MICHIGAN
ROSS SCHOOL OF BUSINESS

Ross School of Business at the University of Michigan

Independent Study Project Report

TERM : **Winter 2013**

COURSE : **LHC 489**

PROFESSOR : **Dana Muir**

STUDENT : **Daniel D. Kaisler**

TITLE : **Nuclear Reactions: Public Policy Based on Shortsighted Responses to Pivotal Events**

Nuclear Reactions: Public Policy Based on Shortsighted Responses to Pivotal Events

by

Daniel D. Kaisler

A thesis submitted in fulfillment of the requirements of LHC 489, March 1, 2013

Acknowledgements

I must begin by thanking Professor Dana Muir for all her guidance and inspiration. Throughout this project, she challenged me personally as well as academically. Because of her I have learned and accomplished more than I could have imagined in the duration of this project. I would like to thank the librarians who have aided my research, particularly Corey Seeman, director of the Kresge Business Administration Library and Paul Grochowski of the Art, Architecture, and Engineering Library. I would like to thank Professor George Siedel, who instructed the Carson Scholars Program, through which this thesis was born. Finally I would like to thank the three people who have been in the same boat as me all along, rowing frantically: my fellow Maize Team members, Ankur, Christina, and Kristy.

Abstract

High energy prices have become the norm in recent times. The average American consumer cannot escape the climb of these prices, and becomes acutely aware of them whenever he or she fills his car or turns on the heat in her house. The federal government, as a representative of the people, recognizes this concern of its constituents and through both rhetoric and action sets a course of action. Nuclear energy is one tool the government has at its disposal to address such a problem. Historically, the federal government has maintained tight regulatory control of the nuclear energy industry. However, the creation of nuclear regulatory policy has proved challenging, and the federal government responds to pertinent industry events, instead of creating anticipatory policies. As a result, the nuclear energy policy of the United States has been a product of inflection points that bring increasingly complex factors into the focus of policy makers throughout the legislative and regulatory processes. Significant inflection points include the use of the atomic bomb, pressure to create a nuclear industry in the United States, the accident at the Three Mile Island power plant, and the current fossil fuel crisis. These inflection points have contributed to complicating the nuclear question by adding to the relevant factors in the policy decision making process. As a result, the issue of nuclear energy has become so complex with so many competing factors that the industry has become stagnant in the United States, despite political rhetoric in favor of its increased adoption. Regardless of presidential aims or partisan support, unless sweeping policy changes are made, the nuclear energy industry will not further develop in the United States.

CONTENTS

Introduction

"Atomic power can cure as well as kill. It can fertilize and enrich a region as well as devastate it. It can widen man's horizon as well as force him back into the cave" – nuclear physicist Alvin Weinberg testifying before a Senate Special Committee on Atomic Energy in 1945 (Mazuzan 2).

The central role of any modern democracy is to provide for the wellbeing of its constituents, protecting them from threats to life, liberty, and the pursuit of happiness. A government must also strive to foster an environment conducive to a vibrant economy. A fearsome threat exploded into existence in 1945, as the world witnessed the destruction wreaked by the power contained within atomic nuclei. The story did not end there, as the world also learned that this phenomenal energy, when controlled, could be used to generate electricity to power factories, hospitals, schools, and homes.

The double-edged sword of nuclear energy has challenged policy makers in the United States (U.S.) to balance safety and utility. Historically, the nuclear energy debate has taken a backseat in policy discussions, only to arise when current events force its notice. As a result, the nuclear energy policy of the United States has been a product of inflection points that bring increasingly complex factors into focus for policy makers throughout the legislative and regulatory processes.

This thesis begins by examining an inflection point of historical and scientific precedence: the creation and use of the atomic bombs by the U.S., and the federal government's response. The next section deals with the Cold War, and the pressure from the scientific community and private industry to create more inclusive policy as a means of scientific achievement and economic profits. Further on, the focus shifts to the accident at the Three Mile

Island nuclear plant and the new challenges that faced policy makers. It then progresses into the new millennium, as widely used fossil fuel energy sources began to cause crises of their own, and examines how this has caused nuclear power to return to light as an economical and environmental sound energy source. The last section explores how the Fukushima Daiichi accident of 2011 will affect nuclear energy policy in the United States.

Background of Nuclear Fission Energy

The Way the United States Produces Energy is at an Important Crossroads

With fossil fuels such as coal and oil becoming increasingly scarce, the United States faces a choice as to how to invest in future energy production. President Obama is quoted on the Whitehouse's website as saying, "We can't have an energy strategy for the last century that traps us in the past. We need an energy strategy for the future – an all-of-the-above strategy for the 21st century that develops every source of American-made energy" ("At A Glance"). The current administration and political climate favors renewable sources such as wind and solar energy. The Whitehouse website further provides, "the administration has approved the construction of 16 commercial-scale solar facilities, five wind, and eight geothermal projects on public lands" ("The President's Record on Energy and the Environment"). Reliance on nuclear energy, a historically promising source, once promised to be so inexpensive that utilities would not have to be charge for it, represents a distinct strategy that could achieve the same goal.

Economic Realities of Fossil Fuels

The rise in energy prices cannot be escaped in everyday life. Cars continue to be more and more expensive to fill, and homes become more costly to heat every winter. The cost of running an appliance makes consumers think twice about their energy use. Between 1980 and 2011, the composite price of fossil fuels rose from $2.55 to $4.85 per million Btu[1] (adjusted for inflation, see fig. 1) ("Annual Energy Review"). The cause of this problem is twofold. To begin, fossil fuels are known to be limited resources. In contrast to renewable energy resources, once

[1] "**British thermal unit:** The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit)" (Glossary).

coal, oil or natural gas is burnt, it is burnt and cannot be converted back into its original form. Thus, each time one of these energy sources is consumed, there is less to consume in the future.

The second cause is increased demand. As populations expand and economies are driven toward growth, the demand for energy increases as more people and businesses require energy to function. Fig. 2 shows that energy consumption in the United States has risen from 84 quadrillion Btus in 1991 to 97 quadrillion Btus in 2011, a 15% growth. Thus, new energy sources are becoming increasingly important to maintain a healthy economic environment.

Nuclear Energy as an Environmentally Friendly Energy Source

While there is much evidence pointing toward human-caused climate change, it is a contested issue, particularly in political circles. This being said, because of the scale of the potential damage, it is essential to be very cautious moving forward, heeding the warning signs, and reducing fossil fuel consumption. Nuclear energy provides a greenhouse gas free alternative. Nothing is combusted in the process of nuclear fission, so no greenhouse gases are released. In this way, nuclear energy production does not contribute global warming and climate change. It is clean and emissions free ("Nuclear Energy"). Thus, increasing the United States' reliance on nuclear energy production helps to mitigate the risk from a potentially devastating scenario. .

An argument of pathos can also be made in favor of alternative energy production in place of traditional fossil fuels. The processes of "fracking" for oil and mountain top removal (a process which involves clearing forest, destroying rock with high explosives, and dumping the rubble into nearby valleys in the interest of mining coal) have made news in recent years (Mitchell 107). Even if these processes are economically justifiable and produce cheap energy, they wreak havoc on the land that people use for both sustenance and enjoyment. As a nation line must be drawn between economic prosperity and protection of its natural resources, and nuclear energy can help policy makers set this line in an efficient way.

About Nuclear Fission Energy

The United States Energy Information Administration explains that nuclear fission describes the process of breaking apart uranium atoms. In the process, massive amounts of heat are released. Water captures this heat, becoming steam under high pressure (“Nuclear Explained”). The steam in turn is used to spin a turbine, which produces the electricity that flows through the grid, powering homes, businesses, and industrial processes alike. The Environmental Protection Agency explains that uranium, a mined material, and is able to sustain the chain reaction necessary for controlled fission (“Nuclear Energy”). Currently, 104 licensed nuclear reactors operate at 65 power plants in 31 states. Fig. 3 maps the locations of these plants that provide approximately 20% of the nation’s energy (“Nuclear Explained”)

Thesis Focus

While nuclear energy promises inexpensive, reliable energy to a thirsty nation, it has had a turbulent history in the United States, particularly from a public policy perspective. The federal government has made it clear that nuclear energy is something that must be strictly regulated. Accordingly, the industry has been at the mercy of Congress, the national budget, and the Nuclear Regulatory Commission (NRC, the agency whose mission is solely to regulate the industry). Because of the regulation first, business second approach, public policy plays a substantial role in dictating the role of nuclear energy in the U.S. Energy portfolio. Accordingly, this thesis examines the role of nuclear energy policy, how it has been influenced by industry events, and what may happen in light of recent events.

Method

Research was conducted largely through the use of historical texts written about nuclear energy policy, the nuclear energy industry, and the pertinent events. The specific pieces of legislation discussed were examined, as well as the congressional processes behind the bills and role the executive branch (both the president and the bureaucracy) played in the policy creation process.

Key inflection points, or points in time where nuclear energy policy veered from its previous path and began in a new direction were identified. Importance to the industry, historical precedence, and the magnitude of the response served to identify these points. After the points were determined, the background of the era was explored to present a context. From this research, the most important factors on which policy decision making was based were highlighted, leading into their role in the resulting policies and policy changes. Finally, these factors and the historical policies became a tool to analyze recent significant events in the nuclear energy industry, and make conclusions about its tumultuous and often contentious history.

While some of the inflection points were determined to be specific events, such as the use of the atomic bomb and the accident at Three Mile Island, other points have a less obvious presence. For example, the Atomic Energy Act of 1954 and the Energy Policy Act of 2005 represent the culmination of pressure from various factors outside of nuclear energy. In these cases, the policy *is* the inflection point, and as will be seen, the federal government reacts to these pressures, instead of anticipating them.

The Beginning of Nuclear Energy: The Atomic Bomb

Inflection Point: The Bombing of Hiroshima and Nagasaki

The end of World War II marked a time of excitement and anticipation for the future as the conflict came to a halt and nations began to rebuild. However, with the surrender of Japan, a frightening, new technology captured the public's attention: the nuclear bomb. The bombs dropped on Hiroshima and Nagasaki were nuclear fission bombs, the first of their kind ever to be used in war. These bombs harness phenomenal energy by splitting an atom's nucleus. Although the United States led their production and usage, other nations were not far behind in the achieving the technologies and capabilities to build and use nuclear weapons. Thus, the U.S. realized a need to safeguard the secrets it had used to unleash the power, controlling the technology. However, by keeping the technology out of the wrong hands, the government also kept it out of the right hands.

