INDIA

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1. ENERGY, ECONOMIC AND ELECTRICITY 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 east 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 including in the fields of atomic energy and space 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 (Power Utilities) as of 31st January 2003 is 107533.70 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	2001	2002[3]	2003[3]	Growth rate[1] (%/yr) 1991 to 2001
Population (millions)	439	548	683	843	1027	1042	1058	2
Population density (inh/km^2)[2]	134	167	208	256	312	317	321	2
Urban Population as % of total	18	20	23	25.7	27.8	28	28.3	2.7
Area (1000 km^2) 3287.3								

[1]Calculated approximate annual growth rate (compound).

[2]Calculated and rounded off figures.

[3]The population figures are for 31st March of the year. The decadal population figures for 1961 to 2001 are by census. The figures for the years 2002 and 2003 are extrapolated with an estimated average (during the current decade) annual growth rate of 1.5%/Yr.

Source: Provisional Population Totals, Paper-1, Census of India, 2001.

The GDP, at factor cost and 1993-94 prices, grew at average compound annual rate of about 5.4 %/yr during the period 1980 to 2000. During 2000-2001 and 2001-2002 the GDP growth rates were about 4.4% and 5.6% respectively [at factor cost and at constant 1993-94 prices, Ref. CSO Release 31st Jan. 2003, http://indiabudget.nic.in/es2002-03/chap2003/tab1.1.htm]. Due to wide ranging economic measures the Indian economy is poised to grow significantly. The confederation of Indian Industry forecasts a GDP growth rate between 6.0% and 6.4% during 2003-04 factoring in the expected buoyant growth rates in industry (6.5%) and services (7.5%) [Ref. http://www.indiainfoline.com/nevi/stec03.pdf]. The historical GDP data are given in Table 2.

TABLE 2. GROSS DOMESTIC PRODUCT (GDP)#

	1970	1980	1990	2000	2001	2002	Growth Rate (%/yr) 1980 to 2000
GDP[1]	46,913	164,571	284,813	406,624	439,086	460,672	4.63
GDP[2]	94,446	127,870	220,871	366,082	403,379	421,007	5.40
GDP[3] per capita	86	241	338	402	428	442	2.59
GDP by sector (%):							
– Agriculture	44	38	32	25	26	25	-2.07
– Industry	24	26	26	27	27	26	0.19
– Services	32	36	42	48	47	49	1.45

Source 1. Statistical outline of India 2001-2002, Tata services Limited, Department of Economics and Statistics, 2. India Profile: overview- Economic Progress: GDP, Sectoral Growth of GDP (http://www.saarcnet.org/newsaarcnet/countryprofile/india/india.htm), 3. Press Information Bureau, GOI (http://mospi.nic.in/t1_26june2002.htm) and The World Bank Group (http://www.worldbank.org/data/) and 4. CSO Data Jan31, 2003 (http://indiabudget.nic.in/es2002-03/chapt2003/tab1.1htm)

[1] Million current US$ at factor cost at current prices

[2] Millions of constant 1995 US$ (at factor cost & at 1993-94 prices, 1US$ = 31.37 Rs.)

[3] Current US $ (at factor cost & current prices)

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 600 billion kilowatt hours annually corresponding to a name plate capacity of 150,000 MWe. On 31.03.2003 the total installed hydro power capacity with utilities was 26910 MWe (i.e. about 18% of the total potential). A capacity addition of 14,393 MWe during the 10th five year plan i.e. during 2002-2007 has been planned. 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, 2003, the geological reserves of coal are estimated to be about 240.75 billion tonnes out of which the proven reserves are about 90 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 (proven about 3.7 billion tonnes) and are being exploited for this purpose in Tamil Nadu and Gujarat. As on January 1, 2003 recoverable reserves of crude oil are placed at 735 million tonnes and of natural gas at 762 billion cubic meters.

TABLE 3. ESTIMATED ENERGY RESERVES[1]

Exajoule

	Solid[2]	Liquid	Gas	Nuclear	Hydro[3]	Total[4]
Total proven amount in place (1-1-2003)	1625	31	29	–	2.16 (e)	1685

[1] India March 2003, Energy Information Administration (www.eia.doe.gov). 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

[2] Proven Coal (of the year 2003) and Lignite (of the year 2001) Reserves (Coal- http://coal.nic.in/reserve2.htm, Lignite- Report of Working Group on Coal & Lignite for Tenth Five Year Plan, July 2001)

[3] Renewable Source in electricity units

[4] Does not include Hydro (being renewable) and nuclear

Uranium reserves in the country are estimated to be about 95,000 tonnes (metal). It does not include reserves in speculative category. After accounting for various losses in mining, milling and fabrication the net uranium available for power generation is estimated to be about 61,000 tonnes (metal). One of the largest resources of thorium in the world is contained in monazite deposits (about 8 million tonnes) in India mainly along the Indian seacoast. Out of this about 4 million tonnes is considered exploitable of which 70% is considered mineable containing about 2,25,000 tonnes of thorium metal.

The estimated power generation potential from non-conventional renewable energy resources is about 100,000 MW. This includes 45,000 MW from wind , 15,000 MW from small hydro, 19,500 MW from bio-mass/biomass-cogeneration, 1,700 MW from urban and industrial etc. Thermal applications of such resources include solar thermal systems, biogas plants, improved biomass cooking stoves etc.

TABLE 4. ENERGY STATISTICS

Exajoule

	1960	1970	1980	1990	2000[4]	2001[4]	2002[5]	Average annual growth rate (%) 1960 to 1980	1980 to 2000
Energy consumption									
– Total[1]	1.43	4.15	6.62	11.25	16.05	16.58	16.59	7.96	4.53
– Solids[2]	1.07	3.1	4.78	7.74	9.45	9.70	9.53	7.77	3.46
– Liquids	0.29	0.77	1.31	2.37	4.43	4.59	4.83	7.83	6.28
– Gases	N/A	0.02	0.05	0.39	1.07	1.14	1.18	–	16.55
– Primary electricity[3]	0.026	0.092	0.17	0.23	0.33	0.34	0.31	9.84	3.37
Energy production									
– Total	1.2	3.74	5.61	10.09	12.57	12.74	12.66	8.02	4.11
– Solids	1.1	3.17	4.69	7.53	8.96	9.09	9.03	7.52	3.29
– Liquids	0.02	0.29	0.39	1.43	1.38	1.37	1.41	16.01	6.52
– Gases	N/A	0.02	0.05	0.39	1.13	1.14	1.18	–	16.87
– Primary electricity[3]	0.026	0.092	0.17	0.23	0.33	0.34	0.31	9.84	3.37
Net import (import – export)									
– Total	0.26	0.5	0.97	1.22	3.57	3.78	3.93	6.8	6.73
– Solids	-0.03	-0.01	0.01	0.15	0.41	0.55	0.51	6.57	20.4
– Liquids	0.29	0.51	0.96	1.07	3.16	3.23	3.42	6.17	6.13
– Gases	N/A	N/A	N/A	N/A	N/A	N/A	N/A	–	–

Years represent financial years from 1st April of the year to 31st March of the next year.

