Government of India

POWER ECONOMY COMMITTEE

REPORT OF

STUDY GROUP-III

CONTENTS

REPORT OF THE STUDY GROUP III OF THE POWER ECONOMY COMMITTEE (1969-70)

FACTORS IN THE CHOICE OF SCHEME FOR EXPANSION OF ELECTRICITY PRODUCTION AND SUPPLY IN THE CONTEXT OF RELATIVE ECONOMICS OF ALTERNATIVE SOURCES

1. Outline of the work of Study Group III (1) of Power Economy Commitiee

1.1 *Main tasks* :

The Resolution setting up the Power Economy Committee states that the cost of electricity supply in India has been rising "despite large scale technological development", and stresses that in order to efficiently utilise the limited resources of the country it is now necessary to implement measures for *bringing down* costs. In this context, the main tasks for Study Group III are :

(a) to review, under *prevailing* conditions the economics of electricity generation from different sources—hydro, thermal and nuclear;

(b) to review their *future* trends; and

(c) to suggest factors, *which* must *prevail* in the choice of alternative schemes in *each region* of the country.

1.2 *Need to review actual generation costs* :

Costs of electricity production from hydro, thermal and nuclear sources have been discussed and analysed in this country during the past 15 years. Most of the past work of economic analysis of alternative sources of power supply has, however, been based on preliminary estimates of costs and expectations of benefits at the time of proposal or sanction of individual projects. A similar analysis does not seem to have been carried out so far of the *actual* costs of production and supply at the *operational* stage. Such an analysis of *actual costs* is, however, essential before making any forecast and drawing any conclusion especially because actuals are found to vary widely from 'estimated' costs.

1.3 *Need to evaluate alternatives both on their own intrinsic value and on their effectual contributions to grids* :

Hydro, thermal and nuclear power stations have widely differing features giving them distinctive economic characteristics. At present, we have power systems which are exclusively hydro-(e.g., the Bhakra, Kerala and Mysore grids), some of which are mainly thermal (e.g., DVC, Bihar, West Bengal, Vidharbha and Madhya Pradesh grids), and a few which are "mixed" power systems with both hydro and thermal stations operating at different levels of co-ordination (U.P., Tamil Nadu, Andhra and Tata-Koyna grids). In future, all our power stations would inevitably operate as constituent parts of a whole "mixed" complex of inter-connected generating stations. As alternatives—hydro, thermal and nuclear stations must therefore be evaluated in future both on their intrinsic economy—reckoned on individual basis under prevailing conditions—and also by their effective or economic contributions to our emerging Regional Power grids.

An example would make the point clear. A nuclear base load station, for instance, may appear economically quite competitive when its cost of generation is calculated individually at 75% plant factor, but if the regional grid has energy potential in adequate measure and its requirement at that time is to cover a large shortage of peaking capacity at very low load factors, the economic contribution of such station to the grid at that stage would be vastly different. Pumped storage peaking stations, on the other hand, would be highly desirable under such conditions to reduce capital outlays and improve overall system performance.

The choice among alternatives for expansion of power generation facilities is, therefore, really assessing at each stage what the integrated power systems actually need to ensure the fullest utilisation of built-up generating capacity and the lowest possible overall costs of electricity supply, and then determining the best possible combination of hydro, thermal and nuclear sources to serve this specific purpose.

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1.4 The regional canvas for study of alternatives :

The canvas on which the choice of alternatives is made is vitally important. Hitherto, the State has continued to be the frame-work for these choices, with rare exceptions. The concept of a regional framework to overcome certain limitations of planning on a State basis was first suggested in 1956, and finally accepted in 1963 but progress in this direction has not been rapid enough. The Committee's terms of reference, however, imply that alternatives must be considered from the point of view of the region as a whole and it is, therefore, necessary to examine why regional planning has not made much headway so far and suggest measures which would actually promote schemes of maximum benefit to the various regions.

1.5 The main economic constaints :

The financial position of most State Electricity Boards is none too sound and of some totally unsatisfactory. With indigenous manufacture of heavy electrical plant and equipment apparently organised to enable a total ban on imports which now prevails, "foreign exchange" which was once the determining constraint in the recent past is no longer so. Foreign exchange is still of concern to the manufacturing industries due to the still sizeable imports of engineering services and components. However, so far as power utilities are concerned shortage of capital resources rather than shortage of foreign exchange has now become the dominant economic constraint. The total capital investment on electricity supply undertakings in the country now aggregates to over Rs. 4,000 crores, and that on Fourth Plan schemes to Rs. 2,440 crores. An Inter-Ministerial Working Group of power for the Fourth Plan, set up in 1968 had recommended that to maintain the historical rates of growth necessary to meet anticipated load demands in full, the Fourth Plan should aim at a target of 26 million kW and had set the capital requirement for this at Rs. 3,462 crores, including Rs. 500 crores for adequate advance action on economic Fifth Plan schemes requiring long gestation periods. Severe shortage of resources has, however, led to the lowering physical targets, and substantially lower capital allocations for electricity expansion which would not only lower the historical growth rate over the Fourth Plan, but worse still, hamper progress during the Fifth Plan also, due to inadequate provisions for advance action on economic Fifth Plan projects. It is, therefore, necessary to consider and suggest measures for (a) achieving maximum benefits from built-up generating capacity and for enabling the limited capital resources to carry the power supply industry the farthest distance, and (b) restoring the perspective approach to economic power development.

2. Costs of Generation and Supply under existing conditions

2.1 The Central Electricity Authority is empowered to collect relevant data regarding costs and accounts of State Electricity Boards/licensees, analyse them and publish the results. This is not being done now by the CEA. The Power Economy Committee, therefore, called for this information for the past 5 years.

2.2 Detailed information regarding capital and operating costs, revenue, etc., is now being collected by Member (Commercial), CW&PC (Power Wing), for reviewing the financial progress of Boards. This information, though not complete, is of considerable value as it has been collected on a fairly uniform basis. It affords a good starting point and together with other published information forms the basis for this report.

2.3 Existing average tariffs :

During 1968-69, electricity supply utilities generated some 47,350 million units from a total of 12974 MW of installed generating capacity, comprising 5906 MW of hydro, 6670 MW of steam and 397 MW of diesel/gas sets. Supply to ultimate consumers aggregated to 37,452 million units (29,219 MW) of which 80% was sold by Boards. The average rates at which this power was distributed is given in Table-1, arranged in ascending order of average tariffs.

TABLE—1

Average Tariffs for power in 1968-69

Sl. No.	State Electricity Board	Units sold (Million)	Average Tariff* (Paise)
1	2	3	4
1.	Orissa	1250	6·9
2.	Haryana	1292	7·6
3.	Kerala	1366	7·8
4.	Punjab	1704	7·9
5.	Mysore	2106	8·4
6.	Maharashtra	3955	8·6
7.	Tamil Nadu	4282	10·9
8.	West Bengal	1655	11·1
9.	Madhya Pradesh	1586	12·4
10.	Gujarat	1752	12·4
11.	Uttar Pradesh	3504	12·6
12.	Desu	957	13·9
13.	Assam	176	15·1
14.	Bihar	1343	15·6
15.	Rajasthan	653	15·9
16.	Andhra Pradesh	1638	17·1

*Obtained by dividing total revenue realised by the State Electricity Board by the units sold.

For an insight into the relative economics of hydro, thermal and nuclear stations as alternative sources of supply, and also to suggest possible explanations for the wide differences in the above tariffs, a review of the actual costs of generation at different power stations and systems is necessary.

2.4 *Actual costs of electricity generation* :

2.4.1 Estimated costs of energy generation are given below separately for hydro (2.4.2) thermal (2.4.3) and nuclear power stations (2.4.4) and combinations thereof (2.4.5). The actual costs of generation during 1968-69 are also given in the corresponding paragraphs under each head.

2.4.2 *Hydel stations and hydel systems* :

(i) Costs of hydro energy generation vary from site to site depending on the nature of civil works, the magnitude of power potential, and the period and speed of construction. Besides, at each developed site, they will vary from year to year, depending upon the actual river flows and the degree of utilisation thereof. It is also important to note that the costs are generally worked out in project reports, in the country, on the basis of their firm output, corresponding to an availability of 90-95% in time, and in all such cases, the costs during most years would be lower due to higher levels of energy generation.

(ii) In general, the costs of hydro energy generation per kWh vary almost directly in proportion to the investment costs. Between the stages of conception of the project and completion of construction, there have been variations in the estimated investment costs of hydro projects during gestation, but once completed, costs of generation are finally determined, and do not vary thereafter except on account of hydrological factors mentioned in paragraph (i) above. By their very nature, the costs of hydel energy generation are relatively insensitive to the load factors at which they are operated, which is the main reason for their almost exclusive choice, whenever available, for meeting low load factor peak variations. (Also see discussion in para 2.4.5 on mixed systems).

(iii) The investment costs on the hydel projects completed during the last decade in the country range from Rs. 1,000 to Rs. 1,500 per kW of installed capacity(2). Expressed in terms of their firm power output (in kW) at system load factor (60%), their investment costs work out to about Rs. 1,500, on the average(3). At this investment cost, the cost per kWh of firm energy generation works out to 2.14 P/unit at an interest rate of 6%. If the investment cost per kW of firm power at a hydel site increases to Rs. 2,000/- which represents the upper limit at the developed sites—the cost of energy generation would increase to about 2.85 P/unit, based on the firm energy output. The above figures ignore seasonal energy generation, as well as the output in average and good years of river flow, when taken into account, would tend to reduce these costs, as pointed out at (i) above.

(iv) An assessment of the expected costs of energy generation from existing and recently completed hydel installations and those under construction has been made on the basis of actual/uptodate estimates of capital outlays and firm energy outputs and the results of this assessment are enclosed as Annexure-I A. It would be seen therefrom that the expected cost of energy generation from hydro stations generally varies from 2 to 3 paise per kWh.

(v) The actual costs of energy generation from the major hydel stations and hydro-electric systems in operation during the year 1968-69 are given in Table-2 and would be seen to vary from 0.88 to 3.6 paise (barring Sharavathi where fractional utilisation placed the figure temporarily at about 4 paise).

(2) Report of the Working Group on Power for the 4th Plan—January 1969.
(3) Report of the Sub-Committee 'B' of the Working Group on Power in the 4th Plan—July 1968.

TABLE—2

Actual cost of energy generation in 1968-69 at Hydro Stations/systems for which data is available

Sl. No.	Station/System	Installed capacity (MW)	Firm annual energy potential	Actual energy generation (1968-69) Million kWh	Cost of generation P/kWh
1	2	3	4	5	6
1.	Bhakra-Nangal	1204	3554	4343	1·66
2.	Koyna	540	2150	2976	1·678
3.	Purna	22·5	39	25	2·664
4.	Sharavathi	534 }	4680	1249	4·00
5.	Jog	120 }		813	0·81
6.	Shimsha	17 }	272	254	1·71
7.	Sivasamudram	42 }			

1	2	3	4	5	6
8.	Kerala hydro system	547	2418	1625	3·38
9.	Machkund (Andhra)	80·3	515	307	2·99
10.	Tungabhadra (Andhra)	57·6	185	244	2·67
11.	Upper Sileru (Andhra)	120	386	481	2·59
12.	Pykara	70	451	293	1·91
13.	Moyar	86		122	2·59
14.	Periyar	140	500	449	1·65
15.	Mettur	40	613	96	1·56
16.	Mettur Tunnel	200		466	2·10
17.	Papanasam	28	111	132	1·73
18.	Kundah	425	1745	1433	3·64
19.	Sarkarpathy	30	157	63	6·52
20.	Gandhisagar (M. P. Share)	57·5	183	140	3·57
21.	Hirakud (Orissa)	232·5	1055	837	2·94

NOTE : 1. The firm annual energy potential corresponds to 90% water availability except in the case of Koyna, where it is based on authorised diversion.

2. In the Mysore and Kerala grids, the actual generation was only 40% and 75% respectively of the total firm energy potential due to lack of demand.,

3. The generation costs at Sharavathi and Kerala hydro system would fall considerably when the energy potential is fully utilised within a couple of Years. The cost of Sharavathi, for instance, would be 2 paise per unit on full development.

4. The actual generation at Sarkarpathy station was lower as some of the diversions had not been completed and full water potential had not been created.

5. The costs of generation have been worked out on the basis of actual expenditure incurred on operation and maintenance, amount set apart for depreciation, proportionate share of administrative expenses and general establishment and interest on depreciation value of assets. They represent the true costs of operation the stations to the various organisations during the year.

