Nuclear Power in India: Failed Past, Dubious Future

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NPEC, May 10, 2006

Initiation

- 1948: Atomic Energy Bill introduced in the Constituent Assembly by Nehru
- Exclusive responsibility of the state
- Reasoning: India became backward (a “slave country”) because it did not develop steam power
- “If we are to remain abreast of the world, we must develop this atomic energy”
- Cuts off any possible opposition

Secrecy

- 1948 Atomic Energy Act – more secrecy over research and development than British or US acts
- Nehru’s reasoning: “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” – both disingenuous and unfair

Debating Secrecy

- Krishnamurthy Rao
  - Bill does not have mechanisms for oversight, checks and balances as US Atomic Energy Act
  - Britain: secrecy restricted only to defence purposes
  - Is secrecy insisted upon even for research for peaceful purposes?
- Nehru
  - I do not know how to distinguish the two [peaceful and defence purposes].

Infrastructure for what?

- Ambitious programme
- Aimed at covering entire nuclear fuel chain
- Mining Uranium, fabricating fuel, manufacturing heavy water, reprocessing spent fuel to extract Plutonium,…
- Never lost sight of the possibility that the facilities constructed and expertise gained could be used for military purposes

Structure

- 1954: Department of Atomic Energy (DAE) set up under direct charge of Prime Minister (i.e., not answerable to cabinet)
- Governed by Atomic Energy Commission
- AEC is headed by head of DAE
- Regulatory and Safety functions is under the Atomic Energy Regulatory Board; answers to the AEC
- Strong Secrecy Act

Predictions and Reality

Year	AEC (1954)	Bhabha & Dayal (1962)	Energy Survey Committee (1965)	Vikram Sarabhai (1969 ?)	Raja Ramanna (1985)	Actual
1971	600		600			320
1975	3000		2000			540
1980	8000		5000			540
1987		20 – 25,000				1200
2000				43,500	10,000	2720

Current Capacity

- Installed Nuclear Capacity = 3310 MW
- Almost commissioned = 540 MW
- Under construction = 3380 MW

Current Projections

- 20,000 MW by 2020
- Will only be 8-10% of projected total electrical generation capacity

Budgets

Year	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005
Revised Budget (bn Rs)	19.96	24.18	26.82	27.45	27.68	33.51	37.38	42.40

- Early 1990s – considered by DAE as the dark years
- Changed with 1998 BJP victory and Pokharan tests
- MNES 2002-03 Budget = Rs. 4.74 bn. (4800 MW of solar, wind, small hydro and biomass)

DAE Claims about Relative Cost

- Homi Bhabha (1958): [in 10 to 15 years] "the costs of [nuclear] power [would] compare *very favourably* with the cost of power from conventional sources in many areas"
- M. R. Srinivasan (1985): 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"

Nuclear Power Corporation Study (1999)

- "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"

Empirical Economics

- Compared the (busbar) cost of electricity from heavy water reactors and coal plant (assumed at 1400 km from coal mines)
- Two nuclear cases: one commissioned, one under construction
- Leading contribution to nuclear power cost: Capital cost of constructing facility, including initial loading of fuel and other materials

Nuclear Reactor Construction Costs (Millions/Rs)

Station	Original Cost Estimate	Revised Cost
TAPS I & II	929.9	-
RAPS I	339.5	732.7
RAPS II	581.6	1025.4
MAPS I	617.8	1188.3
MAPS II	706.3	1270.4
NAPS I & II	2098.9	7450
Kakrapar I & II	3825	13350
Kaiga I & II	7307.2	28960
RAPS III & IV	7115.7	25110

Narora Reactor – CAG 1988 Study

- Ten major heads of expenditure with cost overruns of 188% or more
- Project got approved on unrealistic cost estimates and time schedules
- “Makes financial allocations and controls less meaningful”

Levelised Costs in US cents/kWh

Lifetime of 30 years for coal plant, 40 years for nuclear reactor, capacity factor 80%

Discount Rate	Kaiga I/II	Kaiga III/IV	RTPS VII
2%	2.91	2.70	3.09
3%	3.25	2.98	3.16
4%	3.66	3.25	3.23
5%	4.11	3.57	3.30
6%	4.64	3.91	3.39

Analysis

- More expensive than thermal power for real discount rates > 3.9% (2.7% for operating reactors)
- Multiple demands on capital for infrastructural projects
- Electricity sector being reorganized
- The 2003 Electricity Act emphasizes competition as the basis for energy policy
- Nuclear power not subject to Merit Order Dispatch