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

(2)Solid fuels include coal, lignite and estimated commercial wood. The consumption of the wood is assumed to remain constant at 3.134 EJ (Ref.: S.K. Varma, 'Coal- A Predominant Option' Proc. Power in the New Millennium Plans & Strategies, Indian Nuclear society, Aug 31- Sept 2, 1999)

(3)Primary electricity = Hydro + Nuclear + Wind

(4)Annual Reports 2001-2002 and 2002-03 of Ministries of Power, Coal, Petroleum & natural Gas, Non-conventional Energy Sources, Central Electricity Authority and Department of Atomic Energy of Government of India.

(5) Estimated from the latest results given in the Annual Reports of the year 2002-03 of various Ministries of Government of India. Electricity Figures are actual.

Source: IAEA Energy and Economic Database

1.2. 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 utilisation 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;
- Organisation of training for the personnel engaged at various levels in the energy sector.

1.3. Electricity Sector

Electricity is a concurrent subject as per the Constitution of India implying that both the Parliament and the State Legislature have the authority to legislate on the subject. The structure of the electricity sector derives its character and composition from the Indian constitution and till recently was mainly defined by the following Acts:

- Indian Electricity Act of 1910 legislated over the supply and use of electrical energy in India.
- Indian Electricity (Supply) Act of 1948 enacted in order to secure a fully coordinated development of electricity on a regional basis.
- Electricity Regulatory Commission Act, 1998 had been enacted with a view to providing for the establishment of Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERC).

For speedy reforms in the power sector with the goal of electrifying all the villages by 2007 and all the households by 2012 and to modernise the sector, the Electricity Bill 2003 has been enacted on June 10, 2003.

Electricity Act 2003 (Ref. http://powermin.nic.in/electricity_act_2003/):

This act consolidates all electricity legislations (Central and State) into one comprehensive binding act. It seeks to create a liberal framework of development for the power sector by distancing Government from regulation. The objectives of the Act are "to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto."

The salient features of the Act are as follows:
i) The Central Government to prepare a National Electricity Policy in consultation with State Governments. (Section 3)
ii) Thrust to complete the rural electrification and provide for management of rural distribution by Panchayats (local governing bodies), Cooperative Societies, non-Government organisations, franchisees etc. (Sections 4, 5 & 6)
iii) Provision for licence free generation and distribution in the rural areas. (Section 14)
iv) Generation being delicensed and captive generation being freely permitted. Hydro projects would, however, need clearance from the Central Electricity Authority. (Sections 7, 8 & 9)
v) Transmission Utility at the Central as well as State level, to be a Government company – with responsibility for planned and coordinated development of transmission network. (Sections 38 & 39)
vi) Provision for private licensees in transmission and entry in distribution through an independent network, (Section 14)
vii) Open access in transmission from the outset. (Sections 38-40)
viii) Open access in distribution to be introduced in phases with surcharge for current level of cross subsidy to be gradually phased out along with cross subsidies and obligation to supply. SERCs to frame regulations within one year regarding phasing of open access. (Section 42)

ix) Distribution licensees would be free to undertake generation and generating companies would be free to take up distribution businesses. (Sections 7, 12)
x) The State Electricity Regulatory Commission is a mandatory requirement. (Section 82)
xi) Provision for payment of subsidy through budget. (Section 65)
xii) Trading, a distinct activity is being recognised with the safeguard of the Regulatory Commissions being authorised to fix ceilings on trading margins, if necessary. (Sections 12, 79 & 86)
xiii) Provision for reorganisation or continuance of SEBs. (Sections 131 & 172)
xiv) Metering of all electricity supplied made mandatory. (Section 55)
xv) An Appellate Tribunal to hear appeals against the decision of the CERC and SERCs. (Section 111)
xvi) Provisions relating to theft of electricity made more stringent. (Section 135-150)
xvii) Provisions safeguarding consumer interests. (Sections 57-59, 166) Ombudsman scheme (Section 42) for consumers grievance redressal.

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

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).

- A new company Bhartiya Nabhikiya Vidyut Nigam Ltd. (BHAVINI) was incorporated to set up fast reactors in October 2003. This is also under the administrative control of the 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 generation through non-conventional renewable energy sources comes under the administrative control of 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.

The PTC (Power Trading Corporation) is an entity established to serve as a single point of contract for entering into power purchase agreements with independent power producers on the one hand and the consumers or state utilities on the other.

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.

1.4. Electricity 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 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, 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.

With the enactment of the Electricity Act 2003 the electricity sector is in an evolutionary state. The act itself is subject to modifications. The government is expected to shortly move three amendments to the act. The amendments seek to dilute the anti- theft provisions to avert misuse, set a three to five years time frame for introduction of the 'Open Access' scheme, and clip the powers of the Appellate Court to ensure greater autonomy for the State Power Regulators.

1.5. Main Indicators

The per capita commercial energy consumption has increased from 3 GJ in 1960 to nearly 16 GJ in 2003. During the same period per capita electricity generation from utilities increased significantly from 45 kWh to 505 kWh. The total installed electric power capacity of only 5.58 GW(e) in 1960 has made an impressive growth to about 108 GW (e) in 2002-03. The major contribution of electricity generation during 2002-03 in energy terms (from utilities) is from thermal power constituting about 84.4%, followed by hydro about 12% and nuclear about 3.7%. During the period since 1980 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)	2002(2)	1960 to 1980	1980 to 2000
Electricity production (TWh)									
– Total(1)	20.12	61.21	119.26	289.44	499.45	515.25	533.74	9.31	7.42
– Thermal	12.28	33.53	69.7	212.65	408.21	421.98	448.54	9.07	9.24
– Hydro	7.85	25.26	46.56	71.66	74.35	73.94	63.83	9.31	2.36
– Nuclear	–	2.42	3	5.11	16.9	19.32	19.24	–	9.02
– Wind	–	–	–	–	1.58	1.97	2.13	–	–
Capacity of electrical plants GW(e))									
– Total	5.58	16.27	33.32	74.7	101.15	104.91	107.97	9.35	5.7
– Thermal	3.73	9.47	20.66	54.82	71.91	74.42	76.61	8.93	6.43
– Hydro	1.85	6.39	11.79	18.76	25.22	26.26	26.91	9.72	3.87
– Nuclear	–	0.42	0.86	1.09	2.72	2.72	2.72	–	5.92
– Wind	–	–	–	0.03	1.27	1.51	1.74	–	–

