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THE FRENCH NUCLEAR ENERGY EXPERIENCE: LESSONS FOR INDIA

Manpreet SETHI

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SUMMARY

In September 2008, the Nuclear Suppliers Group (NSG) granted a waiver to India for allowing nuclear commerce with the country without its having to accept full-scope safeguards on its nuclear programme. In October 2008, President Obama signed the 123 agreement. A few months later, India and the IAEA concluded the India Specific Safeguards Agreement (ISSA). With the conclusion of these three steps, India became an equal opportunity partner in international nuclear commerce after suffering from a long period of technology denial regimes.

Over the last two years, since the opening up of the opportunity, India has reached out to many countries for nuclear fuel and reactors. Amongst these, France stands out for several reasons. For one, France is today a nation that is generating a large share of its electricity from nuclear reactors, having embarked on an ambitious nuclear power programme after the oil crisis in the early 1970s in order to substantially reduce its dependence on imported energy sources. Nearly 80 per cent of French electricity needs are presently being met from nuclear power plants. Secondly, France is an active exporter of all nuclear activities and materials and has a lot to offer to an India that strives to put its nuclear energy generation on the fast track. Thirdly, India has a long-standing and largely cordial nuclear relationship with France.

The French tryst with nuclear energy holds several relevant lessons for India. The trigger for their nuclear programme, the manner in which it was pursued, the policy initiatives that made the rapid establishment possible, the kind of a role that the government played in the process, the nature of public-private relationship etc. are some of the questions that are of great relevance to India. This study seeks to derive lessons from the French nuclear energy experience that can be used to guide the Indian programme as it steps on the pedal to fast track nuclear expansion.

Keywords: Nuclear energy programme, India, France, nuclear cooperation, PHWR, FBR, nuclear waste management

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INTRODUCTION

On 18 July 2005, when Prime Minister Manmohan Singh and President George W Bush issued a joint statement envisaging the possibility of Indo-US civilian nuclear cooperation as part of a multifaceted relationship encompassing issues as diverse as terrorism, science and technology, agriculture, infrastructure, health, commerce, energy and defence, not many were convinced of the feasibility of anything worthwhile coming about in the nuclear sector. After all, India and the USA had experienced a long period of nuclear estrangement during which the US had viewed a nuclear weapons capable India as an outcast to be chastised for "illegal" possession of this WMD. New Delhi was advised, repeatedly during the Clinton years to "cap, roll back, and eliminate its nuclear weapons programme". It was also kept outside the system of regulated nuclear commerce unless it agreed to accept full scope safeguards on its nuclear facilities and joined the nuclear non-proliferation treaty (NPT) as a non-nuclear weapon state (NNWS). The US, in fact, put in place a complex network of domestic legislation and international denial regimes that did not allow any scope for a meaningful nuclear engagement with India.

Meanwhile, India maintained an intransigent position, refusing to place its largely indigenously developed nuclear programme under IAEA supervision. Nor did it agree to join the NPT as a NNWS because of its security perceptions. It may be recalled that China had been a declared NWS from 1964 onwards and Pakistan was widely known to have a nuclear weapons capability from 1987. Of course, Pakistan did not test on its own territory until India's nuclear tests, though China did allow Pakistani scientists to be present at its test site in Lop Nor during one of its tests in 1983 and then conducted a nuclear test for Islamabad in 1990.[1] The Indian

[1] Thomas C Reed and Danny B Stillman, *The Nuclear Express: A Political History of the Bomb and its Proliferation* (Minneapolis: Zenith Press, 2009), pp. 375-76.

tests in May 1998 were to address these threat perceptions to its security from a long-nuclearized neighbourhood and these brought the Pakistani capability into the open.

Expectedly, a round of recriminations and criticism of the Indian act erupted around the globe. Eventually though, a dialogue also started between New Delhi and Washington. Bilateral relations gradually thawed over a period of nearly half a decade and change of administration on both sides. Finally, in a sharp reversal of what had until then been the traditional US approach, in 2005, President Bush offered the promise of a constructive nuclear engagement with India. In this *volte-face* was implicit the acknowledgment of India as a rising economic power with substantial energy requirements and as a "responsible state with advanced nuclear technology". The Indian PM confirmed this in his statement before the Parliament on Civil Nuclear Energy Cooperation with the US: "The existence of our strategic programme is being acknowledged even while we are being invited to become a full partner in international civil nuclear energy cooperation."[2]

With a clear demonstration of will from the top leadership in both countries, a long and tortuous period of negotiations began. Given the rather unprecedented nature of the relationship envisaged, it was hardly surprising that the idea itself evoked much disquiet amongst the officialdom, strategic community, scientists, intelligentsia and the media in both countries and elsewhere. There were misgivings on the Indian side about how much India would end up conceding. In the US, fears were expressed at the Congressional hearings and by non-proliferation experts in scores of seminars and through writings that such a civilian nuclear cooperation agreement with India would be seen as rewarding a deviant state and that it would cause the collapse of the NPT. The US administration was advised to extract substantive and meaningful non-proliferation concessions from India in return for the US favour.

In India, meanwhile, debate raged on protecting the strategic programme. A list

[2] PM's statement in Parliament on 27 February 2006. Full text available in *The Hindu*, 28 February 2006.

separating the civilian and military nuclear facilities was drawn up in 2006. Over the next two years, umpteen meetings and negotiations tried to thrash out myriad politically sensitive and technically complex issues. Most details of these are well-known due to the intense media reportage. A number of books have also since been published documenting the many dimensions and implications of the agreement. It is not the purpose here to enumerate or examine these details, but to highlight the relevance of the cooperation agreement for the Indian nuclear energy programme.

In September 2008, the Nuclear Suppliers Group (NSG) granted a waiver to India for allowing nuclear commerce with the country without its having to accept full-scope safeguards on its nuclear programme. In October 2008, President Obama signed the 123 agreement. A few months later, India and the IAEA concluded the India Specific Safeguards Agreement (ISSA). With the successful conclusion of these three steps, India became an equal opportunity partner in international nuclear commerce. Having been a victim of technology denial regimes for over three decades, the landmark developments as a result of the personal push and initiatives of the US President and the Indian Prime Minister opened up new nuclear horizons for the country. India now had the opportunity to undertake as rapid an expansion of its nuclear power programme as its domestic procedures and processes could allow.

Over the last two years since the opening up of the opportunity, India has reached out to many countries for nuclear fuel and reactors. New Delhi has agreements with Russia, France, USA, UK, South Korea, Mongolia, Namibia, Kazakhstan and Niger. Amongst the countries with which India has forged a nuclear relationship, France stands out for several reasons. For one, France is today a nation that is generating a large share of its electricity from nuclear reactors. France undertook an ambitious nuclear power programme after the oil crisis in the early 1970s in order to substantially reduce its dependence on imported energy sources. Nearly 80 per cent of French electricity needs are presently being met from nuclear power plants. While there may be problems in the domestic programme, France is widely acknowledged as having “the most sophisticated and expansive nuclear energy program on the globe".[3] Secondly, France is an active exporter of all nuclear activities and materials and has a lot to offer an India that strives to put its nuclear energy generation on the fast track. Thirdly, India has a long-standing and largely cordial nuclear relationship with France. This contrasts, in the Indian mind, with the bitter experience with the US in the late 1970s, when the US had cut off supplies of enriched uranium for the Tarapur boiling water reactors, originally built with American help. France had then stepped in to help India by meeting the nuclear fuel requirements.

The French tryst with nuclear energy can provide certain relevant lessons for India. For instance, the fact that energy vulnerabilities adversely impact national security was a lesson that France learnt as a result of its experience with the oil crisis. This is relevant for India. But there are other lessons too that can be drawn from the manner in which France has pursued its nuclear programme. What policy initiatives made the rapid establishment of nuclear energy possible? What kind of a role did the government play in the process? What was the nature of public-private relationship? What was the technological trajectory adopted by France? What is the French perspective on nuclear safety and spent fuel management? These are some of the questions that are of great relevance to India at this juncture.

Of course, one cannot deny that there are stark contrasts in the political climate, geography, population size and also the technological level from where the two countries started their nuclear programmes. Of course, those differences have an impact on the pace and nature of the national nuclear programmes. It is not the purpose of this study to recommend modeling the Indian nuclear energy programme on the French one. Instead, it only seeks to derive lessons from the French nuclear energy experience that can be used to guide the Indian programme as it steps on the pedal to fast track nuclear expansion.

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[3] Rahul Sastry and Bennett Siegel, "The French Connection: Comparing French and American Civilian Nuclear Energy Programs", *Stanford Journal of International Relations*, vol. XI, no. 2, Spring 2010.

This monograph is divided into four chapters. The first chapter examines India's energy scenario to explain the role and relevance of nuclear energy for the country in the light of the domestic energy deficit. It also identifies the challenges that the programme must overcome in order to make the most of the current opening that the country has managed to get for itself. The second chapter explores the French tryst with nuclear energy and highlights the factors that made the rapid adoption of nuclear energy possible and the programme successful, besides also identifying some of the problem areas of the programme. Chapter 3 documents the Indo-French nuclear relationship. It explores the possibilities of bilateral nuclear commerce, which would benefit both sides. It also highlights possible areas of joint collaboration between France and India on nuclear research and development especially in terms of new fuel cycle technologies. Besides the scope for technological cooperation, the paper also suggests how the two nations share common concerns on the need for facilitating a responsible international nuclear renaissance so that the dangers of spread of nuclear materials and technology are minimized even as the benefits of peaceful uses of nuclear energy can be enjoyed. As repositories of advanced nuclear technologies and keen to exploit the revival of interest in nuclear energy, India and France share a common responsibility to promote the peaceful uses of nuclear energy in a sensible and sustainable manner. The last chapter identifies eleven specific lessons for India from the French nuclear energy experience.

This study, born out of a post-doctoral fellowship granted to me by the *Centre de Sciences Humaines* (CSH), New Delhi, would be of immense significance for India at this historical juncture when it is embarking on a rapid expansion of its nuclear energy generation. Inclusive and sustained economic growth and development are the twin aspirations of an emergent India. But, among other factors, future economic growth will depend on the long-term availability of energy, particularly electricity. For a country of India's size, population and economy, targeting ambitious growth rates of eight to ten per cent over the next two decades, safeguarding energy is a strategic priority. This will have to be available in increasing quantities and from sources that are stable, dependable, low-cost and low-carbon.

A global nuclear renaissance is well-timed with India's desire for nuclear expansion. Nuclear power, if developed in a planned, timely and safe manner can offer tremendous potential for a power hungry India. This study offers some pointers from the experience of a country that has managed to showcase a consistent and largely successful nuclear power programme. The challenges it has faced and the solutions it adopted provide a rich source of information and experience from where India can choose to derive what it considers relevant. To that extent, this study hopes to contribute to the country's efforts at addressing the challenge of energy security.

1 INDIA AND NUCLEAR ENERGY: THE PAST, PRESENT AND THE FUTURE

India is a severely energy deficient nation. There are rural areas in the country that are still resigned to darkness after sundown. Several urban areas, including metropolitan centres too, suffer from long and frequent power cuts. Agriculture and industry both suffer in the process and this has a direct and indirect impact not only on the national quality of life but also on the overall economic growth potential and the national development index.

In addressing the challenge of energy poverty, the government not only needs to look deep into the future to do a long cast of future national energy requirements but also do it over the entire range of available fuel sources. The advantages and limitations of the various energy resources whether available indigenously or imported from elsewhere must be well considered to arrive at an optimal mix. For instance, it would be counter-productive for the nation to solely invest in those energy sources which do not come with the assurance of secure and reliable supplies, or those that increase dependence on unstable supplier nations and thus raise national vulnerabilities, or those that result in large-scale environmental pollution, thereby adding to the need for greater government expenditure on health mitigation strategies.

Energy demands must be met through safe, reliable, secure and environmentally sustainable fuel sources. This calls for an intelligent diversification of energy sources. At the moment, India draws the bulk of its electricity from thermal sources, especially coal. Hydropower comes a distant second. Renewable sources provide the next small share of electricity. And finally nuclear reactors provide about 3 per cent of the total electricity generation. However, despite its rather meagre contribution at present, nuclear energy holds substantive promise for the future.

This article examines the role that nuclear power could play in providing India a level of energy security in an environmentally sustainable manner. It explores the advantages of investing in nuclear expansion, which is today possible with the conclusion of the Indo-US civilian nuclear cooperation agreement that has opened the prospects of India's participation in international nuclear commerce. It highlights the advantages – some of them unique to this country – of adopting nuclear power as a major input to the future energy mix. It also examines the challenges that lie ahead in the expansion of nuclear power.

While the primary focus of the paper is on nuclear energy, it nevertheless is premised in the belief that there is need for growth and development of *all* energy sources, existing and potential, to power India's socio-economic growth and development. The country's energy requirements are so huge that it just cannot afford the luxury of banking on only one or two fuel sources to power its future.

India's Energy Reality – Need for a Large Booster Dose

Among the challenges facing an emerging India, two could particularly derail the process of its rise, and they are interconnected. The first is widespread social disharmony as a result of skewed economic development and unfulfilled aspirations and expectations of a growing population that is also increasingly aware of its deprivation. The resulting discontentment coupled with the growth of sub-nationalism, opportunistically exploited by domestic vested interests or external adversaries could severely strain and damage the country's socio-politico-economic fabric. Hence, inclusive socio-economic and human development through a sustained level of high economic growth is critical to ensure societal peace and national security.

The second challenge arises from the sheer shortage of electricity that drives the modern economic processes and developmental endeavours so that the benefits of economic growth reach the largest possible numbers. It is widely accepted that electricity has a direct connection with the development and quality of life. Per capita energy consumption is a parameter for calculating the human development index. Therefore, it is hardly surprising that energy and the ability of a nation to access it from reliable, secure, sustainable and safe sources tops national priorities everywhere. Energy poverty is obviously a handicap that a nation that aspires for fast track development and growth can ill afford. This is even more important for a nation like India that expects a phenomenal growth in its energy demand, estimated to be between 6-10 per cent per annum during the first quarter of the 21st century. The Power Policy of India promises electricity availability to all by 2012.[4] This appears practically impossible given that the present total power generation of about 157 GW is woefully short of the demand that is growing by the day. In fact, India's power generation capacity was calculated to be 68 per cent below the target that had been set for 2009.[5] This obviously will result in a huge deficit in the availability of power. Per capita energy consumption in India at present is placed at 631 kilo watt hour (kWh) as compared to 17179 kWh in Canada, 13338 kWh in the US, 6800 kWh in France, 5664 in Italy and 1300 kWh in China.[6]

For this situation to substantially change, the absolute amount of electricity required by India would have to at least double by 2020, double again over the next ten years, and be close to ten times the present day figure by 2050. According to Dr Kakodkar, Chairman, Atomic Energy Commission, even if India's per capita energy consumption was to rise to 5000 kWh (which would still be three times less than the current consumption figures in the US), the country would suffer an energy deficit of 412 GW by 2050.[7] As is evident, the deficit itself is close to three times the current total power production!!

According to another estimate provided in 2006 by a government instituted Expert Committee on Energy, India's power needs would be about 960 GW by 2031-32, assuming a

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[4] MR Srinivasan, "The World's Energy Resources and Needs", *Nuclear India*, vol.39, no. 1-2, Jul-Aug 2005.
[5] "India's Power Generation Capacity 68% below Target in FY'09", livemint.com, 27 May 2009.
[6] International Energy Agency, *Key World Energy Statistics*, 2006.
[7] "Uranium Import can Stave Off Looming Energy Crisis: Kakodkar", *Hindu Business Line*, 05 July 2008.

GDP growth rate of 9 per cent.[8] Since then, the global financial crisis and the consequent economic downturn had brought down the expected rate of growth of the Indian economy to 7 per cent per annum. However, the Indian economy has defied the global slowdown to yet grow at over 8 per cent in 2009-10. At this average rate of growth, the vulnerabilities that would accompany large-scale energy import dependence are clearly evident. A stark contrast in this sector is evident when one compares the rapid strides that China is making. It is today the fastest growing electricity generator. New generation capacity that China will add to its existing capacity in 2010 alone will exceed the total installed capacity of Brazil, Italy and Britain, and these are nations with fairly large generation capacities themselves.[9]

It is therefore obvious that energy poverty alleviation has to remain a critical priority area for India if it is to realize its aspiration of emerging as a major power. Energy security through the expansion of generating capacity will not only improve quality of life of the Indians but also guarantee further growth and development. Secure and abundant availability of electricity to run modern economies makes a nation an attractive investment destination. In this regard, it would be useful to cite a statement made in the context of China, "Cheap, reliable electricity is one reason why China remains the *preferred destination* for manufacturing even as its wages rise above those in such countries as Bangladesh, Indonesia, the Philippines and Vietnam".[10]

The government of India, therefore, must urgently focus on building new generation capacities besides encouraging energy efficiency and conservation technology. Given the enormous energy demand of the country, it is imperative that a diverse mix of energy sources that pragmatically balance considerations of cost, uninterrupted availability of fuel and

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[8] Swaminathan Anklesaria Aiyar, "Nuclear Power Gives Energy Security", *Times of India*, 20 July 2008.

