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## Preface

An important component of India's science and technology policy and one that has been generating considerable public debate in recent years, is nuclear energy. Many factors contribute to its prominence.

To start with, maintaining the current rate of growth of our economy requires a correspondingly rapid increase in energy production. If the country is able to restore its earlier 9 per cent growth rate for the GDP, it will have to be accompanied by the capacity to produce about 600 Gigawatts of electricity (GWe) from all sources by 2030, as against the roughly 200 GWe available today. A somewhat slower GDP growth may require less, but would still set a staggering target to reach by 2030. Such generating capacity is needed not just for our industries, but also for meeting the energy needs of the rural and urban poor. Depending on how you define electrification, anywhere up to about 100 million villages are still not electrified in our country.

Meanwhile, the international community is deeply concerned about the effects of carbon emissions from coal and hydrocarbon fuels. This has led to an increasing interest in generating electricity from non-carbon emitting sources, of which nuclear is a leading candidate. It has a relatively small carbon footprint and in terms of displacement of people from the site, occupies a smaller area per Megawatts of electricity (MWe) than solar, wind, hydroelectric or any other source.

If nuclear energy is to make even a 10 per cent contribution to our projected electricity requirement of 600 Gwe in 2030, this is going to call for a capacity of 60 GWe—a huge increase from the

4.78 GWe, which is currently being generated by the nuclear sector. That is a very challenging goal.

In this context, two major developments have occurred in the recent past, one of them favorable to India's nuclear energy programme, and the other less so. The first was the Indo-US Nuclear Deal achieved in 2008, after three years of hard negotiations by the Indian government, not only with the US and the Nuclear Suppliers Group (NSG) of countries but also with domestic critics. The deal helped lift longstanding international nuclear sanctions imposed against India. We can now buy enough uranium to fuel a large nuclear expansion, our own reserves of this metal being limited. We can also enter into collaboration with reactor builders from other nations to speed up the expansion. After the consummation of the Nuclear Deal, negotiations have been going on with reactors builders from France, the US and Russia.

The second development—this one negative—has some growing concern about, and public resistance to setting up of more reactors. Part of this resistance stems from the 'development versus displacement' dilemma common to any large industrial initiative, resulting from the displacement of the populace from the site of the facility, and the disruption and possible loss of their traditional livelihoods. Another part is special to nuclear reactors, *viz.*, the fear of radiation hazards, not just in the event of a nuclear explosion but also from the daily proximity of nuclear reactors. This last concern has been vastly enhanced by the recent reactor explosions at Fukushima. In recent months, these concerns have led to sizeable public protests especially at Jaitapur and Kudangulam, where new reactors are being planned and built.

There were two other offshoots of public concerns about the hazards posed by nuclear reactors. One was the Nuclear Liability Bill and the other a pending bill for an independent nuclear regulatory authority. The Liability Bill was passed into law by the Indian parliament in 2010. Coming as it did at the same time as the widely observed 25<sup>th</sup> anniversary of the Bhopal gas leak tragedy; the lawmakers were under pressure to ensure that in the event of a similar nuclear tragedy, foreign builders of our reactors

would be held liable for compensation, if the damage could be traced to manufacturing defects. As a result, we got a Liability Bill more stringent in some ways than other nations. India is the first country to demand supplier liability for nuclear reactors. The Bill was also people friendly in setting a total sum of ` 1,500 crore for the compensation (more for instance than China), along with the requirement that the reactor operators (in our case, the government) disburse those funds to affected persons within 3 months, without waiting for elaborate judicial procedures.

The other legal instrument that attracted attention as a result of Fukushima, concerns the nuclear regulatory authority. Up until now, the body vested with this regulatory function was the Atomic Energy Regulatory Board. It was, however, a wing of the Department of Atomic Energy (DAE), that got its funds from the latter and reported to its Head. This was clearly not a satisfactory situation, with the regulator being under the authority of the regulated. The government has accepted the need to correct this situation and a new Nuclear Safety Regulatory Authority (NSRA) Bill has been sent to the parliament proposing a more independent regulatory authority.

Unfortunately, we couldn't arrange a chapter on the Liability Bill, but we do have a detailed discussion of the Regulatory Authority bill currently before the parliament at the time of writing.

In addition to these societal concerns about developing nuclear energy, there are also major technical issues at the core of our nuclear programme on which there are conflicting views among international experts. These include the pros and cons of a closed fuel cycle, the thorium programme, the special difficulties associated with fast breeder reactors, reprocessing technology, the costs and feasibility of safe disposal of spent fuel and decommissioned reactors. Not only is it appropriate for INSA, as an apex scientific body, to discuss these technical matters, it is indeed vital that their deliberations be brought to the attention of those who make or influence policy in the energy sector in a volume such as this. The ultimate success of India's ambitious drive to expand its nuclear energy sector depends crucially on the choice of the technologies

adopted. The DAE's long term flagship plan has been based on Dr Bhabha's 3-stage programme, which aims to use India's large reserves of thorium ore by adopting precisely, the technologies mentioned above, on which international experience has been mixed.

