2012

How the United States Will Find a Sustainable Future Through Increased Nuclear Productivity

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May 2012

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Abbreviations

BWR	Boiling Water Reactor
DOE	Department of Energy (U.S.)
GW	Gigawatt
IAEA	International Atomic Energy Agency
KWh	Kilowatt-hours
MW	Megawatt
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
Pu	Plutonium
PWR	Pressurized Water Reactor
TWh	Terawatt-hour
U	Uranium
USAEC	United States Atomic Energy Committee
LFTR	Liquid Fluoride Thorium Reactor

Introduction

First of all before I begin discussing my thesis, I would like to talk to you about a problem. This problem is one that I have encountered quite often during the course of my environmental studies. The problem I'm referring to is the emission of green house gasses into the atmosphere. Specifically, carbon dioxide created during the energy production process by burning coal, oil, and natural gas. The earth is a very large and very powerful living organism capable of accommodating *some* increased levels of carbon dioxide within its atmosphere, but within the past decade emission levels have continue to rise exponentially to the point where the problem has shifted from the act of burning fossil fuels to the rate at which humans are doing so.

According to the Climate Change synthesis report summary for policy makers produced by the Intergovernmental panel on Climate Change, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level." Keep in mind this report was created by the UN in 2007. Four years ago.

In producing my senior thesis I wanted to solve the problem of green house gas emissions. My research focused on finding and examining a sustainable energy source that made sense in present day terms, an energy source that would not be extremely disruptive but would hopefully be part of the solution for the United States in reducing its carbon footprint.

I'm sure many of you know about the different forms of sustainable energy that exist today. Wind power, hydro electric power, tidal power, geothermal power, solar power, and biomass/waste power. For some reason nuclear power is often overlooked when discussing the future of U.S. sustainable energy production. Nuclear power seems to fall into an in-between state, it's not a fossil fuel, it's not a green source of power… but it could be. I am arguing that increased spending on nuclear infrastructure is the answer… at least for the time being. The sustainable energy sources mentioned above (the solar, wind, water, biomass, etc.) are much cleaner and have even lower overall carbon footprints, but it is my belief that increased nuclear productivity will act as a transitional form of safe, stable, low cost electricity.

If the United States wants to realistically change the way in which energy is produced increased nuclear production will in essence pick up the slack left behind while fossil fuels such as coal, oil, and natural gas are progressively phased out. Increased nuclear productivity will help take the economic strain off of consumers while they transition from the status quo to newer green technologies. During which time, these new sustainable forms of energy production will be allotted more time for development and to prove their overall worth and longevity.

Keep in mind that this theory of increasing nuclear production is a very two sided argument. Typically people are for nuclear or against it. Nuclear energy is by no means the final answer, but through my research and specifically focusing in on the science, economics, and policy I hope to make an argument to support an increase in the use of nuclear energy as a transitional means into a sustainable future.

Nuclear Energy

On March 12, 2012 the United States Census Bureau announced that the world's population had surpassed the seven billion person mark. With seven billion people certain needs exist, chief among them is a need for energy. Energy in order to plant and harvest crops, energy to build homes, energy to light, warm and cool those homes. The list goes on and on. In a world that is experiencing exponential population growth rates; traditional energy production methods such as the burning of fossil fuels (coal, oil & natural gas) are beginning to near feasible operational and sustainable limits. The bright side of the story however is that nuclear energy has the capability to service seven billion humans well into the foreseeable future.

The idea that everything on earth is made up of tiny particles called atoms has existed within human knowledge since the time of ancient Greece. Ever since the discovery of sub atomic particles mankind has been enthralled with the idea of somehow harnessing the immense power that lies within these small structures. Early nuclear research in the United States draws its roots from the Manhattan Project, and the work of such noted physicists as Albert Einstein and J. Robert Oppenheimer. Although the Manhattan Project was originally focused on developing nuclear reactors and enriching Uranium and Plutonium for uses in weapons manufacturing, the discoveries parlayed into the civilian energy sector after the end of World War II.