[9] "Lights and Action: Electricity and Development in China", article reproduced from the Economist (29 April 2010) in *Indian Express*, 05 May 2010. China is in fact slated to produce more power annually than America, the current leader, by 2012.

[10] *Ibid*. Emphasis added.

environmental impact is consciously developed through pragmatic policy formulation and priority allocation. Every potential source of energy needs to be tapped and optimally used. The menu of options should be as varied as possible so as to minimize risks of disruption arising from shortages, price fluctuations and political manipulation.

Nuclear Energy to Meet Environmental Concerns

If the growing Indian economy continues to rely on traditional thermal energy sources, carbon emissions would significantly rise and environmental consequences like greenhouse effect, global warming and climate change would progressively become graver concerns. Thermal power plants pose the problem of greenhouse gas (GHG) emissions that cannot be wished away despite technology improvements and implementation of stringent environmental measures. Pollution is sure to increase with an upsurge in energy production from thermal plants. The following table shows the CO_2 emissions from different energy sources in order to illustrate that coal, oil and gas remain major sources of carbon emissions, while nuclear and other renewable energy sources figure around the lowest.

Carbon Dioxide Emissions from Power Technologies in g/kWh[11]

Coal	Advanced Coal	Oil	Gas	Nuclear	Biomass	Hydro	Wind
960-1300	800-860	690-870	460-1230	9-100	37-166	2-410	11-75

[11] Rangan Bannerjee, "Assessment of Role of Renewable Energy Technologies", Greenhouse Gas Pollution Prevention Project - Climate Change Supplement, The Louis Berger Group Inc. Global Environment Team available at http://www.climatechangeindia.com/gep_ccs/.

As is evident, nuclear power emits the least amount of greenhouse gases. In fact, the complete nuclear power chain, from uranium mining to waste disposal, including reactor and facility construction, has been calculated to emit only 2–6 grams of carbon per kilowatt-hour. Given these figures, it is obvious that the strategies and technologies adopted by countries with large energy requirements will have critical implications for local and global environment. Illustratively, France that meets 42 per cent of its primary energy consumption from nuclear energy has the lowest per capita carbon dioxide emissions in Europe.

At present, India's per capita carbon emissions stand at 1-1.2 tons[12] compared to 20 tons per capita in the US.[13] This is not in the least due to exceptionally good energy policies and practices but due to the fact that a large proportion of the Indian population does not have access to power. This has to change, and will change, if India expects to grow and emerge as a power to reckon with globally. With continued urbanization, a shift from non-commercial to commercial fuels, increased use of motorized vehicles, and prolonged use of older and inefficient coal-fired power plants, India's emissions are expected to increase and nearly triple by 2030.[14] In fact, according to the US Department of Energy, between 2001 and 2025, India's carbon emissions will grow by 3 per cent annually, twice the predicted emissions growth in the US, making India the third largest air polluter after the US and China by 2015 itself.[15] If India is to avoid becoming the holder of this dubious record, then a conscious decision to switch to more environmentally sustainable energy technologies, such as nuclear power, and commit to its rapid growth are required to be adopted at the earliest.

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[12] Economic Survey of India, 2009-10.

[13] "How do we contribute individually to global warming", report available at http://www.thehcf.org/emaila5.html.

[14] Economic Survey, n. 34.

[15] Figures as cited by Condoleezza Rice, Remarks at the Senate Foreign Relations Committee on the US India Civil Nuclear Cooperation Initiative, 5 April 2006. Available at US State Department website.

Nuclear Energy in India's Energy Mix

Nuclear power today accounts for 15 per cent of global electricity generation[16] and the world now has more than half a century's or above 14,000 reactor years of experience in handling this technology. Consequently, the expertise and confidence in it has steadily grown. On the other hand, the occurrence of very high oil prices and growing environmental concerns over the last couple of decades have led to a reconsideration of safe and sustainable energy fuels. In this analysis, nuclear power has surfaced as a keen contender for large-scale energy generation. Consequently, even in the US, after a three-decade long hiatus in new nuclear construction (though upgrades of existing plants continued), there is a renewed emphasis on the role of nuclear power for energy security.[17] In fact, the former US administration of President Bush placed the imperative for nuclear energy as a national security concern. In February 2010, President Obama pledged more than $ 8 billion in conditional loan guarantees for the first American nuclear power plant to be built in three decades.[18] The US Nuclear Regulatory Commission (NRC) today has license applications for 20 new plants pending before it. Even as the NRC hires more people to help cope with the application rush, new factories are also being set up to fabricate parts and components of nuclear plants.

Likewise in Europe too, a report prepared for the European Economic & Social Committee, which advises the European Commission, emphasized that Europe needed nuclear power.[19] Consequently, some of the EU members such as Italy and Germany that were not in favour of nuclear energy are reconsidering their phase-out policies. The UK plans to build 4 more nuclear plants with French help, with the first one likely to be operational in 2017. Sweden and Belgium too have been reported to have reversed their phase-out policies.

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[16] This has dropped from 16 per cent in 2005 as a result of six of Japan's nuclear power plants remaining shut as a consequence of the earthquake early in 2008 and several of France's reactors going in for simultaneous repairs.
[17] MIT Study, "The Role of Nuclear Power", (Massachusetts: MIT, 2004)
[18] Steven Chu, "America's New Nuclear Option", *Wall Street Journal*, 23 March 2010.
[19] "EU Report Supports Nuclear Role", *Nucleonics Week,* 29 January 2004.

Meanwhile, China, where nuclear energy presently accounts for less than even 2 per cent of the total national installed power generation capacity, has already emerged as the fastest growing nuclear power generator and if things go according to its ambitious plans, then it will be the largest producer of nuclear energy at 130 GW by 2030.[20] In fact, of the 55 GW of additional installed nuclear generating capacity projected for Asia, 24 GW is projected for China, 12 GW for India and 12 GW for South Korea.[21] China currently has 21 nuclear power plants simultaneously under construction, more than in any other nation at any point in time in the past. As they attain criticality over the next ten years, China would have spent $150 billion to increase its nuclear capacity nine-fold.[22] It is estimated that by 2030 China may have 94 GW of nuclear capacity compared to a total of 600 GW worldwide.[23]

For India, a constituent of the energy demand heartland along with China, nuclear power holds tremendous promise. The following paragraphs identify the rationale for a rapid expansion of nuclear energy in India.

Akin to the predominant trend worldwide (except in some countries like France and Japan), the bulk of India's existing power generation capacity exists in the thermal sector. In fact, nearly 65 per cent of the total energy generation of India is met from coal, oil and gas. The worrisome aspect of this reality is that India imports these traditional fossil fuels in large quantities to meet its energy demand. This obviously raises the country's vulnerabilities. For a large and rapidly developing country like India, bulk imports of fuel are neither affordable nor strategically prudent. Moreover, with increasing worldwide competition for non-renewable hydrocarbons, their prices can only be expected to rise and this will remain a cause of concern for the future.

[20] At present, the US is the largest producer of nuclear power at 98 GW. At present, China has 11 operational nuclear power plants that provide 1.3 per cent of its total generating capacity. "China Nuclear Power Capacity to Hit 80 Mln kWh by 2020", http://www.chinaknowledge.com, 10 March 2010.
[21] World Nuclear Association, http://www.world-nuclear.org
[22] Tom Slater, "Sick of Coal, China boosts its Nuclear Goals by 50%", 24 March 2010.
[23] "China in Talks with France, Russia on 4G reactors", *Business Week*, 19 May 2010.

India has reasonable coal reserves, which according to British Petroleum estimates comprise 8 per cent of the world total. The country is the fourth largest producer of coal and lignite in the world (after the United States, China, and Australia).[24] However, India's coal reserves are of low quality with high ash content and low calorific value. They are also to be found in few concentrated parts of the country. This necessitates haulage of coal over long distances which not only raises cost but also ties down the transportation network. In fact, transport costs raise the cost of coal three times from when it comes out of the mine. At present, coal remains the dominant fuel responsible for 55 per cent of primary energy generation. This entails a large-scale import of coal. In fact, the Shankar Committee set up to recommend measures to meet the demand-supply gap in coal had foreseen import of 30-40 million tons of high-grade coal by 2011-12.[25] However, coal imports far exceeded that figure in 2010 itself. According to the Chairman of Coal India Ltd., in 2009 itself, India's coal imports stood at 59 million tons and he estimated that it "should be around 100 million tons" for the year ending 2011.[26] If the time horizon is stretched to 2050, *without adding nuclear energy to the Indian energy basket,* then coal imports would have to be to the tune of 1.6 billion tons.[27] The enormity of these figures and the gravity of the situation are self-evident.

India's oil consumption in 2009 was about 2.67 million barrels per day, having doubled from the figure in 1992.[28] As the Indian economy continues to grow, the oil requirement of the country is expected to double again from the present consumption figures by 2030.[29] Such enormous consumption is met primarily through oil imports. In 2006, India was the seventh

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[24] Tata Energy Research Institute (TERI), "Indian Energy Sector", March 2003, http://www.teriin.org/energy/Indian energy sector.htm.
[25] "Capacity Build-up in Coal Essential", *Hindu*, 22 May 2006.
[26] Simon Lomax, "Indian Coal Imports May Rise to 100 Million tons on Power Demand", *Bloomberg Business Week*, 20 May 2010.
[27] As estimated by Dr Kakodkar, n.2.
[28] At 2.67 million barrels per day, India's oil consumption was actually less than in 2008 which had peaked at 3 million barrels a day but then fell due to the economic slowdown.
[29] EIA, World Energy Outlook, 2007.

largest net importer of oil in the world. With 2007 net imports of 1.8 million barrels a day, India is currently dependent on imports for 68 per cent of its oil consumption. The EIA expects India to become the fourth largest net importer of oil in the world by 2025, behind the US, China and Japan.[30] Crude oil prices are unlikely to fall below $50 per barrel in the coming few years even though they have come down from the high peak of $135 per barrel earlier in 2008. This has enormous implications not only for the strain it causes to the Indian exchequer, but also on the strategic autonomy of the nation. It may be recalled that France and Japan realized their vulnerabilities during the oil shock of 1973 and thereafter pursued strategies to secure their energy supplies on a war footing. Fast track expansion of nuclear power generation emerged as the solution for them.

The third source of thermal power generation is natural gas. The use of this fuel for energy generation is expected to increase substantially in the coming years. But, given the limited domestic availability of natural gas in India vis-à-vis the demand, it will have to be sourced from outside through elaborate and long distance transportation networks of pipelines and LNG shipments. These will bring their own risks of terrorism, piracy and environmental spills. While the concept of “peace pipelines” is laudable politically, it has enormous economic and security implications, especially for India since the pipelines will have to pass through politically unstable nations that harbour open hostility towards India.

Research and development continues towards increasing the share of renewable energy sources, including wind, solar, tidal, hydro, geothermal and bio fuels. However, except for hydropower in the few places where it is plentiful, none of these has presented itself as being suitable or economical for large-scale continuous and reliable power generation. It is well-known that reliability and evenness of electricity supply is even more critical for an increasingly digitized information society of today and tomorrow. Development of energy efficient

[30] *Ibid*.

technologies and measures has to continue. But, these efforts cannot be expected to be able to meet the energy demand and can only be complementary to the addition of new generation capacities.

In a scenario where a domestic deficit on fuel sources exists, nuclear energy emerges as a promising energy source. In fact, inclusion of uranium in the global energy portfolio could slow the depletion rate of fossil fuels, since reserves of uranium have no other major use. Nuclear power can replace the heavy dependence on hydrocarbons and the cases of France and Japan amply prove this. France today generates 78 per cent of its electricity from nuclear energy. Meanwhile, Japan had managed to reduce its oil imports from 80 per cent in the 1970s to 56 per cent by the 1990s and today, with a total nuclear generating capacity of 49 GW sources, about 25 per cent of its electricity is generated from nuclear power.[31] 14 new power plants are proposed to be built by 2030.

What is the contemporary Indian situation on the nuclear energy front? At present, India produces 4,560 MWe from its 19 operational nuclear power plants. This amounts to a little more than 3 per cent of the total generation capacity of the country. Construction of four 700 MWe PHWRs at Rawatbhatta in Rajasthan, two VVER 1000 MWe plants in Koodankulam, and one 220 MWe PHWR at Kaiga is currently in process. Once complete, it will bring up the country's total nuclear power capacity to 7280 MWe. Besides this indigenous growth, with the recent opening of India to international nuclear commerce, it is expected that there will be a further surge in nuclear generation capacity in the coming decades as a result of reactor imports. According to India's Prime Minister, the country's installed capacity is planned to be increased to 35,000 MWe by 2022 and to 60,000 MWe by 2032.[32] In a later section of this paper, the challenges that will need to be addressed to make this possible have been identified.

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[31] Jasjit Singh, "Growing South Asian Interests in the Persian Gulf Region: Problems and Opportunities", *Strategic Analysis*, vol. 23, no. 9, December 1999.
[32] Statement of the Prime Minister, Dr Manmohan Singh, at the Nuclear Security Summit in Washington DC on 11-

For now, it would be worthwhile to examine some aspects of the much debated issue of the economics of nuclear energy. Traditionally, nuclear power has been considered an expensive energy source given the high capital cost and long gestation periods required for building power plants. But recent empirical data indicates otherwise. In any case, nuclear power has long been proven a viable economic option in terms of Long Range Marginal Cost (LRMC), or for power supply at locations far away from coal reserves, particularly if hydel sources are also not available in these areas.[33] In fact, a comparative techno-economic analysis that accounts for the location of coal mines, transportation of fuel, availability of railroads, ash content and associated environmental impact and necessary mitigation measures etc., skews the cost benefit in favour of nuclear energy. Even if the cost of uranium has doubled in the last few years, yet given that fuel costs for nuclear plants are a minor proportion of total generating costs, in contrast to coal or gas-fired plants, the long-term economics of nuclear plants work out better. Also, the fuel's contribution to the overall cost of the electricity produced is relatively small, so that even a large fuel price escalation has relatively little effect. For instance, typically, a doubling of the uranium market price would increase the fuel cost for a light water reactor by 26 per cent and the electricity cost by about 7 per cent (whereas doubling the gas price would typically add 70 per cent to the price of electricity from that source).[34]

In fact, contemporary trends such as low interest rates, high oil prices, higher costs of power generation from fossil fuels because of increased environmental standards, improvements in nuclear plant capacity factors[35], reduction in construction time etc. have further rationalized the per unit cost of nuclear electricity. The construction and cost experience

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12 April 2010. Statement as reproduced in *Hindu*, 13 April 2010.

[33] Yoginder K. Alagh, "Economics of Nuclear Power in India", *Nu-Power International*, vol. 11, no. 1-3, 1997, p. 22.

[34] World Nuclear Association, "The Economics of Nuclear Power", http://www.wna.org, April 2010.

[35] Power plant reliability is measured by capacity factor, or the percentage of electricity actually produced compared to the total potential electricity that the plant is capable of producing. On this parameter, nuclear power plants have shown out as the most reliable sources of electricity production, with average capacity factors exceeding even 90 per cent in many countries, compared to only 68 per cent for coal, 35 per cent for natural gas and 34 per cent for oil. Capacity factors for renewable energy sources are also low at about 30 per cent.

of TAPP 3 and 4, among India's latest nuclear plants is illustrative of this. Not only have these plants been constructed in record time but also at a cost lower than expected. According to the Chairman of Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of the DAE that is tasked with the designing, construction and operation of nuclear power reactors, the two units were built in five years at a cost of Rs 6,100 crore against an approval of Rs 6,525 crore.[36] Modern systems of construction and resource management have indeed contributed to the economics of nuclear power.

At the same time, newer methods of cost calculation that include "external costs" of health and environment tilt the balance further in favour of nuclear energy. Unlike thermal plants that do not account for land acquisition costs for waste disposal etc., even though the waste generated in thermal plants is so much more, nuclear power internalizes the cost of waste management and plant decommissioning. An EU study estimated that the inclusion of health and environment costs would double the EU price of electricity from coal, and increase that from gas by 30 per cent. For instance, a study on the environmental cost of the large-scale coal-fired energy growth that China has witnessed concludes that as a consequence of this process, two-thirds of Chinese cities are today considered polluted. According to the Chinese government itself, nearly 30 per cent of the country is afflicted with acid rain, and respiratory and heart diseases related to air pollution are the leading causes of death, with a WHO estimate attributing 750,000 Chinese premature deaths to air pollution.[37] The cost of nuclear power is further enhanced once carbon dioxide emissions begin to carry a significant "price". Emissions' trading provides incentives for investment in carbon-free electricity technologies, and this improves the economics of nuclear power considerably.

[36] IBNLive, 22 May 2006.

