CHAPTER III

DEVELOPMENT OF WATER AND POWER RESOURCES

A. WATER RESOURCES

I. Assessment of Resources

The Indian sub-continent ranging from the lofty Himalayas in the north, through the Indo-Ganga plains, the Rajputana (Rajasthan) desert, and the central plateau to the large peninsula in the south has varied topography and climate. The major part of the country has an average monsoon rainfall of over 100 cm. with the north-eastern and south-western regions receiving over 400 cm. in a normal year. This rainfall as well as the melting of the snows in the Himalayas give rise to a number of river systems which have been sustaining civilizations since pre-historic times. The Indus Valley civilization, the Aryan civilization on the banks of the holy Ganga, and numerous lesser known civilizations in the southern peninsula, all flourished on the water resources made available by the various rivers that flow in several directions in the country. The long coastline with the vast Indian Ocean also gave rise to many a civilization which established trade and cultural contacts with other countries extending from the Mediterranean Sea to the Pacific Ocean. Thus utilization of the natural water resources for the benefit of mankind in this part of the world is not new. But its systematic development, which keeps in view the present requirement, the future needs for the ever-increasing population as well as the equitable distribution of the natural wealth of the country can be said to have begun only with the dawn of independence in 1947.

Rainfall Pattern: Due to the movement of the sun to the northern hemisphere in the summer, seasonal winds, called the south-west monsoon, which are moisture-laden, originate from the huge Indian Ocean in the southern hemisphere, cross the equator and enter the Indian sub-continent from the south-west. Soon afterwards the monsoon bifurcates the Arabian Sea branch and the Bay of Bengal branch, the latter moving into parts of Assam in the month of May. Kerala, on the sea-side of the Western Ghats, receives the south-west monsoon between the last week of May and the first week of June. With the progress of the summer, the monsoon winds from the Bay of Bengal move northward and are stopped and deflected to the west by the Himalayas and this results in the whole country excluding the western parts of Rajasthan coming under the influence of the monsoon by the first week of July. However, the advance of the monsoon is not regular every year and is governed by the movement of depressions and low pressure waves travelling from the Bay of Bengal across the country. Moreover, precipitation in other areas is determined by the orographic features. While Assam, the western coastal plains and the Western Ghats receive heavy rainfall in all years, other parts of the country have to take chances on the number of depressions that occur in the Bay of Bengal during the monsoon months. Therefore, the annual monsoon rainfall variation in the central, northern and north-western parts of the country is much more pronounced than in the regions of abundant rainfall.

The monsoon starts withdrawing from the Punjab downward upto Saurashtra in Gujarat in the first week of September and disappears by the middle of November except in the extreme south and south-east where the receding monsoon gives rains as the north-east monsoon from the Bay of Bengal.

During the winter, the northern parts of the country get some rainfall from western disturbances but these are irregular and not reliable compared to the south-west monsoon. Severe cyclonic storms experienced during the transition months of April to June and October to December also cause heavy precipitation.

Topography and River Systems: The great rivers, Indus, Ganga and Brahmaputra together with their tributaries have their source in the glaciers of the Himalayas and are perennial as they are fed by the melting of snow in late winter and summer and are also rain-fed during the monsoon. The other river systems in the central and southern parts of the country are rain-fed and since the monsoon is limited to approximately 4 months *viz.* June to September, they have very low flows in the pre-monsoon months of March, April and May and even tend to dry up during this period.

The Himalayas may be regarded as a double mountain wall descending into a series of deep valleys towards the north from which the Indus, the Sutlej and the Brahmaputra rivers gather their waters while the southern slopes drain into the mighty Ganga system which forms one of the largest plains in the world extending over 1,500 km. The Indo-Ganga plain lies between the Himalayas in the north and the plateau of the peninsula in the south. This extends from India's boundary in the west to the Bay of Bengal in the east. The Brahmaputra and its tributaries drain the heavy rain-fed regions of Assam. In the Rajputana desert, which occupies a major part of the State of Rajasthan, rainfall is very scanty and till recently this area was thinly populated. The central plateau with the southern peninsula is almost triangular in shape and includes the whole of the country south of the Vindhya range, as far as

Kanyakumari. The plateau slopes up from the southern edge of the Ganga plains with the Vindhya hills ranging from about 500 metres to 1,700 metres in height and stretching from east to west for a length of about 1,300 km. Rivers from this central region flow in all directions contributing to the Ganga in the north, Narmada and Tapti in the west, Damodar and Mahanadi in the east and the tributaries of the Godavari in the south.

Leaving a narrow belt on the west coast, the Western Ghats with an average height of 1,000 metres run from north to south in almost a continuous stretch, dotted by a number of peaks reaching upto 2,400 metres in height. The Eastern Ghats on the eastern side of the plateau are neither as high nor as continuous as the Western Ghats. The average height of the Eastern Ghats is 450 metres and they recede inland as they stretch southwards and leave broad flat tracts of land between the hills and the sea. On the eastern coastal plains the deltas formed by the rivers Godavari, Krishna, Cauvery and other smaller rivers are fairly extensive in area and are fertile and suitable for intensive cultivation. The rivers draining the west coast are short in length, but swift due to the steep slope. The rivers on the east coast, however, are longer, but being in the rainshadow region their flow is meagre and inadequate to meet the needs of the region.

Regions: The average rainfall over the Indian sub-continent is about 110 cm. as a whole, and this rainfall over the country's land area of 328 million hectares gives a total precipitation of about 373 million hectare metres. Although this is an enormous quantity, much of it is lost in evaporation in this hot country and less than half of it appears as run-off. The mean daily evaporation in the country varies from about 2 mm. in the winter months in wet areas to as much as 16 mm. in the summer months in dry areas with the annual average for the whole country at about 6 mm. Therefore, the total run-off in the various river basins which includes the flood flows in the monsoon, dry weather flows from sub-soil storage and groundwater recharge is estimated at only about 167 million hectare metres.

For the purpose of assessment of the available water resources, the country has been divided into six regions as indicated below:

1. **Indus Basin:** This region in the north-west corner of India draining the western and northern slopes of the Himalayas has an area of 35.4 million ha. with average rainfall of 56 cm. The States of Jammu and Kashmir, Punjab, Haryana and Himachal Pradesh are located in this region.

2. **Ganga System:** This large basin of nearly 100 million ha. with

an average rainfall of 111 cm. extends from the southern slopes of the Himalayas in the north to the northern slopes of the Vindhyas in the south and is spread over the States of Uttar Pradesh, Bihar and parts of Madhya Pradesh, Rajasthan and West Bengal.

3. **Brahmaputra System:** The mighty Brahmaputra system rising from the northern slopes of the Himalayas debouches into India at the north-east corner of Assam and is further fed by its various tributaries rising from the heavy rainfall regions of Assam, Nagaland, Meghalaya and the adjoining territory of Bhutan. The area of this region is 51 million hectares and it has an average rainfall of over 120 cm.

4. **Rajasthan (Rajputana):** This forms part of the State of same name and is practically waterless. The total area is 17 million hectares with an average rainfall of 29 cm.

5. **West Coast:** The west coast draining into the Arabian Sea, excluding the Indus system, is also a region of high rainfall and parts of the States of Gujarat, Maharashtra, Mysore and Kerala form this region. The total area of this region is 49 million hectares and the average rainfall is 122 cm.

6. **East Coast:** Basins of rivers falling into the Bay of Bengal other than the Ganga and the Brahmaputra systems form this region which covers a wide area of over 120 million hectares and has a large population. Some areas in the interior are frequently affected by drought. Parts of Madhya Pradesh, Bihar, Maharashtra, Karnataka (Mysore) and the States of Orissa, Andhra Pradesh and Tamil Nadu form this region which has an average rainfall of 109 cm.

From the above description of the monsoon and the topography of the country it may be observed that India gets moderate rainfall which, however, covers almost the whole of the country. But the average rainfall is neither assured nor its distribution favourable for the crops every year. A few regions such as the west coast and Assam get consistently good rainfall; in other regions, although the average appears adequate, the variations in different years are considerable and, therefore, not suitable for dependable cultivation. The run-off records of the various river systems in India are incomplete and an assessment of the water resources from actual gauge-discharge records is therefore not possible for the whole country; but rainfall records are available for a long period and attempts have been made to forecast the run-off from the rainfall to assess the water resources for the whole country.

The Central Water and Power Commission had worked out the surface water resources of different regions during the period

1954-66. This study was based largely on a statistical analysis of the flow data wherever it was available and on suitable rainfall run-off relationships, wherever observed data was meagre. According to this study, in the year 1960 the water resources of the various basins amounted to 1,881,057 m. cu. m. (1,524 million acre feet) as detailed below.

TABLE I

Surface Water Potential

	River Basin	*Water Potential (Million Acre Ft.)*	*Remarks*
	(1)	(2)	(3)
	Zone No: 1 — West Flowing Rivers		
1.	River basins of Kerala	30.03	
2.	River basins of Madras and Bombay below Tapti	146.62	
3.	Tapti basin	16.00	
4.	Narmada basin	32.50	
5.	Basin above Narmada	22.50	
	Total:	247.65	
	Zone No: II — East Flowing Rivers		
6.	Tambraparni and Vaigai river basins	7.08	
7.	Cauvery basin	15.08	
8.	Mahanadi and other basins between Ganga and Godavari	106.52	
9.	Godavari basin	93.52	
10.	Krishna basin	46.83	
11.	Pennar	5.56	
12.	Basins between Cauvery and Pennar	13.70	
	Total:	288.29	
	Zone No: III — Indus Basin		
13.	Indus basin	64.43	Figures as estimated by Khosla's formula.
	Zone No: IV — Ganga Basin		
14.	Chambal river basin	19.71	
15.	Yamuna river basin	53.20	
16.	Ram Ganga basin	15.10	
17.	Tons river basin	5.09	
18.	Gomti basin	5.86	
19.	Sone and other basins between Tons and Sone	40.65	
20.	Gogra	92.65	
21.	Right bank tributaries below Sone	36.60	
22.	Left bank tributaries below Gogra	141.60	
23.	Main Ganga	34.50	
	Total:	444.96	
	Zone No: V		
24.	Brahmaputra and Barak basin	478.90	
	Grand total for Zones I, II, III, IV & V	1,524.23	

Groundwater Resources: A scientific assessment of the groundwater potential of the country was not undertaken until a few years ago. Wells used to be constructed, and are even now being constructed, on the basis of local expertise and on the advice of water diviners. The construction of tube-wells in the Ganga alluvium of Uttar Pradesh was taken up in the thirties but this was based on local knowledge and not on any assessment of the groundwater potential. Groundwater mapping and groundwater exploration were, until recently, sporadic and limited to specific areas.

It was not until 1936 that a large-scale programme for the construction of tube-wells was undertaken in the Ganga alluvium of Uttar Pradesh when 1,500 tube-wells were constructed and channels laid to irrigate 3,367,000 hectares.

Estimate of Available Resources: Although groundwater has been located at a number of places, no systematic quantitative assessment has so far been made. Such an assessment can be made only on the basis of complete data on sub-surface geology, rainfall, evapotranspiration, run-off, percolation zone and extent of saturation, hydraulic gradient, aquiferous characteristics, geo-chemistry of water, etc. The collection, compilation and analysis of such data will naturally take time. The regime of groundwater in various regions has also to be systematically studied over a number of years.

The occurrence of groundwater, according to a recent assessment, is indicated in Table II.

Utilizable Water Resources: So far, no systematic study or analysis of the utilizable water resources of the country has been done except for the Indus river system. The Irrigation Commission (1969-72) has made some preliminary assessments and has indicated in its report that the entire water resources of the Godavari, Krishna, Narmada and Tapti rivers can be utilized. The waters of the Cauvery have already been practically fully utilized.

As regards the Ganga, which carries about 493,400 m.cu.m. (400 M.A.F.) of water on an average, the Commission assessed that it should be possible to utilize about 185,000 m.cu.m. (150 M.A.F.) for the development of irrigation. In view of the topography and the limited opportunities for storage, the rest of its waters will continue to flow into the Bay of Bengal, particularly during the monsoon season.

There is very little possibility of utilizing the Brahmaputra waters except through a few medium and lift irrigation schemes in Assam. Nearly 370,000 m. cu.m. (300 M.A.F.) of the Brahmaputra waters will continue to flow annually into the Bay of Bengal.

