increase in efficiency of transportation will cause the actual amount of oil used to plateau. ExxonMobil reports that advancing technology will cause an increase in miles per gallon, reaching fifty miles per gallon by 2040. This technology is associated with the design of more efficient engines and body design. By 2040, oil is estimated to still be used for ninety five percent of transportation needs, with little increase in electric and hybrid cars. Electric cars will only account for ten percent of



Graph 1.4



vehicle sales. It should be mentioned however, that many hybrid features are predicted to be incorporated into standard gas powered cars.



Along with transportation,

ExxonMobil explores the residential and commercial energy demands predicted through 2040. The report states that the commercial energy demand will increase by twenty five percent, with Africa and China accounting for thirty percent of this demand. Due to the increase in middle class, the demand for residential energy is estimated to increase seventy percent. Although the demand for energy will increase, other sources of energy such as renewable sources are predicted to be implemented, with twenty five percent of the global energy supply estimated to be renewable. This includes not only residential energy consumption, but industrial energy consumption as well, which based on trend makes up almost half of the world's energy usage. In terms of past trends, industrial and commercial trends are similar. However, with the large increase in the middle class and a high economic growth predicted, the two increase at different rates. Graph 1.7 shows the types of energy generated by each major country, with coal being a major contributor. With the increase of CO<sub>2</sub> emissions predicted, the burning of coal is not a viable option in terms of health for the planet and our primary sources of energy must be changed.

The report goes further into energy by exploring the supply of energy in addition to the emissions produced globally. ExxonMobil predicts that emissions will peak in 2030, but then begin to decline by 2040. The idea is put forward that some countries want to put a price on CO<sub>2</sub> emissions, forcing people to be more aware and thus reducing them. This would especially be helpful because mileage is the largest cause of CO<sub>2</sub> emissions, and is estimated to remain the largest cost going into the year 2040. In terms of supply, the report predicts that by 2040, the demand for nuclear energy will double. This demand will result in nuclear and renewable energy

making up approximately twenty five percent of the global energy supply. As mentioned earlier, natural gas demand will increase the most due to the increase of the middle class, however, even with all policies in place oil will still remain the number one source of energy. As ExxonMobil estimates, a staggering \$450 billion will need to be invested in order to meet the global oil demand.

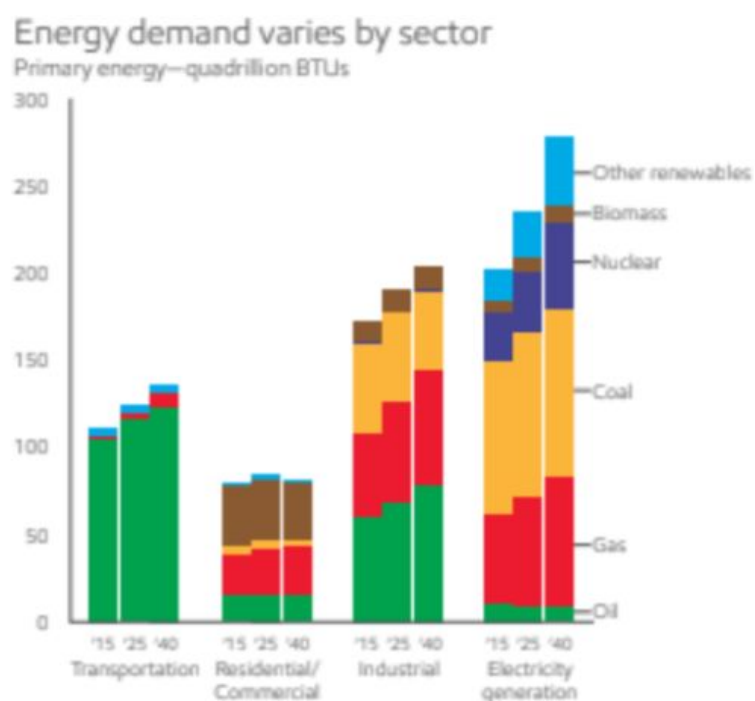
### Critiques of ExxonMobil's Outlook

#### **(1) There is not as much oil as the energy projection insinuates there is.**

Throughout ExxonMobil's report, oil is consistently mentioned as still being a commonly used resource in the year 2040. As mentioned in the report's summary, renewable energy is predicted to only make up about twenty five percent of the world's energy. Although this is the correct direction the world must go in, the report fails to examine the fact that this switch to renewable energy is much too slow. According to the oil company BP, oil prices have gone from \$47.73 a barrel in 2016, to \$51.49 (BP, 2018). This is an indication of the fact that oil is running out. According to BP, there is approximately 53.3 years left where oil can meet the needs at current production [3] (BP, 2018). Based on this analysis, oil is calculated to run out by 2071, thirty years after ExxonMobil's

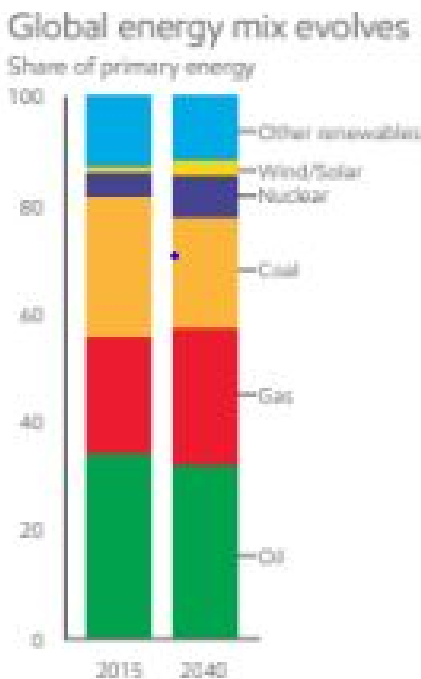
predictions. Based on these predictions, the world would have to switch over seventy five percent of the world's energy to renewable sources in just thirty years. This task seems borderline impossible, indicating that something must be done now. Whether this prediction is accurate with future trends or not, it still shows that change must happen, and it must happen fast. However frightening it may be, this scary reality indicates how much of a problem the lack of oil is, and even more important, how much of a problem our current reliance on oil is.

As shown in Graph 1.2, the energy demand still almost entirely depends on oil in terms of transportation, as well as industrial demand. This is not feasible with the amount of oil we have



Graph 1.2

left, and although the amount of oil required to meet demand of residential and electricity



Graph 1.5

generation is less than industrial, there is still not enough oil to meet the demands of 9.1 billion people in 2040. This is further shown by Graph 1.5, as oil is still the primary source of energy. In order for the human race to continue, renewable resources must increase to being the number one source of energy. As earlier indicated by BP, there is not enough oil to support the human population for much longer.

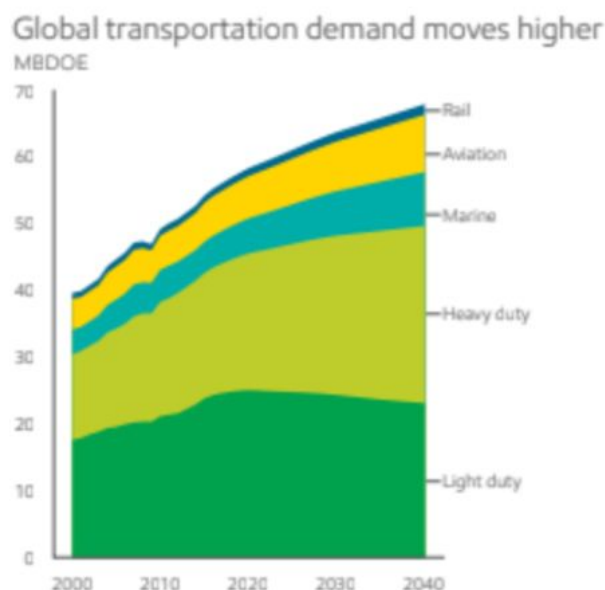
**(2) Electric Cars are not necessarily the answer, but something must be done with more cars on the road.**

ExxonMobil's report offers an optimistic view on the growth of the middle class. Although this is seemingly positive because of better living conditions for more people, it will also bring about more cars on the road. More middle class families catalyzes a greater economic ability to purchase cars and SUVs. What the

report fails to go into is how detrimental this could be. More cars on the road means more emissions of CO<sub>2</sub> gases, speeding up the damage we are already doing to our planet. According to the Union of Concerned Scientists, "Our personal vehicles are a major cause of global warming. Collectively, cars and trucks account for nearly one-fifth of all US emissions, emitting around 24 pounds of carbon dioxide and other global-warming gases for every gallon of gas. About five pounds comes from the extraction, production, and delivery of the fuel, while the great bulk of heat-trapping emissions—more than 19 pounds per gallon—comes right out of a car's tailpipe" [5] (UCSUSA, 2019). Because cars are one of the major contributors to climate change, an increase in cars on the road will cause more damage to the Earth, in a shorter amount of time.

The ExxonMobil report mentions the increase in more energy efficient features added to hybrid cars, as well as the increase of electric cars on the road. In theory, this is a good idea because the electric cars themselves do not have any emissions. However, plugging that electric car in has a cost because the electricity must come from somewhere. An article by the Scientific American points out that in order to power that electric car, coal is usually the primary source of electricity for recharging a car's battery [6] (Scientific American, 2016). Although one may not see it, behind that plugged in cord is a factory emitting tons of CO<sub>2</sub> emissions into the atmosphere.

There are other options of energy to power the electric car, such as using solar panels to create energy to be used to charge the battery.

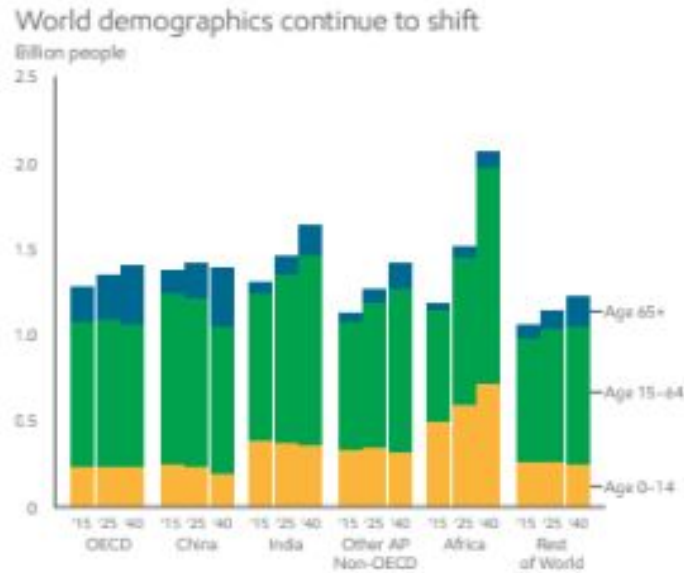


Graph 1.3

However, according to a company called GreenMatch, commercial solar panels that are priced for the average person to buy are currently only efficient enough to process about 22% of the sun's rays [7] (GreenMatch, 2019). This is not enough efficiency, thus not making it an option at current technological rates. These advances must be made at a faster rate, or else humans will run out of non-renewable resources and time.

As can be seen in Graph 1.3, global transportation grows by about twenty five percent by 2040 [1] (ExxonMobil, 2017). Heavy duty vehicles increase the most, with heavy duty vehicle being defined as eighteen wheelers and other large trucks mainly used for the transportation of goods. Light duty vehicles increase the second most, this being defined as personal cars, pick up trucks, and SUVs. The ExxonMobil report relates the eventual plateau and decline of personal vehicles to the increase of more efficient electric and hybrid cars. The issues with this being that this decline happens far too late as the world does not have enough oil to sustain this. The other issue being that these electric cars, although more efficient, still cause emissions indirectly through the burning of coal to create electricity to recharge cars' batteries. Hybrid cars are also a better option, and a more realistic direction at the current transition rate from standard gasoline

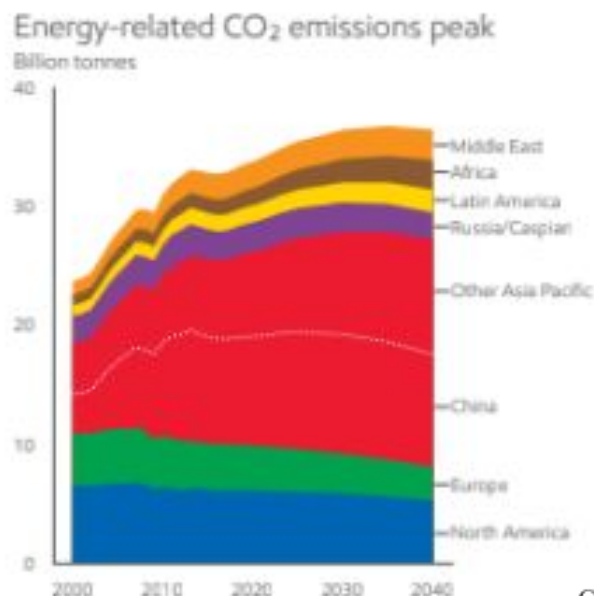
powered cars. However, hybrid cars still rely on gasoline, thus not being a realistic option around the year 2070.



Graph 1.1

### (3) A population of 9.1 billion is not just a number.

Within ExxonMobil's predictions is the concept that by the year 2040, there will be 9.1 billion people on Earth. According to the Australian Academy for Science, most studies report that the Earth only holds the ability to support 8 billion people [8] (Australian Academy for Science, 2019).



