INDIA

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1. GENERAL INFORMATION

1.1. General Overview

India occupies a strategic position in Asia with a distinct geographical identity. Bounded by the Great Himalayas in the north, it stretches southwards and from Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and Arabian Sea on the west. India has seven major physiographic regions: Northern Mountains viz. the Himalayas; The Indo Gangetic Plain; Central Highlands; Peninsular Plateau; East Coast; West Coast; Bordering Seas; and Islands. Major part of the land surface is plateau.

There are a number of rivers flowing in the country i.e. Himalayan rivers, Peninsular rivers, coastal rivers and rivers of Inland Basin. India gets its rains from the south west monsoon during the months of June to September, and north west monsoon during October to December. The rainfall varies in wide degrees in different parts of India. The tropic of cancer passes through the middle part of India. The climate may be broadly described as tropical monsoon type. There are four seasons i.e. (i). Winter (January-February); (ii) Hot weather summer (March-May); (iii) Rainy south west monsoon (June-September) (iv) Post monsoon also known as north east monsoon in the southern peninsula (October-December).

India became an independent nation on the 15th August 1947. It became a Republic on 26th January 1950 and the Constitution of India came into force. India is a Sovereign, Socialist, Secular, Democratic republic with a parliamentary system of Government sustained by a well-developed electoral process. India is a federal polity with a Central Government, 28 State Governments, a National Capital Territory and 6 Union Territories. Ever since its independence till date, the country has achieved significant progress in various sectors such as agriculture, industry, power, science and technology, and services.

According to 2001 census, India's population is 1027 million. The estimated growth of population from 1991 to 2001 is at an annual rate of about 2 % (see Table 1). The installed power generating capacity (Utilities) as of April 2002 was 104,935.50 MW(e) with about 71% contributed by fossil thermal power. In order to meet the growing demand for electricity, significant electricity generation capacity addition is necessary for which various measures are being taken.

TABLE 1. POPULATION INFORMATION

	1961	1971	1981	1991	1996	1997	1998	1999	2000	2001	Growth * rate (%/yr) 1991 to 2001
Population (millions)	439	548	683	843	931	950	969	988	1008	1027	2.0
Population density (inh/km^2)**	134	167	208	256	283	289	295	301	307	312	2.0
Urban Population as % of total	18	20	23	25.7	26.7	26.9	27.1	27.3	27.5	27.8	2.7
Area (1000 km^2)	3287.3										

*Calculated approximate annual growth rate (compound)
**Calculated figures rounded off
Note: The decadal population figures for 1961 to 2001 are by census. The other figures related to population for 1996 to 2000 are interpolated.
Source: Provisional Population Totals, Paper-1, Census of India, 2001.

1.2. Economic Indicators

The GDP grew in real terms at an annual rate of about 5.3% during the period 1980 to 1993. Due to wide ranging economic reforms the annual GDP growth rates in real terms were 7.8%, 7.6% and 7.8% during 1994, 95 and 96 respectively. During 1997, the real GDP growth declined to 5%. However with a significant turnaround the growth rates of 6.8% and 6.4% were recorded during the financial years 1998-1999 and 1999-2000 respectively. The historical GDP data are given in Table 2.

TABLE 2. GROSS DOMESTIC PRODUCT (GDP)

								Growth rate (%)
	1970	1980	1990	1996	1997	1998	1999	1980 to 1999
GDP[1]	57,600	172,370	298,330	359,720	381,570	383,429	447,300	5.4
GDP[2]	109,430	146,760	259,210	359,030	377,810	N/A	N/A	–
GDP[3] per capita	105	251	351	380	396	391	448.4	4.1
GDP by sector (%) :								
– Agriculture	45	38	31	27	25	25	27.7	–1.4
– Industry	22	26	29	30	30	30	26.3	0.06
– Services	33	36	40	43	45	45	46.0	1.46

[1] Millions of current US$
[2] Millions of constant 1995 US$
[3] Current US$ per capita
Source: Data & Statistics/World Bank

1.3. Energy Situation

The energy resources are unevenly distributed in the country and are mainly used for power generation, transport and industrial and domestic uses. Table 3 shows the overall energy reserves and Table 4 the basic energy situation.

Based on a systematic survey carried out, the hydro electric potential in the country is estimated at 84 GW(e) (at 60% L.F.). Out of the total potential available as on April 2002, only about 30% has either been developed or is being developed. More than 70% of the total hydro potential in the country is located in the northern and north-eastern regions put together.

Coal, oil, natural gas and lignite are used for thermal power generation. As on January 1, 2001, the geological reserves of coal are estimated to be about 221 billion tonnes and proven mineable reserves are 84 billion tonnes. Eastern region accounts for about 70% of the coal resources. Lignite reserves suitable for power generation are estimated at 27.45 billion tonnes and are being exploited for this purpose in Tamil Nadu and Gujarat. Recoverable reserves of crude oil are placed at 600 million tonnes and of natural gas at 650 billion cubic meters.

TABLE 3. ESTIMATED ENERGY RESERVES[1]

Exajoule

	Solid[2]	Liquid	Gas	Nuclear	Hydro[3]	Total[4]
Total proven amount in place (2001)	1519	26	25	–	84 GW(e)	1570

[1] B.P. Statistical Review, June 2002 (www.bp.com/centre/energy)
and R.B. Grover, Nuclear Energy : Emerging Trends, Current Science, vol 78, no.10, May 25, 2000
[2] Proven Mineable Reserves (coal, lignite)
[3] Renewable Source, At 60% Load Factor
[4] Does not include Hydro (being renewable) and nuclear
[5] Calorific Value of (i) Coal = 4,200 kcal/kg, (ii) Lignite = 2,800 kcal/kg, (iii) Oil = 10,200 kcal/kg, (iv) Gas = 9,150 kcal/m^3

Uranium reserves in the country are estimated at about 92,000 tonnes-U_3O_8. One of the largest resources of thorium in the world is contained in monazite deposits in India mainly along the Indian sea coast. The thorium deposits are estimated at about 590,000 tonnes ThO_2.

The estimated potential for non-conventional renewable energy resources are 45,000 MW from wind energy, 15,000 MW from small hydro power, 50,000 MW from ocean thermal, 19,500 MW from bio-mass and 35,000 MW/Thousand km^2 from solar. This is in addition to potential for bio-gas plants and efficient wood stoves.

TABLE 4. ENERGY STATISTICS

Exajoule

							Average annual growth rate (%)	
	1960	1970	1980	1990	2000[4]	2001[5] *Provisional*	1960 to 1980	1980 to 2000
Energy consumption								
– Total[1]	1.43	4.15	6.62	11.25	16.05	13.05	7.96	4.53
– Solids[2]	1.07	3.1	4.78	7.74	9.45	7.80	7.77	3.46
– Liquids	0.29	0.77	1.31	2.37	4.43	3.32	7.83	6.28
– Gases	N/A	0.02	0.05	0.39	1.07	0.81	–	16.55
– Primary electricity[3]	0.026	0.092	0.17	0.23	0.33	0.37	9.84	3.37
Energy production								
– Total	1.2	3.74	5.61	10.09	12.57	9.74	8.02	4.11
– Solids	1.1	3.17	4.69	7.53	8.96	7.48	7.52	3.29
– Liquids	0.02	0.29	0.39	1.43	1.38	1.02	16.01	6.52
– Gases	N/A	0.02	0.05	0.39	1.13	0.85	–	16.87
– Primary electricity[3]	0.026	0.092	0.17	0.23	0.33	0.37	9.84	3.37
Net import (import – export)								
– Total	0.26	0.5	0.97	1.22	3.57	2.72	6.8	6.73
– Solids	-0.03	-0.01	0.01	0.15	0.41	0.19	6.57	20.40
– Liquids	0.29	0.51	0.96	1.07	3.16	2.53	6.17	6.13
– Gases	N/A	N/A	N/A	N/A	N/A	N/A	–	–

[1]Energy consumption = Primary energy consumption + Net import (Import – Export) of secondary energy.

[2]Solid fuels include coal, lignite and estimated commercial wood

[3]Primary electricity = Hydro + Geothermal + Nuclear + Wind

[4]Annual Report 2001-2002, Department of Coal, Government of India
Growth of Indian Petroleum at a Glance, Ministry of Petroleum & Natural Gas, Government of India
(www.petroleum.nic.in/ps.htm)
The year represents financial year from 1st April of the year to 31st March of the next year.

[5] For Apr. 2001 to Dec. 2001 except electricity figures which are for Apr. 2001 to Mar. 2002

Source: IAEA Energy and Economic Database

1.4. Energy Policy

The Energy Policy of the Government of India aims at ensuring in a judicious manner adequate energy supplies at an optimum cost, achieving self sufficiency in energy supplies and protecting the environment from the adverse impact of utilizing energy resources. The main elements of the Energy Policy are:

- Accelerated exploitation of domestic conventional energy sources, viz. coal, hydro, oil/gas and nuclear power;

- Energy conservation and Management with a view to increasing energy productivity;
- Optimizing the utilization of existing capacity in the country;
- Development and exploitation of renewable sources of energy to meet the energy requirement of rural communities;
- Intensification of research and development activities in the field of new and renewable energy sources;
- Organization of training for the personnel engaged at various levels in the energy sector.

2. ELECTRICITY SECTOR

2.1. Structure of the Electricity Sector

The structure of the electricity sector derives its character and composition from the Indian constitution and is defined by the following Acts:

- Indian Electricity Act of 1910 legislates over the supply and use of electrical energy in India. It regulates license procedures for electricity undertakings. It prescribes requirements for execution of works and delivering of the supplies. It regulates relations between licensees and consumers. The Act empowers the Government to intervene in cases where a licensee fails to comply with safety requirements prescribed under the Act.

- Indian Electricity (Supply) Act of 1948 was enacted in order to secure a fully coordinated development of electricity on a regional basis. This act provides for (i) rationalization of production and supply of electricity; (ii) taking measures conducive to electrical development, i.e., to operate as a "Grid System"; and (iii) matters incidental thereto. The Act enables constitution of the Central Electricity Authority and semi autonomous bodies like State Electricity Boards, to uniformly organize and develop the Grid System.

