A New Day for Nuclear

The Impact of Nuclear Energy and Its Effects

H. Grace Hilliard

A Senior Thesis submitted in partial fulfillment
of the requirements for graduation
in the Honors Program
Liberty University
Spring 2014

Acceptance of Senior Honors Thesis

This Senior Honors Thesis is accepted in partial fulfillment of the requirements for graduation from the Honors Program of Liberty University.

____
Kahlib Fischer, Ph.D.
Thesis Chair

____
Charles Murphy, Ph.D.
Committee Member

____
David Snead, Ph.D.
Committee Member

____
Brenda Ayres, Ph.D.
Honors Director

____
Date

Abstract

Energy is a resource on which civil society is built. It affects every aspect of life and is vital to the survival of the modern world. This paper explores nuclear power and the effects it has on a national and global scale. The research looks at both the positive and negative aspects of nuclear energy, giving weight to both sides of the argument to present a detailed look at this resource. The research is compiled from a wide range of authors from scientists and nuclear experts to reporters and strategic intelligence agents. A proposed technology for the advancement of nuclear energy is also examined to show its benefits and compare it to conventional nuclear energy. This paper will assist any concerned citizen in making an informed decision on the world's most vital resource, energy.

A New Day for Nuclear

The Impact of Nuclear Energy and Its Effects

Introduction

Oil, coal, solar, wind, or nuclear, energy sources have become a permanent necessity of modern society, and consequently, a hotly debated issue. Since energy holds such a prominent role in the world, it affects political decisions, relationships between countries, the economy, and the environment; it has become the core of most day-to-day activities. Nuclear energy has come to the forefront of these sources because of its relative newness and seemingly limitless supply of energy. Congress debates proposals for funding nuclear energy because many believe that it is the technology for the future with the supply of oil becoming harder to control and solar and wind technologies not being expanded or fully developed. The benefits of nuclear energy are plentiful and valid, and yet, so are the negative arguments against it. It is vitally important to understand some of the history of nuclear power, the implications of decisions made on the advancement of nuclear energy, and the far-reaching effects of the decisions made on such a powerful energy source. With a comprehensive understanding of nuclear energy and the expansion of its technology through products such as SMR's, nuclear energy could be the world's next prominent energy source.

Background

Definition

First, to understand the impact of nuclear energy and how it affects the world, a definition must be examined. Nuclear energy, according to *West's Encyclopedia of American Law* (2008), is defined as "a form of energy produced by an atomic reaction, capable of producing an alternative source of electrical power to that supplied by coal, gas, or oil.” This occurs through a process called fission which creates energy through the splitting of uranium atoms. A nuclear power plant thus uses the heat that is produced during the fission process to create steam in order to run the turbines creating electricity (Westinghouse 2012). It is important to understand how nuclear energy and the nuclear power plants work because many confuse them with plants that create nuclear weapons. A nuclear power plant does not produce nuclear weapons meant for mass destruction. The technology needed to create nuclear weapons is very different than the technology that is used to create nuclear energy in power plants. Both processes use the U-235 isotope of natural uranium, however, the nuclear fuel used to power an electrical plant is enriched for 3%-5% of the total amount of fuel. In order to create a bomb, the uranium must be enriched to account for over 90% of the total. Normal nuclear power plants are unable to process the plutonium needed for nuclear weapons from the spent fuel in their plants. In the entire world, there are only a few plants that have the capabilities to do this, however, they are heavily safeguarded and constantly monitored by various international organizations such as the International Atomic Energy Agency or Euratom. Proliferation of nuclear materials is still a risk with any large nuclear plant. However, regulations and treaties help to prevent this from being a common occurrence (FORATOM, 2011). As with any other topic, it is important to know the origin of nuclear energy and how it is produced in order argue the positive and negative aspects of it.

Fukushima Nuclear Disaster

In March 2011, information about nuclear energy was broadcasted on every major news network when the Fukushima Daiichi Nuclear Power Plant failed after Japan experienced an earthquake and a subsequent tsunami. During this time, nuclear energy became a topic discussed around the world, and the benefits and potential dangers were researched and debated more extensively by scientists and politicians alike. Fukushima was a large nuclear reactor located in the Futaba District of Fukushima Prefecture, Japan. On March 11, 2011, a 9.0 magnitude earthquake shook Japan causing structural damage and the loss of many lives. The earthquake also caused a fifteen meter tsunami to crash onto the shores of the already devastated island. The reactors that were in use shut down immediately when the earthquake hit like they were designed to do, however, they were vulnerable to the tsunami. The massive wave disabled twelve of the thirteen back-up generators that were on site at the plant; it also disabled the power supply to the cooling systems for three of the reactors causing the melting of their cores. A high amount of radioactive release occurred in the following four to six days. Over 100,000 people had to be evacuated from their homes in the surrounding areas that were affected by the radioactive exposure. The air, water, and land all suffered from contamination of radioactive materials (World Nuclear Association, 2014).

It is important to understand the severity of what occurred at the Fukushima reactor because it was a failure in the design of a reactor (WNA, 2014), but also had a large effect on the public opinion of nuclear power. Many do not understand the benefits of such an energy source, but write it off because they are fearful of the possibility of another meltdown which is shown by the decline of public sentiment from 57% to 43% after the Fukushima disaster (Cooper and Sussman, 2011). Understanding the failures of this plant, but also the positive and negative aspects of nuclear power, a logical conclusion can be drawn in order to form an opinion on an energy supply that could change the world.

Nuclear Benefits

Environmental Impact

Nuclear power yields numerous benefits to the world. One such benefit is that it produces fewer emissions than conventional power sources such as fossil fuels (Loudermilk, 2011). Coal is an example of a fossil fuel that is polluting the environment. According to the Sierra Club (2007) which is America's largest and most influential grassroots environmental organization, coal produces twice as much of the global emissions when compared to regular gasoline. Big Coal and its allies have stated that coal or liquid coal, coal that is converted into liquid fuel, would cure the United States of its energy problem, yet in reality, it has been causing countless problems in the economy and the environment such as an increase in carbon dioxide emissions and a costly conversion process (Sierra Club). It is speculated that clean coal causes double the emissions that regular gas does which means that the pricey process to convert it into liquid coal is all for naught (Sierra Club).