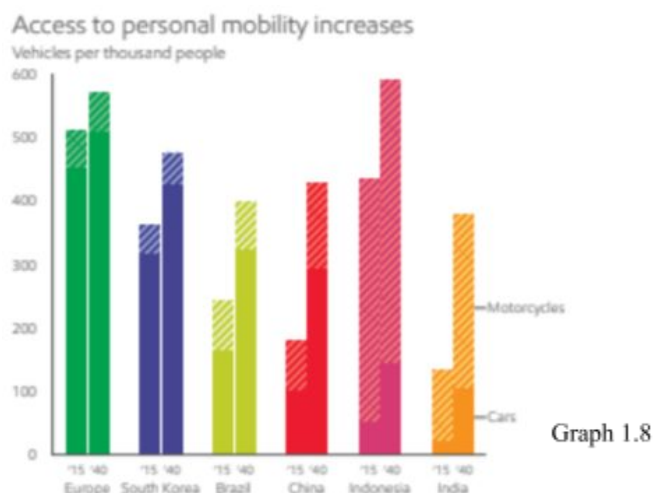
Graph 1.6

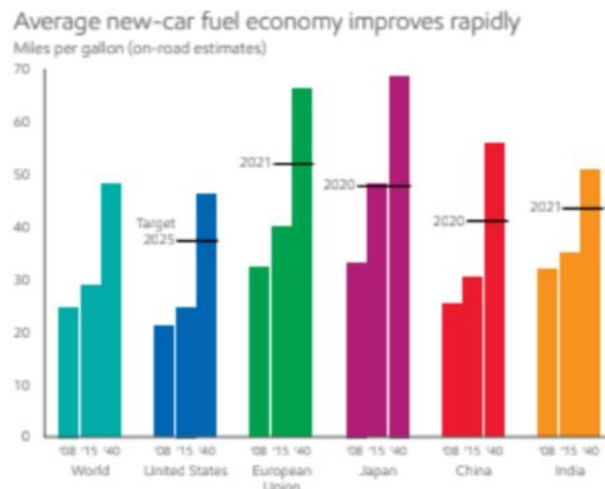
This requires more than twenty five percent of the energy being used in 2040 to be renewable as ExxonMobil states. There is not enough oil, coal, and even natural gas to go around for everyone. With the rate we are going, we will not get where we need to be to support 9.1 billion people by 2040. Although they mention the population, ExxonMobil does not remotely indicate that this population growth will cause extreme overpopulation. Further, a majority of the world population will be at an age to drive, in addition to making up the bulk of the middle class. As a representation, Graph 1.1 shows the shift in demographics across major countries in addition to the rest of the world. This shows the majority of the world being within the age to work (ages 15-64), thus putting even further stress on what percent of the world population will be on the road, increasing the amount of CO<sub>2</sub> emissions. The graph comes from the ExxonMobil energy outlook report.

Related to population is the fact that an increase in population will cause an increase in emissions. ExxonMobil reports both the population increase in addition to the increase of emissions, however they do not mention the relation between the two. For example, Graph 1.6 shows CO<sub>2</sub> emissions peaking in the year 2040, a drastic increase from the year 2000. The largest increase comes from China and the other group categorized as the “Asia Pacific”, which includes India. It is not a coincidence that these two countries are within the largest increase of both emissions as well as middle class. According to the UCS, China currently produces 9040 million metric tons of CO<sub>2</sub> emissions [9] (UCSUSA, 2015). An increase from this will cause major damage to our earth, more than is already being done. The problem of running out of oil and energy aside, this sort of CO<sub>2</sub> emission threatens the health of humans all over the world.

### Graphical Analysis & Summary

**(Graph 1.8)** This graph shows the projected increase of personal vehicles. China and Indonesia have the largest increase which can be associated with the increase in middle class. India has the largest increase in motorcycles. As the earlier projections indicate, these vehicles still rely on gasoline and thus oil. ExxonMobil does not indicate the unrealisticness of this, and the transition must be made to more efficient cars in terms of CO<sub>2</sub> emissions, and energy to power.

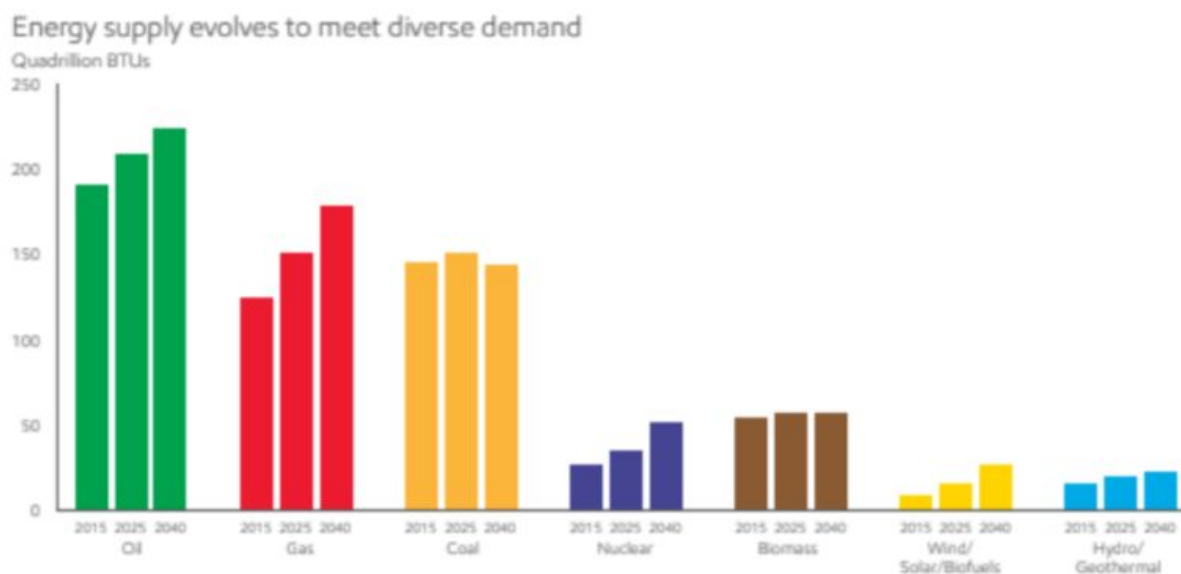




Graph 1.9

**(Graph 1.9)** As indicated, the average miles per gallon will increase which is a positive trend. However, there is not enough oil in the long run to keep gasoline powered cars. Keeping 2070 as a rough deadline of when demands for oil will not be able to be met, the focus must be switched from miles per gallon to other sources of fuel.

**(Graph 2.0)** In terms of supply as seen in Graph 2.0, oil remains the primary source of energy, followed by gas, and then coal according to ExxonMobil. Based on BPs calculation of 53.3 years left of oil, this is not a possible supply. Purely based on calculation and following trend, ExxonMobil is correct in their statements about the supply increase to meet the demand. However, with the quickly depleting source and increase in population, this is not a possibility.

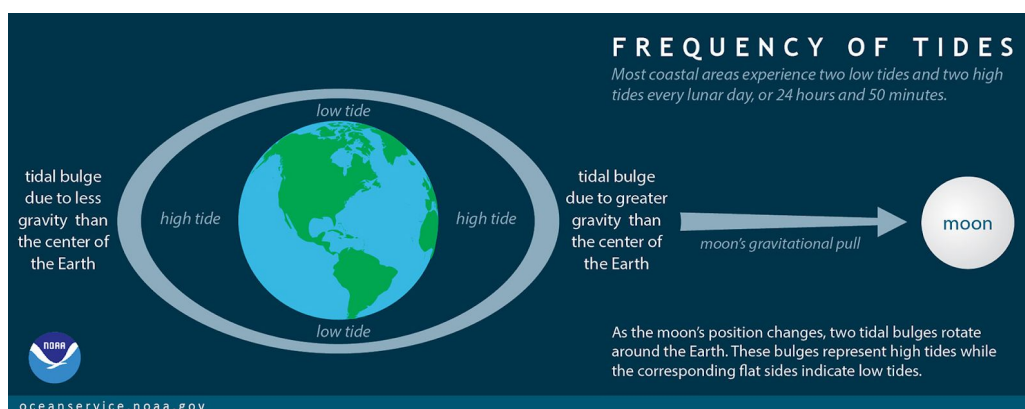


Graph 2.0

## Chapter 2: Tidal and Current Energy

### Introduction To Tides and Ocean Currents

Ocean tides are often a predictable phenomenon in nature that occur in varying degrees all over the world. The tides are a product of the forces beyond the earth, that the sun and the moon create. As the earth spins and the general location of the moon changes, the gravitational forces generated by the moon cause the ocean waves to shift. This is broken down into two different instances, low tide and high tide. During high tide, the moon is either at its closest or furthest point from the earth, causing the ocean waves to land further up on shore. This instance is also known as a tidal bulge, and is due to less or more gravity in effect than the center of the earth [10] (U.S. Department of Commerce, 2013). Low tide occurs at either side of the earth in between the least and most amount of gravity. In terms of a twenty four hour day, there are two high tides and two low tides [10] (U.S. Department of Commerce, 2013). This shift in height that the changing of tides generates is the main focus of tidal energy.

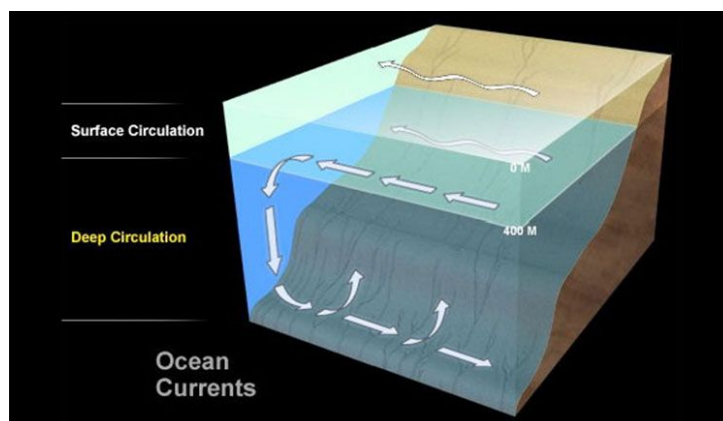


[10] Image Courtesy of U.S. Department of Commerce: Diagram of gravitational pulls on the tide.

Ocean Currents are not always as predictable as the tides, and are often caused by different factors. These factors include: wind, the movement of the tides, and the different circulation that occurs at varying depths of the ocean. The surface currents, for example, are a result of the wind. In general the Northern Hemisphere contains clockwise currents, while in the Southern Hemisphere contains counterclockwise currents. These currents can often be predicted as being at a forty five degree angle to the direction of the wind [11] (Lerner et al, 2014). Currents can also be created due to “density differences in water masses caused by temperature and salinity variations”, thus changing the circulation at which the ocean moves [12] (U.S Department of Commerce, 2013). Currents compared to tides however, are not as easy to predict. The exact direction, although it is usually in the same relative direction, is always changing in



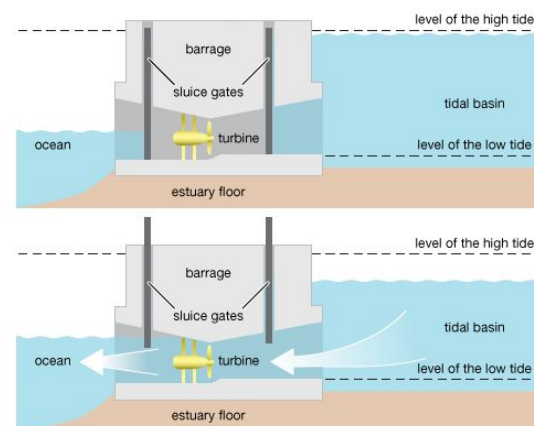
terms of its exact flow location [31] (Tabb, 2017) Although unpredictable, these currents are often extremely powerful and can be put to use in the generation of energy using the ocean.



[12] Image Courtesy of U.S. Department of Commerce: Diagram of circulation of ocean currents.

### Tidal and Ocean Current Energy Harvesting Technology

Due to the rise and fall of the tides, energy could be created from the movement of the ocean water followed by the tides. This movement or kinetic energy of the ocean could be captured, and in turn produce usable energy and power. The main approach to obtaining this ocean energy, is through the use of a large dam called a barrage [13] (Li et al, 2017). From the surface, a barrage appears to be a normal dam, however its technology lies below the surface. Below the waves at the base of a barrage are tidal turbines. These turbines look very similar to wind turbines, however are built much stronger due to water being 800 times more dense than air [14] (U.S. Energy Information Administration, 2018). These barrages are usually placed “across an inlet of an ocean bay or a lagoon that forms a tidal basin” [14] (U.S. Energy Information Administration, 2018). As the tide rises and falls, the water rushes through the openings at the base of the barrage, causing the tidal turbine to spin. Likewise, as the tide falls and rushes back through the barrage, the turbines are again activated and spin due to the force of the ocean. The spinning of the turbines, similar to wind turbines, generates energy that is then powered through wires connected to the barrage.



[31] Image Courtesy of Northwestern: Diagram of how turbines work within a barrage.

Ocean current energy, in theory, would be captured similar to tidal energy. This would be done through the use of turbines, however the use of a barrage would not work effectively.

Instead of barrages, lone turbines would have to be placed on the ocean floor to capture energy created by the currents. These lone turbines would be placed in arrays, and although they would appear similar to wind turbines, they would be much smaller to avoid damage due to the strong ocean currents [33] (U.S. Office of Energy, 2019). The issue with these small turbines at the bottom of the ocean floor is that ocean currents often change, and although the general area of the current can be predicted, the exact flow of the current may not be as predictable. This is why some scientists have come up with the idea to create some sort of vehicle, that would help move the turbine to the most efficient area to harvest energy. A team at the UNC Coastal Studies Institute has an idea that the turbine itself would be “attached to a submersible - an autonomous underwater vehicle, or AUV, with the ability to move to the location of the best resource” [31] (Tabb, 2017). This concept of a movable turbine would allow for the energy from various ocean currents to be harvested, while limiting the possibility for missed predictions of the ocean currents.



[34] Image Courtesy of U.S. Department of Energy: Model of an underwater ocean current energy turbine.

### Costs of Tidal and Ocean Current Energy Plants

The building of a barrage to collect tidal energy is extremely costly. For example, there was an idea to build a tidal barrage from the English coast to the Welsh coast. This project, called the Severn Tidal Barrage, has long been on hold due to the costs. The cost of this barrage was estimated to be thirty three billion dollars [38] (Fortson, 2010). Although this estimation was

based off the most expensive design, other designs still involved costs in the billions. Smaller barrages are still pricey, as a much smaller barrage found in South Korea cost the country five hundred and sixty million U.S. dollars to fund the project. This less elaborate and more realistic barrage was still expensive, however more in reach for an energy producing plant [35] (Kim, 2016). Based on installation costs as well as the cost of constant supervision, it would cost roughly 19.7 cents per KWH [36] (Barnard, 2017). This costs would be the upfront costs for energy users, as it would still incorporate the need to pay off the large upfront cost. This is much more expensive, as coal cost anywhere between from 7 to 14 cents per KWH [20] (Feldman, 2009).