- Electricity Regulatory Commission Act, 1998 has been enacted with a view to providing for establishment of Central Electricity Regulatory Commission and State Electricity Regulatory Commissions, rationalization of electricity tariffs, transparent policies regarding subsidies, promotion of efficient and environmentally benign policies and for matters connected therewith and incidental to.

- For speedy reforms in the power sector, the Electricity Bill 2001 is under consideration in the parliament. It encourages greater participation of private enterprises in electricity generation, supply and distribution.

The Ministry of Power, Government of India (GOI), is responsible for the administration of the above Acts and to undertake such amendments to these Acts, as may be necessary from time to time, in conformity with the policy objectives of GOI.

Electricity is a concurrent subject as per the Constitution of India. The responsibility for electric power production and supply is vested mainly in both the Central and the State Governments. The electricity generating companies in the Central Sector are:

- The National Thermal Power Corporation (NTPC) responsible for construction and operation of fossil thermal power plants in the various power regions under the administrative control of Ministry of Power;

- The National Hydroelectric Power Corporation (NHPC) responsible for establishing and operating regional hydroelectric power plants under the administrative control of Ministry of Power;

- North Eastern Electric Power Corporation (NEEPCO) responsible for establishing and operating thermal and hydro power plants in the North Eastern Region under the administrative control of Ministry of Power;

- Neyveli Lignite Corporation (NLC) responsible for establishing and operating thermal power plants based on lignite reserves at Neyveli in the Southern region, under the administrative control of Ministry of Coal;

- Nuclear Power Corporation of India Ltd. (NPCIL) responsible for nuclear power generation under the administrative control of the Department of Atomic Energy (DAE).

The Government of India has also taken up two joint ventures:

- Nathpa-Jhakri Power Corporation (NJPC), responsible for the execution of the Nathpa-Jhakri Hydroelectric Project which is being developed as a joint venture of the Central Government and the Government of Himachal Pradesh.

- Tehri Hydro Development Corporation (THDC), a joint venture of the Central Government and the Government of Uttar Pradesh to execute the Tehri Hydro Power Complex.

Two statutory bodies i.e. the Damodar Valley Corporation (DVC) and the Bhakra Beas Management Board (BBMB) are also under the administrative control of Ministry of Power. The development of non-conventional energy sources is being carried out by the Ministry of Non-Conventional Energy Sources, GOI. There are also non-utilities with captive generating capacities.

The Rural Electrification Corporation (REC) under the administrative control of Ministry of Power, provides financial assistance to the programmes of rural electrification. The Power Finance Corporation (PFC) provides term finance to projects in the power sector.

State Electricity Boards (SEBs) were set up in terms of the "Electricity Supply Act-1948" for generation, transmission, and distribution of electricity in the respective States. The State Electricity Boards implement power generation, transmission and distribution schemes; consolidate power system and sale of electrical energy to consumers; rationalize power supply by development of transmission and distribution systems in the state; purchase bulk power from state generating companies and Central Sector generating companies; and, operate the state load despatch centres securely and economically. As a part of power sector reforms many States have restructured the activities of their respective SEBs.

India is divided into five Electricity Regions; namely, Northern, North Eastern, Eastern, Western and Southern. For each region, a Regional Electricity Board is constituted. This is essentially to provide guidelines for operation of the grid, co-ordinate exchanges of power between states and regions. The Regional Electricity Board also reviews progress of schemes and plan generation schedule.

The Power Grid Corporation of India Limited (PGCIL) has been established by the Central Government with the mandate to establish and operate Regional and National Power Grids to facilitate transfer of power within and across the Regions with reliability, security and economy on sound commercial principles. All transmission facilities originally under Central Sector organizations were transferred to PGCIL. SEBs also set up the transmission schemes for evacuating power generated from the Power Stations set up by them.

With the amendment in Electricity Laws, transmission activity has been given an independent status and the concept of Central and State transmission utilities has been introduced. While PGCIL has been notified as the Central Transmission Utility, the SEBs or their successor State Transmission Companies would be State Transmission Utilities. These would be Government Companies. The

participation by private sector in the area of transmission is proposed to be limited to construction and maintenance of transmission lines for operation under the supervision of Central and State Transmission Utilities.

Since independence, development of the electricity sector has primarily been the responsibility of the Government with a relatively small contribution from private enterprises in the form of Licensees like the Bombay Suburban Electricity Supply Company (BSES), Tata Electric Company (TEC), Calcutta Electric Supply Company (CESC) and Ahmedabad Electric Company, etc. However, considering the energy shortage, projected growth and highly capital-intensive nature of power sector, the Government formulated a policy in 1991 with the objective to encourage greater investment by private enterprises in the electricity sector. The Electricity Supply Act-1948 was amended in 1991 to provide for a legal framework for facilitating the investments. The package of incentives in the policy, which complements the amended provision in the legislation, comprehensively cover the legal, administrative and financial environment to make the investments in the power sector attractive. The Investment Promotion Cell (IPC) was set up in 1991 under the Ministry of Power as a nodal agency to provide information and assistance to prospective entrepreneurs in the electricity sector. The response from private sector has been encouraging. Major policy initiatives have been taken to streamline the process of project development. A number of incentives have been provided to encourage private sector participation.

The generation of nuclear power comes under the administrative control of Department of Atomic Energy, GOI. The generation through non-conventional renewable energy sources comes under administrative control of the Ministry of Non-Conventional Energy Sources, GOI.

2.2. Policy and Decision Making Process

The Ministry of Power is concerned with perspective planning, policy formulation, processing of projects for investment decision, monitoring of projects, training and manpower development. The Central Electricity Authority (CEA) is a statutory organization constituted under the Electricity Supply Act of 1948. In all technical, financial and economic matters the Ministry of Power is assisted by CEA. CEA is responsible for technical co-ordination and supervision of programmes and is also entrusted with a number of statutory functions. It interacts with State Electricity Boards, Central generating companies and the Planning Commission to ensure consensus. CEA has the responsibility of techno-economic appraisal of power schemes of Central/State/Private sector with estimated cost beyond specified limits notified by GOI from time to time. It also facilitates training of persons in the generation and distribution of electricity.

Under the Atomic Energy Act, nuclear power generation schemes come under the jurisdiction of the Atomic Energy Commission/Department of Atomic Energy. Tariffs for nuclear power generation are notified by the Department of Atomic Energy in consultation with CEA.

The demand for electricity is assessed periodically at the national level by CEA. Based on the generation expansion planning studies, CEA prepares short, medium and long-term national power plans. Based on this, power schemes are conceived and implemented by the different agencies. Planning of schemes are on the basis of the national five-year plans and annual plans through the national Planning Commission. Expert groups scrutinize the formulation of the five-year plan before it is finalized and approved. In line with the five-year plans, annual plans are implemented.

There are different Ministries involved in the Power Sector such as Ministry of Power (being the main), Department of Atomic Energy, State Power Ministries and SEBs, Ministry of Non-Conventional Sources of Energy. Matching plans are prepared by these agencies for implementation in line with the national plans. Respective Ministries/Departments exercise administrative control of the functions relating to their areas. Individual power schemes go through the process of techno-economic scrutiny in terms of the procedures of the administrative Ministry before it is approved for implementation.

The Department of Atomic Energy is responsible for setting up nuclear power generation schemes including the techno-economic appraisal. Transmission schemes for nuclear power generation are implemented by PGCIL as per schemes approved by CEA on a regional basis. The overall integration of all the activities is achieved through the planning process in assessment of demands, decision on the expansion planning strategies, energy policy and national five-year/annual plans. Several policy initiatives have been taken and incentives have been provided to widen the scope of private sector participation in the India's electricity sector.

2.3. Main Indicators

The per capita commercial energy consumption has increased from 3 GJ in 1960 to nearly 16 GJ in 2000. During the same period per capita electricity generation increased significantly from 45 KWh to 495 KWh. The total installed electric power capacity of only 5.58 GW(e) in 1960 has made an impressive growth to about 104.94 GW(e) in 2001-02. The major contribution of electricity generation during 2001-02 in energy terms (from utilities) is from thermal power constituting about 82%, followed by hydro about 14.3% and nuclear about 3.7%. During the period 1980 to 2000 the growth rate of electricity generation in energy terms was more than the growth rate in capacity addition indicating improved capacity utilization. Table 5 shows the historical electricity production and installed capacity and Table 6 the energy related ratios.

TABLE 5. ELECTRICITY PRODUCTION AND INSTALLED CAPACITY

							Average Annual growth rate (%)	
	1960	1970	1980	1990	2000	2001[2]	1960 to 1980	1980 to 2000
Electricity production (TW.h)								
– Total[1]	20.12	61.21	119.26	289.44	501.02	517.20	9.31	7.42
– Thermal	12.28	33.53	69.70	212.65	408.21	421.98	9.07	9.24
– Hydro	7.85	25.26	46.56	71.66	74.35	73.94	9.31	2.36
– Nuclear	–	2.42	3.00	5.11	16.90	19.32	–	9.02
– Wind	–	–	–	–	1.57	1.95[3]	–	–
Capacity of electrical plants GW(e))								
– Total	5.58	16.27	33.32	74.70	101.15	104.94	9.35	5.70
– Thermal	3.73	9.47	20.66	54.82	71.91	74.45	8.93	6.43
– Hydro	1.85	6.39	11.79	18.76	25.22	26.26	9.72	3.87
– Nuclear	–	0.42	0.86	1.09	2.72	2.72	–	5.92
– Wind	–	–	–	0.03	1.34	1.51	–	–

[1]Electricity losses are not deducted
[2]Personal Communication, Central Electricity Authority Coordination Div., R.K. Puram, New Delhi
[3]Estimated
Source: IAEA Energy and Economic Database

TABLE 6. ENERGY RELATED RATIOS

	1960	1970	1980	1990	2000	2001[4]
Energy consumption per capita (GJ/capita)	3	7	10	13	15.9	17.1
Electricity per capita (kW.h/capita)[1]	45	104	161	315	495	504
Electricity production/Energy production[2] (%)	13.7	15.2	18.5	30.9	39.2	35.4
Nuclear/Total electricity (%)	–	4	3	2	3.4	3.7
Ratio of External dependency (%) [3]	18	12	15	11	22.4	20.7
Load factor of electricity plants						
– Total (%)	41	43	41	54	68	NA
– Thermal	38	40	39	44	69	70
– Hydro	49	45	45	44	–	–
– Nuclear	–	66	40	54	82	85

[1] Electricity from utilities only. However electricity from captive power plants is a significant component of the total electricity generation. As per data published in PowerLine Nov. 2001, it is estimated at 27.5 GWe of installed capacity. Assuming the annual capacity factor of 50 % it adds 120 B KWh to total electricity generation increasing the per capita consumption to about 610 KWh.
[2] It includes energy produced based on imported fuel
[3] Net import/Total energy consumption
National Data,The year represent financial year from 1st April of the year to 31st March of the next year.
[4] Estimated from provisional data of April 2001 to Dec 2001
Source: IAEA Energy and Economic Database

2.4. Impact of Open Electricity Market in the Nuclear Sector

In India, the Electricity Sector has so far largely been with the Central and State Governments. In 1991, the Electricity Supply Act –1948 was amended to provide a legal framework for facilitating greater investment by private enterprises in the Electricity Sector. Incentives have been notified by the Government from time to time. Investment Promotion Council has also been set up. The response from the private sector has been encouraging.