[37] Byung Kim, Sean Wang, Dustin Lang, Jean-Baptiste Leger, Ross Perez "Energy Policy in China, US and France: A Case for Government Intervention", http://faculty.washington.edu/craigzb/Geog370/9-Energy-policy-China.ppt., downloaded on 03 August 2010.

With an experience of over half a decade in the field of nuclear technology, India, in the words of Dr Chidambaram, former Chairman, AEC, is "the only developing country that has demonstrated its capability to design, build, operate and maintain nuclear power plants, manufacture all associated equipment and components, and produce the required nuclear fuel and special materials." Indeed, India can claim to have experience in construction, operation and maintenance of a varied range of nuclear power plants – Boiling Water Reactors (BWR), Pressurized Heavy Water Reactors (PHWR), Fast Breeder Reactors (FBR) and Advanced Heavy Water Reactors (AHWR). India has also emerged as the largest producer of heavy water with six operational plants that "have scaled new peaks in the areas of productivity, capacity utilization, energy conservation, safety and environmental protection".[38]

It is well-known that having gathered several years of reactor experience in PHWR operations, India has graduated to the commercial demonstration of the fast reactor programme with the installation of the first 500 MWe prototype fast breeder reactor at Kalpakkam. Given the benefit of uranium use efficiency, many more countries are today interested in fast reactors. According to recent reports, China plans to build two 800 MW experimental fast reactors around 2013 and have them operational by 2020.[39] India, however, has been developing this technology all by itself and is an emerging leader in the development of reactor and associated fuel cycle technologies for thorium utilization too. A 30 KW(Th) research reactor KAMINI has been operational and is perhaps, one of its only kind in the world currently operating with uranium-233 based nuclear fuel.

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[38] ALN Rao, Chairman, Heavy Water Board, as quoted in OP Sabherwal, "A Nuclear Big Leap", *Tribune*, 10 May 2010. Earlier in 2007 too Rao had highlighted that capacity utilization of heavy water plants till December 2006 had been 113 per cent and that they had saved over Rs 700 crore in reaching upto 36 per cent of specific energy consumption. "Heavy Water Board Reaches New High in Export Market", http://www.livemint.com, 18 March 2010.

[39] "China in Talks with France, Russia on 4G Reactors", *Business Week*, 19 May 2010.

The Indian nuclear plants have also achieved many international benchmarks. For instance, in 2002, the average capacity factor of Indian PHWRs was more than any reactor in the US. At the end of September 2002, Kaiga Atomic Power Plant (KAPS) recorded a capacity factor of 98.4 per cent during the preceding 12 months and became the best performing PHWR among 32 reactors worldwide.[40] In 2009, the Nuclear Fuel Complex at Hyderabad made history of sorts by supplying 11,016 fuel rods from the imported natural uranium to NPCIL in a record time of six months. This fuel was meant for the three reactors at Rajasthan, which are now under IAEA safeguards.[41]

It is a recognition of India's nuclear expertise that it has been invited to participate in the multinational International Thermonuclear Experimental Reactor (ITER) being built in Cadarache, France to harness energy from nuclear fusion. Indian research in fusion had anyway been going on for the past two decades at the Institute for Plasma Research at Gandhinagar. India had planned to build an ITER scale reactor by 2030.[42] Participation in the global project will enable it to leapfrog in technology, while making a value addition to the multinational effort.

While the Indian uranium reserves at about 0.8 per cent of the world are considered to be insufficient for a power programme of more than 10,000 MWe if the uranium is used on once-through basis and then disposed off as waste, India has planned for spent fuel reprocessing to complement its nuclear fuel resources. The first stage of this programme involves using the indigenous uranium in PHWRs. The second stage utilizes the spent fuel of PHWRs after reprocessing to extract Pu 239. This is then used in FBRs to breed additional fissile nuclear fuel, plutonium and uranium-233. In the third stage, thorium and uranium-233 based Advanced Heavy Water Reactors (AHWRs) will be able to meet the long-term Indian energy

[40] KS Parthasarthy, "Nuclear Growth Despite Fuel Resource Constraints", *Navhind Times*, 6 June 2008.
[41] Article in Business Standard, 3 December 2009.
[42] "India will Join ITER Next month in Brussels", *Hindu*, 26 April 2006.

requirements. Thus, the available uranium will eventually be used to harness the energy contained in non-fissile thorium, of which India possesses about 32 per cent of the world's reserves or 360,000 tons of high quality thorium, but which needs plutonium to kick-start fission.

Role of International Nuclear Commerce

Envisaging the crucial role that rapid addition of nuclear power generation could play in easing the overall energy deficit in the coming years, the government had begun exploring the option of seeking an exceptionalization for India from NSG guidelines that had long prohibited any transfer of nuclear material or technology to India until it accepted NPT membership as a non-nuclear weapon state and opened all its nuclear facilities to full scope safeguards. An opportunity to realize this presented itself in 2005 when President Bush offered to abandon the long-standing US nuclear policy towards India in order to initiate a constructive engagement in civilian nuclear cooperation. Through three years, the unprecedented agreement between India and US suffered intense scrutiny and criticism and was nearly pronounced dead scores of times. However, braving all odds, the agreement finally cleared its last lap when President Bush signed HR 7081 US India Nuclear Cooperation Approval and Non-proliferation Enhancement Act on 08 October 2008. Two days later, on 10 October 2008, the 123 Agreement between India and US was finally operationalized between the two countries after India’s External Affairs Minister Pranab Mukherjee signed the deal along with his US counterpart Secretary of State Condoleezza Rice in Washington D C. With this, a range of opportunities for the Indian nuclear power programme that had been hamstrung for international cooperation since May 1974 opened up. These opportunities, particularly in four dimensions of the Indian programme, are worth examining.

Fuel Availability

Lack of uranium to power the Indian nuclear reactors stands out as the most serious constraint that had begun to hamper the optimum operational capacities of Indian reactors in the decade of the 2000s. The situation gradually worsened and through most of 2008, the Indian power plants had to run at half their capacity levels owing to inadequate availability of nuclear fuel. This situation arose out of two factors: firstly, though the country's uranium reserves were estimated at 61,000 tons and were calculated by the DAE to be enough for 10,000 MW power generation for 40 years, the uranium prospecting, mining and milling had been relatively ignored over the last few decades. Since 1968, the Uranium Corporation of India Ltd. (UCIL) has been commercially producing and processing uranium ore mainly from the mines at Jaduguda, Bhatin, Narwapahar and Turamdih – all located in Singbhum district of Jharkhand. This was sufficient for the operating power plants and research reactors until the end of the 1990s. However, once fast track power plant construction started from the mid-1990s onwards, a mismatch developed between uranium demand and supply. Secondly, over the decades, the uranium reserves have depleted and the ore at Jaduguda mines is presently being obtained at much deeper levels than earlier. This pushes up the cost of recovery of uranium, which in the case of India is in any case high because of low concentration of uranium in the ore. Indian ore has uranium content as low as 0.6 per cent as compared to some Australian, Canadian and Kazakh ores containing up to 15 per cent of uranium.

To meet the projected demand of the nuclear power programme, UCIL is exploring uranium deposits located in other areas of Jharkhand and in Andhra Pradesh and Meghalaya. Progress in this direction, however, has suffered due to opposition from local populace and non-governmental activists in the regions. Therefore, in order to tide over the domestic uranium crunch, one of the relatively immediate benefits of the recent nuclear cooperation agreement would be to allow India to access uranium from the international market at competitive prices for a programme that has planned at least five more indigenous power plants in the near future.

In fact, with the cooperation agreement crossing the last step in October 2008, the first consignment of 60 tons of imported uranium from France landed in April 2009. The NFC used this and other imported fuel to make 11,016 fuel rods in a record time of six months for RAPS 6.[43] NFC is also reported to have received 120 tons of natural uranium as supplementary contract under the umbrella contract of 2000 tons of natural uranium to be received over a period of 5-7 years.

It is interesting to note that uranium prices that had peaked in 2007 at US$ 136 per lb U_3O_8 had fallen to US$ 44.50 per lb U_3O_8 in 2009.[44] India has already procured uranium from France, Russia and Canada, leading to a 15 per cent increase in reactor capacity factors.[45] UCIL would also be able to bid for uranium prospecting or mining in other resource rich regions of the world. It has already concluded an agreement with Mongolia for capacity creation in Ulan Bator's nuclear sector and uranium mining. With Namibia, Gabon, Kazakhstan, Tajikistan, Niger too, besides France, USA and Russia, India has arrived at uranium mining or supply arrangements.

Import of Larger Reactors and Export of Smaller Ones

Tarapur Atomic Power Plant (TAPP 3), India's 16th nuclear reactor, went critical on 14 May 2006. With this India's indigenous nuclear programme demonstrated the capability to construct and operate 540 MWe PHWRs. TAPS 3 and 4 are today India's largest capacity reactors, with all other indigenously built plants being of 220 MWe capacity. In the future though, the NPCIL has plans to standardize on 700 MWe plants that it today has the capability to build. Larger reactors obviously offer economies of scale and having developed a mature expertise and technological and industrial base, India has felt the need to move on to larger capacity generations.

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[43] "NFC Dispatches Fuel Bundles to Newly Built RAPS Unit 6", *Business Standard*, 3 December 2009.
[44] Uranium Mining Issues: 2009 Review at http://www.wise-uranium.org/uissr09.html, updated February 2010.
[45] Fakir Balaji, "As Fuel Supplies Resume, India's Nuclear Power Output Up" http://thaindian.com, 11 January 2010.

The Koodankulam plants being acquired from Russia are of 1,000 MW. The predominant reactor capacities in many of the countries advanced in nuclear technologies average at least 1,000 MW, with France having a majority of its reactors of 1,300 MW and its future EPRs at 1600 MW. With the opening of international cooperation, India will have the opportunity to import larger reactors for a rapid addition to its generating capacities.

Meanwhile, given the interest in nuclear energy for peaceful purposes in many smaller countries, particularly in the South East Asian region, India has an opportunity to export its 220 MWe reactors that would be ideally suited for their smaller electricity grids. These reactors have proved their competitiveness in capital as well as unit energy costs and have a demonstrated record of safe operations. In September 2009, at an international conference in Vienna, Dr Kakodkar, then Chairman of DAE, announced India's intention to export an advanced design of power reactors that it was developing. This would use LEU along with thorium as fuel and offer the advantage of being proliferation resistant since it does away with having to use plutonium, replacing it instead with uranium enriched to 19.75 per cent.[46] Producing 300 MWe, and designed to operate for upto a 100 years, it is believed to have the next generation of safety features requiring no emergency planning beyond the site boundary. The AEC also claims that the design is ideal for export since the "reactor is manageable with modest industrial infrastructure within the reach of developing countries."[47] Also, since the new fuel produces less plutonium than mainstream LWRs, and what is produced contains three times the proportion of Pu-238, this makes the reactor highly proliferation resistant.

India also has the capability to emerge as a low-cost manufacturing hub for nuclear component supplies to the resurgent nuclear industry worldwide. In fact, India must pay heed to a recent report prepared by the South Korean government that states, "Nuclear power-related business will be the most profitable market after automobiles, semi-conductors and

[46] "Thorium Fuelled Exports Coming From India", http://www.world-nuclear-news.org, 17 September 2009.
[47] *Ibid*.

ship-building".[48] There is a huge opportunity here for the Indian companies like L&T, Bharat Forge Ltd, Bharat Heavy Electricals Ltd. etc. to participate in the nuclear industry at the domestic as well as at the international level. GE Hitachi Nuclear Energy Limited and Westinghouse Electric have already announced plans to use India as a low-cost supplier of nuclear parts for export to US and Europe. Both intend to localize up to 70-80 per cent of production by using local manufacturing and labour.[49]

Participation in International Projects

As has been pointed out earlier in the paper, India has already joined the prestigious ITER project. India is also member of the IAEA's INPRO activity and is participating in eight of the 12 collaborative projects under INPRO's phase II programme. This programme that seeks to build innovative energy systems with better safety, economics, waste management, and which are more proliferation resistant are crucial for the sustained growth of nuclear power. Interestingly, research on such reactors is exploring closed fuel cycles and seriously considering reprocessing technologies as a means of extracting greater energy and reducing waste. India is among the handful of countries that have mastered the plutonium reprocessing technology and has lots to offer from its experience. Meanwhile, Indian nuclear scientists have a chance to interact with the best of their fraternity elsewhere, an exchange that was denied to them since the late 1970s.

Tide over Delays in Moving to Thorium Cycle

India's development of the thorium cycle has now seen 37 years of work on the concept and feasibility demonstration. Of course, problems of high cost and technical complications in fuel fabrication because of high radioactivity of U-233 and reprocessing required to move to the

[48] Michael Richardson, "A Renaissance for Nuclear Power Gets Underway in Asia", http://www.thenational.ae, 13 February 2010.
[49] "India to Supply Low-cost Nuclear Parts for Export", *Pakistan Defence*, December 2009.

thorium fuel cycle still persist. But then, India is among the very few countries pursuing this technology. Even the World Nuclear Association, which is dedicated to the promotion of nuclear technology, sees little scope of development of this technology as long as abundant uranium is available. However, given the peculiarities of the Indian resource base, Dr Homi Bhabha had prescribed a three-stage programme for the country that would culminate with the exploitation of India's large thorium reserves. There is nevertheless, a logical technical progression that is required from the PHWR to the FBR stages to thorium utilization in order to reach an optimum level of fissile material build-up that would then make the use of thorium feasible and effective. While R&D continues on multiple technologies, including through the use of Accelerator Driven Systems (ADS), these are pioneering technologies that India is struggling with alone. Therefore, there can be no pre-determined dates for the advent of the third stage. Estimates vary from 2020 to 2040. In the meantime, the import of reactors from abroad would not only help India in quicker accumulation of requisite fissile material but also help narrow the widening electricity demand-supply gap in an environmentally friendly way.

Challenges before the Indian Nuclear Power Juggernaut

Even though it makes eminent sense for India to not only keep the option of nuclear power expansion open, but to press for it urgently, there are certain limiting factors that must be grappled with.

Availability of Trained Manpower

The Department of Atomic Energy is estimated to have a work force of 70,000 today. Given the additions planned to nuclear generation capacity, it is natural that the need for more nuclear scientists, engineers, craftsmen, construction managers, plant operators and maintenance personnel would significantly swell in the coming years. According to a report prepared by the PricewaterhouseCoopers on the occasion of the 2nd Indo-French Nuclear

Industry Business Meet in 2009, based on a norm of 1-1.4 persons/MW and with a power generation target of 20 GW for 2020, additional manpower requirements will be between 10,000 to 19,000, corresponding to an average recruitment of 1,000 to 1,900 employees per annum.[50] These will not be easy targets to meet.

The AEC has Nuclear Training Schools at the Bhabha Atomic Research Centre (BARC), Mumbai, Indira Gandhi Centre for Advanced Research (IGCAR), Kalpakkam, Nuclear Fuel Complex – Heavy Water Board (NFC-HWB), Hyderabad and RRCAT, Indore to train about 500-700 engineers and scientists per annum. The NPCIL has also set up five Nuclear Training Centres attached to the power plants at Kaiga, Kalpakkam, Kudankulam, Rawatbhata and Tarapur. However, with the need for rapid and increased numbers, it would be a challenge to recruit, educate, train and retain technical personnel especially at a time when the private nuclear industry is also expanding worldwide. To strengthen research at universities, the DAE provides grants for projects through the Board for Research in Nuclear Sciences. A DAE Graduate Fellowship Scheme for IITs has existed since 2002 to promote collaborative research. IIT Kanpur already offers a course in nuclear engineering and technology, and so will Chennai from 2009 onwards. A combined thrust towards creation of a trained manpower pool will be required from academic institutions and the DAE to have enough numbers of nuclear scientists, technologists, regulators and operators available for the future expansion plans.

<u>Limitations of Indian Manufacturing Industry</u>

Given the high technology content, and the sensitive and precise nature of materials, equipment and processes involved in nuclear power generation, it is imperative that the Indian manufacturing industry keeps pace with the advancing nuclear science and technology and

[50] IAEA Nuclear Technology Review 2009 as cited in PricewaterhouseCoopers Report, "Opportunities and Challenges for Indo-French Cooperation in Nuclear Power", http://www.pwc.com/india, downloaded 04 September 2010, p. 15.

provides it with the necessary infrastructure and equipment. In fact, this challenge could be turned into an opportunity by the industry, given that the global nuclear renaissance is exposing the inability of existing manufacturers worldwide to meet the growing demand for reactor components and systems. For instance, the US does not have the capability to domestically manufacture ultra-large forgings that exceed 350 tons. These are necessary for making reactor vessels and its global suppliers are the Japan Steel Works that has the capacity to make 5-6 such forgings every year. Of course, the number of players in the field as well as the capacity of the existing manufacturers is increasing. Yet, the number of suppliers for such high-end products will be relatively few, and it is natural that their manufacturing capacities would be booked years in advance.