Years represent financial years from 1st April of the year to 31st March of the next year.
(1)Electricity from Utilities only. Losses are not deducted
(2)Capacities as on 31st March of the following year. Personal Communication, Central Electricity Authority Coordination Div., R.K. Puram, New Delhi
Source: IAEA Energy and Economic Database

TABLE 6. ENERGY RELATED RATIOS

	1960	1970	1980	1990	2000	2001	2002(3)
Energy consumption per capita (GJ/capita)	3	7	10	13	16	16	16
Electricity per capita (kWh/capita)(1)	45	104	161	315	495	502	505
Electricity Production/ Energy Consumption (%)	13.7	15.2	18.5	30.9	37.3	37.6	38.1
Nuclear/Total electricity (%)	–	4	3	2	3.4	3.7	3.6
Ratio of External dependency (%) (2)	18	12	15	11	22.4	22.8	23.7
Load factor of electricity plants							
– Total (%)	41	43	41	54	-	-	-
– Thermal	38	40	39	44	69	69	72
– Hydro	49	45	45	44	-	-	-
– Nuclear	–	66	40	54	82	83	90

A year represents a financial year from 1st April of the year to 31st March of the next year.
(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 Power Line Nov. 2001 and extrapolated on the basis of data in Power Line Dec. 2002, it is estimated at 29 GWe of installed capacity. Assuming the annual capacity factor of 0.41, as estimated from the captive power data applicable for the year 2000-01 given in Energy 2003 published by CMIE, it adds 104 B kWh to total electricity generation increasing the per capita consumption to above 600 kWh.
(2) Net import/Total energy consumption.
(3) Estimated from the provisional data of Table 4.
(4) Between April of the year and January of the next year (Annual Report 2002-2003, Ministry of Power, GOI).
Source: IAEA Energy and Economic Database

2. NUCLEAR POWER SITUATION

2.1. Historical Development and Current Nuclear Power Organisational Structure

2.1.1. Overview

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 provisions 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, related High Technologies and supports basic research in nuclear science and engineering.

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 DHRUVA (1985) and critical facilities 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 extends the necessary R&D support to the nuclear power programme and associated fuel cycle activities.

In 1947 when India became independent, its installed electric power capacity was only about 1.5 GW (e), which has now grown to about 107.5 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 coalmines 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 and is in commercial domain. This is being followed by 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 electricity and more uranium^{233}.

Table indicating salient milestones of the Indian Atomic Energy Programme is given as Annex-1.

2.1.2. Current Organisational Charts

The Indian Atomic Energy Organisational Structure is shown in Figure 1. 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 organisation 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. It is independent of DAE.

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 Board of Research for Nuclear Sciences (BRNS) and National Board for Higher Mathematics (NBHM) for providing extra-mural funding to universities and other national laboratories.

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

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

- Nuclear Power Corporation of India Limited (NPCIL) engaged in the design, construction, commissioning and operation the nuclear power plants based on thermal reactors;
- Uranium Corporation of India Limited (UCIL) engaged in mining, milling and processing of uranium ore;
- Indian Rare Earths Limited (IRE) engaged in mining and processing mineral sands containing thorium and rare earth minerals and producing minerals such as ilmenite, rutile, monazite, zircon and garnet;

- Electronics Corporation of India Limited (ECIL) engaged in design and manufacture of reactor control and instrumentation equipment related to atomic energy and also to other sectors;

- Bhartiya Nabhikiya Vidyut Nigam Limited (BHAVINI) for setting up fast reactors.

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 centralised purchases and stores.

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 mobilise 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.

Development of FBR is being pursued at IGCAR. The first 500 MWe PFBR is to be constructed by a separate company, BHAVINI, set up in October 2003, drawing the talents of IGCAR and NPCIL.

Development of the 300 MWe AHWR design, for demonstration of technology towards large-scale utilisation of thorium for electricity generation, is being carried out at BARC.