2.4.3 *Thermal Stations and Thermal Power Systems* :

(i) The costs of energy generation of thermal power stations and thermal power systems vary with (a) investment costs (in turn dependent on unit and station sizes), (b) costs of fuel, (c) thermal efficiency, (d) distance of power stations from collieries/sources of fuel, (e) changes in the load factors to which, unlike hydel schemes, they are very sensitive. In a purely thermal power system, the possible energy generation is seldom more than 4,000 kWhr per kW installed due to (a) margins to be maintained over peak capability to cover longer periods of scheduled maintenance and forced outages, spinning reserves, etc., and (b) the limitation on energy generation imposed by the system load curves. In a properly designed, mixed hydro-thermal power systems, where *all* the effective on-line thermal capacity can be operated almost continuously at base load, the energy output of thermal stations can be maximised at about 5500 kWhrs/kW installed on the average. Where thermal installations are planned as 'firming up' complements to hydro systems, their annual output, on a long-term basis, would be much less than 4000 units/kW. Estimates of energy production costs, which do not take these factors into account, could turn out to be wrong by a wide margin in actual practice. In a thermal station/system it is also necessary to note the differences in the cost of energy sent out, and the cost of generation, which includes auxiliary consumption of the order of 9-10% in most stations today.

(ii) The capital outlays on thermal installations are usually well established and are not subject to large variations during periods of construction. However, the costs of energy generation from them vary substantially over the life of the plant, tending to increase steadily on account of decreases in operational efficiency and increases in the cost of fuels and their transport costs with time.

During the decade prior to devaluation, the capital outlay of thermal power stations employing 50/100-120 MW units, was about Rs. 1200/- per kW installed based on imported equipment. At current prices of coal, the cost of energy generation from these thermal power stations, on the basis of their effective capacities operating at 60% system load factor, would be about 4.7 paise per kWhr at the pit-head locations not involving haulage costs. Current investment costs on new thermal installations, taking into account the increases due to devaluation and indigenous manufacture are of the order of Rs. 1700/- per kW installed(4) (In some cases, it has been as high as Rs. 2000/- per kW installed even for units of the order of 120/140 MW). At these higher investment costs, the corresponding costs of energy generation would be about 6.2 paise per kWhr. Generation costs at sites remote from collieries can be roughly assessed by adding about 1.5 paise per unit for every 600 KM of rail haulage.

(4) Report of the Working Group on Power during the Fourth Plan.

(iii) An assessment of the expected costs of energy generation from recently completed thermal installations and those under construction has been made on the basis of actual estimated capital outlays and assuming operation at different plant factors and the results of this assessment are enclosed as Annexure-I-B and I-C.

(iv) Costs of energy generation at a number of thermal stations/systems in actual operation during 1968-69 are given in Table-3.

TABLE 3

Actual cost of energy generation (1968-69) *at thermal station systems for which data is available*

Sl. No.	Station/System	Installed capacity (MW)	Actual energy generation (Million kWh)	kWh generated Per kW of installed capacity	Cost of generation P/kWh	Cost of Energy sent out P/kWh
1	2	3	4	5	6	7
1.	Bandel	350 (4×82·5)	1057	3020	5·54	6·03
2.	Gouripur	25	110	4400	8·75	9·65
3.	C.E.S.E.	461	1915	4150	5·20	5·53
4.	Madhya Pradesh Thermal System . . .	580	1717	2960	6·57	[illegible]
5.	Talcher	187·5	384	2050	8·89	[illegible]
6.	Vidharbha Thermal System	297·5	1169	3930	7·65	[illegible]
7.	Trombay	337·4	1900	5640	6·46	[illegible]
8.	Gujarat S. E. B. Thermal	402	2132	5303	0·90	[illegible]
9.	Ahmedabad	217·5	1046	4700	0·35	[illegible]
10.	Kothagudem	240 (4×60)	991	4139	7·10	7·74
11.	Nellore	30 (1×30)	183	6100	7·35	8·46
12.	Indraprastha (Delhi)	36	160	4445	9·6	[illegible]
13.	Indraprastha Extension (Delhi's share) . .	126	570	4524	9·0	[illegible]

NOTE : 1. The costs of generation have been worked out on the basis of actual expenditure incurred on operation and maintenance, amount set apart for depreciation, proportionate share of administration expenses and general establishment, and interest on depreciated assets. They represent the true costs of operating the stations to the various organisations during the year.

2. Capacity at Talcher is not being fully utilised.

(Figures of Neyveli and DVC thermal stations, including interest and depreciation on a uniform basis, are not available and are, therefore, not included in this table).

It would be seen therefore, that the actual cost of generation at thermal power stations in India generally ranges from 6 to 10 paise per kWhr at the present time.

2.4.4. *Nuclear Power Stations* :

(i) In the case of nuclear stations, their investment costs are relatively high though incremental fuel costs are low requiring base load operation as an essential pre-requisite for competitive electricity generation. Maximum benefits from nuclear stations can, therefore, be derived and optimised in a grid with hydro and thermal generating stations and not as an independent source of supply. Technological factors also appear to require operation at relatively constant levels of power generation. Thus complementary capacity in conventional stations should be available for capacity in conventional stations should be available for meeting the peak loads. Also, significant is the fact that necessary stand-by provisions for nuclear power stations are invariably to be provided on the conventional side, because of the relatively high capital investments on nuclear stations, thus permitting consideration of operation of nuclear power stations at an annual plant factor of the order of 75%.

(ii) At present only one nuclear power station of the Boiling Water Reactor Type (420 MW installed capacity) is in operation in the country in the Western Region. The capital outlay on this station is about Rs. 68.3 crores (Rs. 1,630/- per kWe installed), and the fuel used is slightly enriched uranium. Assuming a plant life of 25 years, annual plant factor of 75%, a fuel burn up of about 16,500 MW days per tonne and relevant assumptions, the average unit energy cost of energy generated and sent out on a comparable basis are estimated at 4.2[illegible] P/kWh and 4.45 P/kWh respectively. The average unit energy selling rate is 5.61 P/kWh. Of these, the fuelling charges are about 2.04 P/unit including customs duty (0.41 P/kWh)

(iii) The present programme of the Atomic Energy Commission is, however, to rely on the natural uranium heavy water moderated CANDU type nuclear reactors for nuclear power stations to be installed in the foreseeable future. The capital outlay on the Ranapratap Sagar (440 MW installed) and Kalapakkam (470 MW installed) nuclear power stations which are under construction and are of CANDU type are presently estimated at about Rs. 125 crores and Rs. 144 crores respectively. This works out to an installed cost per kWe of Rs. 2,850 in case of Ranapratap Sagar and about Rs. 3,100 in case of Kalapakkam. The cost of energy generation and cost of energy sent out from the Station on a comparable basis are expected to be about 5.5 P/kWh and 6 P/kWh respectively at 75% annual plant factor; the net fuelling cost being about 0.83 P/kWh. It has to be noted that the fuel costs for a CANDU type station are significantly lower than the enriched uranium alternative and the difference may almost offset the higher initial financial charges.

2.4.5. *Mixed Power Systems*:

(i) Costs of generation from thermal and nuclear power stations are at their lowest when the power stations are operated at high load factors on base loads. On the other hand, hydro energy generation is relatively insensitive to large changes in load factor. Hydel stations can, therefore, conveniently be assigned the most difficult function of dealing with fluctuating peak demands on electrical power systems. Mixed power systems emerge usually under conditions of scarcity of cheaper hydel energy resources, and are basically intended to take advantage of the above facts, although there are several other advantages also.

(ii) The Energy Survey Committee of 1965, dealt with this aspect of the problems of achieving economies in power supply in detail in their Report [5]. A table compiled by them of comparative costs of typical hydro, thermal and nuclear stations when operating at load factors of 30, 60 and 75% has been extracted and is given in Annex. II. Studies were made by the Energy Survey Committee for two periods viz. 1965-70 and 1970-75, anticipating certain differences in investment costs during these periods. On the hydro side, the investment costs (excluding interest during construction) on typical projects were materially the same at around Rs. 1200 per kW for high load factor operation[6], but it was assumed that the capital outlay on a new thermal would be Rs. 1138 per kW installed in the earlier period and Rs. 934 per kW installed, later on. The investment cost of a natural uranium nuclear station was correspondingly placed at Rs. 1,748 and Rs. 1,500 per kW installed during these two periods. Even with these relatively low investment costs, the Energy Survey Committee established that whereas the costs of generation on a hydel plant varied from 2.6 to 4.3 paise as the load factor varied from 75% to 30%, the cost of generation from thermal stations varied from 4.0 to 7.6p kWhr and that from a Nuclear station from 4.7 to 10.8 paise. As stated earlier, devaluation and indigenous manufacture of heavy electrical plant and equipment have radically altered the investment pattern assumed by the Energy Survey Committee, especially for thermal/nuclear stations. At prevailing investment costs of Rs. 3,100 per kW installed on relatively small nuclear power station (with 2×200 kW units) and Rs. 1,800 per kW of installed thermal capacity, not only would the cost levels of thermal and nuclear alternatives be comparatively higher than those indicated in this table but the range of variations of energy generation costs with load factor would also increase correspondingly.

(iii) Some economic benefits of inter-connected operation can, no doubt, be derived when hydro and thermal stations, *designed for isolated operation,* are linked together. However, the economic benefits of a mixed hydro-thermal or hydro-nuclear power system, can be derived in *full measure* only when hydro stations in these power systems are specially designed for low load factor operation, properly located, and are provided with the required flexibility for maximising these economic benefits. Stated another way, the entire economics of power generation in mixed power systems depends firstly, on a proper planning of the hydel installations, and secondly on a correct proportioning of installed generating capacity from different sources, depending upon the intrinsic economy of each kind of generation in the particular region in question. This can easily be demonstrated.

A typical mixed hydro-thermal system in the country, with roughly *equal* installed capacities of hydro and thermal installations, can be operated at the base of the system load curve at energy outputs of about 5,200-5,500 kWhrs per kW installed on the average. This would represent about the maximum possible, on a total average, from thermal power systems. It may be pointed out in this connection that such studies as have been carried out on the pattern of load variation on integrated power system indicate that the annual load factors vary slightly around 60-62% and that the base load represents about 30 to 35% of the annual peak. This base load also accounts for about 50-60% of the total annual energy content. Assuming current investment costs on thermal installations at Rs. 1,800 per kW and assuming outlay on hydro stations at the higher end of the prevailing range *i.e.*. Rs. 2,000 per kW installed, the total cost of

(5) Report of the Energy Survey Committee of the Government of India (1965).

(6) It needs to be noted that unlike thermal and nuclear stations, unit investment costs on Hydel stations reduce with load factor.

energy of the pooled system would be around 4.3 paise per kW, assuming that the thermal capacity is operated on the base of the system load curve and hydel stations absorb all the peak loads. This cost, it would be noted, is slightly higher than that of a purely hydro system, but well below the cost of generation from purely thermal systems. If, on the other hand, two-thirds of the total installed capacity were in the form of thermal stations, and the balance hydro, the pooled cost of generation in the system would be about 5.2 paise per unit. The calculations are appended as Annex. III. For the above calculations, the thermal station has been assumed to be located at the pit heads.

The decrease in cost of energy from pure thermal to mixed hydro-thermal schemes would be even more significant, and the savings in capital outlay would become compelling, when a hydro station operating at low annual load factor of 30% or even less is constructed at an investment cost of about Rs. 800-1000 per kW installed, which should easily be possible at a number of sites under prevailing conditions in India provided equipment costs are brought to international levels.

(iv) Two of the power systems of the country, the Tamil Nadu and Andhra State grids are typical examples of mixed hydro-thermal grids. The costs of hydro and thermal generation in these two systems are of the same order. However, the relative proportions of hydro and thermal capacity are different, with the Tamil Nadu grid having a preponderance (66%) of hydro and the Andhra grid having a greater ratio (60%) of thermal installations. Their actual pooled costs of generation during 1968-69 bring out the economic differences clearly, and are indicated in the following sub-paragraphs. The U.P. grid is also a mixed one with a preponderance of thermal capacity, but detailed data and pooled costs of generation are not yet available for this system.

In the Tamil Nadu power system which, during 1968-69, had a total installed capacity of 1,470 MW including 500 MW of thermal capacity (including Neyveli) and 970 MW of hydel installations, the pooled cost of generation was 4.5P/unit. The Tamil Nadu system, it must be pointed out, was one of the earliest to design their hydel systems for lower load factors than the overall systems load factor. The Neyveli power station was thus able to operate at a high load factor during 1968-69, supplying roughly half the Tamil Nadu grid's total energy requirements at a cost of about 6 P/unit, whereas the other hydel stations of the Tamil Nadu State Electricity Board, with costs of generation ranging between 2 and 3.5 P/unit met the balance.

On the Andhra power system which, during 1968-69, had a total installed generating capacity of 634 MW comprising 273 MW in hydro installations and 360 MW of thermal capacity, the pooled cost of generation was 5.7 P/kWh reflecting to an extent the relatively unfavourable mix of generation sources, with greater reliance on thermal capacity.

2.5. *Actual pooled costs of the main power systems* :

In para 2.3 the average tariffs of electricity supply in the different States have been given. Actual costs of generation from different power stations—hydro, thermal and some of the important mixed grids—have been indicated in para 2.4. Figures of pooled costs of generation are available for power systems which together contributed about 25,443 million units during 1968-69 and these are presented in Table-4.

