Nuclear Power: The Nucleus of Energy Independence? An Analysis of International Energy Policy

Scott Shackelford, Indiana University-Bloomington

Within the next several decades, energy consumption in developing countries such as China and India will double or even triple. In the developed nations of the world, energy demand will likewise soar to unprecedented heights putting new strains on existing energy infrastructures and requiring the creation of new nonrenewable and renewable sources of power. “It's essential to take some prudent steps now to avoid intolerable costs and impacts later,” said John Holdren, Heinz Professor of Environmental Policy at Harvard University. “The task of energy policy is to ensure the reliable and affordable energy services that a prosperous economy requires while simultaneously limiting the risks and impacts from overdependence on oil, from global climate change, and from other environmental and political liabilities,” (Hall, 2004).

The debate on how to efficiently and economically fuel the economies of tomorrow is underway today, and the differences in the battling ideologies are in no place more apparent than in the United States and European Union (EU). Sharp contrasts have long existed between the energy policies of the US and the member states of the EU. This is partially explained because unlike the US which enjoys significant deposits of coal and to a lesser extent oil, while with few exceptions European nations are relatively poor in fuel reserves necessitating the importation of energy. However, there has recently been a movement to decrease European dependence on foreign energy reserves in the form of a commitment between the majority of EU states to promote the use of alternative energy sources. France, though, has decided on a different path from its European neighbors. It generates only 15 percent of its power from renewable sources with almost 80 percent produced by nuclear power plants. Further, at a time when only a handful of European states are expanding their nuclear power networks, France is moving ahead with the construction of a new generation of nuclear power plants to replace its aging facilities at a cost of $150 billion. Unlike France, the US has not constructed a new nuclear power plant since the 1979 Three Mile Island accident. For the past 25 years the US nuclear industry has been mired by fears of accidents, terrorism and safe waste disposal. Though, with surging oil prices and a second Bush Administration, plans for a US expansion of nuclear power capabilities are currently being formulated.

Given these facts, it is the goal of this paper to compare and contrast the progress of energy policy formulation in the US and EU since the 1950’s specifically in regards to renewable energies such as wind, solar, hydrogen and nonrenewable energies such as nuclear power. To flesh out the differences and their meanings after this brief historical survey, a case study comparing the United States and France with a special emphasis on the nuclear power industry will be offered for consideration. The question, “Why did France choose to go ahead with developing nuclear power despite the risks that deterred the US from doing so?” will be examined. In addition, as a subtopic the question will be asked as to why France has differed so markedly in its stance on nuclear power from other European countries? The results of this project will highlight the contrasting energy policies of two of the richest developed nations and shed new light on the decision of many developing nations such as China to follow France’s lead and pursue an ambitious nuclear power program. This will then lead to a discussion as to what this new direction could mean for the economies and environment of the world.

I. Methodology

The primary methodology behind this comparative investigation of the energy policies of the US and EU, specifically the nuclear power industries in the US and France, will be by use of a case study. This is a widely-known yet elusive approach to research in that it is familiar since it has been promoted by researchers and writers from various disciplines, yet amorphous since authors define the term based on their experience and research interests. Consequently, the exact meaning of 'case study' can be difficult to classify and a comprehensive definition incorporating elements from a number of established sources would be most useful for this multidisciplinary study.

R.K. Yin, in many ways the father of modern qualitative case study research, defined a case study as an empirical inquiry that: "investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident," (Yin, 1994). He further elaborates this definition with the conditions that case study inquiry should also: "cope with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data converging in a triangulating fashion," (Yin, 1994). These stipulations demonstrate how a case study is different from experimental research, which seeks to divorce a phenomenon from its context. Yin's characterization is also important in that he defines triangulation in a different way from other contemporary authors. For example, he includes such research tools as interviews, surveys, observation, records, etc. into his definition (Berger, 2000). Given that this project will incorporate several informational interviews and policy records, as well as a large amount of technical data couched within the framework of international energy policy, Yin's approach to case study research offers the best chance for a successful analysis.

II. Literature Review

A. State of the World: Energy

The world population is expected to double to more than 12 billion with an associated eight-fold increase in gross world economic product between 1985 and 2050. Already, to meet the energy requirements of the world's more than six billion inhabitants, approximately 80 million barrels of crude oil per day are burned. Of this figure, the United States consumes around 20 million barrels, more than half of which is imported. Based on projections, crude oil consumption is expected to reach 120 million barrels per day (BPD) by 2030 (Aubercht, 1995). The Paris-based International Energy Agency (IEA) has forecasted an average annual increase in global energy demand of 1.7 percent a year between 2000 and 2030, adding up to an increase over current consumption levels of about 65 percent. World demand for electricity will likewise increase by 265 percent during the same period (Aubercht, 1995).

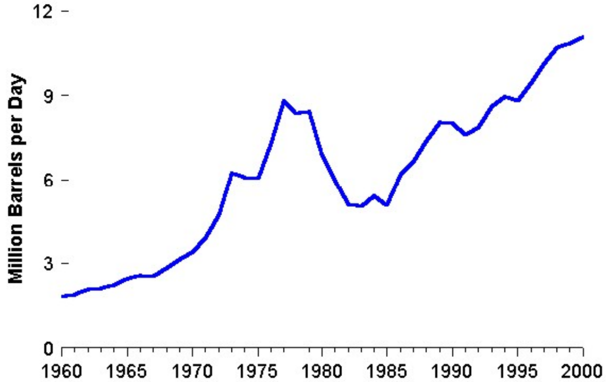
These statistics point to an expected exponential increase in world energy use for the foreseeable future. To meet surging demand over the next 25 years, the IEA has concluded that there is enough oil and natural gas, but argues that more than $500 billion in investment is needed to bring new fossil fuel reserves to market.[1] "Huge investments will be needed in oil fields, tankers, pipelines and refineries," according to an IEA report (Mieszkowski 2004). Meanwhile, petroleum will likely maintain its role as the primary energy source for the world's economy. "Oil will stay the single most important fuel in the world energy mix for some time, driven by the transportation sector," said IEA Chief Economist Fatih Birol (Mieszkowski, 2004). This same state of affairs is likewise true for developing countries, which will probably see the fastest population and economic growth.[2] It is projected that 60 percent of the increase in global primary energy use by 2030 will come from developing countries, particularly Asian states such as China and India (Ho, 2004). The question then beckons as to how these developing nations will choose to fuel their burgeoning economies, and what will developed nations do in order to ensure that their own energy matrix is economically and environmentally sustainable in the long-run?

