Interactive Qualifying Project

Cold Fusion: The Impact on Society and the Reaction from the Scientific World
Final Report

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1. Abstract

This study aims to bring the reader to speed with the events that have transpired in the cold fusion community as well as its impact on society. Part of the project involves how society responded to the Pons and Fleischmann report in 1989. Then experimental setups and scientific theories behind the technology were investigated to provide insights as to which are most feasible, and the potential uses of each method. Lastly, this project speculated what would change in today's society if this technology were to become marketable soon.

2. Executive Summary

Cold Fusion: What is its feasibility in the near future and how would it impact our society?

Nuclear fusion is said to occur when the nuclei of two atoms combine resulting in one new atom. Fusion releases large amounts of energy; the heat and light produced by the sun is the result of the fusion of two Hydrogen atoms into one Helium atom. Cold fusion is a process in which nuclear fusion takes place, except instead of taking place at or near the temperature of the surface of the sun, it occurs at a temperature sustainable in a laboratory setting. In 1989, two electrochemists named Pons and Fleischmann brought cold fusion to the forefront of interest of the scientific world. They devised an experiment that was conducted on a table in front of an audience with claims that sounded too good to be true: claims that they had "solved" cold fusion. It turns out that the Pons and Fleischmann experiment did not function as reported. After twenty four years and hundreds of other experiments, there are still many unknowns in the field of cold fusion, though appears that we may be on the brink of discovery with this topic.

The target audience of this research matter is power energy engineers as well as energy generation scientists. This is a very relevant topic because its impact would affect everyday life; the cost of electricity can skyrocket when public demand is high (this generally occurs between the hours of 10am and 4pm). This effect could be combated with arrays of cold fusion plants which could produce enormous sums of environmentally friendly energy at little cost.

3. Background Understanding

3.1 Notes from Professor Cyganski's CF PowerPoint Presentation

Cold fusion is a very controversial topic in the media, and scientific world. Since the Pons and Fleischmann announcement in 1989, any work in the field of cold fusion looked upon skeptically. Often times experiments are not discussed except within the company of other cold fusion researchers for fear of being labeled a mad scientist. To gain a better understanding of why this is such a desirable phenomenon, the "big picture" of cold fusion must be investigated. Cold fusion is the combining two nuclei to release energy. This can be configured in such a way that the excess heat turns water into steam which then spins turbines to generate electricity. The bi-product of such a fusion is Helium, which is essentially harmless (especially when compared to the alternative of Carbon Dioxide)

Gravitation, magnetic confinement: huge magnetic fields which hold deuterium and cause fusion to take place, magnetic confinement usually takes up a vast amount of physical space. Also, it needs to generate such large magnetic fields that the system consumes more power than it outputs, making it useless for an energy production point of view.

Valuable information on Pons and Fleischmann was also obtained from viewing this presentation.). On March 23, 1989, two electro-chemists called a press conference to make an amazing announcement. This unorthodox method of delivering scientific news boosted excitement, as publishing a paper is the status quo in the scientific world. Pons and Fleischmann reported that they had achieved and repeated experiments that produce cold fusion at relatively low cost. The experiment called for heavy water (water with heavy hydrogen, or hydrogen with an extra neutron) in a bottle is suspended in H_20. A coil of platinum (used as an anode), and palladium rod (for the cathode) were connected to low voltage and because palladium has an affinity for hydrogen, the low voltage was enough to pack a large amount of hydrogen into the palladium rod, causing the fusion of hydrogen atoms. The fusion was said to take place merely because the hydrogen was packed so tightly that it just fused on its own.

To explain in a little more detail, a low level current through the water was claimed to make the device undergo electrolysis and split the atoms of water. This resulted in "free" hydrogen atoms that could be attracted into the Palladium lattice. By over packing Hydrogen into this lattice, the atoms were forced towards one another. When enough Hydrogen atoms were packed together, the repulsion force felt by the Hydrogen atoms is overcome, and two atoms fuse together, producing energy in the form of heat. The only real downside of this process is that Palladium is expensive, which could make commercialization of this type of setup too costly and perhaps unrealistic.

The claims of Pons and Fleischmann were met with skepticism because usually you need temps of up to 100MK or a few million volts of acceleration to achieve fusion of Hydrogen atoms. Pons and Fleischmann however, claimed to have used room temperature and 60V to drive their fusion cell. Usually in a nuclear reaction, you would expect excess heat, neutrons, tritium, Helium, protons, and radiation; Pons and Fleischmann only reported heat and light. In addition, many reputable labs tried to replicate the Pons and

Fleischmann cell to no avail.

Despite the incomplete work done by Pons and Fleischmann, there have been many supposed confirmations of this experiment that have been performed, and professor Cyganski has looked into them, and finds that some of them are credible. Unfortunately, cold fusion has become basically a career killer/academic killer. Funding for cold fusion research is near impossible to find. Most researchers in the field are ridiculed and forced out of their positions. Over time, cold fusion has adopted the acronyms LENR and CANR (for Low Energy Nuclear Reactions, or Chemically Assisted Nuclear Reactions respectively). Potential careers and applications if cold fusion is ever to be perfected are nearly unlimited, from military use, to commercial energy, to even more extreme uses like space exploration. Nuclear fusion is said to release 10 million times more energy per unit mass than liquid transportation fuel. The military applications of this technology could boom and completely transform the whole nature of military operations. It was once said in the past that "The greatest transformation of the battlefield for U.S. forces since the transition from horsepower to gasoline", and cold fusion could prove to be the next big leap in military technology.

In the last few years, an interesting development in the cold fusion world has come from Andrea Rossi. Rossi is the "ECat" creator, and is the biggest name in commercializing cold fusion. However, documentation of his device is iffy (at best) and needs work. Rossi is too paranoid about theft to let scientists dissect his device, and does not provide much information at all about his its inner workings. Some believe he actually doesn't even know how it works. That said, he did demo for NASA and has a 1MW unit for sale. One of these devices was sold to a private buyer, but not much else is known about the transaction.

In his closing remarks, professor Cyganski noted that: this isn't the first time in history that society has shot down an outlandish idea, but the potential benefits possible from this project make it one worth investing in. [1]

3.2 More Technical Background

The following is an overview of the article: 'Cold Fusion' Is Real And Is Being Commercialized.

There are over two dozen theories about how LENR or CANR may be achieved, though none have undergone enough testing to be verified. Many of the theories correspond to experimental setups, whose goal is to produce cold fusion in a safe and repeatable fashion. In order to quantify the usefulness of these devices, energy output is measured as a ratio on energy in to energy out; the higher the ratio, the "better" the device is. The Pons and Fleischmann electrochemical with palladium method is said to output a ratio of 25, while the nickel and hydrogen (E-Cat) method reports gains of up to 400.As previously mentioned, Andrea Rossi sold his device to a private buyer; the person who bought Rossi's E-Cat has reportedly ordered 12 more. If the gains from Rossi's device are accurate, a nickel (the coin that is) could be used to produce enough energy to replace a few barrels of oil. One advantage of the E-Cat system is that although it emits radiation, it does not nuclear waste or greenhouse gases like conventional energy production methods. [2]

3.3 Pons and Fleischmann Technical Analysis

Cold fusion is still considered a taboo subject in the world of science; most professors avoid the subject until tenure is reached to avoid a negative perception. However, it still draws an enthusiastic crowd because of the potential benefits that could be achieved from a cold fusion process. The basic idea behind cold fusion is that if you can force two atoms together, the by product is excess energy. In most cases, the goal is to combine two deuterium (otherwise known as heavy hydrogen) atoms together, as this would produce hydrogen and a proton or helium and a neutron. In either case, four mega electron volts are gained per fusion. Because there can be up to trillions of atoms of hydrogen in something as small as a glass of water, these electron volts quickly add up to an enormous amount of power.

Though we do not often think about it, we are already dependent on fusion for life. The sun produces its heat (and light), by the fusion of hydrogen into helium. The goal of current research is to develop a way of initiating this fusion without the temperature or gravitational force of the sun., Not only are these conditions dangerous, or even unrealistic to produce on the earth, it is possible that creating such an environment would spend more energy to fuse the atoms than we could harvest from it.

There are currently two proven methods of producing a fusion reaction, but neither of them is able to get more energy out than they put in. The Tokomak uses a powerful magnetic field to make hydrogen atoms to fuse together, however the limits of efficiency in producing magnetic fields renders this method useless for energy gains. A Farnsworth Fusor, which attempts to take advantage of electrostatic confinement, runs into the same problems, and is therefore not considered a viable means of replacing fossil fuels.

In 1989, two scientists, named Stanley Pons and Martin Fleischmann claimed that they had solved the seemingly impossible puzzle of cold fusion. Their apparatus involved a jar filled with water into which an energy cell was submerged. The energy cell contained heavy water (water composed of heavy hydrogen) and lithium hydroxide. A palladium rod was then centered in the cell, and a low level current was passed through. The low level current was supposed to split the heavy water into H+ and OH- ions. The palladium rod, which has a high affinity for hydrogen was then said to gather the hydrogen ions and pack them so closely together, that they fused on their own. The Pons and Fleischmann cold fusion experiment is pictured below.

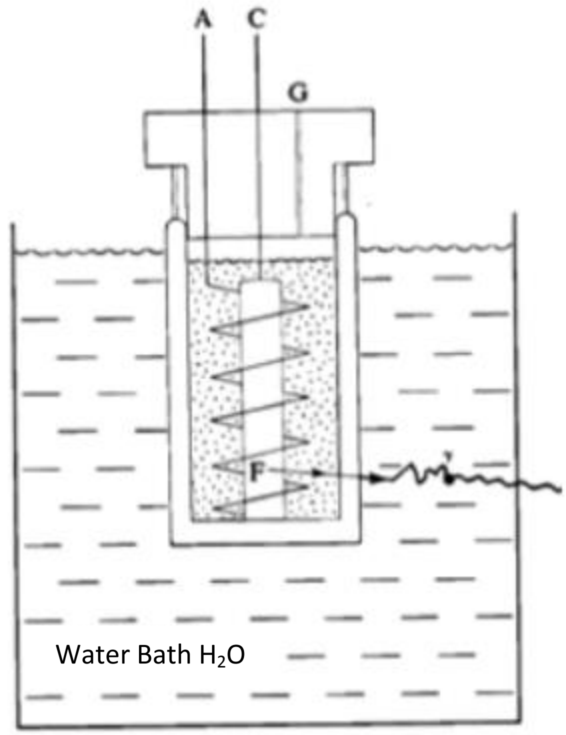

Figure 1: C old Fusion Cutaway Cell

This cold fusion cell did not require the incredible amounts of heat or acceleration that had were called for theoretical calculations, so it sparked immediate controversy. It also did not produce nearly as much heat or radiation (no radiation was observed) that cold fusion was "supposed to". Eager to prove or disprove the method, hundreds of research labs and scientists rushed to replicate this fuel cell. Unfortunately, due to the desire to get an answer quickly, most of the replications were poorly done, and as a result, there were many conflicting reports on the validity of Pons and Fleischmann's claims.

One interesting point in the Pons and Fleischmann cell is the presence of heavy water. If their design were to be replicated with regular water instead of heavy water, the result changes dramatically; little to no heat is produced. Below is a plot of output heat of the system based on the level of input amperage. The solid black line represents current, the red represents heat using heavy water, and the blue represents heat using regular water.

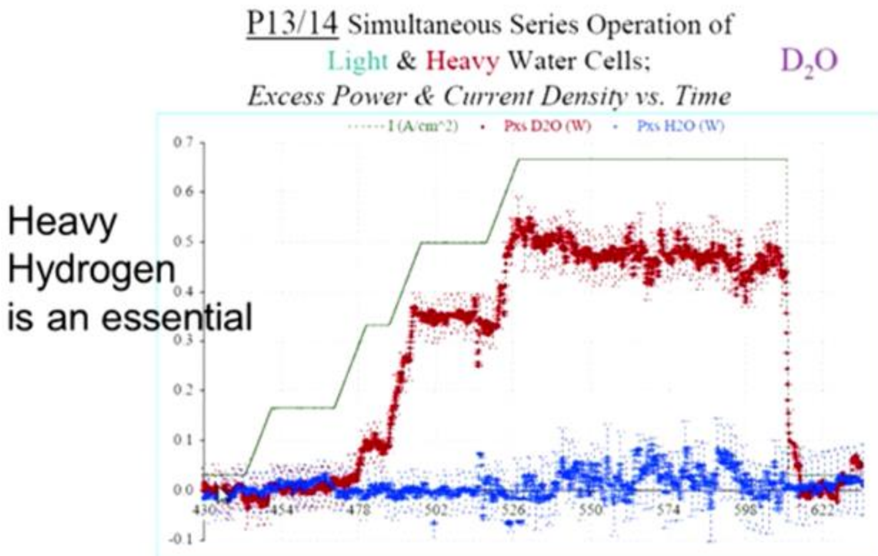

Figure 2: Excess Power and Current Density vs Time of Light and Heavy Water Cells

Twenty years later, cold fusion is still a subject dealt with wearily. There are still researchers trying to discover the secrets of cold fusion, and adjusting Pons and Fleischmann's initial ideas to see if they can produce cold fusion. The original model has been updated from a simple glass jar, to a more modernized piece of equipment. Variations in temperature, pressure, and other conditions are being tested to see if there is an optimal combination for the Pons and Fleischmann cell.