TABLE 4

Pooled costs of generation (1968-69)

System	Type of Grid	Energy generated Million kWh	Pooled cost P/kWh
1	2	3	4
1. Bhakra Power System	Pure Hydro	4343	1·66
2. Koyna Hydro Grid (Ma)	Pure Hydro	2976	1·68
3. Kerala Grid	Pure Hydro	1623	3·38
4. Mysore Grid	Pure Hydro	2539	3·50
5. Tamil Nadu Grid	Mixed Hydro-Thermal	..	4·50
6. Andhra Grid	Mixed Hydro-Thermal	2276	5·74
7. U. P. Grid	Mixed Hydro-Thermal	5318	6·00
8. West Bengal S.E.B.	Pure Thermal	1167	6·37
9. Gujarat S.E.B.	Pure Thermal	2172	6·72
10. Madhya Pradesh	Predominantly Thermal	1859	7·24
11. Vidarbha Grid (Ma)	Pure Thermal	1169	8·54

It would be noted from table-4 and the table-1 of average tariffs, that State Electricity Boards which, during 1968-69, were able to maintain the lowest average tariffs for electricity supply are those which had exclusively hydro power systems. They are followed fairly closely by those with mixed-hydro-thermal systems with a preponderance of hydel capacity, e.g., Tamil Nadu Power System. Purely thermal power systems had the highest actual costs of average generation associated with them. The difference between the average costs of hydel generation of about 2 P. per unit on full utilization of created potential and the actual average cost of energy sent out of thermal stations of about 8 P. per unit is as high as about 6 P per unit.

2.6. *Impact of transmission on cost of power supply from alternatives*

2.6.1. In the past, when the bulk of thermal power generation was concentrated at or near road centres, high voltage transmission costs were associated almost exclusively with hydro power stations. During the past 15 years, a number of pit-heads or fuel resource oriented thermal power stations have sprung up, with large associated high voltage transmission systems. More recently, there has been a striking increase in the number and size of thermal stations located at remote centres from sources of fuel e.g., Ennore (400 MW), Delhi/Badarpur (600 MW), Harduaganj—about (400 MW), Bhatinda—(240 MW), Nasik (240 MW). Though they are located closer to load centres, their magnitudes and the need for close co-ordination with the operation of other power stations require high voltage grids and extension of existing transmission systems to utilize their outputs fully. Nuclear power stations have greater flexibility than conventional alternatives in regard to their location aspects. But even here, the very large sizes required for economy in generation, their dependence on "base loads" and the need for "back-up" from conventional sources, and siting for adequate water-supplies, safety etc., require large transmission systems to be associated with them to fulfil conditions of economic generation and power supply. In the case of nuclear projects, the fact of Central ownership and consequent multi-State sharing of benefits, also involves transmission costs. This will also apply to large conventional power projects selected on regional considerations.

2.6.2. It would, therefore, be seen that the implications of bulk transmission are more or less common to all alternatives, hydro, thermal and nuclear. The relevance of bulk transmission costs, as a factor in the choice between hydro, thermal and nuclear sources would be limited to certain specific situations. For example, bulk transmission of very large magnitudes of hydro power from sub-Himalayan sources to load centres in the Indo-Gangetic plain may have to be compared with the alternatives of large scale thermal/nuclear generation at or close to load centres. In the case of thermal alternatives, as the magnitude of development increases, the high cost of transport of coal over long distances may necessitate critical examination regarding the economies of transport of fuel and electricity. It would be necessary to make, in each case a detailed study of transport of coal and transmission of electricity before a decision is taken.

In this connection, it would be relevant to review some of the studies of comparison of relative economics of transportation of coal by rail and transmission of electricity by EHV lines that have been carried out in the past. In 1963, Shri S. M. Zubair and Shri F. C. Kohli had made a broad perspective study of this problem and they had concluded that under Indian conditions bulk electric power transmission is economical for long distances. A significant conclusion of the study was "Evaluation of electric transmission cost vis-a-vis rail transport cost on a long term basis indicates that a 400 kV transmission system with an initial load of even 300 MW is more economical than rail transport, if the initial load is expected to double itself within the next 5 years".

The findings of Energy Survey of India Committee, who had made a comprehensive study of this problem in 1963-64, show the decided economic advantage of EHV transmission over rail transport cost even at loads of 200 MW and that rail transport cost could be brought down to economic levels only with the introduction of unit trains.

The Tata Consulting Engineers made a study on behalf of the Maharashtra State Electricity Board recently of the relative economics of setting up a coal fired thermal power station in the Bombay area and of transmitting power to the Bombay area from mine mouth power plants set up in the Vidharba area. The basic assumptions and the results of the study are given in Annex IV. It would be seen from the graph in Annex IV, illustrating the calculated overall electric transmission cost as a function of maximum power transfer at a load factor of 70%, that electric transport of energy is cheaper than rail transport for loads above 220 MW at 70% L.F. at a voltage of 220 kV. As the quantum of energy transport increases the higher voltage is more economical, the choice for the bulk energy transfer is clearly for electric transmission at 400 kV or 500 kV.

It must be noted that increase in rail transport cost would increase the economic advantage in favour of electric transmission still further. It may be emphasised that the main cost of electric transmission being due to capital charges,

(7) S. M. Zubair and F. C. Kohli "Economics of Long Distance Extra High Voltages Transmission Lines"—Journal of the Institute of Engieers (India), December 1963.

these remain constant over the life of the transmission system once capital investment has been made. On the other hand for rail transport, the cost is likely to increase continuously over years in line with general increase in price level. If such increase continues, as is to be expected, the advantage of electric transmission would increase further.

3. Future cost trends

3.1. In section (2) the costs of electricity generation and supply under existing conditions were reviewed. The economic trends which may be expected in the fields of hydro, thermal and nuclear development in the foreseeable future, now require consideration. Also, as the Fourth Plan has already been finalised, the trend of electricity supply costs during the Fourth Plan can be forecast.

3.2. *Hydro* :

3.2.1. *Conventional Hydro* ;

There is a general impression that early hydro developments tend to exhaust the most economical sites and subsequent developments would, therefore, require higher unit investment costs. The economic indications given in para 2 above viz. that the capital costs of hydro-electric schemes, have been relatively stable over the past two decades run counter to this general belief. This on a detailed analysis would be found to be primarily due to the fact that though hydel development in the country has a history of 70 years, we have developed only 10% of the total economically developable hydro resources leaving still the bulk of the most economic sites untapped. An even more important point is that the intrinsically most economic hydel sites are also those with very large potentials of the order of 500 MW to 2,000 MW—especially in the sub-Himalayan and Assam Regions—whose development can only be considered when demands are adequate; and it is only recently that they have progressed to the stage at which these sites warrant serious consideration. Detailed studies of the hydro-electric sites yet to be developed led hydel experts to predict, as early as 1956-60(8), that the hydel sites with larger potentials, which had yet to be developed had such favourable economic features that their investment costs on hydro projects would generally tend to the lower limit of the range of prevailing investment costs at that time. Table-5 below gives estimated capital costs of several major hydel projects, where investigations have been recently completed.

(8) "Economic Trends in the Production of Hydro-electric Energy in India"—M. [illegible] and K. L. Vij—Paper presented to World Power Conference, 1958.

TABLE—5

Estimated capital costs of Major Hydro Projects yet to be developed

Sl. No.	Project	State	Installed capacity MW	Firm Power Potential MW at 60% L.F.	Estimated cost (Rs. crores)	Cost per kW installed capacity (Rs.)
1	2	3	4	5	6	7
1.	Pancheshwar (Sarda)	U. P./Nepal	1500	1000	200·00*	1330
2.	Chisapani (Karnali)	Nepal	1800	1650	180·00	1000
3.	Kalinadi	Mysore	1262	1320	145·00	1150
4.	Bhansagar (Sone)	Madhya Pradesh	780	420	93·00£	1190
5.	Narmadasagar (Narmada)	Madhya Pradesh	1000	413	72·13£	720
6.	Upper Indravati	Orissa	600	380	37·38£	620
7.	Upper Kolab	Orissa	180	148	15·00	835
8.	Tikkerapara (Mahanadi)	Orissa	2000	1417	180·00	900
9.	Silent Valley	Kerala	120	94	14·80	1230
10.	Hogene-Kal (Daveri)	Tamil Nadu/Mysore	800	440	55·60	695
11.	Thein (Ravi)	Punjab/J. & K.	420	222	72·10£	1710
12.	Navgam (Narmada)	Gujarat	1400	1153	131·00£	940

*entire cost charged to power even though considerable irrigation benefits are afforded. If the cost of common works is allocated between irrigation and power, the total capital outlay on power will be correspondingly lower.

£ In the case of Multi-purpose projects, the cost chargeable to power is indicated.

The above analysis refers to hydel sites which are primarily major sources of low cost firm electrical energy, and as such involve substantial investments on construction of large storage reservoirs to even out seasonal and annual fluctuations in river flow. In view of their advantages of meeting peak demands in the most economical manner, they have generally been provided with additional plant capacity for permitting these hydel power stations to also discharge peaking functions on the grids of which they form a part. Even in those cases where the stations are intended to operate at high load factor, it is essential that the project layout and the detailed designs keep in view, the need for converting them to lower load factor operation to meet future system requirements.

3.2.2. *Pumped Storage Hydel Developments* :

There is a separate category of hydel developments, however, which are primarily intended to meet the peak load requirements of integrated power systems which derive their actual energy potential from thermal/nuclear generation. Their special feature is that such schemes can be implemented at capital costs which are significantly lower than that of all the energy producing schemes described in the preceding pragraphs. This is because their civil works for regulation of water are limited to the construction of very small head/tail/pool reservoirs, with pondage capacity for operation during a few hours of a day and at many sites, where advantage is taken of existing reservoirs, even these can be eliminated. Such 'pumped storage' developments have not been initiated in this country so far although the time has come in many of our power systems when there is adequate thermal/nuclear capacity for off peak generation. In fact, there are several sites where existing multi-purpose reservoirs and other natural site conditions can be taken advantage of to construct pumped storage hydel stations equipped with reversible machines at extremely low capital outlays, which, as an added attraction, would also permit large blocks of seasonal hydraulic energy generation as well, substantially improving their economics. The scope for such applications under conditions in India has been outlined in a paper presented to the World Power Conference recently(9). It is expected that these sites can be developed at capital outlays of the order of Rs. 800 to Rs. 1000/kW installed, at sites in the Southern and Eastern Regions. The above presumes that equipment costs for hydraulic prime movers/ generators would be reasonable. This is a matter on which doubts can arise in view of the limited capability of indigenous manufacture and the existing ban on imports.

3.3. *Thermal* :

3.3.1. At all existing thermal stations, the general tendency would be towards a steady increase in the cost of generation over times as the thermal efficiency of the station decreases, newer stations relegate them to lower load factor operation, and the cost of coal increases. There is no escape from this inevitable process. This in fact is one of the chief reasons which have led in developed countries to their relatively rapid obsolescence and replacement in the face of mounting pressures to reduce costs of electricity supply.

3.3.2. Future trends in costs of thermal generation would depend on choice of unit size and availability of indigenous manufacture thereof. The Energy Survey of India Committee had made a comprehensive study of the problem of unit sizes in 1963-64 on the basis of data available then. Analysing the trends in advanced countries, they had observed that in an advanced economy, a unit size of 100 MW represented the lowest reasonable economic size and there might be savings as great as 15% in the capital cost of generating equipment by going up to a size of 250 MW, the additional savings in fuel cost per kWh being about 8%. Beyond that size, they considered that the further advantages of scale would be marginal though not negligible. They examined the aspect of adopting higher unit sizes in India, both from the point of view of manufacture of the equipment indigenously and economies to the power supply industry and be to be bold in respect of pure size but cautious in respect of pressure and temperature and the right policy would be almost certainly to advance in size as rapidly but no more rapidly, than is consistent with a low-import content of plant built in India.

The Tata Consulting Engineers had made recently a study of relative economies of extension at a thermal station near Bombay with a 300 MW unit and a 500 MW unit. The detailed budgetary costs were worked out for the entire project on the basis of prices obtaining in U.S. and the results of the study were as follows :

Unit size (MW)	Total capital cost (Rs. Lakhs)	Cost per kW installed	Per cent saving
1	2	3	4
300 . . .	5096	1699	..
500 . . .	7059	1412	16·9

More than 50% of the cost of thermal plant is accounted for by the cost of Turbinegenerator, steam generator and piping. In all these items there are sizeable savings when unit sizes are

(9) "Pumped Storage Development for Better Operation of Power System in India"—K. L. ViJ Paper presented to World Power Conference, 1968.

increased. This is illustrated by the table given below (for U.S. manufactured equipment).

Item	Unit Size 300 MWs.		Unit Size 500 MWs.		% Reduction
	Total cost Rs. (crores)	Cost per KW Rs.	Total cost Rs. (crores)	Cost per KW Rs.	
1	2	3	4	5	6
Turbine generator	10·9	363	14·7	294	19·1
Steam generator	12·1	403	17·7	354	12·1
Piping	2·7	90	3·1	62	31·1

The above is indicative of the savings involved in going for bigger unit sizes on the basis of imported equipment.