By 1945 high ranking officials in the United States government encouraged the research and development of nuclear energy for peaceful civilian purposes. The federal government thought that nuclear energy would be the power of the future, that and the U.S. wanted to maintain nuclear facilities domestically in order to keep up with the rapid expansion of the USSR's nuclear arsenal. In 1946 Congress created the Atomic Energy Commission (AEC) to oversee construction of an experimental Breeder Reactor I at a site in Idaho. The reactor was opened and began electrical generation on December 20, 1951.[1] Following the breakthroughs in Idaho, the first commercial nuclear generator to become operational in the United States was the Shippingport Reactor in Pennsylvania in December 1957. After the first reactors became operational, plant construction grew steadily for the next 30 years. U.S. Construction peaked in the 1970s with 162 plants being built. By 1980 the world had 243 nuclear power stations with a total capacity of nearly 140,000 megawatts (MW). Today there are 438 nuclear power plants throughout the world with 19 having been constructed since 1990.

Worldwide France is by far the largest modern supporter of nuclear power with nearly 80% of its electricity coming from nuclear power sites. Today, nuclear power plants provide about 6% of the world's energy and 13–14% of electricity worldwide, with the U.S., France, and Japan together accounting for about 50% of nuclear generated electricity.[2]

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[1] International Atomic Energy Agency (IAEA) IAEA Home." *International Atomic Energy Agency (IAEA)*. Department of Nuclear Energy. Web. 21 Feb. 2012. <http://www.iaea.org/

[2] IAEA Website.

Technology

For all intensive purposes, a nuclear power plant works like a coal or gas power plant. Water is heated to extremely high temperatures turning it into steam. When the water is turned into steam, it expands very rapidly creating immense pressure. The pressurized steam then turns a turbine (giant fan) that in turn powers a generator that creates electricity. After the steam passes through the turbine section it is cooled by water and returned to a liquid state to repeat the process.

At the heart of the process is the nuclear core. In the core reactor, enriched uranium neutrons are split in half releasing neutrons as well as enormous amounts of energy and heat in a process known as nuclear fission. The released neutrons can cause other Uranium molecules in the core to split thus creating a chain reaction. In order to control the reaction process, facility engineers utilize control rods that in essence slow down the speed of the neutrons as well as water as a coolant. What separates the nuclear process from those of coal, oil, or natural gas is the high energy content of its fuel source, which in the U.S. is typically, enriched Uranium. With an extremely high energy density, one pound of enriched Uranium has the same energy content as 1,800 metric tons of crude oil, 2,600 metric tons of coal, and more than 2.1 million cubic meters of methane. [3] This means that the amount of the mineral needed to produce electricity is very small. For example, a nuclear power plant producing 1GWe per year needs only about 25 metric tons of enriched Uranium per year. [4]

Naturally occurring Uranium found in the earth's crust must undergo an enrichment process prior to the fission process in order to prepare the Uranium Isotope, specifically U-235. The enrichment process ensures that the maximum amount of energy will be produced through the utilization of U-235. Naturally occurring Uranium contains about 0.7% of the U-235 isotope, the remaining 99% is mostly the U-238 isotope which is not used because it does not contribute directly to the fission process. For the most part Uranium-235 and U-238 are chemically identical, but differ in their physical properties, particularly their mass. The nucleus of the U-235 atom contains 92 protons and 143 neutrons, giving an atomic mass of 235 units. The U-238 nucleus also has 92 protons but has 146 neutrons - three more than U-235, and therefore has a mass of 238 units.[5] Once the Uranium has been properly enriched, it is ready for the fission process.

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[3] Maugeri, Leonardo. *Beyond the Age of Oil*. (Prager: England 2010) pg.99.
[4] Maugeri. pg. 99.
[5] Lochbaum, David, Edwin Lyman, and Ellen Vanchko. "Nuclear Power: Safety First. Now." 15 July 2011. Web <ucsusa.org>.

U.S. Civilian Nuclear Energy Production

In the United States there are currently two forms of nuclear reactors used for commercial civilian energy production, the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR).[6] In a PWR water is kept under pressure within the reactor and heated but not boiled. Figure 1 illustrates how the water being used is kept separate from the heat source. In the Boiling Water Reactor illustrated in Figure 2, there is direct interaction with the water and the heating process in which the water is not kept under pressure and allowed to boil. The BWR has advantages in terms of efficiency because it does not require the supplemental steam generator needed by the Pressurized Water Reactor, but since there is direct contact of the water with radioactive materials in the BWR facility engineers are required to wear protective gear when coming in contact with the plants turbines.

