The Limited Future of Nuclear Power in India

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Introduction

For nuclear energy to substantially contribute to reducing greenhouse gas emissions, it would have to expand significantly over the next few decades. Much of this expansion would have to occur in industrializing or developing countries that have fast growing electricity requirements and relatively low levels, or a complete absence, of nuclear generation capacity. For a variety of reasons, some of these countries are still contemplating constructing nuclear reactors despite the accidents at Fukushima (Ramana 2013).

India offers a case study for understanding the challenges facing expansion of nuclear power in developing countries. It is “ahead of the curve” when compared to most developing countries. Thanks to decades of sustained government support for the nuclear program, the Department of Atomic Energy (DAE) has developed expertise and facilities that cover the entire nuclear fuel chain, starting with uranium mining and milling to reprocessing of spent nuclear fuel, and vitrifying and storing the wastes produced. India has also developed nuclear weapons under the aegis of the same program.

Yet, the currently installed nuclear capacity is 4.78 GW (gigawatts),[1] a mere 2.14% of the total electricity generation capacity. There are twenty operating reactors with plans to build several more. Even if the reactors under construction come online, the nuclear share is unlikely to exceed 5% of the generation capacity over the next decade or more. Can this change in the longer term? There are several reasons why nuclear energy will not be a significant part of the answer to India’s electricity demands even in the long term (Ramana 2012).

Before examining those reasons, however, it may be useful to briefly describe the current electricity and energy scenario in the country, as well as projections for the future. India has a total installed electricity generation capacity of 224 GW. Together, these generated 876.4 TWh of electrical energy in 2011-12, with an average growth rate of 5.3% over the last decade (CEA 2012). Given the roughly 1.2 billion population living in India, at a per capita level, the electricity generated turns out to be only about 730 kWh/y; the corresponding figure for the United States in 2012 was about 13,400 kWh/y. About 70% of the electricity generated in India was from coal or lignite, and another 10% was from natural gas. The OECD’s International Energy Agency projects that if current policies continue to be followed, India would generate about 2600 TWh by 2035 (IEA 2012, 180). According to the IEA, this projected growth is driven by rising population and per-capita incomes.

Explaining Poor Performance

To start with, the small share of nuclear power in India’s electricity portfolio is not due to a lack of funding. Practically all governments, regardless of which political party is in power, have favored nuclear energy and the DAE’s budgets have always been high. The only period when the DAE did not get all it asked for was the early 1990s, a period marked by cutbacks on government spending as part of economic liberalization. But this trend was reversed with the 1998 nuclear weapons tests: since then the DAE’s budget has increased from Rs. 19.96 billion (US$ 470 million) in 1997-98 to Rs. 98.33 billion (US$ 1787 million) in 2013-14.[2] In comparison, the Ministry of New and Renewable Energy was allotted Rs. 15.33 billion (US$ 279 million) in 2013-14. The Ministry is in charge of developing solar, wind, small hydro, and biomass based power, which together constitute around 28 GW of generating capacity as of April 2013.

The other element that is not lacking is aspiration. Like nuclear agencies elsewhere, the DAE has a long history of making ambitious projections, none of which have been fulfilled (Ramana 2012). In the early 1970s, for example, the DAE predicted that by 2000, there would be 43 GW of nuclear capacity. Actually installed capacity was 2.7 GW in 2000.

One cause of this failure was India's 1974 nuclear weapon test and not signing the Nuclear Non Proliferation Treaty (NPT). Despite Indian diplomatic effort at trying to make the 1974 test to be a peaceful nuclear explosion, few outside the country bought into that charade. Following the 1974 test, the United States and other countries formed the Nuclear Suppliers Group (NSG) with the aim of preventing exports for commercial and peaceful purposes from being used to make nuclear weapons and India was not allowed to import nuclear reactors or materials from other countries till 2008.