Harvard's Center for Health and the Global Environment has produced research that speculates that coal causes eighty percent of the United States' warming emissions. Epstein and his team (2011) discovered that "The contribution of particulates (from coal, diesel, and biomass burning) to climate change has, until recently, been underestimated. Though short-lived, the global warming potential per volume is 500 times that of CO2" (p. 88). In the same way, the relentless search for oil to use as energy hurts the environment. Greenberg (2011), a writer for the National Wildlife Federation, reveals that the oil and gas companies are responsible for destruction to wildlife and natural habits as well as "hundreds of deaths, explosions, fires, seeps, and spills" (para. 5) because of their negligence. This is based on researched conducted by the National

Wildlife Federation focusing on oil and gas disasters that occurred between 2000 and 2010 within the United States. The never ending search for energy has had a profound effect on the environment that will affect future generations for years to come.

Nuclear power is one solution to the problem of greenhouse gases. Moore (2005), the founder and chief scientist of Green Spirit Strategies, states that "a significant reduction in greenhouse gas emissions (GHG) seems unlikely given our continued heavy reliance on fossil fuels. An investment in nuclear energy would go a long way to reducing this reliance and could actually result in reduced CO2 emissions from power generation" (para. 38). He also speculates that nuclear energy would be a solution to securing the United States' energy and meeting the energy demands of the nation.

Nuclear would play a large role in reducing the greenhouse emissions and solve the climate problem in order to assure that there would not be an escalation in global warming (Knapp et al, 2010). Some suggest that renewable energy sources would be able to achieve the same ends as nuclear power in providing a clean energy source to reduce emissions for the environment; however, they would be unable to meet the increasing energy demands. Compared with nuclear energy, the renewable sources are unable to replicate the type of power generation that is needed to power the grids making nuclear energy a better choice. Loudermilk (2011), a research associate for the Institute for National Strategic Studies, warns that "On the global level, without nuclear power, carbon dioxide emissions from electricity generation would rise nearly twenty percent" (para. 20) He suggests that it is the only power source that could not only meet the growing demand for a stable supply of energy but also reduce green-house gas emissions.

Energy Security

Another benefit of the use of nuclear energy would be energy security for the United States, which means the promise of sustainable energy for the foreseeable future. U.S. military planners are working to prepare for this future, but estimate that within the next twenty years the world's energy demand will increase by fifty percent over what it is currently (Rowell, 2012). The United States Joint Forces Command warns "a severe energy crunch is inevitable without a massive expansion of production and refining capacity" (Rowell, para. 3). Many ideas about how to solve the problem have been discussed and debated, however nuclear energy seems to be the best possible solution. As previously stated, nuclear energy is able to decrease emissions, but also would be able to meet the energy demands. Many politicians and scientists agree. According to Moore (2005), "Prominent environmental figures….have now all stated their strong support for nuclear energy as a practical means of reducing greenhouse gas emissions while meeting the world's increasing energy demands" (para. 43). Securing energy for the future is vital to the well-being of the United States. Other energy sources such as oil, natural gas, and even coal are finite resources projected to last no more than two hundred years if the world's energy demands are to be met. When these resources begin to dwindle, countries will fight in order to have the resources they need. McPherson (2010), a retired United States Navy nuclear engineering officer, advises,

> To avoid further escalation of international tensions and conflict in a scramble for energy, it is imperative to secure sources of energy to supplement those currently available. To move in the direction of energy security, the United States needs a sustainable nuclear power industry that can provide distributed electrical and thermal energy. (p. 20)

Energy provides for the stability to economies, communication domestically and internationally, and is tied to almost everything in the modern world because most actions and products require energy in some form or another.

Gold Standard of Safety

Strengthening the nuclear energy sector for the United States could also help ensure that nuclear energy is used safely throughout the world. The United States needs to have the lead in nuclear technology because of the safety standards for their nuclear equipment. China has been closing in on the United States for many years in relation to nuclear exports, yet safety oversight is the weakest area in their nuclear energy sector (Tu, 2012). A restructuring of China's Ministry of Environmental Protection which is the watchdog for their nuclear industry has been stalled by internal conflicts and the unbalanced hierarchical nature of the government (Tu). An overhaul is necessary to ensure that the nuclear technology that they are exporting from their country is safe. Many countries are looking to China to produce supplies and provide them with knowledge to build nuclear power plants. Tu, a Carnegie Energy and Climate Program senior associate warns of the Chinese nuclear exports that have insufficient safety standards by stating:

> Related, if more nuclear power plants are built in developing countries with little experience of operating a reactor, or bordering a region where terrorism is a concern, or without sufficient financial resources to import state of the art technology, then the chance of a major nuclear accident hitting the developing world will loom large in the coming decades. (para. 9)

Many of these developing countries are looking to buy from China because their technology is cheaper. According to Tu, China has exported their old nuclear generators to Pakistan while they are working on constructing more within their own nation. The two problems in this situation are that Pakistan, a volatile country prone to terrorist activity, has received less safe and more easily proliferated nuclear generators, and China is building new reactors without new safety standards. Both of these situations could easily lead to malfunctions or meltdowns of the reactors (Tu).

If a nuclear plant were to meltdown, it would contaminate the surrounding area and possibly cause the deaths of many people. Lendmen (2011), a research associate at the Center for Research on Globalization, warns that “under a worst case core meltdown, all bets are off as the entire region and beyond will be threatened with permanent contamination, making the most affected areas unsafe to live in” (para. 11) Lendmen points to the Chernobyl disaster which is believed to have killed over a million people globally from radiation exposure. The fallout from this disaster covered the Northern Hemisphere, and it is speculated that a meltdown from one nuclear reactor could affect half the globe with its pollutants. This type of contamination could not only kill people, but also render affected lands uninhabitable (Lendmen).

The United States needs to take control of the situation and be the main exporter for nuclear material since the safety standards that accompany their supplies are better than China’s. Taking the lead in nuclear development would inhibit China’s influence and lessen the attractiveness of their nuclear contracts. Currently, China has a reputation for giving nuclear material to countries that are ill-equipped to handle it. Without proper training, these countries will be unable to probably use the nuclear technology. This could result in them not meeting their energy needs or a malfunction of the equipment because they do not know how to use the equipment safely. United States leadership in the area of nuclear energy is key because of the higher safety standards that are required for U.S. supplies. The Nuclear Regulatory Commission, or the NRC, is known for having the gold standard for commercial nuclear regulation (Domenici and Miller, 2012). It sets international precedence for the most expertise and experience in nuclear energy. International modeling of these standards is common, yet if the United States does not continue to pursue its nuclear capabilities, China will step up to fill the vacuum that is left. The continued advancement of nuclear technology in America will maintain the United States' international standing on nuclear energy and hegemony globally. It is important that the NRC's gold standard is modeled globally in order to ensure the safety of the reactors.

