French Nuclear Energy and Its Environmental Impact

By Maia Dimitrova

THIS article will study some essential aspects of nuclear energy in France and challenge the notion that nuclear energy is a fully carbon-dioxide-free, radioactively safe, energy source. Currently, 79 percent of France's electricity is derived from nuclear energy.[1] France has 58 active nuclear plants that produced 450 billion nuclear kilowatt-hours in 2006. The country is the world's largest net exporter of electricity, as it generates an excessive amount at a very low cost. We will look at the political, social, economic, and environmental considerations that placed France ahead of most of the developed world in the arena of nuclear energy. Despite the fact that France is a nuclear energy leader, the serious issue of completely safe disposal of nuclear waste has not been resolved. While France is considered a country with lower CO_2 emissions, and may emit less carbon than the countries dependent on fossil fuels, nuclear energy is not free of greenhouse gasses (GHG), as many nuclear energy proponents portray. Yet compared with the size of its economy and GDP, France is a nominal CO_2 emitter. Clearly, the reduced level of CO_2 is attributable to its dependence on nuclear energy.

The topic of nuclear energy is a controversial one. Many countries have shied away from replacing coal and natural gas with nuclear energy. In spite of the successful French example, nuclear energy does not resonate well in Germany, Austria, Sweden, the US, etc. Nevertheless, France's example is interesting. The country lacked enough domestic energy resources and would have been destined to depend on importing its energy needs, had it not been for its reliance on nuclear energy. By combining political will and determination with public education, an effective advertising campaign, and highly skilled human capital, France managed to escape a precarious situation of being overly energy dependent on CO_2 pollution-emitting processes, and transformed itself into a relatively clean energy exporter.

The Development of Nuclear Energy

Although it had been on the state agenda since the 1950s, nuclear energy was relatively unpopular in France until 1973. It was the trauma of the oil shock in 1973 that compelled the French government to look for alternative energy sources. At that time, most of the electricity in France came from plants that burned oil, and the oil was imported mostly from the Middle East. France has not been graced with an abundant natural resource base. It does not have oil or gas on which to fall back and its coal fields are already exhausted. The only way to maintain a reliable and sustainable source of energy was by launching a large-scale nuclear energy program. It was this recourse that forged a national consensus among major political parties towards the need to maintain a powerful, nuclear industry which still exists today.

During the course of the next 15 years, France introduced 56 nuclear reactors and managed to transform itself from a net importer to a net exporter of electricity.[2] And yet, well before the Chernobyl disaster, nuclear power as a source of energy for peaceful purposes had powerful foes in France. In the 1970s and 1980s, Green activists protested nuclear power as a source of national energy, culminating with the dramatic protests opposing the building of Superphénix, a nuclear power station. Nonetheless, a majority of the French are now comfortable with the nation's reliance on nuclear plants for most of its energy needs. Indeed, 70 percent of the French approve of the nation's incorporation of nuclear power into its energy portfolio.[3] Energy experts opine that the country's comfort with nuclear energy comes from French mentality and culture. Since the French prefer to be fiercely independent, they were publicly given a choice between dependency on unstable, unfriendly foreign sources and independent, reliable, nuclear energy. The argument for a nearly inexhaustible domestic source of power was made especially compelling by policymakers, who claimed that nuclear energy could be hazardous only in rare occasions. France holds its researchers and engineers in high esteem. They are considered to be part of an unusual elite whom the French not only appreciate, but trust. So it was easy for the population to be persuaded of the merits of nuclear energy. However, French policymakers hardly ever emphasized the dark side of this energy panacea: the fact that it uses uranium, a non-renewable resource, and that the country has still to resolve its nuclear waste disposal challenges. Also, very little acknowledgement has been given to the fact that nuclear energy is not completely CO_2 free.

The Advantages of Nuclear Energy

Extensive reliance on nuclear power has some advantages. Here are some:

1) Relative energy independence: Having an extensive nuclear energy network secures relative independence for France, which lacks natural resources of its own. Since 2003, France has not had any uranium production; its nuclear energy depends entirely on imports. However, dependency on supplier nations is not considered a risk since supplies are not in the hands of foreign hostile regimes.

