## CHAPTER 3

# NUCLEAR POWER IN INDIA: FAILED PAST, DUBIOUS FUTURE

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The general assumption underlying the July 2005 agreement signed by President George Bush and Prime Minister Manmohan Singh seems to be that nuclear power will be an important component of India's energy future. As we shall show both by examining the history and performance of the Indian nuclear power program so far and analyzing problems with some of the plans for its growth, nuclear power in India has not been and will not be a major source of power for many decades at least, if even then. The negative consequences far outweigh any energy benefits that may accrue from a larger nuclear sector in India.

## INITIATION

The Indian nuclear program was established in 1948, barely a few months after independence. The main personalities involved in determining its contours were Jawaharlal Nehru, the first Prime Minister of India; and Homi Bhabha, a physicist who first made his mark as a student at Cambridge University in the United Kingdom (UK). Nehru was of the view that if India had "to remain abreast of the world, [it] must develop this atomic energy" and was therefore very supportive of Bhabha's plans for nuclear energy in India.

The legislative bill enabling the creation of the Atomic Energy Commission (AEC), the apex body in charge of nuclear policy in India, made atomic energy the exclusive responsibility of the state and allowed for a thick layer of secrecy.[1] Nehru gave two reasons, both somewhat disingenuous, for the imposition of secrecy. "The advantage of our research would go to others before we even reaped it, and secondly, it would become impossible for us to cooperate with any country which is prepared to cooperate with us in this matter, because it will not be prepared for the results of researches to become public."

There was some criticism of the secrecy provisions in the assembly as Nehru introduced the bill. One member, Krishnamurthy Rao, compared the bill with the British and American acts and pointed out that the bill did not have mechanisms for oversight, checks, and balances as the U.S. Atomic Energy Act. Further, in the bill passed in the UK, secrecy is restricted only to defense purposes, and Rao asked if, in India, secrecy would be extended also to research for peaceful purposes. Though it may seem surprising for someone who has spoken so eloquently against nuclear weapons, Nehru had to confess: "I do not know how to distinguish the two [peaceful and defense purposes]." Nehru's dilemma is clear from his statements while introducing the bill. On the one hand, he said "I think we must develop it for peaceful purposes." But he went on, "Of course, if we are compelled as a nation to use it for other purposes, possibly no pious sentiments will stop the nation from using it that way."

The connection between developing nuclear energy and acquiring the capacity to build nuclear weapons was clear to Nehru as it was to many of the scientists and statesmen of that period. Indeed, it was perhaps more apparent then, in the immediate aftermath of the U.S. bombing of Hiroshima and Nagasaki, than today. Those developing the Indian nuclear program were no exception, and their plans accounted for the possibility that the facilities constructed and expertise gained could be used for military purposes.

## ORGANIZATIONS AND STRUCTURE

The nuclear establishment in India enjoys unique access to political authority and is protected from external oversight. Unlike most policy matters where the cabinet has the ultimate authority, the AEC is under the direct charge of the Prime Minister. This structure makes it difficult for most politicians or bureaucrats, let alone the public, to challenge nuclear policies or practices.

The role of the AEC is to formulate the policies and programs. The actual execution of these policies is carried out by the Department of Atomic Energy (DAE), which was set up in 1954. The DAE has set up a number of associated or subsidiary organizations. These include five research centers, five government-owned companies ("public sector enterprises"), three industrial organizations, and three service organizations.

Among government-owned companies, the Nuclear Power Corporation is responsible for designing, constructing, and operating the nuclear power plants within the first stage nuclear power program (i.e., not breeder reactors, which are the responsibility of another government-owned company called BHAVINI), and the Uranium Corporation of India Limited is in charge of mining and milling of uranium. Industrial organizations include the Heavy Water Board, in charge of the many plants that produce heavy water; and the Nuclear Fuel Complex, which manufactures the fuel for the nuclear reactors. The best known research centers are the Bhabha Atomic Research Centre (BARC), the most important facility involved in nuclear weapons research; and the Indira Gandhi Centre for Atomic Research, where the breeder program was cultivated.

For a long time, the DAE did not have a separate safety division. It was only in 1972 that the DAE constituted an internal Safety Review Committee. In 1983, the Atomic Energy Regulatory Board (AERB) was set up to oversee and enforce safety in *all* nuclear operations. This was modified in 2000 to exclude nuclear weapons facilities.

The AERB reports to the AEC, which is headed by the head of the DAE. The Chairman of the Nuclear Power Corporation (NPC) is also a member of the AEC. Thus, both the DAE and the NPC exercise administrative powers over the AERB. This lack of independence is in direct contravention of the international Convention on Nuclear Safety, of which India is a signatory.