Given India's cost competitiveness, its reasonably high engineering and technological skills supplemented by innovative techniques, the country could emerge as a hub of nuclear components and graduate slowly to more complex and high-end products over the years. With the opening of international nuclear trade to India, Indian companies have the possibility to enter into joint ventures or technical collaborations with known nuclear players. This could not only support the Indian nuclear expansion but also enable exports. Several joint ventures/partnerships have already been formed by Indian companies such as Bharat Forge with AREVA and Alstom, L&T with Westinghouse, GE Hitachi, Mistsubishi, Punj Lloyd with Thorium Power, BHEL with Siemens and Alstom, NTPC with Alstom etc. for the manufacture and supply of several nuclear related equipments and services.

The government could help build an enabling environment for the Indian industry by drafting necessary policies to this effect. For instance, just as there are offsets in the defence industry, a similar provision may be worked into the commercial contracts for import of nuclear reactors, making it mandatory for the seller to enhance the capability of Indian companies active in the field. It would also be of great value if the indigenous component of every new power plant is kept at a high level. This would not only enable cost benefits but also provide a fillip to the domestic industry and help provide employment to large numbers. The total market potential for manufacturing and engineering services for the nuclear industry arising from India's nuclear plans up to 2020 is estimated to be no less than Rs 1,300 billion.

Necessary Legislative Processes

The existing Atomic Energy Act, 1962 does not allow private players into the field of nuclear power generation. Until now, this has been the exclusive preserve of state owned companies. With the opening of the sector to international markets, it is now necessary to amend the Act in order to allow private companies to set up and operate nuclear reactors.[51] Within India, many private companies such as Jindal Steel and Power Ltd., Tata Power Ltd., Reliance Power Ltd., and NTPC have expressed a desire to step into the field. The last in fact, which is also the largest Indian power company, has already proposed a joint venture with imported technology to set up and make operational a 2000 MWe nuclear power plant by 2017.[52] Several multinational companies would also be expected to bid for the multi-billion nuclear reactors market in India.

In order to enable this, India has enacted the nuclear liability law, which was adopted by the Indian Parliament in August 2010. This provides for attribution of responsibility in case of an accident. India will be required to sign the international legal framework for nuclear accidents, namely the Convention on Supplementary Compensation that covers claims through a global fund to pay victims.[53] Moreover, government support will also be necessary to provide risk

[51] Interestingly, the US Atomic Energy Act, 1946 was revised in 1954 to permit private sector involvement in reactor development, though the Congress retained ownership over nuclear fuel. The 1954 Act also established the AEC as the agency to oversee reactor construction and use. This distinguishes the manner in which the nuclear power generation is regulated as compared to conventional electricity production.

[52] "India to Broaden Corporate Base for Nuclear Power", World Nuclear News Overview, 31 October 2008.

[53] This convention will come into force once five or more nations collectively having 4,00,000 MWe of installed capacity ratify it with the IAEA. Four have already done – the US, Morocco, Argentina and Romania totalling a capacity of 3,19,256 MWe.

insurance for companies building nuclear reactors which would cover events beyond the control of the owner, including regulatory and litigation delays.

Regulatory & Environmental Procedures

Given the sensitive nature of the technology and materials in use at a nuclear power plant, these have existed in a heavily regulated environment to guard against possible threats, natural and man-made, to their safety and security. For a sustainable and safe expansion of the nuclear power programme, ample attention must therefore be devoted to the correct and quick implementation of necessary regulatory and environmental procedures. These are extremely essential because any accident at a nuclear site would have repercussions on the growth of the nuclear industry worldwide. Therefore, safety performance of operating nuclear power plants (NPPs) and its periodic and stringent rule-based evaluation is of vital importance in order to minimize and possibly obviate any danger to plant workers or the public. In fact, for every nuclear plant that is built and operated, the society needs assurance that the facility will be safe on three accounts:

a. It would not suffer an accident leading to the release of large amounts of radioactivity.

b. It would not cause pollution to the environment during the conduct of its routine operations.

c. It would account for the long-term storage and safe disposal of its radioactive waste.

The guarantee of these assurances requires the establishment and maintenance of effective mechanisms and the adoption of requisite measures in the design, site selection, operation and decommissioning of a nuclear plant. At the same time, relevant regulatory bodies need to be instituted to oversee and assess the implementation of safety measures against different parameters so that the individual, society and the environment can be protected against radiological hazards. From the moment of site selection to the actual construction of the plant, a number of other mandatory requirements of seeking environmental clearances, rehabilitation of displaced populations from exclusion zones, development of infrastructure etc. are required to be undertaken. While India's AERB has performed this task well in the past, as the pace of nuclear activity rises, it might be necessary to expand the regulatory organization through additional induction of trained manpower so that the procedures involved in obtaining the necessary licensing do not become bottlenecks. Of course, at the same time, the most stringent standards of safety and security will have to be maintained.

Public Perception of Nuclear Energy

Yet another significant obstacle to rapid and large-scale nuclear power expansion is public perception of nuclear fission as a source of energy. The Three Mile Island incident and Chernobyl have been written about enough to create a deep-seated public fear about nuclear power. Unfortunately, there is very little awareness of the stringent safety regulations enforced and followed in the design, construction and operation of power plants, or of the safety record of India's power plants for nearly three and a half decades. Neither is there adequate knowledge of the fact that natural radiation in some places is much more than in the vicinity of a power plant. Fortunately, the nuclear industry is extremely conscious of the dangers involved in its activities and hence takes sufficient precautions to obviate chances of an accident.[54]

The other major aspect of nuclear energy that causes public concern is that of waste management and disposal of spent nuclear fuel. Fortunately though, for India this is not such a big challenge since it follows a closed fuel cycle in which the nuclear fuel after being used once is not immediately in need of disposal as waste. Rather, the spent fuel is reprocessed and the products left only after reprocessing actually constitute waste which is then vitrified and stored

[54] For more on the safety aspects of the Indian power programme, see Manpreet Sethi, "Nuclear Safety: Critical for Future Nuclear Expansion", unpublished paper in a series of papers for a DAE Project on "Nuclear Energy for India's Energy Security".

under water. This not only lowers the amount of waste generated, but also allows the effective use of energy potential in the spent fuel. However, the public relations department of the DAE must step up its efforts to better educate the public on the advantages and risk mitigation endeavours of the atomic establishment in order to develop the ground for greater exploitation of nuclear energy.

Conclusion

Nuclear technology in India has reached a state of self-reliance. India today has 285 reactor years of safe nuclear power generation. Kaiga 2 set a record by registering 529 days of uninterrupted run during August 2006-January 2008. 17 operating reactors and six more under construction indicate a high level of nuclear activity that will only pick up in the coming years as more fuel and technology is inducted into the domestic programme. The Indian nuclear power programme has also moved into the second stage of development wherein a Prototype FBR is now under construction, and research and development for AHWRs is underway. India today has the capacity, technology and the will to expand its nuclear power programme. International cooperation would facilitate the availability of environmentally sustainable energy to India well in time to avoid stagnation of human development.

The present moment has opened new vistas for the country's energy scenario. It is the bounden duty of the nation to use this to its own advantage after a careful consideration of risks and vulnerabilities. Some trade-offs will be inevitable. However, if human development, economic growth and environmental sustainability are taken as the essential parameters for these decisions, then there is a case for nuclear expansion for electricity generation, especially as part of the strategic need for as wide a diversification of the Indian energy basket as possible.

India, today, adds about 30-35 GW of power capacity every five years, which is half the planned amount. In order to add 60 GW every five years for the next 25 years, the right choices must be made now. For a sustained progress to usher in a resurgence in civilian nuclear power, realistic action will be necessary on several fronts: a supportive policy environment, including through legislative changes, commensurate industrial investments, help from university and training institutes for manpower requirements and support from the academic and strategic community to monitor trends and identify limitations to forewarn against possible dangers. A comprehensive policy on its expansion must be urgently drafted and implemented if India is not to let unavailability of power stand in the way of its economic growth and development.

The IAEA Director General, ElBaradei once rightly pointed out, "Disparity in energy supply, and the corresponding disparity in standards of living, in turn, creates a disparity of opportunity, and gives rise to the insecurity and tensions…." India cannot afford such fissures. It is imperative that the necessary large-scale energy generation is achieved through environmentally friendly resources and technologies, because otherwise the financial and human costs of coping with environmental disasters could severely undercut the benefits of economic growth.

Within this framework, the imperative of nuclear energy for addressing the current and projected energy deficit and ensuring long-term energy security, while simultaneously addressing environmental issues can afford to be dismissed only at India's own peril. Energy poverty and its concomitant implications stare the nation in the face. Nuclear energy, if produced safely, offers promise. The requirement hence is to fast track civilian nuclear expansion while maintaining the highest standards of nuclear safety and security. Today's India has to carefully make the right choices to assure the future generations of a brighter and secure tomorrow. The example of France and the choices that Paris made in the face of a severe energy crunch in the 1970s hold several lessons for India. The next chapter examines the French nuclear programme in some detail.

2 FRANCE'S TRYST WITH NUCLEAR ENERGY

France has 59 nuclear power plants with a total capacity of 63 GWe that cater to the bulk of the electricity needs of the country. With 78 per cent of the nation's electricity coming from these plants, France is the world leader in the production of nuclear energy for electricity production. However, only less than four decades ago, the situation had been completely different. In the 1970s, the nation's energy needs were largely met with oil, most of which was being imported. France's dependence on oil at the time of the oil crisis of 1973 was to the tune of 75 per cent. In 1975, fuel imports accounted for 22.9 per cent of all imports and the figure rose to 26.6 per cent of total imports between 1973 and 1980.[55]

The quadrupling of the price of oil exposed the energy vulnerabilities of the country and drove home a number of lessons not just for France but for other nations too. High dependence on energy imports came to be seen as posing an unacceptable risk to national security, especially as the economies began to get more and more dependent on energy driven processes and activities. Energy security has since come to occupy an important place in national security priorities.

It is well known that France turned to nuclear power in order to address its energy problems. With inadequate domestic sources of oil, gas or coal, but equipped with expertise in heavy engineering and industry, the French maintain that they had no other choice. Nuclear power plants became the logical option for meeting the energy demand of the country in a reliable and sustainable manner. This chapter examines the *modus operandi* that France adopted for the rapid expansion of nuclear energy as the solution for securing its energy independence. What have been the major factors driving the success of the French tryst with nuclear energy? Which have been the significant problem areas and how is France dealing with them?

[55] "France – Energy and Power", Encyclopedia of Nations, http://www.nationsencyclopedia.com/Europe/France-ENERGY-AND-POWER.html, downloaded on 3 August 2010.

France’s Introduction to Nuclear Power

As in every country that is a nuclear weapon state under the NPT, the French nuclear energy industry is an outgrowth of nuclear weapons research. Several French scientists played a role in different capacities in the development of the first nuclear weapons. Meanwhile, France set up its own Atomic Energy Commission (*Commissariat à l’Energie Atomique* or the CEA, which since 2009 is now known as *Commissariat à l'Energie Atomique et Aux Energies Alternatives* - Atomic and Alternative Energy Commission) in 1945. This was tasked to undertake research and development of nuclear science and technology within the country.

In 1955, three government bodies, the CEA, the *Production d’Electricité d’Origine Nucléaire* (PEON—an advisory group to the CEA, which was disbanded in 1981) and the *Electricité de France* (EdF) came together to promote nuclear power. In 1956, a joint project was launched to develop the first all French commercial nuclear reactor. Eight years later, a natural gas – graphite reactor, the nation’s first commercial nuclear reactor became operational at Chinon.

Since France never undertook a separation of its civil and military nuclear facilities, the experience in the research, development, design, construction and operation of weapon-based nuclear facilities was used in the civil sector, as also *vice versa*. Therefore, both advanced in a mutually interdependent manner in terms of knowledge/expertise acquisition and infrastructure development. In fact, the 1973 annual report of the CEA specifically mandated the organization to “adapt the production of military nuclear material to rapidly changing needs by taking advantage of technical progress and civilian programs (which themselves have greatly benefited from military programs) in order to limit the costs.”[56] This remains true till date and France has made no effort to separate its civilian and military nuclear activities.

Over the years, the CEA has emerged as the organization responsible for fundamental research in physics, and for conducting R & D into nuclear reactor designs and development of reactor prototypes. Through consistent efforts and technological breakthroughs, the CEA has improved the PWR technology so that France now has reached the third generation of reactors

[56] As cited in Mycle Schneider, *Nuclear France Abroad: History, Status and Prospects of French Nuclear Activities in Foreign Countries*, Centre for International Governance Innovation (Ontario), Paris, May 2009, p. 9.

– the European Pressurized Water Reactor or the EPR. These have higher capacity factors and also claim improved safety and efficiency levels. The first two of this kind are presently under construction, one in Normandy in France and the other in Finland. However, owing to the slipping of construction schedules and cost overruns at both sites, the EPR is being subjected to critical scrutiny by the nuclear industry in France and elsewhere.

Meanwhile, in January 2006, the French President had directed the CEA to work on the design of a prototype Generation IV reactor to be operational by 2020. Interestingly, all the three Gen IV technologies that CEA has decided to work on – the gas-cooled fast reactor, the sodium-cooled fast reactor and the very high temperature gas-cooled reactor – are all fast reactors which are believed to result in reduced wastes and better utilization of uranium resources. The objective of this R & D being undertaken by France is to have a competitive fast reactor technology ready for industrial deployment and export after 2035-2040. The CEA, therefore, continues to undertake rigorous research on newer generation technologies, and has also expressed interest in working with USA on the development of very high temperature, proliferation-resistant reactors.

Electricité de France (EdF), the state electricity utility, was founded on 08 April, 1946, as a result of the nationalization of a number of electricity producers, transporters and distributors. In 1974, it was tasked with the responsibility of starting and sustaining an intensive nuclear power programme in France. It has since become the main electricity generation and distribution company in France – the sole owner and operator of all nuclear power plants, besides also enjoying near monopoly on the generation and distribution of other electricity.[57] It undertakes long-term planning of the generation capacity as well as purchases the electricity generated by authorized independent power plants such as solar, hydro and wind power. In some cases, it also engages in co-generation with these plants. Nearly after sixty years of its existence as a state owned company, in 2004, it became a limited-liability corporation wherein the government retained 85 per cent ownership but the rest 15 per cent was provided to other shareholders.

[57] In fact, by law, other smaller electricity producers are required to sell their energy to the EdF, which then resells it to the consumers within its power grid.

AREVA emerged out of a government restructuring undertaken in September 2001 of its nuclear fuel cycle sector into a single, state-owned holding company. The primary motivation behind the creation of AREVA was to create an industrial group covering the entire range of nuclear activities (front and back end) and working with a unified strategy in the international nuclear market. Given the large clientele of the French nuclear industry owing to an active French nuclear diplomacy,[58] this was hardly surprising. In fact, given the revival of interest in nuclear energy, France is certainly keen to effectively service an expanded customer base. As per its own reckoning, AREVA estimates new build capacity worldwide between 170 – 500 GW by 2030 and obviously seeks to benefit from this trend as it claims to be "number one worldwide in the entire nuclear cycle."[59] In this venture, it has the complete backing of the government. This was more than evident when President Sarkozy hosted an International Conference on Access to Civil Nuclear Energy in Paris in March 2010. A press release put out for the conference referred to the international "nuclear renaissance" which necessitated "resolute action by those States who, like France, believe that nuclear energy can provide a sustainable solution for their growing energy needs."[60]

The AREVA group, comprising AREVA NC (earlier known as COGEMA *Compagnie Générale des Matières Nucléaires*), AREVA NP (formerly *Framatome*) and AREVA TA (formerly *Technicatome*), today controls the country's major nuclear enterprises, including mining of nuclear fuels, construction of new reactors, treatment and recycling of nuclear waste, and decommissioning of old plants. AREVA NC is responsible for the production and maintenance of nuclear materials in the entire nuclear fuel chain from mining to waste disposal. AREVA NP develops and builds nuclear reactors. AREVA TA develops and builds research reactors and reactors for naval propulsion.

CEA is the main shareholder in AREVA. In 2004, the government announced that it would open 40 per cent of AREVA's shares to the public. Private entities now own about 13 per cent of

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[58] For details on this see next chapter of this monograph.
[59] AREVA, "AREVA at a Glance", March 2008.
[60] Press Release, International Conference on Access to Civil Nuclear Energy, Paris, 8-9 March, 2010, dossierpressegb.pdf

the company. Relations between AREVA and EdF have not been very smooth in recent times. EdF alleged in January 2010 that AREVA had stopped uranium deliveries on 4 January and was refusing to take spent fuel for reprocessing at its La Hague facility. AREVA, on the other hand, refuted allegations of stopping uranium supplies but accepted that it was not accepting spent fuel for reprocessing because of breakdown in talks between the two companies over the 800 million euro contract for reporcessing spent fuel.[61] Owing to such problems and others, pointed out in a report prepared on the French nuclear sector by François Roussely, former CEO of EdF, the government took another step at restructuring the French nuclear infrastructure in July 2010. AREVA and EdF have been placed in a far-reaching alliance "possibly allowing EDF to enlarge its 2.4 per cent stake in AREVA and putting it firmly at the center of France's nuclear sector."[62] The step appears to be an attempt at reinforcing the links between AREVA and EdF that have weakened owing largely to both pursuing business interests in an exclusive rather than a coordinated fashion. As pointed out in the report EdF has sought to diverisfy its suppliers while AREVA has worked to expand its portfolio to foreign clients. In the process, they have ended up distancing themselves from each other.