In terms of the Electricity Regulation Commission Act 1998, Central Electricity Regulatory Commission at the national level has been set up. Setting up of State Electricity Regulatory Commissions is under various stages of implementation. These measures will help in the rationalization of tariffs and the matters thereto. Several State Governments have taken concrete steps towards the power sector reforms including restructuring of the activities of SEBs. With all these measures, developments and new initiatives, the power sector is going through a process of transformation.

The nuclear power generation is governed by the Atomic Energy Act. The nuclear power generation and related fuel cycle activities are under the Central Government. NPCIL, a wholly owned company of GOI, DAE, is responsible for setting up the nuclear power projects. The other related fuel cycle (both front-end and back end) activities are carried out by the different units of DAE, GOI. As of now, there is no equity participation by the private sector in the area of nuclear power generation. Possibility of joint ventures with private sector is being explored. This is essentially with a view to attracting investment in the nuclear power sector for capacity addition. The NPPs presently in operation are generating electricity at competitive tariffs. Measures to reduce construction period of NPPs and standardization are being taken to strengthen the economic competitiveness of nuclear power.

3. NUCLEAR POWER SITUATION

3.1. Historical Development

A major step in the formulation of the Atomic Energy Programme in India was the passing of the Atomic Energy Act in 1948 (subsequently replaced by the Atomic Energy Act of 1962). Under the terms of the Atomic Energy Act, the Atomic Energy Commission (AEC) was constituted in 1948. Uranium exploration and mining required for the nuclear power programme were some of the initial activities that were undertaken.

The Department of Atomic Energy (DAE) of the Government of India (GOI) was established in August 1954. The Department is responsible for execution of policies laid down by the AEC. It is engaged in research, technology development and commercial operations in the areas of Nuclear Energy, High Technologies and supports basic research.

The key policy has been self-reliance. The importance of developing a strong research and development base for the nuclear power programme was recognized early on. Thus, a decision was made, in 1954, to set up a research and development centre, now called Bhabha Atomic Research Centre (BARC) at Trombay. Research reactors Apsara (1956), Cirus (1960), and Zerlina (1961) were set up at the Centre. A number of additional facilities and laboratories were built at the Centre to support the nuclear power programme and related nuclear fuel cycle activities. The Centre has a 100 MW(th) research reactor Dhruva (achieved first criticality in 1985) for carrying out studies in the frontier areas of nuclear science and technology and production of radioisotopes. The Centre extends the necessary R&D support to the nuclear power programme and associated fuel cycle.

Realizing the importance of having well trained scientists and engineers in achieving success in the programme, a training school at BARC was established in August 1957. During later stages when the training needs for the operating nuclear power stations arose, the Nuclear Training Centres (NTC) were set up by the Nuclear Power Corporation of India Limited (NPCIL). To meet the expanding needs of Human Resource, Training Schools have also been set up at the Centre for Advanced Technology, Indore (2000) and Nuclear Fuel Complex, Hyderabad (2001). All the training schools are affiliated to BARC Training School with respect to training of engineers and scientists. Thus human resource development has been given the right importance from the early stages by the DAE.

In 1947 when India became independent, its installed capacity was only about 1500 MW(e) (now grown to about 105 GW(e)). Considering the population growth, low per capita electricity consumption and need for increasing the share of commercial energy sources, large-scale production of electric power was necessary. By the late 1950's, AEC had worked out the economics of generating electricity from atomic power reactors. Based on this study, the Government decided to set up a series of nuclear power plants at locations away from coal mines and nearer to load centres. The strategy adopted by the Indian nuclear power programme is to use the country's modest uranium and vast thorium resources. In line with this strategy, a three-stage programme is envisaged. The first stage is based on setting up of pressurized heavy water reactors (PHWRs) using indigenously available natural uranium producing electricity and plutonium. This will be followed in the second stage by plutonium fuelled fast breeder reactors (FBRs) producing electricity and more plutonium and uranium-233 from thorium. The third stage of reactors will be based on thorium cycle producing power and more uranium-233.

India's first nuclear power station at Tarapur consisting of two boiling water reactors (BWRs) commenced construction in the 1960s. This was essentially to establish the technical and economic viability of nuclear power in India and to gain valuable experience. In parallel, the work on construction of PHWRs was also commenced. Apart from the first two BWR units at Tarapur which are in operation since 1969, twelve PHWR units with two units at each of the four locations Kalpakkam (MAPS), Narora (NAPS), Kakrapar (KAPS) and Kaiga (KGS), and four units at

Rawatbhata (RAPS-1&2 and RAPS-3&4) are in operation. These are in the unit size range of about 200-220 MW(e) (gross). The total installed Nuclear Power Capacity in operation is now 2720MW(e).

The technology for setting up of 540 MW(e) PHWRs has also been developed indigenously. The first 2 × 540 MW(e) PHWR project is being setup at Tarapur (TAPP-3&4). Construction work is in progress. These units are scheduled for completion by year 2006/2007. Design work for increasing the unit rating of PHWRs, to be set up in future, to 680/700 MW(e) has been taken up. Construction work for setting up of 2 × 1000 MW(e) Russian VVERs at Kudankulam is in progress. Several advanced safety features have been provided in these reactors. Construction works for setting up of 2 × 220 MW(e) units at Kaiga (Kaiga-3&4) and 2 × 220 MW(e) units at Rawatbhata (RAPP-5&6) has already started.

Nuclear power projects have been set up and operated directly under the Government of India since the late 1960's, when the construction of the first nuclear power station was commenced, until September 1987, when Nuclear Power Corporation of India Limited (NPCIL), a wholly owned company of Government of India, was formed. Formation of NPCIL was a step to give the required degree of operational freedom and to mobilize funds from the Indian capital market to finance new nuclear power projects. NPCIL is responsible to design, construct, commission and operate the nuclear power plants of the first stage nuclear power programme.

The work on the second stage of the nuclear power programme is in progress at the Indira Gandhi Centre for Atomic Research (IGCAR). The Fast Breeder Test Reactor (FBTR) 40 MW(th) at Kalpakkam is in operation. Its unique carbide fuel has achieved a burn-up of 100,000 MWD/Tonne. The technology development for the first 500 MW(e) prototype fast breeder reactor (PFBR) has been completed and pre-project activities have been taken up. Construction work will be taken up after obtaining all the clearances. Towards building up thorium based reactors, the strides taken by DAE include setting of 30kW (th) neutron source reactor Kamini at Kalpakkam, Tamil Nadu. The reactor has been in operation since 1997. Kamini uses uranium-233 based fuel derived from irradiated thorium. A detailed design report for setting up the Advanced Heavy Water Reactor (AHWR) has already been prepared. This is a vertical pressure tube reactor design utilizing heavy water moderator, boiling light water coolant, thorium-plutonium based fuel and incorporating passive safety systems. It derives 75% of its power from thorium and DAE expects to launch its construction in 2004. Nuclear Power capacities of 1300 MWe by March 2007 and 6140 MWe by March 2012 (including PFBR of 500 MW(e) and AHWR of 300 MW(e) are proposed to be added to take the total nuclear power capacity to 9935 MW(e)) by the year 2012. The goal is to reach a total nuclear power capacity of about 20,000 MW(e) by the year 2020.

Salient Milestones of Indian Atomic Energy Programme

March. 12, 1944	:	Dr. Homi Jehangir Bhabha writes to Sir Dorabji Tata Trust for starting Nuclear Research in India.
December 19, 1945	:	Tata Institute of Fundamental Research, Mumbai is inaugurated.
April 15, 1948	:	Atomic Energy Act is passed
August 10, 1948	:	Atomic Energy Commission is constituted.
July 29, 1949	:	Rare Minerals Survey Unit is set up. Later, this unit becomes Atomic Minerals Division. It is renamed as Atomic Minerals Directorate for Exploration and Research on July 29, 1998.
August 18, 1950	:	Indian Rare Earths Limited is set up for recovering minerals, processing of rare earths compounds and Thorium - Uranium concentrates.

