Strategy Research Project

EXAMINATION OF TERRESTRIAL NUCLEAR ENERGY'S RELEVANCE TO U.S. NATIONAL SECURITY

BY

COLONEL JAMES J. RAFTERY, JR.
United States Army

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U.S. Army War College, Carlisle Barracks, PA 17013-5050

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by

Colonel James J. Raftery, Jr.
United States Army

Kent H. Butts, Ph.D.
Project Adviser

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

ABSTRACT

AUTHOR: Colonel James J. Raftery, Jr.

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This paper is an examination of the relevance that terrestrial nuclear energy has with regard to U.S. national security. Terrestrial nuclear energy is herein defined as energy produced from land-based nuclear reactors. The principal application for terrestrial nuclear reactors is in the generation of electricity. Maritime or space-vehicle propulsion reactors are excluded from this definition, as are nuclear weapons. While the national security implications of thermonuclear warheads and nuclear powered warships are relatively direct, the national security implications of ―benign" nuclear energy are less so. National security interest areas of energy independence, energy security, climate change, economics, public safety, and nuclear terrorism and proliferation are considered. The paper addresses both domestic nuclear energy and aspects of foreign nuclear energy. Through this examination, terrestrial nuclear energy is found to have both direct and indirect implications to U.S. national security interests.

EXAMINATION OF TERRESTRIAL NUCLEAR ENERGY‘S RELEVANCE TO U.S. NATIONAL SECURITY

> Through the release of atomic energy, our generation has brought into the world the most revolutionary force since prehistoric man's discovery of fire. This basic power of the universe cannot be fitted into the outmoded concept of narrow nationalisms. For there is no secret and there is no defense; there is no possibility of control except through the aroused understanding and insistence of the peoples of the world.[1]
>
> —Albert Einstein

The words above appeared in a form letter authored by the Nobel Laureate near the end of 1946. Written under the letterhead of the Emergency Committee of Atomic Scientists (ECAS), an organization which he co-founded, Professor Einstein made an appeal to raise money to fund a —great educational task”[2] to —carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications for society.”[3] The aims of ECAS were —to educate the public about the dangers of atomic warfare, to promote the benign use of atomic energy, and to work for the abolition of war as the only answer to weapons of mass destruction.”[4]

In the more than half century since this letter was authored, the number of nations possessing nuclear weapons has risen from one to perhaps nine.[5] In 1946, no nations possessed nuclear reactors for the generation of electricity. Today there are more than 440 commercial nuclear reactors across 30 countries operated for this purpose.[6] Additionally, 56 countries operate approximately 250 research reactors and some 180 nuclear reactors power roughly 140 ships and submarines.[7] While the abolition of war has not been realized, no nuclear weapons have been used in a hostile act since 1945.

A July 2010 CNA Company report, chaired by retired Army Chief of Staff General Gordon Sullivan, entitled *Powering America's Economy: Energy Innovation at the Crossroads of National Security Challenges,* found that ―America‘s energy choices are inextricably linked to national and economic security.”[8] As ―the most revolutionary force since prehistoric man‘s discovery of fire,”[9] nuclear energy is one of these energy choices.

The purpose of this paper is to further the education process related to nuclear energy by examining the relevance that terrestrial nuclear energy has with regard to U.S. national security. Terrestrial nuclear energy is herein defined as energy produced from land-based nuclear reactors. The principal application for terrestrial nuclear reactors is in the generation of electricity (these reactors are commonly referred to as commercial nuclear reactors). Maritime or space-vehicle propulsion reactors are excluded from this definition, as are nuclear weapons. While the national security implications of thermonuclear warheads and nuclear powered warships are relatively direct, the national security implications of ―benign” nuclear energy are less so. In order to examine the national security implications, national security interest areas of energy independence, energy security, climate change, economics, public safety, and nuclear terrorism and proliferation are considered. The paper addresses both domestic nuclear energy and aspects of foreign nuclear energy.

<u>Background</u>

The first commercial nuclear plant came online at Shippingport, Pennsylvania in 1957.[10] Today the U.S. has 104 nuclear reactors in operation for electrical power generation, the largest number of any country, with approximately 100 gigawatts of total generating capacity.[11] As of 2009, these commercial reactors met 20% of U.S. electrical energy demand.[12] In 2008 this represented approximately 31% of the worldwide nuclear generation capacity.[13] The countries with the next highest number of commercial nuclear reactors are France and Japan with 58 and 55, respectively.[14] The countries with the highest percentage of their electricity needs supplied by nuclear energy are Lithuania with 76%, France with 75%, and Slovakia with 54%.[15] At 20%, the U.S. ranks 17th (out of 30), while China, at 2%, ranks 30th.[16] By one estimate, by 2035 the U.S. electricity demand is projected to increase from 2008 levels by 30%,[17] and worldwide electricity generation capacity is projected to increase by 87%.[18]

Ground hasn‘t been broken for construction of a new nuclear power plant in the U.S. in more than three decades.[19] The last commercial reactor added in the U.S. was in 1996,[20] following 20-plus years of schedule delays and cost overruns. There are currently 27 nuclear reactors under construction in China, with an additional 50 planned and an additional 110 proposed.[21] With the help of Russia, Iran is in the last stages of bringing its first nuclear power plant online.[22] Some advocates exalt nuclear energy as a —green” solution necessary to combat global warming.[23] Critics deride it as dangerous and polluting, pointing to the Three Mile Island and Chernobyl incidents, and to radioactive waste.[24] Energy is important globally, as national wealth and Gross Domestic Product (GDP) can be linked to energy use.[25] Proliferation of nuclear materials and weapons, along with the potential for their destructive use, represent perhaps the gravest existential threat to the security of the United States.[26] Interdependencies, both supporting and conflicting, between energy, environmental, economic, security, and foreign policies are the reality.