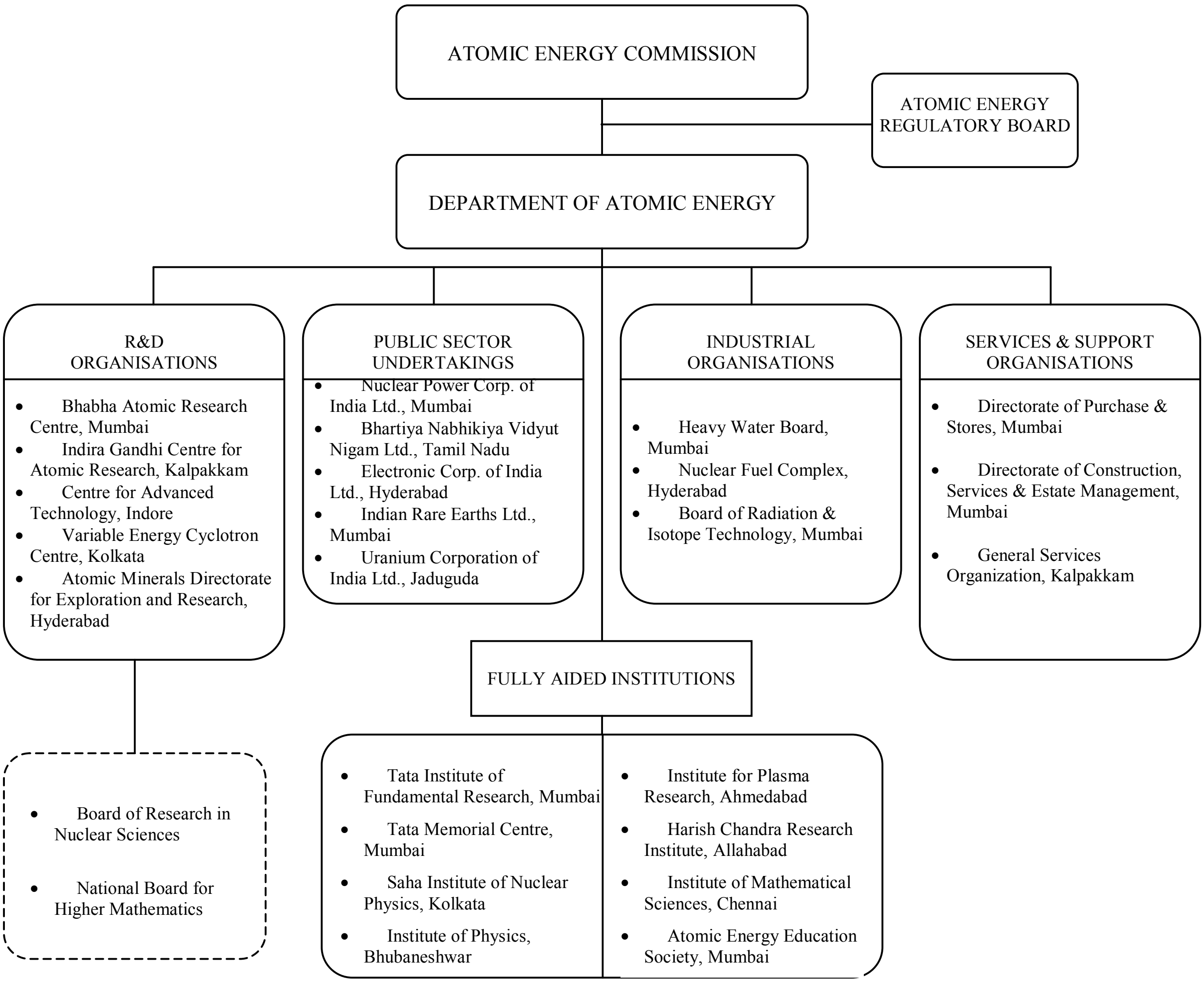

FIG.1. Organisational Structure

2.2. Nuclear Power Plants: Status and Operation

The nuclear power generation comes under the AEC/DAE, GOI. NPCIL, a public sector enterprise of the DAE 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. 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.

2.2.1. Status of Nuclear Power Plants

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 now in operation. These are in the unit size range of about 200-220 MW (e) (gross). The total nuclear power capacity in operation is now 2770 MW(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 set up at Tarapur (TAPP-3&4). Construction work is in progress. These units are scheduled for completion by year 2006/2007. Construction work for setting up of 2 × 1000 MW (e) Russian VVERs at Kudankulam is in progress in co-operation with Russian Federation. 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) have already started. Design work for increasing the unit rating of PHWRs, to be set up in future, to 700 MW (e) is in progress.

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 110,000 MWD/Tonne. The technology development for the first 500 MW (e) prototype fast breeder reactor (PFBR) has been completed. The project has been approved for construction and land excavation work has been launched in 2003.

Towards building up thorium-based reactors, the strides taken by DAE include setting up of 30 kW (th) neutron source reactor KAMINI at Kalpakkam. 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) of 300 MW(e) capacity has already been prepared by BARC. This is a vertical pressure tube reactor design utilising heavy water moderator, boiling light water coolant, thorium-plutonium based fuel and incorporating passive safety systems. It derives about two-third of its power from thorium and DAE/BARC expects to launch its construction in 2004/05 essentially as a technology demonstration project for utilising thorium for electricity generation.

Table-7 gives a status of nuclear power plants in India.

TABLE 7. STATUS OF NUCLEAR POWER PLANTS

Station/ Project	Type	Net Capacity (MWe)	Status	Operator	Reactor Supplier	Construction Start	Criticality Date	Grid Connection	Commercial Operation	Shut down 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	NPCIL	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	NPCIL	01-Apr-85	08-Jan-95	04-Mar-95	01-Sep-95	
MAPS-1	PHWR	155	Operational	NPCIL	NPCIL	01-Jan-71	02-Jul-83	23-Jul-83	27-Jan-84	
MAPS-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	490	Under Construction	NPCIL	NPCIL	08-Mar-00			Jan-07	
TARAPUR-4	PHWR	490	Under Construction	NPCIL	NPCIL	12-May-00			Mar-06	
KAIGA-3	PHWR	202	Under Construction	NPCIL	NPCIL	30-Mar-02			Mar-07	
KAIGA-4	PHWR	202	Under Construction	NPCIL	NPCIL	10-May-02			Sept-07	
KUDANKULAM-1	PWR	905	Under Construction	NPCIL	ASE	31-Mar-02			Dec-07	
KUDANKULAM-2	PWR	905	Under Construction	NPCIL	ASE	31-Mar-02			Dec-08	
RAJASTHAN-5	PHWR	202	Under Construction	NPCIL	NPCIL	18-Sept-02			Aug-07	
RAJASTHAN-6	PHWR	202	Under Construction	NPCIL	NPCIL	23-Jan-03			Feb-08	
PFBR	FBR	470	UnderConstruction	BHAVINI	BHAVINI	2003 (Excavation work Started)			March 2011	

2.2.2. Performance of NPPs.

Figures 2 & 3 along with Tables 8 & 9 give the details of performance of nuclear power plants in operation. At present, the nuclear share of total electricity generation is about 3.7%.