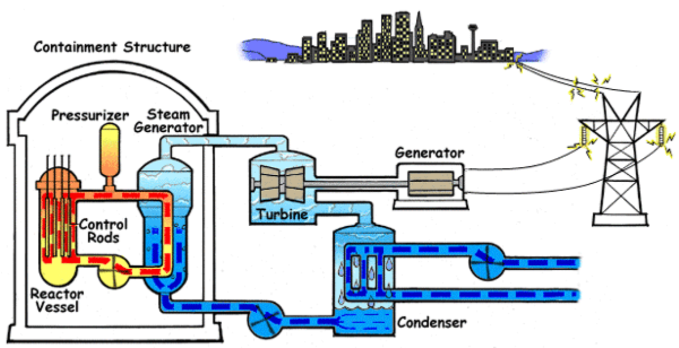

Figure 1.0 Pressurized Water Reactor

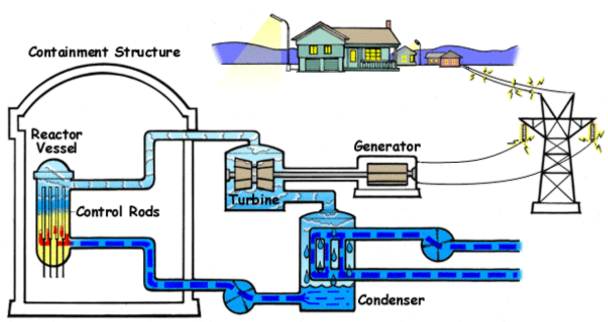

Figure 2.0 Boiling Water Reactor

In the United States today there are 104 licensed to operate nuclear power plants spread across 31 states. Of the 104 in operation, 69 are Pressurized Water Reactors (PWRs), and 35 are Boiling Water Reactors (BWRs).[7] Figure 3.0 is a map produced by the U.S. Nuclear Regulatory Commission (NRC) detailing reactor locations and the number of reactors at each location.

[6] NRC.gov "Students Corner; Types of Reactors."
[7] NRC Website, "Power Reactors."

Figure 3.0 Map of US Commercial Power Reactors

Construction

Since the first commercial reactor went online in the U.S. in 1957 simpler plant designs have cut down on maintenance and repair costs. Shut-downs are now far less frequent, so much so that that a typical station in the U.S. is now in operation 90% of the time, up from less than 50% in the 1970s.[8] New "passive safety" features can shut a reactor down in an emergency without the need for human intervention.

The latest technology acquisition has been from the U.S. Company Westinghouse, (owned by Japan's Toshiba). The Westinghouse AP1000 is the main basis of technology development for U.S. nuclear reactors. By around 2040, advanced PWRs such as the AP1000 are expected to generate around 200 GWe per reactor annually.[9]

The last new reactor to go online for commercial service in the U.S. was in Tennessee in 1996. In 2007 construction resumed on a partially built reactor, also in Tennessee, which is slated for initial operation in 2013.[10] Construction on two other reactors, the Bellefonte 1 and 2 in Alabama, remains suspended, but there is a possibility that the reactors eventually might be completed.

As of 2011, the NRC has had active applications for a total of 28 new reactors, although it is unknown how many of the proposed reactors will be built. In order for an energy company to begin construction on a brand new nuclear reactor, the NRC conducts a review that takes anywhere from 30 to 60 months. The review includes reactor design information, site evaluation, and safety features. Actual reactor construction can take as long as six years for each reactor.[11]

[8] NEI: Nuclear Energy Institute." *Nuclear Energy Institute*. www.nei.org
[9] NRC Website. www.nrc.gov
[10] NRC Website.
[11] NRC Website.

The Southern Company, one of the nation's largest energy providers broke ground on an entirely new facility in 2009. The project located just outside of Augusta Georgia is slated to cost around 14 billion dollars and if delivered on time could begin producing power in by 2016. Funding for construction has been split three ways. The Southern Company and its partners have invested more than $3 billion, Georgian electricity consumers will pay approx. $6.1 billion of the project's costs through rate hikes, and the remainder will come from the Obama administration that have pledged loan guarantees for another $8.3 billion.

Safety

Nuclear safety is without a doubt nuclear energy's worst enemy. The general public is often times misinformed choosing to make the mistake of comparing a nuclear power reactor, used to make electricity, to a nuclear bomb. One of the issues at the heart of the problem is an overall lack of nuclear education. Typically, the average U.S. citizen does not understand how a nuclear power plant functions nor do they know of the immense amount of nuclear safeguards currently in place.