Safety Issues – Possibilities

- Nuclear technology has accident possibilities, some catastrophic
- Chernobyl, Three Mile Island,…
- Similar accident would be disastrous in crowded India

Safety Issues – Accidents in India

- Most nuclear reactors in India have had small or large accidents
- 2004: Kakrapar power surge
- 2003: KARP waste tank
- 1999: Kaiga dome fire
- 1994: Kaiga dome collapse
- Numerous heavy water leaks

Narora Fire of 1993

- Accident that came closest to large radioactive release
- Two blades in the turbine generator of NAPS-I snapped under accumulated stress
- Sliced through other blades and set off fire
- Cables of back-up power systems were burnt
- (Unknown) Operators used torches to climb and release boron solution to shut down the reactor

More on the Narora Accident

- 1989: General Electric Company warned BHEL of the possibility of turbine blade failure – ignored
- Power cables of back-up systems were laid in the same duct without any fire-resistant material – the lesson from the well-known 1975 Browns Ferry (Alabama) accident
- Similar fire at Kakrapar reactor in 1991

Breeder Reactors: Accidents

- History of accidents at breeder reactors worldwide (Fermi, Superphenix, Monju…)
- India’s experience with pilot scale fast breeder test reactor has been poor
- Use of Molten Sodium as coolant – burns when exposed to air and reacts violently with water

Other Safety Related Issues

- No equivalent of Price Anderson Act
- Unclear who would be liable for public damages
- Bhopal – court case against Union Carbide (now Dow)

Why the Deal?

- Mismatch between nuclear energy plans and reality
- Acute Uranium Crunch

- Testimony to influence of nuclear lobby
  - “Every one in India associates the Trinity with Brahma, Vishnu and Maheshwara. In the Indo-U.S. diplomatic dialogue, however, trinity issues mean cooperation in civilian nuclear power, cooperation in civilian space research and export of dual use technology”
    M. R. Srinivasan, former AEC Chairman

Uranium Shortages

- Estimated annual uranium production ~ 300 tons
- Estimated annual uranium consumption ~ 450 tons
- Living off the stockpile from when consumption was lower

- "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 have as well closed down our nuclear reactors and by extension our nuclear programme" -- *Indian official to BBC*

- Local resistance to opening new uranium mines because of impacts of uranium mining and milling on public and occupational health.

Nuclear Weapons Plans

- Plans for an arsenal of 300-400 nuclear weapons to be deployed on land, air and at sea.

Current Fissile Material Stockpiles

- Weapon Grade Plutonium ~ 520 kg
  - 5 kg can make a bomb
- Highly Enriched Uranium ~ 420-650 kg (45-30% enrichment) for nuclear submarine
  - Needs to be further enriched to make weapons
- Unsafeguarded Reactor Grade Pu (Separated and unseparated) ~ 10.8 tons
  - 8 kg can make a bomb

Weapons Implications of Nuclear Deal

- Frees up Domestic Uranium for Military Uses
- Pathways (not mutually exclusive) to Make Weapons Grade Fissile Material
  - Build new Plutonium Production Reactor
  - Use Fast Breeder to Convert Unsafeguarded Stockpile and Future Production of Reactor Grade Plutonium from Heavy Water Reactors into WG Plutonium
  - Produce Highly Enriched Uranium for Weapons
  - Produce Greater Quantities of Enriched Uranium for Nuclear Submarine (determines size of fleet)

Additional Fissile Material Production Capacities at Future Military Facilities

- Dhruva 2 (200 MW) ~ 46 kg/y of WGPu
- Double Size of Uranium Enrichment Capacity ~ 20 - 50 kg/y of HEU (additional)

- Uranium Shortage likely to have been a consideration in not constructing these earlier

Energy Implications of Nuclear Deal

- Purchase of Nuclear Reactors?
  - Indian construction costs are lower
  - Yet, nuclear power is not economical
  - M. R. Srinivasan
    - 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.
    - [The US] is not building at present the type of reactors we are interested in; the ones it is considering in the revival of nuclear power are the types we have no immediate interest in.

Conclusions

- Nuclear power program has made series of tall promises but only (less than) modest performance
- Has come at the cost of investment in other sustainable sources of power
- Deal will result in increased capacity to make nuclear weapons and bail out a failing and expensive nuclear energy program