2) Nuclear energy is regarded as clean energy. Compared to coal, petroleum and natural gas, it emits much lower levels of CO_2. Since nuclear plants generate energy through the fission of uranium, their emissions of nitrogen oxides (NOx), sulfur oxides (SO_2), dust, or greenhouse gases (such as carbon dioxide) are negligible compared to the fossil-burning methods of energy production. In a span of only 6 years from 1980 to 1986, France was able to reduce its SO_2 emissions by 56 percent and NOx by 9 percent. There is little doubt that nuclear power generation is a relatively clean process, especially when compared to electricity produced by coal. Coal plants emit dangerous levels of toxic, heavy, carcinogenic metals such as arsenic, cadmium, lead, and mercury, as well as CO_2, SO_2, and NOx. Finally, coal as a source of energy has increased the level of CO_2 in the Earth's atmosphere, contributing to the greenhouse effect of global warming. Comparatively, France's output of CO_2 emissions has dropped by 80-90 percent.[4]

3) The technology for building nuclear plants is widely available and consequently does not need to be developed. Also, because of the vastness of its nuclear energy sector, France is one of the biggest exporters of nuclear reactors and nuclear technology, which bring additional export revenue.

4) Nuclear plants are much more energy efficient than coal plants. One nuclear plant can generate electricity for an entire region, which can only otherwise be achieved by numerous coal plants. Indeed, 79 percent of electricity in France is generated by 58 nuclear plants.

Drawbacks of Nuclear Energy

France started its nuclear program under French President General de Gaulle in the 1950s. At that time, the country's leadership was more concerned with energy independence than with the portent of nuclear waste. However, in the 1960s and 1970s, the state and the French energy industry had to heed the urgency to deal with nuclear waste in the least harmful manner. "The 58 nuclear reactors in France generate 1 kilogram of radioactive waste per inhabitant per year (about 65 tons), about 900 grams of which are short-lived, low-active or medium-active waste, 90 grams are long-lived medium-active waste, and 10 grams are high-active waste. Ninety-six percent of radioactivity is contained in less than one percent of waste."[5] Nuclear waste management is now considered a topic of national security, and thus, not all information is readily available. The agencies in charge of nuclear waste management are all state organizations, which has led many environmental activists to accuse the French authorities of inordinate secrecy. Agence nationale pour la gestion des déchets radioactifs (ANDRA) manages nuclear waste and its scope of activities includes:

Low-Level Radioactive Waste Management: Low-level nuclear waste's radioactivity reaches non-hazardous levels in less than 300 years. There are two facilities where the low-level radioactive waste is stored: Centre de la Manche and Centre de l'Aube. La Manche is an old facility that has reached its operational limit and has not accepted any waste since 1994. The L'Aube site, opened in 1992, is expected to operate until 2035. Both sites are not considered to be very deep in the ground.

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High-Level Radioactive Waste Management: Waste which requires more than 300 years to reduce its radioactivity to non-dangerous levels is designated as high-level radioactive waste (HLW). HLW is retained at each plant for one year. After that, it is transported to La Hague and Marcoule and stored there for two to three years.

Reprocessing spent nuclear fuel: Along with reprocessing its waste, France recycles fuel from Belgium, Germany, the Netherlands, Switzerland, and Japan. The remaining waste, after recycling, is HLW. It is hardened and kept for decades at the La Hague site. Eventually, the hardened waste will be buried deep in the ground.

Transporting radioactive waste: France has over 30 years of experience transporting radioactive waste.

For long distance transport, the waste is transported by rail in special rail wagons. Trucks are used for shorter distances. If there is an intercoastal connection, five specially designed ships are used to transport the waste. The used fuel's final destination is the waste radioactive depot – La Hague.

Deep geologic disposal plans

A site in Bure, Meuse, in the region of Champagne, has been selected as a deep geological repository for the high-level radioactive waste. The site is expected to be ready by 2025. The storage's depth will be 500 meters beneath ground level. Currently, disposal in natural clay and granite formations are being considered. French officials go to great lengths to project the impression that the disposal of waste management is under control, and the skillful handling of waste by nuclear disposal experts does not pose any threat to the environment. However, many disagree with this reassuring image. Almost all matters concerning nuclear energy and especially radioactive waste are treated as classified in France.

