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The Need for a New, Clear Option: An In-Depth Analysis of Nuclear Energy

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Abstract

The goal of the research presented here will be to provide a comprehensive view of the nuclear industry today. Upon analyzing data from the last 40 years, a pattern of irresponsible, financially untenable policymaking begins to emerge, highlighting the growing disconnect between the general populace, which is most vulnerable to the benefits and pitfalls of the nuclear industry, and the elected officials who make the final decision in many countries regarding nuclear adoption. The primary context of this article will be concerned with analyzing opposing views of how nuclear power normally stands to benefit mankind versus the impacts of a worst case nuclear disaster, as occurred at the Fukushima Daiichi Nuclear Plant. The author provides a brief, general overview of the theory behind nuclear power and its impacts before moving on to the benefits and drawbacks faced by adoptive communities. Next, an analysis of the financial viability of the nuclear industry will be offered, as well as a brief introduction of several means of generating electricity, and their general benefits and drawbacks. The author then offers an opinion on which of these options would offer the best alternative to nuclear power in both the short and long term. Finally, government patterns of dealing with nuclear power will be examined; it very quickly becomes evident that even in the most transparent societies, nuclear adoption encourages dishonesty from policy makers. In closing, the author will leave the reader with a troubling question: "Do we really have a say in our own future?"

Author's Note

It is my firm belief that by examining the problems we face today from a holistic point of view, one where the interconnectedness of the world around us is fully understood and considered, we can create a better future for ourselves. I speak not only of the interconnectedness of the biological world, but that of the artificial world we have created for ourselves, that which we call "society". Through the exploration and examination of how these two seemingly disparate fields are able to influence one another, the world can be made a much better place. It is a curious fact of the world that I have noted: when the world is looked at in a manner which truly captures the "big picture" of the moment, what we as a human race desire and need seems closely tied to the needs and desires of the world as a whole. Failure to see this tendency of the world is a failure born not out of ignorance, but out of society's deception By examining the real truth of the nuclear industry from many points of view, it is my hope that you, the reader, will discover in yourself a desire to help the world at large, not just because it is the right thing to do for the world, but the right thing to do for yourself. The goal of a truly sustainable future is not one that serves all of humanity; there will always be those individuals in this world whose future is built upon the foundations of the past. For them, a sustainable future is one where they no longer hold the power. For the rest of the world, however, sustainability is freedom. It is with this belief in my heart that I thank you for your time, and submit to you the following, with the hope that you will gain some benefit from it.

Keywords: Nuclear power, Fukushima, sustainability, policy, economics, health.

1. Overview

For as long as nuclear power has existed, it has been a hotly debated topic, one whose problems are both multi-faceted and complex. While there are many respected individuals who have spoken out over the years as proponents or detractors of the nuclear industry, nuclear power has, by and large, maintained a steady pattern of expansion and growth over the past five decades, seemingly without regard for the debate which surrounds it. However, in recent years new information and events have brought nuclear power into the mainstream consciousness with renewed vigor. With the information being presented, it is hard to understand how nuclear power has remained at the forefront of energy production for so long.

On March 11th, 2011, a 9.0 earthquake off the coast of Japan triggered a massive tsunami which struck the main island of Honshu. The 15-meter high wave disabled power to the Fukushima Daiichi Nuclear Plant (FDNP), which in turn caused a "loss of cooling accident" in three of the plant's reactors. The resulting criticality that occurred has continued to have numerous deleterious effects on both Japan and much of the Pacific Ocean region. Since the Fukushima Daiichi Nuclear Disaster (FDND) occurred, there have been mass evacuations, commercial fishing bans, and numerous health concerns in Japan. In addition, growing concerns over contaminated wildlife caught along the American west coast and rising rates of thyroid cancer on both sides of the Pacific Ocean have led to an increased global awareness of the effects that nuclear power plants can have on regions remote from them.

In addition to the numerous deleterious effects on humans and other living creatures across much of the planet, we must also acknowledge the financial difficulties faced by the nuclear industry at large. One of the most important factors to consider with any form of energy production is its long-term sustainability. At first glance, a comparative analysis of the costs and benefits of nuclear power when compared to other major forms of energy production shows nuclear as a strong leader; however, when looking at the problem from a "worst-case scenario" viewpoint, a very different picture emerges. Even in the case of a minor incident (relatively speaking), cleanup costs can soar, such as in the 1979 meltdown at Three Mile Island, for example. Despite the fact that there were no reported injuries or deaths, and a long-term evaluation of more than 30,000 people from the surrounding area showed no appreciable impact, it was reported by the World Nuclear Association that cleanup still took over 12 years, at the cost of approximately US$973 million. While some may point out that the Three Mile Island incident was rated as a 5 out of 7 on the international nuclear event scale, it should be noted that a category 5 incident is the <u>lowest</u> rating which is likely to result in the implementation of planned countermeasures; incidents rated 4 and below are generally reserved for events which affect only plant personnel and/or a very limited area around the plant site. Even more disturbing is the overwhelming likelihood that any new nuclear construction project would ultimately fail, with any money invested in the project being lost.

While it can be argued that nuclear power is a strong contender for being the "best" form of energy production we have available today, there are many alternative forms of renewable energy which have grown in popularity in recent years. "Green" technologies such as wind and solar power, as well as the newly forming field of artificial photosynthesis, offer strong alternatives to nuclear power's production capabilities while completely avoiding the dangers inherent with nuclear adoption. With so many reasons not to accept nuclear power, it is perfectly normal for an individual to question the methods by which nuclear adoption takes place. When analyzing the deciding factors for nuclear adoption, three major interest groups stand out: public citizens, elected officials, and private interests (primarily those individuals directly associated with the nuclear industry). However, there is more to the problem than that; it has been seen time and again throughout the history of nuclear power that the government has shown a tendency to mask or hide the truth entirely when it does not serve the best interests of the nuclear industry.

By studying nuclear power from this consumer driven viewpoint, with voice given to both sides of the nuclear power debate, the reader will hopefully gain a greater understanding of the inner workings of the nuclear industry and discover how nuclear power has managed to survive in the wake of the Fukushima Daiichi Nuclear Disaster. It should be noted that while it may seem as though greater weight is given to the arguments against nuclear energy, an equal amount of data for each section was pulled from resources in support of and against nuclear power; quantitative data in particular was pulled almost exclusively from sources such as the *World Nuclear Association* and *Energy Policy* archives, both of which have traditionally taken an either unbiased or slightly pro-nuclear stance in their articles. Therefore, if the majority of the information presented seems to skew in one direction, then that should be taken into consideration when formulating a final opinion based on the facts presented.

2. A Basic Understanding of Nuclear Power

2.1 Introduction

One of the key arguments that has sustained the nuclear industry for so long is the claim that it is an "eco-friendly" alternative to the much harsher and oft-vilified coal, oil, and natural gas which humanity has relied on for much of modern history. The reader will be given a brief overview of how nuclear energy actually "works", along with an impact analysis of normal operations as well as worst-case scenarios, in order to determine whether this is actually so.

2.2 How does Nuclear Power Actually Work?

Due to the radioactive nature of the fuel rods, once damage has been sustained it is exceedingly difficult to repair, and poses a serious hazard to both the on-site workers and the greater region where the plant is located. As seen in Figure 1, below, the nuclear power production cycle is essentially a large loop which utilizes steam to turn a turbine. By splitting apart the individual atoms in the fuel rods (usually composed of uranium-235), massive amounts of heat are generated. Water is constantly pumped into the reactor and transformed into steam, which then moves into a turbine assembly; the steam turns the turbines, generating electricity. The steam then moves into a "condenser" where it passes over pipes which are kept cool by a constant flow of water pulled from nearby lakes, rivers, or other bodies of water. This condensation is then discharged back into the main body of water, or circulated through cooling towers, before the cycle begins again. Failure of any part of the system generally results in a rapid build-up of heat and pressure which results in either an explosion, damage to the fuel rods' containment structure, or both.