The costs for ocean current technology has not yet been thoroughly evaluated. There are little to none ocean current plants in existence yet, and the technology to overcome the changing of the flow of the current is still in development. However, there are three tidal turbines that have been recently installed off the coast of Scotland. These turbines are in the sound of Pentland Firth, Scotland, where the tides are incredibly predictable [32] (ANDRITZ, 2019). Although this is just a small project in the hopes of a much larger turbine array in the future, the project with just three turbines cost about \$64 million [37] (PBS, 2018). This project is the first of its kind and is paving the way for other current driven energy projects. Although the currents due hold potential to produce energy as seen in the first Scotland trial, tidal energy plants technology is further along in terms of development.

#### Tidal and Ocean Current Plants Already in Place

Tidal energy plants however, large and expensive, have been created and are in use in different parts of the world. There is currently a tidal power plant located at the mouth of La Rance river on the coast of France. This plant has been in place since 1966, and produces about 500 GWh per year [39] (EDF, 2019). This tidal power plant on La Rance was the first tidal power plant to actually be utilized, and produce energy. Although there are prototypes of such tidal power plants, there is only one other tidal power plant in the world.

The other tidal power plant is located in Sihwa, South Korea [39] (EDF, 2019). The Sihwa Lake Tidal Power Station is a 254 megawatt project [35] (Kim, 2016). This power station was constructed in 1994 along the Gyeonggi Bay. The plant itself generated one way power twice a day following the two high tides, and uses the turbine system to generate electricity. There eight gates that open and close allowing the tide to enter. The cost in total (in U.S. dollars) was roughly \$560 million. What is important to note in this case is that the power capacity is different than the annual generation. The plant itself generates 552.7 GWh of electricity, which according to the International Hydropower Association, is “equivalent to 862,000 barrels of oil, or 315,000 tons of CO<sub>2</sub> - the amount produced by 100,000 cars produce annually” (Kim, 2016).

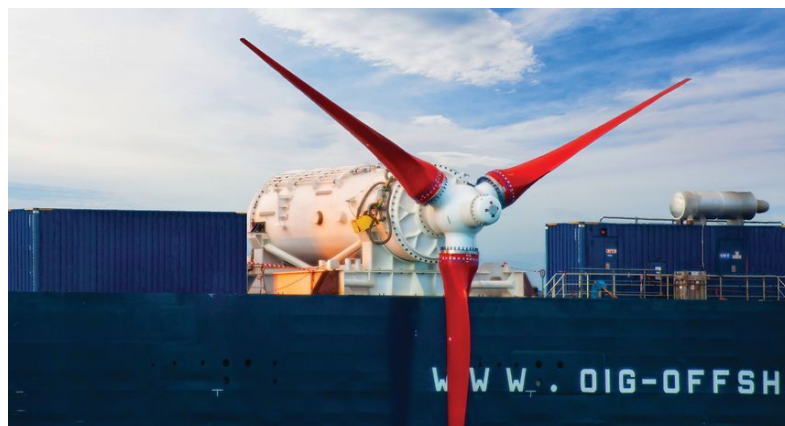


[39] Image Courtesy of EDF: Image of La Rance Tidal Energy Plant, in Brittany, France.



[40] Image Courtesy of K-Water: Picture of Sihwa Tidal Power Plant, in South Korea.

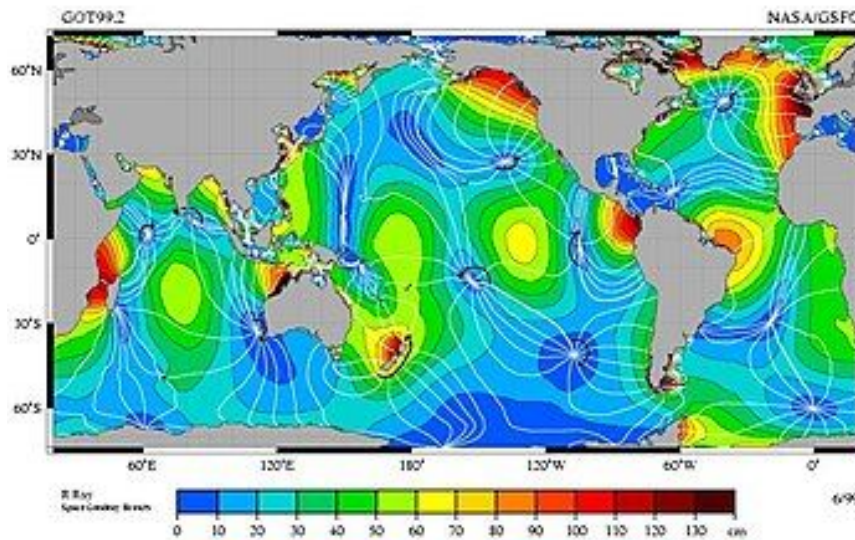
Ocean current energy has not yet been as explored as tidal energy and the use of a barrage. There is a single ocean current energy plant in place, located in Pentland Firth, Scotland. A company called Andritz designed and installed three turbines, one hundred meters below the surface just off the coast [32] (ANDRITZ, 2019). Each turbine has the capability to generate 1.5 megawatts, and since the project began, it has recorded “9,500 continuous hours of operation” [32] (ANDRITZ, 2019). This small field is the first of its kind, but may be key in understanding the constraints and requirements of tapping into much stronger currents such as the Gulf Stream.



[32] Courtesy of Andritz: Picture of underwater ocean current turbine, one of the first of its kind installed in Scotland.

### Possible Places For Tidal Plants

Based on tidal maps a visual representation of the highest tides can be predicted. From these maps, the determination can be made that the three best places for these tidal plants are: the Bay of Fundy in Canada, off the coast of Alaska, and off the coasts of some European countries such as France and Germany. These three sites have some of the largest tides in the world, and have the potential to produce large amounts of energy.



[41] Image Courtesy of NASA: Topographic map of global tidal patterns.

The Bay of Fundy is located off the coast of Nova Scotia Canada, and is 170 miles long. This stretch of coast is home to the largest shifts in tides in the world. The change from low to high tide can exceed fifteen meters, thus peaking interest to employ a tidal energy plant [30] (Garrett, 2004). According to the Offshore Energy Research Association, because of the billions of tons of water that rush through the bay in addition to the dramatic tide shifts, there is “Enough to power over 170 million homes or 13 times more homes than in all of Canada. Realizing this potential will produce high quality jobs, new technologies and global market opportunities for this emerging industry sector in Canada” [29] (OERA, 2015). This new source of green energy could be used as a more efficient source of power for the east coast. With the use of barrages and tidal power technology, the oceans tides along the bay could be harvested and used for large amounts of energy. Overall the Bay of Fundy has an estimated 2,500 megawatts of potential due to the large amounts of sea water that pass through with each tide. Considering 300 megawatts of tidal energy could possibly power one fourth of all homes in Nova Scotia, the installment of

barrages could change the tides of alternative renewable energy production [21] (Nova Scotia Department of Energy and Mines, 2019).



[28] Image Courtesy of Amusing Planet: Image of the change in tides off the Bay of Fundy, in Nova Scotia, Canada.

Another region with high tides is the coast of Alaska. This region is known as the Alaska Bore Tides, and are recorded to reach about nine meters tall. The main areas these tides can be found are along narrow channels, primarily the Alaska's Turnagain Arm and Knik Arm. These two channels surround the city of Anchorage [19] (Alaska Public Lands Information Center, 2019). Although little research has been done to explore these tides in terms of energy, the United States has acknowledged their potential. According to the University of Washington, there have been reportings of a possible "tidal energy pilot project", off the coast of Alaska where these tides are found [26] (University of Washington, 2010).



[19] Image Courtesy of Alaska.org: Image of the Alaska Bore Tide across the inlet.

The last region that contains some of the largest tides in the world is off the coast of countries such as Germany and France. As mentioned earlier, there is already a working tide power plant in place off the Rance River in France, however there is even more potential for tidal energy in the region. The highest tides on this part of the globe however, are found along the shore between England and Wales. These tides are found on the Severn Estuary, or in other terms at the mouth of the River Severn. Here, the tides can reach fourteen meters, which places it among the highest tides in the world [20] (Xia et al, 2010). Proposals have already been made to construct a barrage to harness the energy of these tides, however none have been made yet. According to some estimates, a barrage at place on the Severn could generate up to 25 GWh of

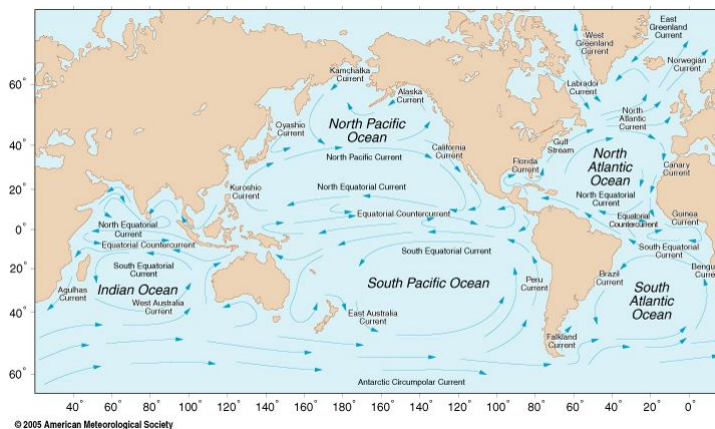
electricity “over a typical mean spring tidal cycle” [20] (Xia et al, 2010). Reasons why a barrage has not yet been built are mainly because of the cost to build one, in addition to concerns about the effects on the species of fish that live in the Severn [16] (Warwick et al, 2010).



[19] Image Courtesy of Natural Environment Research Council: Image of the changing tides at the head of the River Severn in England.

### Possible Ocean Current Harvesting Locations

Although the technology is not yet as advanced as tidal energy, the potential for current energy is also possible. As mentioned earlier, currents are more difficult to predict in terms of the exact flow location. According to NASA, the Gulf Stream contains some of the strongest surface currents in the world. These currents are often recorded at being 3 or 4 km per hour [24] (NASA, 2019). In addition, these currents are also narrow. The average current usually being 50 to 75 km across [24] (NASA, 2019). The important factor however, is that these flows are constant, and huge amounts of water are being moved across the ocean floor [23] (Bureau of Ocean Energy and Management, 2019). In the gulf stream, there are approximately 8 billion gallons of water per minute (NPR, 2007). Multiple proposals have been written in terms of the approach to harvesting the energy of the gulf stream. Some estimates state that the energy of the Gulf could produce up to 300 GW of power. This alone is roughly equal to the power produced in 150 nuclear power plants [18] (Coastal Studies Institute, 2016).



[24] Map Courtesy of NASA: Map showing all the major currents across the globe.

Other currents do have the potential for current energy, although they are not nearly as researched as the Gulf Stream. Other currents such as the Canary Currents and the California Currents also have the potential to be used for current energy. In this part of the world, these currents are estimated to be moving at 1 km per hour [41] (NASA, 2019). The California Currents, for example, has been predicted to have the capability to produce six hundred kilowatt hours per day [110](HydroWorld, 2019). Although this may not seem like much, this is still a billion gallons of water traveling along the stream. Smaller currents such as these (in comparison to the gulf stream), could also be a viable source of energy [22] (Mason et al, 2011). This in total, could add to the worldwide potential of 3,000 megawatts of possible ocean current energy [105] (Selin, 2019).



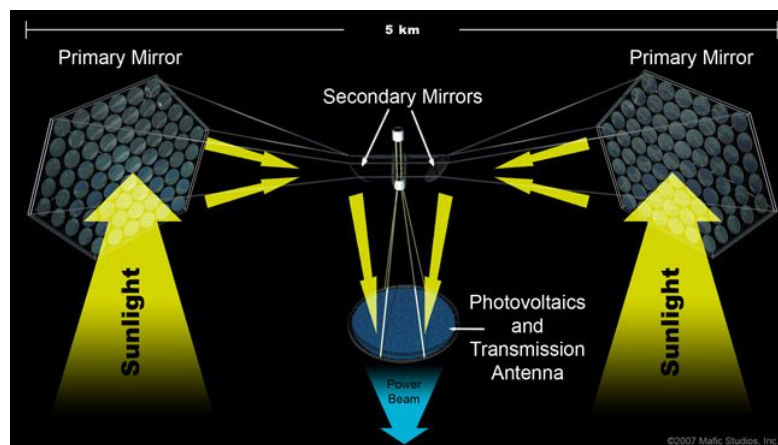
## Chapter 3: Mirrors in the Sky, Space Energy

### Hypotheses Behind ‘Mirrors in The Sky’

In order for renewable energy to be successful, the source must provide continuous power. Hypothetically, total reliance on solar panels would mean the sun must always shine and there can never be anything in the way that could disturb the source. Even on a clear day about thirty percent of solar radiation does not reach the ground due reflection off the atmosphere [42] (U.S. Department of Energy, 2019). Modern research, however, has come up with the idea to install solar panels directly in space, allowing for a continuous generation of power without any disruption from the clouds, seasons, and the night.

In theory, large arrays of solar panels approximately three kilometers long would be launched into space like a satellite, and put into orbit [43] (Wood, 2014). These solar panels would collect the solar energy directly without any interruptions, and using microwave transmittance, would beam the energy back down to a specific point on earth (U.S. Department of Energy). Along with these solar panels would be connected technology such as reflecting satellites that would direct the solar energy towards the solar panels and solar radiation collection units [44].