The west flowing rivers of India (excluding the Tapti and Narmada)

TABLE II

Groundwater Resources (In Million Acre Feet)

State	*Amount of contribution of rainfall to groundwater recharge*	*Possible recharge due to canal infiltration*	*Total*	*Evapotranspiration and sub-surface run-off losses %*	*Net ground-water recharge*	*Annual draft by the end of 1967-68*	*Net ground water recharge available for further groundwater development*	*Area irrigated by groundwater at present (million acres)*
1	2	3	4	5	6	7	8	9
Andhra Pradesh	20.0	4.6	24.6	30	17.2	3.57	13.6	1.4
Assam Region (Including Nagaland, NEFA, etc.)	40.7	1.2	41.9	60	16.7	0.003	16.7	—
Bihar	26.9	4.4	31.3	30	21.9	2.35	19.5	1.2
Delhi	0.5	—	0.5	30	0.3	n.a.	—	—
Gujarat	14.1	0.4	14.5	30	10.2	4.13	6.1	1.75
Haryana	3.0	1.6	4.6	25	3.5	0.75	2.7	0.75
Himachal Pradesh	2.3	—	2.3	60	0.9	n.a.	—	0.003
J & K	9.6	0.4	10.0	60	4.0	0.001	4.03	0.03
Kerala	9.5	1.2	10.7	50	5.4	0.004	5.4	0.016
Madhya Pradesh	43.1	1.4	44.5	40	26.7	4.22	22.5	1.00
Tamil Nadu & Pondicherry	12.9	3.5	16.4	30	11.5	3.47	8.0	2.30
Maharashtra	19.8	1.2	21.0	40	12.6	3.4	9.2	2.00
Karnataka	14.8	1.8	16.6	40	10.0	1.03	9.0	0.75
Punjab	5.1	4.0	9.1	25	6.9	3.3	3.6	3.5
Orissa	19.4	3.4	22.8	30	16.0	0.15	15.8	0.20
Rajasthan	4.0	1.8	5.8	40	3.4	2.07	1.4	3.00
Uttar Pradesh	34.5	10.0	44.5	20	35.5	17.92	17.6	9.00
West Bengal	19.6	3.4	23.0	30	16.1	0.36	15.7	0.10
Total	299.8	44.3	344.1	—	218.8	46.73	170.80	27.00

*n.a. — not available.

are another important and significant source of water. These rivers carry on an average nearly 246,700 m.cu.m. (200 MAF) of water. However, on account of the very short distances traversed by them in their flow to the coast and the nature of the terrain, the possibilities of utilizing these waters for irrigation are very limited. It is, however, possible to divert eastward a limited quantity of water from these rivers for irrigation. Nearly 197,400 m.cu.m. (160 MAF) however will still continue to flow into the Arabian Sea.

The Mahanadi, and other east flowing rivers have a sizable water potential though only partial utilization would be possible on account of the limited land potential and storage possibilities. About 74,000 m.cu.m. (60 MAF) of water from these rivers would still flow into the Bay of Bengal.

The utilizable water resources of the country, as assessed by the Irrigation Commission, can be broadly summed up as shown below:

TABLE III

1.	Narmada, Tapti, Godavari, Krishna, Cauvery, and other southern rivers	246,700 m.cu.m. (200 MAF)
2.	The Indus System	49,300 m.cu.m. (40 MAF)
3.	The Ganga System	185,000 m.cu.m. (150 MAF)
4.	The Brahmaputra System	12,300 m.cu.m. (10 MAF)
5.	The Mahanadi and other east flowing rivers	123,400 m.cu.m. (100 MAF)
6.	The west flowing rivers excluding the Tapti and Narmada	49,300 m.cu.m. (40 MAF)
	Total:	666,000 m.cu.m. (540 MAF)

II. Development of Irrigation

India lies partly in the tropics and partly in the sub-tropical region. The general climate of the country is warm, and therefore, the temperature conditions would permit two or more crops over most of the country. However, since rainfall is concentrated over just 4 monsoon months, without irrigation cultivation is not possible for more than one crop. In regions where the annual rainfall is 100 cm. or less, agricultural production is mainly dependent on the favourable distribution of the monsoon rains. In a majority of the years, even if the average rainfall does not depart much from the normal, the distribution may be erratic and unreliable. In many years only a cash crop is possible. Even in regions with high rainfall, excess rainfall gives rise to floods and inundation of the sown areas, and this, coupled with long periods of break in the monsoons, results in a poor yield in a number of years.

Irrigation has been practised in India from pre-historic times and ancient Indian literature refers to wells, tanks, canals etc., which are said to have been maintained efficiently with the State taking the responsibility of their maintenance and operation. The entire landscape in central and southern India is studded with numerous irrigation tanks, some of which have been constructed centuries before the Christian era. There are a number of small canals in the upper valleys of the rivers of northern India which are equally old.

Among the important ancient irrigation systems still in use is the old stone weir (Kallanai) which is reported to have been constructed by the ancient Tamil King Karikala Chola in A.D. 46 across the Cauvery, at the head of its delta. With the system of river channels and canals from the headworks, a large area of nearly 0.4 million hectares (1 million acres) is being irrigated for centuries. In the British period, the irrigation works constructed during the 19th century were the Western Yamuna Canal, Bari Doab Canal, Godavari delta system, Krishna delta system, Cauvery delta system, Agra Canal, Betwa Canal, Periyar canal system, Kharakvasla Storage Dam, Godavari Canal, Sarda Canal, Ganga Canal, Sone canal system, etc. Early in the 20th century, subsequent to the report of the First Irrigation Commission, some more projects such as the Krishna Raja Sagar, Mettur Reservoir, Nizam Sagar and a few others were taken up. These irrigation projects were in addition to the number of smaller irrigation works taken up all over the country to irrigate small areas. Thus, at the time of independence the total gross irrigated area that remained in India after partition was 22.6 million hectares. The details of important irrigation works in use at the time of independence are given in the following table:

TABLE IV

Sl. No.	*Name of Project*	*Year of Completion*	*Gross area irrigated '000 ha.*	*Total cost of Project in Rs. million*
	1	2	3	4
	Andhra Pradesh			
1.	Krishna Delta system	1898	494	82.5
2.	Kurnool-Cuddapah canal system	1870	60	29.5
3.	Godavari Delta system	1890	508	31.4
4.	Nizam Sagar	1930	76	40.4
5.	Kanigiri Reservoir	1906	38	3.5
6.	Pennar river system	1894	69	7.2
	Bihar			
7.	Tribeni Canal	1914	48	8.2
8.	Sone Canal	1879	275	26.8
	Haryana			
9.	Western Yamuna Canal including extension scheme	1892	547	76.6
	Jammu and Kashmir			
10.	Ranbir Canal	1904	48	5.0

	(1)	(2)	(3)	(4)
	Madhya Pradesh			
11.	Sarathi Reservoir and Wain Ganga Canal	1923	29	5.1
12.	Tandula	1921	65	10.6
13.	Murramsilli Reservoir Mahanadi Canal	1923	88	15.7
14.	Kharung	1931	38	6.6
15.	Maniari	1933	32	6.2
16.	Harsi and Katepo Dam	1934	25	1.7
17.	Bhind canal system	1927	32	11.6
	Maharashtra			
18.	Asola Mendha Tank	1918	10	1.8
19.	Ramtek Tank	1906	11	2.9
20.	Ekruk Tank	1871	25	1.4
21.	Darna Dam and Nandu Madhaweshwar Weir	1916	24	7.6
22.	Wilson Dam and Ozat Weir Parvara River Works	1938	30	12.5
23.	Bhatgar (Lloyd) Dam and Nira Right Bank Canal	1938	39	60.2
24.	Satpal Tank and Nira Left Bank Canal	1906	33	11.7
25.	Mhaswad Tank	1897	10	2.1
	Karnatak (Mysore)			
26.	Krishnarajasagar and Visveswaryayya Canal	1930	40	45.0
	Orissa			
27.	Orissa canal system	1895	100	27.7
28.	Busselkonda Dam and Hinjila Anicut system	1901	45	5.6
	Punjab			
29.	Upper Bari Doab Canal	1879	368	25.4
30.	Sirhind Canal	1887	1,031	27.5
31.	Eastern Canal	1933	108	25.5
32.	Ghaggar Canal	1899	30	1.2
	Rajasthan			
33.	Gang Canal	1928	294	32.1
	Tamil Nadu			
34.	Cauvery delta system	1889	425	10.3
35.	Srivaicuntam Anicut	1889	17	1.8
36.	Shatiatope Anicut	1895	21	1.2
37.	Cheyyar Anicut	1896	12	1.1
38.	Periyar canal system	1897	59	10.8
39.	Lower Coleroon Anicut	1903	54	3.4
40.	Cauvery-Mettur Project	1934	104	66.4
41.	Kattalai	1926	38	4.3
42.	Palar	1896	39	2.6
43.	Kodayar	1906	23	16.1
	Uttar Pradesh			
44.	Upper Ganga Canal from Bhimgoda	1854	695	53.8
45.	Lower Ganga Canal	1878	592	47.5
46.	Sarda Canal	1926	593	195.5
47.	Agra Canal from Okhla	1873	159	21.9
48.	Eastern Yamuna Canal	1854	191	12.9
49.	Doon Canal	1863	12	4.9
50.	Paricha Dam and Betwa Canal	1886	120	96.7
51.	Dhasan Canal	1910	36	4.0
52.	Ghaggar canal system	1917	60	17.8
53.	Ghaggar Pumped Canal	1938	17	13.1
54.	Rohilkhand Canal	1894	21	4.2
55.	Ken Canal (Gangau Weir)	1915	96	16.9
56.	Rampur	N.A.	21	1.2
	West Bengal			
57.	Damodar Canal	1935	90 (Net)	13.3
58.	Midnapur Canal	1889	40(Net)	8.5
59.	Eden Canal	1881	16	2.7

In the early forties, just before independence undivided India was one of the larger irrigated countries of the world. With partition nearly one third of the irrigated area of the country went to Pakistan. On account of the economic slump of the thirties, followed by the Second World War, further development of irrigation had also been slowed down, but the population had meanwhile increased fast. Since India was facing a severe food shortage soon after independence in 1947, greater attention was paid to irrigation to increase agricultural production in the Plans that were formulated since the fifties.

There was urgent necessity to increase agricultural production which could be best achieved only by extending irrigation facilities rapidly. Luckily, a large number of new projects had already been investigated as part of the post-war construction plans. Some of these were immediately taken in hand. Tungabhadra (1945), Hirakud (1948), DVC Project (1948), Malampuzha (1950), Chambal (1953), Lower Bhawani (1947), Manimuthar (1950), Bhadra (1947), Bhakra-Nangal (1945), Matatila (1950) and Mayurakshi (1946) are important irrigation and multi-purpose projects taken up during this early plan period. Most of these projects have by now been completed and full benefits achieved.

During the Plan period which commenced in 1950-51, regular procedures have been laid down for the implementation of the Plan targets. According to the practice thus established, no scheme can be taken up by the States until approval for the scheme is given by the Planning Commission, Government of India. The Central loan assistance given for these projects is also subject to this condition. The system in vogue classified all projects costing more than Rs. 50 million each as major. Irrigation schemes costing individually upto Rs. 1 million were originally classified as minor schemes. This limit was raised to Rs. 1.5 million in 1965 and to Rs. 2.5 million in 1970 (for schemes in hilly regions, this limit is Rs. 3 million). The other schemes costing between Rs. 2.5 million and Rs. 50 millon are called medium schemes. For technical scrutiny of the major and medium schemes the Planning Commission is assisted by the Central Water and Power Commission in the Union Ministry of Irrigation and Power. The minor schemes are processed through the minor irrigation wing of the Union Ministry of Agriculture. In this manner, the criteria to be fulfilled for the inclusion of new projects in the Plan are ensured, and this procedure enables the Union Government to influence the pattern of development according to the national interest.

At the beginning of the First Five Year Plan, total irrigated area from all sources was 22.6 million hectares. The actual water utilization by these irrigated areas was about 9.5 million hectares of surface water. It has also been estimated that 22 million hectare metres of groundwater can be exploited for irrigation purpose, to serve 22 million hectares, of which only 6.5 million hectares was developed at the beginning of the First Plan. The hydro-power potential of the country is estimated at 41.2 million kw. against which the installed capacity in 1951 stood at 0.56 million kw. Inland river water transport was restricted to certain parts of Assam, West Bengal and Bihar. Flood control was confined to a few embankments constructed on certain rivers.

The Planning Commission recognized that the foremost requirement in rebuilding the agricultural economy of the country was by large-scale development of irrigation and power. In this manner, the way for rapid industrialization of the country would also be paved. A target of doubling the area under irrigation in 20 years was set to be achieved by 1974. Rapid expansion of power generation was also aimed for increasing the low per capita generation of 21 kwh. in 1951; this has increased to 120 kwh. in 1972.

By the end of March 1969, India completed three Five Year Plans and three Annual Plans. During the three Five Year Plans and subsequent Annual Plans, 533 major and medium irrigation projects were taken up including 76 major projects. During the Fourth Five Plan since April 1969, 13 major and 33 medium schemes have been sanctioned so far. By the end of March 1972, 361 schemes (22 major and 339 medium) have been completed. The ultimate irrigation potential from major and medium projects has been estimated at 56.5 million ha. The irrigation potential of the major and medium irrigation projects so far undertaken has been estimated at 20.2 million ha. of which a potential of 10.7 million ha. was created by 1972-73 leaving a balance of 9.5 million hectares for development through the continuing schemes. This, together with 9.7 million hectares (23.9 million acres) of irrigation available from pre-Plan projects provides a total of 20.4 million hecteares of irrigation potential from major and medium schemes.