## EXTERNAL INPUTS

Despite much rhetoric about self reliance and indigenous development, the AEC sought and received ample help from other countries. In June 1954, Bhabha requested Sir John Cockroft, an important figure in the British atomic program and a colleague of Bhabha's during his Cambridge days, to help India build a low power research reactor. A few months later Cockroft offered detailed engineering drawings, technical data, and enriched uranium fuel rods for a "swimming pool reactor." The AEC accepted with alacrity and the first "indigenous" reactor, Apsara, became critical in August 1956.

The second reactor to be set up was CIRUS—a 40 megawatt (MW) heavy water moderated, light water cooled, natural uranium fueled reactor using the same design as the Canadian NRX reactor. This deal involved another former Cambridge contemporary of Bhabha's, W. Bennett Lewis, then a senior official with Atomic Energy of Canada. It was supplied by Canada as part of its Colombo plan—a plan that was, in the words of Robert Bothwell, "premised on the relation between misery and poverty and communism." The occasion for the announcement of the gift was the 1955 Geneva conference on the peaceful uses of atomic energy. Based on the 1953 Atoms for Peace speech by President Dwight D. Eisenhower, the conference was the scene of much cold war-era maneuvering, as well as an opportunity for countries to exhibit their nuclear wares and woo potential customers.

A few Canadian diplomats realized that this could lead to potential acquisition of weapons useable plutonium by India. The NRX reactor was known to be an efficient producer of plutonium because of its high neutron economy. Nevertheless, the initiative went through because it was assumed that India would be able to acquire a reactor from some other source. Despite consistent efforts on the part of the Canadians, India, led by Bhabha, adamantly refused to accept any kind of voluntary controls or safeguards on the spent fuel produced.

When it suited his purposes, however, Bhabha did accept safeguards. Examples of this are the reactors at Tarapur (TAPS I and II) and Rawatbhata (RAPS I and II). Bhabha's speech in 1956 at a conference on the International Atomic Energy Agency's (IAEA) statute makes clear the strategy he adopted. Bhabha said,

> [T]here are many states, technically advanced, which may undertake with Agency aid, fulfilling all the present safeguards, but in addition run their own parallel programs independently of the Agency in which they could use the experience and know-how obtained in Agency-aided projects, without being subject in any way to the system of safeguards.

The construction of CIRUS also required help from the United States, which supplied the heavy water needed for the reactor. Likewise, it was an American firm, Vitro International, which was awarded the contract to prepare blueprints for the first reprocessing plant at Trombay. The plant was used to separate plutonium from the spent fuel rods irradiated at the CIRUS reactor; the plutonium was then used in India's first nuclear weapons test of 1974. Between 1955 and 1974, 1,104 Indian scientists were sent to various U.S. facilities; 263 were trained at Canadian facilities prior to 1971.[2]

Despite India terming the test a "Peaceful Nuclear Explosion" and launching a diplomatic offensive trying to prove that it was indeed peaceful, the 1974 test ended the period of extensive foreign support to the nuclear program. The international community, led by Canada and the United States, which were incensed by India's use of plutonium from CIRUS that had been given to India for purely peaceful purposes, cut off most material transfers relating to the nuclear program. It also resulted in the setting up of nuclear material multilateral control regimes. However, a little advertised fact is that various nuclear facilities still procured components from abroad, and foreign consultants continued to be hired for Indian nuclear projects, though only to a small extent. DAE personnel still had access to nuclear literature and participated in international conferences where technical details were discussed freely.

## PROJECTIONS AND ACHIEVEMENTS

From the very beginning, plans for the Indian nuclear program were ambitious and envisaged covering the entire nuclear fuel cycle. Over the years, apart from nuclear reactors, India also developed facilities for mining uranium, fabricating fuel, manufacturing heavy water, reprocessing spent fuel to extract plutonium and, on a somewhat limited scale, enriching uranium. Investment in this wide range of activities often was uneconomical. But it was justified on the grounds of self-sufficiency, a theme popular in India.

The other justification often offered was a grand three-stage program, first announced in 1954, for the development of nuclear energy in the country. The three-stage program was, for example, the proffered justification for the early acquisition of reprocessing technology. The first stage of the three-phase strategy involves the use of uranium fuel in heavy water reactors, followed by reprocessing the irradiated spent fuel to extract plutonium. In the second stage, the plutonium from reprocessed spent fuel from pressurized heavy water reactors (PHWR) is used in the nuclear cores of fast breeder reactors. These nuclear cores could be surrounded by a "blanket" of either depleted uranium or thorium to produce more plutonium or uranium-233 respectively. So to ensure that there is adequate plutonium to fuel these second stage breeder reactors, a sufficiently large fleet of such breeder reactors with uranium blankets would have to be commissioned before thorium blankets are introduced. The third stage involves breeder reactors using uranium-233 in their cores and thorium in their blankets.