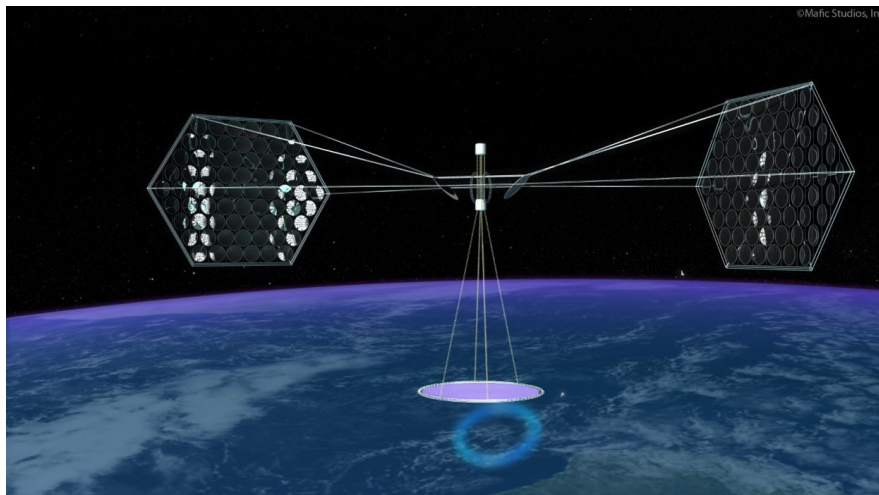
In addition to these supporting technologies, an energy converter would also be needed on the device, as this would allow for the solar energy to be converted to the microwave beams (Reedy, 2017). Although there are many constraints and some of the technology seems years away, this energy source could be a huge opportunity. Speaking purely in terms of potential, the sun produces enough energy so that 430 quintillion joules hits the surface of the earth every hour [46] (Harrington, 2015). If this concept of solar space energy could be implemented and capture even a fracture of that, the course of energy consumption for humanity could be changed.



[45] Image Courtesy of National Space Society: Diagram of space solar power arrays

## Introduction to The Technology

Although there are currently not any solar panels in space, some countries have produced designs and hypotheses on possible technologies. For the most part, all designs have the same basic concepts. For this device, energy collection would be very similar to solar panels on earth. With the use of photovoltaic solar cells, energy could be collected directly from the sun. These photovoltaic solar cells would be set up in large arrays, ensuring enough coverage during orbit [47] (Nankivell, 2018). In addition to the solar cells, the device would also need mirrors directed the sunlight onto the photovoltaic cells. Although there is direct sunlight, there is still a great deal of movement and obstacles in space, especially in orbit. These mirrors would aid in the collection of sunlight, and redirect the energy for collection onto the solar panels (U.S. Department of Energy). As seen in China's prototype for the space energy collection unit, these mirrors would be large in order to optimize the amount of solar energy captured.



[48] Image Courtesy of Mafic Studios, Inc: China Prototype Solar Collectors

Another key piece to this technology is the energy converter that would need to be incorporated. When the solar radiation from the sun is collected, it would need to be converted to microwave energy in order to be beamed back to its respective place on earth via a microwave emittance laser [49] (Snowden, 2019). The distance needed for this transmittance to occur would be roughly 22,000 miles [50] (Chow et al, 2019).

## Costs and Constraints

Launching solar energy collection units comes at a high cost however one may design it. In addition, even when the energy is produced, the price per watt is a great deal more than other sources of energy. This lowers the chances of producing such technology without large private investments. Logistically, the price per watt of solar space energy would be somewhere between two dollars and two dollars and fifty cents. The current cost per kilowatt hour in the United States (using non-renewable resources), falls around twelve cents. In terms of electricity pricing for the user, this cost must come down in order for the cost of solar panels to become realistic. Majority of this cost is due to the high upfront cost of building the technology in addition to the installation. To calculate an estimated cost to launch panels into orbit, a simple calculation can be done based on past satellite launches. Based on past experience, it is roughly \$9,000 per kilogram to launch a satellite into space. With plans to put miles of solar arrays into orbit, it can be estimated that the mass would be roughly 4,000 metric tons. This brings the launch cost to about \$36,000,000,000 [47] (Nankivell, 2018). This does not account for other costs such as maintenance that would constantly have to be done on energy collecting device.

Other constraints besides costs of installation play a role in the prevention of space solar power. The first is the lack of technology and funding most countries are willing to use to advance. Very few countries like China and Japan even have decent funding into space energy programs allowing for the needed technology to be explored [52] (Rosenbaum et al, 2019). The Japanese allotted the most for the space power exploration, with a budget of twenty one billion dollars invested into exploring the technology [54] (Richard, 2009).



[53] Image Courtesy of Rocco: Space Debris Chart

Another constraint is the fact that damage would occur to the panels in orbit on a regular basis. On earth, small scratches caused by twigs or small rocks can greatly harm solar panels and affect the efficiency of the energy output. In space, everything from asteroids to space junk take up large amounts of room and fly at high speeds. This debris could cause great damage to technology, especially when that technology is large mirrors and solar arrays. The average space debris speed in low orbit (less than 2,000 kilometers), is around twenty thousand kilometers per hour. Even when the debris is small, this could cause great damage to solar technology [55] (Aerospace, 2018). Although this constraint seems impossible to overcome, it is important to acknowledge that the international space station, which currently orbits the earth, relies entirely on solar power. With four arrays, “the station generates up to one hundred and twenty kilowatts of energy” (Ashish, 2019). Even when damage is to occur, it can usually be maintained and monitored to ensure the panels continue to run. Large solar arrays are inevitably going to be hit, however with the proper maintenance and monitoring, this damage can be controlled. Even so, in the future artificial intelligence will play a significant role in the maintenance of these large energy devices.

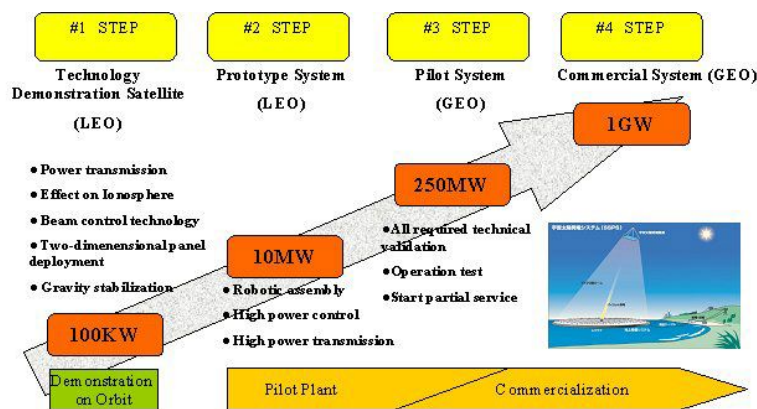
### Countries Involved

Although the United States and some European countries have talked about tapping into the power of space solar energy, there has been no major advancement. The United States has made some progress, however most of the project was killed after the cost to install space power was deemed “unfeasible” by NASA scientists. Recently, the United States Military has expressed an interest in the idea, however very small prototypes solely on earth have been a result of this interest,



[59] Image Courtesy of Science ABC: Conceptual Drawing of Space Station

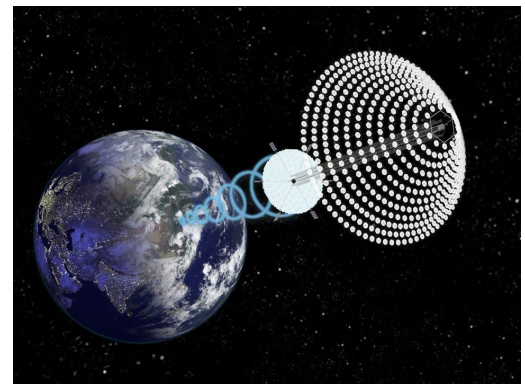
Japan and China however are investing billions of dollars to move further with space energy. Japan alone has invested twenty one billion dollars to move forward with the space energy project [54] (Richard, 2009). Japan has outlined a plan to do a series of prototyping and eventually, commercially produce enough energy. This plan starts with a one hundred kilowatt demonstration on earth. This would show the ability to beam the energy from one source to another. Thus far, a small scale beam of one hundred and twenty watts has been completed [56] (Japan Space Systems, 2013). In terms of more specific technology, Japan plans to send a craft with 1.2 miles of solar panels on each side into orbit. Along with the panels, the use of a microwave beam would be put into place to send the energy back down to earth. The most advanced part of this plan, is to incorporate artificial intelligence ‘astronauts’ into space with the panels to maintain them [57] (Ryall, 2015).



[56] Image Courtesy of Japan Space Systems: Incremental 4 step plan to commercial power

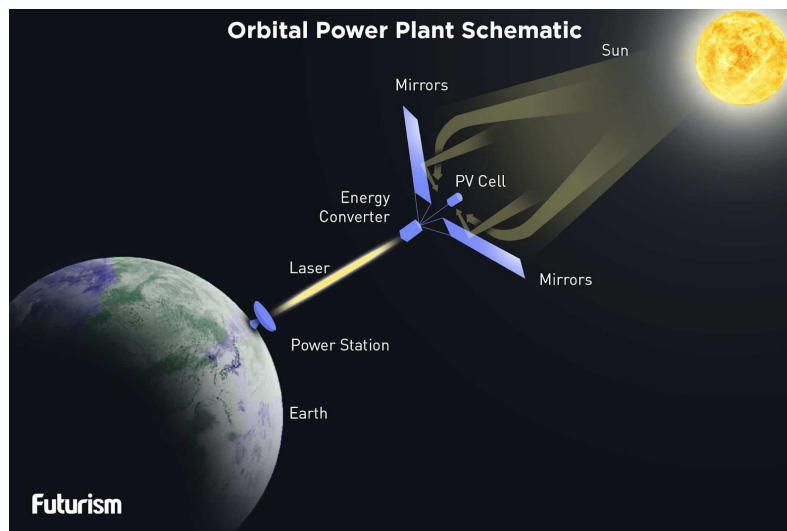
China has gone one step further than Japan, and revisited the concepts NASA came up with decades ago. In addition, China has made plans to launch a prototype into space. China claims that this prototype will be able to generate about one megawatt of energy by the year 2030 (Rosenbaum et al, 2019). Similar to Japan, this prototype would include a large array of solar panels to capture the solar energy produced by the sun. This model would also use a microwave beam to return the energy to earth. By 2050, China plans to have a commercially powerful solar array in orbit that could supply a gigawatt of energy. As discussed earlier, this would come at a high cost, however Beijing has made the pledge to give \$326 billion to alternative energy sources such as space solar power initiative [58] (Snowden, 2019).

[60] Image Courtesy of Forbes: Conceptual Drawing of Proposed Solar Array



## Space Solar Possibilities

Although there are many obstacles in the way of commercial space solar energy, there is no doubt that if solar energy were obtained, could change the course of humanity in terms of energy usage. Paul Jaffe has made predictions based on calculations for how much solar energy could truly hold. These predictions were based on the fact that the sun would be shining at all house, every day, for almost the entire year (1% margin of error was left to account for exceptions). Jaffe predicts that each array, if made to the size as current models estimate, could produce a maximum of five gigawatts of energy (Greenmatch, 2019). For comparison, in order to produce one gigawatt of energy on earth with solar panels, one would need 3.125 million panels [61] (U.S. Department of Energy, 2018).



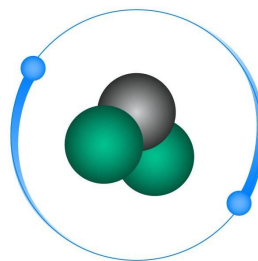
[87] Image Courtesy of Futurism: Collecting solar power directly from space

Overall, the potential of solar energy directly from the sun in space is 1,347 watts per square meter (Greenmacth, 2019). With the use of solar panels in space, there would be zero greenhouse gas emissions, no interruptions in the source of energy, and enough energy to power major parts of the world. With direct solar radiation in space thirty percent more efficient than on earth. If based on Paul Jaffes calculations, only four arrays could power New York City, miles of arrays could change the world.

## Chapter 4: Fusion Reactor

### The Future of Energy

When thinking of alternative renewable energy sources, the first thought may be solar or wind. Although these may be good options, there are still other possibilities that show great potential, and need to be further explored. Fusion reactors have long been thought of as a mega source of power; however, humanity has not yet reached the technology to use them. For almost fifty years now, scientists and engineers have been exploring the idea ‘how’ a fusion reactor could function [62] (Cohen, 2019). If a functional design is created, a clean, more powerful source of energy could take over the market. Instead of something like uranium that nuclear energy currently uses, the future of fusion reactors would rely on helium-3. This isotope is extremely rare on earth, and can only be obtained in extreme circumstances. It is estimated that there are only about fifteen kilograms of helium-3 created on earth each year [63] (Barnatt, 2016). There are other means of retrieving the material, which includes the mining of the surface of the moon where helium-3 is abundant.



**Helium-3**

2 protons, 1 neutron

[64] Image Courtesy of Machine Design: model of the helium-3 atom.

What makes this technology so special is the idea that there would be no greenhouse gases emitted, and the fact that less Helium-3 would go a much longer way than other sources, such as uranium. Helium-3 itself is much safer than other commonly used options. For example, uranium is radioactive, making it dangerous for those using it in nuclear power plants. In addition, the products that uranium creates such as thorium-230 and radium-226 remain a danger long after its use. This puts future generations at risk as well as leaving them with the problem of radioactive waste [65] (Institute for Energy and Environmental Research, 2012). Helium-3 on the other hand, is not radioactive. The use of helium-3 would lead to a safer power plant for people, while producing less waste and emitting less greenhouse gases [68] (ESA, 2019).



[66] Image Courtesy of Extreme Tech: model of a mining facility on the moon by the Chinese.

The reason scientists are diving so deep into fusion reactors is because of the enormous potential the technology has. If achieved, a fusion reactor could produce 500 megawatts from only half a gram of hydrogen, which would be converted into helium [68] (Anthony, 2012). There are different approaches to fusion reactors such as: magnetic fusion reactors, using hydrogen conversion, and the favored helium-3 reactor. The helium-3 reactor however, has another step added to it as this element can be only found in large enough amounts on the moon. In this section, the concept of a helium-3 reactor is explored, and the feasibility with modern technology.