Thirty-four important irrigation projects taken up since independence, each costing more than Rs. 200 million are listed in Table V. Of these projects, Nagarjunasagar, Tungabhadra H.L.C. Stage-I, Kosi Eastern Canal, Gandak, Ukai, Mahi Stage-I, Parambikulam Aliyar, Mula, Tungabhadra, Bhadra, Ghataprabha Stage-II, Hirakud, Mahanadi Delta, Ramganga, Mayurakshi and Kangsabati are programmed to be fully or substantially completed by the end of the Fourth Plan in 1973-74. Bhakra-Nangal and Damodar Valley Corporation projects have already been completed.

Minor irrigation schemes that were undertaken between 1951 and 1969, like tanks, wells, tube-wells, and lift irrigation and protection works provided new irrigation facilities to 6.12 million hectares of agricultural land at the end of 1968-69, and this added to the pre-plan minor irrigation of 12.88 million hectares (32 million acres) gave a total irrigation

TABLE V

Sl. No.	Name of Project	Estimated cost in Rs. Million	Ultimate benefits in million hectares
1	2	3	4
	A. Continuing Projects		
1.	Nagarjunasagar	2,500.00	0.83
2.	Pochampad	757.20	0.27
3.	Tungabhadra High level Canal Stage - I	181.60	0.05
4.	Kosi Project Eastern Kosi Canal	746.00	0.43
5.	Gandak Project	1,800.00 } 390.30 }	1.15 } 0.31 }
		2,190.30	1.46
6.	Ukai (Irrigation and Power)	1,146.0 Irr. portion 932.3	0.16
7.	Narmada	1,097.0*	**
8.	Mahi Stage — I	245.7	0.19
9.	Mahi Stage — II (Kadana)	240.0	0.02 +0.07
10.	Kallada	450.0	0.11
11.	Chambal Stage — I	476.7	0.28@ (For Stage I and II)
12.	Tawa Project	480.0	0.33
13.	Parambikulam Aliyar	500.7	0.10
14.	Bhima	622.9	0.17
15.	Mula	216.4	0.07
16.	Warna	569.5	0.10
17.	Krishna	497.8	0.11
18.	Jayakwadi Stage — I	743.6	0.14
19.	Tungabhadra Project	514.5 } 135.1 }	0.30 } 0.06 }
		649.6	0.36
20.	Bhadra Reservoir	406.5	0.10
21.	Ghataprabha Stage — II	485.3	0.05
22.	Malaprabha	676.5	0.21
23.	Kabini Reservoir	350.0	0.05
24.	Upper Krishna Stage — I	1,166.7	0.41
25.	Hirakud Stage — I	678.2	0.28
26.	Mahanadi Delta	683.8	0.68
27.	Beas Project Unit II (Beas Dam at Pong)	1,475.7	0.42
28.	Rajasthan Canal	2,081.2	1.27
29.	Ramganga	967.9	0.57
30.	Improvement to Lower Sarda Canal System Stage — I	648.4	0.62
31.	Mayurakshi Reservoir	204.6	0.25
32.	Kangsabati Reservoir	459.3	0.38
	B. Completed Projects		
1.	Bhakra Nangal	805.9	1.23
2.	Damodar Valley Corporation	508.5	0.38

*Rs. 1,097.0 million is the cost debitable to irrigation based on Khosla Committee Report.
**Scope not yet finalised.
@Practically completed.

TABLE VI

Development of Irrigation in India (1951-72)

Expenditures during each Plan Period (Rs. Million)

	I Plan	*II Plan*	*III Plan*	*Annual Plans* 1966-69	*IV Plan* (1969-74) *outlay*	1969-72	*Total* 1951-72
I Major and Medium Irrigation	3,797.5	3,800.0	5,760.0	4,364.3	10,919.2	6,348.4	24,252.2
II Minor Irrigation	656.2	1,732.8	4,391.1	5,469.2	11,657.0	5,454.3	17,703.6
Total	4,453.7	5,532.8	10,151.1	9,833.5	22,576.2	11,802.7	41,955.8

Benefits (Irrigation potential in million hectares) to the end of each period.

	Pre-Plan	*I Plan*	*II Plan*	*III Plan*	1966-69	1969-72	1973-74 (target)
I Major and Medium Irrigation	9.67	12.15	14.30	16.53	18.08	19.53	22.02
II Minor Irrigation	12.88	14.05	14.78	17.00	19.00	20.73	22.19
Total	22.55	26.20	29.08	33.53	37.08	40.26	44.21

of 19.00 million hectares by March 1969. The total area under minor irrigation by March 1972, came to about 20.7 million hectares.

Thus, irrigation from all sources in India has increased from 22.55 million ha. in 1951 to 40.26 million in 1972, i.e., after 21 years of planned development of water resources for agricultural purposes. It is expected to reach 44.21 million hectares by March 1974. Table VI gives the progress in expenditure as well as benefits since 1951.

The spectacular progress in extending irrigation facilities has yielded remarkable results in additional agricultural production. The assured supply of water at the required period was the catalyst to farmers to use high yielding varieties of foodgrains and also fertilizers thereby increasing production.

Hydro-Power: The section on "Development of Power Resources" includes a detailed resume of the growth of hydro-power in India as well as future prospects. Here, the progress achieved after independence has been set out briefly. In the field of hydro-power generation the major projects commissioned during 21 years of planning are Bhakra-Nangal, Hirakud, Chambal, Rihand, Tungabhadra, Sharavathy, Kundah, Parambikulam Aliyar, Koyna, Sabarigiri, Machkund, Upper Sileru, Umiam and Bassi. These projects have increased the installed capacity or generation of hydel power by more than ten times since 1951. The installed capacity of hydro units in 1950-51 was 0.36 million kw. and this has increased to 6.61 million kw. in 1971-72. It is expected to go up to 7.5 million kw. by 1973-74. The Table below gives the plan-wise progress.

TABLE VII

Growth of Installed Capacity

Million kw.

Year	*Hydro Plants*	*Total*
1950—51	0.56	2.30
1955—56	0.94	3.42
1960—61	1.92	5.65
1965—66	4.09	10.17
1968—69	5.01	14.29
1971—72	6.61	17.00
1973—74	7.50	20.10

The important hydro power stations which have given benefits since the beginning of the Plan period are listed below.

TABLE VIII

Hydro Power Stations and Installed Capacity

Sl. No.	*Name of Project*	*Installed Capacity (MW)*
1.	Moyar	3 x 12
2.	Sengulam	4 x 12
3.	Machkund I	3 x 17
4.	Ganguwal I	2 x 24
5.	Ganga Sarda System in U.P.	87
6.	Extension of Pykara	2 x 13.6
7.	Extension of Jog	4 x 18
8.	Yamuna I	84
9.	Machkund II	2 x 21
10.	Maithon	3 x 20
11.	Panchet Hill	1 x 40
12.	Porlingalkuthu	4 x 8
13.	Periyar	4 x 35
14.	Gandhisagar	5 x 23
15.	Tungabhadra	8 x 9
16.	Umiam	6 x 9
17.	Penniar	2 x 15
18.	Neriamangalam	3 x 15
19.	Hirakud I	123
20.	Kundah I, II and III	425
21.	Mettur Tunnel	4 x 50
22.	Mettur Dam	4 x 19
23.	Koyna Stage I	4 x 60
24.	Koyna Stage II	4 x 75
25.	Sharavathi I and II	8 x 89
26.	Bhadra	33
27.	Hirakud II	147
28.	Bhakra Left Bank	5 x 90
29.	Ganguwal II	1 x 29
30.	Kotla I and II	2 x 77
31.	Rihand	6 x 50
32.	Bhakra Right Bank	5 x 120
33.	Matatilla	3 x 10
34.	U.B.D.C.	15
35.	Chinani	14
36.	Obra Hydel	3 x 33
37.	Sholayar	54
38.	Sabarigiri	6 x 50
39.	Kodayar	100
40.	Kosi	10
41.	Jaldhaka	18
42.	Rana Pratap Sagar	4 x 43
43.	Bassi	3 x 15
44.	Upper Sileru	2 x 60
45.	Parambikulam Aliyar	185

This increase in generation capacity has made it possible to extend electricity to the villages also. The task of supplying power to nearly 600,000 villages spread out over the different corners of the country is indeed stupendous. Since independence, the boon of electricity has been made available to over 130,000 villages holding a sure promise of prosperity to rural India. This also enables exploitation of water resources available near the farms by installing pump sets. By 1972, over 2 million pump sets were working with power.

Future Programme: Although India has made rapid strides in the development of its water and land potential for increasing agricultural production, the present levels of availability of food and standard of living in India are far below that of most nations of the world.

The achievements in the field of irrigation, though impressive indeed do not yet go far enough to meet the country's requirements. The total cropped area is at present about 163 million ha. but irrigation potential is available only to about one-fourth of this area. Food-grains production currently is around 110 million tonnes, which needs to be increased to about 160 million tonnes to provide at least a quarter tonne per head by 1981. To achieve this objective the area under irrigation will need to be increased at least by another 50 per cent. The increase will have to be in major and medium irrigation as well in minor irrigation, which calls for an increase of 1 million ha. in the area under irrigation every year on an average in each sector.

In the field of hydro power development the preliminary programme for the period 1971 to 1981 has been worked out so as to increase the installed capacity from 6.61 million kw. to 22.0 million kw. This will help increase the total installed capacity of power from 17 million kw. in 1971 to 52 million kw. in 1981.

III. Flood Control

Achievements: While the problem of floods is as old as the rivers themselves, no extensive efforts were made scientifically to tackle it till the country achieved independence in 1947. The earlier efforts were mainly restricted to construction of embankments piece-meal, mainly erected by individual zamindars to protect their own lands from inundation. At the beginning of this century, when irrigation projects were taken up, some embankments were built to protect the irrigated lands from the ravages of floods. After independence, it was realized that these efforts were inadequate and therefore, multi-purpose reservoirs like the Hirakud and the Damodar Valley complexes were taken up for flood control and multi-purpose use of the stored waters. However, till 1954, no major countrywise programme of flood control was undertaken.

The year 1954 brought one of the worst devastating floods in the country which spurred the Government to concerted action. The Government of India, launched a National Programme of Flood Control in that year. The main handicap, at its outset, was the lack of topographical and hydrological data to plan and implement the flood control schemes. The first priority was, therefore, given to collection of data, apart from undertaking immediate measures wherever necessary. This was subsequently followed by taking up properly planned schemes to control floods and to check river erosion. Floods have still continued to damage our economy, at an annual rate of Rs. 196 crores during 1953-1971. The maximum damage occurred during 1971 was estimated at Rs. 632 crores. Flood damage in 1972 was estimated at Rs. 149 crores.

Policy and Future Programmes: Under the Indian Constitution, flood control is a State subject. Investigation, planning, construction and maintenance of flood control, anti-erosion and drainage schemes are entirely the responsibilities of State Governments. In order to give this programme a national perspective, the Government of India announced in 1954, a national programme of flood control as mentioned earlier. To implement this programme effectively, various organizations at the State, Inter-state and Central levels have been set up. The Centre had also to take up another important role, that of helping the States to plan the schemes of Inter-state rivers to ensure that there are no adverse effects from schemes constructed in one State on another State. Upto the beginning of the Fourth Plan, specific allotments of funds were made for the flood control schemes in consultation with the States, depending on the nature and magnitude of the problem in each State and the priority of the schemes. From the beginning of the Fourth Plan, this system has been changed and the States are given various development programmes. The State Governments have, therefore, to earmark the financial outlays for various sectors of development, including flood control.

It is now proposed to accelerate the flood protection works to ensure that, at the end of the decade 1971-1981, at least 80 per cent of the areas in each State which are prone to floods are given protection. It is hoped that by the end of 1981, a total area of 10 million hectares may be provided flood protection in the country. This corresponds to about 66 per cent of the area that can be economically protected from floods. This programme besides benefitting new areas will also stabilize the benefits already achieved in some areas by raising and strengthening the existing embankments wherever necessary, and by enlarging capacities of drains to higher run-off factors. It is also proposed to take up construction of some storage works during this period. It is estimated that such a programme will require an outlay of Rs. 5,000 to Rs. 6,000 million. The various State Governments have been requested to investigate and prepare schemes and work out priorities for their implementation to achieve the targets.

In the national flood control programme, which was outlined in 1954, it was envisaged that the construction of embankments will essentially be a short-term measure. As a long-term measure, it was proposed to construct storage reservoirs on a number of major and minor rivers to control the floods passing lower down. Some storage projects had already been built with flood control in view, notable among which are the Hirakud dam on the Mahanadi in Orissa, and a series of 4 dams on the Damodar river system for the States of West Bengal and Bihar. In addition, a number of multi-purpose river projects have been constructed in the country which, although not providing specific flood storage, help considerably in moderating the flood flows. In the coming decade, more reservoir projects have been envisaged to provide permanent storage protection from the flood ravages. Such reservoirs, wherever feasible, are proposed to be planned for multi-purpose uses like irrigation and hydro-electric generation to make them economically viable.

In order to implement the national flood control programme outlined by the Government of India in 1954, a network of organizations has been set up at various levels.