Era Background

Shortly after the Second World War, nations that had put every effort toward raising and supporting armies encountered the challenge of transitioning to peacetime states. Yet, the consequences of war remained. The past decade left them all a bit wary to abandon the military machines they had built up, should the peace not last. The use of the atom bomb introduced the destruction of nuclear fission to world, adding tension to the newly established peace. However, in addition to having war time applications, nuclear fission had the potential to be controlled and used to produce the energy that societies needed to operate. Indeed, according to George Mazuzan and Samuel J. Walker in their book *Controlling the Atom*, when nuclear Physicist Alvin Weinberg appeared before a United States Senate Special Committee on Atomic Energy in 1945, he gave his vision: “Atomic power can cure as well as kill. It can fertilize and enrich a region as well as devastate it. It can widen man’s horizon as well as force him back into the cave” (2).

Factors Affecting Policy: National Defense

Like Weinberg, many saw nuclear fission as an unprecedentedly efficient and powerful supply of power for industrial and residential use. Contrastingly, the awesome power and destruction of fission bomb was still fresh in the memory of Congress. The ability to create sustained nuclear fission no longer was a military secret; its existence was public knowledge. Scientists, industrialists, and capitalists all wanted access to the technology and material, and the federal government immediately sought to control these activities.

A 1948 article in The University of Chicago Law Review observed that the Atomic Energy Act of 1946 was an unusual piece of legislation, about an issue that worked to “deprive the legislator of his comfortable pattern for reaching policy decisions” (Miller 799). The unique nature of the issue required “an almost pure exercise of judgment” (799). Several factors caused the issue to be distinct. The military, political, and socioeconomic implications of nuclear fission were large, but paled in comparison to the “fear and awe” caused by the atomic bomb (800). These emotions begged for governmental control of the technology causing policy makers to be more illogical and sensational than they otherwise might have been. A second factor was the newness of the issue. Nothing comparable had been dealt with by Congress. The slate was clean, and the traditional avenues for forming positions and seeking information and guidance were absent (799-801). Rational thought was more difficult to come by, and the shockwave caused by the mere existence of the atomic bomb shook Congress.

Resulting Policy: The Atomic Energy Act of 1946

Thus, national defense become the sole basis of The Atomic Energy Act of 1946, which manifests the hurried desire for government control and protection from the power of the atom. American leaders faced the challenge of crafting policy that would allow the safe and effective use of nuclear fission technology, in order to “win the nation’s confidence” (Maszuazan & Walker 2). Congress had initially rushed to pass the bill, but pressure from the scientific community to further investigate the situation slowed the process. Once passed, the law established the Atomic Energy Commission (AEC), an agency whose mission was to “produce fissionable material for weapons and to develop and manufacture weapons as military requirements dictate” (4). A point of contention in the bill was whether the AEC should be controlled by the military or by civilians. A compromise was reached, giving civilians control over the AEC. However, the AEC would work with a military liaison board that represented the military’s interests (4). The 1946 act did not allow for private, commercial application of atomic energy; rather, it created a “virtual government monopoly of the technology” (Walker 1).

The act preempted state and local governments from regulating nuclear matters in order to ‘ “provide for the common defense” ’ and the federal government’s duty to support an army and navy (Zimmerman 52). Protecting secret atomic energy information was a key impetus behind the preemption. Federal control was seen as necessary to safeguard military secrets from enemies of the U.S., particularly Russia, at the beginning of the Cold War. Allowing commercial transfer and use of nuclear material and information was understandably viewed as a danger that would increase the risk of proliferation and the passage of vital information to enemy agents.

The Atomic Energy Act of 1946 was a response to the inflection point, influenced by factors that exploded into existence with the atomic bomb. Congress reacted to a new issue, creating public policy that considered the future, but focused on the past events (the military use of nuclear bombs). Although the act recognized the potential use of civilian nuclear energy and the need to regulate it, it did nothing to establish an infrastructure or guidelines for peacetime purposes, instead briefly acknowledging them and prohibiting their use. The bill was a quick reaction; hurried through the legislative process until scientists pressured congress to explore the issue further (Mazuzan and Walker 3). Furthermore, while congress did create the civilian run AEC, military use was emphasized instead of long-range planning for future applications of nuclear power (Miller 821). As will be seen throughout this thesis, the Atomic Energy Act of 1946 is as many nuclear energy policies since have been: reactions to events that fail to anticipate and create policy for the future, instead focusing on how to respond to those previous events.

Toward Nuclear Energy: Pressure for Industry, Profits, and Progress

Although the Atomic Energy Act of 1946 did recognize the potential peaceful applications of nuclear fission, it failed to create an environment that fostered understanding and application of these uses. It was not until eight years later, when the Act was amended, that private industry was allowed to further develop these uses and implement them as civilian institutions. The 1946 Act necessarily protected a dangerous, new technology. Through it, the government did study and learn much about the atom. However, it did not contain the foresight to create policy for nuclear energy's future. Until the combined pressure of the private industry and political supporters of a more lenient policy forced change, nuclear energy did not became part of the U.S. energy portfolio. The urging of these groups caused the government to consider nuclear power not only as a danger to be contained, but as a technology to be utilized, capitalizing on cheap energy. The potential for peaceful use added an additional facet to the issue congress was challenged with, complicating relevant areas to analyze during policy making.

Inflection Point: Increased Pressure from the Private Industry and Scientific Community

Pressure on the AEC to deregulate nuclear material continued to mount during the late 1940’s and early 1950’s. Both administrative leaders and private citizens alike heavily criticized the federal government. Interestingly, an outspoken critic of the policy was the first Chairman of the Atomic Energy Commission, David Lilienthal. Lilienthal, appointed by President Truman, proved to be key in establishing international nuclear policy for the United States (Mazuzan and Walker 4-5). In October 1947, Lilienthal confirmed beliefs that nuclear power was a reality of the distant future, stating that the necessity for national security precluded private industry involvement. However, he was optimistic that the possibility of a private nuclear energy industry remained. During these remarks, he announced that the AEC would begin examining "classified agency activities for commercial possibilities" (17).

Commercial development was again sidetracked by military goals. Atomic weapons tests in the Soviet Union held the AEC's attention. In February 1950, Lilienthal resigned. Author Mazuzan tells of Lilienthal's remarks several months after his resignation:

> As a private citizen Lilienthal explained his frustration in attempting to open the atomic monopoly even slightly. He began a well-publicized article in *Collier's* in June 1950 with the statement that "no Soviet industrial monopoly is more completely owned by the state than is the industrial monopoly in free-enterprise America." He pointed his finger at the culprit—the Atomic Energy Act of 1946—and emphasized that the law should be repealed so that the industrial atom could be developed in accord with the American System." (18).

Around the same time as Lilienthal's hard-hitting remarks, Charles Thomas of Monsanto Chemical Corporation, a friend of Lilienthal, proposed an enticing plan to the AEC. Thomas proposed that Monsanto be allowed to design and operate a nuclear power plant independently of the federal government. Remarkably, the plan created a brilliant win-win. In addition to giving Thomas the right to the power and technology that would give him the first mover advantage in the nuclear energy industry, his plant would produce plutonium, the fuel in nuclear warheads and a material sought after by the government. The AEC decided to study Thomas' proposal, as well as similar proposals soon offered by Dow Chemical Company and Detroit Edison Company (18-22).

Era Background

Research on harnessing the phenomenal energy of the atom was initially conducted with the goal of creating a weapon unlike any other. The Manhattan project, tasked with developing a nuclear weapon, thought little about the possibility of peacetime nuclear power. The private industry however, had. Pressure from the private sector, coupled with AEC officials sympathetic to the private sector began to draw attention to the issue. The arms race with the USSR and the U.S. goal of creating a hydrogen bomb (a more powerful type of nuclear bomb), put peacetime nuclear energy low on the government's list of priorities. However, some politicians recognized that a sophisticated nuclear energy network could testify to U.S. superiority as a nation in the Cold War. In addition to being pitted against the Soviet Union in an arms race, the Cold War pitted democracy against communism as a social order. The countries vied not only for military superiority, but strived to reign as the most scientifically, artistically, and culturally developed nations (Mazuzan and Walker 23-24).

Factors Affecting Policy

Initially, the most desired product of nuclear power was *not* power. According to Walker, the energy demands of the United States were readily handled by the current means of production, at least in the short-term. Eventually, it might be required to produce enough power for the nation, but this was not seen as a pressing issue (23). As a result of the Cold War, the United States government had a desire to develop a peaceful nuclear energy program as a means of scientific achievement. In a 1953 speech, AEC commissioner Thomas Murray stated that "hungry countries will gravitate toward the USSR if it wins the nuclear power race…" (23), an unacceptable outcome. Later that year, President Dwight D. Eisenhower addressed the United

Nations General Assembly in his “Atomic Power for Peace” speech, which according to authors Mazuzan and Walker, “was partly propaganda” (24). In the speech, President Eisenhower called for an international agency to support the development of nuclear power programs that would “serve the needs, rather than fears of mankind” (24).

Resulting Policy: The Atomic Energy Act of 1954

Although the Atomic Energy Act of 1946 was seen by the federal government as a necessary preemption of regulatory power from the states in the interest of national security, the proposals by Dow and DTE mentioned above strongly captivated the AEC. The plans catalyzed policy that established a framework for the examination of such proposals, beginning to study the issue of a privatized nuclear industry more deeply. It was stressed that an understanding of privatized nuclear power be made before any sweeping policy changes took effect. After conducting the study, it became evident to the AEC that government support would be necessary not only to support such an industry, but to regulate it in order to protect both the public health and national security (18-22).

Pressure from the scientific community, private sector, and from political actors caused the AEC to propose legislation that would radically amend the Nuclear Energy Act of 1946, breaking up the government’s monopoly. Thus, the Nuclear Energy Act of 1954 was passed, opening the door to nuclear power in the United States. The bill begins by stating:

> Atomic energy is capable of application for peaceful as well as military purposes. It is therefore declared to be the policy of the United States that the development, use, and control of atomic energy shall be so as to make the maximum contribution to the general welfare… and the development, use, and control of atomic energy shall be directed so as

> to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise ("Atomic Energy Act of 1954, As Amended").