At present the indigenous manufacturing industries are building units of sizes 100 to 120 MW. It is understood that the question of taking up the manufacture of 200 MW units is currently being examined. The manufacture of units of sizes bigger than 200 MW would probably warrant consideration only after sufficient experience is gained in the country in respect of manufacture of unit sizes already being manufactured. In view of this, the question of adopting unit sizes of 300 to 500 MW in the immediate future can be considered only on the basis of importing them, as only a few systems would justify installation of such big units at present and going in for their manufacture immediately in the country may not result in either lower cost or savings in foreign exchange.

It would be worth while to point out here that adoption of bigger size units in the case of thermal power plants would not materially alter the economics of thermal power with respect to hydro power. However, the relative economics of thermal and nuclear power would require further careful study.

3.4. *Nuclear* :

3.4.1. In para 2 it was indicated that the capital outlays on CANDU type (natural uranium reactor) power stations are currently estimated at around Rs. 3,100/- per KW for twin 200 MWe (approximately) unit Station. The cost of energy generation at such power stations (under construction) is expected to be about 6 P/kWh. In a paper, "Nuclear Power in Developing Countries" by Dr. Sarabhai and others presented at the 12th General Conference of IAEA in September 1968, it has been claimed that nuclear generation from large CANDU type stations in India using natural uranium employing unit sizes of 500 to 600 MW is expected to be fully competitive with thermal generation from stations of equivalent size located at pit heads. In this connection, a more detailed comparison of the nuclear and thermal alternatives would have to be carried out on the basis of the up-to-date capital cost estimates under condition obtaining in the country, operating experience, similar assumptions of load factor etc.

3.4.2. The inhibiting factor in nuclear development is obviously the capital requirements, which, in terms of unit investment costs, are the highest of all alternatives. The AEC's estimates indicate that capital costs on even the largest nuclear units would be 40-80% higher than those of thermal units of equivalent size.[10] In this context, the possibility of achieving capital cost reductions by relying on enriched uranium reactors needs careful consideration. This is important because economic trends require that the bulk of long-term future energy generation would have, inevitably, to come from nuclear stations. At the recent seminar organised by the Department of Atomic Energy at Bombay (January 1970) on Nuclear power, Dr. Sarabhai's statement that 'I have not seen a total calculation how the overall system cost of an enriched uranium plant, taking from the processing right up to the end, compares with heavy water' indicates that further studies are required.

3.4.3. It now transpires that the use of slightly enriched uranium in thermal reactors involving the use of boiling light water in the coollant circuit while still using heavy water as moderator will result in savings in capital costs. The fuelling costs are also likely to reduce. So far, the enrichment of U-235 was considered out of question for India due to its high costs as well as enormous electric power consumption. This analysis was based on a gaseous diffusion technology. With the marked progress now, however, of the gas centrifuge technology which is less expensive, the Department of Atomic Energy is entrusting itself with serious developmental works towards it, which involve not only sophisticated chemistry and machine technology but also production materials which are strong and corrosion resistant.

3.4.4. There are several advantages in going in for nuclear power to optimise a grid with hydro and thermal generating units. Nuclear energy is practically independent of geographical factors, no combustion products are created and fuel transportation net-work and large storage facilities are not needed. The present strategy for development of atomic power in the country aims at reliance on natural uranium reactors during 1970-80 and from 1980-85 simultaneously developing thermal and fast breeder concepts based exclusively on thorium cycle. In the stage

(10) AEC Monogram I (1969)—Nuclear power in developing Countries.

beyond 1985, there would be scope for natural uranium fuelled reactors, advanced thermal (using slightly enriched uranium) reactors, plutonium fuelled fast breeders and breeders using thorium cycle.

3.5. *Trends in cost of generation during the Fourth Plan* :

3.5.1. In the light of what has been stated in para 2 and para 3.1 to 3.4 we can now consider the prospects of changes in the cost of generation of power during the Fourth Plan. This can most appropriately be considered within the regional framework.

3.5.2. *Southern Region* :

Of the total generation during 1968/69, 3,834 million units was derived from thermal and 8,330 million units from hydro sources. The pooled costs of generation in Kerala, Mysore, Tamil Nadu and Andhra are 3.3, 3.5, 4.5 and 5.74 paise respectively—the average for the region as a whole being 4.5 paise.

In Kerala and Mysore where the available energy from hydro stations is not being fully utilised at present and will undoubtedly be absorbed early during the Fourth Plan, there will be an overall reduction in the cost of generation from existing stations. Early commissioning of the 390 MW Idikki Project in Kerala and ensuring simultaneous utilisation of its benefits—possible through the Southern Grid—would provide a large block of additional hydro energy at about the same cost at the prevailing pooled cost in the State. In Madras and Andhra, the bulk of new generation in the Fourth Plan and immediately thereafter will be through thermal power stations and the Kalapakkam nuclear station under construction. The cost of generation would, therefore, increase in these two States.

By the end of the Fourth Plan, the total energy generation in the Region would be about 23,500 million units, of which 8,000 million units would be from thermal and 15,500 million units from hydro. The overall trend would, therefore, be of steady increase in power generation costs with the increases, mainly in Andhra and Tamil Nadu. Integrated operation of the power systems of Kerala, Mysore, Tamil Nadu and Andhra Pradesh power systems can arrest these upward increases in costs of electricity generation and supply. This will, however, require considerable effort at regional co-ordination.

3.5.3 *Eastern Region* :

The pooled costs of electricity generation in the States/systems of the Eastern Region are not available but from indications they appear to be high notwithstanding the proximity to the country's major reserves of coal. This is due to the almost total reliance on thermal power and under-utilisation thereof. The average energy generation from the total thermal station capacit of about 2500 MW was only 3580 kWhrs/kV during 1968/69.

During the Fourth Plan, there will be no nev economic source of hydro generation commis sioned in the entire region. Some improvemen through better plant utilisation is possible bu the scope can be ascertained when Study Group completes its work.

3.5.4. *Northern Region* :

Out of the total generation of 11,500 millior units in the Northern Region during 1968/69 5300 million units came from U.P. at around 6 Paise per unit and out of the balance, Bhakra Nangal with a pooled cost of generation of 1.68 paise per unit. contributed 4340 million units. The costs of generation of Chambal in Rajasthan may be of the same order as that indicated by M.P. viz. 3.5 paise per unit whereas the pooled cost of generation in DESU, Delhi (not yet furnished) may be of the order of 12 paise. The average cost of generation in the region as a whole was thus around 4.8 paise/kWh.

Practically all the increases in the capacity which would materialise during the Fourth Plan period are on the thermal side. There is already a shortage of hydel capacity in the U.P. grid thus, making full utilisation of thermal capacity difficult and leading to increases in the cost of electricity generation. In the Western half of the region also, no major sources of hydel supply are expected to be commissioned until the early part of the Fifth Plan period. Reliance on nuclear sources (RAPP) and thermal capacity (Badarpur, Bhatinda) which are far away from the collieries would push up cost of generation and supply substantially. Relief can be expected only when the Beas, Siul and U.P's hydro stations are developed to their full capacity.

3.5.5. *Western Region* :

The total energy generation in this region during 1968-69 was 12,900 million units, of which Maharashtra contributed 7,660 million. Its hydro component was 4,120 million units or just over half. Gujarat (3,280 million) and Madhya Pradesh (1,950 million) contributed the rest from purely thermal installations. The pooled cost of generation in Madhya Pradesh stood at 7.24 paise, whereas that of Gujarat was 6.7 paise. The pooled cost of the Maharashtra State Electricity Board grid (including Vidharba) worked out to about 3.6 paise. Taking the pooled costs of the Tatas grid and Ahmedabad Electric Co.. the average cost of electricity generated in the region as a whole was about 5.3 paise during 1968-69.

The cost of electricity supply in the Western region is affected by the remotense of important load centres (Western Maharashtra and Gujarat) from the collieries and hydel resources. Efforts to develop the available hydel potential in the region have made no significant headway. The only hydel stations expected during the Fourth Plan are Koyna Stage II, Vaitarna and Ukai—which are essentially peaking stations. Injection of thermal energy from stations under construction and increased resort to thermal alternatives located far from the collieries would naturally increase costs of generation during the Fourth Plan.

3.5.6 *North-Eastern Region* :

Generation in this region of abundant hydel resources is predominantly thermal, and costs paradoxically are the highest in the country. Further extension of thermal capacity is in progress. Improvement in the utilisation factors by load promotion may reduce costs of generation somewhat. Implementation of major economic hydel scheme taken up recently in the Central Sector on regional considerations would make its impact on the prevailing high cost of generation only during the early part of the Fifth Plan.

3.5.7 The above indications of future trends of costs of electricity in the country as a whole are based on the estimated costs of new stations which would be commissioned in the Fourth Plan, and the possibility of controlling costs to the maximum possible extent. They do not take into account further increases of cost of supply on account of the need for a higher return on overall investment than is being achieved at the present time.

4. The time factor

4.1 In the planning process, the time factor can be decisive in choice of different alternatives. Notwithstanding some efforts during 1960-62 at developing a perspective approach to our power supply problems, plans for expansion of generating capacities have actually been finalised mainly at the start of the Five Year Plans.

Commencement of work on power projects coinciding with the start of Five Year Plans creates a hiatus during the early years of the Plan and a concentration of capacity towards the end. On the other hand, the demand for power being a continuous process, what is required is not such planning confined to arbitrary Five-yearly periods involving periodic spurts in commissioning of projects but a perspective approach which ensures a steady and continuous increase in generating capacity. This perspective approach must always allow adequate time for consideration of all the available alternatives so that the most economical one is ultimately chosen.

The rate of growth of demand has first to be correctly established for realistic long-term planning. Once the correct demand trend has been determined, provision must be made not only to meet these anticipated demands in full but to provide an adequate margin to cover unforeseen increases or to accelerate overall economic growth.

On the construction front, there are irreducible minium gestation periods for power generation schemes which must be allowed for in planning. Besides, there are wide differences in performance in the speed of construction of projects by different agencies. All these have to be taken into account in order to achieve a proper choice of alternatives following the lowest cost paths of power generation and supply in each region.

It is evident that the necessary perspective approach has not been developed in the past. This is also amply borne out by the lack of emphasis in the Fourth Plan on initiating work on economic power generation schemes for the Fifth Plan. In the interest of planned development of economic sources of power, such an approach has to be developed by all concerned with planning and implementation of power schemes without any loss of time.

4.2 *How fast are load demands growing? At what rate are they likely to grow in future?*

The actual growth of demand is ultimately reflected in the total energy generation from all power stations combined. This hides the demand which has been suppressed due to non-availability of generating capacity, or restrictions due to limitations of transmission and distribution, but if due allowances for these factors are made, it provides the best indication that is available of the rate of growth of demand for electricity. The enclosed graph (Annex. V) shows the rate of growth of electricity generation for the country as a whole for the last 30 years, which has been at an average rate of 10% per year. During the past two decades, i.e. since the advent of the concept of planning, the rate of growth has been at a constant rate of 12%, which corresponds in turn to a rate of doubling every six years.

The picture of growth of demand in the different regions is somewhat different from the national picture. During the past decade, the rates of growth have been relatively faster in the Southern and Northern regions compared to the Eastern and Western regions of the country. This would also be seen from the graph enclosed (Annex VI). It is necessary to note these variations, when breaking up a 'macro' forecast into its regional components.

Surveys of demand potential have been carried out by the Central authorities, initially by the CWPC(PW) and later on, from 1963, by the All-India Power Survey Committee. Generally, they tend to adopt trends of doubling of demand every 5 years. The authorities make it clear that these forecasts refer not to actual demands but to the demand potential which exist and which would arise in case there are no limitations of capital resources, and ample generating capacity, transmission lines, etc. are provided for. Past experience is of a consistent sizeable gap between these figures of demand potential and actual load demands at any time. The lags in growth of demand in States like Kerala, Mysore, Madhya Pradesh, Orissa, Bihar, West Bengal etc., notwithstanding the fact that adequate generating capacity had been built up is noteworthy, particularly when it is remembered that this situation has arisen in spite of considerable delays in the implementation of expansion projects.

The situation calls for serious introspection within the power supply industry of the real nature of the growth of load demands with a view to arriving at assessments which would be closer to the 'actual' and can be taken as a serious basis for definitive long-term planning. As matters stand, the load surveys tends to become theoretical exercises in assessment of demand potential, are not taken seriously even when they are made, and ultimately lead belatedly to implementation of crash programmes of emergency alternatives, which place heavy long-term burdens on the power supply industry. A special team of the Power Economy Committee is considering how our load forecasts can be made as realistic as possible. The importance of these realistic load assessments which are essential for evolving the perspective approach cannot be over-emphasised.

When planning for entire regions, a macro approach and projections based on trends established during periods of healthy growth could be reasonably accurate for purposes of long-term planning. Short-term accelerations and unexpected lags in development in different States of the region would tend to cancel out, providing a more homogeneous rate of growth for the region as a whole, from which departures or errors are bound to be small. The overall long-term economic projection of the Planning Commission could also be taken into account. Detailed load surveys covering shorter periods would be required to determine the spatial distribution of loads and planning of setting up of nuclear/thermal stations sites, pumped storage development and transmission systems.