At the State level, State Technical Advisory Committees and Flood Control Boards have been set up to examine the technical and economic feasibility of the schemes, to lay down policies for the formulation of these schemes, and to prepare long range plans for flood control. The planning and implementation of the schemes is being done by the irrigation departments in various States. There are no separate departments for flood control so far. However, recently in order to tackle the complex problems of flood control and erosion in a more scientific manner in the Brahmaputra Valley in Assam and in the north Bengal region of West Bengal, separate Flood Control Commissions have been set up. Two separate Boards of Consultants comprising experts in this field assist these Flood Control Commissions. To lay down policies and give direction to these Commissions, the Brahamputra Flood Control Board and the North Bengal Flood Control Board have been set up with the Union Minister of Irrigation and Power as Chairman.

At the Inter-state level, four river commissions have been set up *viz.*, the Ganga, the Brahmaputra, the North-west and the Central India Rivers Commissions. These are presided over by the Chairman, Central Water and Power Commission with the Chief Engineers of the States in the region as members, apart from the representatives of the Survey of India, Geological Survey of India, Ministries of Railways and Transport and the India Meteorological Department. These Commissions are entrusted with the work of coordinating the plans of various States in the river basins and solving Inter-state disputes.

In order to prepare and implement a comprehensive integrated plan of flood control, erosion and drainage in the Ganga Basin as a whole, with the close co-operation of the Government of India, a separate flood control commission has been set up. The Government of India have also constituted the Ganga Flood Control Board headed by the Union Minister of Irrigation and Power and consisting of the Union Minister of State for Finance and the Chief Ministers representing the States of Bihar, Uttar Pradesh, West Bengal, Haryana, Rajasthan and Madhya Pradesh as members.

At the Central level, there is the Central Flood Control Board. This is presided over by the Union Minister of Irrigation and Power and has the Union Ministers of Railways, Transport and Agriculture as well as the representatives of the State Flood Control Boards as members. This Board lays down broad policies for the programme, reviews the progress achieved in the various activities of flood control and gives an overall direction for the implementation of the programme.

In order to assist the Central Flood Control Board, the Union Ministry of Irrigation and Power and the Planning Commission, a separate flood control wing has been created in the Central Water and Power Commission. This organization carries out the technical scrutiny of various flood control, drainage, anti-waterlogging and anti-sea erosion schemes and also assists the State Governments in planning and implementing of the flood control programme. It also provides expert assistance on specific problems referred to it. Since 1969, this organization has also undertaken the work of flood forecasting on major rivers in six States, *viz.*, Assam, Bihar, Uttar Pradesh, Orissa, West Bengal and Gujarat, in addition to the forecasting on the river Yamuna in Delhi which has been taken up from 1959. This has helped State authorities to take timely action, both for the safety of the engineering works as well as the arranging of timely evacuation and relief measures.

Flood warning and flood fighting are the responsibilities of the State Governments. In these fields, varying practices are being adopted by different States. In order to make them uniform and effective, the Central Water and Power Commission has recently circulated a manual of flood operation, indicating the frame work of organization for flood warning, flood fighting, etc.

During the last 18 years, about 40 per cent of the area which can be economically protected has been afforded protection, with an investment of Rs. 2,552 million. The average annual outlay works out to only 11 per cent of the average annual damage caused by floods. In order to set up the programmes and to achieve the objective of minimizing the damage, a decade plan has been proposed to provide protection by 1981 to at least 50 per cent of the area liable to floods.

While the various known methods of flood control have already been adopted the major emphasis so far has been on the construction of embankments. This is now proposed to be supplemented with the construction of storage reservoirs, wherever feasible. In order to tackle the programme on a concerted basis, separate organizations exclusively devoted to flood control have been set up, as mentioned earlier, in the States of Assam and West Bengal as well as for the Ganga Basin as a whole covering six States. It is proposed to extend the flood forecasting systems in the country to reduce the loss of life and property by giving timely warnings. Setting up of organizations to effectively carry out flood warning and flood fighting is also proposed.

While the progress achieved so far is significant in the context of the overall magnitude of the problem as well as its ramifications, it is equally necessary to accelerate the programme and set up new organizations so that the recurring damage is minimised as early as possible. This is particularly important since, with the increase in the pressure of the population and the rapid progress of industrialization in the country, flood control would be vitally necessary to prevent set-backs to socio-economic growth.

IV. Future Perspective

About one-third of the area of our country is subjected to drought. The current percentage of irrigation attained in the drought districts is low as compared to the average of the country as a whole. Moreover, most of the irrigation is through minor schemes, which usually are unable to provide adequate quantities of water and very often fail during critical periods. Even after taking into consideration the increase in the irrigated area by utilizing the balance of the available local waters, the percentage in most cases is still on the low side. In order to improve this proportion to a reasonable level, it will be necessary to consider schemes for importing water from outside the basin. There is an imbalance in the distribution of available water resources in the various regions of the country in relation to the areas of water demand and in relation to the time and need during the year. The northern and eastern rivers fed by high rainfall during the monsoon carry abundant discharges. The snows of the Himalayas help in keeping these rivers perennial although the discharge during the dry season is a small fraction of that in the rainy months. The western and southern rivers on the other hand, being purely rain-fed, have very uncertain flows because of the vagaries of the rainfall and the annual yield of these rivers is also highly variable. These conditions of high discharges available for only the short rainy period point to the obvious need for conserving the flows in the high flow period for utilization in the lean months. Many large storage tanks have already been constructed and several more are in various stages of construction and planning. Even after harnessing the utilizable water resources, many rivers like the Ganga, Brahmaputra, Mahanadi, etc. will carry large volumes of water to go waste into the seas. A country with so many drought prone regions can ill-afford to waste all these surplus waters and it is essential that these are put to use for meeting the needs of the deficient areas.

In order to achieve these objectives, it has been proposed to inter-link the various major rivers, thus enabling transfer of surplus flows to areas of deficit supply. This will remedy, to some extent, the imbalance of the regional water resources. The geographic relation between regions of water supply and water demand will be such that the overall picture will comprise two main groups of water transfer links; one extending from the east to the west and the other extending from the north to the south-west and the south. Subsidiary links, branches and connectors with intra-basin and local projects and other services will also be necessary. When identified, these features will constitute a National Water Grid, investigations for which are proposed to be taken in hand shortly. The major part of this grid would be the ambitious programme of linking the Ganga in the north to the Cauvery in the south probably by the turn of this century.

B. POWER RESOURCES

I. Historical Background

Power Policy: Under the Constitution of the India, electricity is a concurrent subject, with responsibility both of the Centre and the States. It is a field in which private entrepreneurship accounted for most of the earliest developments, whereas today State undertakings predominate. Electricity development in the country started at about the turn of the 20th century. From timely, impressive beginnings, and after an unduly prolonged period of halting growth, progress has been accelerated during the last twenty years of planned development. The total installed generating capacity in the country in March 1970 stood at 15.5 million kw. to which State-owned public utilities contributed 12.5 million kw. (80%), private utilities operating under licences 1.6 million kw. (10%), the rest of about 1.4 million kw. (10%) being in the non-utility sector, i.e., State-owned as well as licensed private industries, which generate electric power for their own consumption. Prior to independence, out of a total installed capacity of 1.7 million kw. in the entire country, State-owned utilities contributed only 0.37 million kw. (21.8%), which is indicative of the subsequent change in the role of the Government in this field.

Early Legislation: From the earliest stages, the power to legislate in the field of electricity development was vested in the Central Government. Legislation to control electricity supply actually preceded the setting up of the electrical utility industry. The first legislative measure was introduced as the Electricity Act of the Government of India in 1887, at a time when electrical installations covered only a few dynamos feeding arc lights and electric candles. The primary object of this bill was to enable the Governor-General in Council to frame rules for protecting the public, person and property from injury from appliances or apparatus utilized in the supply of electricity for lighting and preventing telegraph lines from being injuriously affected by these appliances. The question of control of electricity supply undertakings by means of licences was considered but action was deferred. The Act was regarded as a preliminary measure to be reviewed as soon as some experience in the field had been gained.

In 1891, when proposals were received from the Indian Electricity Supply Syndicate for the establishment of works for supply of electric lighting to the city of Calcutta, the Government of Bengal represened to the Centre that further legislation was called for, either (a) by a general Act applicable to the whole of India or, (b) by a local and special Act for Calcutta, to enable it to issue licences for electric supply, and to exercise control on other related matters such as protection of the interests of the electric supply undertakings and of consumers from excessive charges. The second alternative was recommended by the Central Government and this led to the enactment of a local Act in Bengal, *viz.*, the Calcutta Electric Lighting Act of 1895, applicable to Calcutta and providing for its extension to other municipalities in Bengal. The question of amending the Act of 1887 to provide for control of electric undertakings by means of licences, was again considered by the Government of India in 1895 but it was felt that the more important Provincial Governments, with Legislative Councils of their own, could pass Acts similar to the Calcutta Act whenever required and, in the other minor administrations, no urgency was felt.

In 1900, the Government of Bengal, faced with the need for a modification and extension of the Bengal Act of 1895, suggested that it would be desirable for the Central Government to frame a comprehensive Act applicable to the entire country. It was also represented from other parts of India that promoters of electric enterprises would welcome such legislation. The Provincial Governments were also generally in favour of a general Act. In this context, the Electric Supply Act of 1903, which repealed the Act of 1887 and the Calcutta Electric Lighting Act of 1895, was passed. This Act specifically provided for control by licence, of undertakings supplying electricity to the public, for purposes of traction etc. and also for making rules and reference of disputes for arbitration. It was, however, recognized that even this Act was a tentative measure requiring amending legislation at an early date.

In the early years of power development, the electricity supply industry was organized predominantly by private enterprise for serving the needs of populations in large towns and cities. Soon many difficulties were encountered in the working of the 1903 Act. While the power to issue licences under this Act rested with the Provincial Government, yet authority or previous sanction of the Governor-General in Council in regard to certain matters was required. This resulted in dual administration and almost every application for a licence had to be referred to the Governor-General in Council resulting in inordinate delays. These being detrimental to promotion of electricity development, a committee of amendment to review the various provisions of the 1903 Act was appointed in 1907, and its deliberations led to the repeal of the 1903 Act, and passing of the Indian Electricity Act of 1910.

The Electricity Act 1910: General administration of this Act, and the granting of licences, subject to the control of the Governor-General in Council, were left in the hands of the Provincial Governments, only the rule making powers being reserved to the Governor-General in Council. The Act provided for the issue of licences for establishment of electric utility undertakings, laid down the responsibilities and duties of the licencees, ensured that adequate safety measures were taken by the utilities and consumers in the distribution and use of electricity, and incorporated generally all the regulations and controls necessary for the smooth running of the industry. It was primarily regulatory in character and concerned itself a great deal with essential provisions of safety. The main purpose of the Act was not so much to promote the development of the power supply industry as to exercise adequate control in the public interest. In 1922, the control of the Governor-General in Council in granting of licences was also abolished in accordance with the spirit of the Montague-Chelmsford Reforms. The Government of India Act of 1935 assigned the subject of elctricity, to the concurrent list, and this resulted in the responsibility of the Central Legislature being confined only to introducing legislation in the field, while the complete administration of the legislative measures vested with the Provincial Governments. The 1910 Act has been modified from time to time in the light of subsequent experience and to suit the changed political situation in the country after independence.

Beginning of Electricity Supply Industry: Electricity was first introduced in the country in the year 1897, when a 130 kw. hydro-electric project, utilizing the unregulated waters of a Himalayan hill stream, was launched by the Darjeeling Municipality in Bengal under a licence.

The first steam-driven power plant, rated 1,000 kw., was installed at Calcutta two years later in 1899 by the Calcutta Electric Supply Corporation. The first major hydro-electric installation was the 4,500 kw. Sivasamudram Station on the Cauvery river, launched in 1902 by the Mysore Durbar to supply power to the Kolar Gold Mines. The capacity of the Station was progressively increased from 4,500 kw. in 1902 to 15,700 kw. in 1920. Sivasamudram was not only the first major power scheme in India designed to promote industrial development but had the distinction of having, associated with it, one of the longest — 145 kms. at 70 kilovolts — transmission lines in the world at that time. In 1909, the Kashmir Durbar inaugurated its Jhelum Power Station (installed capacity 4,000 kw.) at Mohora. Several thermal installations sprang up in 1906, notably in Madras, Kanpur and Delhi.

The most impressive scheme of power development in the period after the enactment of the Act of 1910, and prior to the First World War, was the 50,000 kw. hydro-electric scheme implemented by the Tatas at Khopoli in 1914 under which waters of an east flowing tributary of the Krishna river, were harnessed ingeniously by impounding and westward trans-basin diversion of these waters across the continental divide, to utilize a fall of 500 meters, available in the neighbouring basin. The capacity of the thermal stations in the various cities was increased, and small installations mushroomed at the more important towns. Electricity tariffs were high and development of electric supply on the whole was not progressive.

Impact of World War I: The outbreak of World War I brought matters to a head, when it was found that power was one of the most basic requirements of all war-time demands. The Indian Industrial Commission, while reviewing the power position during 1916-18, emphasized the need for a survey of the hydro-electric resources of India, since the entire industrial future depended upon the provision of cheap power. It further recommended that the survey be carried out forthwith by Government, since only they could estimate the effect of displacing communities under reservoir schemes, ascertain long-term rights, adjust conflicting claims, initiate and carry through joint and inter-dependent power and irrigation schemes, and most important, afford to conduct the long-term gauging operations which were so essential for hydro-electric projects. The Commission also pointed out that unless a systematic survey was undertaken by Government, it would not be possible to formulate precise rules for grant of concessions.