On the basis of this plan and assuming optimistic development times, Bhabha announced that there would be 8,000 MW of nuclear power in the country by 1980. As the years progressed, these predictions were to increase. By 1962, the prediction was that nuclear energy would generate 20-25,000 MW by 1987, and by 1969, the AEC predicted that by 2000 there would be 43,500 MW of nuclear generating capacity. All of this was before a single unit of nuclear electricity was produced in the country.

Reality was quite different. Installed capacity in 1979-80 was about 600 MW, about 950 MW in 1987, and 2720 MW in 2000. The only explanation that the AEC has offered for its failures has been to blame the cessation of foreign cooperation following the 1974 nuclear weapons test. At the same time, these sanctions also provided the DAE with an opportunity: Each development, no matter how small or routine, could be portrayed as a heroic success, achieved in the face of staunch opposition by other countries and impossible odds; while any failures could be passed off as a result of the determination of other countries to block and prevent India achieving technological advancement.

Such continued failures were not because of a paucity of resources. Practically all governments have favored nuclear energy, and the DAE's budgets have always been high. The only period when the DAE did not get all that it asked for (and therefore considers the dark years) were the early 1990s, a period marked by cutbacks on government spending as part of an effort at economic liberalization. But this trend was reversed with the 1998 nuclear weapons tests; since then the DAE's budget has increased from Rs. 18.4 billions in

1997-98 to Rs. 55 billions in 2006-07, i.e., more than doubled even in real terms.[3]

The high allocations for the DAE have come at the cost of promoting other, more sustainable, sources of power. In 2002-03, for example, the DAE was allocated Rs. 33.5 billions, dwarfing in comparison the Rs. 4.7 billions allocated to the Ministry of Non-conventional Energy Sources (MNES), which is in charge of developing solar, wind, small hydro, and biomass-based power. Despite the smaller allocations, installed capacity of these sources was 4,800 MW (as compared to 3,310 MW of nuclear energy). While their contribution to actual electricity generated would be smaller since these are intermittent sources of power, they have much lower operations and maintenance costs. Further, most of these programs, like the wind energy program, started in earnest only in the last decade or two, and there is ample scope for improvement.

Today, notwithstanding over 5 decades of sustained and lavish government support, nuclear power amounts to just 3,310 MW, less than 3 percent of the country's total electricity generation capacity. Over the next few years, this capacity is to increase, largely because of the importation of two 1,000 MW reactors from Russia. The DAE has only just started operating a reactor not fully based on an imported design, a 540 MW heavy water reactor, which is scaled up from the design of the 220 MW reactor that was imported from Canada.

Despite this less than modest history and the hand wringing about international sanctions, the DAE has continued to make extravagant predictions. The current projections are for 20,000 MW by the year 2020 and for 207,000 to 275,000 MW by the year 2052. The likelihood of these goals being met is slim at best. But even if they are met, nuclear power would still contribute only about 8-10 percent of the projected electricity capacity in 2020, and about 20 percent in 2052. There is thus little chance of nuclear electricity becoming a significant source of power for India anytime over the next several decades.

## BREEDER REACTORS

One key element in the DAE's plans for the future of nuclear power in India is a large number of breeder reactors. While country after country has abandoned breeder reactors as unsafe and uneconomical, the DAE stubbornly has been ploughing a lone furrow, heroically in its own eyes as well as in the eyes of the handful of breeder enthusiasts elsewhere, but needlessly by most other counts. Reliance on an unproven technology, or more precisely a technology shown to be unreliable in most countries that have experimented with it, is another strategy that makes it likely that nuclear power will never become a major source of electricity in India.

Despite grand pronouncements for 5 decades about the three stage nuclear program where the second and third stages involve breeder reactors, all that the DAE has to show is a pilot scale Fast Breeder Test Reactor (FBTR). The DAE has claimed that the "technology for design, construction and operation of FBRs has been demonstrated at Kalpakkam with the establishment of the IGCAR, where over the past 25 years, a 40 megawatt thermal (MWt)/13 megawatt electric (MWe) FBTR and various research and development laboratories . . . have been set up." However, the FBTR has not been easy to build or operate, and the experience with it has only demonstrated how difficult breeder reactor technology is. Neither has it ever operated at the advertised 40 MWt; the best it has managed is 17.5 MWt (2.8 MWe), and that well over a decade after criticality.