Energy has always been necessary for production in one form or another, and for this reason as manufacturing has become increasingly energy intensive the energy sector has evolved into a strategic industry to be protected and nurtured. The political economy of energy policy and its existence as a strategic industry is emphasized by the fact that a number of geopolitical events—from the war in Iraq, to civil unrest in Nigeria, to Russian major Yukos' financial straits—spook energy markets and directly affect the world economy. The IEA predicts that these threats will grow in the short-term buoyed by concerns about nuclear proliferation and illustrating the need to couch a discussion of international energy policy within the political and economic realities of the modern world (Mieszkowski, 2004). Regardless though, "If the world economy expands to meet the aspirations of countries around the globe, energy demand is likely to increase even if strenuous efforts are made to increase the efficiency of energy use," (Burnham, 1993). This fact is particularly true in the country that uses the majority of the world's energy reserves at 7.86 tons of coal per capita (in contrast to 4.05 in France); the United States of America.

III. United States Energy Policy

For the past three generations, petroleum has been the dominant fuel in the US transportation sector while a mixture of fossil fuels has powered the nation's utilities to an ever increasing degree. Since World War II when demand began to outstrip domestic supply, America has looked abroad for solutions to its energy problems. Throughout this time "political and regional polarization has produced an energy stalemate, preventing America from adopting sensible approaches to some of our biggest energy problems," according to John W. Rowe, Chairman and CEO of Exxon Corp. (Prindle, 2004). The United States today imports more than 50 percent of the oil it consumes from abroad at a cost of $50 billion annually—though this figure could rise to more than 80 percent over the next 15 years if current trends continue. The situation at present is deemed so grave that the former Secretary of Commerce has determined that oil imports threaten to impair US national security (Kincaid, 1995). In fact, the state of dependence of the American energy sector is worse today than it was in 1973 when the Organization of Oil Exporting Countries (OPEC) embargoed oil shipments to the United States.[3] This condition points to the fact that America is increasingly reliant on foreign sources to satisfy its energy requirements, in the process turning energy production and consumption into a key strategic industry imperative to the nation's economic and political future.

Chart 1.1: US Petroleum Imports: 1960 to 2000



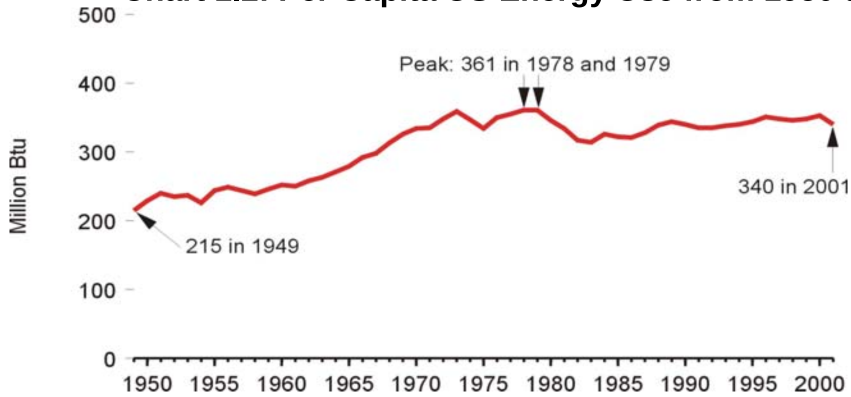
*Source: *Department of Energy website*

Both the United States' and the world's addiction to petroleum has not always been the norm. At the turn of the 20th century the switch to oil signified a radical change from the status quo of steam and electric power as the preferred fuel for conveyance.[4] "In 1900 of the 4,000 cars sold in the United States, 22 percent had gasoline engines, 38 percent had electric engines, and 40 percent were powered by steam," (Rubenstein, 2001). In contrast, by 2005 there is now a fleet of more than 150 million registered private vehicles in the US, or one for nearly every adult, 99 percent of which are powered by internal combustion engines. This dramatic transition underlies a basic conflict between the demands of the driving public and the strategic needs of the nation that has stagnated progress (VerMeulen, 1983).

"Within the past two decades, the United States has experienced two energy crises. Each was caused by forces outside governmental control," (Aubrecht, 1995). In essence, importing foreign oil threatens US national security by upsetting the balance of payments, stimulating inflation, and fostering dependence on countries with interests that may not coincide with that of the United States. This inevitably requires the US become involved in situations that are disadvantageous, tainting its preferred foreign policy with the need for crude oil causing a myriad of policy dilemmas. The current fleet of private cars in the US, as well as petroleum burning plants, adds to this threat by burning fuel at less than optimal efficiency.

"Absent substantial gains in the energy efficiency of motor vehicles, buildings, appliances, and equipment, it becomes difficult to imagine how energy supplies, and especially clean energy supplies, can keep pace with increased US and global demand," said Professor Holdren (Prindle, 2004). The core of the failure of United States energy policy is that the only real flexibility in the oil market is held by OPEC, which not only controls the bulk of global reserves, but importantly for US policy, most of the world's spare production capacity. Indeed, at least for the next four years virtually all the world's additional production lies beneath these states and a few others, including: Saudi Arabia, the United Arab Emirates, Algeria, Kuwait, Libya, Russia, Kazakhstan, Iran, and potentially Iraq and Angola (Ho, 2004). US foreign policy towards these nations reflects our continued need for their oil, effectively tying US hands in dealing with other matters of importance when priorities conflict. To remedy this situation and wean off of fossil fuels, advocates maintain that the US must first stop subsidizing the use of fossil fuels[5] and pursue avenues of intervention ranging from gradually increasing the cost of US petroleum to the world price-level, thereby reflecting oil's true economic cost, to providing additional tax incentives for hybrid car and alternative energy power plants (Aubrecht, 1995). Taking up any one of these possibilities would be a dramatic reform of US energy policy, a goal that has been attempted by administrations from both parties over the past 30 years to varying degrees of success.

Chart 1.2: Per Capita US Energy Use from 1950 to 2001



*Source: *Department of Energy website*

The most recent wave of US energy policy reform began when Republicans in Congress proposed a series of bills in the 1990's amidst calls of an impending energy crisis, though without significant long-term effect. More recently, a bill was authored by Senator Frank H. Murkhoski-R Alaska. Central to the new legislation is a provision for drilling within the Arctic National Wildlife Refugee (ANWR).[6] If passed, this effort could supply as much as one million barrels per day at peak production, which the site will not reach for approximately 10 years. The production of natural gas, coal, nuclear energy and an increase in home-heating assistance for the poor is also trumpeted in the bill. "American dependence on foreign oil threatens our national security and our freedom, and we need to recognize that," said Senator Trent Lott of Mississippi, the Senate majority leader (Lizette 2001). This plan is designed to decrease US dependence on foreign oil from 56 percent today to 50 percent five years after implementation. The between 3.2 and 16 billion barrels of oil that ANWR is estimated at holding would only reduce that number temporarily by one percent. In response, Senator Jeff Bingarman-D, New Mexico has said "We cannot produce our way to independence from foreign oil supplies," (Lizette, 2001).