Acting on these recommendations, a survey of the hydro-electric resources of the entire country was initiated in 1919 under the auspices of the Central Government and was conducted on a country-wide basis for a short period of three years. This represented the first evidence of Government's direct interest in the field of electricity development, either at the Centre or in the Provinces, and led to a preliminary assessment of the water power resources of India, which, for the territories now forming part of the Indian Union was placed at 3.5 million kw. continuous, on firm basis. Although unduly pessimistic and severely inhibited by the limitations of technology at that time, this survey represented a valuable first step undertaken at a timely stage. Unfortunately, in 1920 the Government of India, as a consequence of the Montague-Chelmsford Reforms, decided that all outlay on water storage and water power would be a provincial charge and ruled that the necessary provision for hydro-electric surveys should be made in the provincial estimates from the year 1921-22 onwards. This marked the end of direct participation by the Central Government in the field of power development till World War II. Although some Provincial Governments evinced interest in a few selected schemes, the aims and objects of a nation-wide survey of total resources were soon lost sight of.

The period after 1921 was, however, important because some enterprising Provincial Governments *viz.*, Madras, U. P. and the Punjab entered the field of power development with pioneering hydro-electric projects, *viz.*, Pykara, Papanasam and Mettur in Madras, the chain of power stations utilizing the falls along the Ganga Canals in U.P. and Jogindernagar in the Punjab. Grid systems emerged as power was carried from these hydro stations to remote load centres. The Princely States of Mysore and Jammu and Kashmir expanded their hydro stations and the State of Travancore also joined in the development of hydro power. The Tatas, the great industrial *entrepreneurs*, expanded their hydel stations along the Western Ghats. Expansion of thermal stations continued on load centre basis, as a preserve of private enterprise, operating under licences for production and distribution of power in urban centres. In addition to expansion of the then existing thermal power stations at Calcutta, Madras and Kanpur, new installations were commissioned in Bombay, Lucknow, Allahabad, Delhi, Agra etc. The total power plant capacity in the entire country at the beginning of World War II was about 1.2 million kw. to which State-owned electric utilities contributed about 76% of the total.

During World War II, all the available power supply resources were strictly controlled and regulated from the point of view of the war effort. Expansion of the industry was stifled considerably during the war period and shortly thereafter. At the time of independence, the installed capacity stood at about 1.7 million kw.

The Electricity Supply Act of 1948: As pointed out earlier, the Indian Electricity Act of 1910, introduced during the infancy of the electricity supply industry, was not specifically aimed at promoting rapid development. This inadequacy, pointed to the need for additional legislation and for promotion and rationalization of power development. With the rapid growth of electricity during the post-World War I years, the concept of co-ordinated operation of electricity stations by forming grid systems, and the advantages of centralizing direction and control of bulk supply of energy by a single authority were recognized as essential for fostering healthy and economic growth of electricity. These new concepts introduced by technological advancement in the field were considered in detail by the Power and Fuel Sub-Committee of the National Planning Commmittee set up in 1940 under the chairmanship of Jawaharlal Nehru. This Committee, in its resolution, recommended the creation of Central and Provincial Electricity Boards to implement national policies on power. Its also considered that it would be advantageous if Government were ultimately to own and operate the entire electricity supply industry. The Policy Committee on Electricity and Public Works of the Government of India also recommended in February 1945 that "Steps should be taken to eradicate any factors that retarded the healthy economic growth of electrical development on regional lines whether in the Provinces, States and Local Authority-owned or in commercially-owned electrical undertakings." It was then decided that the needs of the country would best be met by the constitution in the Provinces of quasi-autonomous statutory boards provided with adequate powers to effect the rationalization of electricity supply throughout the Province. Since it was not possible to legislate for this purpose within the framework of the 1910 Act, which had been conceived for an entirely different purpose, specific additional legislation on the broad lines of the Electricity (Supply) Act of 1926, in force in the U.K. at that time, was thought advisable. Accordingly, a bill was introduced in 1946 in the Central Legislative Assembly and its provisions discussed at a conference of prominent representatives of the Assembly as well as of industry and Provincial Governments in the summer of 1947. The bill finally drawn up was referred to a Select Committee of the Central Assembly in December 1947. The revised bill incorporating various amendments and modifications was introduced in the Constituent Assembly (Legislative) in 1948, and passed as The Electricity (Supply) Act, 1948. This Act provides for the establishment of a Central Electricity Authority and for organizations in the States, known as "State Electricity Boards." It also lays down principles for the control of finance of public electricity supply utilities.

The Central Electricity Authority, provided for in the 1948 Act, and constituted in January 1950, is statutarily empowered to:

(a) develop a sound, adequate and uniform national power policy and particularly to co-ordinate the activities of planning agencies in relation to the control and utilizaton of national power resources,

(b) act as arbitrator in matters arising between the State Government or Boards and a licensee or other person as provided in the Act,

(c) carry out investigations and collect and record data concerning the generation, distribution and utilization of power and the development of power resources, and

(d) make public from time to time information secured under this Act and to provide for the publication of reports and investigations.

Some of the functions of the Central Electricity Authority, like collection and publication of statistics pertaining to the electricity supply industry, etc., are discharged for and on behalf of the Authority, by the Power Wing of the Central Water and Power Commission, the technical organization of the Union Ministry of Irrigation and Power. The latter organization was formed by amalgamation of the Central Electricity Commission (1948 to 1952) with the Central Water Power, Irrigation and Navigation Commission in 1953.

The State Electricity Boards provided for in the 1948 Act are semi-autonomous bodies empowered to control and regulate power development in the areas under their jurisdiction with the following specific functions:

(a) to rationalize the production and supply of electricity in any area by preparing and carrying out schemes in which provision may be made for all or any of the following matters, *viz.*,

(i) the establishment of the Board's own generating stations;

(ii) the designation with the consent of the owner of generating stations, whether existing or new, as controlled stations at which electricity shall be generated for the purpose of the Board;

(iii) the inter-connection, by means of main transmission lines to be constructed or acquired by the Board, of any generating station with any others and with any system of licensees;

(iv) where a scheme relates to a specified area, the inter-connection of the system of the Board in that area, with the system of the Board in any other area with respect to which a scheme is being or may subsequently be made;

(v) the construction or acquisition with the consent of the owner of such other main transmission lines as the schemes may require;

(vi) the use by the Board of any transmission lines or main transmission lines of any licensee with his consent;

(vii) such supplemental, incidental and consequential provisions as may appear necessary or expedient for any of the purposes aforesaid;

(b) to supply electricity to owners of controlled stations and to licensees whose stations are closed down under the Act, and

(c) to supply electricity as soon as practicable to any other licensees or persons requiring such supply and whom the Board may be competent under this Act to supply.

One of the important features of the Electricity (Supply) Act of 1948 is that it lays down the financial principles to regulate the commercial working of electric licensees. It introduces the concept of ensuring power supply — a basic need — at economical and reasonable rates, by the provision that the clear profits of a licensee shall not, as far as possible, exceed the amount of "reasonable return". If such a return is not, however, realized by a licensee, a procedure has been outlined by which the licensee could then extend his schedule of rates.

The Delhi State Electricity Board was the first to be formed in 1950, followed soon thereafter by the Madhya Pradesh Board. The Bombay State Electricity Board was formed in November 1954. There was considerable reluctance initially on the part of some States to form Electricity Boards. The question was discussed at a meeting in the Ministry of Irrigation and Power on February 16, 1955, at which it was decided that all the States should constitute the Boards as required under the Act. Thereafter, State Electricity Boards were constituted in the rest of the country. Although State Electricity Boards have since been set up in all States except Jammu and Kashmir, their historical background and experience have varied widely, as should have been expected in a large country like India, and their performance — in their main objective of fostering electricity development — is likewise diverse. While most Boards have comprehensive functions of power generation, transmission and distribution under their charge, in a few cases, investigations and construction of power generation schemes continue with the State Government Departments. In others, private utilities still continue to generate and distribute power in lucrative urban areas. The full objectives of constituting State Electricity Boards have, therefore, yet to be achieved.

Period of Planned Development: After 1950, the electric power industry, whose growth was slow and halting for nearly half a century, received great impetus. Major river valley developments taken up after independence for multi-purpose benefits, with power generation as one of the major aspects, contributed substantially to this boost. In the following era of planned development, and with emphasis on rapid-industrialization, electricity supply became even more important. Power development has generally kept pace with these rapidly growing demands and during the last twenty years, there has been a seven-fold increase in the installed capacity.

The basic approach of the Electricity (Supply) Act of 1948 was to promote electricity development, through tariffs which assured only a reasonable return on investment. More recently, in view of the capital intensive nature of the power supply industry and paucity of financial resources, the view has been expressed and gaining ground that electricity supply undertakings should earn reasonable surpluses also to provide resources for future development towards which end electricity tariffs and duties should be readjusted. A committee, mainly of State Ministers, was set up to examine these and related issues in June 1964. Their report submitted in October 1964, points out that the general financial conditions of most Boards, not being satisfactory, an overall objective of achieving a net return of 3% on the capital base may be aimed at in two successive stages. The question of amending the Electricity (Supply) Act of 1948, to bring it in line with recent thinking is currently under active consideration of Government.

With the institution (in 1950) of the Planning Commission — whose role in overall planning of all national activities, impinges on those of the Central Electricity Authority — the *de facto* position is that the responsibility for planning and co-ordinating developmental activities rests with the Planning Commission, and is mainly exercised through the Ministry of Irrigation and Power and its technical department, the Central Water and Power Commission. The question of strengthening the Central Electricity Authority is also currently under consideration of Government.

II. Role of Coal, Hydro, Oil and Gas and Nuclear Resources

Coal: Coal has played the most significant part in the development of industrially advanced nations from the earliest stages. Though oil and gas have recently been rapidly substituting coal, it still forms the main source of energy in the world today. In India, coal has always been the backbone of the commercial energy supply, its production increasing steadily from about 6 million tonnes at the turn of the century to about 35 million tonnes in 1950 and about 80 million tonnes in 1970. Thermal power stations in 1969-70 in utilities, with an aggregate installed capacity of about 7,200 MW consumed about 17 million tonnes or about 21% of the total coal production in the country. Their output of about 27,000 million kwh. corresponded to a little more than half the total electricity produced in the country that year, more or less in keeping with past trends. Reliability of supply, limited outlays, and relative flexibility of location have been the main advantages of thermal generation in the past. Great advances in technology have taken place in thermal power generation during the past 50 years, leading to lower installation costs and vastly improved efficiencies of energy conversion. Further improvements, including operation at super critical pressures and higher temperatures, development of very large sized generating units, rated at over one million kw. each are being perfected. Thus, although facing increasing competition from the rapidly growing field of nuclear power generation, electricity production through coal-fired thermal stations is expected to continue to play an important role in the production of electricity. In fact, there are compelling reasons, peculiar to the coal industry in India, which necessitate continued reliance to a substantial extent on this form of electricity production.

It is known that coal has been used both as a fuel and for reducing iron ore in India from ancient times. The earliest exploitation for commercial purposes dates back to 1774 when a private company was granted permission to raise and despatch coal from large areas at Sitarampur in the Raniganj field. The work was, however, abandoned soon, and thereafter no further prospecting was done till 1840, when with Government assistance, a mine was opened at Egra near Raniganj. In the early stages, development was slow mainly due to the lack of transport facilities, the only means of reaching the Calcutta market being navigation along the Damodar river during the monsoons. The expansion of the East India Railway during the mid 19th century, was followed by steady progress, the total coal production rising to about 6 million tonnes at the turn of the century, out of which Raniganj alone contributed 2.55 million tonnes. Several coal mines were also opened up in the erstwhile Central Provinces and Hyderabad State during the latter part of the 19th century. At the beginning of the First Plan in 1951, the annual coal production in the country was about 35 million tonnes entirely by private enterprise.

The need for rapid expansion in coal production to meet the demands of transport, industry and other sectors was recognized early and in order to accelerate the development of new coal mines and rationalize production, a corporation — The National Coal Development Corporation (NCDC) — was set up in the public sector in 1956. At the end of the First Plan, coal production stood at 40 million tonnes and this figure was further increased to 56 million tonnes at the end of the Second Plan, out of which 40 million tonnes was by the private sector and 16 million tonnes by the public sector. About 41 million tonnes (or 3/4 of the total) came from the Bengal-Bihar coal fields, and the balance from outlying coal fields — 6.2 million tonnes from those in Madhya Pradesh, 2.6 million tonnes from Andhra Pradesh, and the rest from small mines in Assam, Orissa, Maharashtra, Rajasthan and Jammu and Kashmir. Of the total production, about 4.7% came from deep underground mines at depths over 305 meters about 74.5% from shallow underground mines, and the balance of 20.8% from open cast workings. Coking coal — entirely raised in Bengal-Bihar — accounted for 16.89 million tonnes or about 30% of the total. Despite raisings from outlying coal fields, the large deficits of the western and southern regions, had to be mainly met from Bengal-Bihar, with inevitable long hauls. The average ash content of all Indian coal raised in 1960-61 was about 25% and that of coking coal about 23%.