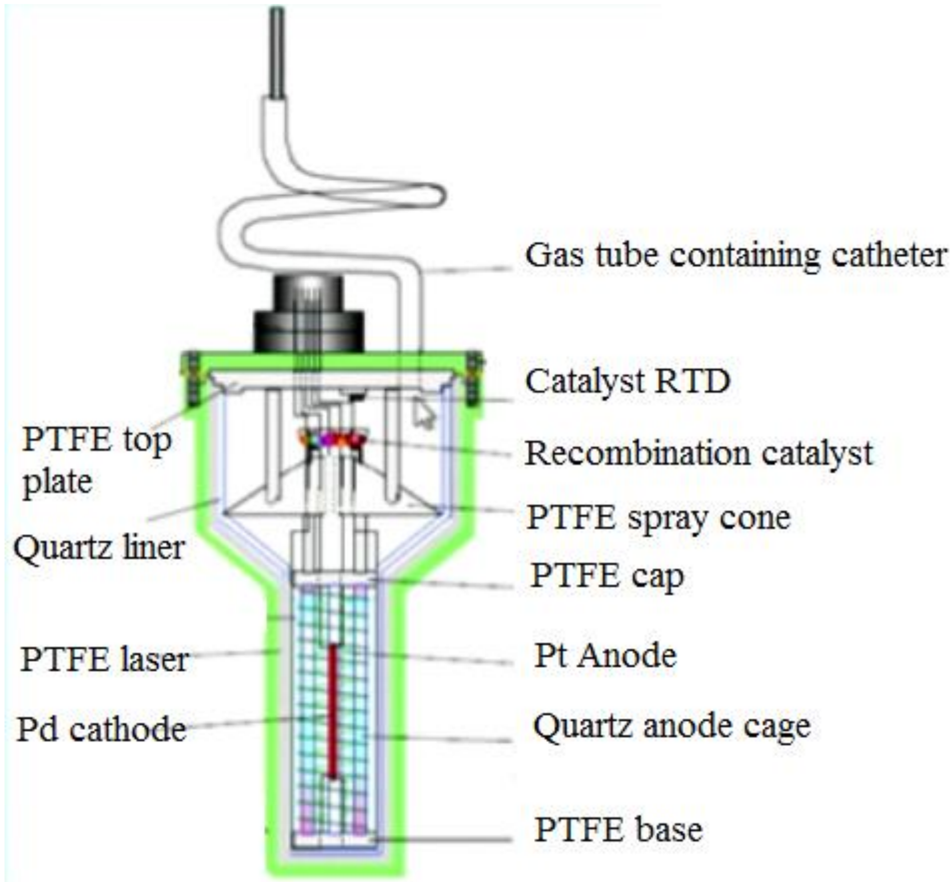

Figure 3: Detailed Cutaway of Pons and Fleischmann's Cell

Though Pons and Fleischmann's cell may be the most well-known experiment with regards to cold fusion, there are many other designs currently undergoing testing around the world. One of these approaches to cold fusion involves palladium black. When palladium is ground into small enough parts, the color appears black, instead of its usual shiny silver-like color. Yoshiaki Arata and Yue-Chang Zhang are developing a similar experiment to Pons and Fleischmann's inside lithium oxide, except that they use this palladium black, and the results have proven to be more stable. Not only does it produce helium as would be expected, but it yields particles exiting at about 24 mega electron volts for every 4 helium produced. The cathode utilizing palladium black and the stoichiometric explanation of the process can be seen below.

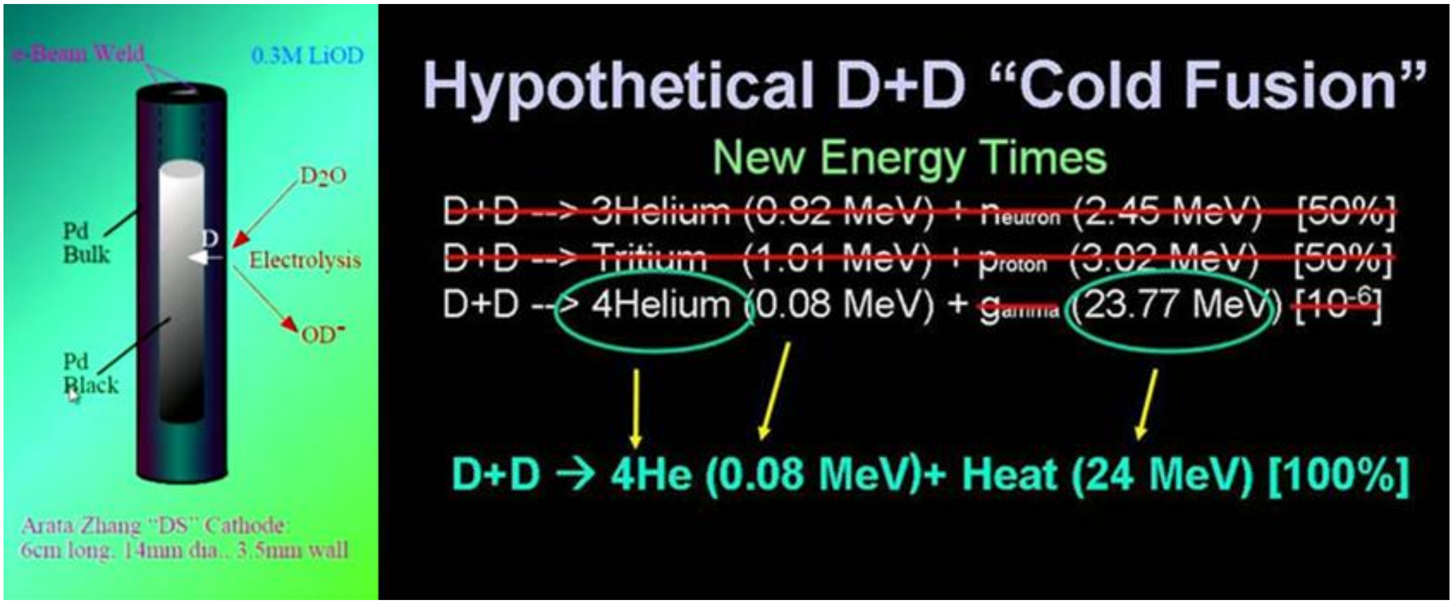

Figure 4: Chemical Component Diagram and Hypothetical Cold Fusion Stoichiometry [43]

The most recent (and possibly least understood) idea for generating cold fusion comes from the mind of Andrea Rossi. His device uses about fifty grams of nickel powder, ground to a specific (though secret) size to maximize performance and one gram of hydrogen gas at 350 psi. This is reportedly able to produce power with the use of a (once again secret) catalyst. Unfortunately, not many other details are known, because Rossi guards his methods very carefully. He does not want his ideas to be stolen, but unfortunately this also means that it cannot be tested, or analyzed by third parties. He has sold a few units to a private buyer, but little else is known about the progress of Rossi. [3]

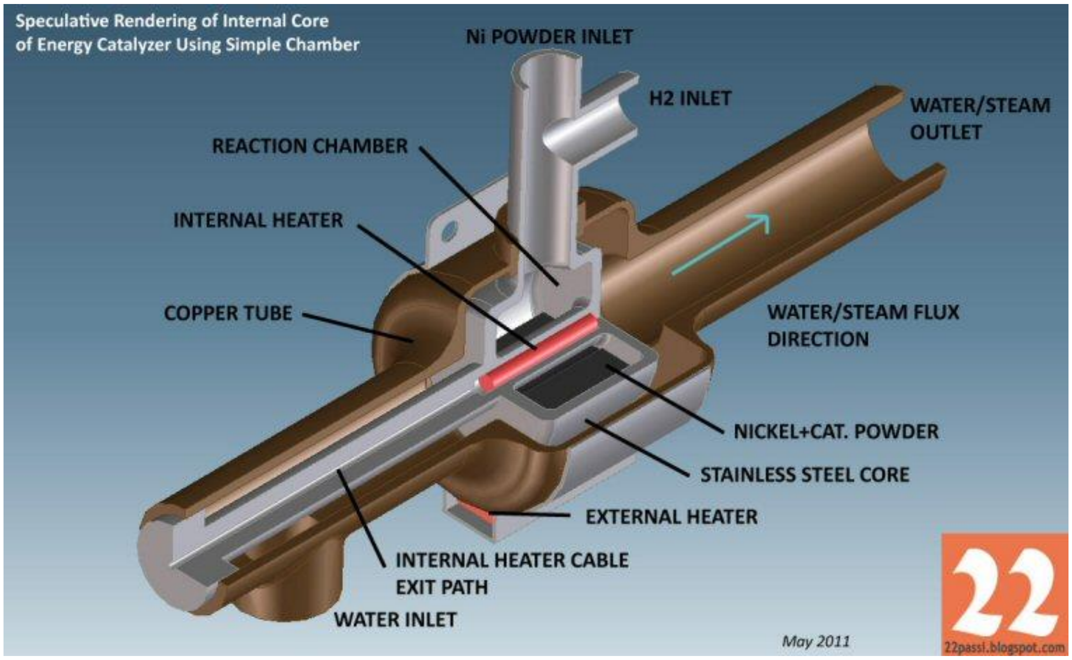

Figure 5: Detailed Component Listing of ECat Device Chamber [42]

After the debacle in the late eighties where do we stand currently in the issue? Apart from using different names such as LENR and CANR, it's still somewhat of a toxic subject.

"Prof. Robert Duncan, vice chancellor for research and a professor of physics, University of Missouri-Columbia, appeared on 60 minutes segment. "Cold Fusion is Hot Again." (April 19, 2009) "...I [Prof. Robert Duncan] was contacted by a highly prominent professor from an Ivy League university, who was just really, really was angry with me. For having done the piece." When asked to review the data the caller's replay was: 'well, you know, us high caliber physicists have done that before, and there has never been anything there. So you charlatans just can go on and do whatever you like. ' My scientific reputation -- I guess, at least to him -- had been stronger before I did the piece." On May 10, 2009 all information about his subsequent lecture was erased and replaced with this message: "Dr. Duncan's

speech and presentation slides are not available." On May 20 the information reappeared. In October of 2010, Energetics moved into a new U. Missouri facility." (Prof. David Cyganski Cold Fusion Presentation). [2]

3.4 Events from 1900 to Present

Cold fusion is not the product of one person's "light bulb moment", but rather the combination of about a century's worth of theories and experiments. The first relevant theory comes from none other than Albert Einstein; in 1911, Einstein finished one of his most famous equations, which relates mass, energy, and the speed of light. His equation E=mc^2 serves as a basis for all nuclear reactions, as it allows us to calculate the amount of energy produced when a particular amount of mass is consumed. Despite coming up with this theory, Einstein had no practical way to prove it, aside from mathematics. In 1917, Rutherford became the first person to split the atom. This had previously been thought to be impossible by many, and though he was not able to do so in a consistent, methodical fashion, it proved that with time, the task could be accomplished. In 1932 the splitting of an atom was done in a controlled manner, allowing for further testing with nuclear reactions. In a mere two years, Enrico Fermi showed that atoms could be split by firing neutrons at high speeds, which is the method utilized for nuclear fission to this day. Years went by with the understanding of how an atom could be split and the potential benefits of doing so before fission was performed to produce power.

In 1942 though, a graphite reactor was completed, and served as the first ever nuclear reactor. Almost another decade passed before the power generated by a nuclear reactor could be harvested and used, but in 1951, a reactor was used to power four 200 Watt light bulbs. This may seem like a trivial accomplishment, but it lead to rapid development of nuclear reactors. Four years later a reactor was completed that was able to output the electricity needed by an entire town. By 1971, 2.4 percent of the electricity produced by the United States was the product of nuclear fusion.

As a reasonably efficient and cheap means of producing electricity, fission was performing admirably until 1979, when a tragic accident at Three Mile Island tainted the work "nuclear" to this day. Nuclear power is, in the public eye, viewed as unsafe largely as a result of this accident which left immense damage in its wake. This negative connotation was further exacerbated in 1989 when Pons and Fleischmann made their claims about cold fusion; most of the scientific world, which had kept its faith despite Three Mile Island, became convinced that fusion was merely a pipe dream which would never become reality. After this, published work has become scarce, since unfortunately any cold fusion enthusiast puts their reputation at stake with every report. However in 2002 the U.S. Navy released a report in which it determined that cold fusion, though potentially unlikely, had such great upside that it was in fact worthy of funding. This has led to greater experimentation in the realm of cold fusion, which at the present day stands in the hands of a select few experimenters, the most famous being Andrea Rossi, with his "ECat" device. The aforementioned events are laid out in a timeline in Appendix I.
[4, 5, 6, 7, 8, 9]

3.5 MIT's Dispute with Physicists

The study of Cold Fusion is riddled with obstacles of scientists opposing the efforts. One of the first divisions of Physicists that worked to disprove the findings, by Pons and Fleischmann in 1989, was at MIT. However, there is a prominent figure at MIT who is currently pushing for the development of Cold Fusion research. Dr. Peter Hagelstein, a physicist at MIT had this to say about the uphill battle in this field of research;

"*The other issue is how to get support for such work. In the United States at the moment, outside of a program under Dennis Bushnell at NASA, there is no currently, as far as I'm aware, there is no other government support for any work in this area for such experiments. I recently had the experience of working with a large company in the U.S. who was interested in pursuing experiments in this area and helping out. So we put in, we discussed with the technical people at this company of the possibility that they might put in some money for the support of the replication of the Piantelli experiment. So they got the agreement, they got the money, they got it to MIT, and we thought "good, now we can make some progress." However, a very famous physicist at MIT, who is involved in the energy program, found out what we were trying to do, and he cancelled the program. And he called up the vice president of the company and said some things that weren't very polite about the research. And not only did the funding not come and the experiments didn't happen, but my colleagues at the company were very worried about where they're going to work next. As you know, there are unemployment issues currently in our bad economy, so there's a fundamental difficulty with* *respect to getting support for the experiments, and what that means is that the science can be expected to go very slowly for these reasons, until a solution is found to this problem."* [10]

There are mixed feelings about the challenges faced by Dr. Hagelstein and physicists alike. On one hand there is scientific ethic and researching standards. On the other hand there are bizarre discoveries and curiosity of the unknown. It seems somewhat foolish for scientists to behave as if they have access to knowledge about everything in our world. Such thinking limits the ceiling which new generations strive up reach with regards to knowledge and understanding. Certainly it is foolish to chase down pipe dreams of underwater cities or light year space travel, and some people believe Cold Fusion technology is no different. However, the amount of research done in the field of alternative nuclear reactions deserves some sort of attention. It's interesting to see that prestigious places, like MIT mentioned above, have a strong backbone to repel the efforts of Cold Fusion research. The very places with the resources to conduct research on Cold Fusion have all turned it down and now the majority of information comes from privately funded organizations. The downfall to this scenario is that those qualified to conduct any experiments are turned away due to job security. And those who do end up facilitating testing are stuck with lesser laboratory setups where the results become skewed. Due to this situation, any research forward is a slow and lengthy process. [10]

4. Where We Are Today

There are many theories which attempt to explain and justify the nature of Cold Fusion. However, the truth is that no one actually knows completely how it works or can work.