4.4 *How fast can power stations be constructed?*

This is a subject on which there have been diverse views. For the purpose of their economic comparisons, the Energy Survey Committee in 1965 assumed construction periods of 9 years for hydel plant, 5 years for thermal plant and 5.5 years for nuclear plant. Table—6 below which summarises the actual record of construction activities on several hydel projects in India.

TABLE—6

Actual Record of Construction of Hydro-electric Projects

Sl. No.	Name of Project	Time taken for commissioning for first unit (years)	Time taken for completion for project (years)
1	2	3	4
1.	Kundah Stage I & II (2×20 MW, 4×35 MW)	3¾	5
2.	Kundah Stage III (1×20 MW, 1×35 MW, 2×60 mW, 1×50 MW & 1×20 MW)	3	5
3.	Metur Tunnel (4×50 MW)	5	6
4.	Panniar (2×15 MW)	7	7
5.	Sholayar (3×18 MW)	5½	7½
6.	Sabarigiri (6×50 MW)	5¼	6¾
7.	Sharavathi Stage I (2×87)	5¼	5¾
8.	Sharavathi Stage II (6×89)	4	7
9.	Koyna Stage I (4×60)	6¼	7
10.	Koyna Stage II (4×75)	1¾	3
11.	Upper Sileru (2×60)	6½	7
12.	Gandhisagar Stage I (4×23)	7¾	10
13.	Ranapratapsagar (4×43)	5¾	7
14.	Ganguwal 1st (2×24)	7	7
15.	Kotla 1st (2×24)	8	8
16.	Bhakra L. B. (5×90)	12	13
17.	Yamuna Stage I (3×11, 3×17)	5	9
18.	Rihand Stage I (5×50)	4½	5
19.	Hirakud Stage I (2×37·5+2×24) (For details, *see* Annex VII-A)	7	9

It would be of interest to note that the pace of construction of most hydel projects, considering the limitations under which we work, compares favourably even with that of hydel projects abroad (see Annex. VII-B).

Actual time taken for construction of some of our thermal projects completed recently is given in Table-7.

TABLE—7
Actual Record of Construction of Thermal Power Plants

Sl. No.	Name of the Project	Time taken for commissioning for First Unit (Years)	Time taken for completion of project (Years)
1	2	3	4
1.	Delhi Thermal (3×62·5 MW)	6	7
2.	Amarkantak (2×30 MW)	3	3
3.	Kanpur (2×32 MW)	5	5
4.	Kalakote (3×7·5 MW)	7	9
5.	Satpura (5×62·5 MW)	6	8
6.	Paras (1×62·5 MW)	6	6
7.	Bhusawal (1×62·5 MW)	7	7
8.	Obra Thermal I (5×50 MW)	4	7
9.	Harduaganj Stage I (2×30 MW)	6	6
10.	Harduaganj Stage III (2×50 MW)	3	4
11.	Barauni (1×15+2×50 MW)	6	9
12.	Kothagudam I (2×60 MW)	4	4
13.	Talcher (4×62·5 MW)	6	8
14.	Bandel (4×82·5 MW)	4	5
15.	Chandrapura Stage I (2×140 MW)	4	5
16.	Dhuvaran (4×62·5 MW)	4	5

Gestation periods of power projects were reviewed in detail by the Working Group on power for the Fourth Plan. They noted that the gestation periods of new schemes involved (a) the period of investigations right from the concept of the scheme to its clearance for construction; and (b) the actual period of construction of the projects. In regard to (a) above, there were inordinate delays ranging from 6 years to almost 2 decades, but, on the basis of actual experience of the speed of construction of different projects during the past two decades, it was noted by the Working Group that once a scheme has been investigated and sanctioned, the actual period of construction of hydro and nuclear schemes was about the same *i.e.* 5-6 years (in many cases of relatively simple projects like Kundah, Periyar etc., hydel schemes have in fact been constructed as fast as in 4 years), whereas coal-fired thermal stations could be built generally in 5 years and sometimes even in 4 years.

The above excludes obviously time-consuming large projects like the Bhakra Project, the Beas Link Project etc. which involve works of large civil engineering features requiring longer gestation periods. The essential point needs to be noted is that in hydro projects, the 'time factor' of actual construction—*i.e.* excluding the periods of investigation up to the clearance for construction, would largely depend on the kind of project. In practically all cases, where natural drops are available and the power station and the water conductor system and the storage works form separate constituent units, and work can be simultaneously accelerated on all of them, the schemes can easily be commissioned within 4-5 years of the start of construction. A large number of our projects fall in this category. It is only in those few cases where the "heads" have to be only artificially created by construction of large dams *e.g.* Bhakra, Hirakud etc. that long gestation periods are involved. Other factors which tend to increase construction periods are (i) when work is commenced on schemes in which foundation conditions have been inadequately explored and give rise to uncertainties during the stage of construction leading to major changes in designs and estimates of costs; and (ii) where adequate financial provisions are not made in time for executing the project with all possible speed.

Studies show that in India, it is the initial period of "investigation and pre-construction activities relating to sanction" which is unduly prolonged. This, therefore, is what has to be controlled through all-round concerted action. From 1956 onwards, power engineers have been emphasising the need for advance action on investigations of hydel projects from different forums. The importance of investigations has perhaps been most succintly and powerfully expressed by the Estimates Committee of Parliament in their 30th report (1962-63) :

> "As it is an established fact that hydel is the cheapest source of power in India, the Committee would urge the Government to investigate and prepare blue prints of all the remaining hydro-electric schemes so that they can be readily available for being taken up to meet the increasing demands. This is all the more desirable as India has all the requisite experience for undertaking investigations and preparation of project reports as also the implementation of hydel-schemes."

The CWPC laid great emphasis in their perspective plan for power development (1960) on the need for investigations of all kinds of power projects, particularly hydel projects. Subsequently keen interest was taken by the U.N. Special Fund authorities, which led to the launching of a countrywide scheme of investigations of 62 major hydel projects in the country whose urgent consideration for implementation was taken for granted. Equipment for the purpose was arranged through the assistance of the U.N. Special Fund, but the actual programmes of investigation work were dispersed to the various State organisations, along with the equipment, as decided by the Planning Commission/Central Ministries. It is unfortunate that most of this work is still incomplete. Out of the 62 projects, detailed project reports on 12 projects have been prepared and a further 6 projects have been reported upon in a preliminary manner.

This again would be seen to be an extremely unfortunate situation calling for immediate remedial measures. In this connection, it has to be recognised that it is not sufficient merely to carry out limited investigations and prepare brief project proposals and estimates. What is required is nothing short of project proposals and designs which would not involve any significant variations in cost or time when action regarding their implementation is decided. The Study Group considered the steps required to be taken to remove present drawbacks and enable proper reports/estimates to be prepared. Their conclusions and recommendations in this regard are given in Section-8.

4.5 Once the time involved in investigations and sanction of projects is controlled (i) by building up proper institutions to undertake such work with streamlined procedures on a thorough and uniform basis, and (ii) by a proper perspective approach to sanctioning projects on a continuing basis and as part of a total programme rather than on an individual basis as at present, the time factor in actual construction of projects would not be materially different in the different alternatives under consideration *i.e.* hydro, nuclear or thermal. In any case, the margin of difference would not be such as cannot be easily taken care of in a perspective plan. While it can be argued that a thermal unit can be brought into commission at a developed site faster than the average rate of 4-5 years, it can equally well be argued that a pumped storage or peaking hydro station can be brought into commission equally quickly. These would, however, be exceptional situations.

4.6 Thus, it would be seen that once it is recognised that the guiding consideration is to make arrangement for power supply in the future along paths of lowest cost developments, timely advance action on preliminaries and a proper perspective approach to planning can ensure that the 'time factor' would not stand in the way of implementation of the most economic developments. The obligatory line of action which follows is again most succintly stated by the Estimates Committee itself in 1963 :—

> "The Committee are glad to note that perspective plans of power requirements till 1981 have been drafted. Planning for power is in fact a continuous process and the perspective plans have to be reviewed in the light of requirements revealed by power surveys. The Committee would like the Government to pay close and continuous attention to perspective planning so that the targets fixed are fully in consonance with the requirements."

4.7 It would thus be seen that the importance of a perspective approach to ensure the most economic paths of power supply and arranging for timely development of indigenous manufacture of equipment had been accepted by Central Planning Authorities in 1960-62. Unfortunately, despite occasional genuflexious to this subsequently, there has not been any sign of adherence to this principle in practice, and to this day, sanctions of new schemes continues to be given on an individual, and often, emergency basis.

5. Basic Energy Resources

5.1 *Need for review now* :

In 1965, the Energy Survey Committee dealt exhaustively with the availability of basic energy resources—coal, water, oil/gas and nuclear fuels—available for conversion to electricity. Broadly, their conclusion was that for the foreseeable future, there would be adequate energy resources for conventional methods of electricity generation all over the country, that in particular there would be very large surpluses of by-product coals constituting a basic problem of utilisation and finally that decisions on implementing nuclear alternatives must be based purely on economic considerations. The main changes since 1965 need to be noted.

5.2 *Hydel Resources* :

5.2.1 In regard to hydel resources, Dr. A. N. Khosla has recently opined that the estimates of the early fifties of our hydel potential (40 million kW) are low and "the actual figure may well turn out to be 'well over' 100 million kW economically feasible and utilisable water power, as with each new investigation the figure is going up". He has further stated that "What appears uneconomical today may become economical in future in terms of cost-benefit ratio'[11].

5.2.2 The CW&PC's preliminary assessment of our hydel resources was carried out during 1953-60 and they (a) included only firm potentials and (b) were estimates of economically utilisable hydel resources on prevailing economic considerations. It excluded seasonal potentialities and the potential in years of average and heavy rainfall. It also excluded sites considered uneconomic according to standards of investment costs at that time.

(11) "CW & PC—April 1945 to April 1970"—Dr. A. N. Khosla—Silver jubilee Souvenir 1945—70 CW& PC).

5.2.3 Studies and surveys carried out subsequently notably in the Indus system have indicated that the firm hydro potentials would be substantially greater than the earlier estimates. For instance, the hydro potential located in Himachal Pradesh was placed at 3 million kW under the earlier Hydro Electric Survey, but subsequent developments have pointed to the fact that these would be of the order of 8 million kW. Similarly, the potential of the Chenab was indicated as 3.26 million kW on the basis of permissible storage under the Indus Water Treaty. It is this conservative figure which is included in the early surveys of the CW&PC. Investigations carried out indicate that this figure would increase to 4.0 million kW and, if storages can be increased in future, under international agreement, the figure of firm potential can well increase to 6.5 million kW.

5.2.4 In the central Himalayas, the hydro-electric potential of the Sarda-Karnali system was assessed at 4.5 million kW, that of the Karnali valley in Nepal adjoining U.P. being set at about 2.75 million kW. Detailed surveys carried out subsequently under the auspices of the United Nations have increased the potentials of the Lower Karnali to 5 million kW at 60% load factor at 3 sites, and that of the entire Karnali valley to about 7 million kW of installed capacity. But this potential lies in Nepal. The assessed power potential of the Sarda valley has been substantiated by subsequent investigations.

5.2.5 On the Deccan River systems, there is no reason to warrant any increase in the estimate of firm potential of 14 million kW at 60% load factor. However, recent technological trends of pumped storage development through installation of reversible pump-turbines have opened up possibilities of developing a number of sites, where economic hydel generation on a seasonal basis would be possible. This energy potential can either be firmed up by co-ordinated grid operation or utilised for saving in costs of coal at existing thermal stations. These seasonal potentials, which have not been dealt with in the earlier hydro-electric survey report, may increase earlier figures of energy potential by about 30%.

5.2.6 The enclosed map (Annex. VIII) indicates the location of the country's hydro-electric resources and the table below indicates the extent of utilisation in each region by the end of the Fourth Plan. On the basis of the latest information regarding hydel energy resources, and their economics of development, it has been indicated that it would be possible to instal about 80 to 100 million kW of hydel capacity on our river systems during the next two to three decades as required for efficient operation of our power stations and grids.

5.3 *Coal* :

5.3.1 In 1963, the coal reserves of India up to a depth of 609 metres (2000 ft.) had been estimated at about 128,000 million tonnes and this figure had been indicated to the Energy Survey of India Committee. This figure was revised to 87,000 million tonnes in 1967, the main reductions being at Singrauli and Talcher coal fields where the estimates of reserves were revised to about 8,000 million tonnes each from the earlier estimated figures of 30,000 million tonnes each. The estimates in 1968 placed the country's coal reserves at about 100,000 million tonnes up to depth of 609 metres (2000 ft.) in the case of the most of the coal fields and 1,219 metres (4,000 ft.) in the case of some of the collieries specifically Raniganj and Jharia.

5.3.2 It would be recalled that the Energy Survey Committee had indicated that 12, 33 and 53 million tonnes of by-product coals would be available in 1970-71, 1975-76 and 1980-81 respectively. Assuming that surplus washery by-products would otherwise be wasted and are potentially available to be used at zero cost they observed that "a low coal-cost thermal station such as can be constructed to burn by-product or waste coals at the coal field, if operated at a plant factor of 60% or better, would provide the cheapest rates of generation of power". Against these, the availability of by-product coal during 1969-70 was only of the order of 3.69 million tonnes and at the end of the 4th Plan (1973-74), the availability is now estimated at 6 million tonnes (Annex. IX). In view of this, conventional thermal power generation would have to rely mainly on non-coking high ash content coals mined specifically for the purpose.