In September 2008, the Nuclear Suppliers Group created a special exception for India that allowed it to import nuclear reactors and materials despite not having signed the NPT. The waiver came about in large part due to pressure from the United States, France, and Russia. For France and Russia, the main motivation was the expectation that they could sell nuclear reactors to India and revive their moribund nuclear sectors. In the case of the United States, which led the process of advocacy for the waiver, there were commercial interests, primarily related to nuclear and military technologies, as well as geopolitical motivations (Ramana 2012, 279–292). Following the NSG waiver, estimates for nuclear power in the country have gone up. The current long-term target is for 470 GW by mid-century. Because of India's rapidly growing demand for electricity, even that roughly hundred-fold increase would leave nuclear power at about 35% of the total projected electrical capacity of the country.

There are multiple reasons for why even this target is very likely to be missed. The first is simply that nuclear power is a complex and difficult technology and it is not easy to develop it very rapidly. This is particularly so in the case of post-colonial developing countries like India because there is pressure not just to generate electricity but simultaneously to indigenously develop the requisite technologies, materials, and equipment, partly for solid developmental reasons (creating jobs, stimulating technical education), partly to avoid dependence on whims of Western countries, and partly for the prestige and glamour associated with nuclear power.

If one looks at the history of nuclear power projects in India, practically each reactor took longer to build, cost more than projected, and performed worse than had been envisaged when plans were made. There were problems that had not been envisioned when the site was selected, leading to delays in construction and reduced efficiency in operations. All of this is despite the fact that most operating reactors are of the same type — pressurized heavy water reactors based on the Canadian CANDU design — and thus India has benefited both from standardization and experience elsewhere. The DAE's projections of rapid growth implicitly assume that all previous problems have been solved and no new problems will ever emerge. Such assumptions have been repeatedly shown to be untenable, not just in India but elsewhere.

In the future, however, construction and operation might fare worse because India plans to import a new reactor type: light water reactors.[3] Light water reactors constitute the most common reactor type deployed around the world; of the 434 reactors currently operating, 354 are of this type (IAEA 2013).[4] Current plans in India envision importing at least four new kinds of light water reactors: the VVER from Russia, the EPR from France, the ESBWR and the AP1000 from the United States of America. Apart from the fact that these are incredibly expensive compared to domestic Indian designs and would make nuclear electricity uncompetitive (Raju and Ramana 2013), a further problem is that Indian safety regulators have no experience with these designs. The primary reasons for the purchase, therefore, seem to have to do with international diplomacy.[5]

The second major reactor type that figures prominently in Indian nuclear planning is the fast breeder reactor — and DAE projections involve constructing literally hundreds of them over the next few decades (Grover and Chandra 2006). Fast breeder reactors are thus termed because they are based on energetic

Note on Thorium
There is a lot of discussion in the literature on the Indian nuclear program about thorium-based breeders. However, even in the DAE's plans, these become

termed because they are based on energetic (fast) neutrons and because they produce (breed) more fissile material than they consume. These are important to India because in the early years of the nuclear program, its leaders adopted a three-stage plan for nuclear power that was aimed at utilizing the country's limited reserves of relatively good quality uranium ore to pave the way for exploiting the much larger resources of thorium. The first phase was to construct and operate heavy-water reactors fueled by natural uranium and then separate plutonium out of the spent fuel. In the second stage, the accumulated plutonium stockpile is used in the nuclear cores of fast breeder reactors. These nuclear cores could be surrounded by a blanket of uranium, to produce more plutonium; if the blanket were to use thorium, it would produce uranium-233. In order to ensure that there was 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 were introduced. The third stage involves breeder reactors using uranium-233 in their cores and thorium in their blankets.

significant only after 2052 (Grover and Chandra 2006). This is primarily because of difficulties in dealing with the highly radioactive contaminant uranium-232 that is produced along with uranium-233, the fissile material produced from fertile thorium. Even if such reactors are constructed they will likely have the same features that make plutonium-based breeders uneconomical: the need for reprocessing and the requirement for extensive safety precautions in fabricating fuel with uranium-233 if it is contaminated even at very low levels with uranium-232.