Fugacity is a term used by electro-chemists. It describes a force that behaves like a pressure due to an electric field and or current in an electrochemical cell. Early on (papers going back to the 1920s) chemists knew they could get huge fugacity, huge effective force, in an electrolytic cell if you pump a current through it. Maybe the forces are so great that they overcome the coulomb barrier – a proton being forced closer to another proton. Maybe the protons are already so close together that this pressure causes them to fuse together. Some sort of transmutation was speculated to have been seen in the 1920s with palladium and heavy water. To prove this they used good samples of palladium (which has an affinity for hydrogen) and electrochemically tried to force hydrogen into places in which should only contain one atom each. Maybe this shear force creates fusion. There is no mathematical model for this theory! "They had a picture in their head and decided to try it and then presented it" [pons and Fleischmann].

In other words, electrochemical forces can push hydrogen together into tiny spaces and cause fusion. However, the main fall back of this theory is that any careful computation of that simple model doesn't exist. There are no mathematical models and therefore no solid ground on which to prove its workings.

It’s important to note that not every has the same opinion on how Cold Fusion technology might work. One radically different theory is the “Widom and Larsen” theory. The Professor Widom and Larsen Theory (BU) revolves around a condensed matter state phenomenon. (Diode, MOSFET working. The behavior of an electron is much stranger and different in a lattice structure. (Electron behaves like a fluid in a wire, behaves like a particle in the air). The electron can behave like a quasi-particle, appear to behave as if it were a thousand times its mass, a group of electrons can in turn create a “hole” somewhere in the lattice. Strange in a diode: I can go through this way but not the reverse way. The quantum mechanics is mathematically describable. When electrons are put into very small “containers” it becomes difficult to describe their behavior. When it comes to overcoming the Coulomb force you first think to apply a great amount to force to overcome the Coulomb force. Widom and Larsen believe that if you go “ultra-slow” the forces won’t stop you. Ultra slow interactions inside a lattice, because of the condensed state phenomenon, allow the particles to pass right through the coulomb barrier.

Other theories:

People who think this another kind of phenomenon, based on quantum mechanics of cavities. When a particle is forced into a small enough “container” it behaves like a wave and eventually expands to fill the space it’s in. Make the box big and you have a particle bouncing around. Make the box small and it just sits there and spreads. They think that there are micro scratches and pits in the material (palladium) where electrons come in and spread and eventually fuse with each other.

Can go on and bring up 35 other sub theories of those cases. The problem is that there so many different cases and setups for experiments that it's impossible to pinpoint any mathematical model to a single theory. It will be easy to disprove theories once there is a repeatable and reliable experimental procedure out there. Those who have reported being the "easiest" to reproduce are also the ones most loosely documented i.e. Rossi, Defkalion.

A recent big disappointment came with Celani, one of the Italian physicists who was in the same group of scientists and Rossi and Piantelli, where Rossi went on with some of the work, Celani last year claimed he had a small scale reproducible desktop operable demonstration of cold fusion which he would show the world how to use and prove to themselves that it works. He took a thin wire of palladium, which was preloaded (full of hydrogen that was electrochemically forced into it); you could take the wire and bring it somewhere else. And just by passing current through that wire and heating it up, the processes would produce excess heat and cold fusion. He arranged a demonstration last year with instrumentation companies. He gave away pieces of these preloaded wires. So it happened and people got their wires. Everyone who has gone on to test these wires rigorously gathered that Celani's results were nothing short of calorimetric errors. That because of the difficulty of the experiment, there appeared to be no access in heat. This is just one moment in the history of cold fusion that is a huge set back. The history of cold fusion is strewn with these kinds of events. The world has suffered many disappointments like this.

Rossi makes his experiments seem like this error is nowhere to be found in his experiments but he is so paranoid and shifty that no one has ever been able to pin down a demonstration and say okay this was a good demonstration and he's not smudging the results. What really hurt was when he was unable to reproduce an experiment for a group of scientists from NASA, claiming things like I changed a couple of things and maybe it went away. So why do people like I [Cyganski] keep believing? … because there are a handful of experiments that were so well done that you cannot but believe them. (Work done by Iwamura, shows transmutation in cells, he has no theories, just results). Work by Iwamura can only really be done with very expensive and elaborate setups. (Mitchell Swartz, nice guy but doesn't have anything to show for real) Then you have the guy in Stanford Research Institute, Michael Mcubre who presents incredibly well done results. Zawodny has done great experiments in NASA. What we're looking for is an experiment that many labs can reproduce! (It sounds like Zwadenee's and Mcubre aren't up to par with the results from Iwamura).

One important thing to keep in mind here is that you cannot take any theory as the "real theory". For instance Blacklight power theory by Dr. Randle Mills. He has a company with millions of dollars invested in it. His company goes back 20 years. He started with a theory and found what it said should happen. Developing research projects around it. However, no qualified physicist would agree with it. Mills believes some parts of quantum mechanics got it wrong. The typical view of electron shell layers are shown with interval layers going up from one. Mills believes that they don't stop at one, that they do down into

fractional intervals of ½, 1/3, ¼ and so forth. Anti-harmonic set of shells. When the electron drops to these fractional layers it gives off energy. However, in order for it to do this, the setup has to be just right. The just right?... small cavities! When you get a hydrogen atom to drop electrons below that first layer they no longer behave like normal hydrogen atoms. Mills calls these guy hydrinos. His theory is that you can make access energy (some form of low energy nuclear reaction) where hydrinos form. He publishes them in articles that aren't physics journals and shows results from his work. He thinks all of the cold fusion stuff people are getting is actually this strange behavior.
Social Impacts! Jed Rothwell "Cold Fusion and the Future" book is a good resource to look at.

Interesting paper, takes in the social impact nature that may not be obvious. This could be called new steam age, micro steam engines to run your iPad. The real impacts-> a complete and total flip of all economies. The importance of certain geographical will shift almost instantaneously. There will be a huge reshuffling of political power. Complete new shift to a new industrial revolution. It'll flip the whole global warming thing upside down. "Few things would impact the world as much as that would." Prices for nickel and palladium go through the roof. The most value places on Earth will be where you can mine for nickel. "The new middle east will be in Canada, the Falkland Islands, and one location in Sweden."

Do you feel as though there would be a resistance to turning everything upside down. -> No people want to get out of the grips of oil. Oil companies wouldn't be opposed either; they would buy in fast and become our new energy companies. Remember when microcomputers had demise in the industry, they said you'll still need a mainframe… nope… goodbye! You're either with new technology or you're not!

To preface the explanation of Pons and Fleischmann, it should be noted that the two were not physicists, but electrochemists. They thought that they stumbled upon the answer to cold fusion in an electrochemical cell. In their experiment, a Palladium cathode was inserted in a bath of heavy water (water made of heavy Hydrogen). An anode was then included in the bath, and a small voltage applied. Palladium has an affinity for Hydrogen, and can therefore be thought of as a magnet for Hydrogen. The two thought that putting a Palladium cathode in heavy water would saturate it with Hydrogen. Then by applying a small voltage across the cathode and anode, the fugacity force, which is an integral part of electrochemical cells, could be applied to move more Hydrogen to the Palladium rod. If the fugacity force were able to overcome the repulsion of two protons from Hydrogen atoms, the two would fuse. Two Deuterium atoms have a combined mass of 4.02820256 amu, or 6.6889923E-27 Kg. A Helium atom weighs 4.002602 amu, or 6.6464815E-27 Kg. By Einstein's E=mc^2 equation, we can calculate the energy produced based on the mass lost. The energy of one fusion reaction is (6.6889923E-27 - 6.6464815E-27)(3E8) = 1.275324E-20 J. This does not seem like much, but when you consider that a mere 2 Kg of Deuterium contains 6.022E23 atoms, the energy that could be harnessed from these reactions is enormous. Pons and Fleischmann reported gains of about 20 degrees Celsius from their table top experiment. If the magnitude of the reactor was increased, and the ratio of regular water insulation decreased, the gains in temperature would be higher. If these values were tweaked enough that the water insulation exceeded the boiling point of water, steam could be harnessed to drive a turbine. Using this process, limitless power could be produced for little cost or pollution.

The entirety of this section was the compilation of notes from an interview. [11]

4.1 Literary Review

There are dozens of reports of the production of heat at smaller energy gains in LENR experiments. In addition, products from nuclear reactions and energetic particles have often been measured. Neither of those signatures of LENR can be produced by chemistry. So, there is a solid empirical database for the ability to produce nuclear reactions by using ordinary chemical energies. There are more than two dozen theories for LENR, none of which has been tested adequately against experiment. Whether or not any of the current theories will provide the much needed understanding remains to be seen. Going beyond the science to engineering and business, an Italian named Andrea Rossi garnered much attention during 2011 by conducting several tests of a system he calls the E-Cat, short for Energy Catalyzer. In the view of some of us, none of the tests was measured so thoroughly as to remove all doubts that Rossi has a source of significant and useful energy from LENR. However, the tests were witnessed by many capable people, and reports on E-Cat performance were made public. Rossi conducted four tests during the first four months of 2011, all for less than a day, with output powers in the 2-10 kilowatt (kW) range and energy gains from around 10 to over 100. These tests triggered thousands of Web postings, but got very little attention in the mainstream media. On October 28, Rossi demonstrated a megawatt-scale E-Cat system in a 20-foot cargo container. It reportedly produced over 470 kW of power for a few hours. An unidentified customer bought the system for about $2 million, and has since ordered a dozen more of the systems, according to Internet reports. They produce steam, which can be used either for heating or to generate electricity. [12]

Hot fusion is the goal of projects such as the National Ignition Facility which, along with the likes of the Large Hadron Collider, are fine examples of "big science." The NIF has cost, so far, in excess of $3.54 billion (the LHC is even more costly, with a price tag of "$9bn ... as of Jun 2010". The concept of cold fusion goes back to the 1920s, but the general public really only became aware of the idea in the late 1980s when two respected electrochemists, Martin Fleischmann of the University of Southampton and Stanley Pons of the University of Utah, announced they had detected "anomalous heat production" in a laboratory setup orders of magnitude simpler than the equipment used by today's hot fusion researchers. Thus we come to last year's Backspin column on cold fusion. At that time, an Italian inventor by the name of Andrea Rossi had been slowly gathering attention for a device he called the "E-Cat" (short for Energy Catalyzer). How the E-Cat works has never been revealed and, despite the involvement of several respected scientists, the question of whether the E-Cat really functions as claimed has yet to be resolved.

This article points out many key stages in the cold fusion history. Part of our research is to create a timeline of events so that when we document discoveries and advances we can reference the timeline to put things into perspective. [13]

Low Energy nuclear Reaction (LENR) Cells are a new way to use nano-structured electrodes in power cells to produce nuclear reactions at low temperature (relative to the temperature for hot fusion). While still in the research stage, this promises ultimate development of "green" nuclear powered "batteries", offering remarkable energy densities well beyond present technology. The background for this technology and current research on LENR are discussed.

This is a very interesting article as it speculates the possibility of commercializing the cold fusion technology in small applications. Part of our research goal is to investigate ways in which this technology could make it to the consumer. What are the safety concerns, what are the risks, how expensive would this product be? And most importantly, when will these be available. [14]

In January 2011, Italian engineer Andrea Rossi of Leonardo Corp and his colleagues announced at a press conference in Bologna, Italy, that they had built a tabletop reactor that produces copious amounts of excess energy via a nickel-hydrogen fusion like process. Given the stigma still attached to cold fusion, Rossi's energy catalyzer, or E-Cat, as he calls it, has received little attention from the mainstream media. To substantiate his discovery, Rossi has held E-Cat demonstrations for potential investors and members of the media. Cold fusion/low-energy nuclear reactions researchers say they are optimistic that the excess heat's commercial applications are still on the horizon. They point out that, realistically, the applications might be only for small-scale heating and not massive energy production as originally envisioned. Rossi hasn't explained how the units would be integrated into an existing structure, other than they will come with a water inlet and outlet.

Part of our research for Cold Fusion will be the investigation of a few leading and most prominent Cold Fusion pioneers. Andrea Rossi claims to be the closest to the largest commercially available Cold Fusion system. Having an article dedicated to the events, claims, and investigations of Andrea Rossi would be a great resource to use. [15]

The Science of Low Energy Nuclear Reaction: A Comprehensive Compilation of Evidence and Explanations about Cold Fusion “An overview of almost 20 years’ research on cold fusion.

One of our research goals is to craft a timeline of events in the history of Cold Fusion. An article such as this, with 20 somewhat year overview would be very useful for creating a timeline of events. What we need to fully understand the underlying experimental setups and feasibility of Cold Fusion is a comprehensive compilation of evidence and explanation of Cold Fusion. [16]

Energy from present sources has proven to have serious limitations. Fortunately for the future of mankind, several new but controversial sources of energy have been discovered. This paper will describe a method to initiate nuclear reactions within solid materials, so-called Chem. Assisted Nuclear Reactions (CANR). Proposed is a new field of study which combines the electron environment (chem.) with the nuclear environment (nuclear physics), two environments which are thought not to interact. The method generates energy without producing serious amts. of radiation or radioactive waste. In addition, the method is suggested as a means to reduce the radioactivity associated with previously generated nuclear waste. A wide range of experience obtained world-wide over the last ten years is described as well as the controversial nature of the method. [on SciFinder(R)]

This article uses the terminology CANR (Chemically Assisted Nuclear Reaction) which a term used more recently in the cold fusion history. This article claims to investigate the chemical and nuclear physics study of CANR. An article from this point of view could prove to be very useful as we need to understand CANR from all angles of study. Also, because is references Cold Fusion as CANR we can assume that this is a more recent study. Lastly, the abstract discusses the importance of low radiation which will be helpful to start learning about because it will be a talking point in our future case study about commercializing Cold Fusion. [17]

Ultra low momentum neutron catalyzed nuclear reactions in metallic hydride system surfaces are discussed. Weak interaction catalysis initially occurs when neutrons (along with neutrinos) are produced from the protons that capture “heavy” electrons. Surface electron masses are shifted upwards by localized condensed matter electromagnetic fields. Condensed matter quantum electrodynamics processes may also shift the densities of final states, allowing an appreciable production of extremely low momentum neutrons, which are thereby efficiently absorbed by nearby nuclei. No Coulomb barriers exist for the weak interaction neutron production or other resulting catalytic processes.