According to a Congressional Quarterly report on the act, the Atomic Energy Act of 1954 gave the private industry the privilege to process "special nuclear material" and "build atomic power plants" ("CQ 1954"). However, through the act, the AEC retained tight regulatory control. This was possible through the use of licenses. Companies were required to seek approval and enter a contract with the AEC in order to operate. The act created the basis of these partnerships between the government and the private industry. Because of capital costs and technology to which the federal government had better access, partnerships appeared to be the most efficient relationship. For example, the AEC would conduct research of proposed reactors in already established and long-running national laboratories. The goal of this method was to speed the process of adaptation of nuclear power, through the utilization of the private industry's ingenuity and the federal government's ability to centralize resources and knowledge. Although the initial costs were high, the hope was that these partnerships would eventually create power that "was too cheap to meter" (Walker 5)

The AEA of 1954 set the field for the rapid rise of nuclear power in the United States. Over the next two and a half decades, the AEC (and later Nuclear Regulatory Commission[2]) oversaw the achievement of these technological marvels. The Atomic Energy Act of 1954 attempted to correct what the government had failed to do in the past: implement a strategy to

[2]In 1974, Congress split the Atomic Energy Commission into two separate organizations: the Energy Research and Development Administration and the Nuclear Regulatory Commission (NRC). The AEC had come under criticism because it served for both "developing and regulating the technology " (Walker 44). One critic made the analogy stating it was " 'like letting the fox guard the henhouse" (44). The NRC served to regulate the nuclear energy industry through the same licensing and rule-making as had the AEC (45).

utilize the benefits of nuclear fission. Once the insistence of the scientific and political communities convinced Congress of the benefit of utilizing the private industry, the legislature was forced to balance their responsibility for the defense of the nation with their duty to foster a strong and technologically advanced economy

Fear in Harrisburg: The Domestic Nuclear Threat

National defense captured the spirit of the times as the world rose from the ashes of World War II, and directly led to the passage of the Atomic Energy Act of 1946. As time marched on, the push of the scientific community and private industry compelled policy makers to consider an additional factor in their decision making: the need for progress. The United States rapidly adopted nuclear power in the subsequent years. However, a series of events that nearly led to a nuclear disaster at a plant presented a new threat to the nation: the domestic threat of nuclear accidents. Confounding an already complex situation, the crisis precipitated contention among different government officials at various levels of government. As after the previous two inflection points discussed, another issue was catapulted into prominence, sparking reactions from citizens and policymakers alike.

Inflection Point: Partial Meltdown at the Three Mile Island Nuclear Plant

On March 28, 1979, what critics of nuclear energy feared would happen, happened: there was an incident at a civilian-run nuclear power plant known as Three Mile Island. Three Mile Island, home to two nuclear power plants, (TMI-1 and TMI-2), is located 10 miles southeast of Harrisburg Pennsylvania (Kemeny 81). The plants had the combined capability of 1,700 megawatts, enough to power 300,000 homes (83). Together, Pennsylvania Electric Company, Central Power & Light Company, and Metropolitan Edison Company owned the plants, while Metropolitan Edison operated them.

Around 4:00 A.M. on the 28th, several water pumps failed in Unit 2 of the Three Mile Island facility. Nuclear fission generates immense amounts of heat, which are used to create steam. This steam turns a turbine, which generates electricity. The steam captures the immense amount of heat generated, preventing the reactor from melting. However, on the day of the accident, a failure of the pump robbed the reactor of its much needed coolant. Operators attempted to fill the reactor with coolant, but a pressure release value became lodged in the open position, causing coolant to escape from the reactor. As a result, the reactor began to heat to dangerous levels. Mechanical failure, coupled with human error, caused a partial “meltdown” or a core-melt accident, defined by the NRC as “an event or sequence of events that result in the melting of part of the fuel in the reactor core” (“Full-Text Glossary”). Around half of the reactor core had melted, creating one of the most dangerous accidents a nuclear plant could face. In the worst-case scenario of a meltdown, the melting fuel would breach the walls of the containment building, releasing massive amounts of radioactive material into the environment. However, this did not occur, and the radioactive fuel was contained (“Backgrounder on the Three Mile Island Accident”).

Era Background

For the 25 years since the Energy Policy Act of 1954, the nuclear industry was on the steadily on the rise. Plans for plants were drawn up, approved, the plants were constructed, atoms were split, turbines were spun, and power was delivered to customers. The industry ran full steam ahead, and the dream of unbelievably cheap energy seemed to be a realistic prospect. Simultaneously, the industry’s antithesis was growing in the form of the anti-nuclear movement. The movement consisted mostly of people concerned with environmental and health risks of nuclear energy (Walker 34-41).

A sizable portion of the nation relied on nuclear power as a source of energy, and a central public policy aim was to keep power flowing to the consumer. According to Bertrand

Goldschmidt in his book *The Atomic Complex*, in 1979, 80 nuclear power plants in the United States supplied 13% of the nation's energy needs, and President Jimmy Carter proclaimed any disruption to the nuclear program would wreak havoc on the U.S. economy (81). In contrast to the initial policy aims, (the Atomic Energy Act of the 1946, which placed national security and safety as a priority), it seemed safety measures would come at the cost of economic wellbeing. At the time, economic pressure proved to be more compelling than the calls for safety, at least *prima facie*, as rhetoric by government officials indicated support for expanding nuclear energy.

Factors Affecting Policy

The accident at Three Mile Island cast what was already a contentious issue into the public's eye. "No event since the last days of Richard M. Nixon's presidency had been the subject of national debate on such a scale" (Goldschmidt 451). Walker writes that for the first time, respondents to a survey who opposed the construction of additional nuclear reactors outweighed the number of respondents who favored new plants. However, these polls also showed that closing existing plants or abandoning nuclear power all together was not something the public supported (Walker 49).

Not only did the public become more vocal in their opposition to nuclear energy, but so did state and local governments. As a reflection of the will of their constituents, several states refused to participate in emergency drills that were necessary for a plant to receive an operating license (Walker 52). The NRC fought these road blocks, claiming that a state's refusal to create emergency plans would cost billions of dollars to the utilities that built the plants in question. Author Zimmerman argues that the unprecedented contention begged the question of whether or not federal preemption and control of the nuclear energy industry is favorable for the industry.

"Cooperation and not compulsion is the key," writes Zimmerman, referring to effective safety plans (63).

Although quite unsettling, some viewed the accident at Three Mile Island as a testament to effective safety measures and proper regulation. Peter Hodgson writes in his book *Nuclear Power, Energy, and the Environment* that the amount of radiation absorbed by people in close proximity to the plant was comparable to a dose received from natural sources received in one *day* (81). The prevention of a much larger disaster was in part due to the emergency systems included in the design of the Three Mile Island plant. Once human error was eliminated and the reactor's safety systems began to run, the reactor began to cool as designed (Walker 48). The near miss raised several difficult questions about nuclear safety, complicating the response. Were the events it too close for comfort? Or was it an assurance that the safeguards in place were effective and policy and plant design had successfully mitigated the danger?

President's Commission Report

After the accident, President Jimmy Carter established a Presidential Commission to "conduct a comprehensive study and investigation of the recent accident involving the nuclear power facility on Three Mile Island in Pennsylvania" (Kemeny 1) The commission's investigation was to include "an evaluation of the NRC's licensing, inspection, operation, and enforcement procedures, and appropriate recommendations based on the findings" (1). The commission's findings were summarized as so:

> To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices – and above all – in the

> attitudes of the Nuclear Regulatory Commission and, to the extent that the institutions we investigated are typical, of the nuclear industry (Kemeny 27)

While the report neither condemns nor condones nuclear power, it makes recommendations for its safe use should other organizations with the authority opt for its continued role in the U.S. energy portfolio. The report stresses a failure in the management of the NRC and chastises the seemingly lackadaisical attitude of the industry, recommending that instead of having a five-member leadership board, the NRC should have a single leader to more efficiently run the organization. The report criticizes the current structure "because there is insufficient direction in the present statute" (Kemeny 61). The President's Commission believed that a single leader with a significant term could provide continuity to the NRC. By the recommendation, the commissioner was to have a strong hand over the NRC to ensure the effectiveness of the organization.

Secondly, the President's Commission believed that the industry had become too complacent about the danger of nuclear energy. Because no major accidents had occurred before the Three Mile Island incident, "the belief that nuclear power plants are sufficiently safe grew in a conviction. One must recognize this to understand why many key steps that could have prevented the accident at Three Mile Island were not taken" (Kemeny 9). At the time, "large-break" accidents were the focus of regulators – major disasters with catastrophic causes. However, this focus allowed accidents caused by small mistakes and equipment failure, where each component was small, but the sum was significant, to be overlooked in emergency preparation. Thus, while the equipment failures in the Three Mile Island accident were "significantly less dramatic," plant management did not know how to respond, and worsened the situation. For the third time, a lack of foresight by policy makers in regard to nuclear energy hindered its successful adaptation and operation as a power source.

Nuclear Regulatory Commission Reaction

Both the President Carter and the NRC responded to the President's Commission report without the vigor that the commission had envisioned. Four of the five commissioners opposed the single commissioner model, because they felt that "a collegial body composed of members with differing viewpoints could more accurately reflect the views of the public," as the American public was deeply divided on the issue of nuclear energy (Temples 357).

While Congress did not act to halt work on plants under construction or even place a moratorium on new permits, the NRC did regulate the industry by issuing its own moratorium on the issuance of new plant licenses until the accident was investigated ("Nuclear Plant Licensing"). The NRC's position on its own structure differed from the President's Commission recommendation on this matter, but the two organizations did see eye-to-eye on other issues. For example, the report suggested the preparation of more detailed safety and evacuation plans for operating plants (Temples 356). The NRC did consider closing down several plants close to large cities, citing a lack of effective evacuation routes as a hindrance to safety, but never went through with the plants. Undoubtedly, the cost of following through with this would have been high, and as President Carter had stated, would be very detrimental to economic health.

The NRC's licensing moratorium ended in 1980, and the NRC began granting licenses for full-power operation once again (Walker 51). However, these licenses were for plants that had already been constructed, having been granted construction permits in the mid-1970s, before the TMI accident (Walker 51).

Imagining for a moment that the accident had been significantly more serious, with loss of life and significant property, the response may have been more substantial. The close call caused a stir, and while changes were put into effect (new training programs, improved emergency contingency plans), regulation of civilian operated nuclear power plants did not change significantly. Indeed, Professor Temples writes that superficially, the NRC changed, but really still operated with the same philosophies as before (360). No real change had come from what amounts to a near (or maybe not so near) miss.