Both sides of the energy debate in the US are beginning to realize that dependence on foreign supplies of energy is a national security issue that goes beyond partisan politics. To illustrate, former President Bill Clinton stated "Imports of crude oil threaten to impair national security. I accept the recommendation that existing policies to enhance conservation and limit the dependence on foreign oil be continued," (Clinton, 2000). In order to address the nation's energy situation, President Clinton established a Commission entitled "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges" that recently reported to Congress. Its mission statement was to move beyond contentious political issues such as ANWR and to find common ground that could lead to real progress in redrafting United States energy policy.

"Taken together, the Commission's recommendations aim to achieve a gradual but decisive shift in the nation's energy policy**,** toward one that directly addresses our long-term oil, climate, electricity supply, and technology challenges," said William K. Reilly, former EPA Administrator and Commission co-chair (Prindle, 2004). The Commission focused on oil reliance, for example, since it is an issue that the US will face for some time. In response to this, the Commission recommends the establishment of incentives to spur global oil production, to increase domestic vehicle fuel economy, and to increase investment in alternative fuels.

Specifically, this proposal would offer incentives for low and non-carbon sources like natural gas, renewable energy, nuclear energy, and advanced coal technologies with carbon capture and sequestration. To reduce risks from climate change, the Commission suggested implementing a mandatory, economy-wide tradable-permits system by 2010. This would be designed to curb future growth in the nation's emissions of greenhouse gases while keeping the costs of doing so at $7 per metric ton of carbon dioxide or its equivalent.[7] "The Commission's climate plan explicitly caps the total cost to the economy while reducing emissions. By 2020, the estimated cost of the plan per household will only be $30-100 a year," said Reilly. "This is no Kyoto," (Prindle, 2004).[8]

An emissions-intensity metric is also the basis of President Bush's current approach towards mitigating climate change, which calls for voluntary greenhouse gas intensity reductions of 1.8 percent per year from 2002-2012. Although a step in the right direction, this scheme would mean a variety of disparate permit systems with little centralized control and therefore a lesser chance for attaining any real success at reducing overall emissions. However, if implemented, these recommendations could reduce US oil consumption in 2025 by 10-15 percent under today's levels, translating to 3-5 million barrels saved per day. "For more than 30 years, energy has been the graveyard of many a brave policy titan," said Reilly. "But the Commission's analysis shows that these recommended policies can curb US oil use, begin to address greenhouse gas emissions, develop viable new technologies, and put the US in a much stronger energy posture," (Prindle, 2004). In policy terms, this shift in US energy policy can be accomplished by:

Table 1.1: U.S. Energy Policy Initiatives

* Increasing federal support for renewable technology research and development by $360 million annually, targeted at overcoming key hurdles in cost competitiveness and early deployment.

* Extending the federal production tax credit for a further four years (i.e., from 2006 through 2009), and expanding eligibility to all non-carbon **energy** sources, including solar, geothermal, new hydropower generation, next generation nuclear, and advanced fossil fuel generation with carbon capture and sequestration.

* Supporting ongoing efforts by the Federal Energy Regulatory Commission (FERC) to promote market-based approaches to integrating intermittent resources into the interstate grid system.

* Establishing a $1.5 billion program over ten years to increase domestic production of advanced non-petroleum transportation fuels from biomass (including waste).

*Source (Prindle, 2004)

To make this energy policy successful requires significant research and development investments. "Overcoming the energy challenges faced by the United States and the rest of the world requires technologies superior to those available today," said Holdren. "To accelerate the development and deployment of these technologies, the federal government must increase its own investments in energy-technology innovation as well as its collaboration in this domain with the private sector, with states, and with other nations," (Prindle, 2004). However, so far under the energy plan proffered by the Bush Administration these funds have not been allocated, placing the primary emphasis on increased petroleum and coal production with only lip service played to any long-term sustainability. According to Reilly the time to split hairs is over: "As a nation, we no longer have the luxury of fighting over whether we need more nuclear, fossil or renewable energy resources or greater efforts in conservation and efficiency. We need them all, and we need them now," (Prindle, 2004). The passage of the new US energy policy will be a highly politicized and contentious issue that will impact the US energy sector, from nuclear power to geothermal and biodiesel fuel, and the economy as a whole. Reilly stresses that during the coming debates "we also must not lose sight of the broader goals of the legislation by allowing individual provisions to impede the work of several Congresses and at least two administrations," (Hall, 2004). President Bush called upon Congress on March 9, 2005 to once again take up his energy plan, though a debate is currently unscheduled. Regardless of the final result the US approach to energy will continue to be markedly different from other Western nations, those of Europe in particular.

IV. European Union Energy Policy

Energy policy has been front and center as an area of concern for Europe for more than half a century. After World War II, and as a condition of the Marshall Plan, a number of European leaders became convinced that the only way to secure a lasting peace in Europe was to unite the continent both economically and politically, and that the fastest way to go about this was by making their energy sectors interdependent. In 1950 the French Foreign Minister Robert Schuman proposed integrating two strategic industries, coal and steel, with the idea of making the nations of Western Europe so economically intertwined that they could never go to war again. In 1951, the European Coal and Steel Community (ECSC) was created with six original members: Belgium, West Germany, Luxembourg, France, Italy and the Netherlands. The ECSC was such a success that within a few years these same six countries decided to go further and integrate other sectors of their economies. In 1957 they signed the Treaties of Rome, creating the European Atomic Energy Community (EURATOM) and the European Economic Community (EEC). These three institutions then merged into the EEC in 1967. The 1992 Treaty of Maastricht ultimately created the European Union with an expanded mandate, but one still loyal to the founding principle of energy interdependence. Though, how that energy is generated has changed substantially over the decades.

In the 1960's, the majority of Western Europe ran out of coal. This event, coupled with the horrific environmental impact that coal burning had on Northern France and Scandinavia through 1945, led Europe to change its energy production techniques. The transition was hastened when England, France, and Germany lost their African colonies that could have at least partially supported the continued European use of coal and oil for power production. Thus, with the exception of the United Kingdom and Norway which had discovered substantial oil reserves in the North Atlantic, Western Europe gradually began to change its energy policy that had persisted for generations from coal and petroleum-intensive to promoting alternative sources of energy, especially nuclear power, and importing the remainder.[9] Opposed to this strategy of importation, France departed in its energy policy from its European neighbors in the 1950's and decided to pursue complete energy independence with the 'nuclear option.' In the era that France made this decision the possibilities of nuclear power seemed limitless, and was heralded by the likes of then President Eisenhower as "an energy source that will be so cheap one day that it will not even be monitored," (Brabsen, 2005). Thus, although historically on the same page, as Europe looks ahead to the future its population growth and energy demands differ markedly from those of the United States.