The first sentence of this abstract mentions ultra-low momentum conditions, in other words, low energy. We're interested in how these conditions can facilitate the catalyzing of nuclear reactions. Based on the terminology present just in this abstract we can expect the article to be written scientifically. This is a good sign that many specific parameters and features in experiments will be well documented. This could possibly lead us to a technical explanation of how cold fusion fundamentally works. [18]

4.2 MIT Cold Fusion 101 Lecture Visit

Professor Peter L. Hagelstein is a principal investigator in the Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT). He received the B.S. and the M.S. in 1976, and the Ph.D. in electrical engineering in 1981, all from MIT. He was a staff member of Lawrence Livermore National Laboratory from 1981 to 1985 before joining the MIT faculty in the Department of Electrical Engineering and Computer Science in 1986.

Professor Hagelstein's early work focused on EUV and soft X-ray lasers, relativistic atomic structure and electron collisional physics, ionic auto ionization and dielectric recombination processes, plasma population kinetics, radiation transport, and large scale physics simulation. He received the Ernest Orlando Lawrence Award in 1984 for his innovation and creativity in X-ray laser physics.

His recent efforts have included the invention of semiconductor technology that could allow efficient, affordable production of electricity from a variety of energy sources, as well as continuing investigations of low-energy nuclear reactions. Professor Hagelstein is the co-author of a new textbook, “Introductory Applied Quantum and Statistical Mechanics,” and chaired the Tenth International Conference on Cold Fusion in 2003.

Notes During / Recap of Visit

During our search of cold fusion experts in the surrounding area, we were fortunate to stumble upon Professor Hagelstein at MIT. He was kind enough to invite us to a lecture he had prepared on the topic of cold fusion. The main purpose of the lecture that Professor Hagelstein put on was to dig into the mathematical relationships between the physical properties of various experiments. . Down the “mile long hallway”, as it was nicknamed, we found a room filled with tension between skeptics and believers. Most, if not all, of the attendees were professors: physicists, mathematicians, and electrical engineers. Upon arrival, Dr. Hagelstein asked us about our background in school and what the scope of our project was. He explained to us that there was a potential that not much of the information to be presented would be of use to us, but he would be happy to answer some questions after the lecture was over. He returned to the front of the room, and a woman in front of us turned and told us that she was a reporter for infinite-energy.com, and that she was glad to see someone else who was not a long time academic in the room. After some brief conversations with various lecture-goers, the power point presentation began.

Professor Hagelstein started his “class” with a very solemn and serious warning. The entire first slide was dedicated to a heartfelt reminder that cold fusion is, as he said “a career killer”, and that though he encouraged those interested to stay and listen to what he had to say, he did not want to be responsible for ruining the lives or reputations of people in the room by imparting his knowledge on them. He then quickly moved on to the subject we had all been waiting for; cold fusion. He started off by reminding the attendees about Hamiltonians and how they are often used to mathematically model experimental findings. A theory is essentially proven if and when a model can be produced that explains an observation in a lab. He then went through the progression of a few models which had attempted to prove the existence of cold fusion, but had failed to do so. However, with mathematical savvy, he was able to alter one of the equations in order to represent a cold fusion reactor. The only problem was that it is yet to be tested in a lab setting, because it requires an oscillator on the order of terahertz frequency, and a large apparatus that could easily fill a normal sized room. The audience appeared skeptical upon arriving at this conclusion because of the impractical setup it would require. He proceeded to mention a colleague who he has worked with before by the name of Karabut, who has been doing experiments in Russia. Not long ago, Karabut sent him a paper after getting unexpected results from a recent experiment. Professor Hagelstein read the paper, and came to the realization that Karabut had seemingly gotten the exact result that Hagelstein was trying theorizing about, except that Karabut used a device that could sit on a table top. Karabut’s documentation of the experiment is not quite complete, partially because he was not aiming to produce the experiment that professor Hagelstein had thought up. Because of this, professor Hagelstein speculates that Karabut is actually using tainted equipment. In particular, he believes that Karabut has mercury on one of his sources, and that is why he is getting possible proof that cold fusion can exist. If Hg201 (which has the lowest energy nuclear transition) can produce a collimated x-ray effect, the quest for proof is complete. After seeing Karabut's experimental results, professor Hagelstein tried to apply his mathematical model to the apparatus (under the assumption of mercury presence), and was disappointed to find that he once again needed to do some tweaking. In August of 2012, he had what appeared to be a working model, until a mistake was found in October. Since then, Hagelstein has been devoting all of his time to modifying his model to match the results of Karabut. His presentation ended with his explanation that he is about one week away from finishing the model. In fact, he said that if he had not taught his "crash course" on fusion, that he would most likely be done. Once he is done, he will once again compare his model to Karabut's experiment. He has high hopes, stating that he believes he has done it this time. In our brief "interview" afterwards, he said that if he is successful, he expects the paper to be published mid-summer of this year.

Concluding the presentation, we had the opportunity to pull Dr. Hagelstein aside and ask questions that were tailored for our case study. Even though we had seen he was not much interested in the implementation of the technology, we were still interested in his opinion from a technical standpoint. Below is a paraphrased account of our interview with Dr. Hagelstein.

Q: Is cold fusion technology a matter of time or is it proven?

A: Proven, yes. Experiments which showed commercially interesting applications have been done. The NANOR device is one which is commercially interesting and the good thing about it is that it's reproducible.

Q: What types of failure would a device of this nature most likely fall subject to?

A: This experiment at question here is the Pons and Fleischmann setup and was deemed unsuccessful from an early start. However, the most probable cause of failure in this setup was the fact that the scientists testing their experiments did not wait long enough to observe excess heat.

Q: How close are we to a device that is ready for the market?

A: The NANOR device uses technology that is commercially interesting. It had gone through scrutiny as its output power fell to zero unexpectedly. However, diagnostics revealed that there was a physical leak in the system and once fixed, the output levels returned to normal.

Q: What sort of technology is in place to effectively translate this heat to electricity? What's the best way to do this?

A: I am more concerned with getting the science down first, before moving on to the commercialization phase. Mitchell (in reference to Mitchell Swartz) has more experience with the engineering aspect for the conversion.

Q: What has been the biggest impact on Cold Fusion from society?

A: The first thing that comes to mind is how society has pushed scientists out of jobs and completely discredited many who have worked in the field of Cold Fusion. This kills their personal life.

Q: What do you see the biggest impact Cold Fusion technology will have on society?

A: The biggest impact/ most important implementation would be with areas that have poor water quality. This system could be used to boil water and bring clean water to poor communities in Africa. This could also be used to heat gas to replace the combustion engine.

Q: What sort of safety measures/ techniques would be used to make this technology safe in a commercially available device?

A: The palladium deuterium setup runs clean; one neutron for every 100 joules of energy. The Nickel Hydride setup (like Rossi) gives of gamma emissions. This would require some type of shielding. Materials like concrete, lead, and boron infused water.

Q: We've read that the MIT community had previously shut down operations to advance research in Cold Fusion. How has the community responded to these Cold Fusion lectures you're offering?

A: The MIT community has ignored what I'm doing here. As you can see, no one from MIT attends these lectures; they are "too smart" (he said while rolling his eyes) to follow it. [19, 20]

5. Crystal Ball Overview

The purpose of the following section is to discuss some of the potential societal changes that may be brought about by the advent of cold fusion. This is not an exact science; however the predictions made will be reinforced by our thought process.

The "peek into the crystal ball" was broken down into three main aspects, the first of which being residential. In this we aim to explore how the average homeowner would benefit from cold fusion. Be it a cold fusion generator for backup power, or a lower energy bill thanks to a cold fusion power plant, we expect that the consumer would be able to reap many benefits from cold fusion. The second section of the future predictions involves the commercial ramifications of cold fusion. Jobs may be gained or lost due to cold fusion, depending on how it is implemented, and what scale upon which it is used. Finally, we aim to highlight some of the potential effects cold fusion may have on the military. With nearly unlimited, clean energy, the military may be able to further its use of unmanned apparatus to perform tasks over extended periods of time. Cold fusion may also lead to the creation of new weaponry, or defense tactics.

5.1 Future Event Timeline

Thought Process behind the Timeline

We decided that it might be of interest to provide our own thoughts about the future of cold fusion in the form of a timeline (see Appendix II). Based on our expectations of its use, we aim to predict the evolution and growth of cold fusion. The first event on our timeline is the proof that cold fusion can be a commercially feasible venture. Until this is done, cold fusion will probably be no more than a science experiment. As with many new technologies, especially involving nuclear reactions, it will be heavily regulated by safety committees. Four to five years after becoming commercially advantageous, the first cold fusion plant will be opened in the United States. There are two reasons to expect a delay between proof of concept, and the first plant; the first being that it would take some time to manufacture cold fusion reactors on a large scale. Because the technology will be in its infancy, there may be very few companies capable of making the devices, which would stunt the growth of these power plants. The other limiting factor is that the pioneering power plant would require time to undergo safety testing, and pass the requirements of safety organizations. For the first few weeks or months of this plant's existence, we expect the public to oppose its use because of the word "nuclear", and its connotations. People are generally resistant to major changes, especially when it is something that they do not understand. The only foreseeable consequence of the public's fear is that cold fusion takes a little while longer to gain traction in the US.

The first predicted use of cold fusion is merely to generate electricity. It can be funded by large corporations, and the infrastructure for delivering it to consumers is already in place, in the form of our electric grid. For this reason, it is expected that one of the first implications of the rise of cold fusion is the expansion of electric cars. It is not only beneficial to the environment, but with the availability of nearly free electricity, cars that can be charged from a house outlet would seem very appealing to anyone who is tired of the weekly expense at the gas station. The electric car industry will likely grow significantly, at the expense of gas stations. Larger chains like Shell and BP will be able to survive on lower than normal profits, but many smaller chains will be put out of business in a matter of months. Around this same time period, the development of a car run directly from cold fusion is expected to begin. This is a project that we foresee taking extensive research and time, but its early stages will begin shortly after the advent of cold fusion.

Ten years after cold fusion makes its breakthrough, an unforeseen problem will arise; the electric grid will begin to malfunction due to higher than ever demands placed upon it. The high strain on the grid will be facilitated by the abundance and cost effectiveness of electrical energy; cold fusion will make electricity the cheapest and cleanest energy source on the planet. To take advantage of electricity's appeal, manufacturers of devices that never used electricity in the past will begin to develop models that use rechargeable batteries, or even run from a wall socket. For instance, electric cars may find themselves in a larger percentage of homes, all requiring to be charged overnight. This would add an enormous amount of pull on the electrical grid, and with aging equipment, we foresee the need for an upgrade of the grid. In fact, within fifteen years, we expect that about 25% of the entire Unites State's energy production will be cold fusion. As all of this will be harvested in the form of electricity generated from heat, a new strategy of developing cold fusion powered devices will be the goal of more and more research and development companies. Soon enough, we think that companies who stood by traditional power production methods will either make a last-ditch effort to switch to cold fusion, or be driven out of business by more cutting edge competitors.

Twenty five years after cold fusion becomes reality, the generators will be far more efficient than they were in the beginning. After being given enough time to "perfect" the technology, we estimate a feasible improvement to be about 33%. Due to the increased effectiveness of the devices, and the increasing public opinion of cold fusion, by twenty five years after cold fusion becomes available, we predict that it will account for 75% of the energy production in the United States. By forty years after our year of creation, cold fusion will be found in the engines of cars, planes, boats, and other larger machinery. At that point, cold fusion will have replaced the internal combustion engine as we know it today.

5.2 Residential

One thing that all average families have in common is a car being their mode of transportation. In a study reported by *AutoSpies* the average family owns 2.3 vehicles [21]. When gas prices rise or repairs need to happen to a vehicle, every family feels those cost pains. People rely heavily on this technology to make a living. Recently in our automobile history there has been a shift to electric powered cars in the form of either a hybrid or an all-electric. The main problem faced with purely electric power is its energy density. The optimistic article reported by *Scientific American* points out a few breakthroughs in new energy densities of car batteries [22]. This claims that the best battery can give 400 watt-hours per kilogram, twice as good as the existing. However, this comes at a cost, a cost of $125 per watt-hour as listed in the article. That means for every kilogram of the battery mass, it would cost $50,000! How many kilograms does a typical electric car battery weigh you may ask? The article on *HowStuffWorks* reports "The lithium-ion battery pack in a Tesla Roadster weighs about 1,000 pounds (453.6 kg)" [23] Using this "new battery" we would only need have of that battery size, so 226.8 kg * 50000 $/kg = 11,340,000 using the numbers given on the optimistic article about this energy dense new battery. Simply put, this is a staggering price. The amount of money this battery costs is not appealing to an everyday commuter. Because of this, it's exciting to discuss the possibility of using Cold Fusion as a fuel source for a car. If some people are desperate enough to spend millions of dollars to avoid gas powered cars, then they might also be in the price range for a 400 watt-hour Cold Fusion reactor.

With the possible rise of Cold Fusion technology in vehicles or any other power source there would be an incredible growth in the job market. Cold Fusion could first start showing up in course curriculums at Universities and Colleges alike. Technicians would be required to maintain the operations of small and large scale Cold Fusion reactors. Aside from the operational and maintenance point of view, there would be a large opening for manufactures to assemble these devices. Fabrication companies would need many working hands or engineers to design robotic arms/ machines to create the reactors. Furthermore, there would be a large demand for the natural resources and materials which are unique to such a device. One of which is palladium. Over the years 2002 to 2006 the United States production statistics for palladium have remained in the 13,000 - 14,000 [kg] while the imports have increased from 117,000 - 140,000 [kg] in the same year span [25]. This is probably due to the availability of raw materials in the U.S. being lower than in other countries. More research needs to be done to look into these exact totals and possible cost impacts if all of a sudden Cold Fusion manufactures needed to import lots of palladium.