August 03, 1954	:	Department of Atomic Energy is created.
August 01, 1955	:	Thorium Plant at Trombay goes into production.
August 04, 1956	:	APSARA - first research reactor in Asia, attains criticality at Trombay, Mumbai.
January 20, 1957	:	Atomic Energy Establishment, Trombay (AEET) is inaugurated
August 19, 1957	:	Atomic Energy Establishment Training School starts functioning.
January 30, 1959	:	Uranium Metal Plant at Trombay produces Uranium.
February 19, 1960	:	First lot of 10 Fuel Elements for CIRUS reactor is fabricated at Trombay
July 10, 1960	:	CIRUS – the 40 MW(th) research reactor, attains criticality.
January 14, 1961	:	Research Reactor ZERLINA attains criticality. (It is Decommissioned in 1983)
January 22, 1965	:	Plutonium Plant is inaugurated.
January 12, 1967	:	Atomic Energy Establishment Trombay (AEET) is renamed as Bhabha Atomic Research Centre.
April 11, 1967	:	Electronics Corporation of India Limited (ECIL) is set up at Hyderabad for producing electronic systems, instruments and components.
June 1, 1967	:	Constitution of Power Projects Engineering Division, Mumbai, which was subsequently converted to Nuclear Power Board on August 17,1984.
October 04, 1967	:	Uranium Corporation of India Limited is set up at Jaduguda, Jharkhand for mining and milling of uranium ores.
December 31, 1968	:	Nuclear Fuel Complex is set up at Hyderabad.
March 12, 1969	:	Reactor Research Centre is started at Kalpakkam. It is renamed As Indira Gandhi Centre for Atomic on December 18, 1985.
May 01, 1969	:	Heavy Water Projects is constituted. Later, it becomes Heavy Water Board.
October 28, 1969	:	Tarapur Atomic Power Station starts commercial operation.
September 06, 1970	:	Uranium-233 is separated from irradiated thorium
February 18, 1971	:	Plutonium fuel for Research Reactor PURNIMA-I is fabricated at Trombay.
May-June, 1971	:	Zirconium Oxide and Sponge Plants of Nuclear Fuel Complex,

Hyderabad are commissioned. Subsequently all the other plants of NFC went into production by 1974.

May 18, 1972 : Research Reactor PURNIMA-I attains criticality.

December 16, 1973 : Unit -1 of Rajasthan Atomic Power Station at Kota begins commercial operation. Unit -2 commenced commercial operation on April 1, 1981.

May 18, 1974 : Peaceful underground Nuclear Experiment is conducted at Pokhran Rajasthan.

June 16, 1977 : Variable Energy Cyclotron becomes operational at Kolkata.

Nov 18, 1979 : Plutonium-Uranium mixed oxide fuel is fabricated at Trombay.

November 19, 1982 : Power Reactor Fuel Reprocessing Plant at Tarapur is commissioned.

November 15, 1983 : Atomic Energy Regulatory Board is constituted.

January 27, 1984 : Madras Atomic Power Station-Unit I at Kalpakkam starts commercial operation. Unit II goes commercial on March 21, 1986.

February 19, 1984 : Centre for Advanced Technology at Indore (Madhya Pradesh) is inaugurated.

March 08, 1984 : Plutonium-Uranium mixed Carbide Fuel for Fast Breeder Test Reactor is fabricated in BARC.

May 10, 1984 : Research Reactor PURNIMA-II, a Uranium-233 fuelled homogenous reactor, attains criticality.

March 05, 1985 : Waste Immobilization Plant (WIP) at Tarapur is commissioned.

August 08, 1985 : Research Reactor DHRUVA (100 MW(th)) attains criticality. It attains full power on January 17, 1988.

October 18, 1985 : Fast Breeder Test Reactor (FBTR) at Kalpakkam attains criticality.

September 17, 1987 : Nuclear Power Corporation of India Limited is formed by converting the erstwhile Nuclear Power Board.

December 30, 1988 : 12 MV Pelletron Accelerator at Mumbai is inaugurated.

March 12, 1989 : Narora Atomic Power Station Unit-1 attains criticality. On January 1, 1991 this unit commences commercial operation. Its criticality on October 24, 1991 and commenced commercial operation on July 1, 1992.

November 09, 1990 : Research Reactor PURNIMA-III, a Uranium-233 fuelled reactor, attains criticality

September 3, 1992 : Kakrapar Atomic Power Station Unit -1 attains criticality and on May 6, 1993 this unit commences commercial operation. Its Unit –2

attains criticality on January 8, 1995 and commences commercial operation on September 1, 1995.

March 27, 1996 : Kalpakkam Reprocessing Plant (KARP) is cold commissioned.

October 20, 1996 : Kalpakkam Mini Reactor (KAMINI), with Uranium-233 fuel, attains criticality at Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamilnadu.

March. 31, 1997 : Rajasthan Atomic Power Station Unit-1 is recommissioned after repair of OPRD valve.

September 17, 1997 : Research Reactor KAMINI attains full power level of 30 kW(th).

May 11 & 13, 1998 : Five underground nuclear tests are conducted at Pokhran Range, Rajasthan.

May 27, 1998 : Rajasthan Atomic Power Station Unit-2 is recommissioned after en-masse replacement of coolant channels.

August 10, 1998 : 500 KeV industrial electron accelerator developed indigenously by the BARC is commissioned for its first phase of operation.

September 15, 1998 : Kalpakkam Reprocessing Plant (KARP) is dedicated to the Nation.

April 22, 1999 : 450 MeV Synchrotron Radiation Source Indus-1 achieves Electron beam current of 113 milli-ampere superseding the design value of 100 milli-ampere.

September 24, 1999 : Unit -2 of Kaiga Atomic Power Station attains criticality and on March 16, 2000 this unit commences commercial operation. Its Unit-1 attains criticality on September 26, 2000 and commences commercial operation on November 16, 2000

December 24, 1999 : Unit -3 of Rajasthan Atomic Power Station attains criticality and on June 1, 2000 this unit commences commercial operation. Its Unit-4 attains criticality on November 3, 2000 and commences commercial operation on December 23, 2000.

January 1, 2000 : BRIT's plant for radiation processing of spices commissioned at Vashi, Navi Mumbai.

April 21, 2000 : Folded Tandem Ion Accelerator (FOTIA) delivers first beam on target.

March 31, 2002 : Kudankulam Atomic Power Project : first pour of cement.
: Kaiga Atomic Power Project : 3&4 first pour of cement.

3.2. Status and Trends of Nuclear Power

Figures 1 & 2 along with Tables 7 & 8 give the details of performance of nuclear power plants in operation. At present, the nuclear share of total electricity generation is about 3.7%. Table 9 shows the status of nuclear power plants including those under construction.

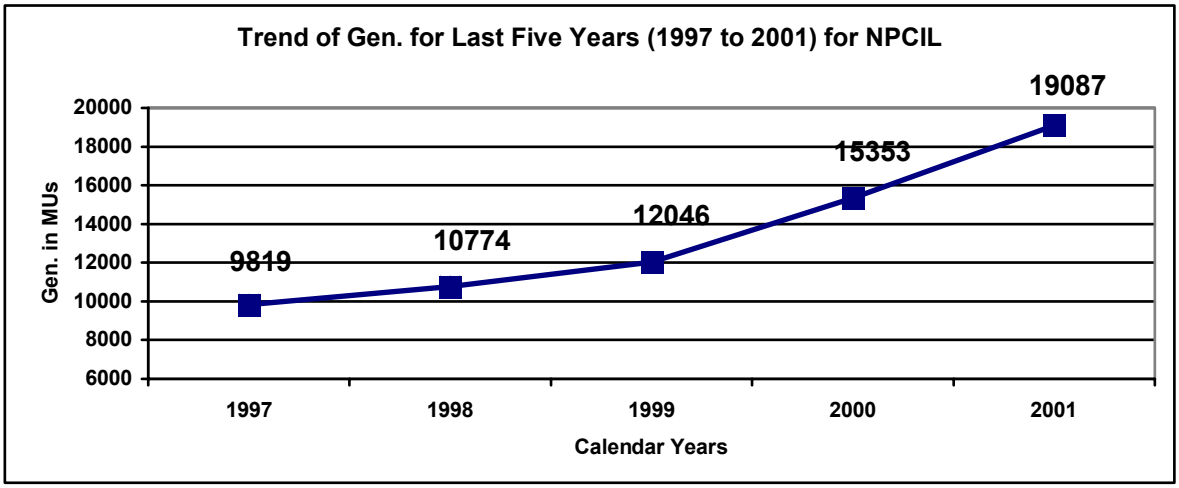

FIG. 1. Generation Trend

TABLE 7. PERFORMANCE OF NPPs IN OPERATION (GENERATION IN 10^6 KWH)

Units	Installed Capacity (MWe)	Calendar Years				
		1997	1998	1999	2000	2001
TAPS-1	160	1078	1284	944	1296	1190
TAPS-2	160	867	974	1219	1122	1316
RAPS-2	200	–	599	1361	1628	1482
MAPS-1	170	1026	803	1356	765	1321
MAPS-2	170	1091	1258	994	1439	1271
NAPS-1	220	1755	1665	1271	1556	1744
NAPS-2	220	1736	1476	1580	1487	1484
KAPS-1	220	1039	1239	1592	1850	1710
KAPS-2	220	1227	1476	1704	1674	1885
KAIGA-2	220	–	–	25#	1215@	1440
RAPS-3	220	–	–	–	1024*	1535
KAIGA-1	220	–	–	–	224$	1369
RAPS-4	220	–	–	–	73X	1340
Total NPCIL	**2620**	**9819**	**10774**	**12046**	**15335**	**19087**

Notes:

1. RAPS-1 (100 MW(e)) is not included
2. RAPS-2 was under long capital maintenance outage for en-masse replacement of coolant channels, from August 1, 1994 to 6th June 1998.
3. Kaiga-2, RAPS-3, Kaiga-1 and RAPS-4 commenced commercial operation in March 2000, June 2000, November 2000 and December 2000 respectively.

\# includes Infirm Power Generation
@ includes 99 MUs Infirm Power Generation
* includes 129 MUs Infirm Power Generation. Commercial operation from June 1, 2000.
$ includes 31 MUs Infirm Power Generation
X includes 48 MUs Infirm Power Generation. Commercial operation from December 23, 2000.