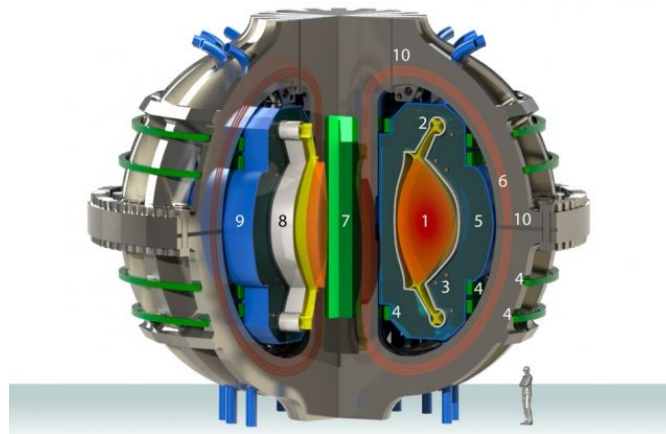
[69] Image Courtesy of Popular Mechanics:  
Fusion reactor located at MIT.



## Plans For Technology

Helium-3 fusion technology all stems from the idea of the fusion between deuterium and tritium (otherwise known as helium-3). The fusion of the two can result in high kinetic energy, reaching levels of 17.6 million electron volts. This kinetic energy can then be put forth to create steam which would drive the turbine generators, creating high amounts of energy [70] (Schmitt et al, 2006). This sort of reaction take high amounts of energy and high temperatures. Special materials would be required to build such a machine, in addition to these materials being changed every couple years to keep up with the damage.

Fusion reactors have been in development all over the world since the 1940s. The technology however, has made little progress in terms of net energy. There are no current helium-3 fusion reactors that can output more energy than they need to take in. Recently, Massachusetts Institute of Technology made a breakthrough in magnetic fusion plant technology. Their design included a more efficient way to let out the excess heat caused by the plasma in the device. Although the design of the fusion reactor is better development than those in other parts of the world, the device only uses one percent helium-3 to help fuel it [71] (Chadler, 2018).

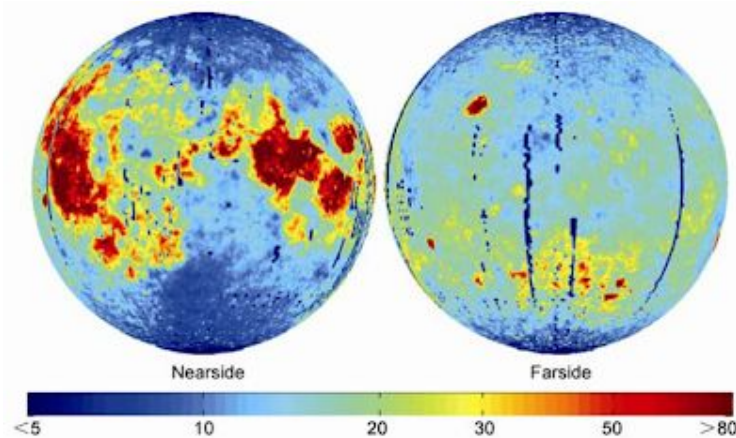


[74] Image Courtesy of MIT: Magnetic field fusion reactor design.

Technology for a helium-3 fusion reactor still has a long way to go before it can be commercialized, the technology later discussed in constraints with moon mining has an even further way to go. What can be confirmed however, is that whoever is to unlock the technology behind the fusion reactor, will hold large enough amounts of energy to change the course of the world.

## The Power of Helium-3 and The Moon

The power of helium-3 has not been explored experimentally a great deal due to its scarcity on earth. Helium-3 is formed due to the solar winds produced by the sun. Due to the magnetic field of the earth, these solar winds do not affect the earth's surface. For this reason, there has only been some experimentation performed with samples of helium-3. The moon however, is not protected by these solar winds, and therefore has an abundant amount on the surface [72] (ESA, 2019). Although there is no proven amount, researched estimates predict there are roughly 1.1 million metric tons of helium-3 on the surface of the moon. This is roughly fifty part per billion, which would need a large refinery process before the helium-3 could be used [73] (Veronese, 2012). Although this seems like a daunting task to mine the moon, majority of this helium is predicted to be within a couple meters of the surface [63] (Barnatt, 2016). In terms of collection and mining, there is a huge opportunity to realistically collect the helium-3 with advancing technology such as artificial intelligence.



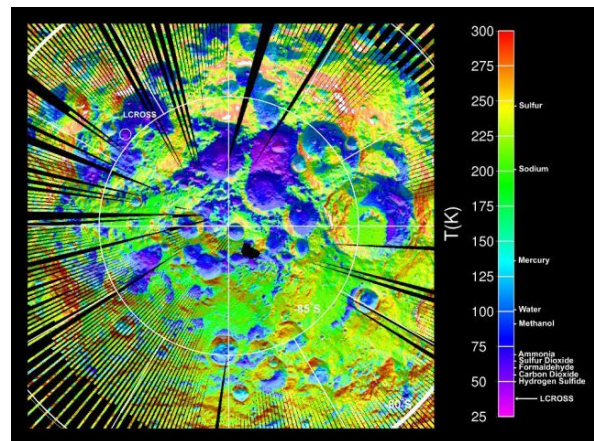
[78] Image Courtesy of Fudan University: Map of possible Helium-3 location (based on abundance), on the moon..

In terms of energy, helium-3 could provide the most power eco-friendly source to date. For comparison, some scientists have predicted that the energy produced by 5,000 tons of coal is equivalent to only forty grams of helium-3 [76] (Seth et al, 2019). Not only would this be a much larger trade off in terms of energy, because of the nonreactivity and no emission abilities of helium-3, this source would be much better for the planet. As mentioned earlier, only half a gram of hydrogen would be needed to produce about 500 megawatts of energy. To put this into perspective, the average American household uses about 10,000 kilowatts of energy each year. This is equal to about 10 megawatts, meaning that fifty American households could be powered for an entire year on just half a gram of helium-3 [76] (U.S. Energy Information Administration, 2019).

## Constraints and The Future

A helium-3 fusion reactor includes many constraints and challenges engineers and researchers must face. The first being the development of a fusion reactor. The helium-3 fusion reactor would give off extremely high temperatures, meaning the enclosure and technology in place would have to withstand such an environment.

Obviously mining the moon would involve more technological advancements, as present technology will not suffice. For example, collection of helium-3 on the moon's surface could only be done with artificial intelligence. The temperature on the moon ranges from about 127 degrees celsius to minus 173 degrees celsius. This varies based on when and where the sun shines, in addition to the height of the surface (bottoms of craters are much colder than other places). [77] (Sharp, 2017). These extreme temperatures would not allow for constant human exploration to manually do the mining. Such circumstances would call for robots.



[83] Image Courtesy of Space: thermal map of lunar temperatures.

At this point in time humans do not have the technology to send artificial intelligence into space to mine helium-3. Other challenges must be overcome before robots are the main priority. However, this does not stop some countries from beginning the race to mine the moon. Australia has been looking to mine the moon for about six years, and this plan includes robots. The University of New South Wales may not be looking for helium-3, however they are designing a generation of artificial intelligence that could tackle the exploration and mining of the moon for humans. This group of researchers has been writing a proposal to the Australian Research Council with the hopes of mining water on the moon, but like helium-3, the plan requires robots. Professor Andrew Dempster is leading the team, trying to find the balance between what should be the robots responsibility, and what should be controlled by humans [79] (Casey, 2019). Dempster is quoted saying, “There’s a real trade-off between how much bandwidth you have available to perform your command functions or your control functions, and the autonomy that

you allow the machines to have” [79] (Casey, 2019). This balance of how many humans will be needed, compared to the abilities the robots will have programmed, is a similar constraint to the lunar helium-3 project, however for success it must be achieved.

In theory, after the helium-3 is mined by robots it must be brought back to earth to be used in the fusion reactor. The first step is helium-3 is packed into a shuttle and sent off back to earth. This however, is extremely expensive and would have to be done multiple times to support multiple countries. The space shuttle itself would cost roughly \$1.7 billion, in addition to the \$450 million it would cost per mission [80] (NASA, 2017). This is calculated based on past missions such as the Space Shuttle Endeavour. At maximum capacity the shuttle could hold 25 tons of helium-3 and, “would power the United States for one year at our current rate of energy consumption” [81] (Bennett, 1999). Considering the United States uses seventeen percent of the world energy, multiple trips would have to be made, costing in the world in total, billions of dollars [82] (American Geosciences Institute, 2019).



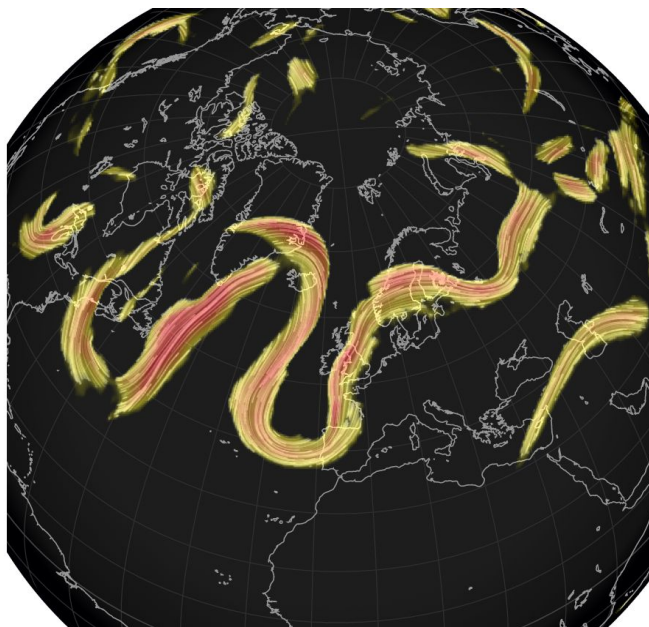
[88] Image Courtesy of PBS: image of the Endeavor shuttle before launch.

## Chapter 5: Jetstream Energy

### Introduction to Jetstream Energy

Jetstream energy is a newer concept focused around the idea of harvesting the winds of the jetstream. These winds are found approximately seven miles above the surface of the earth, and move at high speeds. The average speed of a jetstream, is wind moving at one hundred and ten miles per hour. It is not common however, for these winds to exceed two hundred and fifty miles per hour [90] (Baer, 2016). To visualize these winds, they are most often described as “rivers of wind”, due to their strong forces. In terms of geographic, these streams usually blow from west to east. Considering their force, they are somewhat narrow, meaning there would be specific zones that would need to be predicted in order to capture the energy [91] (Zimmermann, 2013). The concept of a jet stream and how humans would capture its energy, is much like the concept of wind turbines or tidal energy. A large ‘turbine’ would be launched into the air, and energy would be generated by the strong winds.

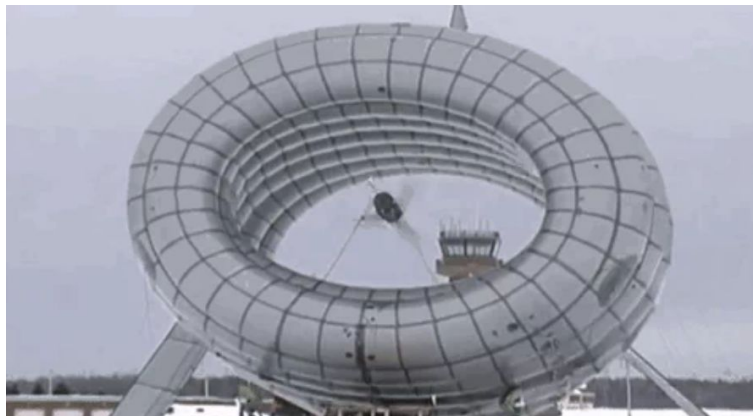
The below image is a map of just some of the jet streams (red and yellow lines), that travel across the earth. As can be seen, these streams travel all over the globe meaning that the energy produced would affect a multitude of places. This is beneficial because multiple setups could be done all over the world, so no one place would be relied on by many other places. This technology and concept is becoming increasingly popular, and is attracting the attention of some high standing investors such as Bill Gates [92] (Baer, 2016). With the energy crisis approaching, energy collection ideas such as jetstream energy must be explored.



[93] Image Courtesy of NetWeather: Map of the jetstream currents across the northern half of the globe.

## Jetstream Energy Technology

The main ideas for jetstream technology are somewhat of a turbine and blimp hybrid. These large machines must be durable to face the strong winds that blow up to seven miles above the earth. Since this idea (in terms of advancing technology), is relatively new, the current design can only rise to about one thousand to two thousand feet. The model image below is an actual energy harvesting device built by Altaeros Energies. This ‘blimp’ is called the Buoyant Airborne Turbine. This particular model was developed in 2014 [92] (Baer, 2016).



[94] Image Courtesy of Business Insider: Actual jetstream energy harvesting prototype. First developed in 2014 in Alaska.

More specifically, these Airborne Turbines are lifted into the air via helium. This technology floats into the atmosphere in the direction of the jetstream currents. Through wires and other cables, the sky turbine is held in place while the wind rushes through. The energy is then transferred back to earth. There are other ideas of how to collect energy though via the strong winds of the jetstream. Another type of technology are known as ‘rotary turbines’ which would be held in the air like kites (image pictures below). Although there is some criticism with this design, it is being explored. These ‘turbine kites’ are similar to the blimp in that they are released into the air, and strapped down via wires and cables. They remain in the jetstream and collect energy [95] (Bishop, 2011).