The worst accident in commercial nuclear power plant history occurred on March 28, 1979 at the Three Mile Island facility in Pennsylvania. The immediate problems associated with the core meltdown were human related and had no similarities to the destruction created by nuclear weapon. There were neither immense explosions nor areas of vast nuclear fallout, nor lingering levels of increased radiation. In terms of safety per amount of energy created, nuclear is much more safe than coal, petroleum, natural gas, biofuel, and hydro energy. For the *Journal of American Physicians and Surgeons*, Bernard Cohen, a physics professor at the University of Pittsburg created the graph you see from figure 4. You can find nuclear at the far right with .04 deaths per tera watt hour of energy.

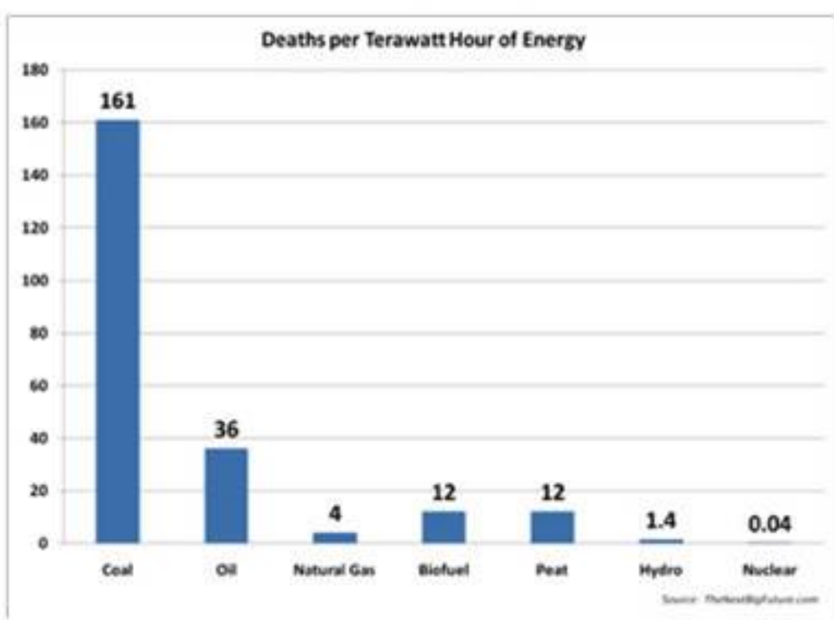

Figure 4 Deaths per Terawatt Hour of Energy

In 2009 Steven Chu, the secretary of energy under Barack Obama, was asked to compare coal to nuclear power. He responded "I'd rather be living near a nuclear power plant." Rumors of living next to nuclear plants often say that because of your close proximity you receive increased levels of radiation. This is not the case, in order to dispel this, I have included Table 1.0 below demonstrating the amount of radiation an average person receives annually.

Table 1.0 Typical Yearly Radiation Doses

Source	Radiation Dose (mR/year)
Natural Radiation	240
Natural in Body*	29
Medical (Average)	60
Nuclear Plant (1GW electric)	0.004
Coal Plant (1GW electric)	0.003
*Included is the natural total for a 75kg person	

If anything the events at Three Mile Island serve to remind regulators and safety technicians that while the likelihood of a nuclear power plant accident is low, its potential consequences are grave. Given this reality, the United States and legislators understand that steps need to be taken in order to avoid serious shortcomings in nuclear plant safety for the future. No technology can be made perfectly safe, but the United States can and must do more to guard against accidents as well as the threat of terrorist attacks on reactors.

Current nuclear safety measures in the U.S. are industry leading but there is always room for improvement. Nuclear Safety is an industry term that covers the actions taken to prevent nuclear and radiation accidents or to limit their consequences. This covers nuclear power plants as well as all other nuclear facilities, the transportation of nuclear materials, and the use and storage of nuclear materials for medical, power, industry, and military uses

The topic of nuclear safety covers:

- The research and testing of the possible incidents/events at nuclear facilities,
- What equipment and actions are designed to prevent those incidents/events from having serious consequences,
- The calculation of the probabilities of multiple systems and/or actions failing thus allowing serious consequences,
- The evaluation of the possible timing and scope of those serious consequences (the worst-possible result in extreme cases being a release of radiation),
- The actions taken to protect the public during a release of radiation,
- The training and rehearsals performed to ensure readiness in case an incident/event occurs.
- Accidents that have occurred.