Work on the FBTR started in 1971, and it was anticipated that the reactor would be commissioned in 1976. But the reactor attained criticality only in October 1985, at a fraction of the original design power. Since it was commissioned, the FBTR suffered numerous accidents and component failures. Some of the incidents and accidents involving the FBTR during just the first 5 years include the following:

- In 1987, there was leakage of Nitrogen in the flanges/valves of the preheating. Later that year "a complex mechanical interaction due to fuel handling error in the reactor damaged certain 'in-vessel' components." This took 2 years to rectify.
- In September 1988, problems of failure of the cores of the trailing cables were noticed during the process of retrieval of damaged sub-assemblies in the reactor.
- In February 1989, the load cell failed, and the Capsule Transfer Gripper (CTG) got damaged. This was rectified in April 1989.
- In July 1989, the reactor was shut down as the desired availability factor could not be achieved due to noise pick-up by the reactor protection logic and unsatisfactory operation of speed control system for primary sodium pumps.
- In November 1989, due to certain construction deficiencies, interference of the hangers with the complimentary shielding was observed in the primary sodium system.

The litany of accidents and incidents continued through the 1990s. It was only in 2000 that the FBTR even managed to operate continuously for 53 days.

On the basis of this experience, spotty at best, the DAE has started to build a 1,250 MWt breeder, the Prototype Fast Breeder Reactor (PFBR), scaling up the FBTR by a factor of about 70. Instead of the carbide fuel used in the FBTR, the PFBR will use plutonium and uranium oxide based fuel that the DAE has no experience with. All of this adds up to a recipe for cost and time overruns, as well as operational difficulties, with the PFBR.

The PFBR has been talked about for a long time. Plans have been made beginning over 2 decades ago. The first expenditures on the PFBR were made in 1987-88. In 1990, it was reported that the government had "recently approved the reactor's preliminary design and has awarded construction permits" and that the reactor would be on line by 2000. In 2001, the chairman of the AEC announced that the PFBR would be commissioned by 2008. Construction of the reactor finally was started in October 2004 and is now expected to be commissioned in 2010. There already may have been a further setback due to the disastrous tsunami of December 2004. Given that even the second stage of the three-stage nuclear program is yet to start, more than 50 years after the initial announcement, the third-stage—breeders involving thorium and uranium-233—is unlikely to materialize anytime in the foreseeable future.

Such delays may well be a blessing in disguise. Both safety and economical arguments weigh against breeder reactors. There are several reasons why accidents involving fast breeders are both more likely and could cause greater damage to public health than other power generation systems. One problem arises from the use of liquid (molten) sodium to transport heat from the reactor core. Sodium is highly reactive; it burns when exposed to air and reacts violently with water. Therefore there are risks associated with leaks, sodium fires, and explosive steam-sodium interactions.

Unlike small test reactors (such as the FBTR), large fast breeder reactors often have what is called a positive sodium void coefficient. What this means is that if for some reason the sodium were to heat up and vaporize, then it would increase the reactivity of the core of the reactor. If the operating system failed to insert control rods fast enough, the increased reactivity would, in turn, heat up the sodium further; this chain could ultimately cause a fuel meltdown into a supercritical configuration and a small nuclear explosion.

Another problem arises from the use of mixed oxide fuel (MOX) in the PFBR. Because the fuel contains plutonium that is about 30,000 times more radioactive than uranium-235, there are more severe health effects coming from exposure (especially through inhalation) to this fuel. Further, the spent fuel from FBR typically has a greater buildup of highly radioactive fission products. Thus, the impacts of a full-scale (beyond design basis) accident would be much more severe than in a light water or heavy water reactor.

The plutonium or uranium-233 (derived from thorium) that provides the basic fissile material required to drive the reactor is extracted by chemically treating highly radioactive spent fuel at reprocessing plants, producing large quantities of radioactive wastes during the process. Reprocessing is also prone to accidents. Indeed, it was an accident at the Kalpakkam Reprocessing Plant on January 21, 2003, when six workers were exposed to dangerously high levels of radiation, that has been described by the director of the Bhabha Atomic Research Centre as "the worst accident in radiation exposure in the history of nuclear India."

Reprocessing is also expensive. Based on the budgets allotted to the most recently constructed reprocessing plant at Kalpakkam, which is to serve as a standard design for future plants, we estimate that the cost of reprocessing each kilogram of spent fuel would be approximately Rs. 26,000 (approx. $600) with assumptions favourable to reprocessing, and close to Rs. 30,000 (approximately $675) under other assumptions.[4] These costs are lower than the corresponding figures for reprocessing plants in Europe, the United States, and Japan. As in their case, however, it is unlikely to be an economically viable method of waste disposal.

Since the fuel for breeder reactors is obtained through reprocessing, it will increase the costs of producing electricity at these reactors. There are further reasons to expect that electricity from breeder reactors will be very expensive. First, due to greater safety requirements, breeder reactors tend to cost more to construct than water moderated thermal reactors. The same also goes for associated fuel fabrication plants. Finally, as mentioned earlier, these reactors use molten sodium as coolant. Sodium is opaque and cannot be exposed to air or water. Hence, operating such reactors requires extensive precautions and even minor maintenance tasks become difficult. Thus, in comprison with other reactors, breeders will be capital-intensive, be fuelled at greater expense, and will have higher operations and maintenance costs, all of which will make electricity from these reactors costly.