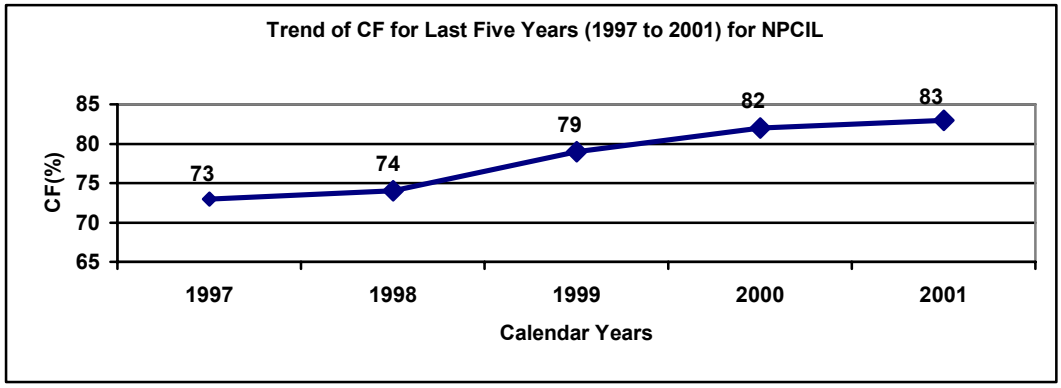

FIG.2. Capacity Factor Trend

TABLE 8. PERFORMANCE OF NPPs IN OPERATION (CAPACITY FACTORS %)

Units	Installed Capacity (MWe)	Calendar Years				
		1997	1998	1999	2000	2001
TAPS-1	160	77	92	67	92	85
TAPS-2	160	62	69	87	80	94
RAPS-2	200	–	60	78	93	85
MAPS-1	170	69	54	91	51	89
MAPS-2	170	73	84	67	96	85
NAPS-1	220	91	86	66	81	90
NAPS-2	220	90	77	82	77	77
KAPS-1	220	54	64	83	96	89
KAPS-2	220	64	77	88	87	98
KAIGA-2	220	–	–	-	73	75
RAPS-3	220	–	–	-	79	80
KAIGA-1	220	–	–	-	73	71
RAPS-4	220	–	–	-	89	70
Total NPCIL	**2620**	**73**	**74**	**79**	**82**	**83**

Notes:

1. RAPS-1 (100 MW(e)) is not included
2. RAPS-2 was under long capital maintenance outage for en-masse replacement of coolant channels, from August 1, 1994 to 6th June 1998.
3. Kaiga-2, RAPS-3, Kaiga-1 and RAPS-4 commenced commercial operation in March 2000, June 2000, November 2000 and December 2000 respectively.

TABLE 9. STATUS OF NUCLEAR POWER PLANTS

Station	Type	Net Capacity (MWe)	Status	Operator	Reactor Supplier	Construction Start	Criticality Date	Grid Connection	Commercial Operation	Shutdown Date
KAIGA-1	PHWR	202	Operational	NPCIL	NPCIL	01-Sep-89	26-Sep-00	12-Oct-00	16-Nov-00	
KAIGA-2	PHWR	202	Operational	NPCIL	FRAM	01-Dec-89	24-Sep-99	02-Dec-99	16-Mar-00	
KAKRAPAR-1	PHWR	202	Operational	NPCIL	NPCIL	01-Dec-84	03-Sep-92	24-Nov-92	06-May-93	
KAKRAPAR-2	PHWR	202	Operational	NPCIL	FRAM	01-Apr-85	08-Jan-95	04-Mar-95	01-Sep-95	
KALPAKKAM-1	PHWR	155	Operational	NPCIL	NPCIL	01-Jan-71	02-Jul-83	23-Jul-83	27-Jan-84	
KALPAKKAM-2	PHWR	155	Operational	NPCIL	NPCIL	01-Oct-72	12-Aug-85	20-Sep-85	21-Mar-86	
NARORA-1	PHWR	202	Operational	NPCIL	NPCIL	01-Dec-75	12-Mar-89	29-Jul-89	01-Jan-91	
NARORA-2	PHWR	202	Operational	NPCIL	NPCIL	01-Nov-77	24-Oct-91	05-Jan-92	01-Jul-92	
RAJASTHAN-1	PHWR	90	Operational	NPCIL	AECL	01-Aug-65	11-Aug-72	30-Nov-72	16-Dec-73	
RAJASTHAN-2	PHWR	187	Operational	NPCIL	AECL/DAE	01-Apr-68	08-Oct-80	01-Nov-80	01-Apr-81	
RAJASTHAN-3	PHWR	202	Operational	NPCIL	NPCIL	01-Feb-90	24-Dec-99	10-Mar-00	01-Jun-00	
RAJASTHAN-4	PHWR	202	Operational	NPCIL	NPCIL	01-Oct-90	03-Nov-00	17-Nov-00	23-Dec-00	
TARAPUR-1	BWR	150	Operational	NPCIL	GE	01-Oct-64	01-Feb-69	01-Apr-69	28-Oct-69	
TARAPUR-2	BWR	150	Operational	NPCIL	GE	01-Oct-64	28-Feb-69	05-May-69	28-Oct-69	
TARAPUR-3	PHWR	486	Under Construction	NPCIL	NPCIL	08-Mar-00	31-Jul-06	30-Nov-06	31-Jan-07	
TARAPUR-4	PHWR	486	Under Construction	NPCIL	NPCIL	12-May-00	31-Oct-05	30-Dec-05	30-Apr-06	
KAIGA-3	PHWR	202	Under Construction	NPCIL	NPCIL	30-Mar-02			31-Mar-07	
KAIGA-4	PHWR	202	Under Construction	NPCIL	NPCIL	30-Mar-02			Sept-07	
KUDANKULAM-1 (2)	WWER	905	Under Construction	NPCIL	ASE	31-Mar-02			Dec-07	
KUDANKULAM-2 (2)	WWER	905	Under Construction	NPCIL	ASE	31-Mar-02			Dec-08	
RAJASTHAN-5	PHWR	202	Under Construction	NPCIL	NPCIL	18-Oct-02			Aug-07	
RAJASTHAN-6	PHWR	202	Under Construction	NPCIL	NPCIL	18-Oct-02			Feb-08	

(1) Construction works have started, country information.
(2) Country information.

3.3. Current Policy Issues

The nuclear power technology in India has matured as is evident from the good performance of the indigenously constructed plants of the first stage nuclear power programme. The performance of these units has seen progressive improvements during the past years. The current emphasis is on accelerating the growth of nuclear capacity addition. The factors receiving attention are:

- Speedy construction of the projects by standardization, higher level of mechanization in construction and strengthening measures for project management;

- Finding financial resources for capacity addition. NPCIL's current operating base is small to generate sufficient internal surpluses to finance significant capacity addition. In addition to financial resources through borrowing from the capital market, budgetary support from Government and internal resources through the operating stations, strategies such as joint ventures are being explored;

- Focus on further enhancement of performance and safety of NPPs in operation by adapting front line information technology, improved techniques for predictive maintenance, in-service inspection and component replacement;

- Achieving an installed capacity of 20,000 MW(e) by 2020. Strategies are being worked out on the possibility of achieving this objective. Additional capacities are envisaged through PHWRs and FBRs based on indigenous technology and Advanced Light Water Reactors (ALWRs) based on imported technology.

3.4. Organizational Chart

The Indian Atomic Energy Organizational Structure is shown in Figure 3. Development of nuclear power and related nuclear fuel cycle and research and development activities are carried out in various units under the AEC/DAE. The organization is broadly divided into research and development sector, industrial sector, public sector, services and support sector and provides for close interaction needed between the production and R&D units.

i. Atomic Energy Regulatory Board (AERB) comes directly under the Atomic Energy Commission as the independent Regulatory Authority.

ii. Research and development sector includes Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Atomic Minerals Directorate for Exploration and Research (AMD), Centre for Advanced Research (CAT), Variable Energy Cyclotron Centre (VECC), and fully aided research institutions like Tata Institute of Fundamental Research (TIFR), Institute for Plasma Research (IPR) and others. It also includes BRNS and NBHM for providing extra-mural funding to universities and other national laboratories.

iii. Industrial sector includes Government owned units Heavy Water Board (HWB) manufacturing heavy water, Nuclear Fuel Complex (NFC) manufacturing nuclear fuel, zircaloy components and stainless steel tubes, and Board of Radiation & Isotope Technology (BRIT) for radioisotopes.

iv. Public Sector Enterprises under the control of DAE are as follows:

- Nuclear Power Corporation of India Limited (NPCIL) is responsible for design, construction, commissioning and operation the nuclear power plants;

- Uranium Corporation of India Limited (UCIL) is responsible for mining, milling and processing of uranium ore;

- Indian Rare Earths Limited (IRE) is responsible for mining and processing mineral sands containing thorium and rare earth minerals and produces minerals such as ilmenite, rutile, monazite, zircon and garnet;

- Electronics Corporation of India Limited (ECIL) supplies commercial electronics, reactor control and instrumentation equipment related to atomic energy.

v. Directorate of Construction Services and Estate Management is responsible for construction and maintenance of residential housing/office buildings and other related facilities; Directorate of Purchase and Stores is responsible for centralized purchases and stores.