Civilian nuclear safety in the U.S. is regulated by the Nuclear Regulatory Commission (NRC). The safety of nuclear plants and materials controlled by the U.S. government for research, weapons production, and those powering naval vessels is not governed by the NRC.

Internationally, the International Atomic Energy Agency "works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies."

Waste Disposal

"Love it or hate it, we have it."

-Burton Richter Nobel Prize winning physicist and author of *Beyond Smoke and Mirrors: Climate Change and Energy in the 21st Century*

One of the main problems, if not THE main problem that nuclear power faces is what to do with nuclear waste. The main problem encountered in nuclear waste disposal stems from the last 1% of spent nuclear fuel that is composed of Plutonium (PU) and other elements called minor actinides: Neptunium (Np), Americium (Am), and Curium (Cm). These four elements are not as radioactive as leftover uranium but their respective half-lives can be greater than 100,000 years.

The Nuclear Waste Policy Act (NWPA) supports the use of deep geologic repositories for the safe storage and/or disposal of radioactive waste, but currently there is no licensed facility capable of storing the 60,000 tons of spent nuclear fuel that has already been produced by the operating U.S. plants, so most used fuel from nuclear power plants is stored in steel-lined concrete pools filled with water, or in airtight steel or concrete-and-steel containers like the one pictured in the slide

For economic and national security reasons, the United States does not currently recycle used nuclear fuel, although it is investigating advanced recycling technologies.

The main problem encountered in nuclear waste disposal stems from the last 1% of spent nuclear fuel composed of Plutonium (PU) and elements called minor actinides: Neptunium (Np), Americium (Am), and Curium (Cm). These four elements are not as radioactive as leftover uranium or iodine-129 or technetium-99 but their respective half-lives can be greater than 100,000 years.

The Nuclear Waste Policy Act (NWPA) supports the use of deep geologic repositories for the safe storage and/or disposal of radioactive waste. The Act establishes procedures to evaluate and select sites for geologic repositories and for the interaction of state and federal governments. It also provides a timetable of key milestones the federal agencies must meet in carrying out the program. The NWPA assigns the Department of Energy (DOE) the responsibility to site, build, and operate a deep geologic repository for the disposal of high-level waste and spent nuclear fuel. It directs the Environmental Protection (EPA) to develop standards for protection of the general environment from offsite releases of radioactive material in repositories. The Act directs the Nuclear Regulatory Commission (NRC) to license DOE to operate a repository only if it meets EPA's standards and all other relevant requirements.[12] The Federal government to claim all spent fuel and to put it away in a deep geological repository

[12] NRC Website.

where it will remain, isolated from the surface world for the time required for its radioactivity to decay to safe levels. In order to fund this underground waste disposal, electricity produced by nuclear reactors has a surcharge of 0.1 cent per kilowatt-hour. Currently there is no licensed facility capable of storing the 60,000 tons of spent nuclear fuel that has already been produced by the operating U.S. plants, so most used fuel from nuclear power plants is stored in steel-lined concrete pools filled with water, or in airtight steel or concrete-and-steel containers like the one pictured in Figure 4.0

Figure 5.0 nuclear waste silos

For economic and national security reasons, the United States does not currently recycle used nuclear fuel, although it is investigating advanced recycling technologies. The nuclear industry endorses this plan, which could result in long-term environmental and energy security benefits for America. Through recycling, the separated uranium would become new fuel for commercial nuclear power plants. The long-lived radioactive elements, including plutonium, become fuel that could be used in advanced reactors that would be developed commercially as part of the research and development program.[13]

Cost Benefit Analysis

Technology has undoubtedly improved the economic benefit of nuclear power. In terms of start-up, the capital costs as well as time needed to build a nuclear reactor are higher than the costs and time needed to build traditional gas and coal fired plants. Once built however, nuclear plants are very cheap to run. Gas and coal fired power stations on the other hand are the exact opposite, cheap in the beginning to build, but very expensive to operate. Since gas producing plants provide the extra power needed when energy demands rise, the gas price sets the electricity price. Costly gas has therefore made existing nuclear plants extremely profitable.