5.4 *Oil/Gas Resources* :

Under prevailing conditions in this country oil/gas resources have an insignificant effect in the total picture. No major variations from the trends indicated by the Energy Survey Committee, have been reported.

5.5 *Nuclear Fuels*:

In 1965, the Energy Survey Committee pointed out that, even assuming a burn up of 10,000 MWD/tonne of fuel, the then estimated reserves of Uranium (in Bihar) would be sufficient only for the operation of one million kW of nuclear capacity during its useful life. They noted that the Department of Atomic Energy had since indicated the possibility of increasing the figure fivefold. The AEC monograph 1 on "Nuclear power in developing countries (1970)" indicates that the reserves of uranium available may sustain 5000-10,000 MWe of Nuclear plant for their life time.

In view of these limitations, the Energy Survey Committee pointed to the reserves of 500,000 tonnes of thorium—described as being equal in magnitude valued to all the world's uranium ore containing 0.1% and above—with the reservation that thorium could be used for production of nuclear energy only after solution of a number of problems. They also believed that the conversion of thorium could best be done in a breeder type reactors and that only when these processes have been developed and, especially when suitable breeder type reactors are commercially available, could the country regard itself as being richly endowed in nuclear fuels.

An extract from "Uranium Resources—Revised Estimates December 1967"—A joint report by the European Nuclear Energy Agency and the International Atomic Energy Agency—which presents the position of our resources as on December 1967 is enclosed as Annex. X.

5.6 The position regarding the availability of different conventional resources of energy on a regional basis is given in table-8.

TABLE—8

Conventional energy resources and their regional Distribution

Region	Total coal reserves 10^6 metric ton	Total lignite reserves 10^6 metric ton	Hydro resources (MW) at (60% L.F.) Total	Developed & under development	Total oil reserves 10^6 metric tons	Total natural gas reserves 10^6 cubic metres
1	2	3	4	5	6	7
Southern	5515·00	2032·00	8097·0	3220·5 (39·80%)		
Western	22887·00	11·10	7168·9	941·5 (13·12%)	153·87	63,600
Northern		22·30	10731·5	2450·7 (22·80%)		
Eastern	74227·50		2693·7	574·0 (21·30%)		
North-Eastern	3629·60		12464·4	37·5 (0·30%)		
TOTAL	106259·60	2063·40	41155·5	7224·2 (17·60%)	153·87	63,600

NOTE : The hydro resources are based on C.W. & P.C.'s Hydro-Electric Survey.

6. Implications of Regional Development for Power supply

6.1 The fact that the energy resources of the country are not evenly distributed amongst its political constituents—itself a changing pattern—was realised by Power Engineers for quite sometime, leading to pleas for rapid development of an All-India Grid. The CWPC's survey of the hydro-electric resources of India (1953-60) brought these problems of uneven distribution of the country's energy resources into sharp focus. A regional demarcation, based primarily on consideration of distribution of energy, resources and presenting a lasting geographic basis for rational planning of power was first proposed in 1957(12). According to these proposals, the country was to be divided into 8 regions, self-sufficient in resources and demands. The intention was that the economic plans drawn up on the basis of this regional convas could be then broken up into State components for actual implementation according to State fiscal plans.

6.2 In 1960, the Planning Commission, realising the serious weakness introduced by planning for power in the framework of short-term five-year plans, called for a perspective plan for power development for the period up to 1980 indicating the clear order of priority, the hydro, thermal and nuclear power stations to be constructed, with their precise locations. This perspective plan was prepared by the CW&PC (Power Wing) in 1961 and circulated to the Planning Commission and the States. It was drawn up on the regional framework indicated at para 6.1. above, with the slight alteration that two of the regions in the southern part of the country were merged to form one, reducing the total number of self-sufficient regions from 8 to 7.

6.3 This regional framework was adopted by the Power Survey Committee in 1962 for the first of the current series of All-India Power Surveys. Its implications for ensuring integrated operation of existing power systems and also

(12) "A Regional Plan for Power Development in India"—K. L. Vij & C. K. Chandran, Journal of Institute of Engineers (India) June 1957.

for planning for future power development in India were considered in detail by the Chairmen of the State Electricity Boards and by the Co-ordination Committee of Ministries in 1962. The first annual power survey report published by the Central Electricity Authority in 1963 records in detail these deliberations from which it would be seen that at the State level this rational approach to electricity development in the future found ready acceptance.

6.4 These proposals for regional development of power were also described by the Ministry of Irrigation and Power to the Estimates Committee of Parliament who, in their Report 1963, observed as follows :—

> "The representative of the Ministry stated that State Electricity Boards had agreed in principle to setting up of Regional agencies for planning and generation of power. The Committee notes that the Executive Group of the Electric Power Survey had recommended in February 1963 that the country might be demarcated into the following 7 Regions. It has been proposed that the Regional Power Agency should be vested with the responsibility of planning new power stations and major transmission lines and integrated operation of power system in the Region as a whole. The Committee feels that the establishment of Regional grids and regional power agencies were developments in the right direction. They note that a Committee will examine the scope of the Regional Agencies and the Central Agencies and their powers and ancilliary matters. The proposal is of sufficient importance for a Committee to go into the question in detail and bring out all the implications after ascertaining the reactions in the places which would be effected by the proposal."

6.5 The position was reviewed by the Ministry of Irrigation and Power in 1964 when the constitution of these regional agencies was taken up. Some major departures from the earlier policies were made at this stage. The geographically based, seven regional demarcation suggested earlier was changed into a five-regional assembly of adjacent States into five regions *viz.* the Northern, Southern, Western, Eastern and North-Eastern. It was also decided that, in the first instance, the regional agencies would concentrate on arrangements for integrated operation of existing power system in each of the region. They were to function in a purely voluntary capacity but were also expected to ensure that the power stations in each region are so operated as to derive the maximum possible benefits to the region as a whole.

6.6 Study Group II is now engaged upon a study of the progress of integrated operation in the country and the development of technical arrangements for load despatch, and other institutional and financial arrangements. We have to await the report of this Study Group.

6.7 It is necessary to consider afresh the implications of regional approach to planning for future power development in this country, which is an inevitable step in the development of an All-India Grid or of uniform power policy in the country. It is not difficult to choose the most economic schemes in each region at a particular stage. Techniques of optimisation and arriving at the best mix of sources of power supply have already been developed in other countries, and are being actively considered in India also. The main problems lie in arranging for implementation of schemes chosen on a regional basis, within the framework of financially independent State power systems, with whom lies the primary responsibility for promotion of schemes for expansion of power supply. Two clear alternatives are possible *viz.* (i) Central control of all Regional generation schemes, and (ii) joint ownership of these schemes by the States on a mutually agreed basis. In actual operation of these regional schemes, the aspect of ensuring equitable distribution of the anticipated economic benefits becomes a difficult and crucially important problem. Within the present institutional framework all this work would have to be done on a purely voluntary basis. Some feel that the only course is centralisation of generation (major) and bulk transmission. There are, however, others who feel that this work should be left to Regional Electricity Generation Boards, which are given formal legal and financial status.

6.8 The Energy Survey Committee, while noting that it was not certain whether voluntary collaboration of States can or cannot succeed in providing the means of effective organisation and efficient operation of State power systems, also pointed out the limitations of centralisation of generation and bulk supply.

> "Centralisation of planning and strategic organisation of the industry cannot, however, imply centralised day-to-day execution of the centrally determined policy in all its details. It is unthinkable that the Indian Electricity Supply system should be run in practice as a single unit. The areas covered are too vast. Thus even if there were central ownership and strategic control, there would have to be decentralisation of detailed day-to-day execution."

After considering various alternatives, including establishment of the Central Electricity Generation Board, they finally recommended as follows :—

> "Careful consideration has been given to the organisation of electricity supply that is most appropriate to the changing technical conditions and the need for greater

integration than has existed in the past. We welcome the creation of Electricity Supply Regions. We hope that this very necessary integration of the planning and operation of the generation of electricity may be achieved *without any formal re-organisation and by the voluntary cooperation of the State Boards* within the various regions and of the regions themselves. It will, however, be necessary to watch carefully the progress of cooperation on this basis and it may, at some stage, be necessary to consider whether a greater degree of central ownership and control of generation is necessary condition for an effective generation policy."

The institutional arrangements for preparation of perspective plans for power development at Central, Regional and State levels were discussed in detail by the Study Group and their conclusions and recommendations are summarised in Section-8.

7. Problems of matching indigenous manufacture of Heavy Electrical Equipment to the Economic Requirements of the Power Supply Industry

7.1 Although all early indications and CWPC's perspective plan (upto 1980) called for primary dependence on hydel development for expansion of our power supply system, the heavy electrical equipment manufacturing industry was, for inexplicable reasons, organised with a bias towards larger capacities on the thermal side, and the emphasis of initial efforts was also in that direction. These matters were discussed at an inter-ministerial meeting held in 1962 to consider manufacturing programmes of the new factories at Tiruchi, Ramachandrapuram, and Hardwar (Ranipur), when it was decided to allow "the programmes of installed capacity and output as envisaged by them (Heavy Electrical's Ltd., Bhopal)" to go ahead. The targets for steam and hydro plants were fixed at 2.6 million and 1.7 million, the 1970-71 outputs being set at 1.87 million and 1.1 million kW respectively. There was, of course, the proviso that, should the requirements of hydro units turn out to be larger, Heavy Electricals would try to meet them by making fuller uses of installed capacity and conversion of part of the capacity at Ranipur to meet hydro-requirements. During the deliberations of the Working Group of Power Development in 1968, it became apparent that provision for such conversion at Ranipur has not actually been incorporated. The actual capability for manufacturing limited hydro electric units appears to be far less than what was sanctioned, leading to strong preferences by the manufacturing industry towards use of costlier steam equipment on our power systems. The manufacture of pump turbine hydro units most essentially required in the Fifth Plan period for achievement of capital savings and improvement in the utilisation of existing installations, and of system performance, has not been programmed. The net result is that, at present, the manufacturing programmes of the heavy electrical industry, and the requirements of economic power supply in the power supply industry stand opposed to each other.

7.2 The question of high prices being charged for the equipments manufactured indigenously is under consideration by a high level Committee, and it is not necessary to examine all its aspects here. But it must be mentioned that the larger differences in cost as compared to world market prices are on the hydro side, they being much higher than international prices. Their delivery times are even more uncertain. The position of supply of hydro units is so uncertain in fact that in the case of units ordered for some of the hydel stations under construction in U.P., delays in commissioning of these projects due to delays in supply of equipment, have led to consideration of augmentation of thermal capacity to meet the "gaps". In a recent article (1967) by the Chairman, Bharat Heavy Electrical Ltd., it was indicated that orders for hydro electric machines would have to be placed 6 to 7 years in advance, to ensure deliveries in time. This has to be compared with a normal delivery period of 2 years in the case of imported equipment. Not so long ago in this country and as practised every where-else ordering of equipment for generating plants was the item of lowest priority in the construction of hydro-electric projects. At present, State Electricity Boards are faced with the problem not only of ordering this equipment ahead even of the sanctioning of projects but advance payments are being demanded and made even before the civil works at site have commenced. It reflects the drastic change in the equipment supply position following organisation of indigenous manufacture.

7.3 It would be interesting to review the foreign exchange requirements of indigenous manufacture, for one of the main objectives of this industry was to reduce them, and thus enable higher targets of achievement in the power supply industry. In the report of Committee on Public Undertakings it was indicated that the import content as a percentage of sale value in the products that were then fairly established, was as follows :

(i) hydraulic turbine 47%

(ii) hydro generator 70%

(iii) steam turbine 84% and

(iv) steam turbo alternators 75%.

(13) Twelfth Report of the Committee on Pulic Undertakings For the Lok Sabha—Heavy Electricals (India) Ltd., Ministry of ID and C.A. (1964).

Recent figures of the imports content of indigenous manufacture are not available. For a proper economic comparison it would be necessary to obtain this information both as percentages of prices and in actuals from the Heavy Electrical manufacturing industry. It would also enable rational view to be taken regarding the policy to be followed in the future. The Study Group, therefore, suggests that the Chairman of the Power Economy Committee may obtain information regarding foreign exchange involved in indigenous manufacture of different items of heavy electrical equipment to enable analysis of the problem in the correct perspective.

7.4 It would be admitted by all that manufacturing industries must subserve the requirements of the power supply industry in which the investments already are of the order of over Rs. 4,000 crores and Rs. 2,440 crores are to be added in the Fourth Plan period. It cannot obviously be the other way round. In the interest of securing economic operation of the power supply industry, the heavy electrical factories would have to orient their manufacturing programmes to meet the genuine economic needs of the power supply industry. If the requirement of the power supply industry dictates are almost a total reliance on nuclear, hydro-electric plant, the industry should gear itself to be capable of adjusting its product pattern to suit these requirements. As the problem of providing peaking capacity in the most economical manner can be solved in many of our systems by introducing pumped storage installation, the indigenous manufacture should organise themselves to manufacture reversible pump-turbine units and deliver them in quick enough time. Till then these and the requirements of low gestation period conventional hydro schemes, which cannot be met by indigenous manufacture in time, should be allowed to be imported so that large savings in capital outlays and operating expenses can be effected and power demands are met in time.