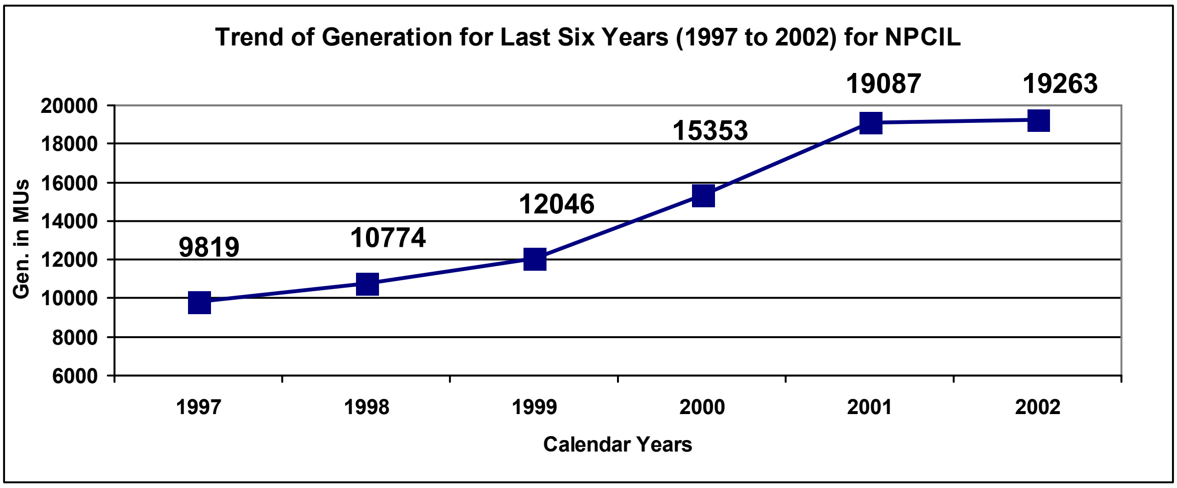

FIG. 2. Generation Trend

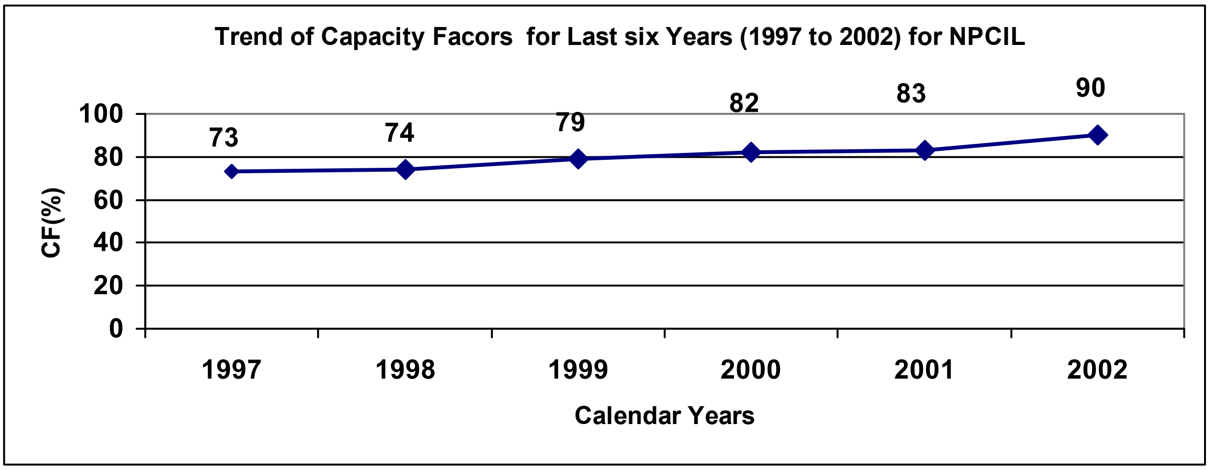

FIG.3. Capacity Factor Trend

TABLE 8. PERFORMANCE OF NPPs IN OPERATION (GENERATION IN 10^6 kWh)

Units	Capacity (MWe)	Calendar Years					
		1997	1998	1999	2000	2001	2002
TAPS-1	160	1078	1284	944	1296	1190	1296
TAPS-2	160	867	974	1219	1122	1316	1277
RAPS-2^	200	–	599	1361	1628	1482	1568
MAPS-1	170	1026	803	1356	765	1321	1017
MAPS-2	170	1091	1258	994	1439	1271	30
NAPS-1	220	1755	1665	1271	1556	1744	1744
NAPS-2	220	1736	1476	1580	1487	1484	1870
KAPS-1	220	1039	1239	1592	1850	1710	1897
KAPS-2	220	1227	1476	1704	1674	1885	1763
KAIGA-2	220	–	–	25#	1215@	1440	1656
RAPS-3	220	–	–	–	1024*	1535	1483
KAIGA-1	220	–	–	–	224$	1369	1801
RAPS-4	220	–	–	–	73X	1340	1861
Total -NPCIL	**2620**	**9819**	**10774**	**12046**	**15335**	**19087**	**19263**

^ Includes energy equivalent of steam supply to nearby Heavy Water Plant; # Infirm Power Generation;
Includes Infirm Power generation - @ 99 Million kWh ; *129 Million kWh; $ 31 Million kWh; X 48 Million kWh .

TABLE 9. PERFORMANCE OF NPPs IN OPERATION (CAPACITY FACTORS %)

Units	Capacity (MWe)	Calendar Years					
		1997	1998	1999	2000	2001	2002
TAPS-1	160	77	92	67	92	85	92
TAPS-2	160	62	69	87	80	93	91
RAPS-2	200	– (2)	60 (2)	78	93	85	89
MAPS-1	170	69	54	91	51	89	68
MAPS-2	170	73	84	67	96	85	91 (2)
NAPS-1	220	91	86	66	81	90	90
NAPS-2	220	90	77	82	77	77	97
KAPS-1	220	54	64	83	96	89	98
KAPS-2	220	64	77	88	87	98	91
KAIGA-2 (3)	220	–	–	-	73	75	86
RAPS-3 (3)	220	–	–	-	79	80	77
KAIGA-1 (3)	220	–	–	-	73	71	93
RAPS-4 (3)	220	–	–	-	89	70	97
Total- NPCIL	**2620**	**73**	**74**	**79**	**82**	**83**	**90**

Notes Fig-2 &3 and Tables-8 &9.:

1. RAPS-1 (100 MW(e)) the first PHWR not included. It generated 313, 709, 964, 772, 105, 293 Million kWh in 1997, 98, 99, 2000, 01, 02 respectively including energy equivalent of steam supplied to nearby heavy water plant. This unit is under shut down since May 02 for detailed in-service inspection for a decision on en-masse coolant channel replacement and upgradation.
2. RAPS-2 was under long capital maintenance outage for en-masse replacement of coolant channels, from August 1, 1994 to 6th June 1998. MAPS-2 was under capital maintenance for en-masse replacement of coolant channels from January 9th, 2002 and has commenced commercial operations from Aug 03. The capacities of these units for the corresponding periods not included for computing capacity factor.
3. Kaiga-2, RAPS-3, Kaiga-1 and RAPS-4 commenced commercial operation in March 2000, June 2000, November 2000 and December 2000 respectively.

During the rolling 12 months period (1.10.2001 to 30.9.2002), KAPS-1 achieved the distinction of being the best performing unit amongst PHWR category. It was ranked first in the world amongst 31 operating CANDUs/ PHWRs with a Gross Capacity Factor (GCF) of 98.4%.

For the calendar year 2002, three NPCIL plants were amongst the best five PHWR plants in the world. KAPS-1 with a GCF of 98.4% is at number two, NAPS-2 with a GCF of 97.0% is at number four and RAPS-4 with a GCF of 96.6% is at number five.