At the end of the Third Plan, the production was of the order of 70 million tonnes. The target for the Fourth Plan has been set at about 93.5 million tonnes.

India's coal reserves are yet to be intensively explored in their entirety. The Geological Survey of India is at present engaged in the task of a systematic assessment of these reserves through a committee on the assessment of coal resources appointed by the Coal Council of India. An estimate of about 106,000 million tonnes of proved, indicated and inferred reserves upto a depth of 609 meters in the case of most of the coal fields and 1,219 meters in the case of some of the collieries, specifically Raniganj and Jharia, has been indicated recently. The coal fields are mainly concentrated along a belt that runs from the eastern part of the Damodar Valley towards Central India, down to the Godavari Valley. In addition to these reserves of coal, there are reserves of lignite around 2,060 million tonnes, most of which are located at Neyveli in Tamil Nadu.

In view of the fact that the reserves of coking coal are limited and these as well as high grade non-coking coals are required with priority in the industry and transport sectors, thermal plants have to rely mainly on lower grade or slack coals available in ample measure. Further, the high ash content of all coals, requiring upgrading by washing as an essential prerequisite to industrial and other uses, introduced large quantities of by-product coals (middlings) from washeries which can be utilized in power stations. Because the ash itself is deeply interspersed in the coal and is not so readily separable, there are difficulties in reducing the ash content by washing. A major programme of washing coal is currently under implementation, with the object of supplying clean coal with an ash content of about 17% for coking purposes. The actual output of by-product coals, would depend upon the production of coking coalfor metallurgical purposes, which, in turn, depends upon the targets for development of the iron and steel and other allied industries. At the end of the Fourth Plan, it is expected that about 6 million tonnes of these by-product coals would be available for power generation and these are expected to be fully utilized by the thermal stations in the Eastern Region, which are being designed to utilize these by-product fuels. Including these, the total coal consumption of all thermal stations by the end of the Fourth Plan is expected to be of the order of 30 million tonnes.

From inception and during the entire first half century of growth, coal-based thermal generation comprised small load-centre installations supplying urban requirements of power at Calcutta, Bombay, Madras, Kanpur and other cities and towns. The first station was commissioned at Calcutta in 1899 followed by Madras and Kanpur (1906) and Delhi (1908), etc. These developments were exclusively by private enterprises which were freely allowed to expand their stations. Actual development upto World War I, was, however, extremely slow, the pace increasing somewhat thereafter. The installed capacity just prior to World War II was 540,000 kw. distributed among some 50 stations all of which were established and operated by private licensees.

There was a further spurt in activity following the end of World War II, when thermal stations in the urban centres continued to expand. The first major step in the development of economic thermal power through advantageously located large-mine-mouth installations was taken when the Damodar Valley Corporation (DVC) inaugurated work on the installation of the Bokaro Thermal Station with 3 generating units of 50 MW each in 1948-49. The total installed capacity of thermal plants in the utility sector in the country was increased from 1,004,400 kw. in 1951, to 1,546,800 kw. in 1956 and 2,436,255 kw. at the end of the Second Plan. The most important stations to be commissioned during this period were Bokaro (225,000 kw.) and Durgapur (150,000 kw.) in the DVC area, Trombay (187,500 kw.) and Chola-Kalyan (96,000 kw.) in the Bombay area, and Korba (99,000 kw.) in the Madhya Pradesh area.

The total installed thermal capacity including those of self-generating industries in the country increased to 5,560 MW at the end of the Third Plan and is expected to increase to about 12,700 MW as per the target for the Fourth Plan. Most of the recent additions to plant capacity have been in the public sector, as would be seen from the Table below:

TABLE IX

Thermal Installed Capacity in kw.

	Private Utilities	*Public Utilities*	*Total Utilities*	*Private as %age of the total*
1. Prior to 1st Plan (31.12.1950)	758,520	245,914	1,004,434	76
2. At the end of 1st Plan (31.12.1955)	809,434	737,368	1,546,802	52
3. At the end of 2nd Plan (31.3.1961)	992,836	1,443,419	2,436,255	41
4. At the end of 3rd Plan (31.3.1966)	1,395,770	3,019,515	4,415,285	32
5. At the end of 1969-70	1,302,500	5,893,890	7,196,390	18

There has been a decided shift in the location of thermal power stations from urban load centres to pitheads. Obra (550 MW), near Singrauli collieris, Patratu (620,000 kw.) near Karanpura coal fields, Chandrapura (660,000 kw.), Durgapur (575,000 kw.), Bandel (330,000 kw.) and Santaldih (240,000 kw.) near Raniganj, Talcher (250,000 kw.), Satpura (312,000 kw.) and Neyveli (600,000 kw.) near coal fields of the same names, and Ramagundam (100,000 kw.) and Kothagudam (460,000 kw.) near Singareni collieries and Koradi (480,000 kw.) near the Pench Valley collieries are sites, at or close to collieries/washeries where the bulk of recent expansions completed/contemplated have been concentrated. These large mine-mouth washery stations, have very extensive extra high voltage grids, necessarily associated with them, to cover their large areas of reticulation. Sizeable investments are involved in developing these sites, arranging for water supply etc., and these major power stations are now being implemented mainly by the various State Electricity Boards.

The trend towards more rational development would also be seen from the Table below indicating the progressive increase in the unit sizes, to drive the twin benefits of reduced costs and improved efficiencies:

TABLE X

Year	*Capacity of the biggest station in MW.*	*No. of stations above 200 MW capacity*	*No. of Units greater than 50 MW but less than 100 MW*	*No. of units greater than 100 MW (including 100 MW unit)*
1. 1950	121	—	1	—
2. 1960	225	1	10	—
3. 1970	600	14	43	11

The average gross efficiency of all thermal stations, which was only of the order of 16.3% in 1951 and 20.1% in 1961 has increased to 25.1% in 1969, steadily approaching the higher standards achieved in advanced countries where efficiency levels of the order of 40 to 43% have been reached.

The costs of thermal energy production depend on the cost of fuel and the load factors. They range in India from about 3 paise per kwh. at high load factor stations near the collieries to about 5 to 6 paise per kwh. at stations located about 966 km. from the collieries and operated around annual system load factors of about 60%.

An adverse feature of thermal development in the country so far has been the almost complete dependence on sources outside the country, both for the plant and equipment, and the engineering services required for designs and erection of plant. To minimize this to the extent possible, the Government has embarked on a programme of indigenous manufacture of equipment associated with thermal stations. Boilers are to be manufactured by both public and private sectors — the

Heavy Electricals at Tiruchirapalli in Tamil Nadu and A.C.C.—Vickers-Babcocks Ltd., at Durgapur. Steam turbogenerators will be manufactured by the Heavy Electricals at their Bhopal, Ramachandrapuram and Hardwar plants, where attempts are being made to standardize designs for overall economy in design, manufacture and operation. To undertake all the complex engineering works of design and erection, the various Central and State organizations are being strengthened and the growth of private consulting engineering organizations has also been encouraged. It is expected that, with these measures, the dependence on foreign sources for equipment and services would soon be eliminated.

Hydro: Hydel development gained momentum during the third and fourth decades of this century when State Governments undertook electricity development in the public sector. It has since steadily gained in importance with installed capacities varying from about 33-40% of the total electrical energy production since 1950. Their importance is due primarily to their fairly even distribution over the country, and relative economy. That they are inexhaustible perennial sources, and their low costs of production remain constant throughout the useful lives of these schemes, i.e. 100 years and more, are also vital factors. A compelling avantage is that they involve the least import component of all alternatives for electricity production, since the bulk of the investments are on civil works, e.g., dams, water conductor systems and power stations which are designed and constructed almost entirely indigenously. The total hydro energy generation in 1969-70 at 23,000 million kwh. represents utilization of only about 10.2% of the available resources. This is due partly to the fact that hydel developments involve relatively longer gestation periods — covering extensive periods of investigation and construction work at remote sites — and quite often solution of complex problems associated with riparian rights and inter-State aspects. Long-term perspective planning is expected to overcome these limitations and lead to a quicker pace of utilization of hydro resources.

Hydel generation was initiated in India in 1897 through a 130 kw. station for municipal town lighting in Darjeeling (West Bengal). In 1902, the Mysore Durbar set up the first major station at the famous Cauvery falls at Sivasamudram (4,500 kw., raised to 15,700 kw. by 1920), to supply power to the Kolar Gold Mines. It was also the first industry-oriented power scheme. In 1909, the Kashmir Durbar inaugurated its 4,000 kw. Jhelum Station at Mohora near Srinagar. Municipal stations for town lighting were installed at Mussoorie (450 kw.) in 1913. Among these early developments, the 50,000 kw. Khopoli Scheme pioneered by the Tatas in 1914 to meet the electricity demands of Bombay City, and which involved westward, trans-basin diversion of waters of the

Gokak falls 1887

tributaries of the Krishna river to utilise a fall of 500 meters, was easily the most impressive. At the beginning of World War I, the aggregate capacity of hydel installations in the country stood at 70,000 kw.

Shortly after World War I, the Tatas followed Khopoli with a similar 72,000 kw, Bhivpuri Station in 1920 and the 110,000 kw. Bhira Station in 1927, in the same area, to meet growing demands of the city. Mysore State increased the capacity of Sivasamudram to 42,000 kw. in stages and followed it up with the 17,200 kw, Shimsha Hydel Project nearby in 1940. During the late twenties, several Provincial Governments undertook hydel development under public ownership. In 1931, Tamil Nadu (Madras) launched its Pykara Scheme — in the Nilgiris — with an initial capacity of 18,750 kw., utilizing a fall of 1,000 meters, one of the highest in the world then, —and followed it up with a 30,000 kw. power station at the toe of the Mettur Dam, which was constructed to extend irrigation under the time honoured canal system of the Cauvery delta. Uttar Pradesh developed the falls along the Ganga Canal with a chain of 7 power stations with an aggregate installation of 18,900 kw. from 1927 to 1937. The Punjab inaugurated its 48,000 kw. Jogindernagar Station (now in H.P.) in the Beas Valley in 1933. Kerala (Travancore) undertook systematic development of the steep Mudirapuzha of the Periyar river system, commissioning the Pallivasal Station with an initial capacity of 13,500 kw. in 1939. Through these efforts, the aggregate hydel capacity increased to 470,000 kw. in 1940, and during the period 1940 to 1947, little progress was made, the only addition being 21,000 kw. at Papanasam in Tamil Nadu, and 48,000 kw. at Jog in Karnataka. It is noteworthy that most of these installations were single-purpose in character conceived for and financially justified entirely by their power benefits.

After 1947, Central and State Governments initiated programmes of development, in which multi-purpose river valley projects—primarily for irrigation, flood control and power generation — constituted an important corner-stone. The Bhakra Project, intended to irrigate about 1.62 million hectares of land, and with an aggregate plant capacity of 1,204,000 kw., was one of the earliest to be taken up, and its last phases of development are still under execution. The 660,000 kw. Beas—Sutlej Link Project and the 240,000 kw. Pong Dam Scheme currently under construction are sequels to this major step in the economic development of the region. Almost simultaneously with the Bhakra Project, the first phase of the Damodar Valley Project envisaging construction of four dams at Tilaya, Konar, Panchet Hill and Maithon for the prime purpose of controlling the devastating floods of the Damodar, but with ancillary facilities for production of 104,000 kw. of power and extended irrigation to 10.28 lakh acres, was taken up and this phase of development has been substantially completed. The Hirakud Dam Project in

Orissa — with a projected installed capacity of 270,000 kw. and irrigation command of 2.4 lakh hectares — was taken up in 1948 as the first of a series to harness the large water resources of the Mahanadi river. Systematic development of the resources of the Chambal river was taken up in 1953 in Madhya Pradesh and Rajasthan to provide 386,000 kw. of power and irrigation to 5.7 lakh hectares. The other important multiple-purpose projects taken up and completed are the Tungabhadra in Karnataka/Andhra and Bhadra in Karnataka, under construction are the Parambikulam Aliyar Project of Tamil Nadu, Ukai in Gujarat and Ramganga in Uttar Pradesh. These multi-purpose projects have contributed substantially to the rapid growth of hydel installations since 1955.