Whatever be the nature of the relationship in the future, it is nevertheless clear that few players and a high degree of state integration characterize the French nuclear industry. EdF controls electricity production, transmission and exports. CEA administers research and controls all nuclear activities. AREVA, through its three subsidiaries, monopolizes the fuel cycle processes and plant construction.

Factors in the French Nuclear Energy Success Story

Strong Government Role in Energy Policy-Making

The decision to embark on the path of large scale and rapid nuclear expansion was taken in the face of the Middle East oil crisis by a small group of French "technocratic imperialists",[63] without any major public debate. As stated by an analyst, "the government's energy program

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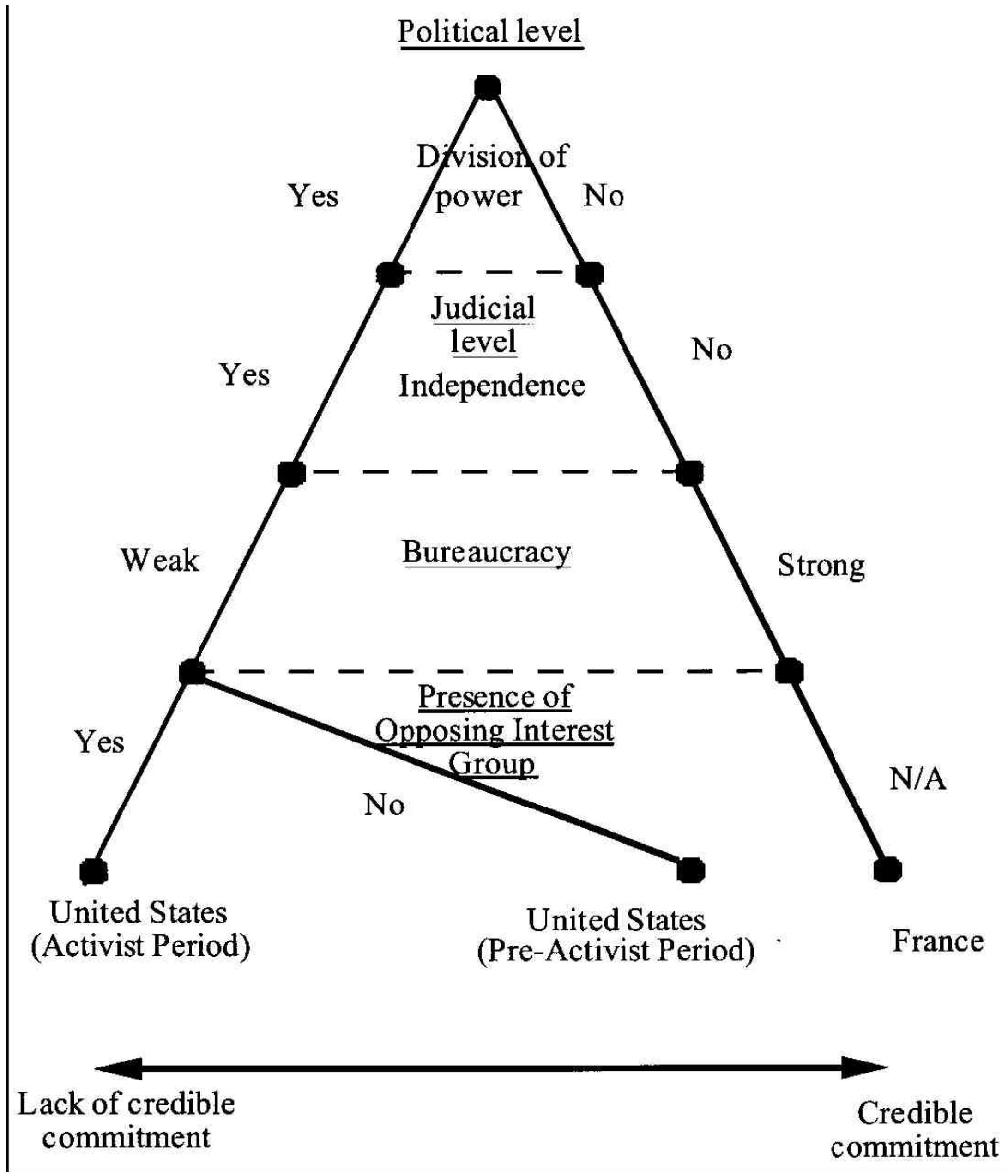
[61] Adam Sage, "Bitter Row Throws French Nuclear Industry into Turmoil", *Times Online*, 18 January 2010.
[62] "French Government: EdF, AREVA in Strategic Nuclear Partnership", *Dow Jones*, 27 July 2010
[63] BAS, January 1976, p. 41

wasn't even brought before the National Assembly until May 1975, where a perfunctory debate ensued..."[64]

In the face of insufficient energy sources, substantive engineering expertise and a sound science and technological base, turning to nuclear power became an almost natural choice. Strong government support to nuclear power translated into a rapid expansion of the nuclear infrastructure. No noteworthy public debate or scrutiny of the nuclear programme is documented before 1999. Of course, there were some anti-nuclear groups, such as the Friends of the Earth, *Sociétés de Protection de la Nature* etc. In fact, by mid-1975, several influential French newspapers, such as *Le Figaro*, had raised concerns over questions of radioactivity, risk of nuclear accidents, nuclear waste, and the like. A large and even violent demonstration against construction of the FBR Super-Phenix at Creys-Malville took place in June 1977. In France, support for nuclear power fell from 74 per cent in 1974 to 47 per cent in 1978.[65] Yet, France continued to experience growth in its use of nuclear power. This has been attributed to "the impermeability of the institutional setup—no division of power, weak judiciary, and reliance on bureaucratic expertise— [that] effectively prevents activists from influencing policy outcomes."[66]

Consequently, the government commitment to the growth of nuclear power remained high. The image reproduced below from an analysis carried out by Levy and Spiller in 1994 illustrates how the differences in the institutional and governmental characteristics in the US and France contributed to the differences in the credibility of government commitment to nuclear power, and hence to the growth trajectory of this sector.

[64] Magali Delmas and Bruce Heiman, "Government Credible Commitment to French and American Nuclear Power Industries", *Journal of Policy Analysis and Management*, Vol. 20, No. 3, 2001, p.445
[65] Ibid. p. 439
[66] Ibid. pp 433–456. The authors have pointed out the contrast in this matter with the American system where little reliance on bureaucratic expertise and an independent judiciary have undermined the ability of the US government to commit to the nuclear industry.



Source: B. Levy & P. Spiller, "The institutional foundations of regulatory commitment: A comparative analysis of telecommunications regulation", Journal of Law Economics and Organization, vol. 10, no. 2, pp. 201–246, 1994

It was only in 2003 that France's first national energy debate was announced in response to a "strong demand from the French people" as the country sought to define its energy mix for the next 30 years. Results obtained from the debate helped establish a law in 2005 that defined guidelines for energy policy and security. While the law defined a research policy for developing innovative energy technologies, including in the field of renewable energy to reduce carbon emissions, it nevertheless retained the role of nuclear power as central to the nation's energy policy. The aims of the French energy policy were set out in Programme Act 2005-781 of 13 July 2005[67]:

- contribute to national energy independence and guarantee the security of supplies
- ensure competitive energy prices
- protect human health and the environment, particularly by combating the worsening
- greenhouse effect
- guarantee social and territorial cohesion by ensuring universal access to energy

Subsequently in 2008, a Presidential decree established a Council on Nuclear Energy chaired by the President and consisting of the Prime Minister and cabinet secretaries in charge of energy, foreign affairs, economy, industry, foreign trade, research and finance besides the head of CEA and secretary general of national defence and the Chief of Staff. The high profile and wide-ranging constitution of the Council illustrates the importance that the country accords to nuclear planning and implementation. Indeed, firm and consistent government backing for the nuclear programme has been able to sustain the centrality of nuclear power in the French energy mix.

Role of the* Corps des Mines *in Nuclear Decision-Making

The French nuclear establishment has followed a unique system wherein key positions in public administration, economy and industry are drawn from the *Corps des Mines,* a small elite group of technocrat-engineers who are key figures in the development, orientation, design and implementation of energy, and more specifically nuclear policy in the country.[68] In fact, most officials central to the formulation and implementation of energy policy (as in CEA, EDF, or even AREVA) have come from this administrative elite. With a common educational background and

[67] Press release, n. 7

[68] *Corps des Mines* was first set up in 1810 to oversee the mining sector, primarily consisting of the main ingredients of the war industry, namely coal, steel and gun powder. Since then the Corps' area of responsibility has been expanded to include all departments that dealt with industrial matters. Since 2009, the Corps is attached to the Ministry of Economy, which also oversees industry. It participates in the "conception, implementation and evaluation of public policies" in a wide range of sectors including the nuclear industry.

corporate interests, these members of the elite group populating most administrative bodies of the French nuclear decision-making bureaucracy share a certain *esprit de corps* that helps overcome potential conflict within the government or with outside elements and makes them "unified in their response to criticism and opposition from outside groups".[69]

Every President has the right to choose his advisors in the energy (including nuclear power) or other industrial sectors. But his choice is confined to members of the *Corps* since they occupy key positions in the EdF, CEA, AREVA and other nuclear companies.[70] The IAEA Bulletin of 1986 explained this unique French attribute by citing the French representative to the IAEA Board of Governors,

> "Since 40 years the big decisions concerning the development of the French nuclear program are taken by a very restricted group of personalities that occupy key positions in the government or in the top administration of EdF, CEA and the few companies involved in the program. The approach remains unchanged in spite of the change of ministers thanks to the permanence of these personalities that occupy the same position generally for some ten years."[71]

The singular importance granted to the members of the *Corps des Mines* in nuclear decision-making has facilitated a high level of constancy in French nuclear policy that may not ordinarily have been possible if it had been left to the personal orientations and choices of the elected representatives of the government. The Corps has been able to create, pursue and implement a long-term policy perspective, which is especially significant for an issue such as the nuclear policy that has a long gestation period and slow rate of results that would normally extend beyond the electoral term of a government. In any case, elected representatives have had little understanding or influence on the development and implementation of nuclear policy. The *Corps des Mines* has virtually dictated the French nuclear energy sector.

Use of a Standardized Reactor Design and Technology

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[69] Delmas and Heiman, n.10, p. 449

[70] For more on the positions held by members of *Corps des Mines* in the French nuclear and energy administration see Mycle Schneider, n. 2, p. 11.

[71] *IAEA Bulletin*, Autumn 1986.

The Pressurized Water Reactor (PWR), whose basic design has not changed over decades though improvements have been carried out for better performance, remains the major workhorse of the French nuclear power programme. While a standardized plant design and technology is seen as one of the positives of the French nuclear programme today, it is interesting that in the period 1965-70 a lack of agreement on the type of nuclear plant that France should develop had almost brought the country's fledgling nuclear power programme to a halt. While the CEA was in favour of the graphite-gas cooled reactors, the EdF voted for light water reactors that the US was operating.[72] The first eight reactors were of the gas-cooled variety that CEA championed, but then the EdF prevailed with its choice of PWR reactors supported by a national enrichment capacity.

All French nuclear plants are now PWRs of three standard types designed by Framatome, now known as AREVA NP. The first category of PWRs is of 900 MW capacity and these have been constantly upgraded to be technically identical to the newer models. France operates 34 of these. The second type of PWRs are of 1300 MW capacity of which there are 20 units. These have single unit designs instead of the paired unit design of the earlier generation. The third class of PWRs are of 1450 MW capacity and France operates six such units. Therefore, with all French nuclear reactors being PWRs of three standard types, the country enjoys a very high degree of standardization. This has obviously brought many advantages. The first of these has been the economic benefit of allowing industrial processes to be standardized for serial production of components and systems. Secondly, it has helped in easy dissemination of experience across the plants and in case of any fault detected in one plant, rectification has been quickly possible along the entire fleet of reactors. In fact, standardization or the 'common plant template' has significantly enhanced the possibility of probabilistic safety analysis and enabled easier maintenance and operation.

In 2004, design approval was granted to the European Pressurized Water Reactor (EPR), which has also been developed by Framatome (AREVA NP) along with Siemens of Germany to meet the European utility requirements. This 1650 MWe reactor has now been designated as the standard design for the future. In mid-2004, EdF decided to build the first demonstration

[72] Etienne Bauer, Louis Puiseux, Pierre- Frédéric Tenière-Buchot, "Nuclear Energy: A Fateful Choice for France", *Bulletin of Atomic Scientists*, January 1976, p 40.

unit of an expected series of this reactor and the decision was confirmed in 2006 after a public debate.[73] Work started at Flamanville on the Normandy in December 2007 and the estimated construction time was put at 54 months. So, the reactor was projected to become operational by May 2012. However, by the end of 2008, the cost estimate had been raised by 21 per cent and the schedule had already been revised several times, inviting severe criticism on the type of the reactor. Yet, in January 2009, President Sarkozy confirmed that the EdF would build a second 1650 MWe EPR at Penly, near Dieppe, expected on line in 2017.

While EdF and AREVA maintain that the EPR is the best model of a third generation nuclear reactor, the complexity involved due to its high power generation, containment requirements and redundancy of systems has implications for the construction time and cost of the reactor. A report recently released by a former president of the EdF recommends careful deliberation on the feedback received from the construction experience of these reactors at Flamanville and Olkiluoto to refine the process for other reactors planned to be built in France and China. In fact, unless these issues can be sorted out, the French advantage in having standardized reactors could actually become a handicap.

High Emphasis on Maintenance and Safety Record

The French nuclear establishment has accorded a high level of importance to maintenance of nuclear plants from the point of view of nuclear safety. After capital and fuel related costs, 60 per cent of the remaining budget is allocated for maintenance tasks and the plant engineers are subjected to rigorous training at the EdF's specialized Maintenance Preparation and Qualification Centre for PWR Systems (Cetic). All reactors undergo a review after every ten years and, in most cases, lifetimes of the units have been extended by ten years above the initial projected operation period, mostly with minor modifications. Most of the 900 MWe reactors started up in the late 1970s or early 1980s are reviewed together in a process that takes four months at each unit.[74] In July 2009, the French Nuclear Safety Authority (ASN) approved the EdF's case for a 40-year operation of the 900 MWe units based on a generic assessment of the 34 such reactors.

[73] It has been alleged that most decisions on the French nuclear programme have been thrust upon the public by the all powerful *Corps des Mines* and that a genuine public debate has not really taken place.

[74] World Nuclear Association, *Nuclear Power in France*, May 2009.

In order to provide a specific legal framework for nuclear safety and security, with a specialized authority to monitor its implementation, the government enacted the French Transparency and Nuclear Security Law (known as the "TSN Law") on 13 June 2006. This also created an independent Nuclear Safety Authority (*Autorité de Sûreté Nucléaire* ASN), which sets out the rules applicable to nuclear facilities. The organization performing this task prior to 2006 had been under the aegis of the Ministries for Industry, the Environment and Health. But in 2006 the ASN was established as an independent regulatory body with five commissioners. It is now tasked with the functions of nuclear safety and radiological protection, providing public information on nuclear security, monitoring nuclear facilities and activities, and taking all necessary enforcement action such as suspension of operations, etc when necessary as well as any emergency measures. It also has an important international role in helping to draw up and disseminate best principles and practices in the field of nuclear safety. Its activities and missions, as well as the status of nuclear safety and radiation protection in France are detailed in its annual report, which is sent to the Parliament, the Government and the French President. The ASN is aided in its tasks by the *Haut Comité pour la Transparence et l'Information sur la Sécurité Nucléaire* (High Committee for Transparency and Information on Nuclear Safety) which was created by Act 2006-686 of 13 June 2006 on transparency and security in the nuclear field. Besides providing information, the committee is a forum for consultation and debate on the risks connected with nuclear activities and the impact of such activities on human health, the environment and nuclear safety.

High Public Support

The nuclear industry everywhere is highly dependent on public opinion. The understanding in France that its nuclear programme brings the benefit of energy independence has translated into a high support for it. Simultaneously, with a high level of emphasis on nuclear safety, France has managed to avoid any serious nuclear mishap. This unblemished safety record also feeds into the public support for nuclear power. In 2006 with the enactment of the TSN Law, the government also increased the transparency of its nuclear programme. The right to information on nuclear facilities was strengthened by supplying a legal framework to the Local Information Committees (CLIs, which were set up in 1981) and by establishing a High

Committee for Transparency, in order to provide for discussions at national level. This reinforced the faith of the general population in the nuclear power.