Tarapur Atomic Power Station completed "Refuelling Outage" of unit-2 in a record time of 27 days. This record was broken by the first unit of Tarapur Atomic Power Station, which completed "Refuelling Outage" in 20 days and started operation on 12.4.2003.

TAPS-unit 2 also achieved impressive performance of continuous run of 194 days from 22.12.2002 to 4.7.2003.

KAPS-2 completed its Annual maintenance shutdown (ASD) in a record time of 18 days.

2.2.3. Plant Upgradation and Plant Life Management

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. Tools for In-service Inspection of Coolant Channels and Garter Spring relocation have also been indigenously developed.

Plant life extension activities are progressively being implemented at TAPS. Enmasse coolant channel replacement and up-gradation work of RAPS-2 was completed based on indigenously developed tools and technology and the unit was put back in service in 1998. The repair of Over Pressure Relief Device (OPRD) at RAPS –1 was successfully carried out based on indigenously developed tools and technology. Enmasse replacement of coolant channels and upgradation of plant systems for MAPS-2 was successfully completed and the unit has been put back into service in August 2003. MAPS-1 has been shutdown for taking up EMCCR and upgradation works from August 20,2003.

2.2.4. Nuclear Power Development Projections and Plans

Based on the nuclear power projects under construction and upgradation works, capacity additions of 1350 MW (e) by March 2007 and further 2660 MW (e) by December 2008 will materialise. With this, the total nuclear power capacity will grow to 4120 MW (e) by March 2007 and 6780 MW (e) by December 2008. Excavation work for PFBR has been started and on its completion in December 2011, installed capacity will reach 7280 MW(e). Additional units are also proposed to be added [including a mix of units of PHWR-700 MW (e), LWR-1000 MW (e), FBR-500 MW (e) and AHWR-300 MW (e)] to reach a total nuclear power capacity of about 20,000 MW (e) by the year 2020.

2.2.5. Decommissioning Information and Plans

No nuclear power reactors are planned as of now to be taken up for decommissioning. The emphasis is on plant life extension.

2.3. Supply of NPPs

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 Atomic Energy of Canada Limited (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 utilises 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. The strategy of adopting large EPC/supply-cum-erection packages has been adopted in the projects under construction with the growth of domestic industry. Fuel, heavy water, zircaloy components, reactor control equipment, are supplied by the units of DAE from the facilities set up for this purpose.

2.4. Operation of NPPs

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 Organisation 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. Training simulators are used to provide training in all aspects of operation, including handling of unusual incidents. Key operations personnel are also imparted rigorous training in various systems of the plant on training simulators.

NPCIL is a member of World Association of Nuclear Operators (WANO). WANO Peer Review of the nuclear power plants are being undertaken progressively by NPCIL. NPCIL is also a member of Candu Owners Group (COG). All the nuclear power stations namely TAPS-1&2, RAPS-1&2, MAPS-1&2, NAPS-1&2, KAPS-1&2, RAPS-3&4 and Kaiga-1&2 have been certified as per ISO-14001 for Environmental Management System.

2.5. Fuel Cycle, Spent Fuel and Waste Management

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 FBRs. 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.

2.6. Research and Development

2.6.1. R&D Organizations and Institutes

- 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. 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 been completed and excavation for construction of the reactor at Kalpakkam has been started by Government of India.

- 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, biosciences etc. and also in basic science areas such as physics, chemistry, biology 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.

2.6.2. Development of advanced and new generation nuclear reactor systems

A number of initiatives have been taken on the development of new reactor systems. The details are as follows:

- All PHWRs beyond those presently under construction are proposed to be of 700 MWe unit size. Design work on scaling up the 540 MWe unit PHWR to 700 MWe by permitting partial boiling in the channels, has progressed. These units are proposed to be launched in the next 2-3 years.

- The first 500 MWe PFBR has been authorised for construction. The excavation work on this project has commenced. This will signify the launch of the second stage FBR programme in the country.

- A 300 MWe AHWR is under design. This is a technology demonstration project for large-scale utilisation thorium for electricity generation.

2.7. International Co-operation and Initiatives

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 organisations. Also many Indian professional have participated as Reviewer / Lead Reviewer in the WANO Peer Review of Plants abroad. NPCIL teams have 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.

The details on international, multilateral and Bilateral Agreements are given in Annex-2.

2.8. Human Resource Development

Realising 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 Resources, Training Schools have also been set up at the Centre for Advanced Technology, Indore (2000) and Nuclear Fuel Complex, Hyderabad (2001). NTCs and training schools at Hyderabad and Indore are affiliated to the 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.

3. NATIONAL LAWS AND REGULATIONS

3.1. Safety Authority and the Licensing Process

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

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 organisation is shown in Fig. 4. The AERB conducts in-depth reviews so that nuclear facilities do not pose any radiological risk to the public and plant personnel. The review process is shown in Fig. 5. The authorisation process involves various major activities like site approval, construction, commissioning, operation and decommissioning. The authorisation 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 principles, 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