Greenpeace reports that Russia is a recipient of tens of tons of nuclear waste every year. For instance, each year the French nuclear plant Eurodif, located 700 km south of Paris, sends about 4,000 to 5,000 tons of its waste to Russia. Greenpeace critics claim the waste travels without the necessary safety measures in place via several Western European countries, and that it passes through cities in Russia such as St. Petersburg and Tomsk with only sporadic supervision. They assert that the used fuel is enriched in Russia, and only a fraction of it is returned back to France. The rest remains stored in Siberia in unsafe and unsecure conditions. Greenpeace says that France has over 1,000 temporary nuclear waste sites, some of which are not protected. As its nuclear energy network grows, so does the amount of nuclear waste it produces. It is estimated that each year, radioactive waste increases by 1,200 tons.

These opponents of nuclear energy, such as Greenpeace, accuse the nuclear reprocessing industry of storing nuclear waste in unsafe conditions. Once the used fuel is disposed of, there is no way to retrieve it from the contaminated site. The impact of the waste is not yet fully known. However, one thing is certain: with our current level of scientific knowledge, the environmental damage resulting from modern disposal methods will be felt by this generation and passed onto future ones. Both low- and high-level radiation sites have been leaking radioactive elements into underground water. The Centre de la Manche, one of the largest nuclear waste sites in the world, which has been closed since 1994, still has a high level of contamination. The water from La Manche seeps into the underground aquifer, from where it flows to the rivers and wells. There are concerns by the farmers who use this water to feed cattle. The level of radioactivity in the area is 750 Becquerels per liter of water, which is seven times higher than European safety requirements. The contaminated water may contain plutonium and strontium, which can cause cancer and genetic defects.

In addition, tritium has been found in the aquifer near the Centre de l'Aube, which opened in 1994. Since the plant does not have a license to release any of its radioactive elements, radioactive alpha-emitters have been detected in the area. They remain radioactive for thousands of years and are linked to lung and bladder cancer. The Centre de l'Aube is designed to store low-radiation waste, whose radiation lasts for less than 300 years. It is not equipped to handle high-radiation waste. Ominously, the Centre de l'Aube is located in Champagne, famous for its production of sparkling wine. If the water is contaminated, as Greenpeace claims, its effects will be felt for decades, and possibly for centuries. If this is not bad enough, France's nuclear authorities are compounding the problem with nuclear pollution in the area by reprocessing the waste for other countries. In fact, ten percent of the reprocessed waste comes from Areva/Cogema and its foreign clients from Germany, Belgium, Holland, Japan, and Australia. And since French law does not allow discharging of foreign nuclear waste in France, it is clear that Areva/Cogema[6] are responsible for the region's increasing contamination.

If the plan to open a deep geological repository in Bure, Champagne materializes, a huge quantity of radioactive waste will be deposited for an undetermined period of time. The problem with such a depository is that radioactive pollution might remain active for hundreds or even thousands of years. Although its building has been carefully planned and supervised, there is no guarantee that tectonic changes will not disrupt the depository and release radioactive pollution into the area. Climate change's effects on the site might cause damage and leak radioactive waste into underground waters. However, strong opposition from residents, such as the famers from Rhone Valley (another strong wine producing region) has prompted cancellation of a second high level waste depository.

Proponents of nuclear energy praise it as the least expensive of all energy generation options. However, this does not take into consideration the costs for disposal of the waste. Invariably, when these costs have been called into question, the figures have been

underestimated. For instance, in 1996, ANDRA projected that the cost for a deep geological repository would be 14 billion euros. In 2003, it revised its budget based on estimates that it would cost between 16 and 58 billion euros. Since the EDF, which generates and distributes the electricity nationwide, is a limited-liability company, the costs for a repository are passed on to its customers. Operating and maintaining the repository depends on the financial health of EDF. If at some point EDF's financial stability is compromised, it will be up to the state to take over the security of the depositary and eventually the cost for running it.[7]

Is Nuclear Energy CO_2 free?