Another appealing attribute of Cold Fusion generated electricity is the speculated cost. By nature, the device produces more power than put in by tapping into its stored potential energy. Therefore, you're costs would be to purchase the device and provide its startup energy.

One thing that we have given much thought on the topic of consumer cold fusion is how the energy would be provided to the average person. We found that it would be impractical and inefficient to expect each household to purchase and maintain a cold fusion reactor. Instead, we foresee a compromise between this possibility, and the current grid system. We think that the most effective way to take advantage of cold fusion is to allow groups of people to purchase a reactor themselves, and use it for their energy needs. In most cases, this would mean a town, or section of the town pitching in to buy a cold fusion generator. There are many pros and cons that come with this option, which we plan on discussing, and providing a reason for the conclusion we have come to.

One drawback of a communal reactor is that it would require maintenance, which cannot be trusted in the hands of just anyone. One caveat that potential generator customers would have to keep in mind is that they would be responsible for finding, and paying for a technician that would be in charge of repairs and updates if and when they become necessary. This system would work similarly to the way homeowners today hire a plumber or electrician, except that in this case the serviced area is a town or neighborhood instead of a singular house. The users of the generator would also have to devise a way to keep the reactor safe from people, and Mother Nature. Because of the severity of any tampering, it would be vital to protect the cold fusion reactor from any interaction other than the previously mentioned technician. That being said, there are some positive effects that can come from this setup. For instance, this opens up an entire field of new jobs for the economy; there would suddenly be a demand not only for reactor technicians, but also for schools that teach the necessary tools to individuals interested in that field. Another positive result is that the power that the customer would receive is more localized in this new setup. This means that the dependence on long distance electricity transfer could be lessened. As energy is always lost across these long distance conversions, the localized generator "grid" could be very efficient in delivering power. Another advantage to more bounded energy production is that power outages would likely span lesser areas in a theoretical storm. By spreading out power stations as opposed to one interconnected system, the setup is less susceptible to large failures.

Because of the nature of cold fusion, heavy regulations would likely be put in place to protect people from adverse effects. New laws would be put in place that would harshly punish those who tamper with cold fusion reactors, because of how many lives that any mishap could ruin. Aside from purposeful destruction, we expect that the government would require annual (or even more often) checkups on the devices. Whatever the expense of maintenance on a cold fusion reactor, the users must be willing to pay for, or deactivate the generator. To prevent accidents from happening, we imagine that the government would be very strict about the rules which cold fusion generator beneficiaries would have to abide by.

One last concern in the implementation of cold fusion to our energy grid is the potential health effects they may have. Without proper testing, and the ability to understand how to adequately protect people from radiation and any other byproducts, we do not expect cold fusion generators to ever be put into use. Due to the need for assurance that people and animals are not put in harm's way by these devices, we foresee the demand for long term, in depth testing to prove that the devices are safe. Once this is done, we believe that there *can* be a slow shift towards nuclear fusion reactors. The reason the transition is expected to be slow is the mindset of the public. The word nuclear can be scary, especially when it is in the form of a nearby generator. We think that the first people to use nuclear fusion power to run their homes will be people directly involved with the designing process of the generator itself. After some time, the environmental groups may see it as an alternative energy that is safe to sustain mankind's energy needs over the long term. Despite this, it is believed that the general public will take a long time to "warm up" to cold fusion. Myths still exist about the health hazards of 60 Hz, even though tests have shown no evidence of adverse effects from this frequency, and the fear of cold fusion would be even more resilient. Hopefully with time, the world can see the potential of cold fusion, and begin to take advantage of what may be a truly amazing technology.

5.2.1 Cost Analysis

E-Cat Use in Homes and in Power Plants

A cost review and Social Review

Originally we theorized that if Cold Fusion technology could develop into larger systems, it would be useful to set up many localized power systems with mid-sized generators. The benefits of this system would mean you would be less prone to power outages, the power averages for output would be better fit for each area, and in theory it would exhibit less loss in power over long transmission lines. However, in practice, this strategy may not work out so well. In an article documented by *New York Times* we have a better view of the power grid system. [26]

This interesting take on the grid system looks into the crystal ball to theorize what would happen in a world of localized power systems. In a nutshell the article concludes that different sectors of localized power plants would not all operate with the same efficiency or reliability. This is because pockets of communities are very wealthy; a concentrated source of wealth would in turn want a better localized power plant. This power plant would be much better than the power plants in poorer communities. As a result, there would be more neglect in towards the power plants in the poorer communities because it would cost more money to fix their problems and maintain operation.

We believe that if Cold Fusion technology were to manifest into a viable power plant energy source, this same dilemma would occur. Localized power stations using Cold Fusion Technology would require specialized technicians on site as well as security and any other power technicians to run power lines.

For these reasons we will be looking into two systems;

1) E-Cat systems installed in each house and operated individually

2) Replacing some of the existing 18,530 Power Plants in the US [27].

As a bird's eye view we can acknowledge the change in demand for energy throughout the day. This response can be simplified and viewed as AC curve peaking in the early afternoon and falling down in the night hours. In order to avoid turning off Cold Fusion power plants during the night hours we could offer a better solution. If we maintain an average power output from power plants that was between the peak demand and lowest demand overnight we could rely on large battery banks to store the surplus energy produced during the night hours. These battery bank storage devices could in turn release energy during the peak hours to relieve the load on the power generators. [26, 27]

To determine the feasibility of the E-cat system powering our country, we first had to obtain some figures to use as a benchmark. We found that the average household consumes about 90 million Btu per year [28]. Then we needed to get an idea of what type of output to expect from the E-cat device, and we were lucky enough to find a (slightly confusing) report with estimates of energy produced. Rossi claims that when he ran 100 of his E-cat systems in parallel for 5.5 hours, 2,635 kWh resulted as an output gain [29]. We then needed to do some conversions to makes sense of this data.

To calculate the output of 1 E-cat in Btu:

$$\frac{2635\ kWh}{5.5\ h} * \frac{3412\ Btu}{kWh} = \frac{1.63E^6\ Btu}{h}$$

$$\frac{1.63E^6\ Btu}{h} * \frac{1}{100\ E - cats} = \frac{1.63E^4\ Btu}{h}$$

Now if this were to be left running all day every day for an entire year, the total output would be as follows:

$$\frac{1.63E^4\ Btu}{h} * \frac{24\ h}{day} * \frac{365\ day}{yr} = \frac{1.43E^8\ Btu}{yr}$$

Because the expected usage of energy is only 90 million Btu ($9E^7$ Btu), it is clear that the device gives off more than enough energy to power a home. In fact, the exact time that it must be left running can also be calculated.

$$\frac{9E^7\ \frac{Btu}{yr}}{1.43E^8\ \frac{Btu}{yr}} = .6285$$

So the E-cat would only have to be on about 63% of the time (or about 15 hours a day) in order to generate enough energy to sustain a household.

As it stands, most people get their energy from power plants across the nation. We wanted to see how much the average plant outputs in energy, so we found a website that gave us a few useful numbers to work with. We found that plants in the US output about $1.15E^6$ Megawatts, and use 18,530 plants to do so [27]. Of this energy produced, about 40% is for residential use [6].

$$\frac{1.15E^6\ MW}{18530\ plants} = \frac{62.1\ MW}{plant}$$

This means that in order to switch the residential portion of the United States over to 100% E-cat devices made by Rossi, each power plant would have to be replaced by 6200 of his 10kWh systems.

18530 * .4 * 6200 = $4.59E^7$ MW E-cat setups

However, if you instead decided to put one E-cat in every home, and let them use it as a private generator, you would need many more. We found that there are about 130 million homes in the US [31]. This means that you would need 130 million (or $1.3E^8$) E-cat devices.

From previous estimates in regards to cost (provided by Rossi himself), one unit would cost about $1000 (conservative estimate), and would have to be "refilled" twice a year at about $10 per refill. This equates to $20 a year in energy costs, with an upfront investment of $1000, which is an amazing deal by today's standards. The only question raised by these findings is whether it would make more sense for each home to have an E-cat generator, or if current power plants should just be renovated to replace old means of production with the E-cat systems.

5.3 Commercial

Cold Fusion Future Impact on Commercial Aspect

The advancement of transportation, delivery of goods, and manufacturing has greatly impacted the world. This aspect of society is seen everywhere. Similarly, if something big happens in society, like the release of the latest iPhone, the results are immediately seen in society. People are seen more and more often with this item on their person. Furthermore, if gas prices skyrocket then the overall price of goods goes up and everyone feels some sort of pressure. The aim of the section below is to outline and draw conclusions about the future of cold fusion and how it might impact the commercial aspect of society.

As it may be one of the largest impacts companies and business have ever seen, we must first draw connections between the inner workings of society to understand how this technology can impact it. The most promising setups for cold fusion involve some amount of either palladium or nickel powder. Professor David Cyganski mentioned in an interview that some of the most sought after places on the earth will be for nickel and other materials for manufacturing cold fusion units. Three major locations for mining nickel are known. They are located in Canada, in the Falkland Islands, and in Sweden. The price of nickel may grow exponentially if no other mining locations can be established, as nickel will quickly become a necessity for many cold fusion based companies.

In addition to the changes in worth of raw materials, we predict a ripple effect that cold fusion may bring upon society. This effect is most easily understood in picture form (see Appendix IV), but is explained in words below.

Emergency power backup: In the event of a large natural disaster, like the ice storm of 2008, small companies and businesses alike scramble to find backup power generators. At the risk of ruining cold perishables or disrupting important mechanical processes, businesses need reliable power. Cold Fusion technology has the potential to mitigate company losses due to power blackouts by providing cheap, reliable energy backup solutions. In the case of a large natural disaster, the smaller businesses are at a greater risk for losses because they may not have the money for big expensive generators. Cold Fusion technology will be able to provide backup energy generation with localized power plants for emergency situations. Cold Fusion technology could provide a solution which is non-air or water polluting, little noise, and compact which is perfect for emergency backup systems.

Localized power Stations: For residential sites, the localized power station idea is a poor one, and is described in greater detail in the consumer section. However, for the commercial section, localized power stations might be an appealing power backup idea for large corporations which require on site and reliable power.

Make power more reliable: The general idea behind a localized power system is to eliminate the uncontrollable variables of error in power transmission. Such mishaps include natural disasters which wipe out transmission lines, or degrading climate affects causing power loss over transmission. Not to mention, if there was any mechanical failure, it would be isolated at the source of the company for easy repair as opposed to an off-site station.

Cheaper overhead cost in a business/ manufacturing plant: There is a fixed cost associated with any business. Let's take an example company that manufactures large quantities of paper plates. They can reduce the cost per plate by buying cheaper materials to make the plates. In fact let's say the company can get those raw materials for free. In order to have a profit the company sells the goods at a price higher than the overhead cost. This overhead cost consists of worker salaries, maintenance, defects, and power consumption. This cost seems unchangeable; however Cold Fusion technology can provide cheaper energy and thus lower the cost of goods. If the cost of energy goes down, then the cost of transportation goes down. When a product arrives on the shelf for the consumer will be far less expensive than it would be using conventional energy systems.

Improved lifespan/ reliability of products: Could the technology of Cold Fusion improve the average lifespan of the common person?

Provides opportunity for new businesses: The rise of a new technology means a rise in new products. This correlates to an opportunity at new businesses and jobs.

More jobs for the US: There is a current problem in America with outsourcing jobs to different nations. A new technology, if founded in America, could help build more jobs for America. Cold Fusion technology is a complicated concept and requires many skilled technicians to operate. That being said, if Cold Fusion were ever able to become a reality, it would require a large set of technicians. This creates space for available jobs. Furthermore, there needs to be professors and a knowledgeable staff to educate upcoming technicians. This demand for teaching also creates a need for jobs.

This depends on who develops the technology first**;** the potential profit for the first organization to create a reliable Cold Fusion device is enormous. Most likely this drive for wealth and power will lead to a global race for the perfect Cold Fusion setup

Fight for material market: In order to create a successful company which deals with Cold Fusion, the resources for manufacturing the devices must be well thought about. Some of the most sought after places on Earth will be those which contain naturally occurring Nickel. This global impact could rearrange the importance of different trade routes and ultimately turn the global market upside down.

How CF technology could affect raw material extraction: One unique impact of Cold Fusion technology could be improving raw material and mineral extraction. This technology has the potential to be utilized in remote locations due to its enormously high energy density. One big struggle with mining operations for raw materials is the fact that they are remote. By using Cold Fusion technology we can provide the energy right at the source. Imagine automated mining machines operating miles below Earth's surface powered by Cold Fusion that would run for weeks or months at a time and be remote controlled.

Deep water operations: Other uses for remote Cold Fusion include deep sea operations. Robotic submarines have the ability to remain at the depths of the sea for long amounts of time. Imagine if these autonomous crafts were able to stay on the sea floor for many weeks or months at a time.

Space operations: Another use for remote Cold Fusion includes space exploration. One way of providing power to rovers and space station segments is through solar cell collection. However, when a rover is on the surface of another planet the solar panels may be rendered useless due to a large dust and debris build up. Cold Fusion technology can offer a reliable and continuous power output on a relatively small amount of fuel.

5.4 Military

The beginnings of Cold Fusion, and any technology in the matter, will be expensive. The division of society with the greatest amount resources to spend is the military. Therefore, military divisions would most likely be the first to use the technology. The long lasting energy production that Cold Fusion promises makes it very attractive for use in remote military applications. Cold fusion research and development has primarily been all independently funded. However different Department of Defense agencies have "provided funding, confirmed results, or reviewed cold fusion research". [32] Such agencies include Naval Research Laboratory, Defense Threat Reduction Agency (DTRA), Defense Intelligence Agency (DIA), Defense Advanced Research Agency (DARPA), and Army Research Lab (ARL). The implication of this technology justifies Cold Fusion technology as something that is worth looking into, especially from a military perspective. If there is a chance that the wild theories may have some truth to them, it would be beneficial to be the first ones to have a working prototype.