If China is able to gain a foothold in the market and surpass the United States in exporting supplies, the safety standards will be lowered (Domenici and Miller, 2012). Construction on new reactors has already begun in many countries around the world with China comprising forty percent of the new reactors being built. Domenici and Miller explain that (2012):

> Ensuring a strong U.S. nuclear energy sector should be a high priority for federal energy and national security policy and national security policy. Nuclear energy is critical to maintaining a reliable, affordable, and clean electric power sector, and a strong domestic nuclear industry strengthens America's position in international nonproliferation matters. (p. 14)

The gold standard for safety allows for the exploration of an energy source with strong guidelines and measures in order to keep it as safe as possible. It buffers against security threats and proliferation of nuclear materials. If the safety standards are followed, the ability to proliferate nuclear material will be less than if standards like China's were followed.

Public Sentiment

In the current political environment, nuclear energy is popular among the public. After the Fukushima meltdown, its popularity took a dip shrinking from 57% to 43% as reported by the New York Times (Cooper and Sussman, 2011). This sharp dip and recovery has occurred previously. The slow growth of the industry can be traced back to the Three Mile Island disaster because the public was nervous about expanding it (MIT). A March 2012 Gallup poll, however, said that 57% of Americans support nuclear energy and the bolstering of the nuclear energy sector (Whitman 2012). Another poll taken by the Nuclear Energy Institutes reveals that as of April 2013, 68% of U.S. citizens look favorably on using nuclear energy as a source of electricity. One contributing factor to this increase could be the push to reduce the use of fossil fuels and the growing threat of global warming. This has been a major concern for many years, and the use of nuclear energy would be able to solve the problem because it does not release greenhouse gas emissions. Environmentalists have very strong sway in this area because they are the group that most desperately wants to see a reduction in fossil fuels. How the public feels about nuclear energy is vitally important to its success in the market. Public sentiment has the power to sway political decisions that will affect licensing and regulations on nuclear energy. If the public does not want to have nuclear energy in the country, politicians tend to side with the majority rather than doing what is most beneficial for the country. Though it is a viable concern, as of now, public sentiment is on the side of nuclear energy.

Nuclear Energy Negatives

Costs

As is the case with most things in life, there are two sides to every story. Many problems and concerns accompany nuclear energy. The benefits many times do not outweigh the fears that are commonly associated with such a strong energy source especially after the disaster at the Fukushima power plant. The average American could not explain nuclear energy or how the plants work, yet because of previous disasters, they are weary about what could happen. One of the specific negative aspects of nuclear energy is the exorbitant costs that are associated with building up the industry. The cost of a nuclear facility commonly is comprised of four individual costs: capital or construction costs, back-end costs or the cost of decommissioning an old nuclear plant, fuel costs, and Operations and Maintenance (O&M) costs, which are costs related to the management and upkeep of a nuclear plant (Kessides, 2009). These divisions of cost create multiple avenues for cost over-runs which cause delays, licensing problems, and increased complexity in the management of a plant. This is evident in the average construction time of nuclear plants worldwide. When forty-eight nuclear plants were built between 1965 and 1970, the average construction time worldwide was sixty months; in contrast, between 1995 and 2000, twenty-eight nuclear plants were built with an average construction time of 116 months (Kessides). Nuclear power is notorious for not meeting deadlines and causing cost over-runs (Kessides). Cost over-runs have been estimated around 209%-381% over the estimated cost of construction according to an historical look at the United States' experience with cost construction beginning in 1966 (Kessides). These facts often deter private investors from putting their money into a technology that will not yield quick returns because construction is so costly and time-consuming (Kessides). The risk that is associated with nuclear power plants does not put much confidence in investors for them to stake their money on the construction of a new plant. Costs to construct a new plant have increased making the construction times longer and exceedingly more expensive. Investors are not excited about this prospect even if federal funds were also given to offset costs (Severance, 2009). Their hesitancy is due to their concern that the risks of building a new nuclear facility will cost more than projected and not return their investment. The exorbitantly expensive cost is one of the main issues facing the expansion of nuclear power.

Lack of Workforce

Manufacturers. A second negative to nuclear power is the lack of workforce to run the facilities and create the materials for the construction of a new nuclear plant. First, a shortage of manufacturers able to produce the necessary equipment and supplies for the construction of a nuclear plant is one reason for the delays in the building process. David Schlissel, a senior consultant with Synapse Energy Economics (2009), speculates that there are fewer than eighty suppliers of the nuclear materials compared to the four hundred in business two decades ago. The lack of manufacturers creates bottlenecking of supplies delaying any and all new construction projects for years.

Workers. The shortage of skilled laborers is another reason for the delay in construction which does not reflect well on the nuclear energy sector. In order the meet the demands that are required to maintain the United States' international standing in the nuclear market, the number of workers needs to be increased. “Strong global demand for skilled construction labor, and the retirement of many experienced worker is also leading to labor shortages… more than 45 percent of the engineering labor pool is eligible to retire in the next five years” (p. 17) warns Schlissel (2009). The pending retirement of these workers is cause for concern because there are no trained workers to fill their positions. Even if these workers were not retiring, the expansion of nuclear energy globally would require more workers than are in the nuclear field now. Much of the labor and manufacturing must be outsourced to other countries which incur more costly delays on the construction of a new power plant. Schlissel suggests that the cost of a new plant could be up to six million dollars more than it previously was. Besides increasing the costs for a new plant, outsourcing would also not ensure the safety standards of the United States. Other countries do not have the same expertise and knowledge of nuclear materials or the construction of supplies to build a new plant meaning that security could be compromised if the work was outsourced. Also, the countries where the work would be sent to would not likely have the experts required for such construction projects. In order to bolster the nuclear energy sector, more experts and engineers need to enter the workforce to fill the jobs that will be opened up or created with the expansion of nuclear energy.

Trade-off from Renewable Energy

If nuclear energy receives more funding and focus, it would take those valuable resources from renewable energy sources which many argue is not a good option. Scarcity of research and development funds and natural resources means that only one type of technology is going to reap the full benefits of the nation’s focus. Many argue that renewable energy such as solar or wind would be better than nuclear energy because of fewer risks and the size of the technology. Verbruggen, an Energy and Environmental Economics professor at the University of Antwerp (2008), highlights five reasons that nuclear power and renewables are incompatible. The first is that nuclear "is architect of the business-as-usual that has to be changed urgently and drastically" (p. 4046). This means that nuclear would not allow for a radical shift from fossil fuels which is necessary for the expansion of renewable energy. Verbruggen argues that renewable energy needs an immediate expansion that would be thwarted by nuclear power. Next is that renewables and nuclear yield very different results when they are added to fossil-fuelled power plants. To convert a fossil-fuelled plant into one with a different energy source, the nuclear add-on would be bulky and cumbersome while the renewable add-on would be flexible (Verbruggen). The third incompatibility is with the power grids that are connecting millions of power sources. Nuclear would need a new type of grid in order to make its output functional. Fourth, Verbruggen states that the risks for nuclear power make it unsustainable while renewable energy is believed to be safer and have fewer risks associated with implementing it. The final aspect is that nuclear and renewables are not the only ones fighting for funding (Verbruggen). Renewables and nuclear would not be able to co-exist because of the extraordinary amount of money that is involved in funding both of these technologies. Renewables need a flexible source of energy to complement them. According to Roberts (2012), a staff writer for the environmental organization Grist, nuclear would not be able to fit that mold because it is a big, constantly powering energy source making it unsuitable to be compatible with renewable energy. Some may consider that nuclear taking the money in place of renewable energy sources such as solar and wind would be a negative aspect on a world stage, however, one must compare the advantages of renewable energy to those of nuclear in order to make a decision between the two.