Besides these multi-purpose projects, a number of power projects, single-purpose in character, were also implemented all over the country since 1947. The 115,000 kw. Machkund Station in Andhra Pradesh and Orissa was completed in 1955, and this scheme has fostered development lower down the Sileru Valley at Upper Sileru (120,000 kw.) which has been completed and Lower Sileru (300,000 kw.) and Balimela (240,000 kw.) which are currently under active development. In Tamil Nadu, the 36,000 kw. Moyar Scheme was completed in 1952 and this was followed up by the 140,000 kw. Periyar Station in 1958, which has also been completed. The cascade of five stations of the Kundah Project utilize a total fall of about 1,900 m. Kerala implemented the 48,000 kw. Sengulam Station in 1954, and 32,000 kw. Poringalkuthu Station in 1957. The last in the chain of Mudirapuzha developments, Nariamangalam (45,000 kw.) and Penniar (30,000 kw.) were commissioned in 1960-61 and 1963-64 respectively, and the Sholiar (54,000 kw.) Scheme in 1968-69. Also the 300 MW Pamba-Kakki (Satirigiri) Project was completed in 1967-68. At present the 390 MW Idikki Project is under constructon. In Karnataka, all efforts were concentrated on the giant 890,000 kw. Sharavathi Project — one of the most economical sites in the country where the first unit of 89,000 kw. was commissioned in 1964 and 712,000 kw. capacity has so far been commissioned. The main 240,000 kw. Koyna Station was commissioned in Maharashtra in 1961, and has since been followed by the 300,000 kw. second stage development of the same project. In Uttar Pradesh, the 300,000 kw. Rihand Project was commissioned in 1961-62 and has been followed up by the 100,000 kw. Obra Station, and the first stage of the Yamuna Valley Development (84,000 kw.). The further stages of the Yamuna Valley Development with an aggregate installed capacity of 390,000 kw. is presently under construction. In Assam, the 8,400 kw. Umtru Station commissioned in 1956 has been followed by the recently completed Umiam-Barapani Project (54,000 kw.). Besides these, three Central sector hydro-electric projects *viz.* Siul (180 MW) in Himachal Pradesh, Salal (270 MW) in Jammu and Kashmir and Loktak (70 MW) in

Manipur are at present under construction for regional benefit. When most of the major developments now underway are completed, about 18% of the country's total hydel potential would have been developed.

The firm hydel potential of India's rivers was placed at around 3.5 million kw. continuous (18,400 million kwh. of annual energy output) by J. W. Meares, the then Chief Engineer, Hydro Electric Survey of India and Electrical Adviser, in 1921. This was long known to be a serious underestimate but no systematic reappraisal was carried out till the Central Water and Power Commission (Power Wing) conducted a comprehensive survey from 1953-58 through which the total firm hydel potential, comparable of economic exploitation, was placed at 41.15 million kw. (corresponding to an annual energy output of 216,000 million kwh.) based on 260 specific schemes. The latest assessment takes into account all practical limitations on development such as reservoir storage due to submergence and other priority uses for flood control etc., abstractions of river flows for irrigation, reservoir operation for other uses and those set by economic considerations. It leaves room for slight upward revision only in the Upper Himalayan ranges.

Of the country's total potential, about 10,300,000 kw. represents the potential of simple "run-of-the-river" type projects in the Himalayan ranges and the rest of "storage type" projects. "high head" type projects utilizing drops over 300 m. — account for about 13,630,000 kw.; "medium head projects" in a head range of 30-300 m. — account for 23,860,000 kw., the bulk of the total; and "low head projects" — ranging from 7.5 m. to 30 m. — form the smallest category with a total of about 3,660,000 kw.

India's hydel resources are fairly evenly distributed all over the country, there being few regions which are situated more than 480 km. from major concentrations of hydro power. The north-eastern region covering Assam and NEFA, (now Arunachal Pradesh) endowed with the most favourable relief, and unfailing fast flowing Himalayan streams and rivers of the Shillong plateau which drawn in the heaviest precipitation in the world, naturally has the highest potential estimated at 11,600,000 kw., of which only 2,570,000 kw. depend on reservoir storage. The bulk of the utilizable power potential of the Himalayan rivers are located all along the foot-hills and command the entire Indo-Ganga and Brahmaputra plains. The most important concentration of potential hydro power beyond the region of influence of these Himalayan sources, lies in the high ranges of the Eastern Ghats, where tributaries of the Godavari have an aggregate potential of about 6,148,000 kw. The potential of the Western Ghats aggregate to about 4.7 million kw. of which about 2.7 million kw. lie in the north-western corner of Karnataka State, the balance being in the Nilgiri and Anamalai (Cardamom) ranges of Tamil Nadu and Kerala.

The economics of hydel development involve consideration of a large number of factors, which vary considerably from site to site, and normally no generalization is easily possible. Development costs vary from time to time. Allocation of costs of common works of multiple-purpose schemes affording several benefits, is complex. These difficulties are further enhanced by the fact that hydel sites have different values and potentialities when operated in isolation and in co-ordination with other stations of a large inter-connected grid. Generally, however, it would be accurate to state that the costs of hydro energy generation vary almost in direct proportion to the investment per kw. of firm capacity, at a rate, which taking into account prevailing interest rates would, in general, not exceed 9%. The cost of energy production from various schemes in operation today generally varies from about 2 paise per unit to 4 paise per unit. The costs of development of hydro power during the next two decades is expected to fall well within this range, taking into account the relative magnitudes of the works involved on these projects and their costs.

While on purely economic consideration, hydro resources should have played a greater role in development of electricity supply in this country, an important handicap in the past has been the lack of sufficient number of investigated schemes capable of timely implementation to meet rapidly growing demands for power. Two important decisions taken in the early sixties by the Government of India are expected to improve the situation and hasten future development. The first was in regard to preparation of long-term Perspective Plans, within the framework of which, hydel schemes, involving relatively longer gestation periods, could be suitably dovetailed. The second was the decision to embark on a country-wide scheme of extensive field investigations of hydel projects, so that fully investigated schemes would be available well ahead of time for implementation under the country's Five Year Plans. Special assistance in procuring drilling and other equipment required for this purpose is being obtained under a programme of assistance from the U.N. Special Fund. The first phase of this work of country-wide surveys covering about 62 schemes, out of the various potential sites pin-pointed by the Hydro-electric Survey of India, when completed, will not only remove an important lacuna, which hampered development of hydel power in the past but also pave the way for rapid detailed surveys of the rest of the schemes, and enable a more exact appraisal of the entire hydro resources of the country.

Oil And Gas: During the last few decades, oil and gas have been playing increasingly important roles in the industrially advanced countires in the energy field. The ease and efficiency with which they can be handled has been primarily responsible for their pre-eminent role.

However, in the particular field of electricity production — where alternatives are available — the important influencing factor, apart from availability of indigenous resources, is their cost. In this context, it is worthy of note that even in countries rich in oil and gas resources, these have not been used to any large extent for electricity production compared to other resources. India is disadvantageously placed both in respect of availability of resources of oil and gas and their costs. The impact of oil and gas on electricity development till fairly recently has, therefore, been negligible, being limited to small diesel driven generators, used either as nursery units to built up demands for emerging grid systems or to meet local requirements of electricity at isolated points beyond the reach of other sources of power supply. To an extent, they have been used as emergency alternatives or as small ancillary sources to coal firing in boilers. Over the last decade, only about 5% of oil and gas consumption has been used for electricity production.

A major programme of expansion of refinery capacity has recently been undertaken to meet growing demands for various petroleum products. Some of the by-products of refineries such as furnace oil, pitch, refinery gas, naptha etc. could advantageously be used for electricity generation. Sizeable resources of gas which can also be used for power generation have also been recently discovered. These have stimulated some local interests in these resources for electricity development.

Oil can be used directly as fuel in prime movers driving electrical generators as in diesel installations or as fuel in power station boilers to feed conventional steam turbo-generator sets. While gas also can be used in power station boilers, its direct use in gas turbine driven generators is gaining application in specific situations.

At present, the total installed capacity of diesel installation in the utility and non-utility sectors is only about 400,000 kw. forming only about 1.5% of the total installed capacity. With the emergence of nation-wide power grids, these diesel stations are being shut down gradually and their capacity would soon become relatively insignificant.

After the setting up of refineries at Bombay, their by-products have been used for power generation at the 337.5 MW Trombay Station, though the station is not entirely dependent on these fuels. Similar stations to use by-product fuels of Koyali and Barauni refineries have been envisaged while building the 534 MW Dhuvaran Thermal Power Station in Gujarat and 145 MW Barauni Thermal Power Station in Bihar. Surplus fuel oil from the Koyali refinery is proposed to be utilized in the 217.5 MW of Sabarmati Station at Ahmedabad. The 30 MW power station under construction at Gauhati in Assam and the 400 MW power station sanctioned for construction at Ennore near Madras will also use by-products from refineries close by.

The 69 MW gas turbine power plant at Noharakatiya in Assam is the first station in the country to use the naturally available gas in gas-turbine driven generating units. The main advantages of this type of installations are their low capital costs and ease of construction and operation. They are also ideally suited for intermittent operation for peak loads as they can be started and stopped quickly. The major disadvantages are their poor efficiency and higher costs compared to conventional steam stations. As such, they are selected generally either for installation in areas where the fuel is very cheap or to meet demands due to unexpected rate of load growth. Recently, it has been finding wide application to meet system peak demands which occur only for short periods during the day.

Two gas turbine units, 27 MW each, have been recently installed in Gujarat. Two units of 10 MW each at Hyderabad to meet emergent requirements and peak loads in Andhra Pradesh and two more units of 12 MW each, one at Gauhati and one at Muradnagar in Uttar Pradesh been have installed. These units are designed to operate on petroleum products like furnace oil.

Future trends in the use of oil and gas for electricity production have to be seen in the context of our resources and present pattern of use. It was only during the Second Plan, which emphasized industrial development, that an intensive programme of exploration of the country's oil and gas reserves was initiated and some notable discoveries made. India has an area of about one million sq. kilometers of sedimentary rocks which theoretically may be taken as 'potential for oil'. These sedimentary regions are located along the vast Indo-Ganga and Brahmaputra plains, around the Gulf of Cambay and the Rann of Kutch in Gujarat, along the west coast between Bombay and Goa, along the Kerala coast and along the eastern coast of Tamil Nadu, Andhra Pradesh and Orissa. Of the regions explored for oil and gas so far, the most promising are those in Assam and Gujarat. The proved and indicated recoverable reserves of oil, according to present knowledge, have been estimated at about 150 million tonnes, almost all of which are located in Assam and Gujarat. Gas reserves in these fields are estimated at 63,600 million cubic metres.

Prior to independence, indigenous production of crude oil and its refining was restricted to a small oil industry near Digboi in Assam. Subsequent developments have been at a relatively rapid rate and, in 1968-69, India produced about 6 million tonnes. This is expected to increase further to around 8.5 million tonnes per year by 1973-74. India has at present a refining capacity of about 17 million tonnes per year. The refining capacity is proposed to be expanded to 26 million tonnes per year by 1973-74.

India's petroleum industry is being rapidly expanded to meet mainly the growing demand for petroleum products in the transport, industrial and domestic sectors. Even to meet these essential requirements, the present picture is that reliance has to be placed heavily on imports. As such, oil and gas are not expected to play a significant role in power development in India and would be limited, as in the past, to the use of by-product fuels from the expanding refinery industries which are surplus to other essential uses.

Nuclear Resources: In 1945, the world first became aware of a new and apparently unlimited source of energy through the nuclear explosions at Hiroshima and Nagasaki in Japan. During the subsequent two decades, vast strides have been taken in the technology of harnessing this energy for electricity production, which have brought it within the realm of economic feasibility. Nuclear reactors have now been developed in which heat is derived in a controlled manner, and utilized thereafter to generate steam for use in conventional turbo-generators. That this discovery has not come a day too soon would be apparent when one is confronted with the staggering energy requirements to sustain, for a population as large as India's, a standard of per capita consumption prevailing today in the advanced countries of the world. India's conventional resources of electric power fall far short of these requirements. Apart from its importance as a new source of energy, its special significance for energy deficient areas lies in its relative freedom from the geographical limitations imposed on development of conventional resources, like water power and the mine-head thermal stations.

Nuclear energy stems from the destruction of mass during nuclear disintegration, or fission, the transformation following Einstein's well-known equation $E = mC^2$, according to which the energy equivalent to conversion of 1 lb. of matter is 11,000 million kwh. or roughly the output of a 200,000 kw. power station, when run continuously, for six years. However, it is only a very rare isotope of uranium (U235) — with an occurence of 1 part in 140 of natural uranium (U238), itself not too abundant in nature — which is fissible, i.e., capable of such fission. The separation of this isotope, constituted the most challenging aspects of nuclear technology. The relatively more plentiful natural uranium (U238) and thorium (U232) are also equally important since they are "fertile", i.e, they are capable of being rendered "fissible", by nuclear bombardment, when, by neutron absorption, they are transformed into plutonium (U239) and an isotope of uranium (U233). The development of nuclear energy centres round fuels with varying concentrations of these isotopes of uranium, U233 and U235, and plutonium (U239).

Unlike the conventional methods of electricity production, where the energy value of potential water power resources and of fossil fuels, can be readily assessed on the basis of well established conversion factors, in the nuclear field, the energy that can be obtained from a given quantity of nuclear fuel, varies substantially with methods of use.

It is well known that the only naturally occurring fissible material is uranium (U235), which occurs to the extent of 0.7% in natural uranium. Thus, if one of the inert (fertile) uranium is converted into fissile material, a tonne of natural uranium will yield energy equivalent to about 21,000 tonnes of coal. The know-how reserves of uranium in India upto 1956 was 15,000 tonnes. On this basis, equivalent energy would be about 315 million tonnes of coal.