Presidential Reaction

Like the NRC, President Carter opposed placing a single commissioner at the forefront of the NRC, possibly because of political pressures he was facing at the time (Temples 357). However, Carter emphasized his support for a nuclear energy program, stating that the country's energy needs required such a resource for economic livelihood. President Carter stressed that energy independence was a central public policy objective, as foreign oil was becoming increasingly risky to obtain. Additionally, Carter created the Nuclear Safety Oversight Committee to be a watchdog of the NRC, monitoring their implementation of the changes called for in the President's Commission report (Temples 358).

Strong Rhetoric, Weak Action

Although the NRC opposed reorganization, and the Carter administration pledged to support nuclear energy programs, licensing data indicates the accident at Three Mile Island did indeed seriously hinder nuclear energy. Looking at a graph (see fig. 4) of the number of licenses issued by the NRC for the construction and operation of civilian nuclear reactors clearly tells this story. Prior to the 1979 accident, 162 construction licenses had been issued. Since 1979, only 16 new construction permits have been allowed by the NRC. It can be argued that once the Atomic Energy Act of 1954 became law, civilian nuclear power had initially taken off, but by the late 1970s had reached the capacity required by the nation. However, fig. 5 shows that only around 20% of the all energy produced in the United States comes from nuclear sources. After 1985, the total percentage of production has remained more or less constant. Granted, between 1985 and 1996, 34 new reactors began operating ("What is the Status of the U.S. Nuclear Industry?"). However, these are plants had been licensed *before* the Three Mile Island Accident. As of 1986 when the Chernobyl accident[3] in the USSR occurred, no new nuclear power plants had been ordered since 1978, and cancellations of existing plans were on the rise (Walker 51).

Pietro Nivola, a senior fellow at the Brookings Institute writes that increasing capital costs, which began to stifle nuclear plant construction after Three Mile Island, are due largely to construction delays resulting from the regulatory process. He explains that prior to 1979, constructing (groundbreaking to operation) a plant took seven years on average. By 1990, this had risen to twelve years. "One estimate imputed to the post-TMI standards as much as 60 percent of capital costs for plants completed after 1979" (Nivola 3).

New Administration, New Promises

In 1981, when the Roland Reagan administration took office, it appeared that nuclear energy would be revitalized. The administrated indicated support of a more robust nuclear energy program, beginning with a request for a 30% increase in spending for civilian nuclear power programs (Temples 359). The administration and lobbying groups pressured the NRC,

[3] Since the accident at Three Mile Island essentially stopped progression of the nuclear age in its tracks in the United States, the Chernobyl accident was not found to have had a significant effect on nuclear energy policy, and thus is not discussed in this thesis.

arguing that the licensing process was too slow, costing the American public. The process, made more rigorous as a consequence of the Three Mile Island Accident, caused plant construction to be nearly twice as long in the United States as in other developed nations. The president's support of such changes was met with little success, as "the whole American nuclear machine had lost its past momentum" (Goldschmidt, 453).

The recommendations of the President's Commission on the Accident at Three Mile Island cited planning and preparation for a wide variety of emergencies as central for continued existence of a safe civilian nuclear energy program in the United States. The United States Nuclear Regulatory Commission readily accepted most of the changes the President's Commission urged for, but was criticized as not substantially changing the way it operates. Safety from the threat of a domestic accident suddenly factored into policy decision making with an added pertinence, further confounding the difficult decisions for Congress and the NRC. While both the Carter and the Reagan Administration pledged support for an increased emphasis on nuclear energy, data indicates that this did not become the reality. Opposition for the public and state and local governments created tension within the nuclear power movement, destroying the momentum it once had as a revolutionary scientific achievement that would help the United States of America gain superiority over the Soviet Union.

Stagnation: the 1980s and 1990s

The time after the accident at TMI can be seen as nothing short of stagnation for the nuclear energy industry. A limited number of new licenses were issued, likely for plants that had already been far along in the planning process before the Three Mile Island accident. For the most part, any venture to build a nuclear plant faced several issues. The first was finding a location. After TMI, people thought a little harder about living near a nuclear plant. Not in my back yard likely captured the attitude. Also, the regulatory process became long, drawn-out, and very expensive. So, for the next 25 or so years, while existing plants continued to operate, were maintained, and contributed a significant amount (20%, fig. 5) to U.S. energy production, the industry did not grown by any substantial amount; it was stagnant.

Price, Source, and Greenhouse Gases: Economic and Environmental Health

Inflection Point: The Energy Policy Act of 2005

. The Energy Policy Act of 2005 represents the culmination of several different social and economic pressures experienced recently in the United States: the rise of energy prices (secondary to an increase in energy demand and consumption), a goal to become an energy independent nation, and fear of climate change from the consumption of fossil fuels. In the past decade, these issues outlined above have become increasingly important in the energy policy landscape, causing many policy makers to reconsider nuclear energy as a tool of U.S. energy production. Predictably, these additional factors do not make the nuclear energy policy questions easier to answer, and government officials have had to balance the achievement of the above three goals with the factors already discussed.

Era Background: The Nuclear Renaissance

The World Nuclear Association, an "international organization that promotes nuclear energy and supports the many companies that comprise the global nuclear industry," claims that the Western World is in a "nuclear renaissance." This renaissance is characterized by the return of public support of nuclear power, which has not been the case since the 1980's, right after the Three Mile Island accident. The WNA's website gives several reasons why this is the case: increasing energy demand, security of uranium supply, and climate change ("The Nuclear Renaissance").

Indeed, evidence for a renaissance can be seen in fig. 4 by the uptick in licenses granted by the NRC in 2007**.** According to the United States Energy Information Administration, the last new reactor to come online in the United States began operation in 1996 ("Nuclear Explained"). Again, fig. 4 shows the lack of permits granted by the Nuclear Regulatory Commission in the 1980s, 1990s and early 2000s testifies to the stagnation in the industry, setting the stage for the purported renaissance.

The increase in permits has not come easily or expeditiously, however. An article by Alvin Weinberg of the Institute for Energy Analysis explains that uncertainty is the main stumbling block of a sustained nuclear revival. He writes that uncertainty in regulation, price, and public perception (in light of the Three Mile Island accident) contribute to the high cost of nuclear plants. Nuclear policy that is "more flexible and reasoned" would reduce this uncertainty. For example, when a deficiency in a certain plant is discovered, usually all plants must be backfitted. While this sometimes is essential to safety, other times, plants of different design do not require the same measures, and the illogical and arbitrary rule drive up the cost of owning and operating a nuclear reactor (4).

Factors Affecting Policy: Energy Security, Supply and Demand, and Emissions

A 2010 *Energy Policy* articles further supports Weinberg's claim. Robert Dixon explains that over the past thirty years, three factors have driven the shift to new energy policy: energy security, environmental protection, and economic development (6401). The article continues by explaining that energy security aims to decrease the amount of energy the United States imports. As demand for energy both globally and in the United States increases, it becomes more risky to rely on other countries to supply fossil fuels to the United States. "Concerns have increased due to rising prices, declining world reserves, and increasingly also fear of dependence on imports from the Middle East where instability and anti-Americanism is growing" (Bang 1). Alternative energy, such as nuclear, would reduce this risk by allowing the United States to have a more independent energy supply (the United States has a significant uranium reserve) ("U.S. Uranium Reserve Estimates").

The second factor, environmental protection, is the motivation to reduce pollution. In more recent years, global climate change caused by greenhouse gas emission has become a basis for change in energy policy. While government policy has not necessarily moved at the speed many members of the scientific community urge it to, the goal of a cleaner energy supply has driven policy. As an emissions free technology, nuclear energy holds the hope of alleviating some of the stress to the planet. A 2003 multi-disciplinary study conducted by a group of MIT professors and researchers attempted to construct a complete picture of nuclear energy in the United States, the challenges it faced, and how to best address these challenges. Central to the study was the belief that "Over the next 50 years, unless patterns change dramatically, energy production and use will contribute to global warming through largescale greenhouse gas emissions" ("Future of Nuclear Power" ix).

Finally, economic development cannot be ignored when assessing energy policy, as Jimmy Carter recognized after the Three Mile Island Accident in 1979. “The need to manage energy costs for consumers, increase energy productivity, and more recently, jobs creation” affect the decisions of the legislative branch and executive branch make when creating and administering energy policy (Dixon 6401). Energy can easily be taken for granted when the simple action of flipping a switch produces light, or simply filling up a car can transport someone at 70 miles per hour for several hundred miles. However, when people receive the bill for their energy use, the economic realities snap them into a different mindset. As energy prices continue to rise, people begin to care more and more about energy issues, and in turn, politicians begin to care about them more as well.

Energy Policy Act of 2005: Promises for Nuclear Revival

After collectively analyzing the issues mentioned above, a substantial energy bill was passed by Congress and signed into law by President George W. Bush, on August 8, 2005. Known as the Energy Policy Act of 2005, this law attempted to alleviate many of the problems the public faced in acquiring affordable, safe, clean, and reliable energy for industrial and private use. In his remarks on the signing of the bill, President Bush emphasized the benefit it would have to individual American citizens in their daily lives. Additionally, he stressed the need for national energy policy. “For more than a decade, America has gone without a national energy policy” (“Weekly compilation” 1264). He states, “It’s an economic bill, but also as [Senator] Pete [Domenici, R-N.M.] mentioned, a national security bill” (1264).

The Energy Policy Act of 2005 focused on broad energy reform, and incentivizing domestic production of energy, from both traditional fossil fuel sources (coal, oil, natural gas, etc.) and alternative sources (nuclear, wind, solar, geothermal, etc.) ("Energy Overhaul Includes Many Bush Priorities — But Not ANWR"). The bill includes several provisions for creating a revitalized nuclear power industry, with the hope of returning it to the glory of the pre-Three Mile Island era. President Bush explained,

> Nuclear power is another of America's most important sources of electricity. Of all our nation's energy sources, only nuclear power plants can generate massive amounts of electricity without emitting an ounce of air pollution or greenhouse gases. Yet America has not ordered a nuclear plant since the 1970s. To coordinate the ordering of new plants, the bill I sign today continues the Nuclear Power 2010 Partnership[4] between Government and industry. We will start building nuclear power plants again by the end of this decade (Remarks 1266).