## EXPENSIVE POWER

Though perhaps not as costly as electricity from breeder reactors, electricity from the DAE's existing reactors has not been cheap either, especially in comparison with the staple source of electricity in India, namely coal-based thermal power. Since nuclear reactors clearly were much more expensive than thermal plants, the DAE's strategy was to compare nuclear power costs with thermal power plants that were situated far away from coal mines, thereby increasing the transport cost of coal and thus the fuelling costs of thermal power.

In 1958, Bhabha projected "the contribution of atomic energy to the power production in India during the *next 10 to 15 years*" and concluded that "the costs of [nuclear] power [would] compare *very favourably* with the cost of power from conventional sources in many areas" (emphases added). The "many areas" referred to regions that were remote from coalfields, which was estimated as 600 kilometers (km) in the early days. By the 1980s the DAE had changed this distance and stated that the cost of nuclear power "compares quite favourably with coal-fired stations located 800 km away from the pithead and in the 1990s would be even cheaper than coal fired stations at pithead." This projection was not fulfilled, and a 1999 NPC internal study came to the less optimistic conclusion that the "cost of nuclear electricity generation in India remains competitive with thermal [electricity] for plants located about 1,200 km away from coal pit head, when full credit is given to long-term operating cost, especially in respect of fuel prices."

Even this claim does not stand up to analysis. The costs of generating electricity at the Kaiga atomic power station and the Raichur Thermal Power Station (RTPS) VII—both plants of similar size and vintage—have been compared using the standard discounted cash flow methodology.[5] The coal for RTPS VII was assumed to come from mines that were 1,400 km away. The nuclear reactors were assumed to have an economic lifetime of 40 years (as against a much longer radioactive lifetime), but the coal plants were assumed to have an economic lifetime of only 30 years. The comparison showed that nuclear power would be competitive only with unrealistic assumptions; for a wide range of realistic parameters, nuclear power is significantly more expensive. These results are summarized in Figure 1, which shows levelized cost (the bare generation cost which does not include other components of electricity tariff like interest payments and transmission and distribution charges) of Kaiga I and II (operating nuclear reactors), Kaiga III and IV (nuclear reactors under construction; projected costs), and the Raichur VII (operating coal fueled thermal plant) as a function of the real discount rate (a measure of the value of capital after taking out the effects of inflation) at 80 percent Capacity Factor.

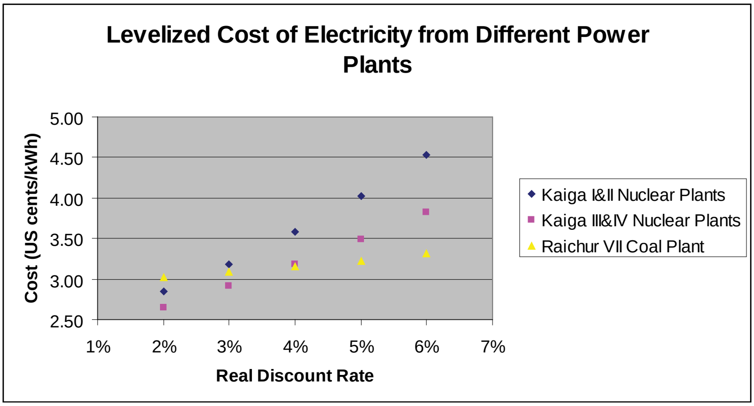


**Figure 1. Levelized Cost of Electricity from Different Power Plants.**

One particularly key variable is the discount rate, a measure of the value of capital. Nuclear power, because of its capital intensive nature, is competitive only for low discount rates. In a country where there are multiple demands on capital for infrastructural projects, including for electricity generation, such low discount rates are not realistic. The electricity sector in India, as elsewhere, is being reorganized to make it more economically viable. The 2003 national Electricity Act emphasizes competition as the basis for energy policy. The nuclear establishment has so far managed not to be put to the economic test, but this state of affairs could change.

This economic comparison is based largely on assumptions favorable to nuclear power. In particular, following the methodology adopted by the DAE, we have not included the costs of dealing with radioactive wastes from nuclear power. Since there is no credible solution to the problem of radioactive waste, the best that can be done is short-term management. The DAE treats spent nuclear fuel by reprocessing it and segregating the waste into different categories on the basis of their radioactivity. As mentioned earlier, reprocessing is expensive. If our estimate of the cost of reprocessing in India is included in the tariff for nuclear power, it would increase the unit cost by roughly 1 percent. This would make it even more expensive than thermal power from coal.