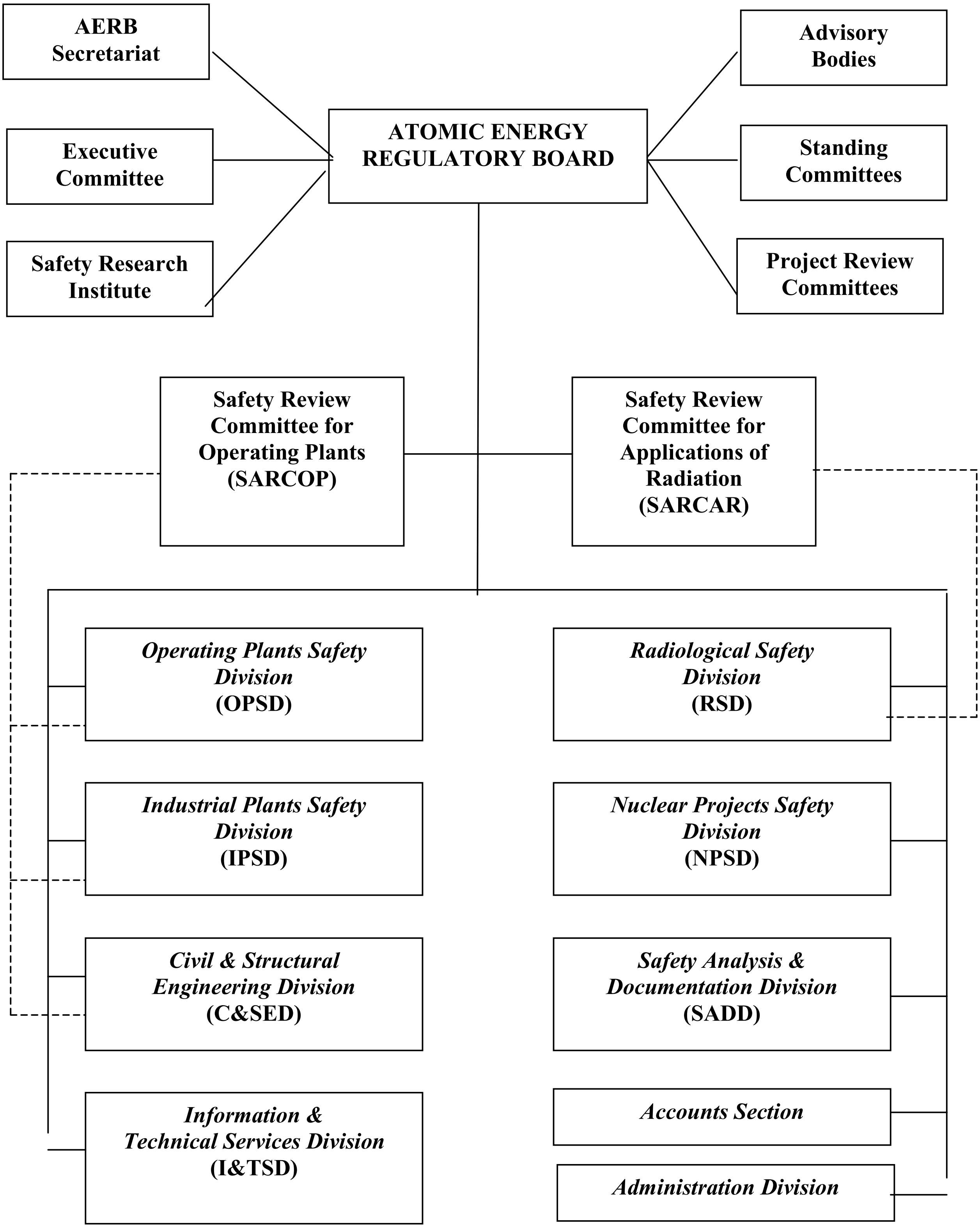

FIG. 4 ORGANISATION CHART ATOMIC ENERGY REGULATORY BOARD

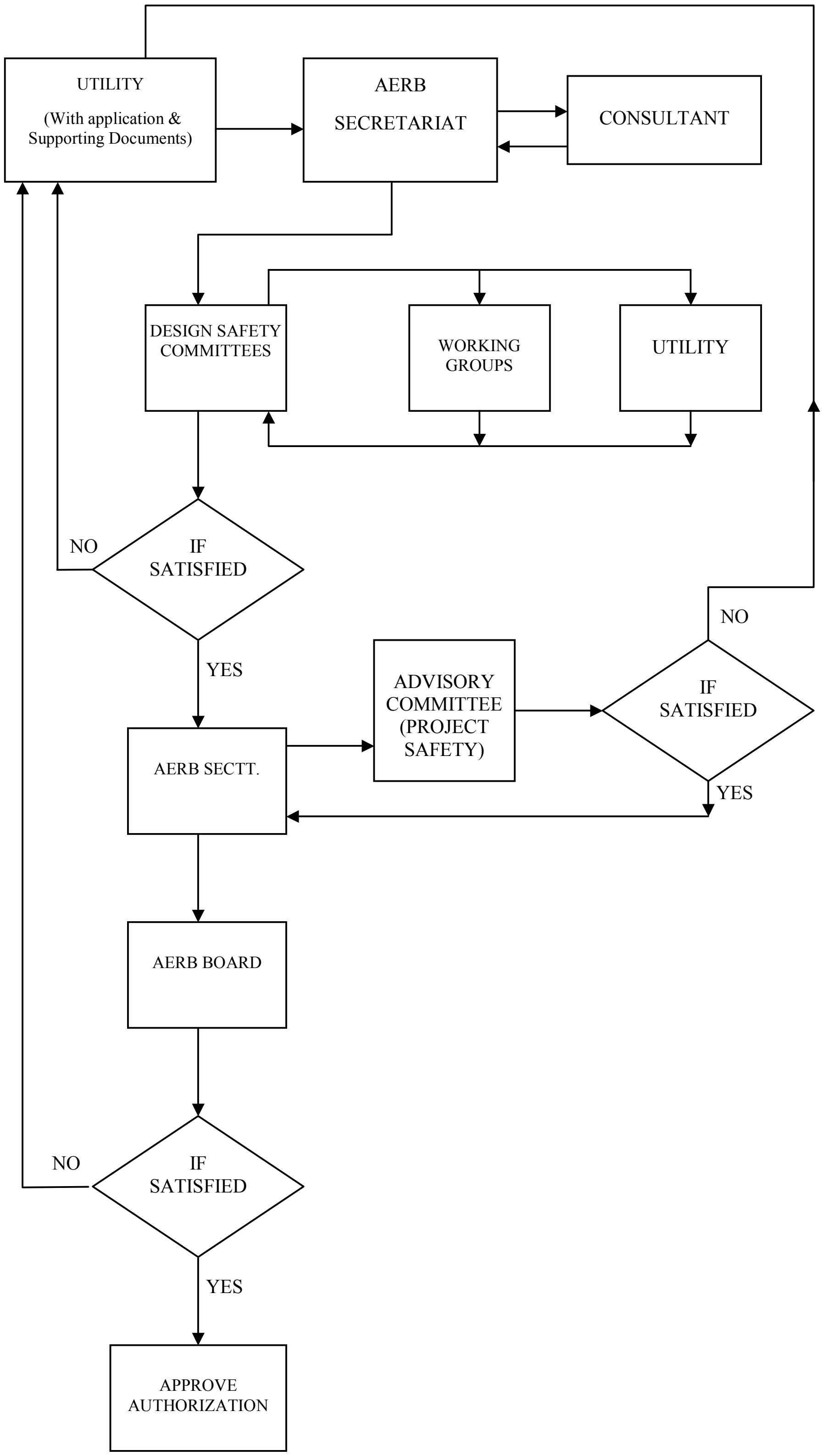

Fig 5. AERB Regulatory Review Process for Authorization

AERB has advisory committees for site selection, design review and authorisation, 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 authorisation based on the recommendations of the advisory committee. Safety assessments during plant operation are done by the Safety Committee for Operating Plants (SARCOP). Authorisation is granted only for a limited period and further authorisation is required beyond that period. Authorisation 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 organisation.