The Naval Research Academy has conducted experiments with the following results: "i) experimental confirmation of the *excess heat effect* correlated with the creation of *helium*, ii) evidence for nuclear reactions detecting the production of *neutrons*, *tritium*, and other *transmutation products*, as well as sporadic x-rays. Confounding attempts to fit the process into conventional theories, the particles are not seen in great quantity, nor do they occur in all experiments." [32]. The Defense Intelligence Agency reported evidence which suggest nuclear type reactions were occurring under conditions never seen before. Several scientists at the Defense Threat Reduction Agency presented results "confirming cold fusion as a source of energy. The report acknowledged this conclusion with the statement: 'legitimate experiments by reputable researchers worldwide continue to demonstrate excess heat production'." [32] Furthermore, the reports from the Army research Labs provide a good military application summary. The nature of "Cold Fusion" nuclear reactions is much different than typical fission or hot fusion. Due to the relatively slow release of energy in Cold Fusion reaction it is very unlikely to see it used for any sort of weapon technology. Instead, the dense energy power for medical support, electricity, transportation, and heating are all attractive qualities for use in the military.

Andrea Rossi has been put in the spotlight of Cold Fusion technology in recent years. His claims of having commercially available equipment give rise for a lot of excitement in the energy world. It follows as no surprise that when Andrea Rossi mentioned that his first customer for the 1MW E-Cat system was sold to a military research division. [33]

Cold Fusion has potential use in unmanned vehicles. Due to the high energy density of the technology, small planes will be able to travel vast distances without the need for refueling. The problem would then be with pilots and copilots needing rest. However, if the vehicle was unmanned, then it could be a very useful piece of equipment, as this restriction would no longer exist.

One article brings up a few line items which strongly suggest Cold Fusion research at DARPA. "Darpa may be home to many crazy ideas, but they don't talk about cold fusion, either, at least not openly. However, a close look at their budget documents under 'Alternate Power Sources' reveals that in 2007 they 'Completed independent evaluation of recently reported experimental protocol for achieving excess heat conditions in Pd cathodes.'" [34] Furthermore, in the following year's budget, DARPA was set to "Determine the correlation between excess heat observations and production of nuclear by-products." [34]

The advances brought about by cold fusion may change the face of warfare as we know it. With addition of immense energy storage, the range and place of battle could be in very exotic locations. This has the possibility of bringing warfare to places as far as beyond our atmosphere.

The advance of Cold Fusion technology could mean longer missions. The military division of society is the largest consumer of gasoline fuel. This division would therefore be the most affected group with regards to an evolution in fuel technology.

5.5 Analysis of "Cold Fusion and the Future" by Jed Rothwell

Jed Rothwell is a cold fusion enthusiast who has written a book (available in PDF version for free) on his thoughts about cold fusion. Though the book is based primarily on speculation, and very little on physical evidence, it is a useful tool for the purposes of hypothesizing what may become of cold fusion. The author himself provides the disclaimer "This is a book of predictions, not engineering specifications. If, in the future, these problems are fixed with cold fusion powered machinery, the machines will be far different from anything I have portrayed here, or indeed, anything I can imagine. I am only suggesting what might be done in principle, to show that solutions are possible" [35].

The first part of the book focuses on why cold fusion is desirable for economic reasons, and also why we should not give up on it despite its early troubles. He draws an interesting parallel between cold fusion and other technologies that took time to perfect, stating that “from 1948 to 1952, transistors existed only as rare, delicate, expensive laboratory devices that were difficult to replicate. One scientist recalled that, ‘in the very early days the performance of a transistor was apt to change if someone slammed a door. By 1955, millions of transistors were in use, and any of these later mass produced devices was far more reliable than the best laboratory prototype of 1952” [35]. On that note, imagine if transistors were given up on in the late 1940s; we would not have smart phones, flash drives, computers, or hundreds of other amenities that we cannot imagine living without. Rothwell then provides his own explanation of the evolution of technology with the simple phrase “first a toy, then a luxury, then a necessity” which manifests itself in almost every new invention. For example, when cars were first being developed, they were merely a toy for the scientists and engineers who worked on them. After some time, the rich were able to purchase cars as a means of travel, but also to display their wealth. And finally cars developed to the point where almost every person uses a car in some way, be it a taxi, a bus, or a personal car. Even though cold fusion may take years or even decades to comprehend, it will be time well spent if the technology is ever realized. Shown below is a table that compares energy sources in use to fusion to demonstrate how valuable cold fusion might be if it can be perfected. [35]

	Pollution free	Very safe	In-exhaustible	Unlimited	Low fuel cost	Low reactor cost	Compact	Locate anywhere	Works 24/7 (4)	Ready now
Fossil fuel						✔	✔	✔	✔	✔
Hydro-electric	✔	✔	✔		✔	✔	✔			✔
Wind	✔	✔	✔		✔					✔
Solar	✔	✔	✔		✔					✔
Uranium fission	(1)		✔	✔	✔		✔	(3)	✔	✔
Plasma fusion	(2)		✔	✔	✔		✔	(3)	✔	
Cold fusion	✔	✔	✔	✔	✔	✔	✔	✔	✔	

Figure 6: Comparison Chart for Different Energy Sources

Rothwell goes on to elaborate on the monetary advantage of cold fusion, citing that "every day, worldwide, people spend $3.7 billion on fossil fuel, to generate 0.9 quads of energy. Cold fusion would generate that much energy from 15 tons of heavy water, which would cost approximately $3.5 million" [35]. This corresponds to a ratio of 1000:1 in spending on energy; for every thousand dollars that are spent on fossil fuels, the equivalent cost with a cold fusion device would be one dollar. This could single handedly end problems of heating and cooling homes around the world, as the cost to do so would become negligible. As he further explains why this could serve as a panacea for energy woes, he reminds the reader that the only byproducts of a cold fusion device would consist of oxygen, helium, and radiation (which can easily be shielded within the device enclosure).

Rothwell continues his analysis of cold fusion devices in the context of automobiles. With a hint of sarcastic cynicism, he reasons that "the average automobile will consume about a gram of heavy water per year. This is assuming that first generation cold fusion heat engines will be only as efficient as today's gasoline engines, converting 20% of the heat into vehicle propulsion. (It is hard to imagine they would be less efficient. It would take a perverse genius to devise a modern vehicle more wasteful than today's conventional automobile.)" [35].

One potential downside of cold fusion in the Pons and Fleischmann setup is that "demand for palladium [already] outruns production", and if palladium's demand is increased by the advent of cold fusion, it will become even harder to gather enough palladium to meet requirements. It follows that "if cold fusion only works with palladium, we will have to make maximum use of the palladium we have, by generating power from it 24 hours a day in large, centralized, baseline power company plants". This is not necessarily a bad thing; however it does limit the potential uses of cold fusion by not allowing it to power devices directly. [35]

Another aspect of cold fusion that Rothwell discusses is its journey into use. With a buzzword like *nuclear*, it may be difficult to convince the public that cold fusion is safe to use in their homes. Rothwell also points out that "before cold fusion can be commercialized, it must overcome many hurdles, starting with the political opposition that has prevented funding. That achieved, large-scale research can begin. Progress may be slow until a comprehensive theory emerges, and no one can say when that will happen. Once we have a theory and we learn how to completely control the reaction, engineering development can begin". It may be troublesome to come up with an explanation of cold fusion that is satisfactory to those in charge of regulations on power and energy, which may stunt the early growth of cold fusion. Another problem that he calls attention to is people's instinct to resist change in general. A great analogy used to defend this notion is "the typewriter QWERTY keyboard was invented to keep the typewriter keys from tangling together when people typed quickly. It has been obsolete for over a century, and other layouts would make typing faster and easier. Stephen J. Gould described QWERTY as 'drastically suboptimal'". Even though there are sometimes better options available, people get used to what they know, and are unwilling to stray from that for something new. [35]

If however, people are willing to change, Rothwell claims "there will be millions of beneficial changes to machines of all types … I cannot guess what they may be. Engineers and product designers will soon learn how to use cold fusion, just as they learned how to use microprocessors when they became available in the 1980s"

Another change explored by Rothwell involves technology related to cold fusion. The energy that cold fusion produces is in the form of heat, and though this in itself is not a bad thing, to be useful for powering most modern day devices, it must be converted to electrical energy. It is possible to convert this heat to electric energy with the use of steam powered turbines, but he points out that thermoelectric chip may also be a solution. Currently these chips are inefficient, and therefore not practical, but if cold fusion were to be perfected, it would provide a strong motive for development of these chips. Rothwell points out that "a thermoelectric chip converts heat into electricity without moving parts, similar to the way a photovoltaic chip on a calculator converts light into electricity"[35]. With respect to economic changes brought about by cold fusion, Rothwell believes that both gasoline and electric companies will fail. He mentions that gasoline will meet an abrupt end because their product will become obsolete and “fossil fuel energy companies will have difficulty entering the market for cold fusion products for a simple and strictly practical reason: they have no relevant qualifications” He has a little more faith in the resilience of electric companies; though he thinks they will be driven out of business in the long run, they will find a niche in the market for the near future. The two things that Rothwell believes may keep electric companies afloat are that he believes they will “remain competitive with home generators and may even replace some of their outdated plants with centralized fusion plants, which is a topic we had also considered.

The main themes from Jed Rothwell in the final section of his book are based around his exuberant support for a well-functioning and friendly society. One of the best quotes which describe the emotion from this section is: “technology is best when it is invisible.” [35]. Due to the nature of the application for cold fusion, it should be used in remote places which do not interfere with society. Jed Rothwell is mainly concerned will restoring society and communities back to a state of simplicity.

Jed Rothwell pushes the importance of advances and scientific research in the Cold Fusion department because he believes that humanity is currently living in a pivotal situation. The global population is rising, and fossil fuels will be depleted with the mass consumption of material. He further explains that it is in common interest of all humans to want material goods and more things in general. This demand can only be kept up with by major societal shift or advance in technology. Rothwell believes that Cold Fusion technology has the potential of being this technologic advance and enabling a new age in humanity. Stating the ultimate purpose of cold fusion, or any technology, is to give people the freedom to do for themselves [and] take charge of their lives" [35]. He does however warn that "cold fusion can bring us a little closer to Utopia, that elusive ideal. It can certainly bring health, leisure and material wealth to everyone, which is probably as close to Utopia as we can wish for. But Dystopia is always a possibility. People can turn any blessing into a curse" [35]. By this he means that cold fusion is not something that should be used for wasteful purposes. Unlimited energy sounds spectacular, however the misuse of energy (or power) is a consistent theme in the history of our species, and we must proceed with caution. An example he uses is lighting; it may be great to not have to worry about leaving large lights on for an extended period of time, but this is detrimental to our own health, as well as the health of the surrounding ecosystem.

Despite these warnings, he ends this topic on a more optimistic note, noting that cold fusion will give us wider choices and more opportunities. It will give us the means to undo nearly all of the damage we have done in the past and to make life better for everyone". [35]

6. Conclusion

6.1 Our Opinions

As a recap of significant events in the history of Cold Fusion research we can look at perspectives of scientists. In the beginning (right after 1989 when Pons and Fleischmann made their announcement), those who believed in the legitimacy of cold fusion seemed to rely only on hope. The vision of a cold fusion powered fusion by this simple table top experiment seemed to be such a good answer to the world's power problems. And those who were against the theory stood firmly behind hard evidence that they collected from the attempted replications of the Pons and Fleischmann experiment. They suggested output values that were exaggerated from the unexciting values that all other scientists were getting.

Over the past few years however, it seems as though the tables have turned. Though we do not yet have a practical, working device for cold fusion, it seems as though multiple groups are approaching the coveted mechanism for almost limitless energy. Andrea Rossi claims to have a working cold fusion apparatus, Michael McKubre has seen breakthroughs his studies of low energy nuclear reactions, and Osaka University professors Arata and Zhang have also recorded improvements in their methods. Although these reports are often met with skepticism, the critics are now the ones arguing based on faith, whereas the pioneers for cold fusion have physical data to back their affirmations. This could be due to the fact that reputations and pride are at hand. Nobody wants their work to be discredited, and it's possible that the people who previously "*proved*" that cold fusion was impossible are now *hoping* that they were right for the sake of the validity of their work. The cold fusion products are not yet finished, nor are they supposedly perfect, but they do exist, and are constantly being improved.

It is our collective opinion that it is a matter of when, and not if, cold fusion will become reality. It might not be a panacea for the worlds energy needs, but given time, it will become one of the most environmentally friendly means of energy production. Cold fusion is a strange research subject for those who are quick to dismiss its feasibility. However, it would only be strange if it worked from the start and skyrocketed with success. If the history of scientific advances has taught us anything it's that discoveries come first as miniscule steps towards a larger end. Take the transistor for example. Its first form was a vacuum tube in 1906 and appeared to be a useless device with little contribution to the electronic world. It wasn't until the 1940's when computers were starting out being made up of thousands of vacuum tubes. Still these were slow and size wise impractical. It took another decade to move away from vacuum tubes and into point contact transistors. [36]

For another example take the current day Light Emitting Diode (LED). The phenomenon was first noted in the early 20th century. However it was poorly understood and was horribly inefficient. It wouldn't be until 1962 when the first available visible light (red colored) LED came out into the world. [37] As with all current energy production methods, there are pros as well as cons. Cold fusion may never produce an unlimited supply of energy for anyone who needs it, but it will someday outperform fossil fuels, and perhaps even solar and wind power. There are various techniques for facilitating low energy nuclear reactions; they all need time and fine-tuning to become efficient, but there is a cold fusion reactor in mankind's future.

With the belief that cold fusion is but a matter of time, the only question in our minds is how such an invention would be utilized. Although the potential applications are limitless, the most practical use would be to provide energy to homes for use on things like appliances, heating, and cooling. And even before hitting the market for homeowners to take advantage of, military divisions would dominate the use of its technology. If electricity were in such abundance that there were few downsides to using it, we foresee a shift in the way heating and cooling systems are made. Instead of using oil or natural gas to heat a home, electric powered heaters would become a more friendly option, not only for the environment, but for a homeowner's wallet. Things like lawn mowers, snow blowers, and even cars would most likely be altered to work on rechargeable batteries. This would allow for usage of the machinery without exorbitant costs or harsh effects on the environment. Localized power stations would most likely take over the need for power plants that cover larger areas. One potential problem with cheap energy is the irresponsible use of inexpensive energy. Only recently in our human history has there been observed effects of city's whose ground is several degrees warmer than abutting rural areas. This is due to an enormous concentration of energy depletion. Its effects are not well known but one fact is that the more energy present means more of an impact on the surrounding ecosystem. For example, some bird species navigate with the moon and due to bright city lights, they fly in circles for hours until they fall out of the sky from exhaustion [38].