But in the course of liberating atomic energy, the fertile materials uranium (U238) and thorium (U232) can be converted into the fissile materials, plutonium and uranium (U233) respectively.

As an average figure for a reactor working on natural uranium, one may assume that new fissile material is produced equivalent to 80% of the fissile material burnt. The total energy released from a tonne of natural uranium is then increased by a factor 5.

Since it is the intention in India to avoid the construction of a gaseous diffusion plant, it is clearly necessary to set up in the initial stages atomic power stations which operate on natural uranium and effect the maximum conversion of fertile to fissile material. This pure or enriched material could subsequently be used in breeder power stations (where the fissile concentrations of fuels increase with use due to higher rates of conversion of fertile material) thus enabling our entire reserves of uranium and thorium to be utilized for power production. On this basis, the reserves of uranium and thorium indicated are equivalent to 600,000 million tonnes of coal.

For practical and economic reasons, therefore, the spent fuels of nuclear reactors, after specific periods of Irradiation in the reactors cannot be discarded as those from conventional stations, but have to be taken out and specially reprocessed progressively to recover their unused fissile components. The extent of fuel "burn up", while they are in the reactors, and of conversion of fertile material into fissile ones varies with the type of fuel used, its degree of enrichment, the type of arrangements to moderate and control nuclear reactions, and several other factors, and these have all to be taken into account in any assessment of the practical value of nuclear fuels. While such a detailed examination is beyond the scope of this review, it is interesting to note that in the type of reactor proposed to be installed at Rana Pratap Sagar, 2,000 tonnes of uranium are expected to be adequate for a 1,000,000 kw. power plant, for operation at a load factor of 75% for 20 years.

In 1956, the total amount of uranium available in India was estimated at about 15,000 tonnes — 7,000 tonnes from the monazite sands of Kerala, 4,000 tonnes from the Singhbhum fields of Bihar, 3,000 tonnes from the Aravali fields, Khetri, Dariba, Khandela, etc., the rest representing additional reserves from the above uranium fields, available at less economic rates. The resources of thorium were then placed at about 150,000 to 180,000 tonnes from monazite sands.

Recent investigations have shown that the uranium deposits in Bihar, Rajasthan and Tamil Nadu aggregate 30,000 tonnes. Thorium reserves have been revised upwards to 340,000 tonnes. These thorium resources have been described as equivalent to all the world's known uranium in ores, containing 0.1% and above. It has, however, to be remembered that, while ultimately this thorium can be utilized, a number of problems involved in the conversion of thorium into fissible U233 remain to be solved. When this is done, India would indeed be very rich in sources for nuclear fuels.

The basic components of a Nuclear Power Reactor are (a) the core, where fission takes place, with its associated "moderation" and "control" systems; (b) the coolant systems to transfer heat from core to a heat exchanger, where it is used to raise steam for operation of conventional turbo-generators; and (c) a heavy shield surrounding the core and ancillary parts, to contain lethal emanations. Reactors can be fuelled either by natural uranium, enriched uranium — where the fissible content is artificially increased — or thorium. Those where "moderators" are used to slow down neutrons emerging at high velocities from fission reactions, are called "Thermal Reactors", whereas others, without moderators, using fast neutrons, are known as "Fast Reactors". There are "Homogenous" type, where the fuel is intimately mixed with the moderator and the "Heterogenous" type, where the fuel is in the form of individual blocks located at intervals within the moderator. The moderator itself can be either of light water, heavy water, or graphite. Carbon dioxide, water liquid sodium, etc., offer alternatives for cooling. The fairly wide choice of fuels, moderators and control systems, and coolants, give rise to a very large array of possible reactor types, from which a choice has to be made of the most advantageous techniques for indigenous development. This choice of technique is influenced, not inconsiderably, by the ancillary facilities required for production (including enrichment) of fuel, its chemical reprocessing, disposal etc., all of which require very substantial investments and technological skill.

The broad strategy of development of nuclear power in India has been influenced by the decision to avoid construction of a gaseous diffusion plant for separation of U235 — in view of its heavy cost and large requirements of electricity — and, initially to concentrate, instead, on indigenous production of natural uranium fuels to be employed in special power reactors, which, besides affording heat for generation of electric power, would also enable conversion of fertile U 238 to fissile plutonium (U239). These first stage power reactors would provide sufficient fissile material for fabrication of enriched fuel elements for second stage power reactors of the fast type, with which it is expected that the far more abundant thorium U232 can be converted to fissile U233 for use in later stage reactors. In the third stage, when sufficient quantities of Uranium 233 are produced, they are proposed to be used in improved reactors of the "Breeder" type, where the rate of conversion of fertile material would be so high that the reactor would, in effect, produce more U233 than it would consume.

India's nuclear development programme has been broadly oriented to this method, and development work has been initiated by the Atomic Energy Department of the Government of India, set up in 1954 as the Atomic Energy Commission, on several fronts covering exploration and mining, fabrication, processing and re-processing of fuel elements and other related aspects. Over 7,000 scientists and technicians are engaged on this vast and rapidly expanding programme of work.

In 1958, the Planning Commission approved the inclusion of an atomic power station in the Power Development Programme of the Third Five Year Plan and to install it in the energy deficient western region of the country, to feed the power systems of Maharashtra and Gujarat States. After preliminary investigations, a suitable site was selected at Tarapur on the western sea board near the inter-state border. In May 1964, a contract was placed with M/s. G.E.C. of U.S.A. for construction of a two-reactor power station with an output of 380,000 kw. and had been commissioned in 1969-70. The total outlay on the power station is estimated at Rs. 68.3 crores. The Department of Atomic Energy of the Government of India has estimated that the cost of power from the station would be about 4.5 paise per kwh.

The second in the chain of power stations proposed to be set up in this country is to be located in another energy deficient region of the country i.e., Rajasthan, at Rana Pratap Sagar, on the foreshore of the Rana Pratap Sagar reservoir of the Chambal Valley Project. The station will ultimately house two reactors, with an electrical output of 200,000 kw. each, of which one reactor would be installed in the first stage. The cost of power generation from this station has been estimated by the Department of Atomic Energy at 5.5 paise per kwh. In the southern region of the country, which has scarce fuel resources, the hydro-electric resources, which have mainly substained power development in the early years, are being gradually fully developed to meet rapidly increasing demands. This is another region of the country which has been recognized as a potential energy deficient area for early initiation of nuclear power generation. Here, the Planning Commission has approved the proposal to build the third atomic power station with an output of 400,000 kw. at Kalpakkam in Tamil Nadu.

The Tarapur Atomic Power Station will be fuelled initially with enriched uranium fuel elements from the U.S.A. It is proposed to fabricate subsequent replacement charges in this country, although enriched uranium would still have to be imported. The nuclear fuel complex being set up at Hyderabad will supply the initial and further replacement requirements of CANDU type stations likely to be set up in the future. The projected nuclear fuel complex at Hyderabad will cover the entire range of operations from raw mineral concentrates to finished fuel elements and other reactor components for power reactors of different designs. The heavy water-cum-fertilizer plant at Nangal, has been designed to produce heavy water as a by-product with an annual capacity of 14 tonnes. Plans are afoot substantially to increase the indigenous output of this most essential requirement for future power stations. Besides these activities, the Atomic Energy Department is actively implementing a large number of projects covering explorations, mining, extraction of materials, fabrication of fuels and material requirements, building up indigenous expertise all along the field. According to present anticipations, the total installed capacity of nuclear power stations at the end of the Fourth Plan would be of the order of 580,000 kw.

III. Trends — Present and Future

At the end of March 1970, the total installed capacity of all power stations of the country was about 15.5 million kw., of which 14.1 million kw. was from utilities, the balance representing the capacity of industrial units, generating their own power mostly through thermal installations. Of the capacity of power utilities, private sector installations would aggregate to only about 1.6 million kw. or about 10% of the total. The break-up between thermal, hydro and diesel installations would be about 9.0 million kw., 6.1 million kw. and 0.4 million kw. respectively. Notwithstanding the massive increase of nearly 300% during the last decade in power plant capacity, the average per capita consumption of electricity of the country in March 1970, was only of the order of 84 kwh., varying from about 50 kwh. in Andhra Pradesh to about 255 kwh in Delhi territory. In comparison, the per capita consumption in some of the advanced countries in 1969 was 7,000 kwh. in the U.S.A., 3,700 kwh. in U.K., 2,400 kwh. in France and 2,630 kwh. in the U.S.S.R. Admittedly one of the most urgent needs of the country is to accelerate electricity development as rapidly as possible and ensure the most wide-spread benefits therefrom. According to present anticipations, the targets for total installed capacity in the country at the end of the Fourth Plan (1973-74) would be about 23 million kw., and at the end of the decade 1980-81 about 52 million kw.

The country has ample resources to sustain the large programme of development that lies ahead. The field, however, is capital intensive requiring use of materials and equipment which are still in scarce supply, and require heavy imports. During the First, Second and Third Plans, the outlays on power including generation, transmission and distribution were of the order of Rs. 302 crores, Rs. 525 crores and Rs. 1,012 crores respectively, representing about 12.7%, 11% and 13% of the total Plan outlays. The import or foreign exchange component of these investments were of the order of Rs. 117 crores, Rs. 160 crores and Rs. 362 crores in these successive Plan periods. During the Fourth Plan, the outlay on power is Rs. 2,523 crores, representing 10.1% of the total Plan outlay. It is, therefore, clear that a rapid rate of growth can be maintained in future only on the basis of limiting outlays by choice of the most economic alternatives available and maintaining utmost efficiency of operation by system inter-connections and better use of existing plants. The broad strategy of development would be to rely on development of coal-based thermal power in and around the colliery areas, to develop available hydro resources to the maximum feasible extent, to rely on nuclear resources in increasing measure in the regions of the country where resources of conventional resources fall short of demands. On this basis, it is expected that at the end of the Fourth Plan and the decade 1971-81, the approximate contributions of thermal (including diesel plants), hydro and nuclear resources to the total would be as given below:—

TABLE XI

	Hydro	*Thermal*	*Nuclear*	*Total*
		(Million kw)		
End of Fourth Plan (1973-74)	9.4	12.7	1.0	23.1
End of Decade 1971-1981	22.0	25.8	4.2	52.0

While planning for future development, it is essential to note that the power resources of the country are so distributed that economic development cannot be ensured on the basis of Plans drawn up within the political division of the country into different States. On the thermal side, the need to utilize the by-products (middlings) of coal in large power stations would necessitate consideration of a wide area of reticulation, extending beyond the State boundaries around washery oriented sites. Similarly, if advantage is to be taken of the economic trend towards use of very large thermal installations, their zone of influence would again have to be based on purely economic considerations. In the case of hydel development, it is even more obvious that geographical considerations would have to predominate in the selection of schemes, and that the large and economic concentrations of hydel power, should be utilized in the widest possible region, irrespective of the actual location of hydel sites with reference to State boundaries. These considerations have led to the concept of regional planning for power development in India with super grids, transmission networks, and distributing power in an economic manner throughout these regions. Closely integrated operation of all power stations in economic regions would result in a variety of benefits. They make it possible to keep reserve capacity to a minimum, and to maximize benefits from existing installations, reducing energy production costs in the bargain. They would enable the choice of the most economic sites for further development, adoption of larger sizes for reducing costs and attaining higher efficiencies, and last, but not least, they render invaluable assistance to stricken areas during breakdowns. These compelling reasons have led to general agreement on this aspect of power policy.

The country has now been divided into five main regions, and under the Central Electricity Authority, five Regional Boards have already been constituted. These are:

(i) Northern Region comprising the States of Punjab, Uttar Pradesh, Rajasthan, Jammu and Kashmir, Himachal Pradesh and the Union Territory of Delhi.

(ii) Eastern Region comprising the States of Bihar, West Bengal and Orissa.

(iii) Western Region comprising the States of Gujarat, Maharashtra and Madhya Pradesh.

(iv) Southern Region comprising the States of Tamil Nadu, Kerala, Karnataka and Andhra Pradesh.

(v) North-Eastern Region comprising the States of Assam, Manipur and Tripura.

The general functions of the Regional Boards will be to :

1. plan generation and major transmission programme in the region taking into account the load anticipations;
2. advise on joint projects involving generation and major transmission to the extent necessary;
3. review the progress of projects in the region;
4. plan and ensure the efficient integrated operation of the constituent systems in such a manner that, at any given time, the total amount of electricity generated and transmitted shall give optimum benefits to the region as a whole;
5. develop generation schedules and the amount of power to be exchanged between the various power systems in the region from time to time;
6. work out a co-ordinated overhaul and maintenance programme of the generating plant for the entire region;
7. schedule exchanges with other Regional Power Agencies; and

8. lay down a suitable tariff structure which should govern the exchange of power within the region and with other regions and devise suitable machinery for billing and collection and settling of any disputes on this account.

The growth of these Regional Grids would represent a major step in the development of power resources in the country. The day is not far off, when these Regional Grids would, in turn, be inter-connected to form a single All-India Grid, traversing the length and breadth of the country and fulfilling an important socio-economic objective, i.e., harnessing all the natural resources available in an area or region as economically as possible, according to the latest known techniques, ensuring the utmost reliability of supply to the consumer wherever he may be situated.