8. Conclusions and suggestions on factors which must prevail in the choice of alternatives in each region

8.1 *Relative costs of energy generation-hydro, thermal and nuclear alternatives.*

8.1.1 In this respect, "certain conclusions leap to the eye" to borrow an expression from the Energy Survey Committee. Under existing conditions, and according to expected trends in the near future of the three main alternatives-hydro, thermal (coal fired) and nuclear, conventional thermal schemes involve, by far, the highest costs of energy generation in this country, which during 1968-69 varied from 6-10 paise per unit even at relatively new and large power stations. In terms of capital outlays, they cost nothing less than Rs. 1800/KW installed today or about Rs. 2500 per KW of firm capacity on purely thermal systems-allowing for the usual margins to cover scheduled maintenance, spinning reserves, etc. Even the resort to unit sizes of the order of 200 MW-may not help bring down costs of future thermal generation appreciably under conditions of indigenous manufacture and rising costs of coal.

8.1.2 The costs of generation at nuclear stations, existing and under construction on a comparable basis are estimated at about 5 paise to 6 paise per kWh. With the adoption of large units of the order of 500 to 600 MW, it has been estimated by A.E.C. that the cost of generation will reduce significantly. More detailed studies are required to establish a realistic picture of cost of nuclear power from stations with bigger units and adpting advanced reactor concepts. Nevertheless, it has to be noted that even the cost of energy generation from 200 MW CANDU type reactors at about 6 paise per unit would be competitive, with prevailing cost of thermal generation at most of our thermal stations which are remote from collieries, ever after allowing for the necessary standby provisions. We are therefore, undoubtedly on the right path of low cost generation in depending on nuclear power stations as the cheaper of these two alternatives, at most sites which are remote from the collieries. But to accept this as a major policy decision, we must have better assurances of figures of capital and running costs on the basis of the actual operating performance of these stations for a few years.

8.1.3 Hydel schemes have established themselves as undoubtedly the cheapest source of electricity generation in India involving in the past decade comparable and in many cases even lower capital outlays per kilowatt of effective capacity. Their energy generation costs range from 1 to 3 P/KWH, 2P being the overall average (not representative in all regions). Besides these obvious and great economic benefits, the Working Group on Power (1968) recognised the fact that non-utilisation of hydel resources represented a colossal irrecoverable loss of valuable natural resources. Hydel developments over the next 2/3 decades are expected to be about the same levels of intrinsic economy as prevailing at present, and it has been indicated that our river systems are capable of providing 80-100 million KW of hydel capacity at favourable sites compared to the 7 million KW installed today.

It would be noted that maximum utilisation of capacity is possible at thermal installations which operate on the base of the load curves of the respective mixed hydro-thermal systems having adequate hydel capacities to operate complementarily to take the low-load-factor peaks. Examples are Neyveli (5800 kWh/kW installed) and Trombay (5640 kWh/kW installed). On the other hand, the average energy output of power stations of our purely thermal systems during 1968-69 was generally less than 4,000 kwh per kW installed as a system average-one or two new stations in a system may have exhibited better figures-pointing to the conclusion that even in areas proximate to our collieries, it would have been decidedly more economic to rely on mixed hydro-thermal power systems with their potential for full utilisation of generating capacities and other great economies, rather than on purely thermal installation as at present. Providing these primarily thermal systems also with complementary hydro peaking stations to improve their utilisation is one of utmost priority for the 4th & 5th Plans.

8.2 Relative Priorities for Development of *Different alternatives, hydro, thermal and nuclear* :

8.2.1 In regard to the relative priorities for development of different alternatives hydro, thermal and nuclear power, in view of what is stated at para 8.1 above, there is little to add to the conclusion of Dr. H. J. Bhabha in 1965 *viz.*,

> "The obvious conclusion is that, wherever power is needed and it is feasible to generate it by water power, this should be done in preference to other methods.",

the recommendations in CW&PC's perspective plans (1962) viz.

> "In view of the above capital cost comparisons, the far lower foreign exchange components required for hydro schemes, their much lower costs of generation, and the fact that there is no depletion of natural resources, it is obvious that, on purely economic considerations, hydro power should be resorted to wherever feasible and thermal (including nuclear) resources developed to a complementary extent to meet the expected deficits. This therefore has to form the basic principle for a perspective plan for future power development during the next two decades",

the recommendations of the Energy Survey committee (1965), *viz.*

> "In the light of these estimates, it seems clear that India will be well advised to continue to exploit hydro resources wherever there are suitable sites available".

and the recommendations of the Working Group on Power for the Fourth Plan (1968) viz.

> "As power generation has to be planned on the basis of the most economic schemes, both in capital investment and in recurring costs, it is inevitable that a greater part of the additional capacity (required in the Fourth Plan) would have to come from hydro schemes."

8.2.2 The above conclusions have been derived from an analysis of the direct costs to the power supply industry. The actual costs of generation during 1968-69 represents the true costs of power generation to the industry, as accounted. We may benefit from a more comprehensive analysis including present worth analysis etc. Typical studies of this sort on selected power projects in this country are being carried out by Dr. Venugopal, Member of the Power Economy Committee in consultation with the Member-Secretary. The results of these studies may be awaited to consider whether the above conclusions need to be modified on any account. However, as the time factor of actual construction remains practically the same in all these alternatives, and the capital costs of hydro schemes are either comparable to or lower than the other alternatives, it does not appear, prima facie, that the conclusions above would be altered. On the other hand, a fuller economic analysis of the total investments required for different alternatives not only in the power supply industry, but also in the associated mining and fuel processing industries, and those associated with transport and disposal of fossil and fissile fuels would tend to increase the margin of differences between the hydro costs and its alternatives in its favour.

An economic factor, which requires further analysis is regarding the relative foreign exchange components of these alternatives under existing conditions. At the stage when all heavy plant and equipment was being imported, the preference lay with hydro-electric schemes as their capital investment had the highest indigenous content. With recent trends of indigenous manufacture, the position has become somewhat different and complex. During earlier stages of manufacture the information given by our manufacturers to Parliament's "Committee on Public Undertakings" indicated that manufacture of hydro units had already developed to a stage where it involved relatively lower import content than manufacture of steam sets. We have separately recommended that the PEC may obtain information in this regard. The exact position may be reviewed when this information is received.

8.2.3 Both CWPC's perspective plan for most economic development of power supply and the Energy Survey Committee's Report (1965), had recommended—with indications of exact sites to be developed—that 52% of the total capacity during 1969-74, should be of hydel installations. Actually, they account, instead, for just 40% of the total now (Annex. XI). Failure to develop the country's hydel resources at a faster pace during the past decade, and the resort instead to large-scale thermal generation, especially in areas within economic reach of hydel potential and remote from our collieries, thus saddling our power systems with energy generation costs 5-6 P higher than necessary, emerges as the most important contributing factor to current high prices for power supply. If the admittedly more economic path of lowest cost developments suggested earlier had been followed, at prevailing tariffs, the power supply industry would be generating additional Revenue surpluses of the order of Rs. 180 Crores during the 4th Plan.

(Annex-XII). This figure of cost benefit would increase during the 5th Plan if steps are not immediately taken to put the country's power development plans back on the path of lowest cost developments. The main reasons for our inability to ensure choice of schemes for expansion of power generation and supply following the path of lowest cost developments in the past are (i) delay in adopting the regional approach to power development—which alone would have provided the necessary wide canvas for choice of the most economic alternatives, (ii) a consistent lack, in the final stages of planning, of a perspective approach designed to secure lowest cost developments, (iii) expectations of large surpluses (subsequently behind) of by-product fuels from coal washeries, (iv) and a general prevailing impression about large and decisive differences in the "construction time" factor in favour of conventional thermal generation. Other reasons, less important, are the large-scale dependence during the past decade on foreign aid and hence on alternatives which inevitably involved choices with higher import contents, and the orientation of our public sector heavy electrical equipment factories towards manufacturing steam generating units. Now that the reasons for higher power supply costs are apparent, and it is desired that they should be reduced, remedial measures must be taken and rational considerations allowed to prevail in the future in the choice of schemes for expansion of power generation and supply.

8.2.4 Costs of energy generation and supply in this country have now to be drastically controlled and reduced; full utilisation of generating facilities already built up has to be ensured; and we have also to ensure that limited capital allocations to the power supply industry go the farthest distance in meeting our estimated deficits. To achieve these objectives, it is inescapable that, during the Fifth and Sixth Plans, the bulk (about two-thirds) of new generating capacity to be added must be derived from hydro sources, both of the energy intensive and peaking categories, as laid down most recently by the Inter-ministerial Working Group on Power for the Fourth Plan (1968) which took into account the requirements of the Fifth Plan. For, this alone can arrest the steady increases in costs of power supply. The balance of new generating capacity should be derived from super-steam power stations, employing the largest possible unit sizes, and located at the coal washeries/coal mines, since this alternative is bound to be cheaper in the immediate future, and in the long run than locating the thermal stations far away from the collieries. Nuclear power generation would have to be resorted to preferentially at all points which are remote from collieries and involve long haulage of coal in steadily increasing measure. The above provides the broad guidelines for future power policy to ensure utmost economy in power generation and supply for the foreseeable future, accordingly the current costs and trends in the fields of hydro, thermal and nuclear generation. It has to be noted, however, that a predominantly hydro based power plan involves considerably greater effort at the stages of investigation and planning, and the institutional apparatus for this has to be arranged.

8.3 *Institutional changes necessary to ensure that economic plans are drawn up, implemented and that the power stations are operated for optimum economy* :

8.3.1 The Study Group noted that in the past high cost power stations have come to be developed at several places and on an extensive scale, in preference to cheaper alternatives. The impact of these departures from the economic plans drawn up by the perspective plan and Energy Survey Committee during the Fourth Plan has been estimated as high as Rs. 180 crores of additional costs of power supply. This has largely been the result of the lack of adherence to the perspective plan for power development and advance action thereon at the appropriate time. It was the unanimous conclusion of all members that it is imperative now that a perspective plan aimed at securing the lowest cost paths of development should immediately be drawn up at the Central level and its adherence ensured. All necessary efforts should be made for progressing investigations on a country-wide basis and on preparation of proper reports. The Study Group considered that the main weaknesses lie in the institutional arrangements and that building up adequate machinery to improve the present state of affairs is the paramount need. The objectives and the work involved has first to be spelt out.

8.3.2 The work involved in ensuring economy in power supply could be considered broadly in three categories; (a) investigations and planning, covering the entire process from the station or project concept, its preliminary and detailed investigations in the field, project designs, fitting the scheme into perspective plans, and extending right up to the stage of initiation of construction; (b) actual construction; and (c) coordination of operation of the station into State/regional power systems. It is a highly complex technical function, which also involves extensive co-ordination of the activities of a number of organisations at State/regional and Central levels. The Study Group felt that, as at present situated, it would have to be tackled from two points of view, one, the long-term (when the desired institutional re-modelling is completed); and the other, to meet the immediate short-term requirement of suitably orienting the Fifth Plan programme, which would have to be done within the existing frame-work.

The long-term economic perspective plan, it was felt, would have to be drawn up independently for the power sector and co-related and fitted into the overall economic plans. As future power development cannot be organised rationally and economically on a state basis, the study group felt that the perspective plan should be prepared on a Regional basis. The Fourth Plan recognises this as a basis feature of future planning which has been accepted by the National Development Council.

The Study Group felt that perspective plans could easily be made on the basis of regional demands for power, projected from historical trends. These demands for power could be adjusted for any departures that would be seen to be necessary, on a comparison with overall perspective projections, which, it is understood, are made from time to time by the Planning Commission. The long-term plan would have to be reviewed at regular intervals, which may correspond with the periods for which the perspective plans of the Planning Commission are prepared, and in any case should be reviewed every year, on the basis of up-to-date information available. The Study Group felt that the longterm perspective plan must provide sufficient flexibility for changes which may be required to meet short-term requirements of the overall economy but must always be such as to ensure power supply ahead of demand. Once finalised, there should be a firm commitment to implementation of this perspective plan at the desired rate, at the Central/State levels. No uneconomic schmes should be considered as individual additions thereafter.

8.3.3 *Planning at the Central level*

The Study Group reviewed the present position of responsibility for planning for power at the Central level, and found that it is at present divided between the Planning Commission, the CW&PC (Power Wing), the Technical Advisory Committee (now the *Ad hoc* Committee), the Ministries of Irrigation & Power and Finance. The Study Group considered that this division of responsibility was not conducive to a unified and purposeful approach which is so essential now for economic planning in the power supply industry. It felt that the entire work of preparing long-term perspective plans should be entrusted to a single centralised agency which is competent to carry it out, and ensure that the above objectives are achieved. The work involved being primarily of a technical nature, the main question to be decided is whether this central responsibility should be discharged by the CW&PC (Power Wing) or the Central Electricity Authority.