The Nuclear Energy Strategic Environment[27]

During a January 26, 2009, White House address, given at a time of ―deepening economic crisis,”[28] with the U.S. engaged in open hostilities in Iraq and Afghanistan, President Obama stated: ―At a time of such great challenge for America, no single issue is as fundamental to our future as energy.”[29] In his January 17, 2010, State of the Union Address, the president called for ―a new generation of safe, clean nuclear power plants in this country.”[30] Twelve days later he issued a memorandum to the Secretary of Energy, establishing a Blue Ribbon Commission on America‘s nuclear future. The opening paragraph of that memorandum stated:

> Expanding our Nation's capacity to generate clean nuclear energy is crucial to our ability to combat climate change, enhance energy security, and increase economic prosperity. My Administration is undertaking substantial steps to expand the safe, secure, and responsible use of nuclear energy. These efforts are critical to accomplishing many of my Administration's most significant goals.[31]

This statement qualitatively expresses the president‘s desired objective for domestic nuclear energy. In the May 2010 National Security Strategy, the president stated ―we must develop the clean energy that can power new industry, unbind us from foreign oil, and preserve our planet.”[32]

For more than a decade, Gallup has been querying Americans to answer the following question: ―Overall do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose the use of nuclear energy as one of the ways to provide electricity for the U.S.?”[33] In each year, except 2001, favorable responses outnumbered opposing ones.[34] In an article dated March 22, 2010, Gallup reported that:

> Support has edged up in the last two years, eclipsing 60% this year for the first time. In addition, 28% of Americans now say they "strongly favor" nuclear power, also the highest Gallup has measured since the question was first asked in 1994.[35]

In its October 2010 report, titled *The Geopolitics of Energy: Emerging Trends, Changing Landscapes, Uncertain Times*, the Center for Strategic & International Studies (CSIS) offered ―In recent years, the notion of a nuclear ‗renaissance' has become fashionable as countries around the world have sought to meet burgeoning energy demand with stable, base-load, and low-carbon sources of energy."[36] There are currently 56 commercial nuclear reactors in construction worldwide, though only the Iranian reactor would be the first for any country.[37]

It is within this context that the relevance of nuclear energy with regard to U.S. national security is examined. The national security interest areas of energy independence, energy security, climate change, economics, public safety, and nuclear terrorism and proliferation are considered.

<u>Energy Independence</u>

During the January 26, 2009, White House address, President Obama stated: ―Today, I'm announcing the first steps on our journey toward energy independence, as we develop new energy, set new fuel efficiency standards, and address greenhouse gas (GHG) emissions."[38] This concept of energy independence can be expressed in terms of absolute or strategic energy independence. Absolute energy independence means a country produces all of its own energy, which was largely the case in the U.S. prior to 1950.[39] Strategic energy independence means a country allows imported energy, but only if the imported energy does not create vulnerability, such as economic, political, or military vulnerability.[40] For example, strategic energy independence might be achieved by the U.S. while importing petroleum from Canada and Mexico, whereas it would not be achieved when dependent on imports from the Middle East. It has been argued that U.S. energy policies under Presidents Nixon, Ford, and Carter, which were influenced by the Arab oil embargo of 1973, eventually lead to strategic energy independence for the U.S. during the period from 1982 – 1985.[41]

Unites States oil imports declined sharply from 1980 through 1985, reaching pre-1974 levels in 1983.[42] While partially attributable to the opening of Alaskan oil fields, this reduction was also due to reduced oil consumption by the combination of alternative fuels, increased fuel efficiency, and conservation.[43] One such contribution came from the U.S. electrical energy sector. United States electrical utilities responded to the economic and regulatory environment by replacing petroleum fuel oil with domestic coal, nuclear energy, and natural gas.[44] As a result, the U.S. no longer depended on petroleum to generate electricity for the power grid and since the mid-1980s has effectively achieved absolute energy independence with regard to electricity generation.[45]

Attributed largely to shifts in energy policy beginning with President Reagan,[46] the U.S. net petroleum import percentage, as a share of product supplied, increased from 27% in 1985 to 52% in 2009.[47] This situation was likely a factor contributing to President Obama's 2009 announcement:

> America's dependence on oil is one of the most serious threats that our nation has faced. It bankrolls dictators, pays for nuclear proliferation, and funds both sides of our struggle against terrorism. It puts the American people at the mercy of shifting gas prices, stifles innovation and sets back our ability to compete.[48]

The July 2010 CNA Company report summarizes:

> Economically, the nation's heavy oil dependence diverts hundreds of billions of dollars out of the economy each year and leaves American businesses and governmental agencies vulnerable to unpredictable price volatility.[49]

As previously related, the electrical energy sector within the U.S. has effectively achieved absolute energy independence.[50] Because nuclear energy supplies this sector, and the U.S. demand for foreign petroleum is predominantly in the transportation sector,[51] there is not a direct path for increasing overall U.S. energy independence by way of nuclear energy. There are, however, at least two plausible indirect methods by which an expanded role for nuclear energy could make a positive impact.