The aim of this collection of articles and of the INSA Symposium on which it was based, is to discuss these issues in some detail. What, in our view, makes our exercise very unique is that for the first time a mix of the top leadership of the government's nuclear programme on the one hand, and a set of non-governmental expert critics with serious concerns about the programme on the other, have amicably participated in both.

One might have thought that in 60 odd years that our nuclear programme has been on, there would have been many such symposia representing all viewpoints on its pros and cons, since such debates are clearly healthy and essential for providing checks and balances in any democracy. Unfortunately, however, meaningful interactions between proponents and critics of the nuclear programme have rarely taken place in the past.

Primarily, this was not the fault of either side, but a consequence of how the nuclear programme in India was established and how it evolved.

Opponents attribute the absence of such debate to unwillingness on the part of the nuclear establishment to engage in serious discussion with the public or with non-governmental scientists. To some extent this may have been true in the past, and that should not be too surprising. Few large governmental organisations go out of their way to be more transparent than is necessary for their functioning. The DAE, set up with a total monopoly in the nuclear field, generous governmental funding and wide support across the political spectrum, was particularly under little pressure to do so. On top of that, having to develop complex new technology under the handicap of international nuclear sanctions, may have lead to closing of ranks and a siege-like mentality. Lastly, the fact that the same DAE was also engaged in developing nuclear weapon

capability, an unavoidably secret activity, contributed further to opacity.

Having said that, it must be acknowledged that as far as the production of this volume of articles and the organisation of the INSA seminar was concerned, DAE has been most supportive. They readily agreed to engage with any responsible critics in a non-confrontational discussion and offered their most distinguished scientists as speakers. Despite the busy schedules that go with apex organisational positions, their speakers also took the trouble to submit their contributions to this volume on time.

Turning to critics of the nuclear energy programme, they too were, by and large, unwilling to engage in calm and serious discussions despite their sincerity and commitment to their concerns *viz.*, reactor safety, hazards of radioactivity and other environmental effects. These are very valid issues to raise, but they all necessarily involve fairly complex science and technology in which, 'with notable exceptions', most critics were themselves not experts. They based much of their criticism on anecdotal evidence and hearsay laced with emotional and ideological arguments, rather than on first hand technical knowledge or comprehensive empirical data. Some of them adopted the methods of social activism over detailed substantive discussions. As a result, in place of a meaningful dialogue, each side has ended up preaching to its own choir.

Yet, anti-nuclear activists and writers can also not be entirely blamed for their approach. They too had little choice. The fact is that almost all the technical expertise in India in nuclear technology lies inside the walls of the DAE. This happened by design from the start, presumably to conserve manpower in this new technology. The DAE set up its own training school whose graduates were absorbed into its various emerging nuclear facilities. Outside of this, there was no programme of graduate courses in nuclear technology in universities, or with one small exception, in the IITs. As this pattern continued for decades, there developed a skewed situation with a mass of high level nuclear expertise within the DAE and practically none outside.

The net result has been that strongly conflicting views in the public domain on the safety and desirability of nuclear energy came no closer to resolution than before, leaving the larger intelligentsia (let alone the lay public) unable to make an educated decision on this very crucial component of India's energy policy.

But, in the past decade things have improved on this front. Gradually more and more people in India, outside the atomic energy establishment have picked up some expertise in one or the other aspect of nuclear technology, its environmental and radiation effects, its economics, legal structure etc. The three year long public debate on the Indo-US Nuclear Deal also spurred commentators from academia, the media and the political class to learn about Plutonium, Uranium, Breeder reactors and so on. The number of 'outside experts' is still not large, but was large enough to allow us to gather together an excellent set of expert contributors for this volume.

The range of topics covered in book is such that there is some inhomogeneity in style and content between the different chapters. Some, dealing with the overall policy matters, future plans for the nuclear programme, legal and regulatory instruments etc., are discussed in plain English prose. Other chapters, which discuss radiation hazards and environmental issues or the choice of technology involving with a closed fuel cycle are presented inconsiderable scientific detail, to the point where they could well belong to a standard scientific journal.

While such lack of uniformity within the same volume may violate editorial aesthetics, we feel it is unavoidable here if we are to achieve our main goal—to address issues of public policy and concern in some definitive fashion, using whatever style and form of discussion each issue permits. For instance, while concerns about reactor safety and health hazards can be stated in plain language, their resolution necessarily involves going into considerable scientific detail. Otherwise, the debate reduces to just conflicting assertions from each side, where neither party convinces the other. We do not intend that every reader should wade through all the scientific portions. Most may be content with the introductory and

concluding sections. But, for those who would like to come to their own conclusions based on hard information, much of the required material is given right there in the chapter, with full references to the literature.

Last but not least, this entire initiative would not have been possible but for the kind encouragement of Dr Krishan Lal, the President of INSA. Equally important was the support of the DAE leadership, particularly Dr R. Chidambaram and Dr S. Banerjee, both former Chairmen of the Atomic Energy Commission (CAEC), and Dr Ravi Grover, member, AEC.

I am also grateful for the unstinting cooperation of officials of the INSA Secretariat, particularly our Executive Secretary Dr Alok Moitra and Dr Seema Mandal.

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