Unlike the world average, the population growth of central and Eastern Europe is expected to decline slightly making energy demands rise relatively moderately. Europe's population as a whole is slated to increase from 456 million to 468 million from the present to 2030. To supply the energy needs of its growing citizenry, the EU energy infrastructure is expected to remain dominated by fossil fuels over the next 30 years, much like that of the United States, with an increase of two percentage points in its share to 2030 (Trends to 2030, 2004). Throughout the EU, energy growth is expected to increase at an average of 0.6 percent annually through 2030 (compared to the projected GDP growth rate of 2.3 percent, illustrating improvements in energy efficiency). After 2015 a number of EU member states are planning to initiate a program to phase-out aging nuclear power plants. To take its place, solid fossil fuels and imported oil will be used along with clean-coal and alternative technologies such as wind power. In this way, Europe mirrors the rest of the world in that its projected energy needs are in line with the four fuels ranked most important worldwide; oil, coal, natural gas and renewable energies with shares of 36 percent, 25 percent, 17 percent and 12 percent respectively.

Renewable energy forms are projected to remain the fastest growing segment in the EU energy system at 1.9 percent per year, signifying that by 2030 their share will amount to nine percent of total power usage (compared to three percent in the US) (Trends to 2030, 2004). If this comes to pass, the EU, like the US, will need to import up to two thirds of their energy from foreign sources. In addition, burning more fossil fuels will mean that the EU will increase its CO_2 emissions by 19 percent from 1990 to 2030, necessitating additional measures to meet targets set under the Kyoto Protocol. It is the goal of the European Union not to succumb to this fate and instead to double how much European energy comes from alternative energies to 21 percent through conservation and the continued development of renewable sources such as wind power, hydrogen and geothermal sources (Trends to 2030, 2004). Yet nuclear power will still have an important role to play in the future of European electrical power generation, as it does in the United States and many developed and developing nations.

V. Results of Case Study: The Nuclear Power Industry in France and the United States

A. Nuclear Power in Perspective

"Nuclear power plants currently generate 16 percent of the electricity the world consumes; they account for 78 percent of electricity generation in France**,** about half of Belgium and Sweden's electricity, 28 percent of Germany's electricity, 20 percent in the United States, and 17 percent in Russia," (Mihailescu, 2004).[10] Nuclear fuel reserves (Uranium 238 and Plutonium 239) are comparable worldwide to coal supplies, fueling demand for at least 50 years (Brabsen, 2005). With 439 reactors operating in 31 countries, nuclear energy use is increasing at a rate of 1.9 percent per year and is primarily driven by growth in Japan and developing countries. One reason for its popularity is that, even though the initial capital expenditures for a nuclear power plant are daunting and can easily run to the billions of US dollars, once completed, operating costs of nuclear power plants are one tenth the cost of coal plants: $0.04/kilowatt hour for coal vs. nuclear at $0.025/kilowatt hour (Brabsen, 2005). Further, the external costs of both energies, defined as those actually incurred in relation to health and the environment and quantifiable but not built into the cost of the electricity, differ greatly. If these costs were in fact included, the EU price of electricity from coal would double and that from gas would increase 30 percent. These costs also do not take into account costs from global warming. However, even as nuclear power becomes increasingly popular worldwide for a number of reasons, some developed countries are considering shutting down their plants amid plant malfunctions at a cost of between nine and 15 percent of the original construction cost (Prindle, 2004).

Belgium, the Netherlands, Germany, and Sweden have decided to gradually phase out their nuclear power programs.[11] The rationale for these decisions is partially to do with the fact that recently there have been massive leaks in some of the world's supposedly safest nuclear power stations. Increased safety measures by the International Atomic Energy Authority (IAEA) have not helped prevent further accidents. The third-safest power plant in Russia, the Volgodonsk facility in the Rostov region, had to be stopped twice within nine months due to emergencies in November 2003 and January 2004. Even Japan's Mihama plutonium-thermal plant, considered the world's safest power plant, saw four workers killed when steam leaked from a turbine reactor on August 9, 2004. Japan's Asahi Shimbun reported the blunder to be the worst ever in Japan's nuclear power plants: “Trust was lost and the accident will have a great impact on future nuclear power development,” (Mihailescu, 2004). This sentiment was echoed by Russian Greenpeace head Ivan Blokov on Aug. 8, 2004 when he stated that “There will be accidents as long as the nuclear power industry exists. There could be a new Chernobyl at any moment,” (Mihailescu, 2004).[12]

Despite calamites, France has chosen to ambitiously move forward with its nuclear power program unlike its European neighbors. One reason for this is that “since the nuclear power plants in France are all publicly owned, they can afford to take the long-term view,” according to energy physicist Ben Brabsen (Brabsen, 2005).[13] Other rationale for this split with the rest of Europe in regards to nuclear power includes the disproportionate impact that coal burning has had on French cities, the toll that both World Wars had on the country, and the wish of the French people to be independent and embracing of the promises of nuclear power. This perspective perhaps helped to put the dangers of nuclear power in perspective. To exemplify, despite the well-publicized accidents, to date the numbers of deaths and injuries associated with coal mining and processing are higher than nuclear power. In fact, on average 17 Chinese coal miners are killed each day. These facts make nuclear power one of the least dangerous ways to generate energy (Aubrecht, 1995).

B. The French Nuclear Industry

France produces almost 80 percent of its energy in nuclear power plants, and is now second in the world in terms of dependence on atomic energy after Ukraine. “They (the French) are now reaping the benefits of a nuclear power program that is 30 years in development, thus with low operating costs they are in good straights…that is until the plants wear out and new ones need to be built,” (Brabsen, 2005). Currently, the only European countries with plans to build new nuclear plants are France**,** Finland, and some of the former socialist bloc nations. France has an existing stock of 19 nuclear power plants including some 58 reactors. From this stock, France produces more than 75 percent of its electricity from “second generation” nuclear installations (Hicks, 2004). The earliest of these installations at Fassenheim near the German border went into service in 1977 and has a life expectancy of about 40 years. The "first generation" consisted of the prototypes built in the 1950's and 60's that have since been retired. Taking a different perspective from the rest of the European Union, France has decided to begin an aggressive program of retiring its aging second generation plants and to begin construction of a new series of "third generation" power facilities that promise to be the most advanced of their kind in the world.

Construction of the advanced EPR (European Pressurized Water Reactor) is due to begin in 2007 at Flamanville near Cherbourg on the Cotentin peninsula, with the first electricity being produced five years later. At a cost $3.8 billion, the reactor will be the first of a so-called "third generation" of nuclear power stations.[14] Among much else, the new reactor should reduce the risk of accident by ten due to its double casing which also makes it able to withstand the impact of an aircraft flown by terrorists. The design also signifies that even if there is a disaster, the reactor core will collapse in on itself to contain radiation leaks rather than explode outwards. If successful, the EPR should generate 1,600 megawatts of electricity—compared to 900 for most current reactors—need less regular recharging, and have a life span of 60 years. Of course, cost estimates require this long of a timeline for the plant to achieve ultimate profitability (Brabsen, 2005). Although many in France welcome the county's leadership in the nuclear field, so to is there a growing anti-nuclear movement. "The EPR reactor offers no greater guarantee against terrorism than any other reactor," said Stephane Lhomme of the Get Out of Nuclear Collective (Hicks, 2004). This sentiment is shared by French Greenpeace, "We are investing three billion euros in a technology that is almost obsolete for political reasons that have no connection with a rational, properly thought-out energy policy," (Hicks, 2004).