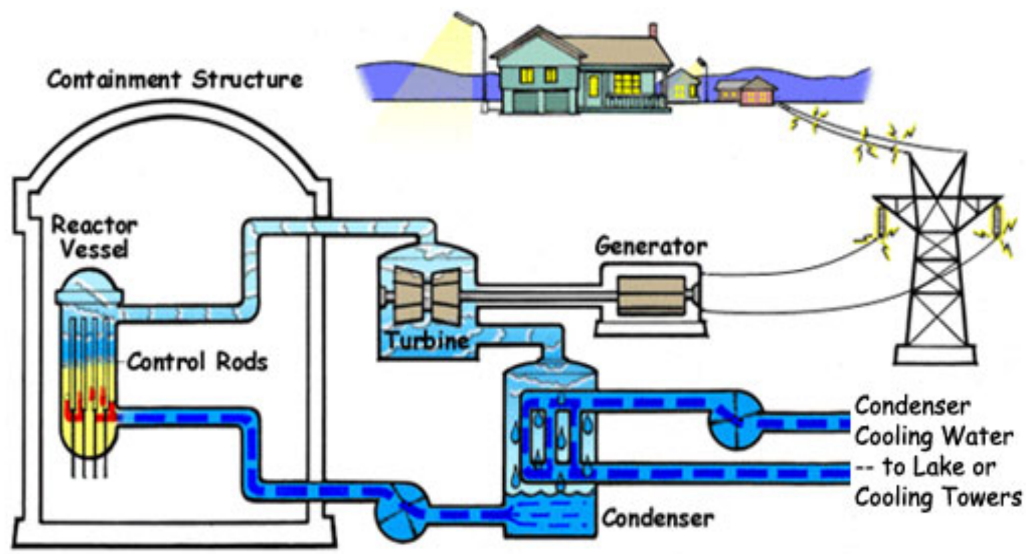

Figure 1: General Design of a Boiling Water Reactor (BWR)

2.3 When Things Go Right?

Nuclear power is often hailed as the solution to our current climate change woes. However, this is simply not true; not only is nuclear power not carbon-free, it is actually more harmful to the environment than traditional coal or natural gas means of production. How could this be, you may ask? Mary Olson, of the Nuclear Information and Resource Service, tells us that, "A number of recent studies have found that when mining, processing, and extensive transportation of uranium in order to make nuclear fuel is considered, the release of carbon dioxide (CO_2) as the result of making electricity from uranium is comparable to burning natural gas to make electric power. Additional energy required for the decommissioning and disposition of the wastes generated increases this CO_2 output substantially (Olson, 2006). Even more disturbing, a 2003 study at MIT revealed that "expanding nuclear generating capacity worldwide to 1000 billion watts would be required to address the climate problem to any meaningful degree. This would roughly mean adding one new reactor every two weeks until 2050" (Olson, 2006). As you will see in the coming sections, such a solution is unequivocally impossible, both from a scientific and economic standpoint.

2.4 When Disaster Strikes

Now let us take a look at the other end of the "impact spectrum": The Fukushima Daiichi Nuclear Disaster. As stated in the introduction, a 9.0 earthquake off the coast of Honshu, Japan triggered a massive tsunami on March 11th, 2011. The resulting wave disabled power to the Fukushima Daiichi Nuclear Plant (FDNP), which in turn caused a "loss of cooling accident" (LOCA) in three of the FDNP's reactors. For those not familiar with the term, "LOCA [involves] the safety of the emergency core cooling system (ECCS), a fail-safe mechanism to prevent core meltdown in the event of abrupt loss of primary coolant. The dramatic increase in reactor size in the late 1960s increased uncertainty about the integrity of the containment shield in the event of a meltdown" (Surrey & Hugget, 1976). Basically, in the event of a power outage, emergency systems (usually powered by diesel fuel) are designed to kick in and allow for continued cooling of the reactor in order to prevent an explosion. It therefore stands to reason that, "since the core of a reactor continues to generate heat for years, even 'off-line', it is vital that emergency cooling equipment be operable around the clock" (Olson, 2006). For reasons which remain unclear, the ECCS at Fukushima Daiichi either failed or was manually shutdown, resulting in a massive explosion which led to the largest release of radioactive contaminants ever recorded. Later sections will go into greater detail about the exact nature of the FDND's negative impacts worldwide, so for now we will leave the reader with Steven Starr's words on the continuing difficulties faced by cleanup crews:

"Meanwhile, the destroyed Fukushima reactors and spent fuel ponds, which hold huge quantities of radioactive waste, are far from being stabilized. Reactors #1, #2 and #3 every day discharge radioactive gases that emit a billion Becquerels of radiation. The uranium cores of reactors 1, 2 and 3, which completely melted down and then melted through the bottom of the steel reactor vessel, will continue to produce enormous amounts of radiation and heat for many years. Every day, ten tons of seawater is poured upon each of the melted cores; the water becomes intensely radioactive and then rapidly leaks out of the containment into the adjacent turbine building. It is then pumped trough an expensive cooling system that traps the radioactivity in filters the size of small cars, which become highly radioactive and are being placed in a nearby field. Fifty million gallons of intensely radioactive water have already been collected and stored on site. Thousands of additional radioactive gallons continue to accumulate daily, and the jury-rigged pipe system connecting the storage tanks remains at risk, should another large quake strike the area" (Starr, 2012).

2.5 Conclusion – Nuclear Power is NOT Safe

At the end of the day, behind all the fancy verbiage and technological jargon, the goal of nuclear power as a means of energy production is to boil water, creating steam which then generates electricity by turning turbines. After reading the excerpt in Section 2.4, consider this: "There are 23 nuclear reactors of the same design as those at Fukushima now operating in the US, [and] US spent fuel pools contain many times more spent fuel than the spent fuel pool at reactor building 4 in Fukushima Daiichi" (Starr, 2012). These facts alone should be enough to convince an objective reader that nuclear power is not the safe, reliable, or logical choice to make for providing electricity for our communities.

3. Happiness vs. Health – A Human Perspective

3.1 Introduction

When examining the positives and negatives of the adoption of nuclear energy as a mainstream industry, it is best to first examine the impacts that the adoption of nuclear power has on individuals and communities, without considering any financial, ecological, or ethical arguments. If the goal of nuclear power is to benefit mankind, then it must be shown that it possesses the potential to improve human quality of life. For the purpose of this article "quality of life" benefits can be broken into two primary forms:

1) Lifestyle Benefits – Lifestyle benefits are primarily assumed to mean better access to or affordability of basic utilities, such as running water and electricity. However, secondary lifestyle benefits could also include an improvement to either the infrastructure or job sectors of a given area, assuming such improvements are a direct impact of the adoption of nuclear power.

2) Health Benefits – One of the most studied and discussed aspects of nuclear power. It must be acknowledged that any attempt to quantify the health "benefits" of nuclear power will by necessity be an analysis primarily of the negative effects which can result in an area following the adoption and proliferation of nuclear power.

It will be the goal of this section to empower the reader to weigh the positives and negatives of nuclear power as they pertain to both individual lifestyle and health; and to determine which of the two carries a greater weight in society.

3.2 The Benefits of Nuclear Power on Day-to-Day Life

The adoption of nuclear power can lead to a plethora of lifestyle benefits in the communities where it occurs. In many cases, it has been found that the incentives and subsidies which accompany nuclear adoption can both revitalize and revolutionize an area. Building a nuclear power plant requires a certain amount of basic infrastructure, manpower, and materials; and this need can drive the vitalization of a community as jobs become more readily available, utility grids are overhauled, and roads are built (or improved) to handle new traffic to the area. Any local businesses which are able to supply these needs may see a great deal of growth as a result of commercial ordering, which in turn can lead to even more jobs. In addition, as mentioned above, certain areas have also seen added benefits (such as the construction of new community spaces) which are offered as incentives for nuclear adoption.

3.3 The Drawbacks of Nuclear Power on Day-to-Day Life

While it has been argued that the adoption of nuclear power creates many positive benefits for the community, this is simply not so. The local benefits are no greater than those associated with any other large public works project despite the economic incentives linked. The amount of development which is needed to construct a nuclear power plant calls for huge amounts of traffic, manpower, and materials to enter a community very suddenly and often without regard for the surrounding areas. This sudden influx has the potential to create a great deal of economic strain on an area, as prices are driven up by increased demand for certain goods, and can lead to an area's citizens becoming victims of a localized economic depression as their own incomes are no longer able to keep up with the changes in their community. Even more concerning is the cost faced by the surrounding ecosystems, as clear cutting for the construction zone, waste runoff, and noise/air pollution strangle the surrounding flora and fauna. When you calculate the effects of the operations of said plant, including the fact that "[t]he waste from mining, enrichment and spent fuel rods will be present for thousands of years, much of it where it was produced or utilized" (McCally, 2007), things begin to look very bleak for nuclear power's new home.