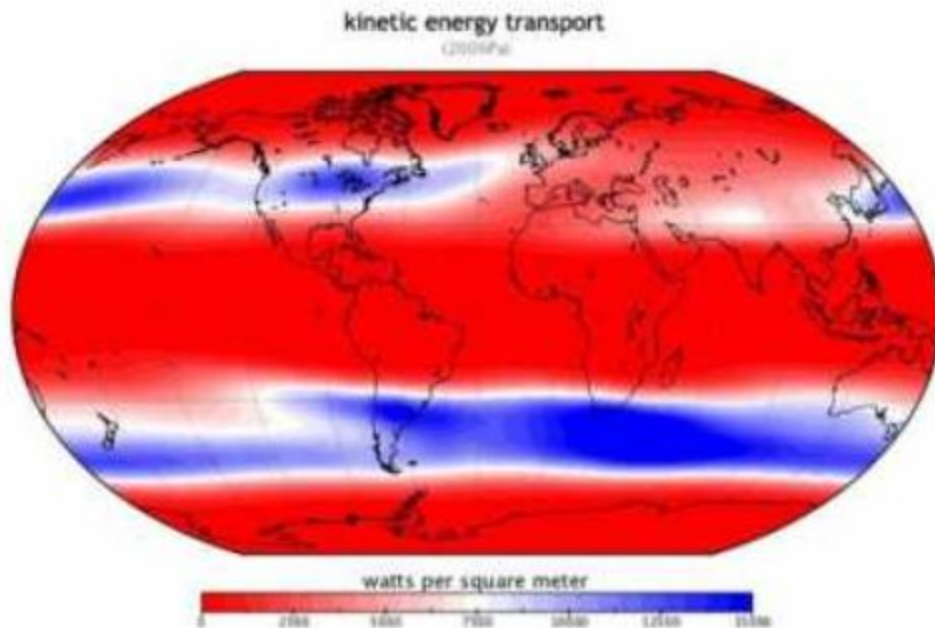


[96] Image Courtesy of Earth Times: Prototypes of ‘turbine kites’ attempting to collect energy in the jet stream. Note, these kites do not reach the full seven mile heights.

## Potential in The Future

There are many conflicting views as to the impact jetstream energy could make on the renewable energy industry. One study obtained results concluding that the maximum potential output would be roughly seven point five terawatts [95] (Bishop, 2011). This is a huge amount of energy when in combination with the other alternative resources discussed in this paper. The criticism for this sort of potential is described in two ways. The first is said by Lee Miller that jetstream energy can not power the earth so there is no point in tapping into it. When speaking in terms of jetstream energy powering the world alone, Miller is correct that no this energy source (in terms of alternatives), cannot be the sole source of power. The counter to this statement is that when combination jetstream energy with tidal or space energy, for example, a large chunk of the world could be powered. With the addition of jetstream energy to other alternative energy sources, there could be enough green energy to sustain the world.

The other criticism is that such kites and blimps suspended in the jet stream could ultimately destroy the jet streams all over the world. Such traffic in the air could make the streams less powerful, thus diminishing the potential for energy output. There is no conclusive data to support this criticism. The technology has not yet been advanced enough to test any of these claims. In conclusion, such an energy source could possess great potential in aiding the world's transition to green energy.

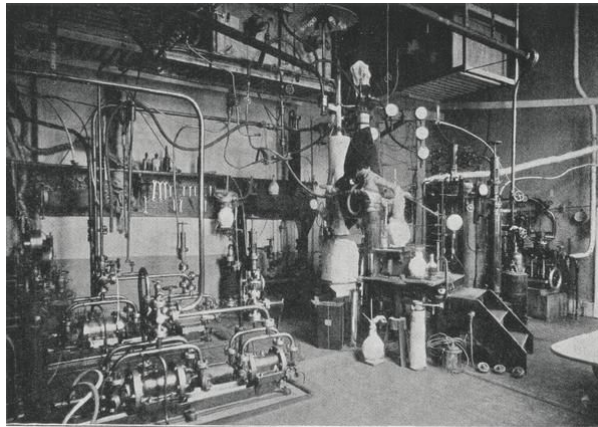


[97] Image Courtesy of Earth Times: Map of the kinetic energy due to the jetstreams all over the world (in terms of watts).

## Chapter 6: Superconductors

### A New Solution to the Energy Crisis

When approaching the need to change humanities energy consumption habits, eyes immediately turn to the source. However, a new addition to the solution could not necessarily be the source, rather the conductive material that takes energy where it needs to go. Superconductivity is the concept that when materials go below their critical temperature, there is no resistance in terms of electrical current [84] (CERN, 2019). When dropped to this extremely low temperature, some materials will allow current to pass freely through, with little to no loss. This concept was first discovered in 1911 by Heike Kamerlingh Onnes while he and his team were experimenting with mercury. They found that when the temperature was dropped to four point two degrees kelvin (negative two hundred and sixty nine Celsius), there was no resistance in the electrical current passing through the mercury [84] (CERN, 2019). Considering sixty nine trillion BTUs of energy were lost in 2013 during transmission in the United States, discovering a superconductive material at room temperature could change the outlook of energy usage [85] (Wirfs-Brock, 2015).



[89] Image Courtesy of Linear Collider Collaboration:  
image of Heike Kamerlingh Onnes Lab in 1911.

Superconductivity goes deeper than just mercury. Other materials have been tested and recorded zero energy resistance at very low temperatures. The main concept (and second part to superconductivity), relies on something called the Meissner effect. This phenomenon is that at extremely low temperatures, the material has a loss in its magnetic field. This expulsion contributes to the ease of conductivity, thus creating the superconductive material [86] (Starr, 2019). At this point in time there has been no superconductive material developed at room temperature. All materials thus far operate at low temperatures, however the field is expanding to a more realistic stand point. Recently, German scientists have just discovered a superconductor



that can operate at two hundred and fifty kelvin, or negative twenty three degrees Celsius. Some reports confirm that this experiment reached as close as negative thirteen degrees Celsius. With this sort of leap in technology, energy and how the world uses it, could be changed.

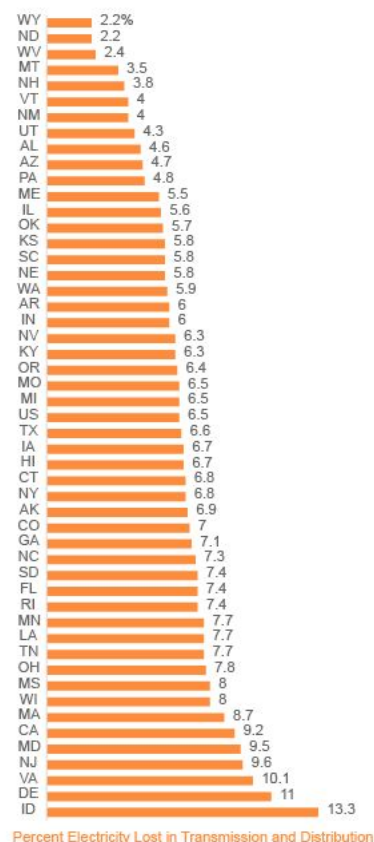
### The Potential of Superconductivity

Besides the fact that scientists do not yet have a superconductive material that operates at room temperature, the amount of energy it takes to cool the current superconductive materials is extremely high (Johnston, 2013). If superconductivity could be achieved at room temperature however, it could be implemented in different ways that would benefit both people and the earth. Transmitting power is one of the largest and most beneficial uses superconductors have to offer. In the United States the average amount of power lost during transmission is around six point five percent. This differs by states with some states averaging a loss of eleven percent. Although this seems like a small percentage, this adds up to numbers in the trillions over time [99](Snavelly, 2000). The use of superconductors in this instance could save energy, in addition to saving money. One study done found that just two hundred and fifty pounds of superconducting wire could replace up to eighteen thousand pounds of typical copper wire. Replacing such material would allow humans to transport energy more efficiently in addition to longer distances (with little to no loss) [99](Snavelly, 2000).

Transmission is not the only issue superconductors could address. Superconductors could also play a role in the commercial setup of energy sources. If energy generators were to use superconductive wiring, money, energy, and space could all be saved thus contributing positively to the world energy crisis. The company General Electric has greatly explored super conductivity, and continues to explore its potential.

One study GE completed found that use of super conductive generators would be about ninety nine percent more efficient than normal generators. In addition, these generators would be only half the size of standard generators that are currently used [100](NSTA, 2019). GE also explored that within the next ten years, the market for superconductors would reach roughly between twenty and thirty billion dollars. For these reasons, U.S. Department of Energy gave General Electric roughly twelve million dollars to move forward with their research for a superconductor material that functions at room temperature [100](NSTA, 2019). If this technology is to succeed, superconductors could alter the timeline of the energy crisis.

Average Electricity Losses By State, 1990 to 2013



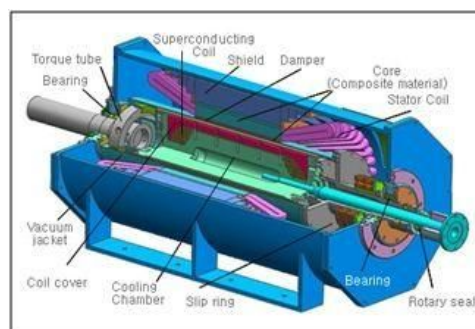
Percent Electricity Lost in Transmission and Distribution

Data Source: Energy Information Administration, compiled by Inside Energy

[98] Image Courtesy of Energy Information Administration: Energy loss over transmission by state.

## Types of Superconducting Materials

There are different types of superconducting materials, that can be sub-grouped into different categories. As later mentioned in this chapter lanthanum hydride shows the most promise in terms of reaching room temperature operation. Many different types of materials can be used as superconductors, however this does not mean that they necessary show promise of advancement. For example, hydrogen sulfide can become a superconductor at two hundred kelvin and two million atmosphere pressures. The main group of superconductors first discovered in the 1980s, are called perovskites. This group of materials can occur at ninety two kelvin (Mudur, 2019). Overall however, lanthanum hydride currently holds the record as the best superconductor.



[101] Image Courtesy of Electrical Installation and Energy Efficiency Electrical Engineering Company: diagram of an energy generator using superconductive material.

## Timeline of the Technology

Currently there are no superconductors that can function at room temperature. This does not stop scientists from attempting to get closer to room temperature functionality. What scientists have set as the goal, is to operate a super conductor at above zero degrees Celsius. Although this may seem far from reach, different companies and groups are investing large amounts of money to reach these goals. Scientists have made a great deal of progress in the last decade, breaking the record for functionality closest to room temperature.

The most recent advancement was in 2018, when German scientist were testing the super conductive abilities of a material called lanthanum hydride. Energy is needed to jump start the superconductivity, and in this case the team used about one hundred and fifty gigapascals of pressure [for comparison earth's core is about three hundred and thirty gigapascals] [86](Starr, 2019). Under these conditions, German Scientists were able to accomplish functional operation at just about two hundred and fifty kelvin (negative twenty three degrees Celsius) [86](Starr,

2019). This major breakthrough breaks the temperature record, only four years later from the last record broken. At the rate of advancement, superconductor technology could very well be up for commercial use in the near future.

### Superconducting Conclusion

It is important to acknowledge that superconductivity itself is not an alternative energy source, and alone would not stop nor solve the energy crisis. What it could do however, is slow the decline toward the crisis in addition to saving time, energy, and money. Super conductive capabilities also play a necessary role in the future of alternative energy solutions.

Superconductors could ultimately help ‘rewire’ the planet more closely together. As Professor Suchitra Sebastian at the University of Cambridge states, “Imagine a world where ultra-fast levitating trains zip between destinations, where wind energy from the North Sea and solar energy from the Sahara power the electric grid in New York...” [102](Sebastian, 2018). With a more closely wired planet, the high tide of the Bay of Fundy, or the strong sun in the Sahara desert could help to power places much further than are currently in reach.

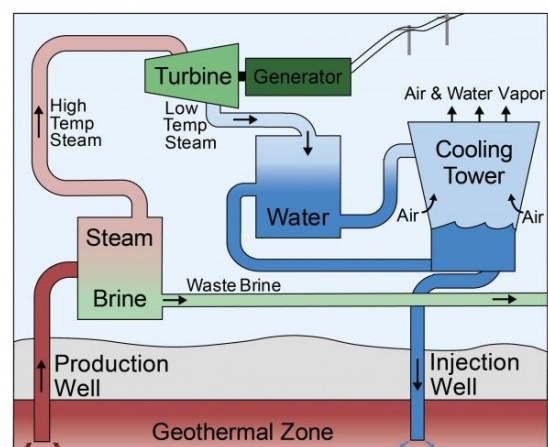
## Chapter 7: Geothermal Energy

### Introduction to Geothermal

Geothermal energy is often looked down upon due to its lack of exploration into the source. This source of energy is the least explored energy of all the renewable source because of the little energy feedback possible. However, it is important to acknowledge that it is a possible resource. In terms of this paper, it is a stable resource that would supply continuous power, in addition to being green with no emissions. This qualifies geothermal as a capable possibility to add the list of resources that could help change the course of the way humans use energy.

Geothermal itself is entirely based off of heat from inside the earth. For the sake of scales, this portion of the analysis is purely based off of facts from the U.S. There is no doubt that the temperature is different in each of the continental United States. However, the earth itself is actually almost the same temperature across the country. In the shallow ground (which is defined as the top ten feet of the surface), the temperature only ranges from ten to sixteen degrees celsius. This constant temperature is the center of geothermal, and the key to how geothermal works [107] (Renewable Energy World, 2019). Geothermal energy is captured by digging down into the earth's surface, where the temperature is more constant. The further down into the surface, the more possible energy to generate. However, the most common depth at the moment is about two hundred meters. At this level, the earth is at a constant six to eight degrees celsius. The goal however, is to dig down further. The University of Bergen says it is possible to dig ten thousand meters down where the temperatures could be three hundred and seventy four degrees celsius [108] (Renewable Energy Focus, 2010).

These stable temperatures can be used to heat and cool buildings (primarily), however there are other uses. For example, tapping into these temperatures could aid in producing steam. This steam could then be used to power turbines which create energy. Such energy does have great potential. Currently in the United States, there are approximately “3.567 MW of geothermal power plants in operation in the United States” [109] (University of Michigan, 2018). This is not enough power to provide energy for everyone, however it is a good piece to add on the journey to clean energy.



[109] Image Courtesy of the University of Michigan: Diagram of how geothermal energy is produced.