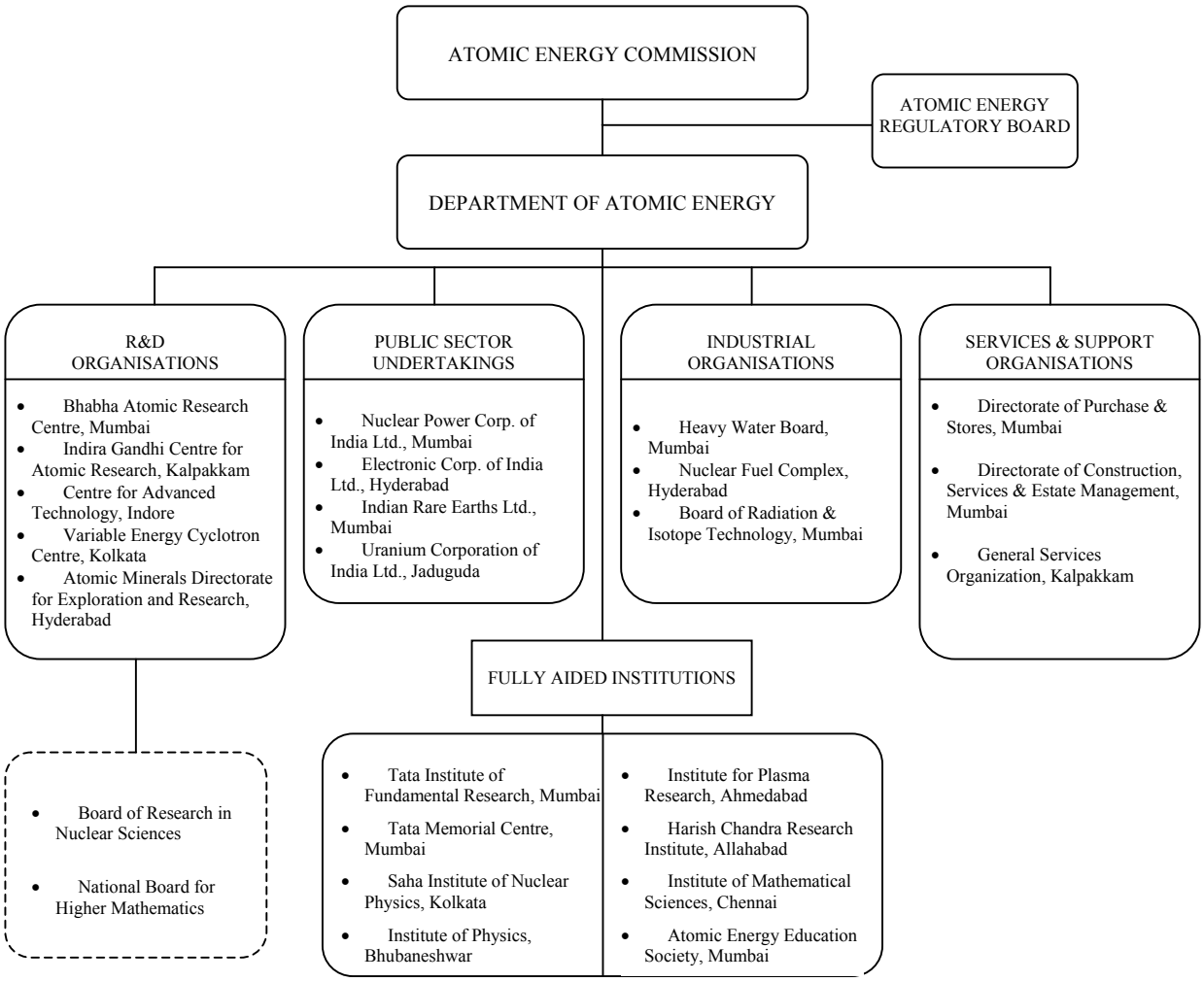

FIG. 3. Organizational Structure

4. NUCLEAR POWER INDUSTRY

The requirements of electricity demand at the national level are assessed by the Central Electricity Authority (CEA) in the Ministry of Power, GOI. The electricity generation expansion-planning studies are carried out by the CEA. The capacity addition programme for all the sources of electricity is planned through Five-Year Plans and Annual Plans by the Planning Commission, GOI. The nuclear power generation comes under the AEC/DAE, GOI. Development of nuclear power and related activities have separately organized in the DAE, GOI, due to the special requirements and R&D support needed for the programme. NPCIL, a public sector enterprise of the Department of Atomic Energy is responsible for design, construction, commissioning and operation of the nuclear power stations. It is supported by the different units of the Department for R&D, supply of fuel, heavy water, etc. Power generated from the nuclear power stations is sold to State Electricity Boards as per the power purchase agreements. The power supplied is shared by the States in the respective Electricity Region in which the nuclear power plant is located. The laying of transmission lines for evacuation of power from the nuclear power plants is carried out by the Power Grid Corporation of India Limited (PGCIL), a public sector enterprise of Ministry of Power, GOI. This is based on the transmission scheme approved by CEA on a regional basis. The tariffs for generation of electricity generated by the nuclear power stations are fixed based on the applicable norms and notified by the DAE in consultation with the CEA. AERB is the Competent Authority for the regulation on the safety aspects of nuclear power. Environmental clearances for the nuclear power plant sites are obtained from the Ministry Of Environment and Forests, GOI apart from the clearance of AERB.

4.1. Supply of Nuclear Power Plants

India's first nuclear power station, Tarapur, was constructed by the International General Electric Co., USA based on a turnkey contract. The second nuclear power station at Rajasthan was built as a collaborative venture with AECL Canada. For all subsequent nuclear power stations, DAE/NPCIL assumed total responsibility for design, manufacture, construction, commissioning and operation. NPCIL carries out the nuclear design. Balance of plant engineering is done by Indian Consulting Engineering firms (employed by NPCIL) who have expertise in the fossil thermal power plant engineering.

Manufacturing of most of the materials, components and equipment required for nuclear power plants is done indigenously. India has heavy engineering plants in both public and private sectors, manufacturing large steam generators, turbines, electrical equipment, heat exchangers, pumps, pressure vessels and other industrial equipment. The Indian Nuclear Power Programme utilizes these facilities for manufacture of nuclear and conventional equipment. In the early stage of the programme these facilities were augmented, whenever necessary, with balancing machinery and technical inputs to meet nuclear quality assurance requirements. Quality surveillance representatives of NPCIL are posted at the major manufacturer's shops for this purpose.

NPCIL integrates all the activities relating to setting up the nuclear power plant. It plays the role similar to that of a turnkey supplier. Fuel, heavy water, zircaloy components, reactor control equipment, are supplied by the units of DAE from the facilities set up for this purpose.

4.2. Operation of Nuclear Power Plants

NPCIL operates and maintains the NPPs in operation. Each station has Operation, Maintenance, Technical and Training Groups. These functions are carried out by specially trained and qualified operating and maintenance personnel at each nuclear power station. The NPPs include reactor components and process systems, turbine generators, electrical system equipment, instrumentation and control systems (I&C), cooling water intake and out fall structures, heavy water upgrading plant (at PHWR stations), waste management facilities and the like, to be operated and maintained. Whenever required, the services of equipment suppliers are availed through contracts for major maintenance and overhaul. Three groups of technical and scientific personnel are required for

the nuclear power programme: qualified professionals, i.e., engineers and scientists who later become senior engineers and managers; semi-professionals having engineering diplomas or advanced trade certificates who constitute the supervisory personnel; and, technicians like operators and maintainers with high school education and trade certificates.

Professionals get inducted into the Atomic Energy Organization by completing one-year training course at the BARC training school in Trombay or its affiliates at Indore, Hyderabad and NTCs of NPCIL. Separate training programmes at different levels are conducted at the NPCIL's Nuclear Training Centres of operating stations for qualifying and licensing of operating personnel, as per the regulatory requirements.

Technology, tools and procedures have been successfully developed and deployed based on indigenous efforts for in-service inspection, complex in-core maintenance and major refurbishment work. Plant life extension work is also in progress at TAPS. The replacement of coolant channel and up-gradation work of RAPS-2 was completed based on indigenously developed tools and technology and the unit was put back in service. The repair of Over Pressure Relief Device (OPRD) at RAPS –1 was successfully carried out based on indigenously developed tools and technology and the unit has commenced service. Similarly tools for In-service Inspection of Coolant Channels and Garter Spring relocation have also been indigenously developed.

NPCIL is a member of World Association of Nuclear Operators (WANO). WANO Peer Review of the nuclear power plants being undertaken progressively by NPCIL. NPCIL is also a member of Candu Owners Group (COG).

4.3. Fuel Cycle, Spent Fuel and Waste Management Service Supply

Fuel cycle and waste management services are provided by various units of the Department of Atomic Energy (DAE). Uranium Corporation of India Ltd., (UCIL), a public sector company of DAE, carries out mining and processing of uranium deposits surveyed by the Atomic Minerals Directorate of Exploration & Research (AMD) of DAE. Nuclear Fuel Complex (NFC), an industrial unit of DAE, utilizes the uranium concentrates supplied by UCIL to fabricate PHWR's nuclear fuel assemblies. For the BWR's in Tarapur, NFC manufactures the fuel assemblies from imported uranium. NFC also supplies the required zircaloy components. Heavy water required for the initial charge and subsequent make-up requirements of the nuclear power plants are supplied by the Heavy Water Board of DAE.

Spent fuel from the PHWRs is reprocessed to extract the plutonium contained in it. Build up of plutonium inventory is vital for development of the second stage of the Indian nuclear power programme consisting of fast breeder reactors. The fuel reprocessing plants are set up by the BARC based on the technology developed by it. Power Reactor Fuel Reprocessing Plants at Tarapur and Kalpakkam are operational.

Processes for treating reactor produced wastes have been established and plants meeting regulatory requirements have been in operation during the past several decades. This is also the case with waste generated from fuel reprocessing plants. The first waste immobilization plant at Tarapur is in service and a Solid Storage Surveillance Facility (S3F) has also been set up for interim storage of waste. A Waste Immobilisation Plant (WIP) has been installed at Trombay and another WIP is under construction at Kalpakkam. R&D work for ultimate disposal of high level and alpha bearing wastes in a repository is in progress.

4.4. Research and Development Activities

- BARC, is the national research centre for multidisciplinary R&D work in nuclear sciences, reactor engineering, reactor safety, nuclear fuel, control and instrumentation, material science, spent fuel reprocessing and radioactive waste management, development of radiation technology applications etc. R&D work on development of the AHWR is in progress at this Centre and the

prototype unit is expected to be launched in a few years (see also Section 3.1). Development works on plant life extension, ageing and in-service inspection are given due importance.

- IGCAR is responsible for R&D related to development of FBR technology. Technology development for the first 500 MW(e) PFBR has significantly progressed and construction of the reactor will commence at Kalpakkam shortly.

- Atomic Mineral Directorate for Exploration and Research (AMD) at Hyderabad, is responsible for survey, exploration and prospecting of atomic minerals, etc.

- The other R&D institutions of the DAE are carrying out advanced research work in hi-tech areas such as accelerators, lasers, bio-sciences etc. and also in basic science areas such as physics, chemistry and mathematics, etc.

- Academic Institutions and Universities also extend R&D support in specific areas as per needs.