The adoption of nuclear energy poses serious health risks not just for the home community, but for areas and people far removed as well. When the FDND occurred, not only was the immediate area instantly rendered useless to everyone who lived nearby, but in truth nearly the entire population of Japan suffered. This may seem to be a wild claim, but let us examine the numbers. It was reported by the Japanese Science Ministry that "long-lived radioactive cesium had contaminated 11,580 square miles (30,000 sq km) of the land surface of Japan" (Starr, 2012). This is equivalent to ~13% of the total landmass of Honshu, the main island of Japan and the one directly affected by the FDND. 13% may not seem like a lot, but consider this: according to census data from 2012, Honshu is home to roughly 103 million people, approximately 81% of Japan's total population. Assuming a relatively even distribution of people on the island (with areas of large population cancelling out areas with few residents), we can see that as many as 13.3 million people were exposed to radioactive cesium following the event. However, when we analyze Fig 2, below, we see that the amount of land exposed to this highly dangerous, radioactive element was essentially "all of it", to say nothing of the millions of gallons of ocean water contaminated every day. This becomes even more disturbing when the reader stops to consider that this was just 38 days after the FDND; we are now at 1322 days (as this is being written) and cesium is still leaking into the environment daily.

3.4 Conclusion – No Appreciable Benefits to Nuclear Adoption

In closing, it would seem that nuclear energy has a long way to go before it can make the claim that it offers any true health benefits, whether of a physiological or psychological nature. It is important to note that, although it may seem as though undue focus has been placed on the effects of a "worst-case scenario", this is by necessity rather than a desire to paint nuclear energy in an unfair light. As is stated in other sections of this work, the International Nuclear Event Scale (INES) does not consider an event below a category 5 (the rating ascribed to the reactor meltdown at Three Mile Island) to have any "significant" effects beyond the range of the employees and locale of the plant site itself. For category 4 incidents and below there is no expectation of a planned emergency response other than an analysis of local food crops for contamination. Therefore, any analysis of the negative effects of nuclear energy on a community at large must be based on data from large-scale incidents such as Three Mile Island, Chernobyl, or indeed Fukushima Daiichi. The argument that there is no danger to the populace so long as everything goes according to plan should not be enough of a "health benefit", per se, to support the adoption of nuclear energy in a community.

Though proponents of nuclear power will claim that the benefits of construction of a plant alone should make the option attractive to many struggling communities, this is simply not the case. When considering the lifestyle benefits of nuclear expansion, the initial benefits and drawbacks during the construction phase are similar to those of any other large construction project. The difference is that once construction has been completed, the nuclear plant offers little when compared to, say, a shopping mall, which creates just as many jobs while also providing a niche for economic growth and variation. Even the claim that there is no change in an adoptive community seems tenuous at best, and trying to justify an industry which profits off the ability of others to break even (in an optimal scenario) is somewhat nebulous when weighed against the risk of catastrophe. For this reason, I must conclude that there are no appreciable health or lifestyle benefits to nuclear adoption.

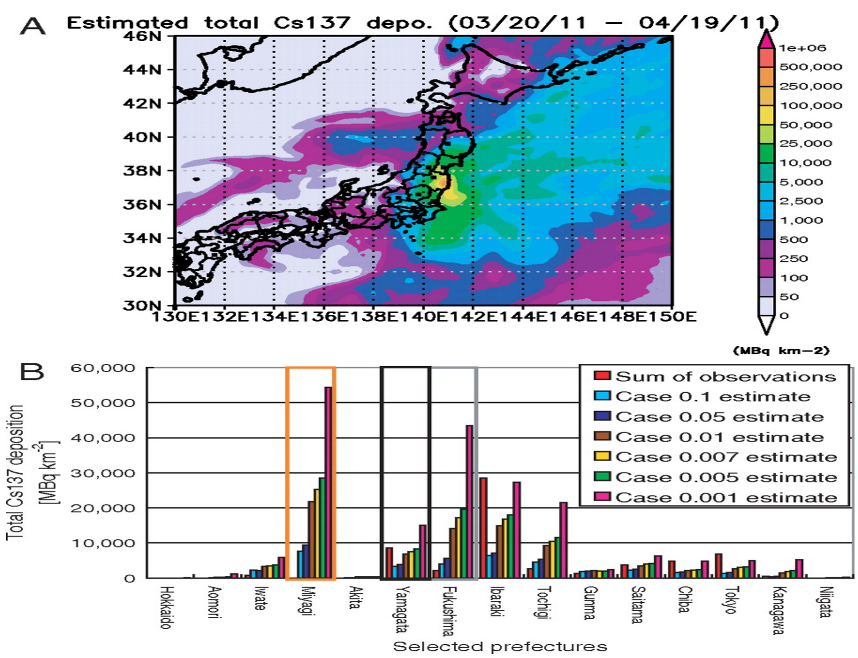

Figure 2: Estimated Total Amount of Cesium-137 Deposited from March 11 – April 19, 2011 (Yasunari et al.)

4. Economic Advantages and Drawbacks of the Nuclear Industry

4.1 Introduction

The lack of financial viability (whether perceived or real) has haunted the nuclear industry for over 40 years now, and though proponents of nuclear energy champion the nuclear plant as a "money-making machine", there are many experts who say that the numbers just don't add up. When analyzing the pros and cons of nuclear economics, it is important to tackle the problem from several angles:

A) Capital Costs – These are the initial costs of any nuclear plant; the amount of time, money, and manpower required for such a project to reach operational status.
B) Costs to the Consumer – The cost of electricity generated by ANY plant is directly related to the presence or lack of competing interests, the overall economy of an area, and the amount of money which must be recouped by the plant to pay for capital costs.
C) C) Local Economic Impact – What effect, if any, such a project would have on the economy of the area where it is being built. This could include, but not be limited to, the creation of new jobs in the area for the construction and/or continued operation of the site as well as the depreciation of surrounding properties.
D) D) Incidental Costs – Incidental expenses could be the cost of insurance, repairs, and the general maintenance of a nuclear plant, as well as the secondary costs which occur in the event of a major incident, such as the one which occurred at Fukushima Daiichi. These secondary costs could take the form of cleanup costs, property loss, contamination of agricultural production zones, and psychological or health impacts related to the disaster.

The goal of this section will be to help the reader gain a better understanding of the arguments for and against the economic viability of nuclear power.

4.2 Economic Advantages of Nuclear Energy

The capital costs associated with the construction of a new nuclear plant are the same as those of any other major public works project, such as a mall, school, or hospital. The seemingly high costs associated with nuclear energy are primarily due to the high costs of concrete and steel, which are both needed in enormous quantities for a building project of this magnitude. The construction costs associated with nuclear power plants increased worldwide after the Fukushima accident, driven by the public's demand for additional safety measures (Hayashi and Hughes, 2013). What sets the nuclear industry apart, however, is the number of highly beneficial subsidy programs (such as the *Energy Policy Act of* 2005 in the United States) evident in many parts of the world which help to offset these costs in a way that many other forms of electricity cannot match.

While it is true that competing interests in an area can have an impact on the costs of electricity, this is rarely an issue for nuclear power plants. It has been shown time and again that the monthly savings produced by the introduction of nuclear power to an area can have a huge effect on the average family. What's more, the sheer amount of electricity produced via nuclear fission generators means that nuclear plants can very quickly recoup the costs associated with construction, which in turn can lead to a noticeable decline in energy prices after a period of years. As can be seen in Table 1, the prices of electricity generated by nuclear energy are consistently lower than those from other major sources.

As stated above, the impacts of a nuclear plant on the economy of the surrounding area cannot be denied. Due to the huge need for manpower, an area selected for such a site would see an enormous influx of jobs available for both skilled and unskilled labor until the completion of the project. Furthermore, it is a known fact that, once established, the costs associated with the ongoing operation of a nuclear plant are very low when compared to other similar works. Finally, it should be noted that, while the depreciation of properties can occur, it rarely does so due to the fact that areas which embrace nuclear power plants are often subject to additional subsidies and incentives which can have a secondary effect on the values of properties and the quality of overall infrastructure in the surrounding area. While some adversaries of nuclear power have labeled such incentives as "bribes" Kato et al. (2013) point out that in a social survey of the Kanto region in Japan, "perceived risk, not perceived benefit, [was found] to be the most important factor influencing the acceptance of [nuclear power plants]".