The first of these methods involves a greatly expanded role for vehicles that are either partially or fully energized by electricity, as is the case for plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV), respectively. The Chevrolet Volt (PHEV) and the Nissan Leaf (EV) are but two examples of consumer automobiles that can be powered from the electric grid. The performance of PHEV or EV vehicles is not currently adequate for replacing gasoline or diesel powered vehicles in all applications, but it is completely capable of doing so in certain applications. To reinforce this assertion, each is being offered in the U.S. market in the 2011 model year. A Chinese PHEV-60 vehicle (implying it is capable of 60 miles of electric only travel), the BYD Auto F3DM, was the world‗s first production PHEV, offered for sale to business and government buyers December 15, 2008.[52] Like the hybrid electric vehicles (HEV) that preceded them, PHEV and EV have the potential to reduce the demand for petroleum in the transportation sector. Unlike HEV which did so solely through increased fuel economy, PHEV and EV also displace energy from petroleum with energy from the power grid. In the case of the U.S., this contributes to energy independence. In his 2011 State of the Union Address, President Obama called for the U.S. to ―become the first country to have a million electric vehicles on the road by 2015."[53]

The second method involves the use of nuclear energy to produce hydrogen. Hydrogen could be used to cleanly power transportation, either by direct combustion or as a fuel for fuel cells. The term “hydrogen economy” has been widely used with regard to this concept.[54] There are established methods for producing hydrogen using electricity or heat to energize the processes. A clean and abundant energy source is required for such an “economy” to be viable, as the energy required to produce hydrogen is greater than the energy that is later available from it.[55] Nuclear reactors could be the source of the required electricity or heat. The Department of Energy has an ongoing research effort investigating this concept.[56] In addition to the need for economically viable large-scale sources of hydrogen, there are many other practical limitations, such as the physics of energy density[57] and nationwide infrastructure.[58]

Contrary to President Obama, there are some who see U.S. energy independence as itself destabilizing.[59] Additionally, should the U.S. achieve energy independence, but nations with whom the U.S. shares vital interests do not, the U.S. will likely continue to face many of the same threats mentioned by President Obama.

The largest contribution made by nuclear energy in terms of energy independence was its contribution to absolute energy independence in the electrical energy sector which has lasted since the mid-1980s. The significance of nuclear energy within this sector will be examined further in the section on climate change. The potential for nuclear energy to impact the transportation sector, and subsequently overall U.S. energy independence, is currently marginal, though the outlook with respect to PHEV and EV is promising, and the potential for a much larger impact exists should breakthroughs in complementary technology areas occur.

Energy Security

Energy security in its basest definition means having assured access to the energy resources necessary to meet demands. Energy security and independence are sometimes used interchangeably, and though interrelated, are not strictly the same. Energy security can be greatly enhanced when a nation enjoys absolute or strategic energy independence, though these situations are generally uncommon. A more recent definition of energy security is provided by the International Energy Agency as: ―the uninterrupted physical availability at a price which is affordable, while respecting environment concerns.”[60] On its webpage entitled ―Energy Security,” the Department of Energy‘s (DOE) Energy Information Administration simply lists the main headings of Oil, Natural Gas, and Electricity, with subordinate headings like: Disruptions and Vulnerabilities; Shipping, Chokepoints, and Spills; Infrastructure and Nuclear Energy.[61] A more comprehensive definition is proposed in a United Nations (UN) publication as:

> A nation-state is energy secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The five dimensions of energy security include energy supply, economic, technological, environmental, social and cultural, and military/security dimensions.[62]

Nations often weigh heavily their other national interests with energy security considerations in mind and employ their military forces commensurately. Former Marine Corps Commandant and U.S. National Security Advisor, retired General James Jones explains:

> Our entire economy depends on the expectation that energy will be plentiful, available, and affordable. Nations like Venezuela and Iran can use oil and gas as political and economic weapons by manipulating the marketplace. Half of our trade deficit goes toward buying oil from abroad, and some of that money ends up in the hands of terrorists.[63]

With regard to nuclear energy, there are three primary energy security considerations. The first has to do with the physical security of the nuclear facilities themselves. A Brookings policy report states:

> In recent years there have been a number of terrorist plots against nuclear facilities, including the “alleged” plot by a group of Pakistani Americans to attack the Karachi nuclear reactor, initial plans by Al Qaeda to crash an aircraft into a U.S. nuclear facility, and the 2006 “Toronto 18” plot by an Islamic fundamentalist group to use a truck bomb to attack a nuclear power facility in Ontario, Canada.[64]

This threat is shared not only by the nuclear reactors, but also by the locations where spent nuclear fuel is maintained. The second consideration is the potential vulnerability of the power grid and the nuclear facilities to possible cyber attack. The third consideration is related to the previously mentioned concept of a worldwide nuclear “renaissance.” The Brookings report cites this renaissance as posing challenges and opportunities for corporations, governments, and international organizations with regard to the nuclear fuel cycle. While noting that these issues are not new, the renewed interest by nations to acquire domestic uranium enrichment and/or reprocessing capabilities, together with a projected construction rate for nuclear reactors not seen in decades, makes these challenges significant. The Brookings report proposes that these actions might be motivated “either by perceived commercial opportunities or energy security concerns about relying on other nations for the provision of these services.”[65] The impact is more nuclear facilities worldwide, facing the physical and cyber security threats mentioned. With increased worldwide use of nuclear energy, especially new nuclear fuel processing/reprocessing, comes increased potential for proliferation of nuclear materials and weapons.

Climate Change

The JOE 2010: Joint Operating Environment, produced by U.S. Joint Forces Command, states: “Climate change is included as one of the ten trends most likely to impact the Joint Force.”[66] In the 2007 CNA Corporation report, titled *National Security and the Threat of Climate Change*, the following statement is made: “Climate change can act as a threat multiplier for instability in some of the most volatile regions of the world, and it presents significant national security challenges for the United States.”[67] This concept of climate change as a “threat multiplier” is echoed by the October 2010 CSIS report.[68] The CNA report further offers: “The consequences of climate change can affect the organization, training, equipping, and planning of the military services.”[69] From these statements and those made by the president, climate change is certainly a pressing global matter with national security implications.