Interestingly, President Bush emphasizes partnerships between the government and industry, as was the case in the early days of civilian nuclear energy (recall the Atomic Energy Act of 1954). The administration recognized the heavy capital costs nuclear plants required, and the centralization of capital and knowledge the federal government could supply.

A key conclusion of the previously mentioned MIT study was the need for an external source to bear some of the prohibitively high capital costs, as the free market paired with the current regulatory climate, does not promote nuclear plant production at the scale needed to have an effect on climate change. "The government should cost share for site banking for a number of

[4] According to the United States Department of Energy, the Nuclear Power 2010 Partnership is "a joint government/industry cost-shared effort to identify sites for new nuclear power plants, develop and bring to market advanced nuclear plant technologies, evaluate the business case for building new nuclear power plants and demonstrate untested regulatory processes" (Nuclear Power 2010). The program, introduced in February 2002 aims to bring the next generation of nuclear reactors online. However, the number of construction licenses granted around this time (see fig. 4,) would indicate that the impact of this partnership has been minimal.

plants, certification of new plant designs by the Nuclear Regulatory Commission, and combined construction and operating licenses for plants built immediately or in the future…" (8).

Incentivizing Nuclear Energy

Specifically, in order to bear some of the costs, the Energy Policy Act of 2005 provides insurance for the any construction delays resulting from the regulatory process. For example, if the NRC misses a deadline or if the litigation process results in project delays, the federal government can be held responsible for up to $500 million per reactor ("Details of the Energy Policy Overhaul"). Practically, this makes building a nuclear power plant a much more enticing economic prospect. This large sum eliminates much of the risk in such a project. Companies will be much less worried that construction will be delayed without fault on their part, and because even if delays do occur from regulatory measures, they (and investors) will not have to bear the cost. Government guarantees increase the likelihood of project completion, allowing both owners and investors alike to reap the rewards of cheap, plentiful electricity.

A second provision in the Energy Policy Act of 2005 that should be noted is an increased emphasis on research. The Act authorized $1.25 billion for research of next generation reactors (through 2015, and additional amounts for later years) ("Details of Energy Policy Overhaul"). Research creates "buzz" around an issue. Dollars going toward a research area means scientists, universities, and private laboratories chase after these dollars. Competition among organizations creates innovation, additional research, and publicity for projects. This may result in a more welcoming attitude by the public, and allow nuclear energy to once again become central to the U.S. energy portfolio.

Renaissance in Remission

Despite a promising future outlined in the Energy Policy Act of 2005, it has received much criticism in its implementation. According to Kennedy Maize in *Power*, the Bush administration failed to nail down the loan guarantees after being so beseeched by the nuclear energy industry. Maize writes:

> The final Republican administration in control of implementing the 2005 law and providing for some $18 billion in nuclear loan guarantees (maybe enough to help three plants get financed) proved to be typically feckless. No loans got guaranteed. No spades turned dirt. Nobody poured concrete. Then, as the most pro-nuclear administration in recent history exited Washington, the economy collapsed. Credit? Forget it (Maize).

Indeed, during the financial crisis of 2008, money was shifted from many less urgent government projects to areas that were more pressing.

Additionally, Maize, citing NRC commissioner Gregory Jaczko, explains that after the Act was passed in 2005, the NRC was met with a flood of applications for construction and operating permits, including many from companies that had not really given their proposal proper thought, but applied while they could. This, according to Jaczko, is the recipe for disaster. “As a result, said Jaczko, ‘we now find ourselves again making some of the same mistakes of the past. One of the challenges of the 1960s, 70s, 80s was that applicants, vendors, and the regulator were attempting to do everything — designs, site/environmental issues, and applications — all at once.’ ” (Maize). Regression, not progression, necessarily defeats the purpose of the nuclear renaissance – the policy intended for the development and maturation of the industry is not achieving its goals.

A 2009 update to the MIT study cited previously also reflects the idea that the nuclear renaissance may not quite be a reality. Between the initial study and the present time, the study is keen to note that ground had not been broken on one new plant in the United States. The study explains that while the Energy Policy Act of 2005 offered many incentives for nuclear energy, they have had limited effectiveness for three reasons. First, the implementation of loan guarantees has been slow. Secondly, because of the adaptation of renewable portfolio standards (RPS) by many states, resources are diverted to other energy projects. RPS requires that a certain percentage of energy come from carbon-free, renewable energy sources, of which nuclear is excluded ("Update of the MIT 2003 Future of Nuclear Power").

Again highlighting the dynamic nature of public policy and the competing motivations of confounding variables, a parallel can be drawn to this scenario and the happenings after the Three Mile Island accident. Government rhetoric and intention supported nuclear energy. Legal avenues were leveraged in creative ways to block such nuclear goals. Here, although the confrontation is not direct, other public policy aims incidentally cause nuclear energy to fall by the wayside.

After the Three Mile Island accident, the speeding train of nuclear energy was slowed dramatically. Few efforts were made for its acceleration in the 1980s and 1990s, as no strong arguments could be made for its necessity. However, as energy prices began to increase and imported oil became a much more risky prospect, priorities changed. Interest in nuclear energy as an environmentally friendly and inexpensive alternative to coal and oil began to take hold of many politicians. The Energy Policy Act of 2005 sought to revitalize the nuclear power industry, heralding in the dawn of a second nuclear age: the nuclear renaissance. However, as happens time and time again, the unexpected occurs. Recently, the financial crisis of 2008 dimmed the hope of the renaissance. Other policy goals took priority over nuclear energy projects, and as a result, the train seems to not have regained the speed it had in the 1960s. As the MIT study predicts in the reference to the idea of a sustained nuclear renaissance, “At present, however, this is unlikely: nuclear power faces stagnation and decline” (ix).

Reactions to Fukushima: Into the Future

Inflection Point: Triple Disaster at the Fukushima Daiichi Nuclear Power Plant

The promise of a nuclear renaissance – in spite of an unfavorable economic and regulatory environment and empty promises from Congress and Presidential administrations become an even more remote prospect on March 11, 2011 when a 9.0 magnitude earthquake struck Japan (Ohnishi). As if the massive earthquake did not cause enough damage, a tsunami ensued, further damaging an already stricken country. The disasters "…together killed over 20,500 people and resulted in the evacuation of over 320,000 people from the devastated areas" (Ohnishi).

A third disaster struck the nation of Japan as the earthquake encountered the Fukushima Daiichi nuclear power plant. According to an article in *Radiation Research*, when the earthquake hit the area local to the plant, power generation stopped (from sources outside the plant), resulting in a loss of power (Ohnishi). Per protocol, plant operators shut down the nuclear reactors, and giant diesel generators (located in the basement of a building) began to power emergency systems. However, the tsunami subsequently destroyed these generators, leaving only batteries to power the systems essential to keeping the plant in a safe state. "The batteries were intended to protect against short electrical outages and were not capable of driving the main cooling system for a prolonged period. The batteries were apparently depleted in about eight hours. The complete loss of electrical power systems created severe problems and resulted in a significant release of radiation" (Ohnishi).

Several explosions, caused by reactions of water with the coating of the nuclear fuel, occurred a day after the earthquake (Ohnishi). Because the interior of the reactors could not be visualized directly, any damage that occurred had to be inferred from reactor data such as temperature and pressure. As a result, it was initially thought that no serious damage had occurred, and the government and the plant operator attempted to allay public fear that meltdown (see pg. 18) had occurred. Several days after the accident, American military personal and scientists confirmed the presence of radiation in the area surrounding the plant. “The values reported… were greater than the yearly limit for the general public according to the International Commission for Radiological Protection (ICRP) recommendations” (Oshini). Evacuations of surrounding areas ensued. Additional studies found contamination in seawater (100 times the acceptable level), and food sources (although the food was said to be safe to eat) (Oshnini).

Domestic Response

The troubling disaster in Japan caused the nations around the world to evaluate their nuclear energy infrastructure. A 2013 Standard & Poor’s report explains that shortly after the accident in Japan, President Obama ordered the NRC to comprehensively evaluate all of the commercial nuclear reactors in the United States. The report states that two California (a state with a high likelihood of experiencing earthquakes), reactors caused concern, but plant operators ensured the NRC that the plants could both withstand large earthquakes, and based on location and seawall protection, would avoid a disaster similar to the one in Japan (McCann 4). What may be more concerning, however, is that nearly one-third of reactors in the United States were found to have “some vulnerability to extreme emergencies” (4). Many of the shortcomings were the result of inadequate emergency procedures and personnel training, eerily reminiscent of the President’s Commission report after the Three Mile Island accident.

In response to the Fukushima Daiichi accident, the U.S. NRC established the Near-Term Task Force to assess the state of American power reactors, and determine if they presented a risk for a similar catastrophe. Additionally, the Task Force examined the NRC's regulatory framework and many of its policies. In short, the Task Force concluded in their report that the United States nuclear regulation employed effective strategies that would seriously mitigate the risk of an accident caused by natural disasters ("Recommendations for Enhancing Reactor Safety for the 21st Century" 18).

The report explains that in the construction of a nuclear plant, potential accidents are characterized in several different ways. Design-basis events, defined by the NRC glossary as events "that a nuclear facility must be designed and built to withstand without loss of systems, structures, and components necessary to ensure public health and safety," such as natural disasters ("Design-Basis Phenomena"). Safety measures and contingency plans were made for these types of events, and where the focus of licensing in the initial onset of commercial nuclear power.

Design-basis events exist in contrast to beyond design-basis events, which are defined by the NRC as "accident sequences that are possible but were not fully considered in the design process because they were judged to be too unlikely" ("Beyond design-basis accidents"). The loss of power at Fukushima Daiichi was considered one such event. While the earthquake and flood (design-basis events) and the direct results of these events were taken into account in the planning of the plant, the indirect consequence of the loss of all power from the grid is a beyond design-basis event.

Unintended Consequences and Empty Policy

The book *SuperFreakonomics* introduces the Law of Unintended Consequences as "among the most potent laws in existence" (Levitt and Dubner, 138). This economic concept states that any decision made (particularly by governments) can and will have unforeseen outcomes, because it is impossible to plan for every scenario. The Fukushima Daiichi disaster demonstrates the potency of this law. The Law of Unintended Consequences directly parallels the beyond-design basis logic by the NRC's own definition. The earthquake alone would not have caused the disaster. However, coupled with the tsunami, natural disasters testified to the inherent danger of nuclear power. So even if the rules are followed and billions are spent to construct safe nuclear reactors, some event, unimagined by anyone, could destroy the plant and cause a nuclear explosion or release radioactive material into the air or water.