- The Board of Research in Nuclear Sciences (BRNS) and the National Board of Higher Mathematics (NBHM) support research activities in national institutes and universities in the fields of nuclear technology and mathematics.

4.5. International Co-operation in the Field of Nuclear Power Development and Implementation

International co-operation is through multilateral mechanism with IAEA as well as through bilateral mechanisms. Under the aegis of the IAEA, India has trained a number of personnel, particularly from the developing countries. India has also hosted a number of workshops, seminars and training courses. The expertise of India's scientists and engineers is made available to other countries through IAEA.

NPCIL is a member of WANO Tokyo Centre, WANO Atlanta Centre and Candu Owners Group (COG). Many Indian Professional have participated in the workshops/seminars/training courses, conducted by these organisation. Also many Indian professional have participated as Reviewer / Lead
Reviewer in the WANO Peer Review of Plants abroad. NPCIL team has also visited other NPPs outside India under the Technical Exchange Visit (TEV) programme of WANO. Similarly NPCIL plants have also received TEV team from other NPPs worldwide.

5. REGULATORY FRAMEWORK

5.1. Safety Authority and the Licensing Process

Enforcement of safety related regulation at all nuclear facilities lies with the Atomic Energy Regulatory Board (AERB), empowered by the Government of India. The regulatory organization is shown in Figure 4. No activity related to atomic energy can be carried out by any agency or utility without authorization by the AERB. Before granting authorizations, the AERB conducts an in-depth review so that nuclear facilities do not pose any radiological risk to the public and plant personnel. The review process is shown in Figure-5. The authorization process involves various major activities like site approval, construction, commissioning, operation and decommissioning. The authorization process is an ongoing process starting with site selection and feasibility study, continuing through the construction and operation of the facility until the decommissioning of the plant. The applicant is required to provide all relevant information, such as safety principle, analysis, criteria and standards proposed for each major stages, and quality assurance demonstrating that the plant will not pose any undue radiological risks to site personnel and the public.

ORGANISATION CHART
ATOMIC ENERGY REGULATORY BOARD

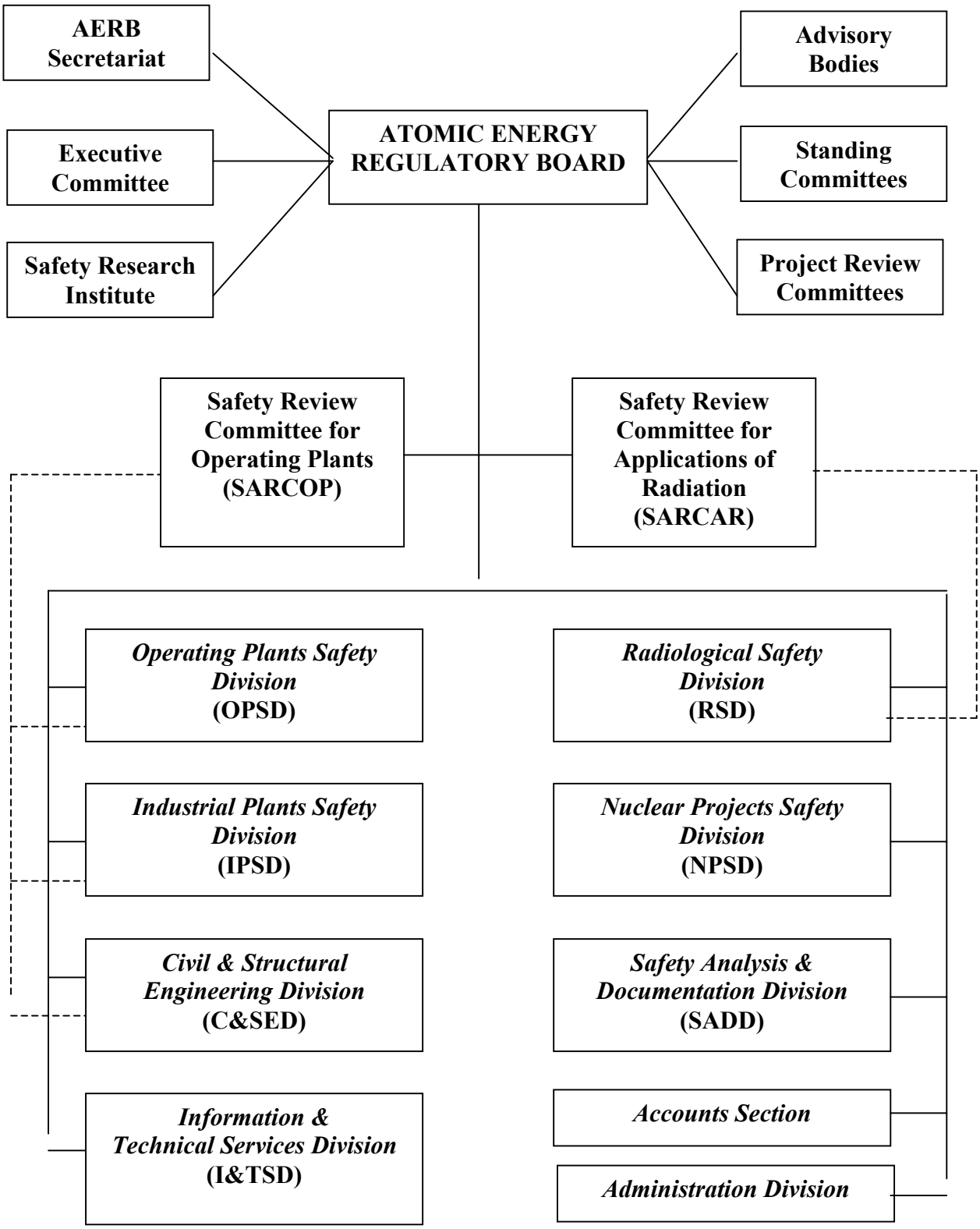

FIG. 4 ORGANISATION CHART ATOMIC ENERGY REGULATORY BOARD

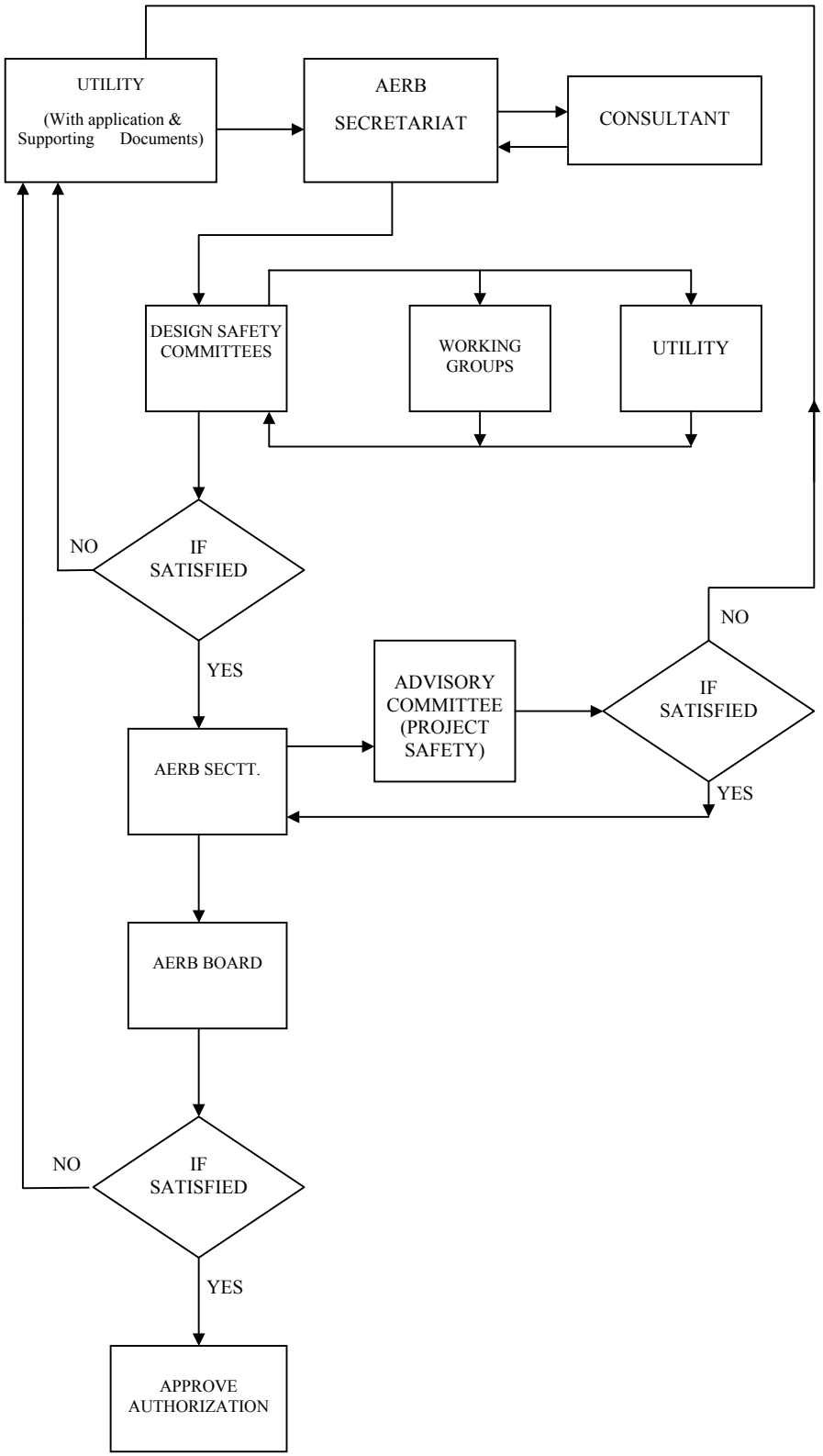

Fig 5. AERB Regulatory Review Process for Authorisation

AERB has advisory committees for site selection, design review and authorization, and licenses for commissioning. The advisory committees are assisted by unit level safety committees, which undertake detailed safety assessments at the design and commissioning stages of nuclear facilities. AERB then issues its authorization based on the recommendations of the advisory committee. Safety assessments during plant operation are done by the Safety Committee for Operating Plants (SARCOP). Authorization is granted only for a limited period and further authorization is required beyond that period. Authorization also includes explicit conditions that the applicant must adhere to. AERB also ensures that all the nuclear facilities have put in place an emergency preparedness procedure and organization.