Small Modular Reactors Benefits

Much of the public is weary of nuclear energy because of past events though they know very little about how it works or the safety measures that accompany it. A large power plant and the knowledge that one just like it melted down causing mass panic across the globe is enough to put any person on edge. Instead of scrapping the idea of nuclear power all together, researchers have come up with safer and smaller reactors that should be able to calm the public's worries. Nuclear power has too many benefits to give up on the idea fully. Large nuclear plants are where many of the fears about nuclear energy have stemmed; new advancements and technologies, however, have emerged that could quell many of the concerns of the public. Small modular reactors (SMR's) seem to be the perfect solution.

Design

Small modular reactors or SMR's designs are a major asset for this new technology both in terms of safety and cost.

Safety. The first benefit is that SMR's are inherently safer than large conventional nuclear reactors. Rosner and Goldberg (2011) and their team at the Energy Policy Institute at Chicago identified three major differences between large scale reactors and SMR's that made them safer. Firstly, the designs of the SMR's rely on battery power in order to maintain safety operations; this feature lessens or potentially makes obsolete the need for electrical or back-up generators in case of an emergency. The second safety aspect of SMR's is that they are better able to withstand earthquakes. This is achieved though "containment and reactor vessels in a pool of water underground" (p. 5) explains Rosner and Goldberg. The third safety feature in SMR's that minimizes susceptibility or damage that could occur with nuclear energy is the large underground pool storage for spent fuel. The fact that the pools are stored underground greatly reduces the chances that the spent fuel will be uncovered or dangerously leak (Rosner and Goldberg). The International Trade Administration agrees that the underground facility will help minimize any harmful effects. They confirm that "All U.S. SMRs are designed to be deployed in an underground configuration. Industry observers contend that this would limit the risk for above ground sabotage (which is a serious consideration for traditional nuclear power plants) or for radioactive release" (ITA, 2011, p. 3). SMRs are also small which allows them to be placed in remote locations where large reactors could not be located. This aspect of its design is helpful for military operations when temporary bases need energy quickly. Its size also means that there is less fuel within the apparatus so if there was ever a malfunction with the equipment, it would affect less land area than a conventional reactor. Szondy (2012) emphasizes that the smaller size of the SMR "makes it easier to design emergency systems" (para. 15).

The cooling systems for SMRs allow it great flexibility. Compared to conventional reactors which must be cooled by water, SMRs can be cooled by water, air, gas, low-melting point metals or salt. This feature makes possible a SMR's ability to be placed inland and underground (Szondy, 2012). SMRs also provide for a better waste management strategy than conventional reactors. Spencer and Loris (2011) argue that if waste management becomes the responsibility of those producing nuclear waste, it will increase innovation and allow for better waste-management technologies such as SMRs. They consume fuel and produce waste differently than conventional reactors which make their waste management strategy much more economical because they are more waste efficient reactors.

Cost. The cost of any new project is always a factor in considering whether it is a viable option. Any new infrastructure is expensive and will need capital to be invested. Small modular reactors are no exception. They are, however, much cheaper and more economically viable than their competition. First, SMR's are a third cheaper than the large reactors that they would be replacing. They are also able to generate a cash flow more quickly than the large nuclear reactors. After one SMR is online, it will immediately begin to produce energy and money which allows manufacturers to funnel more money into the next module. The cheaper cost is due to the simplicity of the design as well as reduced siting and building costs according to Kidd (2011), director of Strategy and Research at the World Nuclear Association. The cost of the SMR's are also offset by the benefits that it yields.

Kessides and Kuznetsov (2012), economists at the World Bank, researched six reasons why SMR's would be economically beneficial. The first is that the reduced construction duration would drive the price down while also allowing them to be mass produced and generate revenue quicker. Factory made modules reduce the field work and can be made much more quickly than constructing a new nuclear power plant. The second cost-saving benefit is its investment scalability and flexibility. SMR's are able to be added to which means that if the capital in unavailable at the moment, another SMR can be added later. Capital can also be generated from the SMR that is already at work in order to pay for the one that needs to be added on so that no outside investment is needed. The third benefit is that the SMRs are better able to match the grid and power plant capacities. The SMRs are able to meet the needs of the established electrical infrastructure and avoid grid instability with some of the weaker grids that they will be placed on. Fourth, SMR designs allow them to be mass produced and built in factories which will drive down the costs and allow them to be built more quickly. Another cost-saving benefit is the learning curve that will be associated with manufacturing each module. The building and siting of each module will allow for learning opportunities in order to save money for next time. This is uniquely different from large module reactors since they are so large and few comparatively, the learning curve is much less. The sixth and final benefit is the design of the SMR's allows for simpler, yet still safer modules (Kessides and Kuznetsov).

The infrastructure is already in place in the United States to be able to mass produce SMR's which is another reason why it would be cheaper than other energy sources (Spencer and Loris 2011). There would have to be major changes made to the infrastructure in order to accommodate sources such as renewables. Also, companies within the United States such as those that focus on manufacturing, engineering, and uranium enrichment are expanding and could meet the demands of mass producing SMRs (Spencer and Loris). The economic benefits are overwhelming because these expanding companies will allow for more job creation which will bolster the United States economy. Though there would be initial startup costs, the long-term benefits of SMRs would be well worth the beginning capital.