One thing we do not think we will ever see is "home cold fusion units" or fusion powered cars. At first, we debated over whether or not this technology could even be achieved; cold fusion in itself is a great feat, but to make them small enough to fit inside a car would be incredible. After taking a step back, we both agreed that our previous argument was moot. When it came down to it, this is a simple case of safety in our minds. Although it would be great to drive a car that could get 100 miles to the gallon of water, we do not know if that is a good idea to even attempt. People make mistakes (just ask Pons and Fleischmann), and people drive cars. If a collision were to cause a reactor to explode, it could be devastating to much more than just the drivers involved. Even disregarding accidents, there are concerns about the ability to trust people with a nuclear device. To maintain and protect low energy nuclear reactors from those who would use them to commit criminal acts would be an impossible task for any organization. It is therefore unfeasible to produce cold fusion for use at home.

6.1.1 Landon's Opinion on How Cold Fusion Could Realistically Work

Throughout this research project we have found that Cold Fusion technology is in a serious identity crisis. There are many fantastic theories out there which all identify the Cold Fusion as a new type of energy source in separate ways controlled by different physical mechanisms.

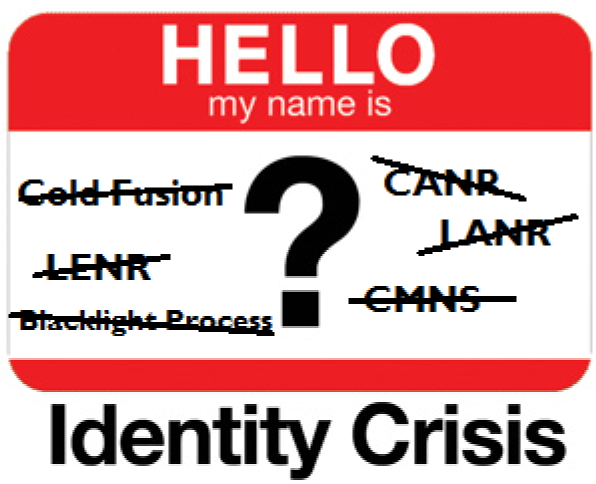

Figure 7: Identity Crisis Nametag

As exciting as some of the exotic theories sound, I have a hard time believing most of them. Here is a short list of some of the major theories:

Cold Fusion,

Low Energy Nuclear Reactions (LENR),

Chemically Assisted Nuclear Reactions (CANR),

Lattice Assisted Nuclear Reactions (LANR),

Condensed Matter Nuclear Science (CMNS),

Lattice Enabled Nuclear Reactions,

The Blacklight Process.

If this new energy source phenomena were ever to become commercially available and theory for how it works solidified, I suspect it would closely follow one from the above list. The "Blacklight Process" is the most logical explanation for this observed heat anomaly. This idea was the work of Randell L. Mills This process concerns dropping hydrogen atoms below their lowest electron energy state. Electrons exhibit different orbital shell layers. These shell layers start at the lowest energy state and count upwards getting further from the nucleus. The Blacklight Theory describes a condition where the single electron in the hydrogen atom and drop to a lower state of energy than the conventional "lowest state" in a typical setup. In fact the theory states that there is a subset of lower energy shells which fall from 1 to 1/2 to 1/3 to 1/4 and so on. Assuming that traditional physical models still hold true in this new state, there is energy released when the electron drops to these lower cells. The material which has been under testing for these unique transitions is Hydrogen. When the electron drops to a much lower state it is considered to be Hydrino. [39]

In order to get the Hydrogen atom to form a Hydrino the conditions must be "just right". The Blacklight Power Corporation performs these experiments in what they call Catalyst Induced Hydrino Transition (CIHT) Cells. Each cell contains a cathode, electrode and Anode depicted in the figure below.

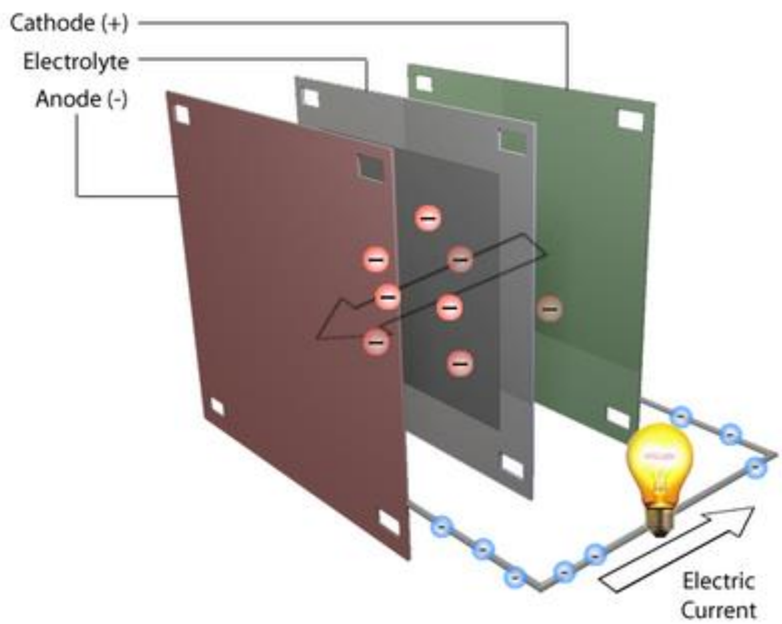

Figure 8: Exploded View of a Catalyst Induced Hydrino Transition Cell

Exploded View of a CIHT Cell [39]

When the cell is hit with an electric current, oxygen and hydrogen are produced through electrolysis of trace H2O vapors. These vapors surround the cathode, anode and electrolyte. When the cell is setup for discharge, hydrinos are formed at the anode supposedly by an atomic reaction with the newly formed water. This nascent H2O is a catalyst for forming hydrinos.

There are, however, some parts of the theory which I have questions about. I envision a crude analogy for this Blacklight process similar to that of extracting juice from grapes. Originally a grape is full and plump (Hydrogen atom at original ground state). The catalyst forces the Hydrogen Atoms to shrink its electron orbital shell into lower energy states. This is done to attempt to extract a small amount of power (juice) from the system.

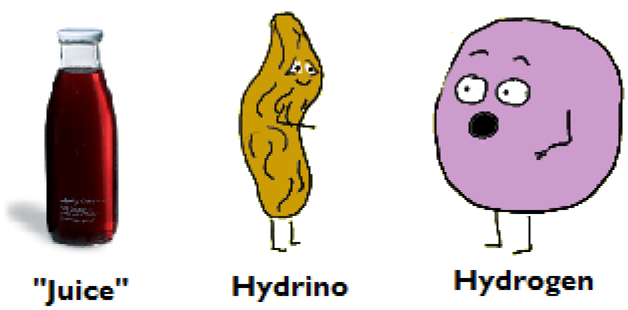

Figure 9: Humorous Hydrino - Hydrogen Comparison

Say this does work and we are able to transform a liter of Hydrogen into Hydrinos and collect the byproduct of energy. Will those Hydrinos ever be useful again? Will thermal energy around them excite the electron back to a higher state of energy once it's been released from the system? With the behavior of Hydrinos not fully understood, will an abundance of Hydrinos degrade the materials within the laboratory experiment? [39]

6.1.2 Kevin's Opinion on How Cold Fusion Could Realistically Work

Upon review of many theories that may explain the phenomena of cold fusion, I have found that the original Pons and Fleischmann explanation to be the most likely explanation. Although they were unable to consistently replicate their supposed breakthrough, I believe that saturation within a lattice (be it palladium, or a similar metal) is the best approach. Pons and Fleischmann theorized that if heavy water was placed in a container with palladium, and a voltage was applied between the palladium and the water, cold fusion could occur. What they were trying to accomplish with the voltage was separate the Deuterium atoms from the heavy water. When that has been done, the positively charged Hydrogen atoms are attracted to the Palladium lattice. This can be pictured as a grid, which is being filled up with Hydrogen atoms (see picture below).

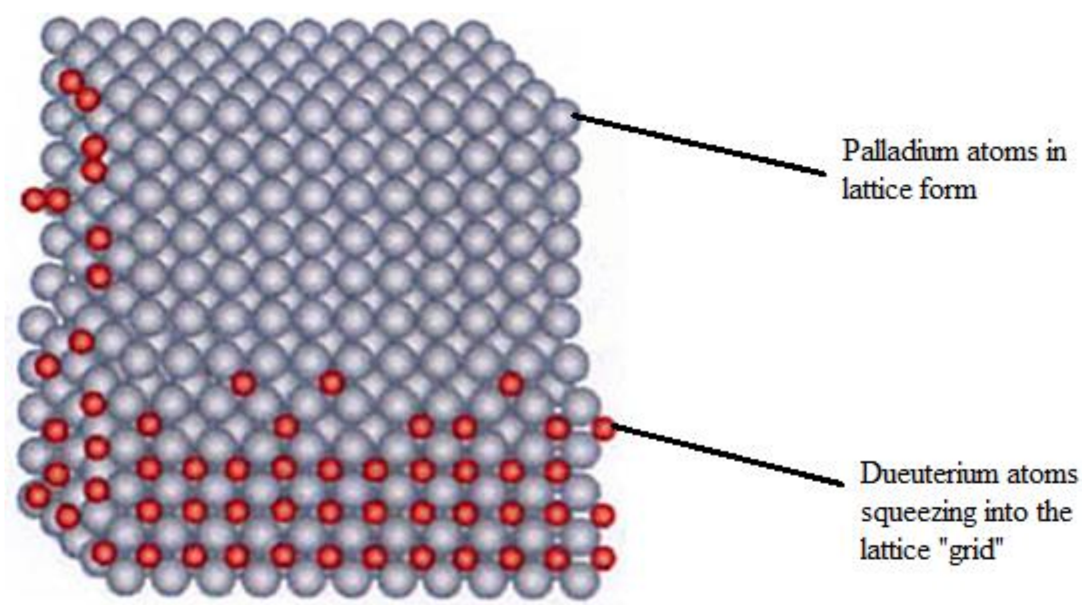

Figure 10: Illustration of Hydrogen Atoms Electro Chemically Forced into a Lattice Structure

Hydrogen atoms being packed into a lattice structure [40]

As the lattice reaches a saturation point (the point at which the grid is "full") the Hydrogen atoms begin to behave in an interesting way. Due to the positively charged Hydrogen's repulsion from each other, they tend to move in a pattern; if one grid point shifts up, others around it will do the same to avoid the nearing positive charge. Eventually, a state is reached where the attraction of the Palladium overcomes the Hydrogen's repulsion of each other, and the grid shifts back to its original position. As this is happening, more and more Deuterium is being separated from the heavy water. When the atoms in the lattice shift away from the outer edge, Hydrogen atoms will find their way in. This results in over-saturation of the Palladium lattice. When the pattern regulates to its original position, too many positively charged atoms are present, and the forces between them push them apart. This causes a disturbance in the grid of flowing electrons, and pushes them in differing paths. However, there is a limited area with which to travel in, and as the Palladium fills up even more, a "breaking point" is achieved where atoms of the same charge are forced to collide with each other. This multiplies the speed at which they collide, until the speed at which they are moving overcomes the repulsion between them, and forces a fusion of the atoms. As the mass of two Deuterium atoms is larger than the mass of the one resulting Helium atom, a famous equation from Einstein can be applied; the energy released from the fusion of two atoms is the mass "lost" multiplied by the speed of light squared ($E=mc^2$). The following equations demonstrate the energy that can be released by cold fusion reactions.

$$D + D \Rightarrow He$$

$$(2.0141017778) + (2.0141017778) \Rightarrow (4.00260325415)$$

$4.028203556 - 4.00260325405 = .02560030155$

This value is in atomic mass units, or $1.66053892 \times 10^{-24}$ grams. It must be converted to grams for Einstein's equation

$.02560030155 * 1.66053892 \times 10^{-24} = 4.25102970875113 \times 10^{-26}$ grams

Plugging in to $E=mc^2$ yields

$4.25102970875113 \times 10^{-26} * (2.99792458 \times 10^8)^2 = 3.820635 \times 10^{-9}$ joules

Isotopic masses found at source [41]

This is the energy from just one reaction, and is released in the form of heat. As the heat is not yet particularly useful to us, we can use that heat to boil water, and use the resulting steam to power a turbine. This turbine would essentially convert the heat energy to electrical energy, which could then be injected to the electrical grid. The ideal conditions for facilitating the over-saturation of Hydrogen in a lattice is yet to be discovered, but in my opinion, it is the most likely approach to succeed.