Nuclear energy presents a contemporary paradox when it comes to environmental considerations. In the past, nuclear power was nearly universally vilified by environmentalists due to the radioactive waste produced primarily by the fission of its nuclear fuel. In U.S. reactors this fuel is a particular isotope of uranium, called uranium-235 (U-235). When reactor grade uranium[70] is consumed, highly radioactive byproducts, including plutonium, result. In 2005, “liberal”[71] columnist Nicholas Kristhof wrote in his New York Times op-ed: “If there was one thing that used to be crystal clear to any environmentalist, it was that nuclear energy was the deadliest threat this planet faced.”[72] Kristhof then went on to offer:

> But it's time for … us to drop that hostility to nuclear power. It's increasingly clear that the biggest environmental threat we face is actually global warming, and that leads to a corollary: nuclear energy is green. Nuclear power, in contrast with other sources, produces no greenhouse gases.[73]

As mentioned, nuclear energy satisfies 20% of the U.S. electrical energy demand. Approximately 68% is met by fossil fuel fired power plants, with coal being the greatest single fuel source, used to meet approximately 45% of the electrical energy demand.[74] While the detrimental effects of acid rain have been largely curtailed in the U.S. in the last 30 years,[75] the polluting byproduct of fossil fuel combustion now receiving great attention is the GHG carbon dioxide (CO_2). Coal combustion is the second largest source of CO_2 emitted in the U.S and the single largest source on the planet.[76]

It is with respect to combating climate change that nuclear energy could perhaps make the greatest direct impact. As previously stated, the president seeks to expand the use of nuclear energy. Since this is not quantified, the following two cases are examined. Option 1 is herein defined as substantially expanding nuclear energy capacity within the next twenty-five years to meet 50% of the U.S. electrical energy demand. Based on projections, this would necessitate a fleet of 340 reactors by 2035.[77] Even without an expected increase in capacity from renewable sources, this option would reduce the absolute electrical energy needed from fossil fuels, and subsequent CO_2 emissions, by nearly 10% from 2008 levels. Option 2 is herein defined as expanding the nuclear capacity only to compensate for growing demand over the next twenty-five years, maintaining the status quo of 20% of the demand met by nuclear energy. Based on projected energy demand, this would necessitate a fleet of 135 reactors. This option would not contribute to a reduction in fossil fuel use as a percentage of demand, so an absolute increase in terms of fossil fuel use and CO_2

emission would likely result. With Option 2, substantial increases in renewable sources would be required to slow the growth of CO_2 emission related to electrical power.

In the section on Energy Independence, the potential for nuclear reactors to energize PHEV and EV by way of the electrical power grid was discussed. The greatly expanded use of PHEV and EV in the U.S. automobile fleet is also extremely attractive with regard to climate change considerations, but only if the energy used to power them comes predominantly from sources cleaner than today‘s coal.[78] The 2009 U.S. national mixture of energy sources for electrical power is approximately 45% coal, 23% natural gas, 20% nuclear, 7% hydro, and 5% other renewables.[79] The July 2010 paper titled ―The Dirty Truth About Plug-In Hybrids"[80] makes a comparison between EV and PHEV relative to HEV. In a regional scenario, where the regional power grid is supplied by 84% natural gas and 16% nuclear, the notional EV carbon emission is 37% better than a notional HEV, while the PHEV is 20% better than the HEV (gasoline consumption for the EV is 100% better than the HEV, while the PHEV is 47% better).[81] In another regional scenario, where the regional power grid is supplied by 75% coal and 25% natural gas, the EV carbon emission is 36% worse than the HEV, while the PHEV is 12% worse (relative gasoline consumption same as previous case).[82]

By reducing the demand for petroleum, both scenarios offer great improvements with regard to energy independence. However, only the first scenario offers an improvement with regard to GHG emissions, while GHG emissions in the second scenario are considerably worsened by adding EV and PHEV vehicles. Given this data, it is understandable that the president consistently couples climate change with energy independence,[83] so that the latter is not optimized without consideration for the former.

Given the current mix of energy sources supplying the U.S. power grid, it makes sense to replace as many non-hybrid vehicles as possible with PHEV or EV. It is also clear that to obtain the greatest reduction of GHG, reducing the percentage of coal and increasing the percentage of non-GHG sources, such as nuclear and renewables, is necessary.[84] Coupled with his call for a million electric vehicles on U.S. roads by 2015, President Obama also challenged the country to join him in setting a new goal: ―By 2035, 80% of America's electricity will come from clean energy sources."[85]

Despite the potential positive impact to the environment of replacing fossil fuel generated electricity with nuclear produced electricity, there are several more points to consider. Nuclear energy is not considered to be a renewable energy source, such as hydro, solar, wind, or bio-mass energy generation. Overlooked by Kristhof in his earlier comments due to their very relatively small contributions at the time, solar and wind are also near-zero CO_2 producing technologies. The CO_2 released by burning bio-mass fuel is largely gas that was recently removed from the atmosphere by photosynthesis, hence it is said to be carbon neutral with no net increase in CO_2 concentration. These renewable technologies do not share the radioactive downside of nuclear energy. Despite these points, Dr. Stephen Chu, U.S. Secretary of Energy and Nobel Laureate, offers: ―As a zero-carbon energy source, nuclear power must be part of our energy mix as we work toward energy independence and meeting the challenge of global warming."[86]

Economics

When it comes to national security considerations and economics, it is generally accepted that the healthier a nation's economy, the more robust its capacity to address national security issues. Current Chairman of the Joint Chiefs of Staff, Admiral Mike

Mullen, has stated: “Our national debt is our biggest national security threat.”[87] Relating energy, economics, and security, *The JOE* states:

> Another potential effect of an energy crunch could be a prolonged U.S. recession which could lead to deep cuts in defense spending (as happened during the Great Depression). Joint Force commanders could then find their capabilities diminished at the moment they may have to undertake increasingly dangerous missions.[88]

The president has identified energy as the single most fundamental issue affecting our future.[89] The president has been consistent in expressing the need for clean and sustainable energy.