Meanwhile, EdF has also proven that the large-scale dependence on nuclear energy in France has enabled it to cut down emissions of greenhouse gases that accompany thermal power plants. Also, public support for nuclear power has been based on the evidence of increase in business activity and prosperity in regions with nuclear power plants. The nuclear industry has not only provided job security for employees and employment opportunities for local labour force, but has also brought an influx of population into a locality, thereby giving a boost to the local businesses in the region.

Not surprisingly therefore, owing to all these factors, more than 70 per cent of the French population in 2005 recognized the importance of nuclear power. Seven out of ten people believe that nuclear power is good for the economy, creates jobs, is an environmental asset and hence a symbol of national pride.

Monopolistic Rule of EdF

The Nationalization Law of 1946 established the EdF as the primary importer and exporter of electricity transmission within all of France and outside. EdF is also the leading exporter of electricity in Europe. It exports 13 per cent of its total production to Britain, Switzerland, Italy and Germany. At the same time, EdF has a monopoly over electricity generation. In fact, the EdF is the world's second largest electricity producer. Owned completely by the state, it has managed with the help of government subsidies to provide cheap electricity to the French industrial users as well as to the residential and commercial sectors. This has not only enabled the nation to attract foreign investment but also helped maintain a high level of public support for nuclear power. EdF's monopoly has allowed it to evolve its own tariff levels. It was once reported in the Economist, "A complex set of cross-subsidies ensures that consumers of each category pay identical electricity tariffs, even if they live in remote rural areas."[75] This geographic unity of prices has been touted as an advantage of the national nuclear power programme to forge national unity.

[75] "How the French get power", *Economist*, 11 May, 1996, p. 62.

Owing to its vast experience and expertise in safe plant operation as well as efficient transmission and distribution of electricity, the EdF has managed to tap into the international nuclear market. For instance, in the 1990s, EdF took over Edenor SA, the power distribution company in Argentina that was doing poorly and has managed to turn it around with the help of its technical and managerial expertise. In China too, EdF has entered into joint ventures with China Light and Power (CLP), besides acting as a consultant for the Daya Bay nuclear power plant in which the CLP has a 25 per cent stake. CLP and EdF had also formed a joint venture in 1994 with the Shandong Electric Power Bureau to build three 1200 MW power plants. The main role of the EdF in these ventures has been to oversee construction and train Chinese engineers and managers to operate the facilities. More recently, EdF has also taken over British Energy and a substantive portion of the Constellation Energy in the USA.

Such joint ventures abroad not only increase the profitability of the organization but also buttress the perception of EdF's expertise before the domestic audience, thereby justifying its own monopoly in the home energy sector.

Problem Areas in the Nuclear Powerhouse

Allegations of Inefficiency and Lack of Competitiveness in Nuclear Energy Sector

Lack of democratic decision-making in the nuclear sector owing to the large influence of the members of the *Corps des Mines* has resulted in France not being able to objectively evaluate its nuclear policy. Even in 1974, when the decision was first made to step up the country's nuclear programme, "no public debate took place, except hastily before a sparsely attended and indifferent legislature; no authorized or strong voice was raised to attack or discuss these decisions."[76] This has led to allegations that the path towards nuclear generation has been followed without an objective review of its actual benefits in terms of energy independence and cost competitiveness. In fact, given the many subsidies that are provided to the EdF, it has been alleged that the cost of nuclear electricity generation is not what it would be otherwise. Evidence questioning the cost benefit ratio of nuclear power is mounting with the

[76] Etienne Bauer, Louis Puiseux, Pierre- Frédéric Tenière-Buchot, "Nuclear Energy: A Fateful Choice for France", *Bulletin of Atomic Scientists*, January 1976, p. 38.

rising debts of the EdF, even as it is constrained to increase the price of electricity being provided to the consumer. In fact, the French government has regulations that require EdF to keep its electricity price increase to 1.5 per cent below the national inflation rate.

The overarching role of the *Corps des Mines* has also been held responsible for non-democratic decision-making that has hampered an objective analysis, adaptation, or reorientation of the policy. For instance, it has been alleged that despite realizing that France had overbuilt its nuclear capacity far ahead of the domestic consumption requirements by the mid-1980s, no cancellation of units that were yet to be constructed was undertaken.[77] Such decisions have cast a shadow on the national nuclear decision-making.

Questions over Future Viability of Nuclear Power in France

Integration of France with the European Union has opened the possibility of foreign electric utilities being allowed to sell their electricity within French borders. As has been mentioned earlier, the EdF enjoys monopolistic rule in French energy sector. However, the movement of the European Union towards electricity liberalization has led to opening of the option for the European consumers to choose among electricity suppliers, instead of having to buy compulsorily from the monopoly seller. In fact, the European Commission has alleged that the monopoly of the EdF violates the Treaty of Rome that allows free movement of goods across EU nations. The EdF in its campaign to resist deregulation of the electricity utility sector has argued that the increased competition would make the electricity utilities ignore safety and environmental standards in a bid to make profits and woo customers with lower prices. To the domestic audience it has raised the specter of loss of jobs leading to a dip in the support for nuclear power within the country. France is extremely sensitive to unemployment and hence these decisions are not easy for the government to make.

Meanwhile, artificially depressed prices of electricity generation through high subsidies have also raised questions over the continued viability of nuclear power. A double blow to the French nuclear sector seems to have been dealt as a result of the cost overruns on Flamanville nuclear plant. The 1650 MW EPR was to have cost $1.3 billion, but its price has gone up to $6.5

[77] Schneider, n. 2, p. 13, footnote 28.

billion and the schedule has been delayed from 2013 to 2015. This has shaken the faith of the country in not only the new design of the reactor and its feasibility but also the future of nuclear power. A report on the state of the French nuclear industry has suggested that new reactors would have a better chance of success if they were of smaller sizes and hence easier to construct quickly. This is a direct attack on the EdF's decision that all future nuclear power stations would be of the EPR variety. It had also placed a large stake on the export of such reactors. China is already in the process of building two such reactors and the ones to be built in India are of this kind.

A problem of human resources has also been anticipated in the French nuclear energy sector. It is reported that 40 per cent of EdF's operators and maintenance staff will retire by 2015, which will result in shortage of skilled and trained manpower.[78]

Decommissioning Challenges

As the nuclear reactors reach the end of their operational life, these have to be safely decommissioned in order to mitigate risks to human health and environment. This costs money and the EdF claims it puts aside EUR 0.14 cents/kWh for this purpose. "Early in 2006, it held EUR 25 billion segregated for this purpose, and is on track for EUR 35 billion in 2010."[79] The organization had initially set aside a fund for the purpose, but it has been seriously depleted by the need for new investments or debt repayment. Unfortunately, the French had not originally included the cost of decommissioning while computing the price of their nuclear electricity for fear of the electricity becoming more expensive for the consumers and hence losing the overwhelming public support that the nuclear programme has enjoyed in the country.

Radioactive Waste Management and Storage Concerns

The relatively strong support for nuclear power among the French populace falters mostly over the issue of management of nuclear waste. For nearly 60-70 per cent of the French, this is the "most compelling argument against nuclear power".[80] Indeed, like many nations

[78] Mycle Schneider, "The Reality of France's Aggressive Nuclear Power Push", *Bulletin of Atomic Scientists*, 3 June 2008.
[79] "Nuclear Power in France", World Nuclear Association, July 2010.
[80] Roussely report as translated by Nuclear Engineering International, available at http://www.neimagazine.com, downloaded on 4 August 2010, p. 11.

producing nuclear electricity, France will soon face the issue of long-term storage of high level wastes. For the moment, it has been storing low-level waste in the Manche region. But underground storage sites are yet to be earmarked.

A national radioactive waste management agency, ANDRA (*Agence Nationale pour la Gestion des Déchets Radioactifs)* was created within the CEA by a government order of 07 November 1979. But in December 1991, as per the Waste Act No. 91-1381, the organization was made independent of the CEA by transforming it into a public industrial and commercial establishment under the authority of the Ministries of Industry, Research and Environment. Further, a national law of 28 June 2006, the Planning Act No. 2006-739, tasked the ANDRA to work towards the establishment of a deep storage centre.[81] Of course, ANDRA has been working since 1999 to build an underground research laboratory at Bure to prepare for disposal of vitrified high-level wastes and long-lived intermediate level waste. But, the law more specifically set the deadline of 2015 for ANDRA to submit its request for authorization in this matter and foresees the opening of the repository by 2025. However, this not only requires careful selection of the site but also its being subject to safety inspections to rule out radioactive leaching due to the composition of the soil or the geological activity in the region. Public protests by the residents of the region are only to be expected and the government must be prepared to mount a public awareness programme in order to provide sufficient reassurances on the safety of the storage sites and processes.

Meanwhile, ANDRA's own annual report of 2008 claims an effort by the Agency to reach out to the public on the purpose and procedures of waste disposal. A concerted education campaign was launched through participation in municipal councils and public meetings. As the report states, in response to the call for expressions of interest in June 2008, nearly 40 municipalities indicated their willingness to consider hosting the future disposal facility for low-level, long-lived waste.

[81] ANDRA, 2008 Activity Report, *Fostering Dialogue and Outreach*, http://www.andra.fr/English.

Conclusion

The French decision to pursue nuclear energy was the result of a combination of circumstances of the decade of the 1970s. The high dependence of the French industry and society on coal and oil when the oil crisis hit the world in early 1970s left the country with little choice on energy alternatives. As opined by an article in 1976, "Any other solution will lead to dangerous economic or social tensions, either because of the necessity of outrageously raising the cost of production or because of the need to force a drastic reduction in long-term energy demand. These solutions would be followed not only by unwelcome results: limited automobile driving, reduction of the temperature within homes, and so forth; and also above all by *large-scale unemployment in industry for lack of energy*".[82]

So, as a result of circumstances where domestic, indigenously available energy sources were limited but the industrial and engineering expertise was high, France almost by default turned to the development of nuclear power as a means of attaining energy security. A strong government commitment, the role of a few strong actors such as CEA, EdF and later AREVA who shared good cooperation and coordination enabled the programme to rapidly establish its viability and reliability. A good safety record reinforced public acceptance, which was anyway influenced by the subsidized pricing of nuclear electricity enabled by the government. The strength of the French nuclear programme has been its consistent effort at R & D to improve reactor technology, build standardized plants in large numbers and master the complete set of nuclear services at the front and back end of the nuclear fuel cycle.

In more recent times, some problems have arisen between EdF and AREVA. Criticism of delays and rising costs of the EPR reactors under construction at two sites, the loss of the contract for four reactors to be built in UAE to South Korea, and the limitations highlighted in the Roussely report are some of the reasons for the discord. However, given that Presidential decrees and orders have always driven the French nuclear programme, President Sarkozy issued another such order to strengthen the alliance between the two main players in the French nuclear programme – EdF and AREVA. Indeed, every actor in the nuclear game in France is well aware of the need to position themselves as the leaders in the field if they have to enjoy a

[82] BAS, January 1976, p. 40. Emphasis added.

worldwide presence. Technologically, they do have an edge. Politically, they must put forth a coherent and credible front in order to reap the benefits of a much-awaited global 'nuclear renaissance'.

3 INDO-FRENCH NUCLEAR COLLABORATION – PROSPECTS AND CHALLENGES

"…the underdeveloped countries are all countries that do not have energy or that have not figured out how to use their energy; consequently, to offer it new energy is to give more than technology, it is giving it hope. This is why the export of atomic energy generating materials constitutes a political gesture…." Louis Armand, a key French nuclear strategist in the 1950s and negotiator of the Euratom Treaty, made this statement in the French Parliament in 1956. More than half a century later, President Sarkozy is still promoting his country's nuclear exports in the same spirit.

France has a long history of sharing its nuclear technology with other countries. In fact, by the end of the 1960s itself, Paris had concluded civilian nuclear cooperation agreements with as many as 25 countries.[83] Another ten countries were added to the list in the 1970s.[84] Indeed, France has "used nuclear technology assistance as a geopolitical tool from the very earliest stages".[85] In the much anticipated global nuclear renaissance in the coming years, France hopes to seize a significant share of the world nuclear market by providing access to its nuclear information, technology and materials. Pierre Gadonneix, the chief executive of the EdF until 2009 was absolutely clear that his company was poised to "take part as investor, builder and operator in the global rebirth of nuclear energy".[86]

President Sarkozy has been especially aggressive in leveraging the French lead in civilian nuclear technology "to gain diplomatic, commercial and military advantages with countries in the Middle East, as well as parts of Africa and Asia".[87] He has stressed his country's expertise in the nuclear sphere as one of France's biggest export opportunities for commercial gain as well

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[83] These included Canada, India, Israel, Sweden, Switzerland, the US and Yugoslavia in the 1950s. Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Chile, Germany, Indonesia, Iran, Italy, Japan, Pakistan, South Vietnam, USSR, Spain, Tunisia and Uruguay were added in the 1960s.

[84] These included Bangladesh, China, Libya, Mexico, Philippines, Portugal, Qatar, Saudi Arabia and South Korea.

[85] Mycle Schneider, *Nuclear France Abroad: History, Status and Prospects of French Nuclear Activities in Foreign Countries*, Centre for International Governance Innovation (Ontario), Paris, May 2009.

[86] Matt Gil, "The Man Behind the French Nuclear Power Expansion", *International Herald Tribune*, 22 December 2008. It was during Gadonneix's time that EdF acquired half of Constellation Energy's US nuclear plants and also took over British Energy.

[87] Michelle Smith and Charles Ferguson, "France's Nuclear Diplomacy", *International Herald Tribune*, 11 March 2008

as an important foreign policy tool for reinforcing the country's relationships with others. In March 2010 he hosted in Paris an International Conference on Access to Civil Nuclear Energy in which France "expressed its willingness to assist any country wishing to use nuclear technology for peaceful purposes which fully abide by their non-proliferation obligations."[88] With an estimated 450 new reactors due to be built worldwide by 2030, a market worth billions of dollars, France is obviously keen to reserve a sizeable piece of the pie for itself as it considers its nuclear industry and expertise as a viable commodity for export.

AREVA, in fact, has managed to establish French dominance in the international nuclear sector. Covering all aspects of the nuclear fuel cycle, it has emerged as a powerful industrial group employing 65,000 people, owning manufacturing facilities in 43 countries, and a sales network in a 100 countries. AREVA is today a participant in 20-25 per cent of global uranium mining, 25-30 per cent in global uranium conversion, 20-25 per cent in uranium enrichment and 30-35 per cent in low enriched uranium fuel fabrication. It also holds a quarter of the world share in reactor building and servicing. Meanwhile, it holds two-thirds of the world market share in back-end activities such as spent fuel reprocessing and MOX fuel fabrication.[89]

Over the last three years, France has negotiated a number of nuclear cooperation agreements with several nations who are first-time entrants into the nuclear field. These include Algeria, Jordan, Libya, Morocco and Tunisia. While not every agreement signed by France might result in a nuclear reactor being built in the recipient nation, nevertheless, the agreements serve broader strategic and political purposes for both partners. For France it helps to expand its nuclear client base into newer nations and regions. It provides it with a platform to showcase itself as a developed country that is concerned about the less privileged and ready to share its expertise with them. In fact, well aware of the fact that it could take a long time - as much as fifteen years[90] - to build the necessary framework in terms of the domestic legislation, regulatory bodies, trained manpower, maintenance capacities, etc. in countries starting down the nuclear path for the first time, the French government has created the *Agence France Nucleaire International* within the CEA with the specific objective "to help foreign states to

[88] "Sarkozy Hosts Conference on Nuclear Energy", http://www.france24.com/, 8 March 2010.
[89] Figures as cited in Schneider, n.2, p. 5.
[90] As estimated by the head of the ASN in 2009.

prepare the institutional, human, and technical environment necessary for the development of a civil nuclear program".[91] At the March 2010 Conference too, Sarkozy acknowledged that "States wanting access to civil nuclear energy have specific needs with regard to training, financing, and support for the implementation of the highest safety and security standards, and must be given help with regard to setting up the necessary technical and regulatory framework and infrastructure."[92]

Accordingly, the AFNI is equipped to offer legal support on drafting domestic nuclear legislation, aiding the conclusion of necessary paperwork and other support for international treaty framework, creation of domestic nuclear safety and regulatory authorities, conducting environmental and risk assessments, and offering training of human resources. The AFNI is guided by a steering committee that comprises representatives from all ministries – Energy, Foreign Affairs, Industry etc. – as well as representatives from major French nuclear institutions. Thus, it functions as a coordinating body that can offer expertise from all French nuclear organizations such as ANDRA on nuclear waste management, ASN for nuclear safety, and CEA, EdF and AREVA for other services.

For many of the developing countries that have concluded civilian nuclear cooperation agreements with France, it becomes a matter of prestige that boosts their image before the domestic as well as the regional/international audience. Nuclear power is widely conceived as high technology and is a matter of prestige for every nation. Therefore, a nuclear cooperation agreement does provide a nation with a sense of national pride and achievement.