Since precise data on France's nuclear plant emissions of CO_2 is not available, we'll use data of CO_2 emissions garnered from research of nuclear power plants in different parts of the world. This will be the basis for our conclusions regarding France's CO_2 emissions.

As previously noted, many proponents would like to promote nuclear energy as CO_2 free. However, examining the life cycle of a nuclear power plant from the first phase of uranium mining to its final, permanent nuclear waste storage clearly shows that nuclear energy generation does produce carbon. While nuclear power itself does not emit CO_2, there are numerous externalities which contribute to GHG (greenhouse gas) emissions. Since these externalities vary, there is no agreement in the scientific community over how much CO_2 one nuclear plant emits. There is, however, a consensus that on the low end of the scale, it contributes 1.4g CO_2 e/kWh and on the high end of the scale it emits 288g CO_2 e/ kWh. There is a semi-consensus that on average, a nuclear plant emits around 66g CO2 e/ kWh.[8]

The emissions start with the mining of uranium. Depending on the quality of the uranium ore, emissions from mining and milling lie between 0.4g CO2 e/kWh and 67g CO_2 e/kWh. Different mining techniques will release different amounts of CO_2. The energy used to extract the metal also plays into how much a plant emits. Using energy efficient mining techniques will produce less CO_2 emissions. Conversely, mining in remote areas using diesel powered generators for mining energy will increase CO_2 emissions.

CO_2 emission during the uranium enrichment phase varies according to the technology being used. A gaseous diffusion approach requires much more energy, especially if powered by a fossil fuel generator, which can give off as much as 80g CO2 e/kWh. Enrichment by centrifuge brings the CO_2 emissions down to 9g CO_2 e/kWh. France uses gaseous diffusion processes[9] [10], and thus, this cycle emits more CO_2.

Even boiling water in the nuclear reactors is a source of GHG. There is no agreement as to how much these emissions amount to, but some scientists see them in the range of 5-12g CO_2 e/kWh. Others claim that they are ten times higher. There are more than 30 different reactor designs, and each of them has a different fuel cycle, level of efficiency, and cooling procedure. On average, the amount of CO_2 from a commercial reactor is 66g CO_2 e/kWh. At this time, the reactors considered the most efficient are the CANDU reactors, produced in Canada. Their level of greenhouse emissions is a quarter of the commonly used medium – 15g CO2 e/kWh.

The construction of the plant is another factor in the CO_2 emission bouquet. It may vary according to building techniques; materials, which are often imported (copper, concrete, steel); transportation; the energy supplied from the local companies (renewable or fossil fuel); and commute to and from the construction site for laborers and experts who do not live in the area. A plant built in Canada using a CANDU reactor with highly energy efficient technology, domestic uranium, and located close to the construction site would, at minimum, emit 15g CO_2 e/kWh. On the other hand, a plant built in a developing country that uses imported uranium, low energy efficiency, workers that need to be brought in from elsewhere, and lacks advanced technologies or skilled labor can raise CO_2 emissions to 80g e/kWh.[11]

During the operational cycle, which is usually 30 to 40 years, the amount of GHG depends on the load factor. On average, the CO_2 emissions during this phase stay at 11.58g CO_2 e/kWh.[12]

At the back end of the plant's life cycle, which includes fuel processing, temporary and permanent storage, and transportation to the sites, the amount of CO_2 is 9.2g CO_2 e/kWh.[13]

The decommissioning of the reactor can last as long as 60 years; hence, the energy required to complete this cycle can be quite substantial. Studies attribute from 12.01g CO_2 e/kWh to as much as 49.1g CO_2 e/kWh to this final phase of a plant's cycle.[14] Nuclear energy is not carbon free. Yes, it emits much less CO_2 than coal, oil, diesel, fuel cell, and natural gas. However, can it truly be called "clean energy"? It contributes to the greenhouse effect and also leaves radioactive waste with dangerous consequences that are not yet fully understood.