Table 1 Actual Costs of Electricity (US cents/kwh) (WNA, 2014)

Technology	**region or country**	**At 10% discount rate**	**At 5% discount rate**
Nuclear	OECD Europe	8.3-13.7	5.0-8.2
	China	4.4-5.5	3.0-3.6
Black coal with CCS	OECD Europe	11.0	8.5
Brown coal with CCS	OECD Europe	9.5-14.3	6.8-9.3
CCGT with CCS	OECD Europe	11.8	9.8
Large hydro-electric	OECD Europe	14.0-45.9	7.4-23.1
	China: 3 Gorges	5.2	2.9
	China: other	2.3-3.3	1.2-1.7
Onshore wind	OECD Europe	12.2-23.0	9.0-14.6
	China	7.2-12.6	5.1-8.9
Offshore wind	OECD Europe	18.7-26.1	13.8-18.8
Solar photovoltaic	OECD Europe	38.8-61.6	28.7-41.0
	China	18.7-28.3	12.3-18.6

Table 2 : Economic Incentives (Kato, Takabara, Nishikawa & Homma, 2013)

Category	*Financial source*	*Major examples*
Local tax	*Utility*	*Property tax, local corporation tax, nuclear fuel tax, spent fuel tax*
Subsidy	*National government*	*Subsidies based on the Three Laws for Power Source Development*
Donation	*Utility*	*Construction of public facility, money*
Local economy	*Utility and government expenditure*	*Job opportunities, propagation effect*

Incidental expenses associated with nuclear energy have grown over the years, but this is mainly due to more stringent safety requirements and the push to reformat, streamline, and update older existing plants in favor of constructing new ones. For the most part, the growth of the nuclear industry has been a direct result of the desire to reduce pollution; the Japanese government announced in 2002 that "it would rely heavily on nuclear energy to achieve greenhouse gas emission reduction goals set by the Kyoto Protocol" (WNA, *Nuclear Power in Japan*). In cases such as the Fukushima incident, it must be acknowledged that the reactors which failed had just recently passed their 40-year expiration date, and the fact that they were approved to run for 10 additional years shows a failure on the side of human error rather than being indicative of safety flaws in the reactor itself. In fact, there were previous issues in Japan involving nuclear plants, such as when scandal broke out in 2002 in connection with equipment inspections at nuclear power plants (WNA, *Nuclear Power in Japan*). Cleanup costs associated with a major incident can be high, but are effectively combated by better safety training, more skilled operators, and a quick response time in the early stages of any such an incident. Compared with other industries, the safety record of the nuclear industry is high; the precautions against mishaps and theft of dangerous materials are stringent, and the risk of major accident is less than that of natural disasters such as earthquakes and hurricanes, and accidents associated with coal mining, aircraft and cars (Surrey & Hugget, 1976). As further proof of the commitment to safety and rapid emergency response, which is a major hallmark of the nuclear industry today, it must be noted that while "the Fukushima accident was rated level 7 (the highest level) on the International Nuclear and Radiological Event Scale—as serious as the Chernobyl accident in 1986" (Hosoe & Tanaka, 2012) not a single death was reported as a direct result of the accident.

From these facts, it should be obvious that the image of rampant costs in the nuclear industry is a false one, and that the costs associated with nuclear power are more than reasonable in the face of the industry's commitment to safety and reliability. While it may be possible for some countries to get by using their own natural resources, this is not always the case; Japan, for example, needs to import ~84% of its yearly energy needs (WNA, *Nuclear Power in Japan*). Faced with such numbers and a world characterized by massive oil crises, nuclear energy is simply the best option available to meet that demand. Though there have been minor setbacks for nuclear energy, the fact remains that the industry will remain strong, as Senator James Inhofe [R-OK] asserted in his 2007 piece *Nuclear Power Use Must be Expanded*:

"once it has revitalized, [nuclear energy] will financially sustain itself"(Inhofe, 2007). What's more, the growing nuclear presence around the world is one that will lead to lower costs for consumers and higher profit margins for plant operators and, in turn, the countries where they are based. In short, nuclear power will continue to be seen as "an essential way of improving energy security in many countries and, despite what its critics may say, will probably continue to be used as a significant source of low-carbon electricity" (Hayashi and Hughes, 2013), both due to the overwhelming positive benefits as well as the absence of any other widely available low-carbon options.

4.3 Economic Drawbacks of Nuclear Energy

The primary issue with the capital costs associated with nuclear power is simply this: they are far too high. As early as the 1970s, it was observed that "the reduction of nuclear ordering has been aggravated by cost escalation and financing problems. Like many other types of capital equipment, nuclear plants have sustained cost escalation well in excess of the general rate of inflation" (Surrey & Hugget, 1976), and this trend has not abated with time. In fact, many construction projects have a final cost which is many times higher than its initial projected budget, with the difference being made up using taxpayer dollars. "Wall Street is not putting a penny of private capital into the industry, despite 100-plus percent subsidies" (Lovins, 2008).

While many individuals claim that the generation costs of electricity using conventional power versus nuclear are much higher, the fact is that this is only true in areas where additional taxes are levied from producers based on annual carbon emissions. It is also important to mention that the savings associated with nuclear energy are ONLY significant in regions where there is little to no competition, or where the demand for electricity is much higher than normal. As seen in Table 1, the average cost/kWh (cost per kilowatt hour) of electricity from a nuclear plant tends to be ~2-4 cents US lower than other forms of electricity generation, which is less than 10% of the total cost/kWh in most countries. While the amount of electricity generated by nuclear reactors is high, the lower utility cost in areas where nuclear power has been introduced can actually have a deleterious effect on consumers, as they tend to be more "energy wasteful" because of the lower cost/kWh. This in turn can lead to a higher-than-average bill for many families, even though the costs are technically lower.

The economic advantage of integrating nuclear power into an area is generally negligible, and never last more than a few years. While the initial stages of construction for such a site DO require large amounts of manpower, the workers needed are generally unskilled, and the presence of such work invariably leads to an influx of new residents to the area. When the jobs go away at the end of the construction period, the new residents often do not, and this in turn can have a disastrous effect on local economies as unemployment rates quickly skyrocket, leading to a greater demand for government welfare in the area. Furthermore, the jobs that DO remain are generally those which require a highly specialized degree of training and knowledge, and as such the workers employed to fill such positions are statistically unlikely to be from the surrounding area, at least for the first generation or so of workers employed by the plant. The most pressing issue, however, is the fact that "The huge economic incentives during the construction phase result in the creation of many public facilities and the expansion of public welfare programs. However, the expense incurred in maintaining these facilities and services often cause financial problems later" (Kato, Takahara, Nishikawa & Homma, 2013). As time goes on and the economic benefits go away, host cities have been forced to request that more reactors be installed on their lands, as "the social changes caused by the economic incentives made it difficult to manage the local communities in a sustainable way" (Kato, Takahara, Nishikawa & Homma, 2013).

Perhaps the greatest economic drawback of all is the staggering incidental costs associated with a nuclear disaster; in the case of Fukushima alone, "[e]stimates of the total economic loss range from $250-$500 billion US" (Starr, 2012). What's more, not only does the financial impact totally eclipse the possible gains (it should be noted when referring to Figure 5 below, that US$58 billion was an estimate only of the "cost of cleaning up the radiation contamination from Fukushima around farms and towns […and] does NOT include other costs, such as compensation and dealing with reactors" (McKeating, 2013)) the area affected by the disaster usually extends far beyond the region that could have ever benefitted from the existence of the plant in the first place. Following the destruction of the Fukushima Daiichi plant in March 2011, it was reported that "all of the land within 12 miles (20 km) of the destroyed nuclear power plant, encompassing an area of about 230 square miles (600 sq km), and an additional 80 square miles (200 sq km) located northwest of the plant, were declared too radioactive for human habitation. All persons living in these areas were evacuated and the regions were declared to be permanent "exclusion" zones" (Starr, 2012). In addition, some "4,500 square miles […] was found to have radiation levels that exceeded Japan's allowable exposure rate of 1 mSV (millisievert) per year" (Starr, 2012).