India and France – A Tenacious Nuclear Relationship

India's nuclear relationship with France goes back to the 1950s. It was in 1951 that the two countries first signed an agreement to study beryllium. It was a little more than a decade later, in 1965, that a full-scale cooperation agreement on the Uses of Atomic Energy for Peaceful Uses was signed. Subsequently, in 1969, agreements for a heavy water production plant and the

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[91] Mycle Schneider, "The Reality of France's Aggressive Nuclear Power Push", *Bulletin of Atomic Scientists*, 3 June 2008.

[92] Press Release, International Conference on Access to Civil Nuclear Energy, Paris, March 8-9, 2010, dossierpressegb.pdf

fast breeder reactor were concluded. In 1974 when India carried out its first peaceful nuclear explosion, France did not condemn the nation. Even as the US, UK and Canada spearheaded the institution of the Nuclear Suppliers Group post the Indian PNE, France continued to cooperate and exchanged notes on the supply of enriched uranium in 1976. It was France that came to India's rescue in 1982 when the US refused to supply enriched uranium fuel for the two Tarapur Boiling Water Reactors that had initially been set up with American assistance.

On 30 September 2008, days after the grant of the NSG waiver to India on 06 September 2008 that exempts India from placing its entire nuclear programme under full scope safeguards of the IAEA (a stipulation adopted by NSG members in 1992), but before the US Congress passed the 123 agreement in October 2008, France had signed a new cooperation agreement with India. The agreement envisages a wide range of cooperative activities, including nuclear power projects, R&D, nuclear safety, education and training. Importantly, the agreement allows for reprocessing rights over the spent nuclear fuel from French reactors under safeguards and also provides assurance of lifetime supply of nuclear fuel for these reactors. Nor does it bar the transfer of enrichment and reprocessing technologies. The French Parliament unanimously approved the accord on 24 November 2009. Meanwhile, on 18 December 2008 AREVA signed an agreement with NPCIL for a supply of 300 tons of uranium, thus becoming the first foreign supplier of uranium to the country after the NSG waiver. It may also be recalled that Prime Minister Manmohan Singh had been the chief guest at the Bastille Day celebrations in Paris in July 2009 while President Sarkozy had been the chief guest at the Indian Republic Day parade in January 2008. These diplomatic gestures symbolize the contours of the bilateral strategic relationship.

Among the many civilian nuclear cooperation agreements that France has recently concluded with nations across the world, the one with India stands out for several reasons. For one, India is the only country with whom France can hope to actually see the results of cooperation relatively quickly since in the case of the many newcomer nuclear nations, they are yet to establish proper nuclear regulations, train the requisite manpower and in some cases even set up the organizational frameworks for the many dimensions of safe nuclear operations.

India also offers a chance for the French nuclear industry to tie up with the fairly advanced Indian industry for manufacture of nuclear components and systems. The Indian industry has been able to meet the requirements of the indigenous nuclear power plants, including steam generators, turbines, electrical equipment, heat exchangers, pumps, pressure vessels etc. Besides, the fuel fabrication, heavy water production and reprocessing of spent fuel are also performed by different entities under the aegis of the government. Therefore, the Indian domestic capability offers French nuclear vendors the opportunity to localize their supply chain for plants they plan to set up in India as well as for export to their other projects elsewhere. As was highlighted by the Chairman of NPCIL, Indo-French industrial cooperation in manufacturing PWR components in India would not only be an important element in competitiveness of French PWRs in India but also enhance the competitiveness of French PWRs worldwide.

Not surprisingly, therefore, joint ventures between Indian and French companies have already been formed. Such business models serve the interest of both sides. While for the parent company, the local support partner brings the benefit of already developed facilities, trained people, manufacturing experience, and awareness of the local context, the second partner of the JV gains through technology transfer, access to international markets, and exposure to global operating best practices.

In July 2009, BHEL announced the decision to form a joint venture along with AREVA and Bharat Forge Ltd, and Sheffield Forgemasters of the UK as a technical partner, to set up a manufacturing facility for heavy forgings in India. The plant is expected to begin operations by 2012 and to supply 8-10 forgings during the first year of operation.[93] Meanwhile, in January 2009, AREVA had already signed an MoU with Bharat Forge, wherein it decided to invest $4 million in two shell companies. Bharat Forge will hold 51 per cent share in the first shell company which will manufacture steel smelting and forgings, while AREVA will hold 51 per cent stake in the second company that will set up assembly lines for the finished forgings. AREVA has also finalized the terms of agreement with the Indian engineering company Tata Consulting Engineering Ltd for the supply of engineering services. The regular interaction between Indian

[93] "Suppliers Seek Slice of Indian Market", World Nuclear News, 13 July 2009.

and French nuclear industries in the past has opened the possibility for them to explore business cooperation in manufacturing and supply of equipment for nuclear plants.

The French nuclear industry is looking at an aggressive marketing strategy, especially as there is little scope for capacity build-up at home. With the current plateau in the domestic energy demand and since the life spans of the French reactors are over forty years, the French nuclear sector is saturated at home. India is an attractive and profitable market for the French nuclear establishment to gain a few positives on its record of nuclear cooperation agreements, which in many cases has not yet and may not for many years result in any tangible gains. The Finnish reactor is running behind schedule and suffering from cost overruns. Therefore, the French successes in the Chinese and Indian nuclear markets will mean a lot for its own nuclear industry and the critics at home.

This is doubly important since criticism of the French nuclear industry has risen over time. It reached a new high when AREVA failed to bag the contract for the construction of nuclear reactors in the UAE. In July 2010, François Roussely, former President of EdF published a report clearly identifying the major problems afflicting the French industry. Among those that he identified, two have direct implications for the export component of the French industry – lack of export competitiveness and delays; and cost overruns in EPR construction projects, which could reduce the attractiveness of the French reactors. In fact, both these factors have led to degradation in the image of France as a model in the field of civilian nuclear energy. The report suggests a total of 15 recommendations to arrest the downslide. These include a careful scrutiny of the EPR construction experience in order to refine the process as well as the offer of smaller models for export to countries whose grid cannot support such large rectors. It also draws attention to the fact that the international nuclear market is segmented and varied, depending on whether a country is a first-time nuclear buyer or already has experience of nuclear electricity generation. In order to respond appropriately to this different type of buyer, the report suggests placing different contract models on the table.

In order to consolidate the French nuclear export potential, the report recommends making the EdF as the "architect-engineer of Team France".[94] Lamenting the lack of coordination between the many players of the French nuclear industry, the report emphasizes the need to project EdF as the leader and the prime coordinator with the buyer nation. The reason for promoting EdF in this capacity is listed as its unique experience as a builder and operator of nuclear plants, unlike the model of the US engineering companies that build the reactors but do not operate them. With AREVA being able to offer the complete service for the operation of the reactor – from uranium mining to plant decommissioning, the report seeks giving a "new impetus to strategic ties between EdF and AREVA". This is seen as logical since "EdF is the main client of AREVA and AREVA is EdF's leading provider".[95] Lamenting the weakening of links between the two organizations in recent times as a result of both launching a process of diversifying their contacts, the report recommends that both should rather exploit their complementarities to project themselves as strategic partners to a third party. As the report suggests, "this agreement is a strategic imperative for France to unite effectively its civil nuclear industry internationally, to prepare for the challenge of the renewal of French nuclear power plant fleet, to accompany the necessary revitalization of the French economy".[96] As a follow up to the report, it is not surprising that the EdF has closed its international activities division in an effort to "accelerate synergies at group level" and its own activities are to be reassigned to three business lines – production, downstream and networks.[97]

For India, its collaboration with the French nuclear industry brings the benefit of engaging with the most powerful global nuclear player that controls significant market shares in all nuclear activities ranging from uranium mining to nuclear waste management. Also given the nature of the French nuclear decision-making where a small group that operates outside the electoral considerations controls the nuclear decision-making in the country, it allows India the assurance of a long-term relationship unlike the case with the US where the nuclear relationship is governed by the predilections of the elected government. Like France, India too has mastered the full fuel cycle that comprises the long chain of activities from uranium prospecting and

[94] Roussely report, NEI translation, 30 July 2010, p. 6
[95] Ibid., p. 7
[96] Ibid. p 7.
[97] "EdF Closes International Division in Reshuffle", *Nuclear Engineering International*, 22 November, 2010.

mining to uranium conversion and fuel manufacture to spent fuel management and reprocessing. But it is among the few countries (along with China) that are looking at rapidly expanding its nuclear generation capacity and France is currently the most active nation in extending the use of civilian nuclear technology.

NPCIL is engaged in negotiations with AREVA to work out a business model for the proposed 3,300 MW nuclear plant at Jaitapur in Ratnagiri district of Maharashtra. The EPR will not be a turn-key project and hence there is need for arriving at a clear demarcation of distribution of work such as construction activity, training and commissioning processes etc. It may be expected that nearly 50 per cent of the plant would be localized right at the beginning and this figure could progressively increase with time. Land acquisition for the six reactors to be built at this site has been completed and a draft environment impact assessment study has also been submitted to the Union environment ministry.

Besides import of nuclear fuel and reactors from France, yet another field for possible Indo-French collaboration is that of fast reactor technology. Like India, France chose the closed fuel cycle at the beginning of its nuclear programme. This was based on the philosophy of recovering the uranium (up to 30 per cent more energy can be extracted) and plutonium in spent fuel through reprocessing and thereby reducing the volume of high level waste for disposal. To this end, the reprocessing plant was set up at Normandy. It is able to extract 99.9 per cent of the plutonium and uranium for recycling, leaving 3 per cent of the used fuel as high level wastes which are vitrified and stored under water for later disposal. 8.5 tons of plutonium and 810 tons of reprocessed uranium are recovered each year from 850 tons of spent fuel that is treated at the plant. The plutonium is fabricated into MOX fuel which is currently being used in about 20 of the 900 MWe reactors. The reprocessed uranium is converted into U3O8 for interim storage or to UF6 for re-enrichment in the centrifuge facilities. With these arrangements working well, EdF claims that 20 per cent of its electricity is now produced from recycled materials.[98] Meanwhile, this reprocessing capability has also emerged as a significant export industry for France. Contracts were signed in 2006 with Japanese utilities for MOX fuel and in 2008 AREVA was reported to have about 30t/yr in export contracts for MOX fuel.

[98] World Nuclear Association, *Nuclear Power in France*, May 2009.

CEA has traditionally had an interest in fast reactors on the grounds that they produce less waste and better exploit uranium resources. Given that France has a huge stockpile of depleted uranium and some reprocessed uranium, the interest in fast reactors is understandable. Two significant breeders have been built in France. The first of these was the 233 MWe Phenix reactor which started operation in 1974, shut down for modification between 1998-2003 and then returned into operation at 140MWe. However, it ceased power generation in March 2009 and continues now only in test operation and for research programmes run by the CEA. The Super-Phenix, a 1200 MWe fast reactor was started up in 1996 but closed down within two years due to political reasons.

France has been pursuing the Generation IV sodium cooled fast reactors and in this draws upon its experience from the Phenix and Superphenix reactors that it operated for a while during the 1980s and 1990s. A prototype of the sodium cooled fast reactor is estimated for start up by 2020. This is expected to improve the efficiency, competitiveness and safety of this reactor type. Meanwhile, a gas cooled fast reactor is also planned as a parallel alternative option. AREVA and CEA have signed an agreement on initial design studies for a prototype of the fourth generation sodium-cooled fast reactor known as ASTRID. This will allow the French government to decide in 2017 whether to go ahead with the construction of this demonstration facility.[99] This would also help demonstrate advanced recycling processes in order to address the challenge of long-term high level radioactive waste management. The objective of both these research and development exercises is to equip France with at least one type of competitive fast reactor technology that can be ready for industrial deployment and export around 2035-2040.

India is engaged in the building of its 500 MWe Prototype Fast Breeder Reactor at Kalpakkam, which is expected to be operational by 2011-2012. This reactor technology would take India to the second stage in its three-stage power programme with a closed fuel cycle. The third stage will involve reactors designed for use of local and plentiful thorium reserves.

[99] CEA – AREVA Press Release on agreement to collaborate on the design of the Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID), available on their websites, 09 November 2010.

Both countries could share their experiences in this field to further improve commercial performance of the fast reactors. However, there could also be a chance for competition between India and France in this field in case the commercial viability and hence exports of fast breeder reactors become a possibility in the future.

Tabular Comparison of French and Indian nuclear programmes

Parameter	**France**	**India**
No. of reactors (2010)	59	17
Total nuclear generation	63 GWe	4000 MWe
Electricity derived from nuclear energy	78%	3.9%
Total electricity generation	116 GWe	1
Export of nuclear electricity	60-80 kwh	Nil
Per capita electricity consumption	6800kwh	600 kwh

Collaboration on Conclusion of Universal Nuclear Safety Norms

Despite the high level of emphasis on nuclear safety and the need to maintain the highest standards in this field because any mishap in the nuclear industry anywhere in the world could spell doom for the entire industry worldwide, safety rules are generally defined at the national level. This is quite unlike some other equally high risk sectors, for instance the aerospace industry, which has internationally mandated and followed regulations for safety. Given the prospect of nuclear renaissance, a universally accepted regime on nuclear safety regulations would rather help consolidate the industry's gains.

In this context, both India and France have a shared interest in helping frame international nuclear safety regulations. The need to bring some clarity on acceptable safety requirements is critical not only from the viewpoint of the risks inherent in this dual use technology, but also in order to not overly burden the industry with unnecessary safety regulations since that would hamper its cost competitiveness. There are some technological risks that are acceptable and the industry should be universally on the same page on this matter.

A report prepared on the French nuclear industry proposes a national task force to compile best practices in nuclear safety and to balance them with economic costs to arrive at an internationally applied corpus of safety provisions. India could offer to participate in this process or even conduct a similar national exercise and then share the results with France so that both could put out a joint nuclear safety regime for universal acceptance. As a budding nuclear supplier and definitely as a country aiming for rapid nuclear expansion with the help of different nuclear suppliers, it would be in India's interest to push for a universal safety regime. This would also help alleviate some of the concerns that exist with the nuclear plants in Pakistan and China.

Collaboration on Meeting the Challenges of Availability of Skilled Manpower

The shortage of manpower with specialist qualifications to cater to the ambitious expansion plans in the nuclear sector has already been highlighted in chapter 1 of the study. India and France could cooperate in this field at multiple levels such as academic institutions, training centers, industrial level etc. to promote the transfer of skills and training.

Conclusion

The Ambassador of France in India, Jérôme Bonnafont said on the occasion of the 2nd Indo-French Nuclear Industry Business Meet in Mumbai in 2009:

> "France is keen to expand and intensify its partnership with India in basic and applied research, nuclear safety and radiation protection, controlled thermonuclear fusion, fuel supply, fuel cycle and waste management, as well as higher education and training in nuclear sciences and technology. The long relationship between France and India,

> established since the 1950s, has proved to be a model of the kind based on mutual trust and appreciation of the value of the other partner. There is a tremendous potential for further deepening this relationship and both parties recognize the immense opportunities of working together in the civil nuclear field although some specific issues still must be addressed."[100]

As is evident from the above statement and the analysis made in the course of this chapter, the prospects for cooperation between India and France are bright. France is keen to export its nuclear technology and expertise to an India that has just entered the field of international nuclear commerce. India, on the other hand, with a fast growing economy is eager to invest in infrastructure for sustainable socio-economic development. The country is eager to dip into the French nuclear kitty in order to meet energy generation projections that estimate the need for electricity supply to grow from the present-day 151 GW to nearly 800 GW by 2030.

The advantage of its civilian nuclear cooperation with France is that it has the ability to offer the entire range of services to India – from constructing the nuclear plant to providing it with lifetime supplies of fuel through its own infrastructure. At the same time, the bilateral cooperation agreement also allows India to reprocess the spent fuel obtained from such reactors built by the French. More importantly, the tie-ups between the Indian and French manufacturing industries allow India to reap the benefit of French quality at Indian prices. Jobs are created in the Indian market and overall this could contribute to an increase of public support for nuclear energy. The emergence of India as a possible nuclear manufacturing hub would not only be a boon for the domestic nuclear programme but also help India to position itself as a meaningful nuclear supplier.

Both countries also share common cause in reinforcing national and international approaches to nuclear safety and non-proliferation. For the growth of a safe and responsible nuclear industry, it is important that safety regulations are accorded the highest importance and the risks of nuclear proliferation are minimized. The French nuclear exports can boom only when these two conditions are met. In the case of India too, the promise of nuclear energy for

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[100] Jérôme Bonnafont, "Foreword", in PricewaterhouseCoopers report, "Opportunities and Challenges for Indo-French Cooperation in Nuclear Power", http://www.pwc.com/india, downloaded 04 September 2010.

large-scale electricity generation can be realized only if safety is ensured. Any accident in a nuclear utility is certain to spell the doom of the national nuclear enterprise. Therefore, it is in the interest of both nations to press for acceptance of international nuclear safety best practices.