Despite the civil societal backlash, France's centre-right government took the decision in May 2004 to press ahead with the new generation of nuclear reactors, arguing that it is the best response to the likely long-term increase in petrol prices as well as demands for a cleaner environment. On the government side, Patrick Ollier, chairman of the National Assembly's economic affairs committee, said "On the environmental front the reactor reinforces France's preeminence in the fight against climate change, and economically it will allow us to ensure supply and limit the effects of a rapid increase in oil prices," (Hicks, 2004). France also hopes to be chosen as the site for the future International Thermonuclear Experimental Reactor (ITER), which aims to develop commercial nuclear fusion by mid-century.[15] To accomplish this, ITER seeks to emulate nuclear fusion of two hydrogen isotopes (deuterium and tritium) that occurs in stars, and to produce helium that would give off a tremendous amount of electricity as a byproduct. French Prime Minister Jean-Pierre Rafarin said in November 2003 that the project would provide "the energy of the future, an inexhaustible source and with no significant problems, thanks to the abundance of hydrogen contained in water," (Hicks, 2004). Scientific data, however, contradict the prime minister's assertions.[16]

The French government plans to earmark $150 billion over the next 30 years for nuclear power plants, including the ITER and EPR plants, despite experts' warnings on technological and environmental problems (Godoy, 2005). Summing up the concerns of scientists, the French nuclear physicists Sebastien Balibar, Yves Pomeau and Jacques Treiner wrote in the October 25, 2004 edition of *Le Monde* newspaper that a thermonuclear reactor poses three technical problems of first magnitude: the production of the elements to undergo fusion, their resistance to fusion, and control of this reaction (Godoy, 2005). These technical drawbacks mean that ITER, though politically attractive, may remain a pipe dream at least for the foreseeable future. However, construction of the EPR plants is going forward as planned and, if successful, could make France the world leader in nuclear technology.

C. The United States Nuclear Industry

During World War II, nuclear research in the United States focused mainly on the development of weapons. After the war, scientists and policymakers concentrated on peaceful applications of their wartime endeavors. Towards this end, Congress created the Atomic Energy Commission (AEC) in 1946 to develop commercial nuclear power and in 1950 authorized the construction of Experimental Breeder Reactor I at a site in Idaho. The reactor generated the first ever electricity from nuclear energy on December 20, 1951. From this beginning, the US nuclear power industry grew rapidly throughout the 1960's and 70's. Utility companies saw this new form of electricity production as economical, environmentally clean, and safe. That all changed though on March 28, 1979 when a serious accident involving a partial core melt took place at the then three-month old Three Mile Island PWR. This event shifted public support for nuclear power from 56 to 33 percent. Although attributed to faulty pumps, the incident rocked the nation and not one new nuclear power plant has been constructed in the United States since (Aubrecht 1995, 67). Still, in 1991 the US had twice as many operating nuclear power plants as any country.

As of August 3, 2004, there were 104 commercial nuclear generating units that are fully licensed by the US Nuclear Regulatory Commission (NRC). Of these 104 reactors, 69 are categorized as pressurized water reactors (PWRs) totaling 65,100 net megawatts (electric) and 35 units are boiling water reactors (BWR) totaling 32,300 net megawatts (electric). The last reactor to come on line in the United States was the Watt's Bar reactor in Tennessee, owned and operated by the Tennessee Valley Authority in May 1996. Despite slow progress, US commercial nuclear capacity has increased in recent years through a combination of license extensions and upgrading of existing reactors that demonstrate an upsurge of public and political support (Bennhold, 2004).

Awakening from a long dormancy, the US nuclear power industry currently has tentative plans for expansion with specifics still to be determined. Already, 26 US plants have received 20-year extensions on their operating licenses and 18 others have applied for extensions at the Nuclear Regulatory Commission after the Bush Administration streamlined the re-licensing process. Three plant operators, Exelon, Dominion and Energy, have asked the Commission to approve sites for future reactors, although no concrete plans for building them have been announced yet (Bennhold, 2004). The Bush Administration is seeking at least $2 billion over the next 10 years in federal research and development projects geared at producing a series of new advanced nuclear power plants to increase this sector of energy production from 20 percent to at least 30 percent.

"Nuclear power achieves several goals: One, it's a renewable source of energy; two, it's a domestic source of energy; and three, it would help us meet our obligations to clean air requirements. Unfortunately, it's an issue that's hard to get through our Congress. I mean, there are a lot of people still fearful of nuclear power, and it's a debate I've engaged in," said President Bush during a recent trip to Europe (Bennhold, 2004). Without Congressional support though, the US nuclear power industry could remain dormant. "The contribution of nuclear energy to meeting the nation's electricity needs will decline absent concerted efforts to address concerns about cost, susceptibility to accidents and terrorist attacks, management of radioactive wastes, and proliferation risks," said Holdren. "Given the hazards of climate change and the challenges that face all of the low-carbon and no-carbon supply options, it would be imprudent in the extreme not to try to keep the nuclear option open," (Prindle 2004). If the Commission's propositions are not heeded and nuclear power is allowed to languish, nuclear energy use could decrease to as low as five percent of total world energy output by 2030 (Trends to 2030, 2004). Additional funding would also be required to meet a number of additional impediments to an across the board increase in nuclear power production.

VI. Obstacles to Nuclear Energy

With worldwide nuclear energy use on the increase especially in the developing world where security precautions are more lax, experts at the United Nations have cited three primary growing security threats related to this area. Among them, theft by terrorists of weapons-grade plutonium stripped out from radioactive waste during reprocessing; an attack on a nuclear installation or transport convoy; and, as suspected with Iran and North Korea, an attempt by countries developing a nuclear power sector to build weapons with the same technology. "If you have more nuclear material in the world, you have a higher proliferation risk—it's a truism," said Alan McDonald, a nuclear expert at the IEA (Bennhold 2004). Yet, with demand for electricity increasing across the globe, he added, nuclear energy remains important despite the risks. It has always been true that nuclear technology can be used to make weapons as well as electricity, and one of the main ways that it does this are through breeder reactors. So-called 'breeders' were invented in the 1970's to make reprocessing nuclear waste a 700 year problem instead of a million-year waste impasse. However, the process was found to be hazardous and was boycotted in the US for a number of base environmental and security concerns. Specifically, the processes involved taking the spent nuclear fuel of Uranium 238, a fissionable material with only roughly half of its energy production capacity spent, and through a refining process changing it in to Plutonium 239 (Brabsen 2005). This new material is then used to power a different type of reactor, thus creating a full-loop and eliminating the need to store nuclear waste. Of course, when commercial nuclear power plants are engineering large amounts of plutonium, there are nuclear weapon proliferation concerns that arise.