Furthermore, while the NRC has a favorable attitude about nuclear energy and "is confident about the safety of existing nuclear facilities, it does not seem likely that the nuclear "renaissance" that had been greatly anticipated a few years ago is going to take place" (McCann 5). Prospects of increased investment in nuclear energy already lagged behind hopes due to the regulatory uncertainties and inadequate federal loan guarantees. "In the aftermath of Fukushima, these prospects seem even more remote" (5).

The NRC and president profess faith in nuclear power, but their faith does not lead to action. Funding has been a problem for nuclear energy programs, and unintentionally or not, has removed nuclear energy from the table of American energy policy. As with planning for disaster, planning for policy has its own unintended consequences. Incalculable factors in an infinitely complex political environment can render even the most well-intentioned policy a meaningless gesture. The word of the law may support nuclear energy, but this does not translate into implementation.

Conclusion

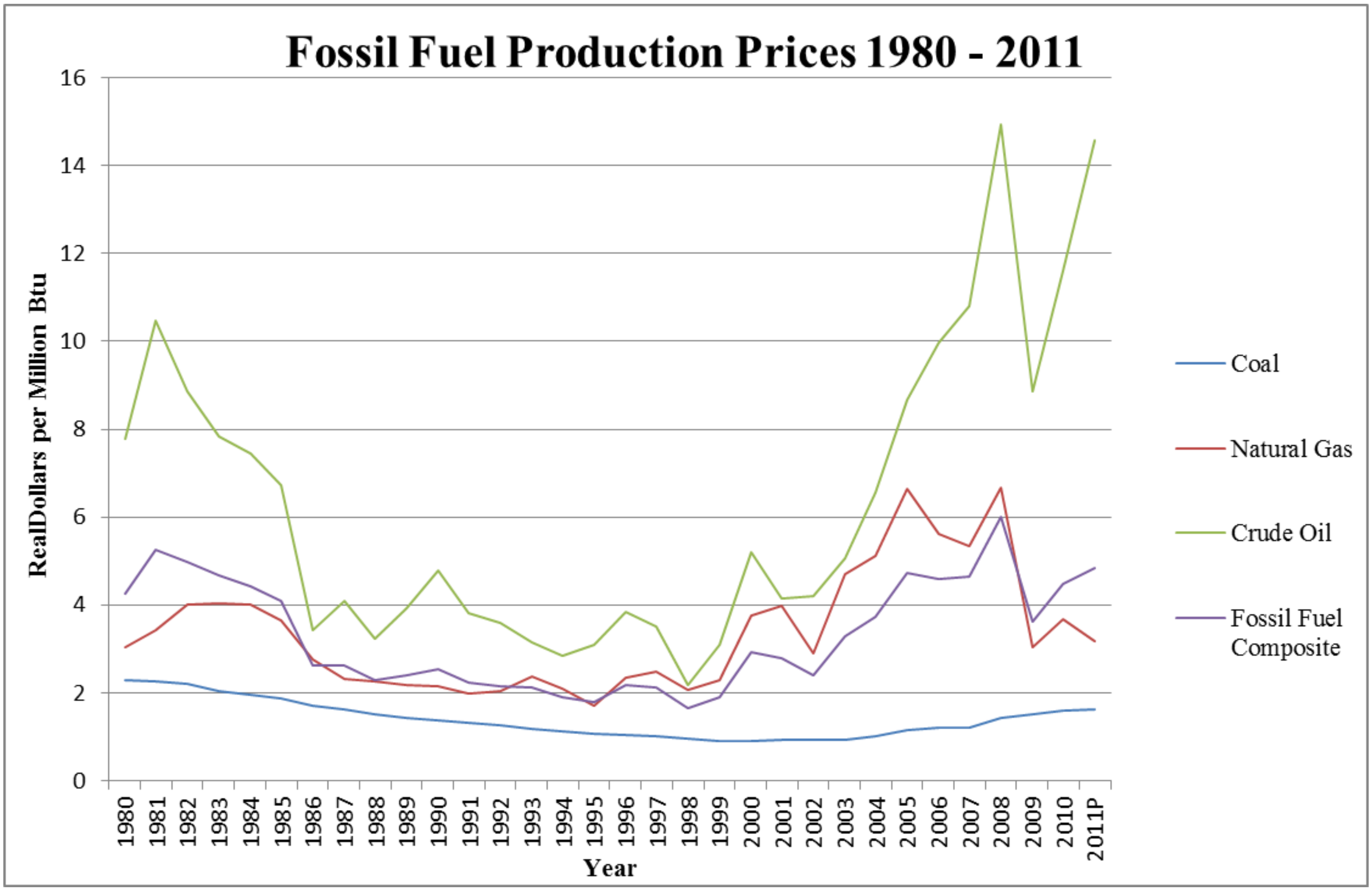
The nuclear era has been relatively short, and few data points (inflection points) were examined in this thesis. Furthermore, since only the events that specifically pertained to the inflection points were analyzed, other current events and surrounding political pressures likely complicated the decision making strategies of the federal government. Both of these factors limit the validity of this analysis. Both deeper and broader study of the specific inflection points that includes more points (including those of lesser individual impact) would lead to a more complete understanding of nuclear energy policy in the United States.

However, the clearest trend emerging from the analysis and study by this thesis is nuclear energy policy has become more and more complex throughout time as additional factors confound the problems considered by policy makers. Initially, national defense and fear of nuclear weapons drove policy, and the solution was clear cut. This did not last long, however, because competing pressure soon mounted for the government to become less restrictive in its policy, as to allow for industrial and scientific adoption of the technology and energy it had the potential to produce. For a period of time, this reasoning held fast, and the nuclear energy industry enjoyed widespread growth in the United States. The growth came to a screeching halt after the accident at Three Mile Island forced the consideration of domestic accidents. The industry stagnated, until factors, exerting negative pressure on fossil fuels, catalyzed a reconsideration of nuclear power. Finally, the accident at the Fukushima Daiichi again raised safety concerns, eliminating hopes of a nuclear renaissance.

As Congress and the executive branch attempt to make policy decisions they must balance the risks and benefits of the issue at question. The nation is quickly learning that there is no economic free lunch: energy, in particular, while absolutely necessary to economic vitality, comes at a cost. Nuclear energy is no exception. The risks of nuclear energy are different than fossil fuels, more tangible, and thus more frightening. However, as the negative consequences of traditional energy sources become more pronounced, the fear of nuclear energy fades in comparison.

Thus, the federal government has struggled with the challenge of balancing nuclear energy policy since 1945. As inflection points occur, the balance not only shifts, but invariably becomes more difficult to achieve as new considerations come to light. As the Law of Unintended Consequences expounds, it is impossible to consider every factor relevant to an issue. As a result of this elaborate balancing act and the increasing complexity of pertinent factors, this thesis concludes that nuclear policy cannot and will never strike a perfect balance. Policy has swung from one side to the other, the motion resulting from current events that demonstrate the positives and negatives of the policy of the era.

The pertinent factors have become so complicated, that with the current political atmosphere, no substantive changes in policy can be made. Policy makers find themselves puzzled as they recognize not only the potentially huge benefit but potentially huge costs (and not just the price tag) of nuclear fission. Thus, as demonstrated by the shortcomings of the Energy Policy Act of 2005, and the uncertain response to the Fukushima accident, despite any effort of the government to rekindle the fire of nuclear power, unforeseen and increasingly complex factors prevent nuclear power from departing from the status quo. Unless sweeping policy changes are made, and the federal government reexamines its entire position on nuclear power, cooling towers and concrete reactor housings will not be seen on the horizons of the future.



Appendix

Figure 1: Fossil fuel production prices in the 1980 – 2011

Source: United States. Dept. of Energy. Energy Information Administration. "Annual Energy Review." *U.S. Energy Information Administration.* U.S. Department of Energy, 2011. Web. 14 Feb. 2013 http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0301

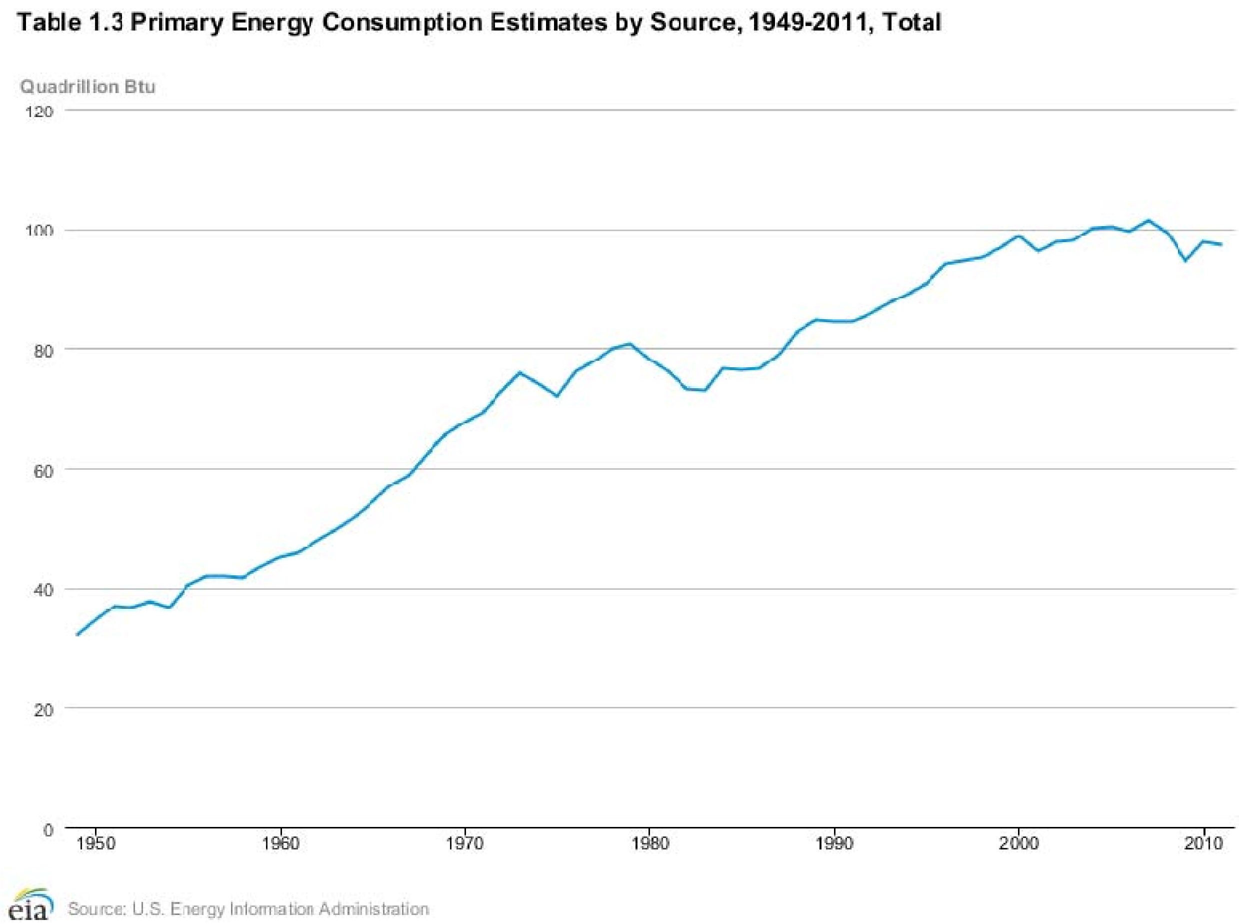


Figure 2: Primary energy consumption estimates in the United States, 1949-2011.