3.2. Main National Laws and Regulations

The Atomic Energy Act 1962 is the main law. The various activities relating to the Indian atomic energy programme are governed by this Act. 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.

4. CURRENT ISSUES AND DEVELOPMENTS ON NUCLEAR POWER.

4.1. Energy Policy

The energy policy includes nuclear energy as one of the options for electricity generation to reach a nuclear power capacity of 20000 MWe by 2020.

4.2. Privatisation and Deregulation

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 and operating the nuclear power plants. The other related fuel cycle (both front-end and back end) activities are carried out by the different units of DAE, GOI. The 500 MWe PFBR recently approved is being set up through a separate company.

As of now, there is no equity participation by the private sector in the area of nuclear power generation. Possibility of joint ventures with public/private sector is being explored. This is essentially with a view to attracting investment in the nuclear power sector for capacity addition. This, however, will require amendments to the Atomic Energy Act, 1962.

4.3. Role of the Government in nuclear R&D

The GOI has a key role in R&D of nuclear technology. BARC and IGCAR are the two key Government organisations devoted to R&D of nuclear technology. R&D is also carried out by other units in the DAE and the university system in the country under funding from DAE.

4.4. Nuclear Energy and Climatic Change

India is a large country and so needs a large electricity generating capacity. Power generation in India was 4.1 billion kWhr in 1947-48 and in 2002-03, it was more than 600 billion kWhr. In the next 50 years, it may increase by a factor of 12 or more. At present, a major component of electricity is generated using fossil fuels and there are environmental concerns like green house gas (GHG) emissions associated with the energy generation using fossil resources. If India continues to rely on fossil resources as at present, it will have serious effects on local, regional and global environment. Therefore, it is necessary that India continues to develop nuclear energy and meets a significant percentage of its electricity needs based on nuclear energy.

4.5. Safety and Waste Management Issues

Utmost attention is given to safety in nuclear power plants. The overriding attention to safety encompasses the entire gamut of activities associated with nuclear power plants (NPPs), that is, siting, design, construction, commissioning, and operation. In all these activities, a major effort is devoted to ensuring safety of operating personnel, public as well as the environment.

A systematic approach using well-defined principles is followed in the design of the nuclear power plants to provide the required safety features adopting principles of defence-in-depth, diversity and redundancy. Nuclear Power Plants are constructed in accordance with the design intent, and with required quality of workmanship to very strict quality standards. Commissioning of the systems to test and demonstrate adequacy of each system and the plant as a whole by actual performance tests to meet the design intent is carried out before commencing the operation of the plant. Operation of the plant is carried out as per defined and approved procedures defining the safety limits for various system parameters, in technical specifications that are thoroughly reviewed by the internal safety committees and approved by AERB. Further AERB, through formal clearances that authorise actions and stipulate specific conditions, enforces safety at various stages of the plant. These include site approval, review and approval of design of systems important to safety and authorisations for construction, commissioning and operation and safety review during operational phase. The regulatory framework in India is indeed robust. All these measures are for ensuring safe operation of the plants, safety of occupational workers and members of public.

All nuclear power plant sites in India are self sufficient in the management of radioactive waste generated there. Adequate facilities have been provided for handling, treatment and disposal of relevant wastes at these sites. Management of radioactive wastes is carried out in conformity with the guidelines specified by the Regulatory Authorities based on internationally accepted principles in line with the guidelines laid down by the international agencies.

4.6. Other Issues and Developments

The NPPs presently in operation are generating electricity at competitive tariffs. Measures to reduce construction period of NPPs, standardisation and scaling up unit sizes are being taken to strengthen the economic competitiveness of nuclear power.

The nuclear power technology in India has matured as is evident from the excellent 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 5 years. The current emphasis is on accelerating the growth of nuclear capacity addition. The factors receiving attention are:

- Faster construction of the projects by standardisation, higher level of mechanisation in construction and strengthening measures/strategy for project management; Scaling up PHWR unit sizes to 700 MWe.

- Launching construction of 500 MWe PFBR signifying the commencement of the second stage FBR programme.

- Design of AHWR 300 MWe a technology demonstration project for utilisation of thorium for electricity generation.

- Finding financial resources for nuclear power 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 adopting 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.

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[5] Annual Report 2002-03, Ministry of Coal

[6] Annual Report 2002-03, Government of India, Department of Atomic Energy.

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[8] IAEA Energy and Economic Data Base (EEDB).

[9] IAEA Power Reactor Information System (PRIS).

Appendix 1

SALIENT MILESTONES OF INDIAN ATOMIC ENERGY PROGRAMME

Date	Milestone
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 in February 17, 1989.
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 near 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.

Date	Milestone
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 Reactor, attains criticality.
March 05, 1985	Waste Immobilisation 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 Unit-2 attains 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

Date	Milestone
April 21, 2000	Folded Tandem Ion Accelerator (FOTIA) delivers first beam on target.
March 31,2002	Kudankulam Nuclear Power Project Units-1&2, First Pour of Main Plant Concrete
March 30,2002	Kaiga-3&4 Project, First Pour of Concrete.
September 18,2002	RAPP-5&6 Project First Pour of Concrete
October 31, 2002	Waste Immobilization and Uranium Thorium Separation Plants at Trombay and the Radiation Processing Plant Krushak at Lasalgaon dedicated to Nation
November 2002	Turamdih Mine, Jharkhand inaugurated.
July 23,2003	MAPS-2 connected to grid after enmasse coolant channel replacement and upgradation of it systems
2003	1.7 MeV Tandetron Accelerator and demo facility and Lead Mini Cell for reprocessing FBTR carbide Fuel on lab scale commissioned at IGCAR
October 22, 2003	Formation of Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI)

Appendix 2

INTERNATIONAL, MULTILATERAL AND BILATERAL AGREEMENTS

Agreements with 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 Vienna convention on civil liability	Not signed	
• 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 peaceful uses of nuclear energy	Russian Federation	22 January 1979
• 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
• 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

Appendix 3

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 2202 2543 Fax: 91 22 2204 8476
Department of Atomic Energy (DAE)	http://www.dae.gov.in/

NUCLEAR RESEARCH INSTITUTES

Bhabha Atomic Research Centre (BARC) Mumbai	Tel.: 91 22 2550 5050 Fax: 91 22 2550 5151 or 2551 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/