Neither does the comparison include any provision for insurance liability against accidents since the government has not required that of nuclear power plants. In the United States, private companies considering the construction of nuclear reactors were concerned that such an accident would likely bankrupt them and tried to get insurance coverage. No insurance company was willing to take on the risk of indemnifying against such a huge liability, nor could they commit to pay beyond their own resources. The U.S. Congress had to introduce the Price-Anderson act that allowed the Government to act as the ultimate insurer, offering in essence a subsidy to the nuclear industry. Such subsidies are not included in the quoted economic costs of nuclear power.

In India, the assumption seems to be that in the event of an accident, the government would deal with the consequences. There is not even the minimal insurance requirement that the Price-Anderson act imposes upon nuclear utilities. Including those requirements would only make nuclear power even less economical in India. However, this is, in part, the result of the NPC being a government-owned company. It is by no means clear what would happen if private companies were to start building or operating nuclear reactors.

## ACCIDENTS AND INCIDENTS

There is reason, though, to be concerned about the safety of the DAE's reactors. Practically all the nuclear reactors and other facilities associated with the nuclear fuel cycle operated by the DAE have had accidents of varying severity. Other facilities associated with the nuclear fuel cycle also have had accidents. These are euphemistically described as incidents by nuclear establishments around the world in order to mollify justified public concerns. One can barely imagine the consequences of a Chernobyl-like accident involving the release of large quantities of radioactive materials in a densely populated country like India.

The observed safety problems seem to be systemic. In 1995 the AERB, which is supposed to oversee the safe operation of all civilian nuclear facilities, produced a detailed report that identified 134 safety issues, of which about 95 were considered "top priority." It is of greater concern that many of these problems had been identified in earlier DAE evaluations in 1979 and 1987 as items requiring "urgent action" but had not been addressed. Not surprisingly, the DAE has kept the AERB report a secret. Even now, not all of these safety issues have been addressed.

The most serious of the accidents at a nuclear reactor in India occurred on March 31, 1993, when two blades in the turbine generator of the first unit of the Narora Atomic Power Station snapped under accumulated stress and caused a major fire in the turbine room, nullifying all electrical safety systems. What saved the reactor from a potential meltdown was the timely action of some technicians, who flooded the reactor with a solution containing boron, a neutron absorber. This was considered "a last-level protection in the event of a prolonged station power blackout."

What is really cause for concern in the case of the Narora accident is that it came after the DAE had been warned by the manufacturer of the turbine blades that they were susceptible to fatigue failure. But the DAE ignored the warning. Further, at least two of the DAE's reactors had experienced major fires in the preceding decade: the Rajasthan 2 reactor in 1985 and the Kakrapar 1 reactor in 1991. In the latter, the fire led to a complete loss of emergency diesel power and a partial loss of D.C. power supply. And, finally, the DAE had ignored what reactor designers around the world had learned from the 1975 fire at the Browns Ferry nuclear plant in the United States: Always put electric cabling to emergency shut down and cooling systems in separate fire proof channels.

A further source of concern is that, as mentioned earlier, the AERB, which is supposed to oversee the safe operation of all civilian nuclear facilities, is not independent of the DAE. This is compounded by the AERB's lack of technical staff and testing facilities. As A. Gopalakrishnan, a former chairman of the AERB, has observed,

> 95 percent of the members of the AERB's evaluation committees are scientists and engineers on the payrolls of the DAE. This dependency is deliberately exploited by the DAE management to influence, directly and indirectly, the AERB's safety evaluations and decisions. The interference has manifested itself in the AERB toning down the seriousness of safety concerns, agreeing to the postponement of essential repairs to suit the DAE's time schedules, and allowing continued operation of installations when public safety considerations would warrant their immediate shutdown and repair.

Elsewhere, Gopalakrishnan has pointed to an example of direct interference from the AEC. This was in the context of the collapse of the Kaiga containment dome that was mentioned earlier.

> When, as chairman, I appointed an independent expert committee to investigate the containment collapse at Kaiga, the AEC chairman wanted its withdrawal and matters left to the committee formed by the NPC [Managing Director]. DAE also complained to the [Prime Minister's Office] who tried to force me to back off.

All of this suggests that the DAE is not an organization that can avoid accidents at its nuclear facilities reliably. Since generating nuclear power involves a complex technology where events can spin out of control in a very short time, even seemingly minor accidents should be cause for serious concern.

In studying the safety of nuclear reactors and other hazardous technologies, sociologists and organization theorists have come to the pessimistic conclusion that serious accidents are inevitable with such complex high-technology systems.[6] The character of these systems makes accidents a "normal" part of their operation, regardless of the intent of their operators and other authorities. In such technologies, many major accidents have seemingly insignificant origins. Because of the complexities involved, all possible accident modes cannot be predicted and operator errors are comprehensible only in hindsight. Adding redundant safety mechanisms only increases the complexity of the system allowing for unexpected interactions between subsystems and increasing new accident modes. All of this means that there is no way to ensure that reactors and other nuclear facilities will not have major accidents.