The total loss of property and livelihoods as a direct result of this disaster may never be known. Fukushima officials stated in September of 2012 that a total of 159,128 people had been evicted from their homes (Starr, 2012), and many of them are even being forced to pay mortgages on homes and property they can never return to. Depending on peculiarities in meteorological patterns at ground zero, individuals many hundreds of miles away can face significant health risks which have a direct impact on both their lives and the economy of an entire region far removed from the nuclear plant. The impacts on an ecosystem can be even more astounding. It has already been stated that "[o]nce a large amount of radioactive cesium enters an ecosystem, it quickly becomes ubiquitous, contaminating water, soil, plants and animals" (Starr, 2012) and in the case of Fukushima, contamination has been reported in crops and fish more than 200 miles away. While supporters of nuclear power will quickly make the claim that better safety training and more skilled operators are needed to combat this, it must be acknowledged that "it can be argued that nuclear risks cannot satisfactorily be compared with natural disasters, nor with accidents from other technologies" (Surrey & Hugget, 1976) in which a reasonable level of preparation is possible.

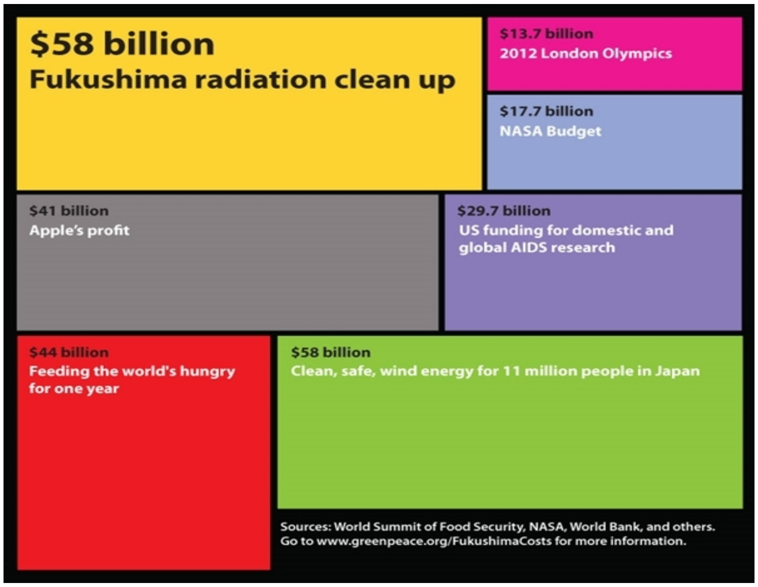

Figure 3: A Comparative Analysis of the Cost of the Fukushima Cleanup Efforts (McKeating, 2013).

In closing, any claim made in support of nuclear power as an economically viable endeavor is either the result of faulty information or is an outright fabrication. The ever-growing costs of construction alone should be enough to put the issue to rest, but there is far more to the problem than that. The money saved when switching to nuclear electricity is neither commonplace nor appreciable, and while some incentive projects have been both well received and communally beneficial, they are short-lived at best and often leave the areas in worse shape than they were before in the long-term. Most importantly, the incidental expenses of nuclear energy are too high to be reconciled regardless of its benefits, not just in terms of financial and human costs, but environmental costs as well.

4.4 Conclusion – Nuclear Energy NOT Economically Sound

The evidence speaks for itself: In order for utilities to develop new nuclear plants, they must have access to adequate financing at a reasonable cost. Before Wall Street will provide that financing, there must be confidence that the project will be successful, that the business risks are manageable and new plants can meet schedule commitments to begin delivering power (Inhofe, 2007). The truth, however, is that skyrocketing costs in construction materials leave the taxpayers holding the bag; since "Wall Street […] will not finance these facilities because future plants are likely to cost more than $5 billion, making them marginally profitable at best. And, a recent Congressional Budget Office report predicts that more than 50 percent of proposed plants would default on loan guarantees" (McCally, 2007). If nuclear energy is so profitable, then why is it so hard to find someone willing to invest money in its future? Supporters of nuclear energy have been quick to say that their detractors tend to exaggerate the financial risks of nuclear energy, but the fact remains that 36 years ago, when the final Report of the Rasmussen group appeared in October 1975, it contained revised estimates of the consequences of the worst imaginable reactor accident, which for property damage was raised from $6.2 billion to $14 billion (Surrey & Hugget, 1976). Accounting for inflation, this would be about US$60.8 billion today (this number should be familiar to readers; as shown in Figure 5 above, current cleanup costs for Fukushima are estimated at $58 billion dollars). Meanwhile, the projects themselves offer only temporary employment to most and can leave an area in a worse economic state than before. Supporters of nuclear energy may tout the benefits of "savings" and "incentives" but these terms are really just part of a concerted effort to distract the average citizen from the fact that they are being bribed to allow nuclear power a place in their communities.

Consider this: it took over 20 years to for the Korean government to receive approval for a low-level waste site; and Jun et al. (2010) acknowledge that this approval was only granted by the public after "[the] Korean government promised to pay a 300 million dollar subsidy and move Korea Hydro and Nuclear Power (KHNP)'s headquarters to the area as the price for constructing low level waste site in the region". Subsidy based policy-making risks not just the homes and families of ourselves and our neighbors, but a huge area surrounding the site which gains no benefit at all from the introduction of the plant. Simply put, there is no way to make a plan for Mother Nature, and any claim made to the contrary is false. The idea that a consumer should offer support to a project which may save him or her a little bit of money every month is fine. But if those savings have the potential to destroy entire ecosystems, contaminate hundreds of square miles of populated land, and expose people thousands of miles away to increased risks of cancer as well as other serious health risks, then it is not worth it.

It has been estimated that ~733,000 curies of radioactive cesium were pumped into the Pacific Ocean in just fifteen months after the Fukushima disaster (Starr, 2012). Since then, there have been reports of contaminated fish and foods as far away as California, and many areas bordering the Pacific have reported rising rates of thyroid cancer in young children. The idea that nuclear power can simultaneously cost less and yet generate more cash flow is a compelling one; however there is no amount of money that can be saved which could ever outweigh such dire risks, which is why I must conclude that the argument for nuclear power as being economically sound is a faulty one. Having considered both the drawbacks and benefits of nuclear power from a variety of standpoints, it now remains to consider alternate forms of energy production available in the world today.

5. Sound Alternatives to Our Growing Energy needs

5.1 Introduction

While it may seem easy to simply bombard the nuclear industry with complaints and charges designed to show that it is a flawed means of production, all this evidence is useless if there are no better alternatives ready to take the place of nuclear power. Any search for an appropriate alternative means of energy production must, therefore, be based on three main principles: A) any positive and negative effects on the local AND global communities, B) the ecological impact of such a production method, and C) the financial viability of the production method. In addition, as Mary Olson points out, "Nuclear power is […] dependent upon a grid that is powered by other sources of energy, typically coal. This is due to the simple fact that nuclear reactors cannot "black start" – in other words, they depend on electric power from the external power grid to be able to come on-line" (Olson, 2006). Therefore, it must be said that the most ideal alternative must either be able to utilize current power grids with little to no restructuring, or to be able to operate independently of existing grids. Thus, it will be the goal of this section to analyze several of the leading forms of energy production in the world today, as well as new technologies that are beginning to see expanded use, and determine which would be the best alternative option in lieu of nuclear power.

5.2 Oil

As a well-understood and time-honored mainstay of the energy industry, the main problem with oil is simply that it is an extremely limited commodity. Even the most conservative estimates tell us that oil resources on the planet will be completely depleted before the end of this century, and even more alarming is the impact that increased oil usage can have on other facets of life around the world. Plastics, asphalt and most lubricants, as well as many organic chemicals, are made using oil, so any strain on the world's dwindling oil supply would have cascading effects on nearly all manufacturing industries. The only part of the world where any sizable reserves of oil have yet to be tapped are in the Arctic Refuge, separated from the rest of the world by hundreds of miles of Trans-Alaska Pipeline. This poses a massive security risk; indeed, while testifying against Arctic drilling, former CIA director Jim Woolsey is quoted as calling the Pipeline, "Uncle Sam's 'kick me' sign" (Lovins, 2008). As troubling as the economics of oil can be, the main issue is the political vulnerability of oil. Bernard Cohen warned in 1990 that rising oil prices could one day lead to US involvement in wars overseas; we will leave that statement to be taken on its own merit. Due to both the dangers presented here, and the many stronger alternatives outlined below, I must agree with Bernard Cohen "that measures which increase our use of oil must be avoided as much as possible" (Cohen, 1990).

5.3 Coal

As with oil, coal burning has historically been a widely used, reliable source of electricity. However, despite its high level of affordability and accessibility, it is also the most ecologically unsound form of energy production available today (except perhaps nuclear energy). For these reasons alone, coal fails to serve as a viable alternative to nuclear power.