When considering the economics of nuclear energy, first and foremost, building new nuclear reactors is expensive, largely due to very high initial capital costs. This is mostly associated with construction costs, which according to a Massachusetts Institute of Technology study have increased dramatically just this decade.[90] Reactor order of magnitude price estimates are $10 billion, plus or minus 50%. Unlike France and China, nuclear power plants in the U.S. are not government owned, though they are very highly regulated. Economic risks are often too high for individual companies considering adding new nuclear capacity without mitigation assistance from the government, often in terms of loan guarantees. Historically in the 1970s and 1980s default rates on these loans were as high as 50%.[91] On February 26, 2010, President Obama announced “that the Department of Energy has offered conditional commitments for a total of $8.33 billion in loan guarantees for the construction and operation of two new nuclear reactors in Georgia.”[92]

Timelines and scale are important considerations as well. Putting a new nuclear reactor online in the U.S. has historically taken more than a decade, though Asian projects have recently been completed in less than five years.[93] The two options discussed in the section on Climate Change projected a need for a fleet of 340 and 135 reactors by 2035 for Option 1 and Option 2, respectively. Optimistically assuming the current fleet of 104 could be extended to remain operational at that time,[94] 236 additional reactors would be needed to meet 50% of the 2035 U.S. electricity demand and 31 additional reactors would be needed to continue to meet 20%. This could potentially require $985 billion in loan guarantees for Option 1 and $130 billion in loan guarantees for Option 2.[95] The engineering and specialized human capital needed to undertake an effort like Option 2 would likely stress the capacity of the nation, and that needed for Option 1 likely does not currently exist within the United States.

Unlike fossil fuels, very little of the cost of nuclear energy comes from the cost of the nuclear fuel itself.[96] Once initial capital costs are met, and a nuclear reactor comes online, it produces electricity less costly than fossil fuel plants.[97] Raw uranium ore is abundant in the U.S. and world-wide, and should not be a limiting consideration for nuclear energy this century.[98] Unlike other fuel sources such as petroleum, nuclear energy in the U.S. is not subject to volatile world markets.[99] Coal, likewise, enjoys this benefit in the United States. The U.S. has very large coal reserves, as do China and India.[100] China averages adding one large (1 gigawatt sized; same output as a nuclear reactor) coal fired power plant weekly.[101] In 2009, China's consumption of coal exceeded three times that of the U.S. and is trending strongly upward.[102] To reduce the economic motivation for the use of coal as an energy source, carbon tax[103] and/or cap and trade[104] concepts have been discussed. Implementation of either by governments on a world-wide scale is clearly problematic. A bottom line near term result wherever either is implemented will be a higher cost of energy for consumers, commercial and private. An impact to the economies asked to absorb this will be real, but this does not mean it is not justified.

Adding new U.S. nuclear capacity will add new jobs, many of them specialized and requiring extensive education and training. Conversely if it is done at the expense of the coal industry, then U.S. jobs are also likely to be lost, many of which are labor intensive and blue collar. Generations of Americans have depended on the coal industry for their livelihood, with nearly 90,000 employed domestically in coal mining operations in 2009.[105]

As is often the case, the direct cost of a course of action will likely determine whether it is implemented and to what degree. The costs of constructing additional nuclear energy capacity will be high. In addition to natural supply and demand, the economics of fossil fuel usage is dependent on what form of carbon tax might be implemented. The true costs of climate change are extremely controversial and at best difficult to forecast. Whether the president‘s objective to expand nuclear energy within the U.S. is even capable of maintaining the status quo remains to be seen. Based on a 2010 outlook, the DOE estimates that only six to fifteen additional nuclear reactors will come online within the U.S. by 2035.[106] If a more ambitious expansion, like that of the Option 1 scenario, is realized, then nuclear energy may make a direct impact on national security by positively impacting climate change. However, the logical argument to incur the costs to do this is weakened if GHG reductions made by the U.S. are rendered moot by increases in carbon emissions from other countries. As a world leader, perhaps it is time for the U.S. to lead.

Public Safety

The 2010 National Security Strategy states: ―This Administration has no greater responsibility than the safety and security of the American people."[107] It is within this context that factors related to public safety implications of nuclear energy are considered.