Source: United States. Dept. of Energy. Energy Information Administration. "Figure 1.3 Primary Energy Consumption Estimates by Sources" *U.S. Energy Information Administration.* U.S. Department of Energy, 2011. Web. 14 Feb. 2013 http://www.eia.gov/totalenergy/data/annual/pdf/sec1_8.pdf

Map of Power Reactor Sites in the United States

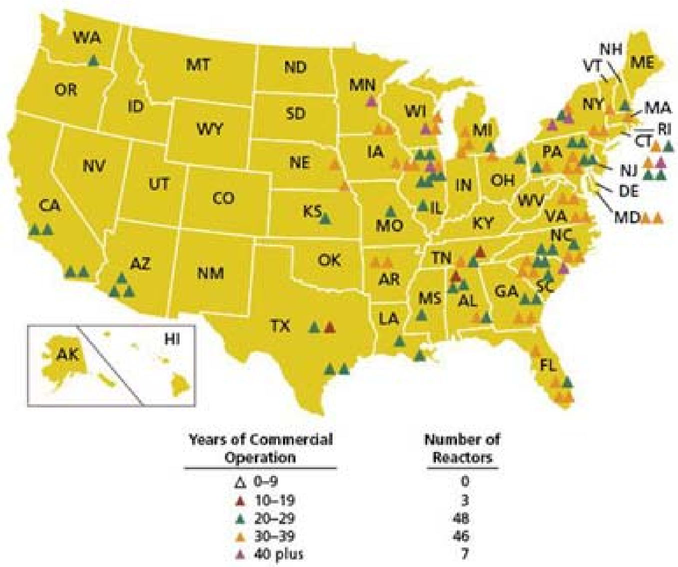


Figure 3: Map of Power Reactor Sites in the United States

Source: United States. Nuclear Regulatory Commission. “Map of Power Reactor Sites” *U.S. Nuclear Regulatory Commission.* U.S. Nuclear Regulatory Commission, 2012. Web. 14 Feb. 2013 http://www.nrc.gov/reactors/operating/map-power-reactors.html

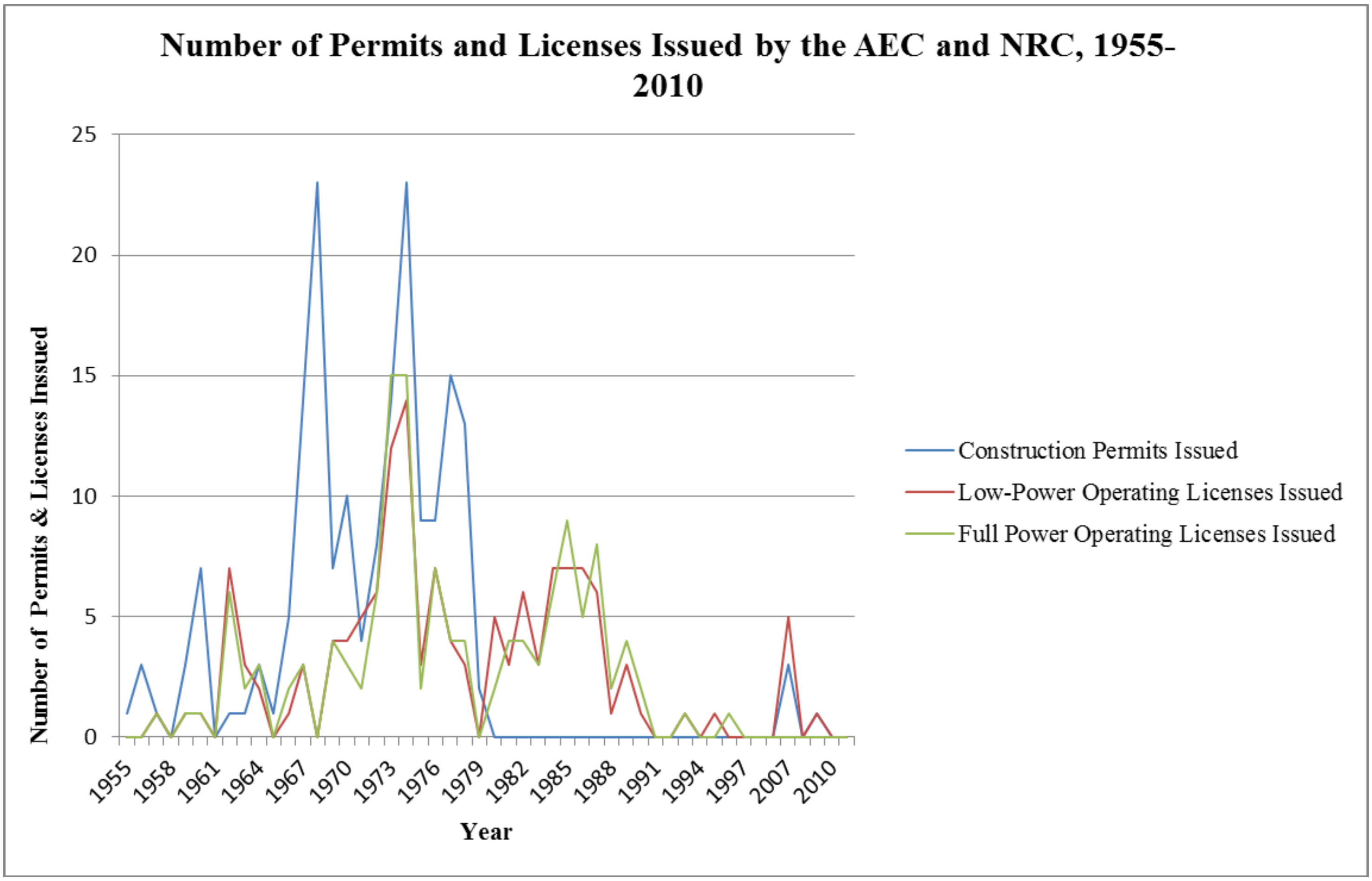


Figure 4: Number of permits and licenses issued by the United States Atomic Energy Commission and Nuclear Regulatory Commission, 1955-2010.

Source: United States. Dept of Energy. Energy Information Administration; *Annual Energy Review*; US Dept. of Energy, 27 Sept. 2012. Web. 12 Jan. 2013. table 9.1. http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0901

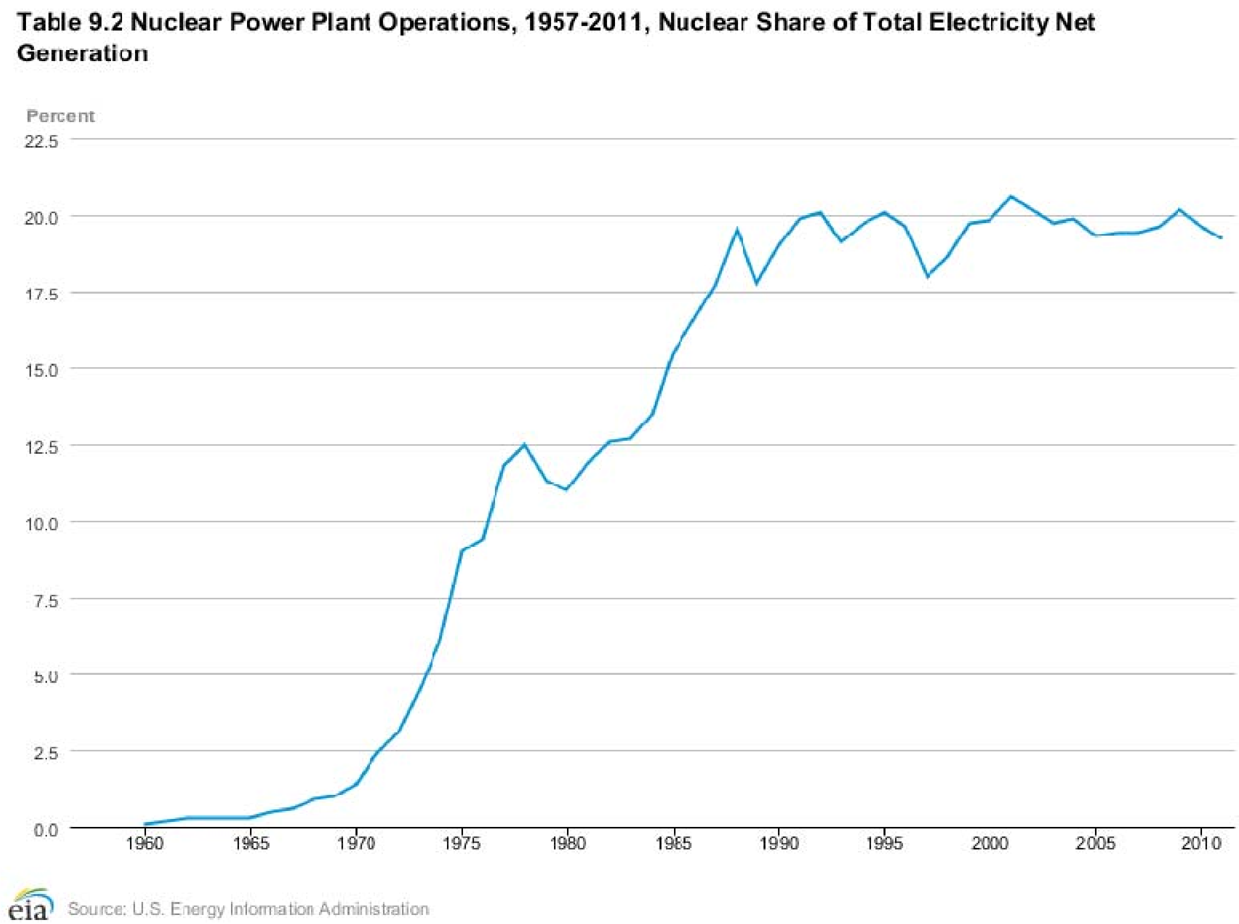


Figure 5: Total electricity generation by nuclear power plants in the United States, 1957-2011.