The latest boost to nuclear has come from climate change. Nuclear power offers the possibility of large quantities of base load electricity that is cleaner than coal, more secure than gas and more reliable than wind. As recently as 2008 car manufacturers have began to release 100% plug in electric cars that could cause a rapid shift from oil to electricity. If this growth continues alongside the quickly vanishing coal deposits and oil fields the demand for power generated from carbon-free sources will continue to increase further. To quote Burton Richter

[13] "NEI: Nuclear Energy Institute." *Nuclear Energy Institute*. Web.

from his book *Beyond Smoke and Mirrors: Climate Change in the 21st Century,* "The industry's image is thus turning from black to green."[14]

As of 2008 nuclear ranks fourth overall in terms of world energy production accounting for 13.6% of the 20,105 Terawatt hours of energy produced.

Table 2.0 World production of electricity by source (2008)

Source	Production (TWh)	Share (%)
Coal	8,243	41.0
Natural Gas	4,277	21.3
Hydropower	3,216	16.0
Nuclear	2,734	13.6
Oil	1,084	5.4
Biomass & Waste	259	1.3
Wind	216	1.1
Geothermal	62	0.3
Solar	9	0.0
Tidal &Wave	1	0.0
Other	4	0.0
Total	**20,105**	**100.0**

Coal, Petroleum, and natural gas have proven world wide reserves that will likely expire within the next 100 years, if not sooner. Within its relatively young history (50 years) nuclear power has been able to establish itself as a potential base load energy source. Yes, radioactive waste materials exist, but developed nations have the capabilities to deal with long-term storage. Thinking long term, nuclear power generation does not result in the emission of carbon dioxide, a potentially expensive problem that will need to be dealt with. Overall costs have decreased with increase efficiency and technological improvements.

Nuclear compares very favorably with coal and gas in cost comparisons to Coal, Gas, and wind in the table below.

Table 3.0 Estimates of electricity costs from various sources

	MIT 2003	France 2003	UK 2004	Chicago 2004	Canada 2004	EU 2007
Nuclear	4.2	3.7	4.6	4.2-4.6	5.0	5.4-7.4
Coal	4.2		5.2	3.5-4.1	4.5	4.7-6.1
Gas	5.8	5.8-10.1	5.9-9.8	5.5-7.0	7.2	4.6-6.1
Wind Onshore			7.4			4.7-14.8
Wind Offshore			11.0			8.2-20.2
Total	**998**	**908**	**90**			

Source: Various Sources

[14] Richter, Burton. *Beyond Smoke and Mirrors* (Cambrige: 2010). Pg. 134.

Today the importance of nuclear power in USA is geopolitical as much as economic, reducing dependency on imported oil and gas. The operational cost of nuclear power – 1.87 ¢/kWh in 2008 – is 68% of electricity cost from coal and a quarter of that from gas. From 1992 to 2005, some 270,000 MWe of new gas-fired plant was built, and only 14,000 MWe of new nuclear and coal-fired capacity came on line. But coal and nuclear supply almost 70% of US electricity and provide price stability. When investment in these two technologies almost disappeared, unsustainable demands were placed on gas supplies and prices quadrupled, forcing large industrial users of it offshore and pushing gas-fired electricity costs towards 10 ¢/kWh.

The reason for investment being predominantly in gas-fired plant was that it offered the lowest investment risk. Several uncertainties inhibited investment in capital-intensive new coal and nuclear technologies. About half of US generating capacity is over 30 years old, and major investment is also required in transmission infrastructure. This creates an energy investment crisis which was recognized in Washington, along with an increasing bipartisan consensus on the strategic importance and clean air benefits of nuclear power in the energy mix.
The Energy Policy Act 2005 then provided a much-needed stimulus for investment in electricity infrastructure including nuclear power. New reactor construction is expected to get under way from about 2012.

U.S. Nuclear Policy

The U.S. Department of Energy (DOE) was formed in 1977 in the midst of America's energy crisis. It brought together activities under the Atomic Energy Commission (AEC) founded in 1946 as the civil successor to the Manhattan Project, the Energy Research and Development Administration (ERDA) which succeeded it in 1974, and other bodies. The purpose was to achieve better coordination of policy by putting previously disparate agencies and programs together into a single Cabinet-level department. The Secretary of Energy reports to the President. The DOE's responsibilities include policy and funding for programs on nuclear energy, fossil fuels, hydropower and alternative sources of energy such as wind and solar power.
The DOE also manages (often through a private-sector operations contractor) the government's 21 national laboratories, including the Idaho National Laboratory (INL), which manages a major portion of the government’s nuclear energy research. The DOE sponsors more basic and applied research, including research done at universities or by industry, than any other government agency. In addition to the DOE's responsibilities for civilian nuclear energy, its National Nuclear Security Administration (NNSA) oversees the military application of nuclear energy, maintaining the country's weapons stockpile and managing the design, production and testing of nuclear weapons.