The fear of nuclear power has been pervasive in the U.S.,[108] though attitudes are improving.[109] In his book *Physics for Future Presidents*, Professor Richard Muller states:

> There is great confusion not only in the minds of the public but in those of our leaders. Many people on both sides of this divisive issue think that their point of view is obvious, and that makes them suspicious of those who disagree. Nuclear power is a problem that future presidents will have to contend with, not only in making decisions, but in convincing the public that their decisions are correct.[110]

The physics of a nuclear reactor are inherently similar to those of a nuclear bomb, but the engineering of a power plant and a nuclear weapon are necessarily and fundamentally different. Nuclear power plants like those used in the U.S. are not physically capable of exploding like a nuclear weapon. The physics of their design makes this impossible, period.[111] More advanced reactor designs, such as next generation light-water reactors and pebble bed reactors, are even safer than those in use today.[112] A proposed type of future reactor, called a fast breeder reactor, is fueled by plutonium and has efficiencies that make it an attractive option to some. The spent fuel from a fast breeder reactor actually contains more plutonium than the initial fuel, meaning it can be reprocessed to provide an even greater amount of future fuel. However, the physics of a fast breeder reactor design do not eliminate the possibility of a run-away reaction which could lead to a nuclear explosion.[113]

Physics also shows that the radiation hazard from nuclear energy is real. The danger generally results from unintended distribution of radioactive material, as in the case of Three Mile Island or Chernobyl. The UN International Atomic Energy Agency (IAEA) estimated that there would be 4000 cancer deaths attributed to Chernobyl.[114] Using the same calculation method, it is estimated that one cancer death would result from the Three Mile Island accident.[115] Radon gas from naturally occurring uranium in the region around Three Mile Island is typically 30% above national average. For the 50,000 people who live in that area, such natural radioactivity would lead to 60 excess cancer deaths above national averages.[116] As a counterpoint, Greenpeace has estimated that the cancer deaths due to Chernobyl are closer to 100,000.[117] Any deaths due to a preventable accident are tragic, but perhaps more tragic are deaths that result from intended usage. It has been estimated that 25,000 Americans die annually due to pollutants resulting from the combustion of coal.[118] Additionally, today it is common for coal burning plants to bury their ash byproduct in the ground, even though these ashes are high in carcinogens.[119]

Development and operation of a more suitable storage solution for spent nuclear fuel must be addressed. Today spent fuel is maintained locally at each nuclear power facility. From a safety and security perspective, it is difficult to justify this situation. To address this issue, tens of billions of dollars have been spent developing a centralized long term storage location at Yucca Mountain in Nevada. This project is not supported by President Obama and has seen its 2011 federal funding nearly zeroed.[120] Direct instructions related to this ―back-end" of the nuclear fuel cycle were provided by the President to the Blue Ribbon Commission.[121]

Nuclear Terrorism and Proliferation

In his seminal 1993 paper, titled —The Clash of Civilizations?," Professor Samuel Huntington relates the response from the defense minister of India when asked what lesson he had learned from the 1991 Gulf War. The defense minister‘s response was: —Don‘t fight the United States unless you have nuclear weapons."[122] Professor Huntington offers that non-Western nations —have absorbed, to the full, the truth"[123] of this lesson.

In his opening statement within the 2010 U.S. Nuclear Posture Review (NPR), Defense Secretary Robert Gates states: —This NPR places the prevention of nuclear terrorism and proliferation at the top of the U.S. policy agenda."[124] The NPR goes on to state:

> The most immediate and extreme threat today is nuclear terrorism. Al Qaeda and their extremist allies are seeking nuclear weapons. We must assume they would use such weapons if they managed to obtain them.[125]

Preventing terrorist organizations from obtaining, creating, or employing weapons of mass destruction (WMD) has been a central theme in the on-going U.S. war against terrorism and al Qaeda. The 2011 National Military Strategy states: —The intersection between states, state-sponsored, and non-state adversaries is most dangerous in the area of WMD proliferation and nuclear terrorism."[126] Additionally, preventing terrorist acts against nuclear energy infrastructure, as discussed in the section on Energy Security, are important both to directly ensure the availability of the resource and to prevent an erosion of public support for nuclear energy which could indirectly deny the resource. The NPR lists nuclear proliferation as today‘s next pressing threat, specifically calling out actions by North Korea and Iran:

> In pursuit of their nuclear ambitions, North Korea and Iran have violated nonproliferation obligations, defied directives of the United Nations Security Council, pursued missile delivery capabilities, and resisted international efforts to resolve through diplomatic means the crises they have created.[127]

There are three key elements listed in the NPR for preventing nuclear terrorism and proliferation. The first element is most applicable to nuclear energy, while the latter two relate specifically to current nuclear weapons. The nuclear energy related element has multiple initiatives, the first of which is to “bolster the nuclear non-proliferation regime and its centerpiece, the Nuclear Non-Proliferation Treaty (NPT), by reversing the nuclear ambitions of North Korea and Iran.”[128] Also identified is the need to strengthen UN IAEA safeguards and their enforcement, and to curb the illicit trade of nuclear materials and technologies. Finally, the NPR calls for “promoting the peaceful uses of nuclear energy without increasing proliferation risks.”[129]

The previously cited Brookings report summarizes the proliferation risks that are currently inherent to expanded peaceful uses of nuclear energy:

> An expansion of the civilian nuclear sector to include new actors will bring with it a wider diffusion of nuclear materials, technologies, and knowledge at a time when the international regulatory regime is struggling to cope with existing security and safety concerns. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the foundation of international efforts to ensure nuclear non-proliferation, is facing both institutional and operational challenges with respect to current nuclear activities. Any expansion of nuclear commerce involving the spread of sensitive technologies such as uranium enrichment and spent fuel reprocessing will put additional pressure on a fragile non-proliferation regime leading to increased risks.[130]

Two aspects of the NPT are essentially, though perhaps unintentionally, at odds with each other. The basic intent of the NPT is to reduce the risk of nuclear war by preventing the proliferation of nuclear weapons. It also openly allows for the peaceful use of nuclear energy. The conundrum is that a nation which possesses a self-sufficient nuclear energy program, subsequently also possesses the capability to conduct a nuclear weapons program.