## NUCLEAR POWER, CLIMATE CHANGE, AND THE ENVIRONMENT

A new argument in support of nuclear power that has become common is in the context of increasing global warming. Pro-nuclear advocates have offered nuclear power as a solution to global warming, and, given the gravity of the likely impacts of impending climate change, it is not surprising that many have started looking at it more favourably. Flailing nuclear establishments around the world, including India's, have grabbed this second opportunity and made claims for massive state investments in the hope of resurrecting an industry that has largely collapsed due to its inability to provide clean, safe, or cheap electricity. Some in the United States and elsewhere also have argued that India should be helped with technology and uranium to expand its nuclear sector so that it could decrease its greenhouse gas (GHG) emissions.

Two implicit but flawed assumptions underlie such claims about the significance of nuclear energy in controlling climate change. The first is that climate change can be tackled without confronting and changing Western, especially American, patterns of energy consumption—the primary causes and continuing drivers for unsustainable increases in carbon emissions and global warming. This is impossible; global warming cannot be stopped without significant reductions in the current energy consumption levels of Western/developed countries. Efforts by various developing countries, especially by elites within such countries, to match these consumption levels only intensify the problem.

The second flawed assumption is that the adoption of nuclear power makes sense as a strategy to lower aggregate carbon emissions. A good example is Japan, a strongly pro-nuclear energy country. As Japanese nuclear chemist and winner of the 1997 Right Livelihood Award Jinzaburo Takagi showed, from 1965 to 1995 Japan's nuclear plant capacity went from zero to over 40,000 MW. During the same period, carbon dioxide emissions went up from about 400 million tons to about 1200 million tons. In other words, increased use of nuclear power did not really reduce Japan's emission levels. The massive expansion of nuclear energy, then, was not motivated by a desire to reduce emissions. If indeed Japan was sincere about doing that, it would have adopted very different strategies.

There are two reasons why increased use of nuclear power does not necessarily lower carbon emissions. First, nuclear energy is best suited only to produce baseload electricity, which only constitutes a fraction of all sources of carbon emissions. Other sectors of the economy where carbon dioxide and other greenhouse gases are emitted, such as transportation, cannot be operated using electricity from nuclear reactors. This situation is unlikely to change anytime soon.

A second and more fundamental reason is provided by John Byrnes of the University of Delaware's Center for Energy and Environmental Policy, who observes that nuclear technology is an expensive source of energy and can be viable economically only in a society that relies on increasing levels of energy use. Nuclear power tends to require and promote a supply-oriented energy policy and an energy intensive pattern of development, and thus, in fact, indirectly adds to the problem of global warming.

As with Japan, nuclear power is unlikely to make much difference to carbon emissions from India. Just about every study on the subject has identified a host of other measures that are far more viable economically. These include running Indian coal plants better, including the use of coal washing and possibly more advanced combustion methods; increased energy efficiency measures in the domestic sector; and improving Indian energy intensity (energy consumption per unit of gross domestic product [GDP]). Increased investment on nuclear power only diverts attention and finances away from these measures.

The other choice that the Indian government has to make is whose electricity needs are met first. As energy analysts like Jose Goldemberg have argued, development and the mitigation of poverty require that energy services be directed deliberately and specifically toward the needs of the poor. Installing a centralized nuclear reactor or thermal plant and extending the grid to cover distant villages is an inefficient way of providing lighting to the primarily rural societies that characterize India, as they do most developing countries. Such communities are better served by distributed renewable energy systems based on a number of different technologies and sources such as micro hydel plants, windmills, photovoltaics, and biomass-based power.

Climate change may be a grave danger confronting humanity, but it should not blind us to other environmental hazards. Nuclear power is unique in many ways. One environmental consequence peculiar to nuclear power is that, among all electricity generating technologies, it alone produces waste that stays radioactive for tens of thousands of years, posing a potential health and environmental hazard to thousands of future generations. This is clearly iniquitous, since these generations would bear the consequences while we use the electricity generated by these reactors. Ethical dilemmas aside, no technology that generates such long lived radioactive wastes can be considered environmentally sustainable.

Further, different stages of the nuclear fuel chain release large quantities of radioactive and other toxic materials into the biosphere. Thus, claims of nuclear energy being environment friendly are absolutely baseless, and it should be considered a polluting source of electricity generation, albeit in a different way from fossil fuels.

## NUCLEAR POWER AND THE INDO-U.S. NUCLEAR DEAL

The above history of unachieved promises explains why the demands from the DAE and other nuclear advocates to gain access to international nuclear markets have became louder and louder over the last decade. It is only with external help that the DAE can ever hope to grow rapidly. That is one primary motivation for the Indian commitment in the July 2005 agreement to separate its nuclear program into a civilian and a military one, which goes against its historical policy: India so far has refused to allow international inspections at any of its indigenously constructed reactors.