"Let us not forget that plutonium is the chief ingredient for basic nuclear weapons, and thus countries involved in making it in mass quantities could intentionally or inadvertently lead to the spread of this technology," said Brabsen (Brabsen, 2005). Perhaps the greatest worry circulating in national defense departments and the North Atlantic Treaty Organization (NATO) in Brussels is the development of nuclear weapons on the back of civilian energy programs. This dilemma goes to the heart of the Nuclear Nonproliferation Treaty (NPT), of which the International Atomic Energy Agency is the guardian. The Treaty on the Nonproliferation of Nuclear Weapons entered into force 35 years ago and has been successful at defying predictions that today there would be as many as 50 nuclear-weapon states in the world. With 188 countries signing up, it is the most universally supported international treaty in history. In addition to nuclear disarmament, the treaty also controls the proliferation of nuclear material and at the same time obliges nuclear powers to offer nuclear technology to other countries for electricity generation. Given the grave perils that nuclear proliferation poses for all states, the NPT has been a true cornerstone of global security (M2, 2005). On the contrary, as one senior diplomat at NATO put it: "You cannot artificially separate the civilian from the military aspect -- everyone here is aware of that. As such, you also cannot separate the debate on nuclear proliferation from the debate on alternative sources of energy," (Bennhold, 2004).

To exemplify the dangers involved in nuclear proliferation, China and Pakistan signed a joint contract to supply a reactor pressure vessel for the second phase of the Chashma Nuclear Power Station in Pakistan. China Nuclear Energy Industry Corporation Deputy General Manager Huang Guojun said Pakistan had pledged that technology would be used solely for peaceful purposes with no transferal to a third parties. Though, he also admitted that “It is difficult to ignore the fact that nuclear technology has benefits in addition to its primary function of electricity generation,” (Mihailescu, 2004). Thus, although there is a growing recognition as to the dangers of non-proliferation, there could also be a willingness on the part of several countries to fully exploit their burgeoning nuclear programs. Of course, in addition to non-proliferation concerns, with an increasing number of nuclear power plants in the world the problem of nuclear waste also takes on a new and pressing dimension.

Some 600,000 tons of depleted uranium sits outside in aging steel cylinders at the two inactive uranium enrichment plants at Oak Ridge, Tennessee, and Portsmouth, Ohio, and the still active plant at Paducah, Kentucky. Every year some 2,000 pounds of radioactive material is added to this total, most of which is dangerously radioactive radium-226 derived from spent fuel rods.[17] After flirting with breeder technology as a possible fix for the nation’s nuclear waste problem, the United States has since moved in the direction of a central repository for which an unexpended balance of nearly $12 billion has been allowed to pile up in the Nuclear Waste Fund (Gold, 2005). Short-term, long-term and transmutation are the three ways of dealing with various types of nuclear waste. After decades of debate, the long-term option has won out in the US but there is still no permanent designated storage site of spent fuel rods.

In order to understand the issue of nuclear waste storage, it is necessary to review the process itself. When the spent rods are removed from the reactor core, they are extremely hot and must be cooled down. Most nuclear power plants have a temporary storage pool next to the reactor where the spent rods are placed. The pool is not filled with ordinary water but with boric acid, which helps to absorb some of the radiation given off by the radioactive nuclei inside the spent rods (Gold, 2005). The low-level (not extremely radioactive) waste can often be buried near the surface of the earth. It is not very dangerous and usually will have lost most of its radioactivity in a few hundred years. The high-level waste, comprised mostly of spent fuel rods, is harder to dispose of though. The most promising option for getting rid of this waste is burying it deep in the ground or ideally a mountain, a process called “deep geological disposal,” (Gold, 2005). Nevada’s Yucca Mountain was chosen for this purpose.

Yucca Mountain is located in a remote desert on federally protected land within the secure boundaries of the Nevada Test Site in Nye County, Nevada and is approximately 100 miles northwest of Las Vegas. This area is still actively used by the US military and has had more than 100 nuclear bombs detonated on site over the past 50 years. Six billion dollars have been spent on scientific studies in order to ensure that Yucca Mountain is an appropriate site to store the nation’s nuclear waste. If built, the casks holding spent fuel rods will be buried about 1,500 feet underground, further preventing the waste from escaping, and will be surrounded by lead and other elaborate safeguards (Gold, 2005).

The Yucca Mountain Nuclear Waste Depository Bill, the first of its kind in the world, is currently stalled in Congress after a veto by President Bush. In order to overcome the Congressional stalemate, a dramatic reconciliation between Washington and the state of Nevada (which has long opposed the project) is needed. The goal should arguably be a greater spirit of trust, an end to the lawsuits, substantial direct and collateral economic benefits for Nevada, and a stronger influence for the state in the Yucca Mountain project (Gold, 2005). The ultimate fate though of Yucca Mountain and the US nuclear waste problem remains to be decided.

Unlike the United States, other nations have chosen to move forward with breeder reactors (most notably the United Kingdom and France) to lower costs and eliminate nuclear waste. It is unclear at this time what direction the developing world will pursue, though given the mammoth costs of long-term repositories versus the economic benefits of using breeders the scale could be tipped in the latter direction. If so, this would have important security and environmental implications for not only those specific countries but the world over.

VII. Energy Policy of Developing Countries

The developing world's share of the global demand for energy will rise from 30 percent in 2003 to an estimated 43 percent by 2030 (Ho, 2004).[18] Amid rising oil prices in these rapidly industrializing countries, nuclear power has become increasingly popular. Armenia has one working reactor; Bulgaria has two; Ukraine three, and Romania one. One nuclear power plant is under construction in Iran and three more are planned. A total of 27 nuclear power plants are under construction in developing countries. China alone plans to add 32 nuclear power plants to its existing 11 by 2020, while India with 14 plants in operation aims to triple its reactor capacity over the next eight years (Bennhold, 2004). These figures point to the fact that, though certainly not speaking with one voice or with an aligned energy policy agenda, the developing world has seen the potential of nuclear power and is seeking to capitalize on the opportunities that it affords. To examine the current energy landscape in the developing world, the situation in China will be explored given the fact that it is the largest player in this area and could act as a leader of the developing world in this area.