Desalination

A third positive aspect of SMRs is their ability to desalinate water. Even though much of the world is covered in water, scarcity of access to this resource is a major problem that causes conflicts around the world. Countries fight over access to rivers and water ways. An example of such conflicts is the tensions between Ethiopia and Egypt over the Nile (Dinar, 2012). Dinar, an FIU International Relations professor, asserts that "There are no strong treaties governing the use of these water reserves in tense territories. Should conflicts break out, there are no good mechanisms in place for dealing with them" (para. 6). Tensions over water create larger conflicts that will eventually escalate because water is a vital resource to life. With the uneven distribution of water and only .008% of the world's water directly accessible for human use, water poverty and wars fought over water are realistic threats (IAEA, 2007). Desalination is the process of removing salt from water, usually from sea water, so it can be viably used as drinking water or for the irrigation of crops (USGS, 2014). The process allows for more of the world's water to be used for human consumption which could eliminate the threat of resource wars fought over water. The option of using nuclear energy to power desalination plants is the best in order to make enough water to meet the growing demands of the world. The IAEA argue that small reactors would be more beneficial in the countries that are in desperate need of freshwater because they commonly have a weaker infrastructure and a smaller electrical grid. They claim "The size of the grid limits the possibilities for integrating a co-generating nuclear power plant into the grid to supply the electricity market, in addition to meeting the energy requirements of a desalination plant" (IAEA, p. 5).

A SMR would be more feasible than a large nuclear plant because a smaller reactor would put less strain on the electrical grid and allow full power to the desalination plant. Seneviratne (2007), a Nuclear News Vienna Correspondent, informs that researchers from ten different countries conducted research that concluded that nuclear energy was economically competitive with other energy sources to use to power desalination plants. Two factors held nuclear desalination back from being used earlier: economy and inappropriately sized reactors. The first challenge was disproven by the studies done by the ten different countries (Seneviratne). The second challenge is remedied by the creation of small modular reactors because they would be an appropriate size for the countries that need desalination for freshwater sources (Seneviratne). In *The Answer: Why Only Inherently Safe, Mini Nuclear Power Plans Can Save Our World,* Palley (2011) expresses the dangers of countries not having a sufficient water supply. He speculates that over one billion people do not have access to clean water, and with population growth inevitable, conflicts over water or the control of waterways will continue to escalate. He concludes that the problem must be quickly fixed in which case only small desalination plants powered by SMRs are a viable option because they have the ability to be put into remote locations where the water is desperately needed. Palley states, “We now have the power, by means of SMRs profile to local conditions, not only to attend to existing water shortages but also to smooth out disproportionate water distribution and create green habitation where historically it has never existed” (p. 170-171).

Mass production of SMRs would be able to help create a stable environment around the world because of easier access to freshwater for those countries that have been deprived. This provides a unique export opportunity for the United States. SMRs open up a new market for the United States to tap in to by exporting them to mostly lesser developed or underdeveloped countries. Not only would they be a great economic opportunity, but SMRs also have the opportunity to spread the United States' non-proliferation policies around the world (Rosner and Goldberg, 2011).

Decentralization

Grid. SMRs are also beneficial in the event of an attack on U.S. soil. Attacks on nations have become more sophisticated in recent years due to the increase in technology. A more viable threat to the United States would not be one from the land or sea, but an attack from cyber space. An attack on the electrical grid of the United States would cripple the country not only militarily but also economically. An attack on the grid has become increasingly more likely. The Annual Threat Assessment of the Intelligence Community for the Senate Armed Services committee in 2009 reported that cyber-attacks have become a serious threat to national security. Both state and non-state actors "are targeting the U.S. critical infrastructure for the purpose of creating chaos that will subsequently produce detrimental effects on citizens, commerce, and government operations" (Robitaille, 2012, p. 5). The interconnectedness of the United States' electrical grid would make any attack on it extremely serious.

SMRs allow for the grid to be decentralized which would mean that any attack on it would be localized instead of knocking down the entire grid. Two major advantages can be gained from decentralizing the electrical grid. First, decentralizing the grid greatly benefits the Department of Defense by solving their vulnerabilities of being connected to the civilian grid. A single SMR would be able to power a military base allowing them to have their own energy supply separate from that of civilians. If the grid goes down, military operations would be jeopardized because of intelligence and communication being compromised by a collapse. Renewable energy sources such as wind or solar would not solve the vulnerability of the military as well as SMRs. Currently, ninety-nine percent of the electricity used by the domestic military installations comes from the civilian grid. If an attack on the grid was successful, military operations around the world would be compromised because there would be no electricity for communication or other military necessities when the civilian grid is offline (Andres and Breetz, 2011).

In order for the United States to maintain its hegemony around the world, its military capabilities must always be ready for any attack. An attack that would crash the grid would also collapse the military readiness of the United States making them more vulnerable to attacks abroad (Gray, 2004). A decentralized grid would localize any attack on the grid and not disrupt operations or communication for the military.

Economy. The second advantage to a decentralized grid is the security of the economy from a cyber-attack. Currently, with the grid interconnected, an attack would bring down the civilian grid and the economy with it. Engleman and Strohm (2012) report that "Companies including utilities, banks, and phone carriers would have to spend almost nine time more on cybersecurity to prevent a digital Pearl Harbor from plunging millions into darkness, paralyzing the financial system and cutting communications" (para. 1). They compare the world where the electrical grid has collapsed to that of the Dark Ages. Such a collapse of the grid would cripple the economic system of the United States which would be nearly impossible to fully recover from. Inevitably, the decline of the economy would cause the United States to pull back from the world stage leaving a power vacuum for another country to fill. When states try to fill the vacuum, war will be almost certain (Friedberg and Schoenfeld, 2008).

SMR Negatives

Fears

Concerns do exist about SMR's. First, it is still a nuclear reactor. Many of the same fears about malfunctions and radioactive material still accompany the new designs. Public opinion could easily turn against SMRs depending on research findings, costs, and deployment sites. The Department of Commerce International Trade Administration (2011) stated that public opposition might rise against SMR's because their deployment could be closer to heavily populated areas. They also believe that education on nuclear energy, SMRs, and safety measures is key in order to alleviate some of the public's anxiety. Public opinion has large sway in the United States affecting the outcomes of many decisions such as an election or a certain law getting passed. During the 2012 election, energy was a major topic of discussion between the two candidates. The position that they took on the issue influenced how many different groups voted for them. The public also sways the passage of laws through lobbying groups and senators who fear upsetting their constituency. Though public opinion is in favor of nuclear energy now, the political tides shift without warning. Fickle public opinion could become an obstacle in the development of SMRs or nuclear energy in general.