5.2. Main National Laws and Regulations

The Atomic Energy Regulatory Board (AERB) was formed in November 1983 by the Government of India in exercise of the powers conferred by the Atomic Energy Act of 1962, to carry out regulatory and safety functions as envisaged in the Act. As per its constitution, AERB has the power of the Competent Authority to enforce rules and regulations framed under the Atomic Energy Act for radiation safety in the country. AERB also has the authority to administer the provisions of the Factories Act, for industrial safety of the units of DAE. AERB has been delegated with powers to enforce some of the provisions of the Environmental Protection Act, at DAE installations. A number of rules, codes, and regulations covering the entire nuclear fuel cycle have been defined by AERB as well as DAE under the Atomic Energy Act of 1962, for instance:

- Radiation Protection Rules, 1971;
- Atomic Energy (arbitration procedure) Rules, 1983;
- Atomic Energy (working of mines, minerals and handling of prescribed substances) Rules, 1984;
- Atomic Energy (safe disposal of radioactive waste) Rules, 1987;
- Atomic Energy (factories) Rules, 1996;
- Atomic Energy (control of irradiation of foods) Rules, 1996.

Prior to setting up of AERB, the DAE- Safety Review Committee (DAESRC) was carrying out these functions. DAESRC was supported by the Unit level Safety Committees.

5.3. International, Multilateral and Bilateral Agreements

AGREEMENTS WITH THE IAEA

• Amendment to the Article VI of the IAEA Statue	Entry into force:	28 December 1989
• Amendment to the Article XIV of the IAEA Statute	Not ratified	
• Agreement on privileges and immunities	Entry into force:	10 March 1961
• Additional protocol	Not signed	
• Supplementary agreement on provision of technical assistance by the IAEA	Non-Party; Text of agreement handed over to authorities by ADG-ADEX on:	6 Oct. 1993
• RCA	Entry into force:	6 July 1987
• The Agency's assistance in furthering projects by the supply of materials	Entry into force:	9 December 1966

MULTILATERAL SAFEGUARDS AGREEMENTS

• Safeguards transfer relating to the bilateral agreement with the United States of America	Entry into force:	27 January 1971
• Safeguards transfer relating to the bilateral agreement with Canada; INFCIRC/211	Entry into force:	30 September 1971
• Application of safeguards in connection with the supply of heavy water from the Soviet Union; INFCIRC/260	Entry into force:	17 November 1977
• Application of safeguards in connection with the supply of a nuclear power station from the USSR; INFCIRC/360	Entry into force:	27 September 1988
• Application of safeguards in connection with the supply of nuclear material from France INFCIRC/374	Entry into force:	11 October 1989
• Agreement for the application of safeguards to all nuclear material subject to Agency Safeguards under INFCIRC/154, Part 1 INFCIRC/433 INFCIRC/433/Mod. 1	Entry into force:	1 March 1994 12 September 1994
• Improved procedures for designation of safeguards inspectors	Accepted on:	9 January 1989

MAIN TREATIES OR AGREEMENTS

• NPT	Non Party	
• Convention on physical protection of nuclear material	Entry into force	11 April 2002
• Convention on early notification of a nuclear accident	Entry into force:	28 February 1988
• Convention on assistance in the case of a nuclear accident or radiological emergency	Entry into force:	28 February 1988
• Vienna convention on civil liability for nuclear damage	Non Party	
• Paris convention on civil liability for nuclear damage	N.A.	
• Joint protocol	Non Party	
• Protocol to amend the	Not signed	

Vienna convention on civil liability		
• Convention on Supplementary compensation for nuclear damage	Not signed	
• Convention on nuclear safety	Signature:	20 September 1994
• Joint convention on the safety of spent fuel management and the safety of radioactive waste management	Not signed	
• Agreement establishing the Asian Regional Co-operative Project on Food Irradiation	Entry into force:	23 May 1980
• Memorandum of Understanding between the IAEA and the Department of Atomic Energy, Government of India, concerning strengthening of Co-operation in connection with the Agency's regional and inter-regional training events, individual and group fellowship programmes carried out as part of the Technical Co-operation Activities of the IAEA		May 2000

OTHER RELEVANT INTERNATIONAL TREATIES etc

• Zangger Committee	N.A.
• Nuclear Export Guidelines	Export control system in place since 1948 when the Atomic Energy Act was passed by the Constituent Assembly
• Acceptance of NUSS Codes regulatory	Summary: Valuable guidance for national requirements. Useful reference in safety assessments. India's regulatory requirements are generally consistent with codes. Aims to meet requirements although they are not binding. Letter of: 17 June 1988

BILATERAL AGREEMENTS

• Co-operation agreement concerning peaceful uses of nuclear energy	Egypt	10 July 1962
• Co-operation agreement concerning peaceful uses of nuclear energy	Belgium	30 January 1965
• Setting up of an Isotope Dispensation Unit at Kabul University	Afghanistan	14 May 1966
• Co-operation agreement concerning peaceful uses of nuclear energy	Czech Republic	9 November 1966
• Co-operation agreement concerning peaceful uses of nuclear energy	Germany	5 October 1971
• Co-operation agreement concerning peaceful uses of nuclear energy	Iraq	28 March 1974
• Co-operation agreement concerning peaceful uses of nuclear energy	Poland	9 September 1977
• Co-operation agreement concerning	Russian	22 January 1979

peaceful uses of nuclear energy	Federation	
• Co-operation agreement concerning peaceful uses of nuclear energy	Syria	1 May 1980
• Co-operation agreement concerning peaceful uses of nuclear energy	Indonesia	9 January 1981
• Co-operation agreement concerning peaceful uses of nuclear energy	Cuba	18 May 1985
• Co-operation agreement concerning peaceful uses of nuclear energy	Viet Nam	25 May 1986
• Prohibition of Attacks against Nuclear Installations and Facilities	Pakistan	31 December 1988
• Co-operation agreement concerning peaceful uses of nuclear energy	Algeria	25 September 1990
• Co-operation agreement concerning peaceful uses of nuclear energy	Philippines	29 April 1991
• Co-operation agreement concerning peaceful uses of nuclear energy	Peru	12 February 1992
• Exchange of Information and Co-operation in Area of Nuclear Safety	France	29 July 1999
• Co-operation agreement concerning peaceful uses of nuclear energy	Thailand	2000

REFERENCES

[1] Country Profile of India 1995-96, Economist Intelligence Unit

[2] Annual Report 2001-02, Ministry of Power, Government of India

[3] Annual Report 2001-02, Department of Coal, Government of India

[3] Annual Report 2001-02, Ministry of Non-Conventional Energy Sources

[4] India 1999, A Reference Manual, Compiled and Edited by Research, Reference and Training Division, Publication Division, Ministry of Information and Broadcasting, Government of India Division.

[5] Annual Report 2001-02, Government of India , Department of Atomic Energy.

[6] Data & Statistics, The World Bank, www.worldbank.org/data.

[7] IAEA Energy and Economic Data Base (EEDB)

[8] IAEA Power Reactor Information System (PRIS)

Appendix

DIRECTORY OF THE MAIN ORGANIZATIONS, INSTITUTIONS AND COMPANIES INVOLVED IN NUCLEAR POWER RELATED ACTIVITIES

NATIONAL ATOMIC ENERGY AUTHORITY

Atomic Energy Commission Anushakti Bhavan Mumbai -400 001, India	Tel: 91 22 202 2543 Fax: 91 22 204 8476
Department of Atomic Energy (DAE)	http://www.dae.gov.in/

NUCLEAR RESEARCH INSTITUTES

Bhabha Atomic Research Centre (BARC) Mumbai	Tel.: 91 22 550 5050 Fax: 91 22 550 5151 or 551 9613
Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam	http://www.igcar.ernet.in/ http://www.barc.ernet.in/
Institute for Plasma Research, Gandhinagar	http://www.plasma.ernet.in/
Institute of Physics, Bhubaneswar	http://www.iopb.res.in/
Saha Institute of Nuclear Physics, Kolkata	http://www.saha.ernet.in/
Tata Institute of Fundamental Research Mumbai	http://www.tifr.res.in/

HIGH ENERGY RESEARCH INSTITUTES

Centre for Advanced Technology (CAT), Indore:	http://www.cat.ernet.in/
Nuclear Science Centre, New Delhi	
Variable Energy Cyclotron Centre (VECC), Kolkata	http://veccal.veccal.ernet.in/

NUCLEAR POWER PLANTS

Kakrapar Atomic Power Station	http://www.dae.gov.in/kapp.htm
Kaiga Generating Station	
Madras Atomic Power Station	http://www.dae.gov.in/maps.htm
Narora Atomic Power Station	http://www.dae.gov.in/naps.htm
Rajasthan Atomic Power Station	http://www.dae.gov.in/raps.htm

Tarapur Nuclear Power Station	http://www.dae.gov.in/taps.htm

OTHER ORGANIZATIONS

Nuclear Power Corporation of India Limited (NPCIL)	http://www.npcil.org/
Electronics Corporation of India Ltd (ECIL)	http://ns.stph.net/ecil/
Heavy Water Board, Mumbai	http://www.dae.gov.in/hwp.htm
Indian Rare Earths Ltd.	http://www.dae.gov.in/ire.htm
Nuclear Fuel Complex, Hyderabad	http://www.dae.gov.in/nfc.htm
Uranium Corporation of India Ltd.	http://www.dae.gov.in/mine.htm
Board of Radiation & Isotope Technology, Mumbai	
Harish-Chandra Research Institute(HCRI), Allahabad	
Tata Memorial Centre:Mumbai	http://www.tatamemorialcentre.com/
The Institute of Mathematical Sciences Chennai	http://www.imsc.ernet.in/
Central Power Research Institute (CPRI) Bangalore	http://powersearch.cpri.res.in/