5.4 Natural Gas

The drawbacks to natural gas are virtually identical to those faced by oil. Supply is largely limited, and natural gas is only cost-effective in areas close to where it is gathered. Additionally, natural gas is far more efficient when put to use heating homes than generating electricity. For most of the world, natural gas resources are highly limited and prohibitively expensive, and thus are better used for other purposes. Subsequently, natural gas offers no benefits as an alternative to nuclear power.

5.5 Hydropower

One of the most significant and historically reliable forms of energy production comes in the form of hydroelectric power. Hydroelectric power operates on the principle of water moving through a series of turbines, generating electricity as it does so. Hydroelectric dams have powered much of Norway and the United States' power grid, as well as parts of Quebec in Canada. Norway derives a great deal of its total electricity from hydroelectric power as well. However, as Professor Bernard Cohen of the University of Pittsburgh points out, there is a major hurdle to face: "[S]ites for generating hydroelectric power must be provided by nature, and in the United States nearly all of the more favorable sites nature has provided are already being used. There have been new projects for harnessing the energy in the flow of rivers, but these give relatively little electric power and cause serious fish kills, which lead to well-justified objections by environmental groups" (Cohen, 1990). This problem holds true in many other parts of the world as well. Hydroelectric power is such an excellent means of energy production that in most developed countries, it is already being utilized to the full extent. Furthermore, the local ecological impacts of creating new dams, lakes, and rivers to power hydroelectric plants can be disastrous for local wildlife. Thus, while hydroelectric is a strong method of energy production in and of itself, it cannot be said to be a strong alternative to nuclear power for meeting future energy demand.

5.6 Wind Power

The fastest growing sector of energy production in the world today is wind power. In fact, according to Amory Lovins of the Rocky Mountain Institute, "[nuclear power] added 1.4 billion watts […] It was a tenth what wind power added" (Lovins, 2008). While older wind farms were known to create many noise complaints and posed a serious danger to local bird populations, newer, more efficient eco-friendly designs have minimized or eliminated these worries. In addition, many experts have cited wind power as being of exceptional economic quality; as Mary Olson states, "Life cycle costs for nuclear power generation (in the USA) have been estimated at 12 cents a kilowatt hour, whereas life cycle costs for wind power in the same analysis is estimated at 4 cents a kilowatt hour" (Olson, 2006). For further data on the cost comparisons of nuclear energy versus wind power, refer back to Table 1, above. The main problem with wind power, if there is one, is the fact that "there is the very sticky question of what to do when the wind isn't blowing [since] using batteries to store the electricity is far too expensive (Cohen, 1990). However, putting that aside, it would seem that wind power is a strong contender for "best alternative", an opinion which seems to be reinforced by solid, openly available industry data and the shifting energy climate in many EU countries.

5.7 Solar Power

At first glance, solar power would seem to be the most ideal option available. What could be more natural, clean, and harmless than using the sun's rays to generate our power? However, traditional photovoltaic generators face a number of problems. While the cost of operating a solar plant is very low, so too is the efficiency of these plants; the rate at which most current generation solar panels work is far too slow to meet demand. Though it is true that in recent years there has been a great deal of technological advancement in the field of photovoltaics, most of these advances are far more economical when used to upgrade existing plants rather than build new ones. This issue is one faced by the nuclear industry as well; Amory Lovins tells us that most of the new electricity generated in 2006 (the last year in which data is available) was "from upgrading old plants, because the new ones they built were smaller than the retirements of old plants" (Lovins, 2008). While there is a great deal that can be said for traditional solar power, the main difficulty faced by photovoltaic plants is similar to that of wind plants; the sheer amount of power generated during operation cannot be stored for later use at an economical rate, and peak generation periods do not coincide with peak demand periods.

5.8 Artificial Photosynthesis

Last on our list is the newly emerging field of artificial photosynthesis (AP). Not satisfied with the rate at which plants naturally photosynthesize light, scientists at the Joint Center for Artificial Photosynthesis (JCAP) have been exploring new methods to determine whether it is actually possible to improve on the efficiency rates of natural photosynthesis. By using a multi-layered design very similar to that of a plant cell in nature, minus all the other components required for life, it is believed that they can "streamline" the process of photosynthesis and enhance it, providing actual liquid fuel made from sunlight. This puts AP in a whole different category of energy production; one which goes beyond simple electricity generation and allows us to make a combustible fuel which is totally renewable that, when burned, does not harm the environment. As Caltech Professor Nate Lewis puts it, "Forty percent of global transportation – heavy duty trucks, ships, and aircraft – cannot be electrified […] you've got to find a high-energy-density, carbon neutral liquid fuel for global commerce" (Silberg, 2013). Meanwhile, Berkeley Labs researchers are also exploring the applications of AP through the development of a nano-engineered micro fluidic electrolyzer. This technology generates hydrogen and oxygen via the use of a chemically inert wall which separates anodes and cathodes. Essentially, water (H_20), is broken down into potential energy (H_2) and oxygen (O_2) on a cellular scale. The greatest advantage of this technology, however, is its flexibility. Virtually any part of the structure can be swapped out for optimization with no loss in basic function. "Proof of concept" designs for AP technology are expected to be completed sometime in 2015. Even more encouraging is the recent discovery of examples of photosynthesis in places devoid of visible light. Through manipulation of the spectrum of light that the subject organisms were exposed to, it was found that some plants are able to photosynthesize lights along the infrared wavelength, though the general consensus is that the process is far from efficient. What this means is that as AP technology advances, new generators will be able to utilize not just the visible spectrum of light, but low energy wavelengths as well; allowing for greater overall energy output from the same level of input.

5.9 Conclusion – Wind Power, and an Eye Towards Future Technologies

While there may not be a clear leader in alternative energy, the fact remains that there are several strong alternatives to be had, none of which can come close to the negative effects caused by nuclear power. However, it must be acknowledged that none of these options are perfect. Oil, coal, and natural gas all face the issues when it comes to availability, ecological impact, and overall cost factors, though they do have an advantage over nuclear power when considering construction and operational costs. Hydropower is an extremely efficient energy producer, but as stated in Section 5.5, there are few suitable locations left which have not already been utilized, and the construction of hydroelectric dams has been shown in the past to have incredibly deleterious effects on surrounding regions, including the destruction of low-lying communities, and wide-scale impacts on local wildlife which are unable to adjust to the changing landscape. Wind power has already been proven to be cleaner, more cost efficient and far more environmentally friendly than nuclear power, with new wind turbine designs having next to no impact on the surrounding area. While solar power is an incredibly clean and readily available source of energy when compared to nuclear, it lacks the ability to act as a standalone energy provider for mass consumption, and would be better relegated to a secondary support role in areas where demands on the local power grid are unusually high. The final option presented, artificial photosynthesis, has a great deal of potential, but even the most optimistic projections indicate that we are still several decades away from being able to utilize it effectively on a large scale.

Overall, wind power serves as far and away the best option we have available today, due to its reliability, flexibility, and low risk when compared to nuclear power. One of the major claims of nuclear power proponents is that nuclear energy possesses long-term sustainability with a high rate of efficiency at a relatively low cost; therefore this should be a major selling point for consideration of alternatives to nuclear power. Wind power more than meets this goal, with the added advantage of having little to no negative ecological impact. It is this researcher’s opinion that given the overall adaptability and potential that we have seen thus far, wind power offers us an excellent current generation solution to the energy crisis we now face; however, a great deal of the capital currently being used to expand nuclear power in developed countries should be diverted to the research and expansion of artificial photosynthesis as a means of mass energy production in the future.

6. Decision-Making Policy in Regards to Nuclear Adoption

6.1 Introduction

Whenever nuclear power is adopted (or expanded, as the case may be) in an area, the decision to do so is generally a result of a long period of analysis and public hearings on the factors discussed in the preceding sections. While it would seem from the facts presented up to this point that nuclear adoption would rarely make it past these proposal stages, this is not the case. Therefore, it is the primary goal of this final section to revisit the main points which are brought up in relation to nuclear power. It is my hope that by analyzing these points from a decision-making perspective, the reader will be able to determine who makes the final call regarding nuclear adoption in a given region: the public majority, elected lawmakers, and private industrial interests.