International Atomic Energy Agency

Another negative aspect of SMRs is their possible effect on the IAEA – the International Atomic Energy Agency. This agency was created to license and inspect nuclear reactors. With an escalation of the production of small modular reactors, a large strain would be placed on the agency in order to be able to inspect and license all of the reactors that would be mass produced. Since SMRs still use radioactive nuclear material, the reactors require more safety and security inspections than any other power generating facilities. The inspection of the sites where the SMRs would be placed would over-stretch the IAEA especially if they are placed in remote locations around the world. Lyman (2011), a global security program senior scientist for the Union of Concerned Scientists, states that “Maintaining robust oversight over vast networks of SMRs around the world would be difficult, if even feasible” (p. 6-7). Concern about IAEA overstretch is the possibility that the SMRs could become less safe than large reactors. If the SMRs are not designed, licensed, or inspected carefully which is the job of the IAEA, then they run the risk of being more of a security threat and have greater risk of proliferation than large reactors especially when they are being mass produced and exported around the world (Lyman, 2011). In order to ensure that SMRs are as safe as possible, more trained personnel needs to be added to the IAEA or the commercialization of SMRs must be slower which would affect their distribution worldwide.

Commercialization

Commercialization of SMRs could become a problem for the industry. According to William Magwood (2011), an NRC commissioner, SMRs would not be able to overcome the poor economic situation of the global economy because many of the countries do not have the capital to fund a nuclear program. Empirically, SMRs have failed in the past due to the large up-front costs of building such a reactor. They are unable to generate enough revenue to cover the costs of its infrastructure like larger plants have succeeded in (Magwood). Internationally, the United States would run into problems commercializing SMRs because of the different licensing requirements for different countries. Even if an SMR met all the requirements and got approval in one country, this does not mean that they will receive approval from another market (ITA, 2011). The international licensing standards are a major obstacle in the commercialization for SMRs. Without a global nuclear liability regime as well, there is great concern for getting international approval for SMRs. The Department of Commerce International Trade Administration or ITA confirms that "U.S. manufacturers face a significant trade barrier in key foreign markets," (p.5) even though other international suppliers access the United States markets with much greater ease. The United States needs to break into the international market better in order to make a splash in the industry. Emphasis must be placed on the extra safety measures to calm the fears of those who worry about liability issues.

Alternative to SMR's

Renewable Energy

Competition with other energy sources can make or break the development of nuclear energy, especially SMRs, because of a limited amount of resources and funding. There is a major debate on whether it would be more beneficial to use and invest in nuclear energy or a renewable energy such as solar or wind (Verbruggen, 2008). Renewable energy is a naturally occurring energy source that is arguably inexhaustible such as solar, wind, or biomass. Non-renewable energy, on the other hand, is an energy source that cannot be replenished in a short period of time such as oil, coal, or nuclear energy (EIA). Some arguments for renewable energy are that it is cleaner and cheaper to replenish. Many worry that if focus is shifted to nuclear energy, the research and development of other energy sources, especially renewables, will decline (Verbruggen). First, nuclear energy causes a trade-off of focus and resources from other, more harmful fuels such as oil and coal. Oxford Economics (2008) studied the shift of investments from fossil fuels to nuclear energy revealing that the use of fossil fuels declined with the rise of nuclear energy. It would not make much of a difference if nuclear did cause a trade-off with renewable energy sources because even a large push on the renewables front would not be able to satisfy the growing energy demands of the world. Current electrical infrastructure is only able to handle a small amount of renewable energy sources. Even then, they struggle to keep pace in order to fill that demand because they do not have the baseload power capacity to meet it (Loudermilk 2011). They are unable to produce or replicate the ability of nuclear power. SMR's are also able to provide convenience and localized power generation. It would be unreasonable to put renewable energy generators such as large wind turbines or rows of solar panels in populated areas. SMR's provide a unique advantage in that they could be put underground and still provide more localized energy without heavily disturbing the area around it (Loudermilk).

Natural Gas and Fracking

Natural gas. Natural gas is another energy source that is in competition with nuclear energy. Many believe that natural gas would be better than nuclear energy because it has currently flooded the energy market and is a cheap source of energy. Whitman (2012), a former EPA administrator, warns against the dependence on natural gas. She states that though natural gas is cheap now, a dependence on it would put Americans at risk economically because they are not looking at the long term energy security risks. An example of the volatile changes in prices of natural gas is the price shift between the 1990s and 2000s. In the 1990s, not unlike now, the prices for natural gas were considered low and stable. However, by the mid-2000's, the price of natural gas was at a record high (Whitman). This price shift works much like any other economic principle where supply and demand are a factor. The Congressional Research Service reports that the average price for natural gas between 1995 and 1999 was $2.23 per MBtu before making an 110% price rise from 2000 to 2004 to $4.68 per MBtu. By December 2005, the price of natural gas hit a peak of 15.38 per MBtu. Then by 2012, the price of natural gas dropped again on average to $2.55 per MBtu (Pirog and Ratner, 2012). These figures show that historically, natural gas has very volatile shifts in its price, and many analysts predict that the price of natural gas will rise once again and continue to increase into the future (Pirog and Ratner). If there is an influx of natural gas in the market with low prices, alternative energy sources will not usually be pursued. If funding was placed in one energy source such as natural gas, eventually prices will increase, as empirically proven, and there will be nothing to offset the cost or an alternative energy source for people to turn to (Whitman, 2012). Spencer (2012), a senior nuclear energy policy research fellow at the Heritage Foundation gives three reasons why dependence on natural gas could be harmful based on empirics of the changing market and studies on the potential effects of better policy: 1) without a diversity of sources prices will rise, 2) unpredictable long-term prices, and 3) the existing infrastructure might not be able to meet the demand. SMR's would be able to provide a more reliable and predictable energy source. "Nuclear power is the sole carbon-free electricity source that is both scalable and capable of meeting baseload power needs" (p. 2) argues Freed, Horwitz, and Ershow (2010). This is true because no other clean energy source at this time is about to meet the baseload demands such as natural gas which would be unable to meet the demands while also providing a stable cost.

Whitman (2012) also argues that nuclear energy will be more beneficial in the long run by creating jobs and boosting the economy in the United States. The building of infrastructure alone will create over three thousand jobs with another four hundred or more needed to operate the new facility. Compared to natural gas, nuclear energy is also able to generate twice as much electricity as a cycle of a natural gas plant because they typically have a larger capacity to do so (Whitman). Also, nuclear is a clean energy source while natural gas still emits about half of the greenhouse gas emissions as a coal plant (Whitman). Though in the short term, it might be cheaper to use natural gas as an energy source, it still produces harmful greenhouse gases, historically has had drastic price shifts, and would put the United States at risk. Overall, nuclear energy would be a safer and more reliable choice as compared to its competitors.