Most of the federal programs concerned with civilian use of nuclear energy are run by the DOE’s Office of Nuclear Energy, including research and development of next-generation nuclear plants, advanced fuel cycle technology, funding for government-industry partnerships for construction of new reactors, and operations and funding for nuclear energy projects at national laboratories. Budgets for these programs have generally grown in recent years as the US government has sought to meet the goals of energy independence, reduction of carbon emissions and meeting the future demand for electricity. However, under the Obama administration the total level of funding for the Office of Nuclear Energy has been reduced. The major increases in the DOE budget are in the areas of alternative energy sources, such as wind, solar and geothermal, and energy efficiency and conservation.

The United States Nuclear Regulatory Commission (USNRC) was created by congress as an independent Agency in 1974. The NRC is responsible for ensuring the safe use of radioactive materials for beneficial civilian purposes while protecting people and the Environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection, and enforcement of its requirements.[15]

There are three regulatory initiatives which enhance the prospects of building new plants in the next few years. First is the design certification process, second is provision for early site permits (ESPs) and third is the combined construction and operating license (COL) process. All have some costs shared by the DOE.

Nuclear cooperation on the International level is largely regulated by the International Atomic Energy Agency (IAEA). In 1957 the IAEA was set up as the worlds “Atoms for Peace” Organization within the United Nations Family. The IAEAs mission is guided by the interests and needs of member states, strategic plans and the agency’s three main pillars: Safety and security; science and technology; and safeguards and verification.[16]

Future

After 20 years of steady decline, government research and development funding for nuclear technology is being revived with the objective of rebuilding U.S. leadership in nuclear power. President Barack Obama’s 2012 budget proposal included $36 billion in loan guarantees for building nuclear power plants. In an effort to bring together government research laboratories, commercial industries, and private research groups, the Federal government has significantly stepped up research and development spending for future plants in order to improve upon current reactor designs. With a goal of increased efficiency and cheaper costs there has been particular attention to the Next Generation Nuclear Plant (NGNP) project to develop a Generation IV high-temperature gas-cooled reactor, which would be part of a system that would produce both electricity and hydrogen on a large scale. The U.S. Department of Energy has stated that its goal is to have a pilot plant ready at its Idaho National Laboratory (INL) by 2021. The total development cost has been estimated at two billion dollars.

On a broader world scope the National Energy Administration (NEA) of the Peoples Republic of China announced in 2011 that China will make nuclear energy the foundation of its power-generation system in the next “10 to 20 years,” adding as much as 300 GWe of nuclear capacity over that period. In September 2010, the *China Daily* reported that China National Nuclear Corporation (CNNC) alone planned to invest CNY 800 billion ($120 billion) into nuclear energy projects by 2020. Total investment in nuclear power plants, in which CNNC will hold controlling stakes, will reach CNY 500 billion ($75 billion) by 2015, resulting in 40 GWe on line,

[15] NRC Website. “About NRC,” www.nrc.gov/about-nrc.html
[16] IAEA Website, “The ‘Atoms for Peace’ Agency.”

according to CNNC.[17] As of March 10th 2012 Mainland China has 14 nuclear power reactors in operation, more than 25 under construction, and additional reactors in design phases.

China's nuclear arsenal will boast some of the world's most advanced facility designs. It is expected that nuclear capacity will grow by at least 60 GWe by 2020, 200 GWe by 2030, and 400 GWe by 2050.[18] If the United States aims to remain competitive with china immediate steps are necessary in order to increase nuclear generated electricity and decrease coal produced electricity.

These are staggering numbers considering most of mainland China's electricity is still produced from fossil fuels. Approximately 80% or 3.7 billion tons (2011) from coal, 2% from oil, and 1% from natural gas. Table 4.0 produced by Dr. Leonardo Maugeri, one of the world's leading experts on oil, gas, and energy places china on top of the list of coal producing countries on earth with over double the consumption of the United States.