As of late 2004 the energy sector in China came under the direction of an Energy Bureau under the ministry-level National Development and Reform Commission (NDRC). Made up of only a dozen staff members, the body has recently been criticized as too weak to oversee an energy industry that now has total assets of more than 10 trillion yuan (1.2 trillion US dollars) (Ling, 2004). Coal mines and oil imports cannot keep up with the surging demand in China as the nation becomes the second- largest oil consumer in the world. This failure of traditional energy sources in China led the country to begin exploring the nuclear option in the 1980's. Equipment problems though have plagued Chinese nuclear power plants, which are primarily Russian-designed (Mihailescu, 2004). Despite this though, China plans to increase its generating capacity to 480 million kilowatts (kW) in 2005 alone from the current 400 million kW. This decision is primarily due to power shortages in a number of provinces that will continue without additional energy infrastructures. In fact, more than two-thirds of the country's territory has suffered frequent blackouts since March 2003 alone, a state of affairs that illustrates the need for a more effective Chinese long-term energy policy.[19] Attempting to confront these issues, the Chinese government is exploring other arrangements that will effectively manage its growing power generation capacity. Following its lead, the most populace democracy in the world, India, is also considering reorganizing its energy bureau while developing nations across the Earth grapple with the same questions evident in China today (Gold, 2005).

Developed nations have been quick to help China, some seeing the fast industrializing nation as an opportunity to help their own energy sector. In early 2005 French President Jacques Chirac traveled to China to lobby for contracts in the country's growing nuclear program modeled after the new French RDC design (Hicks, 2004). However, the nuclear power is not the only avenue that China is pursuing to quench its thirst. Coal has always been and continues to be abundant in China, and by far and away the country has been using this traditional form of power production to solve most of its energy woes. Problems arise though if China were to go increasingly move towards this cheaper option of electricity generation.

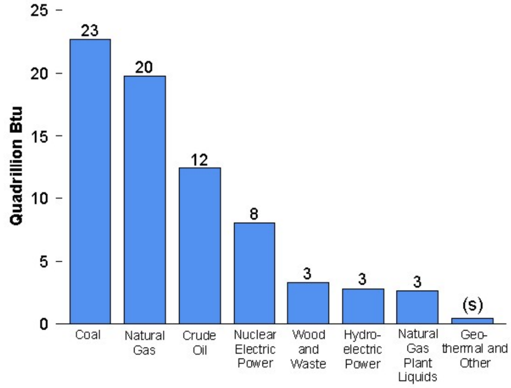
"Coal's abundance in the United States, and in major developing countries like China and India, makes finding clean ways to use it among our highest priorities," said former EPA Administrator Reilly (Prindle, 2004). To combat the environmental threat posed by burning coal without attempting to dictate to China and other developing nations what form their energy policy should take, the United States has begun to send advisors with expertise in new technologies that would limit the environmental effects of increased coal use to China and elsewhere. They attempt to offer evidence that techniques such as coal gasification that, when combined with carbon sequestration, "has the potential to revolutionize energy production around the world," (Prindle 2004). The US as well is approaching the coal conundrum of a large supply with an equally large environmental cost by investing $4 billion over 10 years in integrated gasification combined cycle (IGCC) coal technology.

Ultimately coal and even nuclear power are non-renewable, short-term solutions to the world's energy problems. Although so far taking up only a miniscule amount of total energy output, scientists agree that sustainable energies must makeup a larger proportion of the energy pie if ecological and economic calamities are to be avoided. Though everything from solar energy satellites to hydrogen fuel cell and even fusion could be on the horizon, only a few alternative energy sources are developed to an extent to offer a safe, reusable and economical solution to the energy policy paradox.

VIII. Renewables and the Future World Energy Infrastructure

Carbon dioxide levels are now at their highest point in 160,000 years, and average global temperature is at its greatest since the Middle Ages.[20] Experts believe that human activities could be ending the period of relative climactic stability that has endured for 10,000 years and permitted the rise of civilization (Flavin, 1998). According to the World Energy Outlook 2004 from the International Energy Agency, with oil prices at record highs, governments must accelerate technological innovations "that radically alter how we produce and use energy" to create an energy system that is sustainable economically, socially and environmentally (Mieszkowski, 2004). Since 2000, the use of renewable energy sources worldwide has grown by 1.7 percent per year (Trends to 2030, 2004). According to scientists, policies must be enacted to boost this relatively stagnant growth to lessen the likelihood of a long-term change in climate.

Chart 1.3: U.S. Energy Use by Source



*Source: *U.S. Department of Energy website*

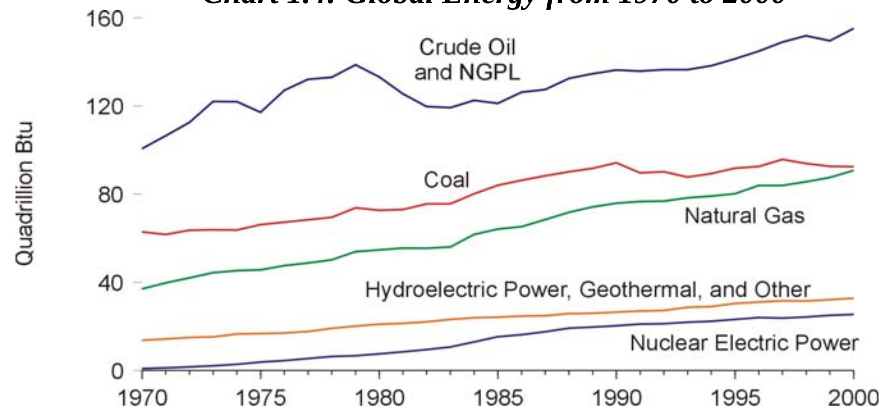
By the middle of the 21st century, advocates maintain that renewable sources of energy could account for three-fifths of the world's electricity if certain incentives are given for their development and use (Prindle 2004). If this were the case, then by 2050 global carbon dioxide emissions would be reduced to 75 percent of their 1985 levels. Advantages of alternative energies include: social and economic development, land restoration, reduced air pollution, abatement of global warming, fuel supply diversity, and reducing the risks of nuclear weapons proliferation (Burnham, 1993). "In order to prevent global climate change, a 50 percent reduction in current greenhouse gas emissions is required in the next 20 years…to achieve this, a mixture of solar, wind, biomass, and nuclear power will need to be employed" said energy physicist Ben Brabsen (Brabsen, 2005). However, a worldwide transition to alternative forms of energy is unlikely to take place in the foreseeable future given current market conditions such as the fact that individual firms cannot currently capitalize on investments in alternative fuels. Moreover, even if all fossil fuels were replaced by clean alternatives today, changing the composition of the atmosphere is a gradual thing taking centuries. This is demonstrated by the fact that even though the industrial revolution is centuries old, 16 of the 17 hottest years on record have occurred since 1980 (Burnham 1993, 12). Thus, a long-term environmental fix will require a long-term approach to energy policy.

Although the energy situation is grave and pressing, there is cause for hope. Currently, China is decreasing the amount of CO_2 that it produces annually while worldwide CO_2 emissions are increasing by a historically moderate 1.4 percent per year. Since the Russian Parliament's ratification of the Kyoto Protocol, this treaty along with a potential international emissions trading scheme offer the best opportunities for reducing global output of CO_2. Though both are imperfect schemes, they are a start that may provide some footing down the slipper slope of a global environmental debacle. Such a dramatic change in the energy landscape is not without historical parallel. A century ago, for example, biomass fuel accounted for over 90 percent of US energy output. As of 1979 though, energy consumption from other sources had grown so much that biomass totaled only 2 percent," (Aubrecht, 1995,). A similar transition can be made again with equally striking effects if government, the private sector and the international community work together to craft economic, environmentally sustainable energy policies.