The two areas specifically called out in the Brookings report are uranium enrichment and spent fuel processing. Addressing the latter first, —plutonium is created in most nuclear reactors, including those built to produce electric power.”[131] Professor Muller explains: —It (plutonium) comes out mixed with other nuclear waste, but it can be separated using relatively straightforward chemistry.”[132] Spent fuel processing or reprocessing are terms used to describe this process. Reprocessing can be used to remove fissile waste materials from spent reactor grade uranium, so that the fuel may be used again. In this case the plutonium is a waste product. Reprocessing could also be used to recover the plutonium. In this case the plutonium recovered by reprocessing can be used as fuel for commercial nuclear reactors like those used in France. Reprocessing could be considered desirable, because in practical terms it ensures a —near-infinite” supply of nuclear fuel and it can reduce the total volume of nuclear waste produced. However, this plutonium could also be a source of nuclear material for a thermonuclear bomb. Because of this inherent risk, provisions were placed in the NPT addressing reprocessing and —developing nations that signed the NPT have agreed that they will not reprocess spent fuel.”[133]

Under President G. W. Bush, the U.S. reversed a long-standing policy to abstain from nuclear fuel reprocessing, funding a program described as nuclear fuel ―recycling.”[134] President Obama has reversed this decision by withdrawing funding for this program before any reprocessing activity occurred. At the president‘s direction, the Blue Ribbon Commission is specifically addressing issues related to U.S. nuclear fuel reprocessing. Dr. James Acton, from the Carnegie Endowment for International Peace, addressed the Commission and spoke against domestic spent fuel reprocessing, stating: ―The real value of American restraint is not that it encourages existing reprocessers to stop; it is that it doesn't encourage new ones to start."[135] Linked to the issues of reprocessing is the need for the U.S. to decide on a path forward for long term storage of nuclear waste.

Uranium enrichment is not prohibited by the NPT and is a fundamental step necessary to produce reactor grade fuel like that used in U.S. commercial reactors. However, a program that is capable of enriching uranium to reactor grade is also capable of producing uranium that is weapons grade. Professor Muller explains:

> The hard part of enriching uranium is handling the large amounts you have to process to convert the uranium from 0.7% U-235 to reactor grade 3% U-235. By the time you've done that, the amount of material you have to handle has been reduced by a factor of four, and further enrichment to 80% or 99% U-235 purity is relatively straightforward.[136]

As such, the NPT can too easily be used as cover for an illicit nuclear weapons program, as is potentially the case in Iran, an NPT signatory nation. The inspection authorities the treaty gives the IAEA are intended to prevent this from occurring, though this is clearly problematic as the statements from the NPR and the Brookings report have indicated.

Consistent with this line of reasoning, the supply of nuclear fuel from Russia to the Iranian nuclear reactor at Bushehr[137] could be considered a stabilizing action with regard to nuclear weapons non-proliferation. Given this supply of nuclear fuel, the on-going Iranian activities to enrich their own nuclear fuel could be considered a de-stabilizing act. The website CNN.com quoted White House Spokesman Robert Gibbs as saying:

> Russia is providing the fuel and taking the fuel back out. It, quite clearly, I think, underscores that Iran does not need its own enrichment capability if its intentions, as it states, are for a peaceful nuclear program.[138]

From a physics perspective, Professor Muller offers: ―No matter what the intentions of Iran are, the capability to make weapons is being developed in that country."[139]

Recommendations

Motivated by the underpinning concept that America's energy choices are inextricably linked to national security,[140] this examination has focused on one of those energy choices: nuclear energy. From the analysis herein, I believe that all six of the national security interest areas considered would be advanced by: 1) substantially expanding capacity for nuclear power generation within the U.S., along with 2) providing worldwide leadership to ensure that the positive contributions of ―benign" nuclear energy are enjoyed and the negative aspects are mitigated. This position is consistent with the vision espoused by President Obama, though the execution of this vision must be long-term and is by no means certain. To this end, the following three recommendations are offered.

First, quantify the goal for nuclear power generation. A vision without a plan can be a difficult thing around which to create policy, commit resources, and execute a decentralized nation-wide program. President Obama's goal of 80% of America's electricity coming from clean energy sources by 2035[141] is a good start. Given the 2009 U.S. percentage for non-fossil fuel electrical energy sources was roughly 32%,[142] a considerable advancement is required. An annual roadmap, by percentage and type of energy source needed to reach this 2035 goal, must be created.

A notional scenario, called Option 1 in the Climate Change and Economics sections, called for meeting 50% of the U.S. electricity demand with nuclear energy by

2035. This would require that other clean energy sources supply the remaining 30% needed to meet the president‘s goal. Option 1 required 236 additional nuclear reactors to be built by 2035. Today in the U.S., there are two reactors in the final stages of planning for construction to begin. As mentioned, a 2010 DOE outlook estimates that only between six and fifteen new reactors will be built by 2035.[143] While these figures are estimates, and relative percentages need not be has defined in this scenario, clearly action must be taken very soon to address the magnitude of this disparity. If one assumes that the president‘s goal for electric vehicles continues to grow from 2015 to 2035, then the demand for electricity is likely to grow beyond the estimate used in the Option 1 calculations by a considerable amount, further widening the disparity. Quantifying the nuclear power generation goal will allow for progress to be tracked, such that policy, resources, and execution can be adjusted accordingly, helping ensure the vision is achieved.