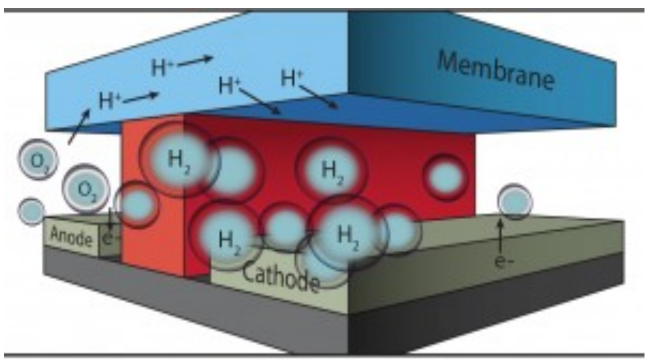

Figure 4 Experimental Design: "Nano-Engineered Micro Fluidic Electrolyzer"

6.2 Public Stances on Nuclear Adoption

Since the mid 1960s, Japan has been among the countries most willing to embrace the potential of nuclear power. The World Nuclear Association, however, reported that "following the tsunami which killed 19,000 people and which triggered the Fukushima nuclear accident (which killed no-one), public sentiment shifted markedly so that there were wide public protests calling for nuclear power to be abandoned" (WNA, *Nuclear Power in Japan*). It is important to note here that a 2009 survey showed that support for nuclear power is far stronger in countries where it has already been introduced (See Figure 5). Kovacs and Gordelier attribute this trend to the idea that "people living in countries with nuclear power plants are more supportive of nuclear energy because they are more familiar with it, better informed about it, and more aware of its benefits". They believe that, through further education of the public, social acceptance of nuclear power will rapidly increase in many countries.

Without being informed, there is no way that the public can ever make an informed decision about nuclear power. That is why when Charlie Smith of *Russia Today* reported on February 14th, 2014 that "a commentator [Toru Nakakita, an economics professor at the University of Toyo in Tokyo] on Japan's Radio 1 resigned after he was instructed not to discuss the nuclear accident until after a gubernatorial election", a dire picture for how nuclear policy is made and reported on within the country is painted. Representatives of the radio station claimed that the reason for the censorship was due to a desire to offer an opposing viewpoint on the topic, but that they were unable to find anyone to do so. This failure to communicate openly with the public seems endemic at every level in Japan; in the *Nature* piece

"*Nationalize the Fukushima Daiichi Atomic Plant*", Japanese House of Representatives members Tomoyuki Taira and Yukio Hatoyama reported that while trying to research the exact cause and nature of the FDND, the Tokyo Electric Power Company (TEPCO) "refused to supply" any information about the plant. When they finally did hand over a copy of the plant's operating manual, key passages had been blacked out due to "intellectual property rights and security concerns". All in all, it was more than six months before investigators were able to obtain full disclosure (as far as they know) about the plant and what transpired there. This speaks to a key concern of many citizens of countries around the world: the idea that "administrative responsibility only works satisfactorily with restraint and reasonableness on all sides, and where the governed have confidence in their elected representatives and the officials serving them" (Surrey & Hugget, 1976). However, given the climate of distrust and secrecy seen today, it would seem that 'administrative responsibility' is nowhere to be found.

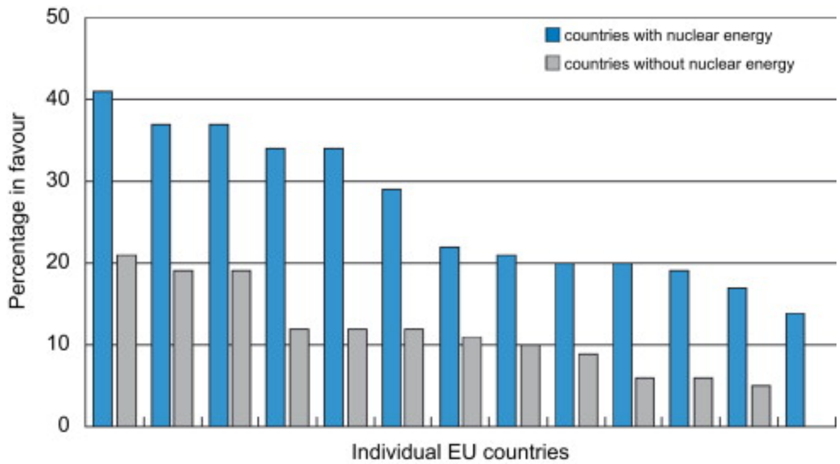

Figure 5: "Percentage of people supporting the use of nuclear power in each of the 25 EU countries, after dividing them into countries with and without nuclear power plants" (Kovacs and Gordelier, 2009).

6.3 Elected Officials' Stances on Nuclear Adoption

The government stance on nuclear power varies from region to region and, as is to be expected, is affected in large part by public opinion. However, there is also evidence to suggest that, in cases such as that of the Fukushima Daiichi disaster, the ruling body also goes to great lengths to avoid controversy, often at the expense of the health and livelihood of the citizens whose interests it professes to serve. A prime example of this occurred roughly a month after the FDND, on April 19th, 2011, when "Japan chose to drastically increase its official "safe" radiation exposure levels from 1 mSv to 20 mSv per year – 20 times higher than the US exposure limit" (Starr, 2012). It did not escape the notice of this researcher that April 19th was the exact day that Yasunari et al. (2011) finished gathering data for their report, "*Cesium-137 Deposition and Contamination of Japanese Soils Due to the Fukushima Nuclear Accident*", the findings for which were not published until fall of that year. In the report, it was stated that large amounts of cesium had saturated not just the majority of the island of Honshu, but had been carried far out into the Pacific Ocean as well. Based on this information, it seems somewhat unlikely that the Japanese government's choosing the exact day that Yasunari's team finished gathering data to increase their safe exposure levels by an incredible 2000% was purely coincidental. Note the gradual shrinkage of the zones deemed too hazardous for human health in Figure 6 despite Cesium-137's marked tendency to "…quickly become ubiquitous, contaminating water, soil, plants and animals [as it] bioaccumulates, bioconcentrates, and biomagnifies [while moving] up the food chain" (Starr, 2012). Given this information, it would seem that the hazardous zone would increase, not grow smaller, as time went by.

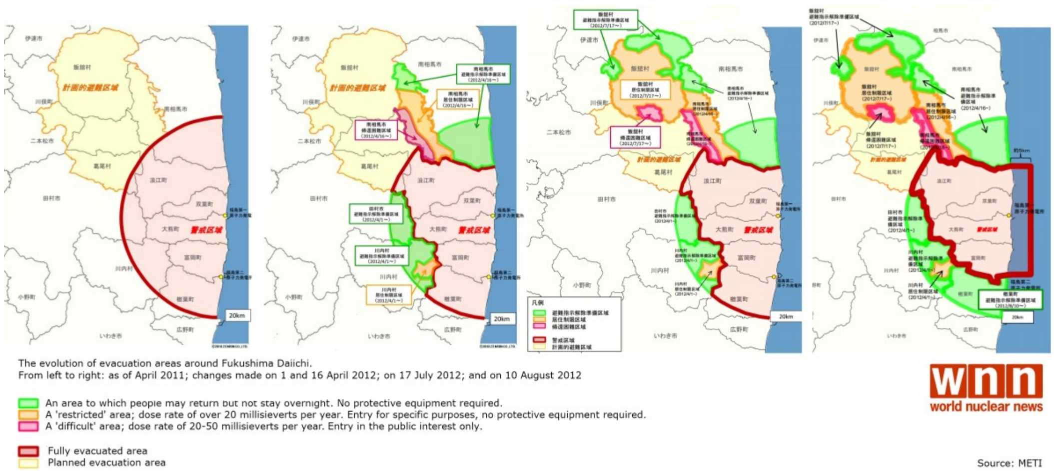

Figure 6: "The Evolution of Evacuation Areas Around Fukushima Daiichi" (Starr)

Japan's stance on nuclear energy has for a long time been well established. As is stated in the opening paragraphs of *Nuclear Power in Japan*, published by the World Nuclear Association, "Japan's first commercial nuclear reactors were brought online in 1966" and, due to its historical reliance on imports (~84% by the WNA's latest numbers), "nuclear power has been a national strategic priority since 1973" (WNA, *Nuclear Power in Japan*). As stated above in Section 6.2, public opinion shifted drastically away from nuclear power following the FDND, with an "Innovative Energy and Environment Strategy" [being] released in September 2012 recommending a phase-out of nuclear power by 2040. In the short term, reactors currently operable but shut down would be allowed to restart once they gained permission from the incoming Nuclear Regulation Authority (NRA), but a 40-year operating limit would be imposed" (WNA, *Nuclear Power in Japan*). However, just four days later, officials switched from a general approval of the plan to one which stated that "flexibility was important in considering energy policy" (WNA, *Nuclear Power in Japan*). While it may be easy for some to dismiss this as the government's way of recovering from a brief period of "crisis-driven, ad hoc energy policy" (Hayashi & Hughes, 2013), the fact remains that in other countries, such as Germany and Italy, the sudden shift in public opinion, as well as the serious long term effects which continue to unfold as a result of the FDND, led to the decision "to immediately shut down some of the nuclear reactors or abandon plans to build new ones" (Hayashi & Hughes, 2013). In fact, as mentioned in Section 5, above, it was noted that the push for denuclearization and a greater focus on "green energy" now seen in many

European nations has not only proceeded without incident, but has resulted in a better standard of living for many citizens.