Competition of other cheaper and more quickly accessible energy resources such as natural gas have become a problem for SMRs. Currently, natural gas is a cheap product that has flooded the energy market. This means that no matter what research says about how cheap SMRs can be, they will not be as inexpensive as natural-gas fired turbines (Biello, 2012). The low price of natural gas is one of the reasons that the development of SMRs have been stalled in the United States which occurred before the meltdown of the Fukushima power plant. The competition between the two energy sources will not likely boost the innovation of the technology, rather it will most likely weaken the nuclear energy market (Biello). The large up-front cost of any nuclear reactors makes its competition look more promising in the short term. A long-term perspective is needed when comparing nuclear energy to its competition such as gas. Its global benefits must also be taken into consideration because in comparison, they far exceed those of its competition such as gas or renewable energy.

Fracking. Meanwhile, many argue that fracking or the process of hydraulic drilling for natural gas alleviates concerns about reliance on fossils fuels, however, this process has the potential to harm the environment more than help it. The supporters of fracking and natural gas state that even though it does burn, it would still significantly reduce human's carbon footprint. The Tyndall Center (2011), an organization through the University of Manchester devoted to climate change research, warns that fracking could lead to some negative environmental effects such as pollution of land and surface water or spillage of fracturing additives. However, Duke University studied the groundwater pollution caused by natural gas and concluded that it was not caused by the fracking process (Grose, 2011). Also, the process of fracking has led better disposal of flowback and cost-saving methods. A common practice is to recycle the flowback of natural gas which makes fracking more effective and uses less water saving the industry money (Grose). Though there are risks to any approach to attaining energy, many states feel as if the risks are too high for fracking. States such as New York and Pennsylvania have moved to place moratoriums on fracking within their states (Wiessner, 2012). However, without a reduction in carbon emissions, experts speculate that the threat of global warming will continue to escalate. SMRs would be a good alternative to fracking because it would still reduce carbon emissions and has much less of a risk of contaminating their placement sites.

Conclusion

After all of the research has been conducted and the data has been examined, the negative aspects of nuclear energy do not outweigh the benefits that it could possibly yield. More research and studies are required to prove the potential benefits of nuclear energy, but there is no question that the world is demanding more energy as it grows and develops. New technology will require more energy, and the current supply will not meet the increasing demand. Other energy sources have been tested and tried. Some, like renewables, are unable to meet the growing demands, while others, such as fossil fuels, make the world a more dangerous place to live in by polluting and contaminating the air and water. An energy source is needed that is sustainable, clean, and able to meet the needs of the world. Nuclear energy is a solution to solve many of the problems nationally and internationally. If the United States were to start the expansion of nuclear technology specifically with SMR's, the political and economic gains would be exponential. Nuclear energy could be the answer that the world has been looking for to move into a new era of prosperity.

References

Andres, R., & Breetz, H. (2011, February 01). Small nuclear reactors for military installations: capabilities, costs, and technological implications. Retrieved from http://www.thefreelibrary.com/Small nuclear reactors for military installations: capabilities-a0291503414

Biello, D. (2012, March 27). Small reactors make a bid to revive nuclear power. Retrieved from http://www.scientificamerican.com/article.cfm?id=small-reactors-bid-to-revive-nuclear-power

Cooper, M. & Sussman, D. (2011, March 22). Nuclear power loses support in new poll. *The New York Times*. Retrieved from http://www.nytimes.com/2011/03/23/us/2 3poll.html?_r=3&

Cullinane, S. (2011, September 28). America falling behind: The strategic dimensions of Chinese commercial nuclear energy. Retrieved from http://www.ensec.org/index.php?option=com_content&view=article&id=319:ame rica-falling-behind-the-strategic-dimensions-of-chinese-commercial-nuclear-energy&catid=118:content&Itemid=376

Dinar et al., S. (2012, October 18). No wars for water. Retrieved from http://www.foreignaffairs.com/articles/138208/shlomi-dinar-lucia-de-stefano-james-duncan-kerstin-stahl-kenneth/no-wars-for-water

Domenici, P & Miller, W.. (2012, July). Maintaining U.S. leadership in global nuclear energy markets. (p. 14) Retrieved from http://bipartisanpolicy.org /sites/default/files/Leadership in Nuclear Energy Markets.pdf

Engleman, E., & Strohm, C. (2012, January 31).Cybersecurity disaster seen in U.S. survey citing spending gaps. Retrieved from http://www.bloomberg.com/news/2012-01-31/cybersecurity-disaster-seen-in-u-s-survey-citing-spending-gaps.html

Epstein et al., P. (2011, February). Full cost accounting for the life cycle of coal. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2010.05890.x/full

The European Atomic Forum. (2011, November). The nuclear industry's significant contribution to non-proliferation. Retrieved from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&ved=0CFUQFjACOAo&url=http%3A%2F%2Fwww.foratom.org%2Fpublications.raw%3Ftask%3Dcallelement%26item_id%3D34%26element%3D0ab27474-adf5-41db-8395 e2f040908c60%26method%3Ddownload&ei=bpIWUMP0N4b50gGXgIGQCQ&usg=AFQjCNFdtzwz7wy-nwPgS1vA7gSun71rw

Freed, J., Horwitz, E. & Ershow, J. (2010, September). Thinking small on nuclear power. *Third Way Idea Brief: nuclear energy.* Retrieved from http://content.thirdway.org/publications/340/Third_Way_Idea_Brief_-_Thinking_Small_On_Nuclear_Power.pdf

Friedberg, A., & Schoenfeld, G. (2008). The dangers of a diminished America. Retrieved from http://online.wsj.com/article/SB122455074012352571.html

Gray, C. (2004). *The sheriff: America's defense of the new world order*. (pp. 91-92).

Greenberg, M. (2011, January 06). Report: Root causes of gulf oil spill "might well recur" without reform. Retrieved from http://www.nwf.org/News-and-

Magazines/Media-Center/News-by-Topic/Wildlife/2010/01-06-11-Report-root-causes-of-Gulf-oil-spill-might-well-recur-without-reform.aspx

Grose, T.K. (2011, September). Get fracking. *ASEE Prism*, *21*(1), 40-43, Retrieved from http://search.proquest.com/docview/893763269/abstract?accountid=12085

IAEA. (2007). Economics of nuclear desalination: New developments and site specific studies. In *Final results of a coordinated research project 2002-2006*

International Trade Administrations. (2011, February). The commercial outlook for U.S. small modular nuclear reactors. Retrieved from http://www.trade.gov/publications/pdfs/the-commercial-outlook-for-us-small-modular-nuclear-reactors.pdf

Kessides, I. (2009). Nuclear power and sustainable energy policy: promises and perils. *Oxford Journals*, *25*(2), 323-362. Retrieved from http://wbro.oxfordjournals.org/content/25/2/323.full.pdf+html