### Small Potential of Geothermal

As some of the other sources discussed in this paper, geothermal is not far out of reach of alternative renewable energy. There are plants already in place as well as some homes using geothermal technology to heat and cool their households. At the current moment in time, geothermal energy adds up to be approximately point four percent of all the energy generated in the United States. This may not seem like much, however any bit of green energy source is a step in the right direction. In addition, some studies show that there may be up to one hundred gigawatts of geothermal electricity capabilities in the United States. This large number would be able to supply ten percent of the United States needed power [109] (University of Michigan, 2018). Although this is only ten percent, this percentage is green, and could easily add up with other renewable source to create a more eco-friendly future.



[109] Image Courtesy of the University of Michigan: Image of a geothermal power plant in Nevada,

## Discussion & Critique of The Results

There is no doubt that some of the ideas presented in this paper are far into the future. The concept of the reality is, that no matter how strange or far off they may be, they are the future. There is data to back up the possibility of all the chapters discussed in this paper, how they will be implemented, is another story. There are different opinions on each energy source, especially in the discussion of an implementation timeline.

Tidal and current energy has had a decent amount of criticism for the large barrages that must be installed. Although this idea seems overwhelming to some, it is already a reality. There are already barrages built in different parts of the world. This shows that the potential of tidal and current energy can be obtained. Further research shows that smaller turbines can be installed and still produce high amounts of power. Of all the ideas discussed, this energy source in terms of a hundred year timeline is the closest to becoming a reality. Within the next ten years, based off the research discussed in the paper, places such as the Bay of Fundy will have installed turbines. This untapped ocean potential will soon be an alternative energy reality.

Space energy is much further along the timeline in terms of energy technology. There is currently no working prototype in space and still no solid way to transmit the energy from space back to earth. In terms of advancement however, the technology has been quickly inclining. With more countries and research center realizing the potential space energy has, the faster the goal will be reached. Will this technology happen in the next ten years? No, this technology needs far too much advancement. Within the next hundred years however, this may be a possibility. With countries such as China and Japan putting billions of dollars into research, there is a good chance within the next fifty years even, space solar will be a possibility. This does not mean it will be available commercially yet, but there may be a working prototype.

Fusion reactors, like space energy, will not be achieved in the next ten years. The closest fusion reactor still requires extreme amounts of power to start the device, and did not produce enough energy to be close to net zero. Within the next hundred years however, fusion reactors may be advanced enough to have small prototype factories. Even such a factory, would be a huge advancement and requires large amounts of power and technology to do so. In addition, the idea of having a fusion reactor or colony on the moon will probably not happen in the next hundred years. This is a far stretch and will call for many other technological advances, besides a fusion reactor and beaming the energy back to earth. Technology such as how to support human life for long periods of time in space would also have to be developed. The concept of catching an asteroid is even further out, as this would require enormous amounts of advancements not created yet. All in all the concept of space energy in total is not a possibility in the next ten years, however there may be a chance of working prototypes in the next one hundred. Even though this idea may seem crazy, there is funding and people work everyday to achieve such a far off goal.

Superconductors are not going to solve any energy source issue. These conductors themselves are not going to solve any direct problems as they are not resources. They could

however, help sources last long and aid sources in being available across the world. The reality is that this scientific concept that could happen in one hundred years, but it is still far off.

Considering research started in 1911, it has been over a hundred years and scientists have still not reached room temperature functioning. It is going to be quite a while before humanity develops the technology, and then even longer to have the technology implemented. In the next hundred years it may be an option, but many advancements need to be made.

Geothermal energy is a reality. It is already in use and there are already plants working towards using it on a normal basis. The stretch is the fact that to achieve maximum energy capacity, humans would have to dig miles down into the earth. Although this is closer than space energy, it would take at least fifty years to achieve such a concept. Especially because other sources are being so heavily explored, such an idea would require millions upon millions of funding. Likewise, jetstream energy is a small group of researchers that do not have the same amount of funding as space or tidal energy. Jetstream energy will not happen in the next hundred years on a commercial level, as there are too many requirements.

Overall most of the energy and ways of implementation is based on a one hundred years timeline. None of this is going to happen tomorrow, and will require tremendous amounts of work, funding, and time to accomplish renewable energy on a commercial level. Time aside however, if any of these concepts are achieved, it will spark a revolution leading the world to use alternative renewable energy.

## **Problem & Solutions: Futuristic Ideas**

### Introduction to The Future

After analyzing and evaluating alternative renewable resources for the future, different ideas as to ‘how’ these resources would be used were furthered and explored. In this section, different futuristic concepts are further explored based on the resources previously explained. In terms of technology, some ideas are extremely new and are not close to full development, but could very well be possible in the future. Other data supporting these ideas can also be found in this section.

### Restating The Problem

The main issue addressed throughout the paper is that there is an energy crisis quickly approaching humanity. There are only so many years of oil left, and humans must find alternative ways to find energy. While wind and solar power are currently being developed, there are multiple constraints that hold these sources from continuous power generation. For example, wind energy is only as good as the strength of the wind. If the wind stops blowing, then no energy can be produced. Solar power is similar in that if clouds or weather stop direct sunlight, the panels cannot achieve high enough outputs of energy to power homes or other everyday life. In addition, these sources are high in energy costs (per watt). This is part of the main reason solar and wind are not being used as heavily as one would think. In order to overcome the energy crisis and achieve a green energy outlook, the power source must be continuous and must not be affected by weather.

The alternative energy explored in this paper are viable because they do not rely on any weather to continuously operate. The main problem may be an energy crisis, however the problem found in the solution is finding a source that allows continuous power generation, at a low cost. In this section, these sources are explained through futuristic suggestion of implementation.

### A Future Based on Tidal & Current Energy

Of all the ideas and energy sources presented in this paper, tidal and current energy seem the most ‘realistic’ in terms of the technology timeline. There is currently an energy turbine in use off the coast of Scotland (as discussed in Chapter 2), and there is potential for much more than just one in the future. In total, the tides hold roughly three thousand gigawatts of potential power across the globe [105] (Selin, 2019). Although realistically not every watt of energy could be harnessed, harnessing even a fraction of these tides and currents could power a substantial amount of homes.



**Table 7.1**

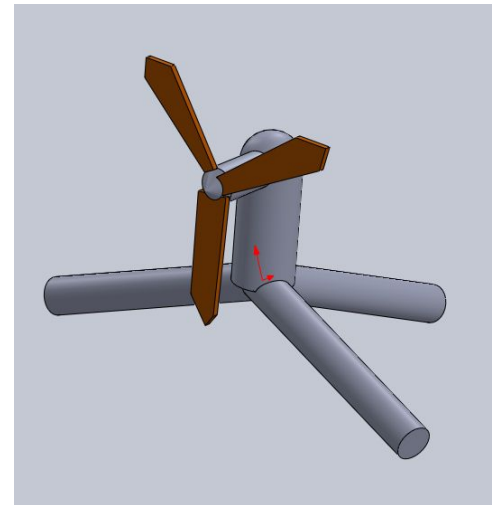
The following Table uses numbers based on energy output recordings from U.S. homes as a baseline. The potential of the turbine was calculated based off the current energy output of working current turbines designed by the ANDRITZ company.

Potential of Tidal Energy	3,000 gigawatts =	$3 \times 10^{12}$ watts
Current Turbine Power	1.5 megawatts =	$1.5 \times 10^6$ watts
Number of Turbines	$(3 \times 10^{12}) / (1.5 \times 10^6) =$	2,000,000 turbines
Power per U.S. Home	10 megawatts	$1 \times 10^7$ watts
Number of Homes powered (with hypothetical no energy loss)	$(3 \times 10^{12}) / (1 \times 10^7 \text{ watts}) =$	$3 \times 10^5$ homes
If all tidal power was collected, then it would take <b>2,000,000 turbines</b> to do so, and would power roughly <b><math>3 \times 10^5</math> homes</b> .		

Table 7.1 calculates the potential that tidal power could offer. In conclusion, two million turbines could power roughly three hundred thousand homes. This is not enough to power the whole world, however it could contribute a major chunk. These numbers are calculated on the estimate of ‘zero energy loss’, but that is to show the true potential that even harnessing a fraction of the oceans power could result in a huge gain.

The design of these turbines would be in arrays such as wind turbines are currently set up. These current turbine farms would differ from wind turbines in such ways as their height. Referring to Model (2) made in Solidwork, these turbines would be much shorter than wind turbines. This would be to withstand the strong forces of the ocean without falling over. In addition to stability, the base would be wide to help stabilize the turbine while it collects energy. These turbines would be placed all over the world, going further than the places mentioned in Chapter 2. In addition to the places discussed earlier, California, Australia, and down the coast of South America could also be used to supply energy.

In conclusion, the futuristic concept for tidal energy would involve large tidal and current turbine farms in places all over the world. Although these farms could not supply the entire



Model (2) Courtesy of Kaitlyn Hess: Solidworks model done of possible underwater turbine design.

world with energy, they would play a major part in the earth's transition to renewable energy. In addition, with the use of superconductors, tidal energy could be used in places further than the coast. With the combination of these two concepts, tidal and current energy could very well change the way people live far beyond the coast in the future.

### A Solar Shell

The following section is not a realistic goal, rather a theoretical interpretation used to introduce the potential space energy offers. Solar space energy eliminates many factors that solar panels on earth must overcome. Factors such as weather and nighttime do not allow solar panels to continuously provide power to the necessary outputs. If the solar panels were to be installed in orbit with the earth, then there would never be any weather related obstacles in terms of collecting power. For potential purposes, Table (\_\_\_\_) shows the potential for how many homes could be powered purely on solar. The catch however, is to show an exaggerated value of the potential, by hypothetically covering the earth in a shell of solar panels.

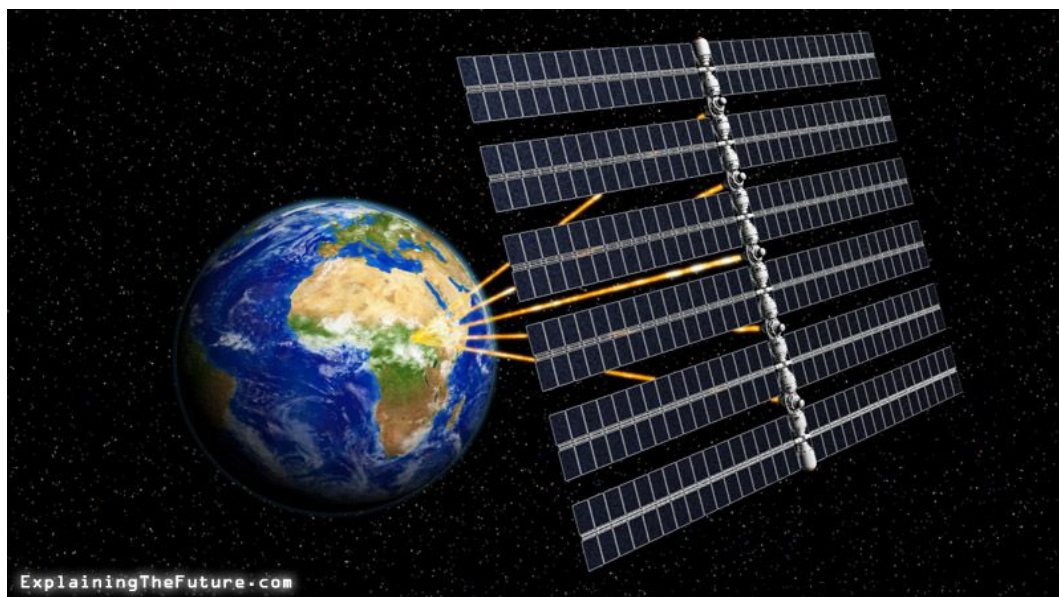


Image Courtesy of Christopher Barnatt: A sketch of what possible space solar panels could look like in orbit with the earth.

**Table 7.2**

The following calculations are based on data from Boeing. These values are considering no net energy loss during the absorption and disregard the energy loss in the transition back to earth. These calculations are meant to show the potential solar mirrors in the sky have to offer.

Number of Joules on earth's surface each year	430 quintillion joules	1 joule hour =0.000278 watts
Watts per hour	$(430 \times 10^{18}) * (0.000278)$	$1.19 \times 10^{17}$ watts per hour
Number of square km on earth	510.1 million km <sup>2</sup> =	$1.19 \times 10^{17}$ watts per hour
Top solar panels by Boeing	40.7% efficiency	
Solar Panel Output per hour	$(1.19 \times 10^{17}) * (0.407) =$	$4.84 \times 10^{16}$ watts per hour
Energy output per year	$(4.84 \times 10^{16}) * (12 \text{ hours}) * (364 \text{ days})$	$2.11 \times 10^{20}$ watts per year
Power per U.S. Home	10 megawatts	$1 \times 10^7$ watts
Total number of homes powered	$(2.11 \times 10^{20}) / (1 \times 10^7)$	$2.11 \times 10^{13}$ homes in one year
If there was zero net loss and a shell of solar panels (using current technology), were to cover the earth, $2.11 \times 10^{13}$ homes could hypothetically be powered each year.		

As mentioned previously, the above table is not a viable option to power the planet. It does, however, show the possible potential for humanity in terms of tapping into space energy. This concept of potential is to partially back up following sections in terms of futuristic space energy ideas. Although some ideas may seem far fetched, they are all based on concrete numbers pointing to the fact that there is potential in space. Although a solar shell encasing the earth is not possible, other space ideas are.

### Fusion Reactors on The Moon: The Power of a Moon Colony

Space energy has long been a source studied by scientists with the dream of having large amounts of energy beamed down from space. Where and how this energy may be beamed are all details in the grand scheme to install some sort of power source in space. As mentioned previously, ideas have come forth such as installing solar panels around the earth in space.

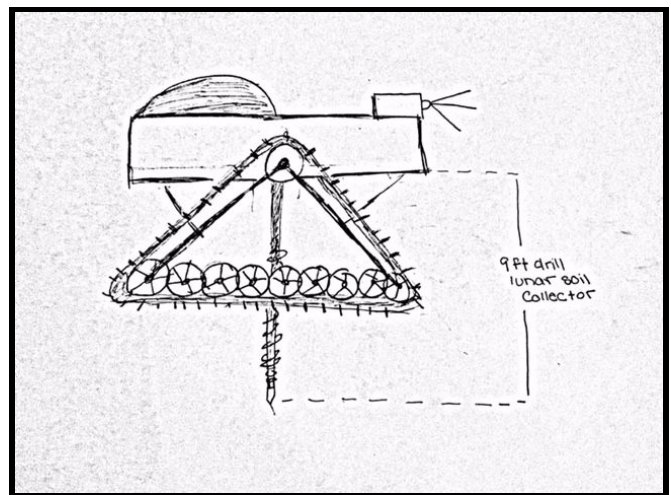
Although this shows a great deal of the potential space energy does offer, there are better options when thinking about approaching the task of harnessing the potential beyond earth's atmosphere.