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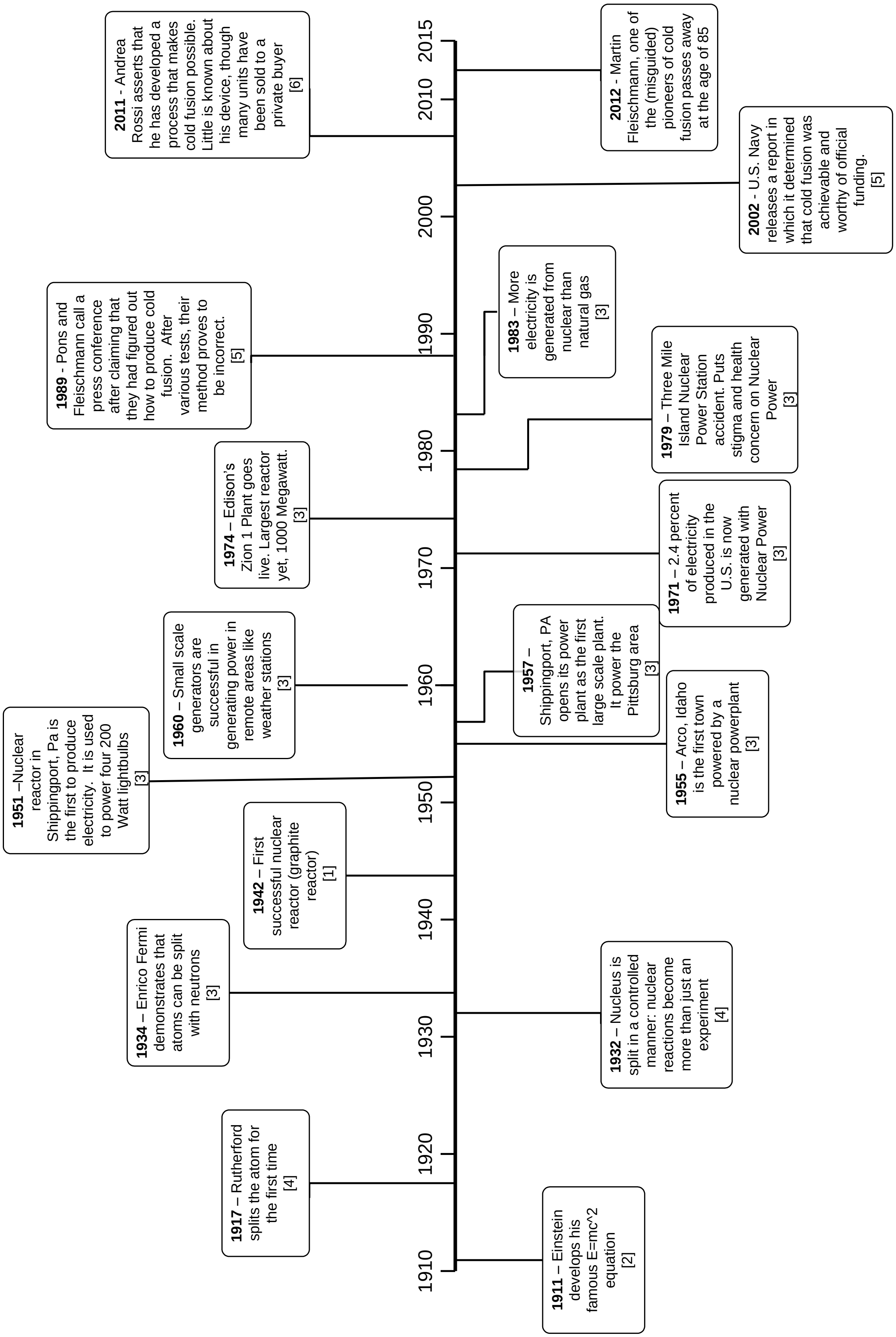
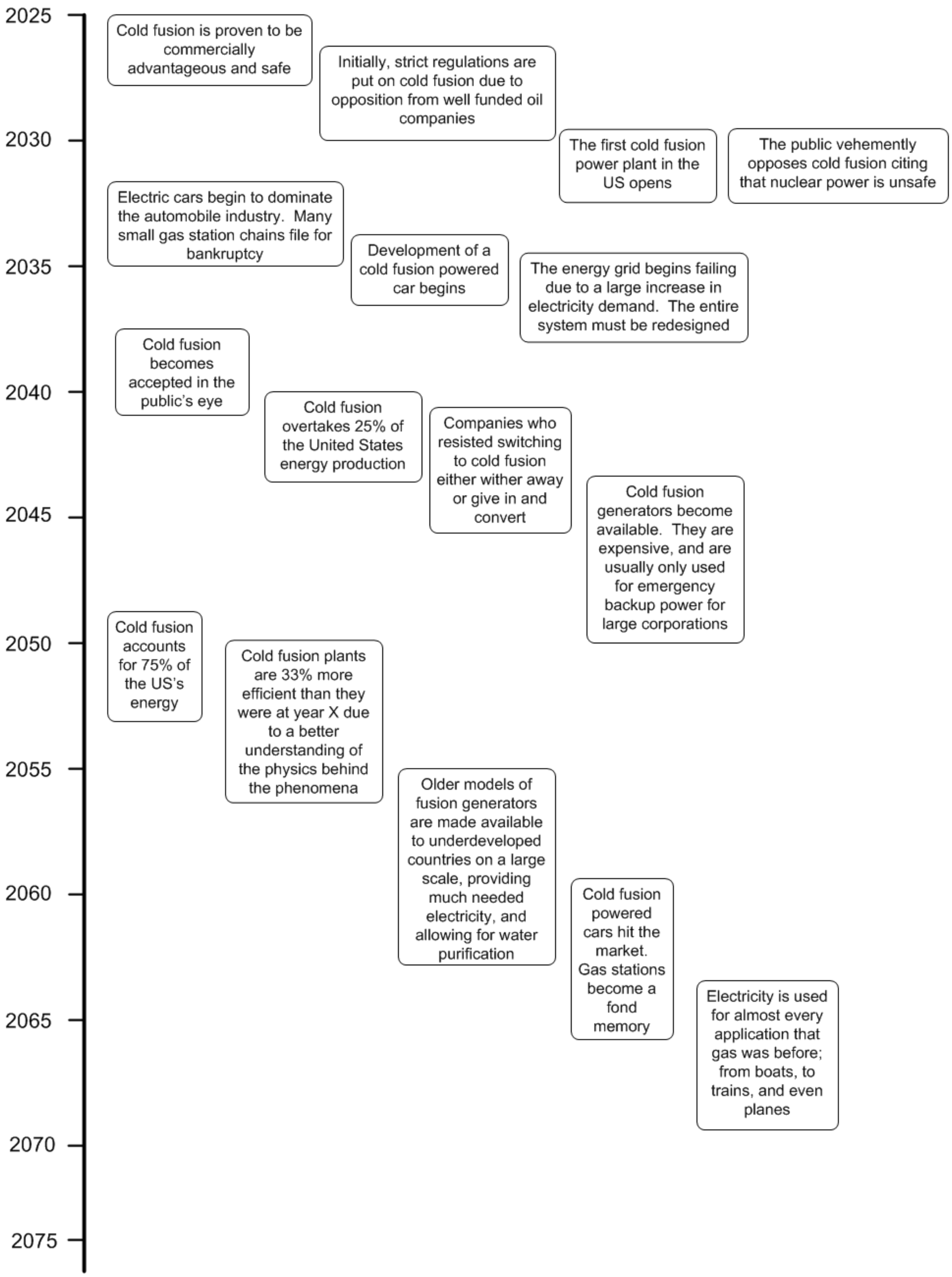
Appendix

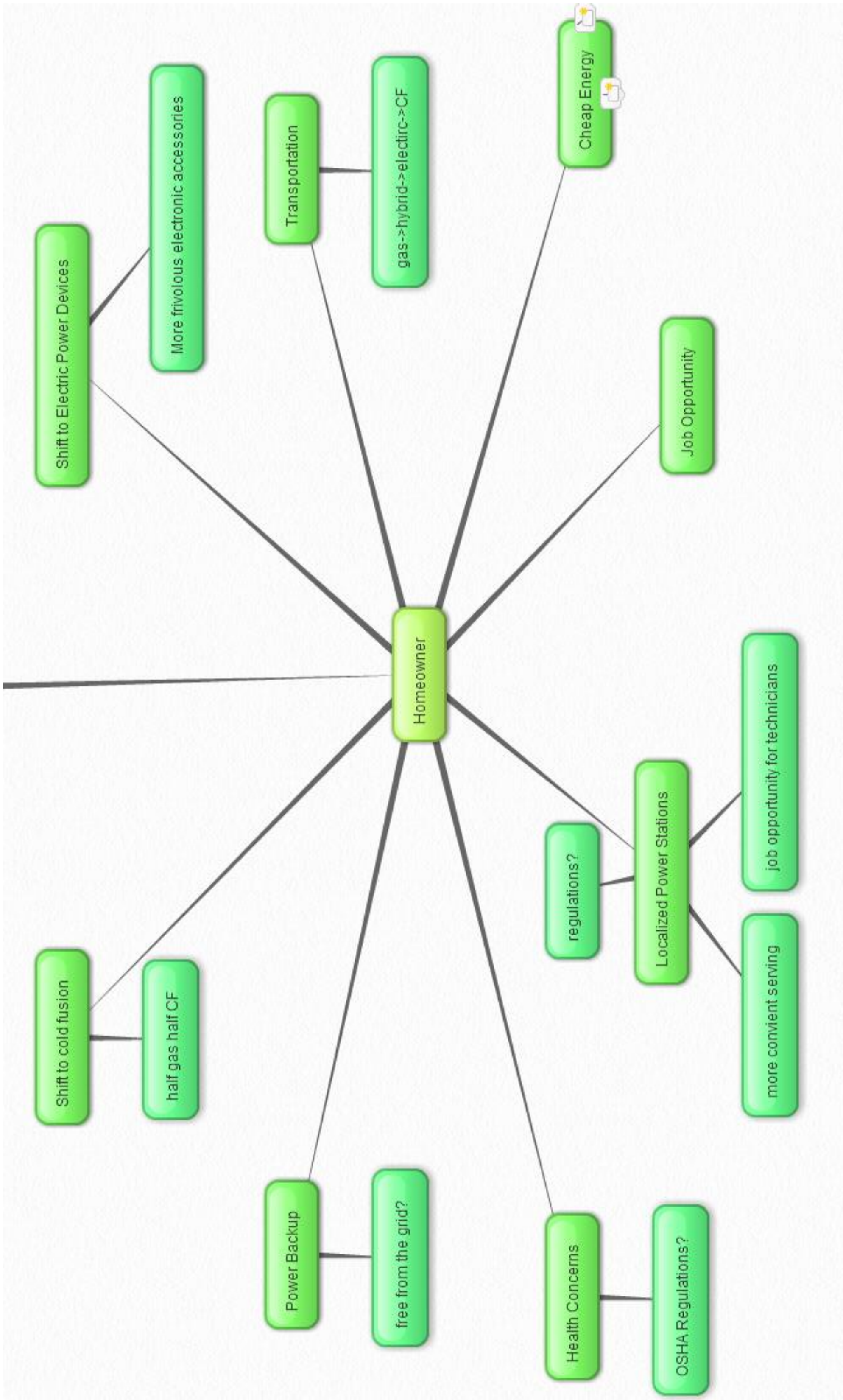
I. Past Timeline



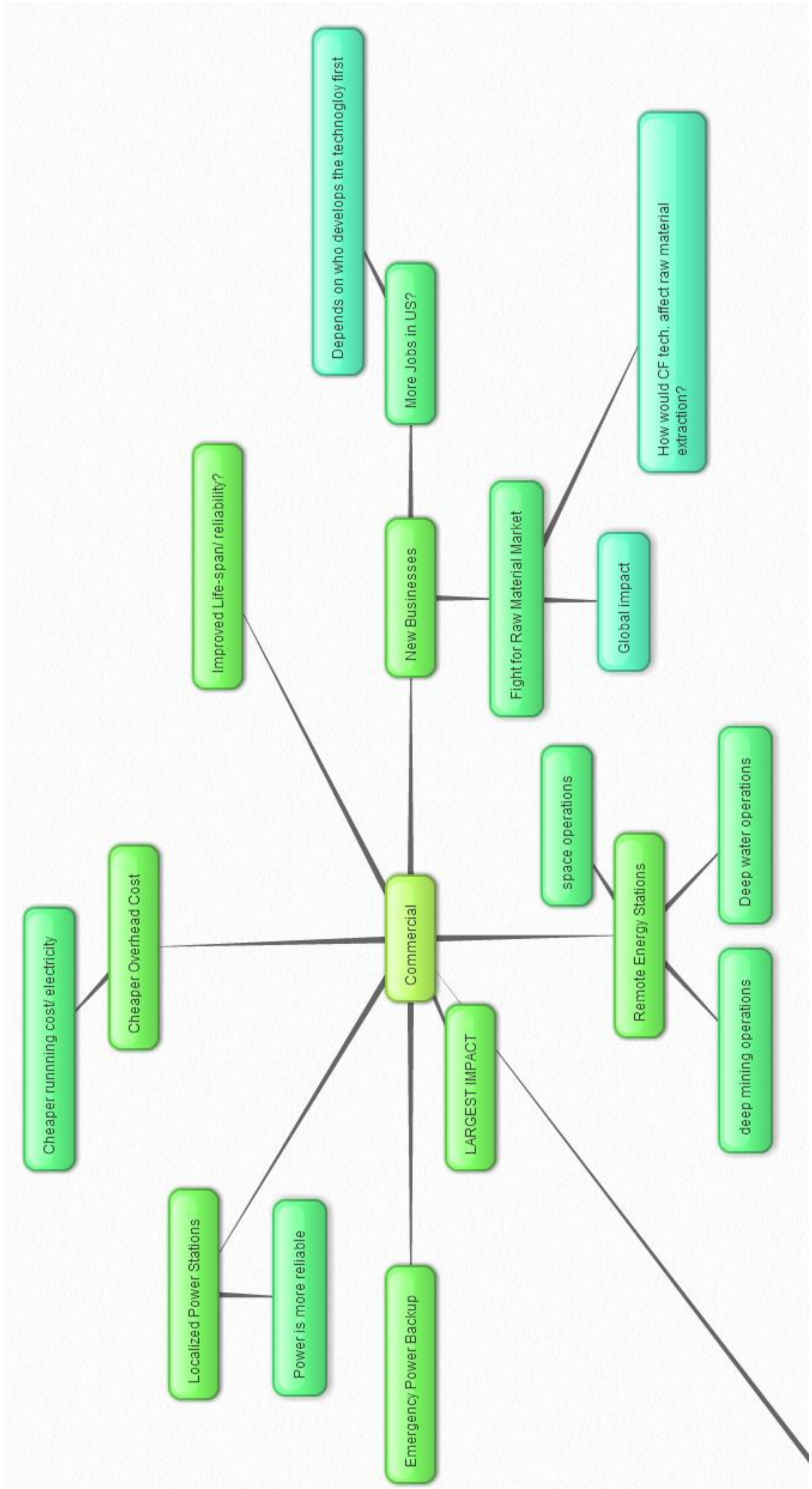
II. Future Timeline



III. Residential Effects Brainstorm



IV. Commercial Effects Brainstorm



V. Military Effects Brainstorm