Table 4.0 Coal consumption (Top 10 countries and world total, 2008)

Country	Consumption (millions of tonnes)
China	2,671
US	1,015
India	579
Germany	238
Russia	233
Japan	193
South Africa	192
Australia	144
Poland	141
Turkey	109
World Total	**6,669**

Since most of the coal, gas and oil reserves are located in China's northern provinces it becomes a logistics nightmare transporting billions of tons of coal across the country to the coastal regions. China is already using close to half of its existing rail lines just to transport coal.

In the rapidly developing coastal areas of china, nuclear facilities are favorable due to lack of available fossil fuels. Chinese urban planners favor the proximity that comes with nuclear plants that can be built in more urban areas and typically have little to no direct impact on the local residents. Generally non-nuclear energy production facilities are detrimental to the living conditions of an area (coal plant, oil refineries, etc.), or require large tracts of open space (wind farm, solar, etc.). Reliance on coal fired electricity generation and at such high volumes has had adverse effects on air pollution. Increasing nuclear energy production would help in slowing if not reversing the effects of the world's largest contributor to carbon dioxide

[17] World Nuclear Association Website. "China Nuclear Power."
[18] World Nuclear Association Website. "China Nuclear Power."

emissions. If no new nuclear facilities become operational The US Energy Information Administration predicts that China's share in global coal-related emissions will grow by 2.7% per year, from 4.9 billion metric tons in 2006 to 9.3 billion metric tons in 2030, some 52% of the projected world total. Total carbon dioxide emissions in China are projected to grow by 2.8% per year from 6.2 billion metric tons in base year 2006 to 11.7 billion tons in 2030 (or 28% of world total). In comparison, total US carbon dioxide emissions are projected to grow by 0.3% per year, from 5.9 billion metric tons in base year 2006 to 7.7 billion metric tons in 2030.[19] China's coal consumption is expected to exceed 4 billion metric tons per year by 2015 - half the world total. [20]

Within the last decade, nations including Japan, China, and the UK, as well as private U.S. and Australian industrial firms have begun test small scale Liquid Fluoride Thorium Reactor (LFTR). The LFTR is an existing technology that has recently reemerged because of its potential to create large amounts of inexpensive electricity. Critics hail the LFTR design as inherently safe with a reactor core that operates at atmospheric pressure, so it cannot explode. While traditional PWR and BWR reactors consume approximately 1% of their Uranium fuel, LFTRs consume almost 99% of their thorium fuel. What's more is that geologists estimate the earth's crust to have available levels of Thorium comparable to available levels of Lead. In terms of radioactive waste disposal, the life span of a spent Thorium fuel rod is around 300 years vs. the 7.038×10^{8} year half life of uranium-235.[21] It's so energy dense, that you can hold a lifetime supply in the palm of your hand. Human kind could potentially use thorium 200 xs more efficiently than we are currently using Uranium now.

The technological push for the Liquid Fluoride Thorium Reactor has largely been spearheaded by president and chief technologist of Flibe Energy, Kirk Sorensen. Further information on the Liquid Fluoride Thorium Reactor and the work of Mr. Sorensen can be found on Mr. Sorensen's website ENERGYFROMTHORIUM.COM

Conclusion

In order for the United States to remain competitive in global energy markets immediate steps must be taken in order to keep up with the depletion and imitations of fossil fuels. Nuclear power is now the only large-scale carbon free system that can produce energy

[19] International Energy Outlook 2009, Energy Information Administration, U.S. Department of Energy
[20] World Nuclear Association Website.
[21] Hargraves, Robert; Moir, Ralph (July 2010). "Liquid Fluoride Thorium Reactors." 304–313

levels that could accommodate U.S. needs. Political problems such as oversight and waste removal have stalled the once world leading U.S. nuclear industry. Nuclear energy now stands at a unique crossroads. Continued support of the nuclear programs in the United States will allow for a new technological age of American development

With increased nuclear education college graduates and jobseekers will have new opportunities in areas they might not have known about. Education will give knowledge to people who might not have known about the vast potential of the nuclear production process both in the elimination of green house gasses, and in the ability to create clean electricity affordably and with little risk. For the United States, maintaining and strengthening safety measures will help prevent accidents and purpose driven legislation will help corporations embark on new nuclear projects. With a healthy nuclear sector the United States will gradually begin to shift from heavy gasoline use to electricity. Sustainability will be thought of as the status quo, and nuclear power will aid in the transition period during the shift to even more green energy sources.

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