Moreover, owing to a long history of cooperation, bilateral meetings etc., both sides have a good mutual understanding of each other's political system, working methods and industry practices. In the nuclear sector, they share similarities such as a strong role of the government and similarity in fuel cycles. Overlapping interests have offered an opportunity to India and France to carve out a productive and constructive nuclear engagement based on a history of a cordial and supportive relationship in the past.

4 CONCLUSION – DRAWING LESSONS FOR INDIA

The pursuit of a resolute and consistent energy policy has enabled France to emerge as a leader in nuclear electricity production. It has not only managed to satisfy the electricity needs for domestic consumption but also made nuclear energy an export item for the country. Besides, with an overall expertise of the entire nuclear fuel cycle, France is also well placed to exploit the possibility of a global nuclear renaissance. In fact, over the last few years, the government of President Sarkozy has taken several steps to support the French nuclear industry to position itself better in the field of international nuclear commerce.

Of course, the growth of the nuclear sector in France has not been without its challenges and share of criticism. As opined by a scholar, "France has demonstrated that nations can successfully address their energy vulnerabilities, but its example also demonstrates that no energy option will be the cheapest, cleanest, and safest."[101] Aspersions have been cast on the economics of nuclear power and its claims at being environmentally friendly.[102] Several have even questioned the manner in which the programme has been pursued without any meaningful public scrutiny.

Both, for its successes and its criticisms, the French nuclear energy experience holds several lessons for nuclear power programmes elsewhere. This chapter derives some of them that are of special relevance for India at this juncture when the latter is poised to undertake a rapid and large-scale expansion of its nuclear programme. According to the projections of the Indian Planning Commission, India will need three to four times more electricity generation capacity in the next two decades compared to what it has today. Nuclear power has been envisaged as an important contributor to the country's future energy mix. The NPCIL has plans for construction of eight PHWRs of 700 MW capacity each based on indigenous technology, four FBRs of 500 MW also based on indigenous technology, and six large capacity LWR parks to be set up with foreign collaboration to make a total of 63 GWe from nuclear generation by 2031-32. Interestingly, this is the exact share of nuclear electricity in the French electricity production today.

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[101] Kurt Zenz House, "In Praise and Fear of France's Energy Policy", *Bulletin of Atomic Scientists*, 29 July 2008.
[102] For more on this, see chapter 2 of this study.

For India's ambitious nuclear plans to materialize, the country will have to take several steps at home as well as engage with foreign suppliers to make the most of the opening it has achieved with the waiver granted by the NSG in 2008. In fact, the articulation of an active policy to support development of the indigenous industry will also indirectly enable international cooperation. For instance, costs of nuclear power, especially developed with a foreign partner, can be lowered by localization of the nuclear supply chain and technology transfer. But for this the local industry may need to be supported through fiscal concessions, simplified regulatory and administrative processes etc. According to the IAEA Nuclear Technology Review, the national support for nuclear development and India's Public Acceptance Index shows an increase in support from below 60 per cent in 2005 to nearly 90 per cent in 2008.[103]

As India embarks on exploiting this favourable domestic and international environment it can learn from the experiences of some of the other states who have developed large nuclear generation programmes. France stands out in this category and it will be an important partner in India's nuclear expansion plans owing to its ability to provide fuel and reactors. In fact, to begin with, two major similarities in the nuclear programmes of the two countries can be highlighted. The first of these is their completeness of scope and mastery over the entire nuclear fuel cycle. From the front end to the back end activities, both nations have indigenous capability at every level of nuclear activity. Secondly, both programmes have been supported by a long-term vision and staunch government commitment. They have weathered changes in political leadership but the focus on nuclear power has been maintained. This, in the case of France, has been enabled by the presence of the *Corps des Mines* (as explained in chapter 2) and in India because of the faith in and commitment to the long-term vision of nuclear power elaborated by Homi Bhabha right at the outset of the programme.

Lessons for India

Perhaps the most important lesson to be drawn from the French nuclear energy experience pertains to the importance of energy security for a nation. The oil shock in the early

[103] IAEA Nuclear Technology Review 2009 as cited in PricewaterhouseCoopers report, , "Opportunities and Challenges for Indo-French Cooperation in Nuclear Power", http://www.pwc.com/india, downloaded 04 Sept 2010, p. 14.

1970s awakened France to its high level of energy vulnerability owing to the large-scale dependence on fuel imports. The government was then jolted into finding ways of securing energy independence and turned to nuclear power. For India, a country that faces a huge energy deficit, low domestic availability of fuel, but which today has nearly 300 reactor years of operating experience in nuclear power, the option of nuclear electricity is particularly relevant. While nuclear power cannot be expected to completely bridge the energy shortfall, it can make a substantive contribution to overall energy production and in an environmentally sustainable manner. Energy security is essential for overall national security and India cannot afford to be lax on this front. It must learn the pitfalls of energy vulnerability from the French experience of the 1970s and build adequate safeguards for itself.

Second, it is almost ironical that France, which turned to nuclear energy as a solution for securing its energy independence after the experience of the oil crisis that had exposed its energy vulnerabilities, has today a nearly 80 per cent dependence on nuclear energy. With such a high level of dependence on only one energy source, the country seems to have fallen into the same trap once again. This makes it overly vulnerable to the shutdown of reactors since the loss of generation from one or more high capacity reactors threatens major loss of energy production. In recent times, such a situation was faced by the country in the summer of 2009 when the heat wave, a strike by power workers and ongoing repairs at some units put a third of French nuclear power stations out of action and the country was forced to import electricity from the UK.[104] The lesson here for India then is that it must develop as diversified an energy mix as it can. In any case, given the huge energy demands of the rapidly developing nation, the country cannot afford the luxury of depending on only one source of energy. It needs to tap every fuel source including placing a heavy emphasis on energy efficiency and conservation. Only then can the country assure itself of true energy security. Even within the nuclear power sector one should plan internal diversity in terms of corporate organization structure, technology, redundancy of fuel and other critical supplies etc. now that we expect each individual segment to be large enough to maximize benefits of scale.

[104] Robin Pagnamenta, "France Imports UK Electricity as Plants Shut", *Times Online*, 3 July 2009.

Third, quite like the case in India, nuclear decision-making in France has largely been conducted without any major public scrutiny. While on the one hand, this has allowed a greater degree of consistency and steadiness in French nuclear policy, it has also led to allegations of nuclear power being made viable in the country only through government subsidies. As the Indian nuclear programme undertakes a rapid expansion, it must open itself to a greater amount of transparency so that it can operate in a more democratic fashion and escape or avert potential allegations of commercial non-viability. This is important for the sake of reinforcing public support for the nuclear programme. To its credit, it must be mentioned that the annual reports of the Nuclear Power Corporation of India Ltd (NPCIL) are in the public domain.

The fourth lesson to be derived from the French experience is the need for high public support for the nuclear programme so that it acquires the character of a national venture premised on a broad-based consensus. Only then can issues such as land acquisition, environment impact assessments, which have the potential to become contentious, can be carried out smoothly. In France, for instance, through the period 1970s to 1990s, the nation perceived its nuclear programme as a symbol of national pride and realized its importance as a contributor to energy independence. The French were able to bring about this mindset not only by the safe, consistent and cheap production of nuclear electricity but also through a conscious and well planned education campaign that included encouraging the common man to visit nuclear plants and related industrial facilities. This helped alleviate public fears about nuclear power and reduced the distance between ‘high technology’ and the common man. In order to address the somewhat reduced support for nuclear power in recent times, particularly over the issue of long-term radioactive waste management, it has been recommended that the government should launch a “national programme for energy education” at the school level as well as “to open again to the public nearby power plants and industrial facilities.”[105] In India, the nuclear establishment and decision-making have been largely removed from the general public. Taking a leaf out of the French experience it would be worthwhile for the government to encourage conducted tours of nuclear stations for school and college students, the general public and most importantly for the media. The electronic and print media can prove to be a

[105] Roussely Report, p. 11.

powerful tool for educating and influencing public opinion on the relevance and importance of nuclear power in India's energy scenario.

Fifth, there is no escaping the fact that governments that desire a high nuclear contribution to national electricity supply must themselves play a large role in the exercise. This is required to provide clear and sustained policy support for the development of nuclear power as well as ensuring its public acceptance by explaining the relevance of nuclear power in the country's larger energy mix and its affordability in terms of pricing. The government's commitment to the industry is evident in its efforts to work towards creating an appropriate environment for investment through an effective framework for nuclear insurance and liabilities, including through establishing an efficient and effective regulatory system. It hardly needs to be said that investments in the nuclear domain require huge sunk costs several years before starting a plant, and hence the utilities need to be secure about the long-term policies of the government, including the sensitivity of the regulatory mechanisms to ease the processes of licensing etc. While strict and fair regulatory processes are extremely important, lengthy procedures do increase the capital costs of the plant by delaying the start of operations and increasing the interest charges on investment loans. Inordinate procedural delays imposed by interest groups through public interest litigation can reduce the investment prospects for nuclear plants. For instance, in the US between 1966 and 1970, the time required to complete the regulatory process rose from an average of 86 months to 122 months, and the plant lead time from order to commercial operation rose from 3 to 13 years, both of which led to higher costs of plant construction and lower faith in nuclear energy as a viable source of electricity. The rise of anti-nuclear groups, an indecisive Congress and activist court action were responsible for the near demise of the US nuclear industry, especially after the Three Mile Island nuclear incident in 1979.

Fortunately, in a parliamentary system of government, such as in India and France, the Executive formulates the policy along with his ministers and the Legislature enacts laws to aid the implementation of that policy. Party discipline plays a key role in this political system in determining legislative behaviour and "strong party discipline in conjunction with the same parties in power in the executive and parliamentary branches suggests that conflict between the two branches is rare."[106] However, unlike the French system where the Judiciary has not played a prominent role, in India the Judiciary is an independent and in recent times an increasingly activist branch of the government. As the nuclear activity and infrastructure expands in the country, anti-nuclear groups who enjoy a fair amount of freedom in the democratic system can play upon an active media and Judiciary to sway public perceptions on nuclear power.

However, the Indian system has the ability to avoid the pitfalls of both the American and French systems. While the disadvantage of the French structure, as pointed out by some scholars[107], has been the alienation between the public and the government when a large segment of the population's concerns are not incorporated into policy, the handicap of the American system was too much interference of the public perception and activism through a strong and independent Judiciary and a weak bureaucracy. As is evident, it is necessary to provide for some opportunities for involvement of experts (not just from the government) in the decision-making process so that different perspectives and apprehensions get an airing. This would help build public support for nuclear power in the long run.

Therefore, the role of the government is absolutely critical. It needs to work with transparency, fairness and strictly by the rules of the game. Any inkling of unfairness could lead to a trust deficit in the public and lead to an anti-nuclear sentiment.[108] In contemporary times, when the media maintains a close watch over the government, nuclear policy will not be the domain of only the government. Public perceptions about risks to public health and environment will have to be accounted for and the government would be well advised to launch public awareness campaigns to undertake perception management. Efforts must be made to disseminate facts on the Indian energy situation in general, its linkages with economic and social development, and the specific advantages of nuclear energy in the Indian energy mix. The existential risks in the nuclear sector must be addressed by explaining how the government and the nuclear industry seek to mitigate them.

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[106] Magali Delmas and Bruce Heiman, "Government Credible Commitment to French and American Nuclear Power Industries", *Journal of Policy Analysis and Management*, Vol. 20, No. 3, 2001, p. 440.
[107] *Ibid.*
[108] An example of this was seen in the recent Parliamentary debate on the Civil Nuclear Liability Bill where a part of the bill stapled to the entire document caused a furor and cast doubts on the motive of the government.

Sixth, the government certainly has a role in ensuring the safety of the entire nuclear chain from uranium mining to management of radioactive waste. The ability of the French nuclear programme to avoid any major mishap generated continued support for itself from the government and the public. In India, until now, the government has managed the entire nuclear programme, including operation of nuclear power plants. With the entry of private players envisaged in the future, adequate terms of reference will have to be drawn for optimum public-private partnership with an apt level of investment risk being borne by private sector investors. Therefore, efficient and responsive nuclear governance will be critical for an expanding nuclear programme in India. The country must demand and the nuclear industry must provide the highest standards of nuclear safety if the promise of large-scale generation of nuclear electricity is to be realized.

Seventh, as was pointed out in chapter two of the study, France gained immensely from its decision to standardize its nuclear units. This resulted in a substantive reduction of construction time, increased efficiency of plant management and easy rectification of faults if detected in any one unit. The monopolistic situation in France with one utility, one vendor of nuclear steam supply system, and of turbine generators led to better organization of work across many plants and facilitated easy transmission of lessons learnt. This is not an advantage that the Indian nuclear programme can enjoy given that it has reactors of different capacities, even if a majority of them are PHWRs. In fact, given that the Indian nuclear power programme is envisaged along the three phase route, different type of reactors – technology and fuel composition – is in any case a reality for the nation.

In the future, as the country imports from many suppliers, no standardization, at least of the kind that the French have, would be possible. Rather, working with different partners who may have different approaches to business, different specifications and differing licensing requirements will bring its own difficulties. A multiplicity of players, architects, designs, and vendors will also lead to greater challenges for procurement of spares and maintenance and also result in poor assimilation of lessons from one plant or experience to another. The country will have to cope with this situation. However, some limited benefit of standardization can be achieved if India sticks to building 700 MWe PHWRs as part of its indigenous programme, as has been planned. Also, given that large parks are envisaged for each imported technology, it might be worthwhile considering the desirability of establishing separate organizational entities to deal with individual technologies of which there would be a large number of identical units per site. Such a strategy could lead to enjoying the benefits of standardization at the micro level while gaining from the redundancy provided by non-dependence on one source at the macro level.

Eighth, investment in nuclear R&D is imperative, independent of the ongoing construction and operation of nuclear plants. Despite the successful running of its nuclear stations, the major players in the French nuclear industry never gave up the focus on R&D and thus were able to graduate to newer generations of reactors. R&D, in fact, is needed in all domains of nuclear activity including in pure sciences such as nuclear physics, materials, chemistry etc. as also in the engineering processes involving use of heavy equipment, hot labs and sophisticated measuring devices, safe reprocessing and waste management etc. For India, this aspect is of particular significance. At the time of the negotiations over the Indo-US civilian nuclear cooperation agreement, several had opined that with the ability of the country to import sophisticated nuclear reactors, the Indian nuclear establishment would lose its motivation and momentum on indigenous R&D. This, however, cannot be afforded and must not be allowed to happen. If India is to graduate to the third stage of the thorium cycle, then the necessary budgetary and human resource investment in relevant research and development activities cannot be allowed to be diluted.

Ninth, a consistent availability of skilled and trained manpower is essential for the nuclear sector. As generations of technicians, engineers and researchers who joined the nuclear industry at the time of major construction activity retire, replacements have to be systematically planned to preserve the knowledge and know-how as well as work on new designs. In the case of the French nuclear industry, a recent report cautions, “The management, maintenance and development of skills of all employees of the French nuclear industry are critical to meet the challenges and ambitions of France in the nuclear field. The efforts made by the French education system are not yet up to the challenge. This statement refers both to the number of people trained and the range of courses covered.” This is equally true for India. As the country embarks on a rapid expansion of its nuclear power programme, more skilled and trained manpower will be needed at every level. Given the specialized nature of this industry, the pool of skilled workmen can only be built over a period of time and through a conscious effort in that direction. Hence there is a case for a coordinated action plan that involves all stakeholders – the government, industry and the education system – to meet this challenge.

Tenth, an effort is required to deal with the problem of nuclear waste. France confronted this problem after twenty years of large-scale energy generation. But, it has become an issue important enough today to bring about a dip in public support for nuclear power. If India is to avoid this, serious thinking on the selection of site and construction of geological repository to house high level, long-term waste must begin now in order to reassure the public on this important matter. And public support will depend upon transparency and education programmes in this field.

Lastly, it needs to be said that every nation has to address its energy vulnerabilities by finding its own answers and the best trade-offs. While coal is cheap and easy to use, it is environmentally the most unfriendly; solar and wind are expensive and intermittent but clean; nuclear power is capable of large scale use, relatively cheap and carbon-free but waste management and storage as also proliferation risks have to be taken into account. A coherent energy policy must take all these aspects into the picture to craft a holistic approach towards assuring energy security. The main elements of such a policy would need broader dissemination of the facts to the general and discerning public to encourage their acceptance and support.

For India, which requires nothing less than an energy revolution to meet the projected electricity demand in the next couple of decades, there is a strong case for careful planning in the determination of the future energy mix. A continued demographic growth, rising aspirations of a young and demanding populace, lack of indigenous fuel resources, mounting proof of climate change requiring GHG reductions are challenges that call for a long-term vision and commitment. Five decades ago Homi Bhabha had stated “No power is costlier than no power”. This is more true today than ever before since an electricity shortfall that hamstrings the economic growth and development of the country would indeed prove to be extremely costly not just in economic but also in social developmental goals.

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