Second, set the stage economically to achieve the goal. Once a roadmap is in place, it must be resourced in order to be executed. An oft-quoted Pentagon saying is —vision without resources is a hallucination.”[144] Offering loan guarantees commensurate with the levels projected by the roadmap is a start. Addressing the causes which lead to high default rates in the past would be critical to ensuring this program succeeds. Tax incentives, to offset the large capital costs that discourage entry into the market, could later be offset by the taxes generated on revenue from the additional capacity and increased economic activity spurred by additional energy. Consistent with the 2011 State of the Union Address, an investment by the federal government in the human capital needed to support the roadmap, possibly in terms of targeted college scholarships or loans for nuclear engineers and technicians, would likely prove beneficial as well.

The federal government has other means to influence resourcing beyond simply spending money from its treasury. Streamlining the federal licensing and oversight process could pay immediate dividends in terms of time and cost savings. An example of such could be the standardizing of reactor designs to no more than two or three for a period of time, say ten years. This would allow for simplified licensing and oversight, while allowing for competition in the marketplace, and ensuring that only the safest designs are used to increase the U.S. commercial nuclear fleet. Lastly, the current stagnation on formulating energy policy regarding carbon taxes or cap-and-trade programs increases uncertainty and discourages private sector investment. The roadmap will be viable only if the economics of the program are viable.

Third, with an increasing emphasis on a nuclear renaissance, the U.S. must remain vigilant on the world stage to ensure that existential threats to the U.S. and its allies are not realized through actions such as nuclear terrorism. The U.S. should work to gain international support for an addition to the NPT to disallow nuclear fuel enrichment by non-nuclear weapons states or by states with a nascent nuclear program, similar to how the treaty addresses nuclear fuel reprocessing. To make this feasible, another provision could create a world nuclear fuel bank[145] to give those nations not producing their own fuel the energy security they require with regard to access to nuclear fuel. An economic incentive for compliance, such as subsidized lease rates for the use of the fuel, might be in the interest of the United States. Nation's with only peaceful intentions for nuclear energy would likely benefit by such provisions.

Nations which refuse to accept or comply with these provisions could lose the cover to pursue a nuclear weapons program that the NPT currently provides. Finally, to further address the viability of a world nuclear fuel bank and to improve upon the current public safety and energy security situations, the U.S. must decide and act upon a long-term storage solution for spent nuclear fuel.

Summary

This paper has endeavored to continue Professor Einstein‘s work to —carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications to society.”[146] In examining the relevance that terrestrial nuclear energy has with regard to U.S. national security, a broad exploration of the national security interest areas of energy independence, energy security, climate change, economics, public safety, and nuclear terrorism and proliferation was conducted. From a systems perspective, it was evident that these six areas were often interrelated. Both direct and indirect ties where presented relating terrestrial nuclear energy to national security. I believe that all six of the national security interest areas would be advanced by: 1) substantially expanding capacity for nuclear power generation within the U.S., along with 2) providing worldwide leadership to ensure that the positive contributions of —benign” nuclear energy are enjoyed and the negative aspects are mitigated. Three recommendations for actions beneficial to implementing this position were offered.

In conclusion, the insights of a third Nobel Laureate are presented for consideration. In 2004, Professor Richard Smalley testified before the U.S. Senate Committee on Energy and Natural Resources, saying: —Energy is the single most important challenge facing humanity today … Electricity will be the key.”[147]

Endnotes

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[110] Richard A. Muller, *Physics for Future Presidents: The Science Behind the Headlines*, 154.

[111] Ibid, 159.

[112] Richard A. Muller, *Physics for Future Presidents: The Science Behind the Headlines*, 168. Professor Muller offers the question: “Could a truly safe nuclear reactor be designed?” He goes on to answer: “Some people say that the U.S. design is already safe enough. But can one be designed that is so safe that we would not have to worry about either a reactivity accident or a loss-of-coolant accident? That answer is yes. One such design is called the pebble bed reactor.” Professor Muller goes on to explain that the “safety of the pebble bed reactor is based on physics.” He concludes that: “The reactor is designed such that if anything fails, it will automatically slow down, thanks to physics, and the reactor will revert to a safe ‘idling’ temperature. You can even remove the control rods and the coolant (usually helium gas), and nothing bad happens.”

[113] Ibid, 163.

[114] UN International Atomic Energy Agency web site, “Chernobyl: Looking Back to Go Forward,” *Proceedings of an International Conference*, Vienna, September 6-7, 2005, 4, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1312_web.pdf (accessed November 13, 2010). Professor Muller also reported this IAEA estimate in his book, *Physics for Future Presidents*, but later revised his estimate to be 36,000 excess cancer deaths. In an e-mail received from Professor Muller, he stated: “I am more comfortable with the 36,000 figure, assuming that the linear hypothesis is correct. In fact, I made that change in a later edition of the book. The smaller number was based on a calculation done by a prestigious group that I believe contained an error.” Richard A. Muller, e-mail message to author, March 16, 2011.

[115] Richard A. Muller, *Physics for Future Presidents: The Science Behind the Headlines*, 166.

[116] Ibid. Also on this page, Professor Muller offers: ―In the Frontline documentary ‗Nuclear Reactions,' a resident near the Three Mile Island reactor was convinced of great harm from the release of radioactivity from the accident. When she was asked about the much larger dangers from ground radon, she responded that she had no fear of that because it was ‗natural.' She didn't appreciate that human cells can't distinguish between natural and artificial radiation."

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[130] John P. Banks, et al., *Non-Proliferation and the Nuclear "Renaissance": The Contribution and Responsibilities of the Nuclear Industry*, vi.

[131] Richard A. Muller, *Physics for Future Presidents: The Science Behind the Headlines*, 136.

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