IX. Conclusion

Significant impediments and advantages are inherent in the nuclear power industry and are not unique to either the United States or the European Union. It has been shown that France has and will continue to approach the question of energy policy in a remarkably different fashion from its European neighbors. Long dependent on foreign sources of energy, it chose a unique path in the 1950's and is today in a position to capitalize on its established nuclear industry and move forward with research and development projects domestically as well as in developing markets, most notably China. The United States as well has been shown to have a new interest in the nuclear option with two thirds of adults now supporting it as an option for energy independence (Aubrecht, 1995). Though substantial questions remain, if the hurdles of nonproliferation, toxic waste and cost are dealt with, then nuclear power could have a bright future indeed in augmenting the world's energy sources.

Chart 1.4: Global Energy from 1970 to 2000



*Source: *Department of Energy Website*

"It is up to us, here and now, to decide in which direction the United States will move forward," said Professor Brabsen. "The energy infrastructure of 2050 will largely be decided in the next 10 years," (Brabsen, 2005). Fossil fuels, especially oil, coal and natural gas, will hold dominant positions in the energy landscape for the foreseeable future. No other technology has yet been able to match their affordability, abundance, and ability to work regardless of the geographic location. Still, supplies of these fuels are finite and with a volatile geopolitical environment, it has never been more expensive, in monetary and political terms, to be energy dependent on foreign nations. The environmental cost of these energy sources as well has been documented and will be a mounting problem.

Economic development could not proceed without energy; it is at the heart of mankind's industries and ambitions. This strategic industry was the first to be shared in Europe to dissuade future wars, since it is evident that countries that are mutually dependent on one another for their energy cannot easily turn against one another. Ultimately, the degree of economic and political interdependence seen in the European Union today could serve as a model for the rest of the world. An international organization that allows its member states to differ in long-term energy policies as long as it works to attain the same energy and environmental goals, such as France does within the EU, seems to be the idealized solution to the global energy problem. Though untenable in the short-term, eventually a regime similar in organization to the IAEA or another related institution could serve as a watch dog for not only nuclear power but for power plants the world over, helping to ensure security and long-term sustainability.

As the developing world increases its share of the world economy and total power output, these issues will become all the more prevalent. Energy policy can no longer be seen as the purview of sovereign actors acting in their own self-interest since the negative externalities of power production are increasingly felt across the globe. Even though no one knows for sure what the energy infrastructure of tomorrow will resemble, it seems a safe bet that nuclear power will have a growing stead, along with alternative energies and, of course, fossil fuels. Such a mixture of energy sources will make neither the climatologists nor the politicians entirely happy. It stands to reason though that the nation that can strike this delicate balance and which has the most effective long-term energy policy will be in far better economic straits than its neighbors: it will have harnessed the power of the atom, the wind, water and sun, be energy independent and secure in a prosperous future.

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XI. Endnotes

[1] Nearly 70 percent of oil found today is being left in the ground.
[2] Africa will increase by 2.1 percent, the Middle East by 1.6 percent, Latin America by 1.1 percent and Asia by .9 percent.
[3] Over the past 40 years “Electric power consumption in the US grew at a rate of 7 percent annually from 1961 to 1965, 5.6% from 1965 to 1969, and at 9.25% in 1970. The energy crises thereafter caused a falloff in consumption,” (Aubrecht 1995, 30).
[4] This dramatic switch was hastened the Royal Navy, at the behest of Winston Churchill in 1911, to change their fuel source from coal to oil so that they could attain a higher performance than the rival German navy
[5] The United States government has tax allotments for major oil producers in which they pay virtually no taxes
[6] The 19-million-acre refuge was set aside for protection by President Eisenhower in 1960, but Congress in 1980 said its 1.5 million acre coastal plain could be opened to oil development if Congress specifically authorizes it.
[7] Under the Commission’s plan the US government would also begin issuing permits for greenhouse gas (GHG) emissions based on a 2.4 percent per year reduction in the average GHG intensity of the economy (where intensity is measured in tons of emissions per dollar of GDP) by 2010.
[8] The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty on global warming. It also reaffirms sections of the UNFCCC. Countries which ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. A total of 141 countries have ratified the agreement. Notable exceptions include the United States and Australia.
[9] Scandinavia was also putting pressure on the rest of Europe to change its ways due to the acid rains that were destroying the Northern forests.
10 A typical nuclear reactor has a few main parts. Inside the “core” where the nuclear reactions take place are the fuel rods and assemblies, the control rods, the moderator, and the coolant. Outside the core are the turbines, the heat exchanger, and part of the cooling system.
[11] The oldest operating power plant in Spain, the Jose Cabrera power station in Almonacid de Zorita, will be shut down on April 30, 2006. In 1994, more than 170 cracks were detected in the cover of the reactor vessel; the cracks were only repaired in 1997. Dismantling the station is expected to start in 2008 and completed in 2014 at a projected cost of $165 million, according to Spain's National Radioactive Waste Company.
[12] On April 25, 1986, the worst known nuclear accident ever came to pass at the Ukrainian generating facility at Chernobyl. A fire combined with a core breached spread radioactive material locally as well as across Europe.
[13] “In making a decision about which type of generating facility to build, a utility must consider several factors: (1) it must assure that sufficient water is available for cooling; (2) it must decide

how much of the facility should be prefabricated as opposed to constructed onsite; (3) it must consider the effect of building a facility on the social structure of the community servicing it; and (4) it must deal with any emissions of pollutants into the atmosphere and water.," (Aubrecht 1995, 159).

[14] The EPR design, conceived over ten years by Siemens of Germany and the French company Areva, is intended to provide electricity more efficiently and more safely than the second generation plants in use today.

[15] ITER was conceived in the 1980s as a cooperation project for civilian use of nuclear energy, with the participation of the European Union, China, Japan, South Korea, the former Soviet Union and the United States.

[16] The bid from the research station at Cadarache in southern France faces stiff opposition from Japan (Godoy 2005).

[17] Spent fuel rods from a nuclear reactor are the most radioactive of all nuclear wastes (giving off 99 percent of the total radiation) and come from power plants as well as nuclear missiles.

[18] The increasing living standards and concentration of population in urban areas will mean that biomass fuels will not be able to support economic growth in developing countries, similar to what happened in the United States in the early 20th century.

[19] Russian Federal Atomic Energy Agency Head Alexander Rumyantsev said that glitches arose in one reactor's equipment but hopes to eliminate those glitches within the next two months (Ling 2004).