The other pressure driving this deal has been the DAE's failure to plan for an adequate supply of fuel for even the existing nuclear reactors. Apart from two very old imported U.S. reactors, Tarapur I and II, India relies on its domestic uranium reserves to fuel its nuclear reactors. As of May 2006, the total electric capacity of India's power reactors that were domestically fuelled was 2,990 MW—this includes the Rajasthan 1 and 2 reactors which are under safeguards but have to be fuelled by domestic uranium. At 80 percent capacity, all these reactors would require about 430 tons of natural uranium fuel per year. The weapons plutonium production reactors, CIRUS and Dhruva, consume about another 35 tons of uranium annually. The uranium enrichment facility would require about 10 tons of natural uranium feed a year. Thus, the total current requirements are about 475 tons of domestic natural uranium per year.

We estimate India's current domestic uranium production to be less than 300 tons/year, well short of its needs. It has had to rely on stocks of previously mined and processed uranium to meet the shortfall. But this might run out very soon. This was evident in the statement from an unnamed official to British Broadcasting Corporation soon after the U.S.-India deal was announced, when he said: "The truth is, we were desperate. We have nuclear fuel to last only till the end of 2006. If this agreement had not come through, we might as well have closed down our nuclear reactors and, by extension, our nuclear programme."

The DAE has been trying desperately to open new uranium mines in the country. But it has been met with stiff public resistance everywhere. This local resistance stems from the widely-documented impacts of uranium mining and milling on public and occupational health. Nevertheless, it is quite likely that such public opposition will be steamrolled, and new mines and mills opened. However, even this expansion is unlikely to satisfy the uranium requirements of the nuclear program in the short to medium term.

While it is undeniable that for the DAE to meet its goals it will require external help, it is by no means clear that access to international nuclear technology will make a significant difference to nuclear power in India. Though the DAE's nuclear reactor construction has been marked with time and cost overruns, overnight construction costs still are comparable to, if not cheaper than, reactors sold on the international market, primarily because of lower labor costs but also because licensing requirements are easier to deal with. In the case of French reactors which are typical of Western supplied power plants, M. R. Srinivasan, former head of the DAE, has stated that, "Recent cost projections show that if an LWR were to be imported from France, the cost of electricity would be too high for the Indian consumer. This is because of the high capital cost of French supplied equipment." Unless foreign countries offer cheap loans to allow for the purchase of imported reactors, India is unlikely to be able to afford them. This is unlikely to be a viable way for a large scale expansion of nuclear power.

## CONCLUSIONS

The experience of over 50 years of experimentation with nuclear power in India and elsewhere demonstrates that it cannot be considered a safe, economical, or environmentally sustainable source of electricity. Despite continued government patronage and much media hype, atomic energy is unlikely to be a major source of electricity for India. There are many who believe India and other countries would be better off giving up this costly and dangerous technology and finding ways of generating electricity that do not threaten their future or their environment.

It is testimony to the political power of the Department of Atomic Energy that it has continued to be the beneficiary of government largesse for decades, while producing so little electricity and that, too, at enormous cost. The only viable explanation for this lies in the DAE's role in designing nuclear weapons and producing the fissile material (plutonium and enriched uranium) to make them.[7] The DAE has, of course, realized that this—namely, the ability to produce fissile material—is the real source of its political power. This is why it has sought strenuously over the course of the negotiations of the Indo-U.S. nuclear deal to keep as large a part of its complex as possible outside of safeguards. As we have elaborated elsewhere, the deal will allow for the retention of a substantial capacity for the production of nuclear weapons useable material.[8] Thus, if it comes through, the nuclear deal will give a new lease on life to a flailing atomic energy establishment that is involved both in the production of an undesirable source of electricity and in the production of even less desirable nuclear weapons.

# ENDNOTES - CHAPTER 3

1. Itty Abraham, *The Making of the Indian Atomic Bomb: Science, Secrecy and the Postcolonial State*, New York: Zed Books, 1998.

2. George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation*, Berkeley, CA: University of California Press, 1999.

3. The conversion rate between the U.S. dollar and the Indian rupee (Rs) has varied over the years. In 1998, it was approximately $1 = Rs. 39. Currently it is approximately $1 = Rs. 46.

4. M. V. Ramana and J. Y. Suchitra, "Costing Plutonium: Economics of Reprocessing in India," *International Journal of Global Energy Issues*, Forthcoming.

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6. Charles Perrow, *Normal Accidents: Living with High-risk Technologies*, Rev. ed., Princeton, NJ: Princeton University Press, 1999.

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8. Zia Mian and M. V. Ramana, "Wrong Ends, Means, and Needs: Behind the U.S. Nuclear Deal With India," *Arms Control Today*, January/February 2006, pp. 11-17.