Why then, have Japan and the United States, arguably the only two nations to suffer any major difficulties as a result of nuclear adoption, insisted on a continued expansion of nuclear power within their borders? In Japan at least, the reasons could be largely based on their "almost total lack of natural resources (in 2010, Japan imported 99.6%, 96.3%, and 100% of its petroleum, natural gas, and coal, respectively)" (Hayashi & Hughes, 2013). In the United States, however, the answer does not seem so simple. Over forty years ago, Surrey & Hugget (1976) stated the very rational concern that "[T]he government may side too easily with the 'Atomic Industrial Establishment' – the community of interest between electric utilities, agencies promoting nuclear power, and the manufacturers of nuclear plant - and may use its party majority to steamroller objections in Parliament". It seems today that their fears have come to fruition.

6.4 Private Interests' Stances on Nuclear Power

The impact of private interests on policy making in regards to nuclear power cannot be understated. "Nuclear power has been written off many times since Three Mile Island yet, despite the crushing blows it has suffered – serious accidents and continuing real increases in costs – it has retained, and even strengthened its support, particularly at the highest political levels" (Thomas, 2012). To some extent, the introduction of benefits and subsidies for nuclear adoption has helped to spur the growth of nuclear power in some countries, but as Kato et al. (2013) note, "After the accident, benefit recognition of utility bill refunds clearly declined, while that of public facilities did not, suggesting the influence of a bribery effect". But where exactly do the "bribes" come from? It can't be from private investors, since as pointed out in Section 4.3, renowned scholar Amory Lovins has stated that Wall Street is not investing capital into the industry, despite the considerable tax benefits and subsidies associated with nuclear power. Since the benefits are given out by the government, and government dollars are tax dollars, we are in effect being bribed with our own money to accept nuclear power.

6.5 Conclusion – Policy is Affected by Personal Interests

When responding to questions involving the continued construction of a nuclear waste storage facility against the wishes of locals, Senator James Inhofe [R-OK] is quoted as saying, "Our generation has a legal obligation to build Yucca Mountain; we've collected the money to pay for it, and we are 20 years overdue in getting it done" (Inhofe, 2007). Let us break down and examine this (seemingly) innocuous statement from an American lawmaker.

"Our generation has a legal obligation…" At any given time in America, there could be five or maybe even six generations represented to some degree in an area, each with their own needs and wants. And what of future generations? Shouldn't they be taken into consideration as well? Given the fact that "Cesium-137 has a half-life of 30 years, and since it takes about 10 half-lives for any radionuclide to disappear" (Starr, 2012), it would seem so. And while we are on the topic, to whom exactly do we hold a legal obligation? The citizens who stand to gain (or lose) the most from nuclear adoption, or the nuclear industry itself? Either way, the nuclear industry is (presumably) made up of US voters, so wouldn't they be held at the same level as any other voting member of the community; and as such be subject to the whims of the majority? Sen. Inhofe doesn't seem to think so.

"…we've collected the money to pay for it…", this is true; the tax dollars to pay for this were collected long ago. If this is truly a determining factor in the decision to continue the expansion of nuclear energy in the United States, then it would seem that the funds in question could be either refunded as an economic stimulus package or diverted for use as subsidies and benefits meant to reinforce struggling communities through public works and infrastructure projects. Indeed, as has been stated in other sections, such works are some of the strongest supports offered in favor of nuclear expansion.

"…and we are 20 years overdue in getting it done." Claiming that you should be allowed to finish a job simply because you are 20 years behind schedule is like a heart surgeon saying he should be allowed to continue an operation "because the patient is dead already". In the professional world, failing to complete a job in a timely manner does not mean you get infinitely more time to complete it; it means you are fired. They even have a term for it: lack of productivity. The American government is not "producing" anything by its continued sponsorship of nuclear energy; why should they be allowed to throw hard-earned tax dollars away "on principle"?

Referring back to Figure 5 above, while it is true that information and education seem to have a strong effect on the likelihood of nuclear adoption, there is not a single country out of the 25 presented where nuclear power was favored by a majority of the population. In fact, out of the 13 countries where nuclear acceptance was highest, the average rate of approval was only ~25% of the total population. Thus, I conclude based on the evidence presented that the final decision to adopt nuclear power rests with the elected officials of a region rather than with the citizens who put them in office.

7. Closing Thoughts

The question we must ask ourselves is, given that the nuclear industry has proven itself time and again to be both a financially and ecologically untenable one, why has it continued to flourish, largely against the will of the public? While there may be no easy answer, the data presented here today seems to support two arguments: (1) that nuclear energy is far less safe and economically sound than we have been led to believe, and (2) there has been an organized effort over the last 40+ years to hide that truth from the general populace.

As seen in the preceding sections, nuclear power has few advantages over alternative forms of energy production when put to scrutiny and indeed manages to outclass every alternative in terms of inherent danger. Even when a majority of the data presented is taken from pro-nuclear or unbiased sources, the information presented here has the appearance of bias simply because an overwhelming majority of the data, including virtually all quantitative data on the topic, undermines the argument for growth of the nuclear industry. We humans as a race have advanced to a level of technological sophistication where scientists are using water to turn sunlight into combustible fuel, and yet we generate electricity using a medium with the potential to cause irreparable damage to our worldwide economy and, more importantly, to the environment. Think back to Steven Starr's words in Section 2.4; three years after the fact billions of dollars are being invested into fixing a mistake that never should have occurred, and the best solution we have is to spend the next several years permanently removing ten tons (~2,641.72 gallons) of seawater every day from our water cycle to prevent a meltdown, a process resulting in millions of barrels of highly irradiated seawater, each essentially a dirty bomb waiting to go off.

Nuclear power is, at its core, a very complex, expensive, and hazardous solution to what might seem to be a simple problem. The nuclear industry thrives on an environment of public ignorance, blind faith, and incentives designed to buy our acquiescence while better alternatives are consistently passed over by policy-makers with questionable motives. When J. Barnie Beasley Jr., President of Southern Nuclear Operating Company, spoke before the Energy and Natural Resources Committee in 2006, he said, "The Administration and Congress demonstrated strong leadership by enacting the Energy Policy Act of 2005, which encourages diversity of energy sources, including emission-free sources of electricity, such as nuclear energy" (Beasley, 2006). However, the truth is that when the entire cradle-to-grave cycle is considered, nuclear power is actually one of the worst forms of energy production for a country aiming to lower emissions. That he could speak such a blatant mistruth and keep a straight face speaks volumes more about his own character than it does about the fundamentally flawed behemoth that is the nuclear industry. I can only assume that his success lay in part with the fact that so many of the committee members were "in on the joke", as it were.

Based on the data gathered here, it is obvious that nuclear power is a means of energy production that should have been done away with long ago. There is little to no documented evidence that nuclear adoption has any appreciable beneficial impact in the long-term for adopting communities, yet it continues to be pushed at the behest of politicians and nuclear lobbyists. It has been proven both in theory and in practice that there are better energy alternatives, both in terms of overall cost and efficiency, yet in certain countries it is still claimed by many to be the answer to all the world's energy needs. What's more, every nuclear plant currently in operation has the potential to devastate huge portions of our world ecology. Yet when things do go wrong, data is manipulated or downplayed in order to minimize cleanup costs and public disapproval, often at the cost of the general public's health and safety. It is only through a concerted effort demanding change that policy will ever shift appropriately. Such change must begin with a greater level of public education and awareness about the costs, both monetary and otherwise, of nuclear power.

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