As mentioned in Chapter 4, Helium-3 Fusion Reactors could supply enormous amounts of power. The catch; however, is that helium-3 is only found in large enough amounts on the moon. This creates a new futuristic idea that could possibly end the energy crisis if it were ever reached. Humanity could create a colony on the moon, and combine the concept of a Helium-3 Fusion reactor and space solar to construct a lunar space energy colony.

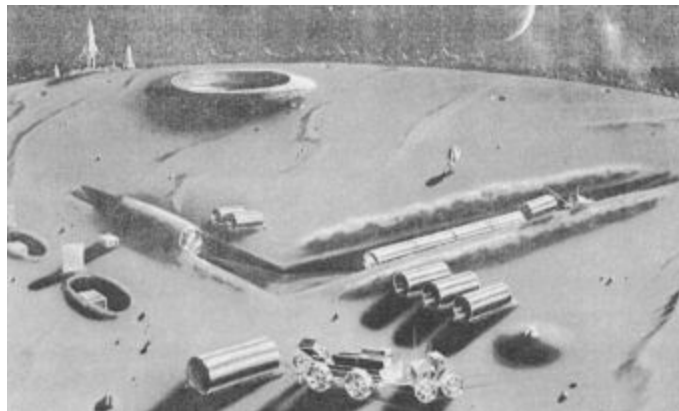
The main focus of this colony would be the Helium-3 Fusion reactor, and would be built around the mining and running of this energy source. That being said, details for the fusion reactor would need to be implemented to ensure the functioning of the energy source. The first detail is that mining would need to be done to

collect the helium-3 on the moon. Due to the dangerous conditions that go along with mining the moon's surface, artificial intelligence would be necessary to collect the helium-3. These robots would have to be programmed to collect the helium-3, and return to base to power the fusion reactor. Mining robots would have a few requirements and constraints of their own. This would include knowing a map of the moon to ensure knowledge of location, ability to dig meters deep into the moon's surface, and programmed ability to collect the helium-3 to bring back to the colony. As shown in Model (3), these robots must have long retractable drills capable of drilling multiple meters into the lunar surface. These robots must also have traction wheels that allow the robot to flip and turn as it moves over the rocky terrain. Finally, the robots must have enough room to store large amounts of helium-3 after drilling. With the aid of these mining robots, humans would be able to remain at the colony, and not have to venture out to collect helium-3.

The colony would have much more than robots and humans. This lunar space center would not only be the epicenter of space energy, but would also contain a lookout for large asteroids and other objects close to earth. Such a space station would require a group of humans to actually live on the moon, being housed in igloo-like shelters. This asteroid outlook post would be satellite connected back to earth, to warn of any oncoming objects. Furthermore, an almost military like station would be around the asteroid outlook post, to detonate the oncoming asteroids. A military-like base on the moon would ensure not only power, but protection from space to earth and everyone living on it.



Model (3) Courtesy of Kaitlyn Hess: a sketch of what a lunar mining robot may look like.



[104] Image Courtesy of Daven Hiskey: The U.S. Government proposed to instal a lunar military base during the cold war. It was later declassified.

One of the many important logistics of this lunar space colony is exactly where it would go. Many studies done show that the best possible place for humans to live on the moon would be inside of the caves and craters located across the surface. NASA has located approximately two hundred caves, some of which are forty meters down. This sort of depth could stabilize the moon's changing temperature, with some studies showing that the temperature could be stabilized at negative twenty degrees celsius (NASA, 2019). Living conditions could be possible at this temperature, exactly why the colony and energy station should be installed within one of these craters. In addition, space solar panels would be an added to the lunar station. This would provide power for the station itself so the energy from the fusion reactor could be beamed back to earth. This would require the station to be placed in the sunniest spot on the moon (as well as for more possible living conditions). The south pole is the sunniest part of the moon, thus the lunar energy station and moon colony should be located there. To be more specific, Shackleton Crater is four point two kilometers deep. Installing living quarters even forty meters down and living in the sides of the crater would allow a better chance for a moon colony. In conclusion, the location of the base that would give such an outside idea the best chance, would be in and around the Shackleton Crater on the southside of the moon.

**Table 7.3**

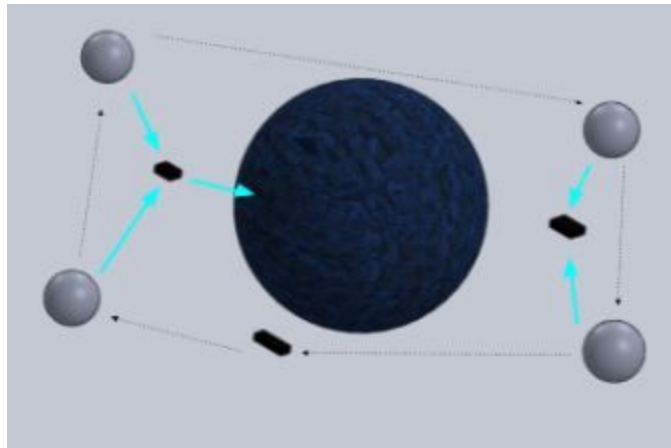
Moon Colony Living Logistics		
Best place for life	40 meters deep	Temp stabilized at -20 C
Shackleton Crater	4.2 km deep	

Although fusion reactor technology has not yet been fully developed, this whole colony is speaking in hypothetical terms, if there was futuristic technology developed enough to install an energy base on the moon. The Helium-3 Fusion reactor itself would be the center and main purpose of the entire moon colony. The fusion reactor would be installed near the Shackleton crater, half underground and half above ground. It would be half below ground to help protect it from any debris that would happen to reach the moon's surface. However, it would remain half above ground to help maintain the fusion reactors temperature. During fusion, the reactor creates a plasma that can reach temperatures of a hundred million degrees kelvin (Früedenrich, 2019). Due to these high temperatures, there would have to be some sort of ventilation system to help keep the fusion reactor from melting down. In addition, the fusion reactors wiring would also be underground, as would all the other wiring on the moon colony. This would prevent any space damage that would require more maintenance long term. There would be a way to access the fusion reactor underground, which is why the crater would play such an important role. That way there would be access for the mining robots in addition to maintenance by humans.

The largest challenge for a lunar energy space colony is the way to send the energy generator by the solar panels and fusion reactor on the moon, back to earth. In studies and as mentioned in Chapter 3 and 4, there are different approaches to doing this. As mentioned in the previous chapters, many researchers suggests the approach to use microwave energy. There are concerns however, that microwave rays would spread out too much over the transmission back to earth. Some scientists, and in the case of this theoretical colony, would suggest using infrared radiation. Infrared rays fall on the light spectrum in between visible light, and microwave rays. They are usually between 0.4 and 0.7 micrometers. This is important because the wavelengths are longer than visible light (which would not allow anyone to see the beam), yet still shorter than microwave. The key in infrared is that when using it within a laser to beam energy back to earth, it would not be stopped by the atmosphere. The atmosphere absorbs most rays of light which is what protects humans, however some infrared wavelengths can pass through. The part of the infrared wavelength that can pass through is that closest to visible light. This is around one micrometer. At this length, an infrared laser could pass through the atmosphere. Thus, allowing the energy to beam from the moon to the earth. The earth would catch the energy, much as humans collect solar energy now, with photovoltaic cells. Through this process, humanity could beam energy from the moon to the earth.

Overall such a moon colony with a focus around a Helium-3 Fusion Reactor could consequently end the energy crisis. Although this technology is far away and major advancements need to be made, scientists all over the world are trying to reach for the moon. If scientists were to accomplish the task of developing a laser that could beam energy back to earth, a special series of satellites would have to be set up. In Model (1) it is diagrammed that a series of satellites would be put in orbit around the moon. This is because in beaming the energy back

to earth, the moon would not be able to directly shoot a beam to the same place every time (due to it being in orbit). This concept is called synchronous orbit, and where the earth the satellite would be 'in synch' with each other. Through this technique, the moon could beam the energy to the satellite closest to it at that point in time. These satellites would beam between each other until the beam reached the main satellite. This 'mother' satellite would then beam the energy to the predetermined place on earth. This, in conclusion, would be how an energy moon colony would operate.



Model (1) Courtesy of Kaitlyn Hess: Solidworks model done of possible synchronous orbit construct using satellites (black rectangles), between the moon and earth.

### Capturing An Asteroid

Another space driven idea is to put a colony on an asteroid. The foundation of this would be that, as discussed previously, the asteroid would be in synchronous orbit with the earth. This concept has been going on since 2011, when NASA announced their ideas to capture an asteroid. If put into synchronous orbit, an asteroid has potential for not only a colony of its own, but other energy related aspects not previously discussed [106](National Space Society, 2011).

In the first instance, a fusion reactor could be placed on an asteroid and beam energy back to earth. Because the asteroid would be in synchronous orbit, there would be no need for a multitude of solar panels surrounding the earth. There would have to be a space shuttle providing the helium-3 from the moon to the asteroid, however the asteroid could stand as a shorter trip rather than bringing helium-3 back to earth (as most scientists want to do). Since a fusion reactor would be placed on the asteroid, there would be a need for a colony on the asteroid as well. This colony could aid with not only the fusion reactor, but aid in the maintenance of the asteroid.

Asteroids are filled with an abundant amount of materials. Referring to Table 7.3, there are many different applications an asteroid could be used for, in addition to energy.

**Table 7.3**

The following information is based off of data from the National Space Society. These values are based off the asteroid 99942 Apophis.

Total Number of Possible Resources	27 megatons in total	
	5 (or more) megatons of iron	
	1 (or more) megatons of volatiles	
Total Possible Number of Asteroid Colony Civilians	100,000 people	



## **Recomendations For Future IQPs**

This project required an open mind and a great deal of ‘digging deep’ to find information. If this project is to be continued, multiple things should be done in advance to avoid the time constraints. The first is to explore the different types of energy in terms of a timeline. All of the energy sources discussed in this paper are plausible to some degree, however not all are developing at the same rate. For example, tidal energy already has barrages across the world while space energy has years of progress to go. This fact should be outlined and researched more fully at the start of the paper. This would allow the paper to show more depth in terms of when technology will actually be available.

Another task that time did not permit was the contacting of alternative renewable energy companies. There were attempts during this project to reach out to some companies in hopes of more information on certain technology. Unfortunately no one responded and there was not enough time to dig deeper and try to contact more people. For example, emails were sent to companies wishing to discuss tidal energy, however no one ever responded to the emails. If there were more time, than other means of communication could have been attempted. In addition more companies could have been contacted. If this was achieved, more strength could have been added to the paper.

Throughout this project models and designs of space colonies and other advanced technology are discussed. There was hope that these technologies could have been outlined better, with the use of things such as digital drawings and CAD models. This was a time constraint in addition to the issue of only one person working on this project. If there was more time, more 3D models could have been implemented. This would have allowed for the reader to achieve a better picture of what exactly these futuristic designs were about.

Finally, this was an extremely interesting project in terms of space. Other regions in space such as Mars could have been explored, but unfortunately due to the time constraints and small team of only one person, this was not done. If this IQP were to continue, a big suggestion would be to start with space, for example, and then move onto other sources (if needed). This would allow a more thorough approach to one direct ‘grouping’ of energy. This would have also allowed for a more thorough final design for ‘futuristic ideas’. If there had been more time, more concepts could have been explored, and thus more futuristic suggestions.

Overall, this project involved large amounts of work. In order to achieve a more thorough and detailed final report, the group should start with space and then work down to the smaller sources. This would allow for a more optimal use of their time, as all the research would be related.

## Conclusions

Throughout this paper various alternative energy sources are explored. Some seem more far off than others, but this is because there must be a shift in energy to ensure the continuing powering of the planet. After researching and exploring these futuristic opportunities, it can be concluded that these ideas are possible. Details such as how such energy options would affect the environment still need to be explored further, however it can be concluded that any of these sources would greatly affect humanity.

If tidal power were to take off in every current of the world, hundreds of homes along the coast could switch over to renewable power. If superconductors were to come into play, even more homes further from the sea would be affected. Tidal energy, unlike the space powered energy, already exists in a couple places over the globe. These plants in place stand as models that outside of the box thinking can lead to impactful change. The plants in place will guide other such places, like the Bay of Fundy, to take advantage of the ocean power they are given. This change will directly alter the lives of many people, by supplying green energy in the beginning of a crisis.

Space energy is explored a great deal throughout this paper, but that is because of the humongous potential that it has. No matter what fraction of space generated power is achieved in the next decade, it will completely change the course that humanity is going in. Solar panels in orbit and fusion reactors on the moon may seem like a science fiction movie, however scientists are working to further this technology in real life. There are models of fusion reactors, and billions of dollars are being poured into the development of space solar panels.

With the amount of energy potential in space, all of humanity could be powered for years to come. This bold statement could very well come true if the technology stays on the same pace of advancement as it has been. People would drive electric cars that were charged from obtained energy of space solar. Houses would be powered from beamed energy of a fusion reactor on the moon. This futuristic vision could save all of humanity from an energy crisis, and further, change the way every person lives. Having such an abundance of energy could also supply energy to those who do not currently have it. Jetstreams for example, cover the globe. If this energy could be captured in places that do not have access to electricity, lives would be changed.

Overall these ideas are outside of the box, however they are the future and would change the way that all of humanity lives. If this were to occur, the way people have been living would be completely changed for the better, by having an abundant amount of clean energy. Although it may not be a nuclear reactor on the moon, science shows that the way we collect energy is, and must change for the betterment of humanity.

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### Chapter 3.3: Fusion Reactor

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