While the data may vary slightly, there is no doubt that France's nuclear-produced energy is no less carbon free than in other parts of the world where the study was conducted. France imports the required uranium and the mining and milling take place outside its borders. Yet, the remaining parts of the life cycle – conversion, enrichment, fabrication, reprocessing and recycling of nuclear materials – are all taking place in France.[15][16] And since France is the recipient of the uranium, the CO_2 emissions should go on its account even as it fails to use the most efficient nuclear reactors. French nuclear reactor emissions are higher than those utilizing a CANDU reactor, and there are currently no plants in France that use them. The country has a highly skilled non-commuting labor force that helps lower CO_2 emissions. If we use the above data, we can conclude that France's CO_2 emissions are in the range of 100-140g CO_2 e/kWh. The exact emission depends on the method used to mine the uranium, the type of reactor used, and the plant's proximity to waste storage site.

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Conclusion

We took France as a case study for the nuclear energy industry because it is considered to be at the forefront of nuclear energy technology. Seventy-nine percent of the electricity in France comes from nuclear plants. France's love affair with nuclear energy began in 1950s but went into full swing only after the country's sense of security was shaken by the shocks of the first OPEC oil crisis. France was not endowed with a bountiful, rich natural resource base, and so it sought to cut its dependence on foreign energy supplies. Above all, what spurred its headlong jump into building a vast network of nuclear plants was the drive to secure France's energy independence. The second reason France took the nuclear route for its energy needs was environmental concerns. Many place nuclear energy in the camp of GHG-free energy sources. There is almost a knee-jerk response to nuclear energy proponents' claims that nuclear energy is less harmful than coal, natural gas, or oil. Yet as we have seen, while the process of generating nuclear energy is CO_2 free, the life cycle of the nuclear process still contributes CO_2 emissions. The more pressing issue, however, is how to effectively and safely dispose of nuclear waste so that future generations do not pay a terrible price for the possible disposal mistakes which may have already been committed and are beyond recall. Nuclear technology is constantly evolving and there is always the possibility that uranium might one day be replaced by a less lethal fuel. Scientists may find a way to dispose of nuclear waste in a safe way with no dangerous consequences to humans, animals, or the environment. Nevertheless, until we reach that point, nuclear waste's toxic effects threaten to contaminate water and land with far-reaching effects that may last for generations to come. Brisk and crisp champagne will continue to be poured into our glasses and French cheese will be served on ornate trays while the majority of us remain unaware that they could be blended with particles of nuclear waste coming from the radioactively polluted areas of Champagne and Normandy.

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1 The nuclear reactors are operated by Electricite de France (EDF). They have a total capacity of about 63 GWe, supplying annually approximately 430 billion kWh of electricity. France's total generating capacity is 116 GWe, of which 63 GWe is nuclear, 25 GWe is hydro and 26 GWe is fossil fuel.

2 Currently, France imports less than 50% of its energy resources.

3 Joe Palfreman, "Why the French like nuclear energy." <http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/french.html> (March 31, 2009)

4 Ilan Lipper & Jon Stone, "Nuclear Energy &Society," at http://www.umich.edu/~gs265/society/nuclear.htm (March 26, 2009).

5 French Ministry of Foreign and European Affairs, 2007, "La France a la loupe" (March 31, 2009) at http://ambafrance-us.org/IMG/pdf/nuclear_power.pdf

6 AREVA is state-owned. The French state owns 90 percent of AREVA.

[7] As of 2004, EDF is a private company; however, through complex stocks, the French government retains almost 85 percent share in it.

[8] Bejamin Savacool," Valuing the greenhouse gas emissions from nuclear power : A critical survey:," *Science Direct* (June 2, 2008) at http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf, pp. 29-49.

[9] The Encyclopedia of Earth, "Uranium enrichment" (April 1, 2009) at http://www.eoearth.org/article/Uranium_enrichment#Gaseous_diffusion_process

[10] France is developing third-generation EPR reactor with high environmental standards, which is expected to be in operation by 2012. The country is also researching a forth generation reactors, which may not come in line until 2040.

[11] Bejamin Savacool," Valuing the greenhouse gas emissions from nuclear power : A critical survey," *Science Direct* (June 2, 2008) at http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf,
p. 2,950 (March 28, 2009)

[12] Ibid. p. 2,949

[13] Idem.

[14] Idem.

[15] French Ministry of Foreign and European Affairs, 2007, "La France a la loupe," (March 31, 2009) at http://ambafrance-us.org/IMG/pdf/nuclear_power.pdf

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