United States. Dept of Energy. Energy Information Administration; *Annual Energy Review*; US Dept. of Energy, 27 Sept. 2012. Web. 12 Jan. 2013; table 9.2. http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0902

Bibliography

Atomic Energy Act of 1954, As Amended. Pub. L. 83—703. 68 Stat. 919. 30 Aug. 1954. Web. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/v1/sr0980v1.pdf#page=13

Bang, Guri. "Energy Security and Climate Change Concerns: Triggers for Energy Policy Change in the United States?" *Energy Policy*, 38.4 (2010): 1645-1653. Web. 17 Jan 2013. http://www.sciencedirect.com/science/article/pii/S0301421509000718

"Details of the Energy Policy Overhaul." CQ Almanac 2005. 61st ed. Washington: Congressional Quarterly, 2006. CQ Almanac Online Edition. Web. 17 Jan. 2013. http://library.cqpress.com.proxy.lib.umich.edu/cqalmanac/document.php?id=cqal05-766-20110-1042549#

Dixon, Robert K., et. al. "US Energy Conservation and Efficiency Policies: Challenges and Opportunities." *Energy Policy*, 38.11 (2010): 6398-6408. Web. 17 Jan 2013. http://www.sciencedirect.com/science/article/pii/S0301421510000637

"Energy Overhaul Includes Many Bush Priorities — But Not ANWR." CQ Almanac 2005. 61st ed. Washington: Congressional Quarterly, 2006. CQ Almanac Online Edition. Web. 17 Jan. 2013. http://library.cqpress.com.proxy.lib.umich.edu/cqalmanac/document.php?id=cqal05-766-20110-1042541#

"Expansion of Atomic Energy Program." CQ Almanac 1954. 10th ed. Washington: Congressional Quarterly, 1955. 09-534-09-552. CQ Almanac Online Edition. Web. 7 Jan. 2013. http://library.cqpress.com.proxy.lib.umich.edu/cqalmanac/document.php?id=cqal54-1360094&type=hitlist&num=16#

Goldschmidt, Bertrand. *The Atomic Complex: A Worldwide Political History of Nuclear Energy.* Le Grange Park: American Nuclear Society, 1982. Print.

Hodgson, Peter E. *Nuclear Power, Energy, and the Environment.* London: Imperial College Press, 1999. Print.

Kemeny, John G., et al. *Report of the President's Commission On the Accident at Three Mile Island.* New York: Pergamon Press, 1979. Print.

Levitt, Steven D. and Stephen J. Dubner. *SuperFreakonomics*. New York: HarperCollins 2009. Print."

Maize, Kennedy. "Birth Pangs Of The Nuclear Renaissance." *Power*, 153.5 (2009): 84-88. Web. 7 Feb. 2013. http://search.ebscohost.com.proxy.lib.umich.edu/login.aspx?direct=true&db=ofs&AN=501421926&site=ehost-live

Mazuzan, George T., and J. Samuel Walker. *Controlling the Atom: The Beginnings of Nuclear Regulation, 1946-1962.* Berkley and Los Angeles: University of California Press, 1984. Print.

McCann, Justin C. "Industry Surveys Electric Utilities." Standard & Poor's. August 2012: 2-5. Digital.

Miller, Byron S. "The Atomic Energy Act of 1946." *The University of Chicago Law Review.* 15.4 (1948): 799 -821. Web. 2 Jan. 2013 http://www.jstor.org/stable/1597968

Mitchell, John G. "When Mountains Move." *National Geographic* March 2006: 104-123. Print.

"Nuclear Plant Licensing." *CQ Almanac 1979.* 35th ed. Washington: Congressional Quarterly, 1980. 693-99. *CQ Almanac Online Edition*. Web. 11 Jan. 2013. http://library.cqpress.com.proxy.lib.umich.edu/cqalmanac/document.php?id=cqal79-1184337&type=hitlist&num=0#

Ohnishi, Takeo. "The Disaster at Japan's Fukushima-Daiichi Nuclear Power Plant After the March 11, 2011 Earthquake and Tsunami, and the Resulting Spread of Radioisotope Contamination." *Radiation Research* 177.1: 1-14. Web. 25 Jan. 2013. http://www.bioone.org.proxy.lib.umich.edu/doi/pdf/10.1667/RR2830.1

"Presidential Remarks and Statement." *Weekly Compilation of Presidential Documents* 41.32 (2005): 1245-1247. *HeinOnline. Web. Jan. 19 2013.*

"The Future of Nuclear Power." *Massachusetts Institute of Technology* (2012): 17 Web. 17 Jan 2013. http://web.mit.edu/nuclearpower/pdf/nuclearpower-summary.pdf

"The Nuclear Renaissance." *World Nuclear Association*. World Nuclear Association, August 2011. Web. 17 Jan. 2013. http://www.world-nuclear.org/info/inf104.html

Temples, James R. "The Nuclear Regulatory Commission and the Politics of Regulatory Reform: Since Three Mile Island." *Public Administration Review*, 42.4 (1982): 355-362. Web. 11 Jan 2013. http://www.jstor.org/stable/975979

United States. Department of Energy. "Nuclear Power 2010." Department of Energy. United States Department of Energy, n.d. Web. 8 Feb. 2013. http://www.ne.doe.gov/np2010/overview.html

United States. Dept. of Energy. Energy Information Administration. "Annual Energy Review." US Dept. of Energy, 27 Sept. 2012. Web. 12 Jan. 2013. table 9.1. http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0901

United States. Dept. of Energy. Energy Information Administration. "Annual Energy Review" US Dept. of Energy, 27 Sept. 2012. Web. 12 Jan. 2013; table 9.2.

http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0902

United States. Dept. of Energy. Energy Information Administration. “Annual Energy Review.” *U.S. Energy Information Administration.* U.S. Department of Energy, 2011. Web. 14 Feb. 2013 http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0301

United States. Dept. of Energy. Energy Information Administration. “Energy in Brief.” *U.S. Energy Information Administration.* U.S. Department of Energy, 2011. Web. 12 Jan. 2013 http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0301

United States. Dept. of Energy. Energy Information Administration. “Figure 1.3 Primary Energy Consumption Estimates by Sources” *U.S. Energy Information Administration.* U.S. Department of Energy, 2011. Web. 14 Feb. 2013 http://www.eia.gov/totalenergy/data/annual/pdf/sec1_8.pdf

United States. Dept. of Energy. Energy Information Administration. “Glossary.” *Energy Information Administration.* Dept. of Energy, 2013. Web. 21 Feb. 2013 n.d. http://www.eia.gov/tools/glossary/index.cfm?id=B#brit_th_unit

United States. Dept. of Energy. Energy Information Administration. “Nuclear Explained.” *Energy Information Administration.* Dept. of Energy, 2013. Web. 21 Feb. 2013 http://www.eia.gov/energyexplained/index.cfm?page=nuclear_power_plants

United States. Dept. of Energy. Energy Information Administration. “U.S. Uranium Reserve Estimates.”*Energy Information Administration.* Dept. of Energy, 2010. Web. 28 Feb. 2013 http://www.eia.gov/energyexplained/index.cfm?page=nuclear_power_plants

United States. Environmental Protection Agency. “Nuclear Energy.” *Environment Protection Agency.* Environmental Protection Agency, 17 Oct. 2012. Web. 14 Feb. 2013 http://www.epa.gov/cleanenergy/energy-and-you/affect/nuclear.html

United States. Nuclear Regulatory Commission. “Backgrounder on the Three Mile Island Accident.” *Nuclear Regulatory Commission.* United States Nuclear Regulatory Commission, 15 Mar. 2011. Web. 12 Jan. 2013 http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

United States. Nuclear Regulatory Commission. “Full-Text Glossary.” *Nuclear Regulatory Commission.* United States Nuclear Regulatory Commission, 10 Dec. 2012. Web. 12 Jan. 2013 http://www.nrc.gov/reading-rm/basic-ref/glossary.html

United States. Nuclear Regulatory Commission. “Map of Power Reactor Sites” *U.S. Nuclear Regulatory Commission.* U.S. Nuclear Regulatory Commission, 2012. Web. 14 Feb. 2013 http://www.nrc.gov/reactors/operating/map-power-reactors.html

United States. White House. "At A Glance." *White House.* White House. n.d. Web. 14 Feb. 2013. http://www.whitehouse.gov/energy

United States. White House. "The President's Record on Energy and the Environment." *White House*. White House. n.d. Web. 14 Aug. 2012

"Update of the MIT 2003 Future of Nuclear Power." *The Future of Nuclear Power: An Interdisciplinary MIT Study* (2009): n. pag. Web. 17 Jan 2013. http://web.mit.edu/nuclearpower/pdf/nuclearpower-update2009.pdf

Walker, J. Samuel. *A Short History of Nuclear Regulation, 1946 – 1990*. Washington: Nuclear Regulatory Commission, 1993. Print

Weinberg, Alvin M. "Emerging Trends in Nuclear Energy." *Energy Policy*, 12.3 (1984): 247-252. Web. 17 Jan 2013. http://www.sciencedirect.com.proxy.lib.umich.edu/science/article/pii/0301421584900247

Zimmerman, Joseph F. "Regulating Atomic Energy in the American Federal System." *Publius,* 18.3 (1988): 51-65. Web 2 Jan 2013. http://www.jstor.org/stable/3330272