The essential principle behind the breeder reactor had been recognized by physicists as early as 1943 and the first concepts were developed by Leo Szilard who was responding to concerns shared by his colleagues, who were engaged in developing the first nuclear bomb, that uranium would be scarce. In the early decades of nuclear power, many countries pursued breeder programs, but practically all of them have given up on breeder reactors as unsafe and uneconomical (IPFM 2010). India's experience with breeders so far has been with one small pilot-scale fast breeder reactor, whose operating history has been checkered (Ramana 2009). Further, a significant fraction of the domestic research and development effort has been spent on breeder reactors and it is likely that India would have much more installed nuclear capacity if they had simply focused on improving their PHWRs.[6]

In addition, the DAE's projections have simply not accounted properly for the future availability of plutonium, because it has not included in its calculations the lag period between the time a certain amount of plutonium is committed to a breeder reactor and when it reappears along with additional plutonium for refuelling the same reactor, thus contributing to the start-up fuel for a new breeder reactor (Ramana and Suchitra 2009). These problems with the projected growth rates are not a matter of differences in assumptions but plain impossibilities. Sociologically this elementary error appears to be a result of the absence of open, peer-review mechanisms.

Another problem with nuclear power for India, and industrializing countries in general, is that they need not just any kind of energy but electricity that is cheap and affordable. Nuclear power is in that sense badly suited to many of these because it is expensive. This has been amply borne out in the Indian case, where coal based thermal power has been much cheaper than nuclear electricity. Future reactors, both imported light water reactors as well as fast breeder reactors, promise to be much more expensive, which will make electricity generated in these unaffordable to the weaker sections of society. Expectations that the nuclear industry will learn from past experience and lower the construction costs have also been belied repeatedly. Nuclear reactor costs have risen steadily in many countries, and this has been best documented in cases of the United States and France (Koomey and Hultman 2007; Grubler 2010). In 1958, during the early years of nuclear power in the country, the British economist I.M.D. Little observed: "electricity is in short supply in India. It is likely to go on being in short supply if one uses twice as much capital as is needed to get more". That prognosis has proven to be prescient.

Finally, there has been significant opposition to every new nuclear reactor that has been planned since the 1980s, most dramatically illustrated by the intense protests over the Koodankulam reactors (Kaur 2012). In addition to concerns about safety or radioactive waste, opposition to nuclear facilities also stems from their impact on lives and livelihoods. Nuclear reactors, for example, require cooling water and land and these compete with the needs of farmers, while discharges of hot water and radioactive compete with the needs of farmers, while discharges of hot water and radioactive effluents into the sea affect fish workers. This source of opposition will likely intensify over the decades as land and other natural resources become subject to tremendous competition.

Conclusion

With a population that is projected to eclipse China's by mid-century, and a rapidly increasing demand for electricity, India has difficult choices to make regarding its energy future. But, despite much media hype and continued government patronage, nuclear power is unlikely to contribute significantly to electricity generation in India for several decades. This history and prognosis offers important lessons in thinking about the future of nuclear power globally, especially in countries that are preparing to embark on constructing nuclear reactors.

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Endnotes

[1] That is the maximum level of power that can be generated when all the reactors are operating. In 2011-12, efficiency of operations as measured by the load factor was on average about 77% (CEA 2012, 11).

[2] The conversion rate between the Rupee and the U.S. Dollar has varied over the

years; during the period being discussed, the rate was approximately Rs. 42 per dollar while the current rate is roughly Rs. 55 to the dollar.

[3] There are two boiling water reactors that were commissioned in 1969, but they have had numerous problems and by 2006, they had undergone over 500 modifications (Mittal, Ramamurty, and Bhattacharjee 2006).

[4] The reasons for this dominance have to do as much with history and politics as with technical features. Technically, both light water reactors and heavy water reactors have advantages and disadvantages.

[5] A former secretary of the DAE candidly explained: “America, Russia and France were the countries that we made mediators in the efforts to lift sanctions, and hence, for the nurturing of their business interests, we made deals with them for nuclear projects” (Kakodkar 2011).

[6] Even the weak justification offered by limited uranium reserves in the country ceases to be valid after the 2008 waiver by the Nuclear Suppliers Group because now India is in a position to import uranium from the international market, and it has been doing so at a steadily increasing rate.