Kessides, I., & Kuznetsov, V. (2012). Small modular reactors for enhancing energy security in developing countries. Retrieved from http://www.mdpi.com/2071-1050/4/8/1806/htm

Kidd, S. (2011, March 04). SMRs-what are their prospects? Retrieved from http://www.neimagazine.com/story.asp?storyCode=2059041

Knapp, V., Pevec, D., & Matijević, M. (2010). The potential of fission nuclear power in resolving global climate change under the constraints of nuclear fuel resources and once-through fuel cycles. *Energy Policy*, *38*(11), Lendmen, S. (2011, March 13). Nuclear meltdown in Japan. Retrieved from http://www.thepeoplesvoice.org/TPV3/Voices.php/2011/03/13/nuclear-meltdown-in-japan

Loudermilk, M. (2011, May 31). Small nuclear reactors and US energy security: Concepts, capabilities, and costs. Retrieved from http://www.ensec.org/index.php?option=com_content&view=article&id=314:small-nuclear-reactors-and-us-energy-security-concepts-capabilities-and-costs&catid=116:content0411&Itemid=375

Lyman, E. (2011, August 07). The nuclear energy research initiative improvement act of 2011. Retrieved from http://www.ucsusa.org/assets/documents/nuclear_power/lyman-testimony-06-07-2011.pdf

Massachusetts Institute of Technology. (n.d.). American attitudes about nuclear power and nuclear waste. In *MIT study on the future of nuclear fuel cycle.* Retrieved from http://mitei.mit.edu/system/files/The_Nuclear_Fuel_Cycle-9.pdf

Magwood, W. (2011). Economics and safety of modular reactors; committee: Senate appropriations; subcommittee. *CQ Congressional testimony*, Retrieved from Lexis Nexis

McPherson, R. (2010). Modular nuclear reactors may hold the key to U.S. energy security. *National Defense*, p. 20.

Moore, P. (2005, April 28). Nuclear power generation as an approach to meeting America’s energy need. Retrieved from http://www.physics.harvard.edu/~wilson/energypmp/greenpeace.html

Nuclear Power. (2008). In *West's Encyclopedia of American Law*. Retrieved from http://legal-dictionary.thefreedictionary.com/Nuclear+Power

Oxford Economics. (2008). Economic, Employment and Environmental Benefits of Renewed U.S. Investment in Nuclear Energy. *Oxford Economics.* Retrieved from Investment in Nuclear Energy," 2008, http://www.nuclearcompetitiveness.org /images/Oxford_State_Benefits.pdf

Palley, R. (2011). *The Answer: Why only inherently Safe, Mini Nuclear Power Plans Can Save Our World* (pp. 168-171).

Pirog, R. & Ratner, M. (2012, November 6). Natural gas in the U.S. economy: opportunities for growth. *Congressional Research Service.* Retrieved from http://www.fas.org/sgp/crs/misc/R42814.pdf

Renewable energy resources. (n.d.). In *U.S. energy Information Administration Glossary.* Retrieved from http://www.eia.gov/tools/glossary/index.cfm?id=R

Roberts, D. (2012, March 23). Why Germany is phasing out nuclear power. Retrieved from http://grist.org/renewable-energy/why-germany-is-phasing-out-nuclear-power/

Robitaille, G. (2012, March 20). Small modular reactors: The army's secure source of energy? Retrieved from http://www.dtic.mil/cgibin/GetTRDoc?AD=ADA561802

Rosner, R., & Goldberg, S. (2011, November). Small modular reactors – key to future nuclear power generation in the U.S. Retrieved from https://epic.sites.uchicago.edu/sites/epic.uchicago.edu/files/uploads/EPICSMRWhitePaperFinalcopy.pdf

Rowell, A. (2012, April 12). US military warns of “severe energy crunch”. Retrieved from http://priceofoil.org/2010/04/12/us-military-warns-about-forthcoming-“severe-energy-crunch”/

Schlissel, D. (2009). Nuclear loan guarantees: Another taxpayer bailout ahead? *Union of Concern Scientists*, Retrieved from http://www.ucsusa.org/assets/documents/nuclear_power/nuclear-loan-guarantees.pdf

Seneviratne, G. (2007, April). Research projects show nuclear desalination economical. Retrieved from http://www.ans.org/pubs/magazines/nn/docs/2007-4-3.pdf

Severance, C. (2009). Business risks and costs of new nuclear power. Retrieved from http://www.nirs.org/neconomics/nuclearcosts2009.pdf

Sierra Club. (2007, April). Liquid coal: A bad deal for global warming. Retrieved from http://www.sierraclub.org/coal/downloads/2007-04liquidcoalfactsheet.pdf

Spencer, J. (2012, March 16). More to the story on nuclear power and cheap natural gas. *Heritage Foundation.* Retrieved from http://blog.heritage.org/2012/03/16/more-to-the-story-on-nuclear-power-and-cheap-natural-gas/

Spencer, J & Loris N.D. (2011, February 2). A big future for small nuclear reactors? *Heritage Foundation.* Retrieved from http://www.heritage.org/research/reports/2011/02/a-big-future-for-small-nuclear-reactors

Szondy, D. (2012, February 16). Feature: Small modular nuclear reactors - the future of energy? Retrieved from http://www.gizmag.com/small-modular-nuclear-reactors/20860/

Tu, K. J. (2012, March 11). China’s nuclear crossroads. Retrieved from http://carnegieendowment.org/2012/03/11/china-s-nuclear-crossroads

The Tyndall Centre. (2011, January). *Shale gas: a provisional assessment of climate change and environmental impacts.* Retrieved from http://tyndall.ac.uk/sites/default/files/tyndall-coop_shale_gas_report_final.pdf

U.S. Geological Survey. (2014, March 17). Saline water: Desalination: Thirsty? How 'bout a cool, refreshing cup of seawater? *U.S. Department of the Interior – U.S. Geological Survey.* Retrieved from http://water.usgs.gov/edu/drinkseawater.html

Verbruggen, A. (2008, July 29). Renewable and nuclear power: A common future? *Energy Policy*, 36, 4036-4047.

Whitman, C.T. (2012, May 9). It's dangerous to depend on natural gas. *CNN.* Retrieved from http://tech.fortune.cnn.com/2012/05/09/christine-whitman-nuclear-energy/

Wiessner, D. (2012, January 6). New York fracking opponents seek extended moratorium. *Reuters.* Retrieved from http://www.reuters.com /article/2012/01/06/us-fracking-newyork-idUSTRE80521M20120106

World Nuclear Association. (2014, January 13). Fukushima accident. Retrieved from http://world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/