The CW&PC has been set up primarily as a high level *Consultant* body to function at the request of State and other organisations. It has no statutory authority for carrying out investigations and this seems to be the biggest bottleneck in implementation of economic plans. Notwithstanding major contributions e.g. national hydro-electric surveys (1953-60). preparation of the first perspective plan for power development (1962) and other important contributions to planning and designs of power projects, it would be noted that the CW&PC was not entrusted by the Central Government with the work of investigations of 62 hydel sites. Its co-ordinating role in this regard has not been effective, judged by results. The position is best summarised by Dr. Bhagvantam, Chairman of the CW&PC Reorganisation Committee in March 1969, in his letter of transmittal of the Committee's report :

> "By and large, the CW&PC had during the course of its existence over the last two decades discharged its functions satisfactorily, *commensurate with the status given to the organisation,* and the responsibility devolving on those at the top level. Nevertheless, the Committee feels that it could have done much better had it been given *adequate powers* to deal with the problems at a national level."

The Central Electricity Authority, on the other hand, even now enjoys statutory status and has the responsibility inter alia to develop a sound, adequate and uniform national power policy, and to co-ordinate the activities of the various planning agencies in the country, to carry out such investigations as are necessary and to collect and record all data concerning generation, distribution and utilisation of power and the development of power resources. These powers, it may be noted were vested in the CEA on the basis of the recommendations of the Select Committee appointed by the Constituent Assembly to consider the Electricity Supply Bill-which ultimately became the Electricity (Supply) Act, 1948—which deliberately widened the scope and functions of the Authority. They had felt even then that non-statutory institutions would not serve the purpose even of discharging the duties of the Electricity (Supply) Act of 1948. The Indian Atomic Energy Act, 1962, while empowering the Central Govt. "to develop a sound and adequate national policy in regard to atomic power", also lays down that the Central Government should "co-ordinate such policy with the CEA". This Act further directs (a) that the Central Government should "fix rates for and regulate the supply of electricity from atomic power stations with the *concurrence of the* CEA", and (b) that "differences of opinion between the Central Govt. and any State Electricity Board in regard to construction of necessary transmission lines (for inter-State supply of power from nuclear power stations), the matter shall be referred to the Central Electricity Authority whose decision shall be binding on the parties concerned". It is clear from the above, that the required status to ensure that the work of planning for power development is carried out unimpeded, already vests in the CEA, in Principle.

It was noted that the Bhagvantam Committee has recommended, though not unanimously, that the Central Electricity Authority should concern itself in future only with *arbitration work* and that its functions other than arbitration should be added on to the Power Wing of the CW&PC, "after undertaking such legislation as may be necessary".

No particular reason has been advanced by the Bhagvantam Committee beyond the statement : "This Committee also feels that the CEA should concern itself with arbitration work only and nothing else". In his dissenting note Shri H. R. Bhatia, recalls the views of the Government of India on the Gokhale Committee's recommendations regarding the CEA :

> "The Central Electricity Authority is charged inter-alia with the development of a sound, adequate and uniform national power policy and particularly with the co-ordination of the activities of the planning agencies in relation to the control and utilisation of national power resources. In view of the heavy programme of power development in the country, *any change in the Constitution of the Central Electricity Authority,* and reduction of its functions to a mere Arbitration *Board would be a retrograde step.*"

This was the view then indicated by the Ministry of I&P to the Estimates Committee of Parliament in 1963. Shri Bhatia has argued that the present situation calls for greater concentration of effort and strengthening of CEA rather than weakening it. It is noted that the present position is that a final decision on the question has yet to be taken by the Government of India.

In this connection, the Study Group feels that, when a statutory authority like the Central Electricity Authority is already in existence, is fully invested with powers to undertake all the work required on rational considerations, and it is admitted on all hands that it is lack of this statutory status which has been inhibiting the work of the CW&PC it is obviously not necessary to look for any other agency to carry out this task. As Shri Bhatia has stated, there is no point in introducing or attempting fresh legislation merely for taking away functions from the Central Electricity Authority and entrusting it to another Commission. The Study Group, therefore, came to the conclusion that the overall responsibility for planning for power, including investigations, and processing of schemes right upto the point of initiation of construction, should be centralised clearly, as required by existing legislation with the Central Electricity Authority. This will, in effect, mean activisation of the Central Electricity Authority which has never been set up as a full-time body, and is, therefore, not adequately equipped now to discharge this responsibility. The CW&PC has been carrying out these responsibilities on a *de facto* basis. In fact, there appears to be no reason why the CW&PC (Power Wing) or the units thereof which are engaged on this work, should not be reconstituted as the Central Electricity Authority, and the Authority further strengthened on a technical and administrative plane to discharge these and other centralised functions indicated in the Bhagwantam Committee report, effectively.

The Study Group realised that the implementation of schemes included by the Central Electricity Authority in the perspective plans would always depend on the availability of funds, and that the Planning Commission are essentially concerned with this aspect. It would be necessary for the CEA to ascertain the position of availability of funds from the Planning Commission and to adjust their programmes accordingly The Study Group felt that the Planning Commission may be requested to advise the CEA of the extent of funds available in a particular 5-year plan or a particular year for the development of power and the CEA may then communicate sanction to schemes within the limits of available funds. It would improve matters further, if a representative of the Planning Commission functions on a part time basis on the Authority. The ministries of Irrigation & Power, Finance and Law are already represented on the C.E.A., in that capacity. Of the basis of these sanctions of the CEA, the regional authorities, the State Government and Electricity Boards may then proceed to issue final sanctions and execute projects.

The Study Group considered in some detail the mechanics of preparation of the perspective plan and of ensuring, on short-term and long-term basis, that investigations of power projects are actually carried out on an adequate basis. The time has clearly come when the original jurisdiction of the CEA for carrying out investigations and overall planning in the best regional and national interests, should be invoked to remedy the prevailing ills. For long-term regional planning, the Study Group felt that advantage should be taken of existing institutions at Regional/State levels for they would be in the best position to evaluate new schemes for expansion of power generation and supply in the best interests of the region as a whole. They should be encouraged to take the help of CW&PC/other consultants in preparing feasibility reports as needed to expedite work. These feasibility reports should be forwarded to the Central Electricity Authority who would fit them into their overall perspective plan. After the inclusion of schemes in the perspective plan detailed designs for projects selected on regional basis may be arranged. In this, again, either the help of CW&PC's design organisation, or of consultants already working in this field may be utilised when needed.

The Study Group felt that the immediate problem concerns the selection of schemes for meeting demands during the Fifth Plan period as it may be some time before the CEA is fully constituted and activised. For this purpose, it was agreed that the Planning Commission would immediately address all Electricity Boards and State Governments asking them to forward to the Central authorities concerned a list of all proposals for expansion of power generation and supply on the most economic lines, along with feasibility reports prepared on the basis of investigations carried out. The Planning Commission would make it clear to the State Governments that the object to locate all economically beneficial schemes and that these schemes will be considered irrespective of the availability of demands for power in the respective States or of financial resources within the State Plans. It would also have to indicate that in future following decisions taken at the National Development Council, priorities for schemes of power generation and supply would be based on choosing the most economically beneficial ones in each Region. The schemes proposed by the State Governments will be scrutinised on these lines by the CW&PC (Power Wing) and thereafter the State Governments/Electricity Boards would be requested to prepare and forward detailed project reports in respect of those schemes which are approved in principle. The Study Group felt that if this position is made clear to various States, on the basis of investigations carried out so far, sufficient project proposals/feasibility reports/detailed project reports would be forthcoming to choose the most economical schemes for the Fifth Plan. It will also act as a great incentive to the States well endowed with natural resources to investigate them quickly and prepare schemes for their development to meet regional requirements. The further programme of investigations can be reviewed by the CW&PC/CEA after the response to this approach is known.

8.3.4 *Construction of Projects* :

The question of the agency for construction of schemes chosen essentially on regional basis was considered by the Study Group. They felt that at times and in certain cases such as nuclear power stations it may be more appropriate for the Centre to directly undertake the construction and maintenance of some of these stations. In other cases, the alternative of the States themselves implementing these projects on a joint venture, perhaps with central assistance cannot be ruled out, as in this manner, it would be possible to utilise local enthusiasm to the maximum possible extent. It is also entirely possible that certain States would have built up adequate technical capacity, though not endowed with all the financial resources to implement large schemes of regional importance, entirely by themselves. In such cases, with an adequate assurance that the States concerned would implement the scheme in time according to the requirements of the entire region, even this alternative of entrusting the implementation of regional projects to such well-equipped individual States should be considered. The Study Group was of the view that a pragmatic approach to the problem of construction of power schemes selected on a regional basis, which would keep all these alternatives open, would be preferable. They felt that the institution of Control Boards which has developed to meet the pattern of requirements of constructing large multistate, multiple-purpose projects and has been extended even to sing-purpose power projects located in one State, can be usefully followed. In regard to the composition of the Boards, their accountability to the authorities, financing etc. the Study Group suggested that it should follow closely the pattern of financing of the projects.

8.3.5 *Regional Electricity Boards* :

The regional organisations would be primarily concerned with ensuring maximum economy at the stage of operation of the power systems. In each region, they would have to be adequately organised and equipped to ensure that the State power systems are operated in an integrated manner, i.e., as if the entire power facilities were under a common ownership. The relationship of the Regional Electricity Boards to the Central Electricity Authority requires to be clarified either the Electricity (Supply) Act, 1948 which creates the Central Electricity Authority, nor the resolutions of the Government which create the Regional Electricity Boards, clarifies the assumption, made in some quarters, that the Regional Electricity Boards function under the Central Electricity Authority. Actually, they are at present only voluntary associations of State Electricity Boards, who have given their consent to the national policy of integrated operation of power systems of contiguous States, for mutual advantage. According to the resolution, the Boards are supposed to function in an advisory capacity, but constituted as they are, of powerful executive bodies, there is nothing to prevent decisions taken by them in concert, from being immediately implemented. Regional load despatch centres are to be set up under the Fourth Plan for ensuring the necessary co-ordination of State-Central power stations/systems for integrated operation. In this connection, the question of the authority for operation of the Regional centres becomes important. This is essentially an operational function and it is obvious that necessary authority for the purpose would have to be relegated to the regional organisation by the State organisations, who own most of the facilities in their respective areas. It is considered however that the regional organisations would have to be considerably strengthened on the technical side, and given statutory recognition—the difference from statutory authority—should be noted. The relationship between the CEA and the Regional Electricity Boards should also be clearly spelt out.

The Study Group felt that once the Central Electricity Authority is constituted as recommended by them, and the Regional Electricity Boards are also duly strengthened they will be in an advantageous position to assist the Central Electricity Authority in planning for expansion of power supply in each region according to the best economic interest and the interest of the region as a whole.

8.3.6 *Special Situations* :

With the suggestions made above, the Study Group felt that it would be possible to deal with problems of the Fifth Plan, and, on building up of the Regional Electricity Boards and the Central Electricity Authority, the problem on a long-term basis also can be effectively tackled. However they recognised that there would be certain areas of the country, such as the Indus Valley, Godavari Basin etc. where the magnitude of the schemes, geographical locations etc. are such that the above institutional arrangements may not be adequate. In such cases, separate River Valley authorities may be more conducive both for conducting of the investigations in their respective valleys and for executing the projects as individual schemes find a place in the overall perspective plan. These are, however, special cases which should be dealt on their merits.

8.4 *Indigenous manufacturing capacity of heavy electrical equipment* :

At present the requirements of different kinds of heavy electrical equipment—hydro, thermal, nuclear etc.—for maximum economy of the power supply industry, and actual capacity built-up in the equipment manufacturing industry, are unfortunately opposite to each other. The industry ostensibily has surplus capacity to meet requirements of thermal units, but is woefully short on capacity to supply hydro units, and consequently strongly prefers the former to be utilised in greater measure on our power system. For every 1000 MW of conventional thermal capacity which is substituted for hydel installations at prevailing investment and operating costs, the power supply industry would have to incur additional working expenses of order of Rs. 25 crores every year, besides arranging for the additional initial investments required, which would vary with the actual costs of the hydel schemes so postponed. It can ill afford to pay this price for the failure of the heavy electrical equipment manufacturing industry to organise itself for manufacture of hydro units, on the originally targeted scale (1.8 million KW annually, plus converted capacity at Ranipur) and at conventional pace. The Study Group recommends that an appropriate resolution oh the subject may be immediately forwarded by the PEC to the Government in view of its importance.

8.5 *Central Assistance* :

The inability of the various States to provide adequate financial resources for expansion of power supply on the scales required even to maintain historical rates of growth has often been set out as one of the reasons for the low allocations to power in the Fourth Plan. Central involvement would obviously have to be on a more generous scale than in the past to correct this situation, but it would have to be judiciously oriented towards those solutions which represent the most economic ones for the States, the regions and the country as whole. At present, there are no clear principles guiding the indirect central assistance which accompanies decisions to construct certain projects e.g. Neyveli, Damodar Valley power stations and nuclear power stations, either wholly or partly in the Central sector. Undoubtedly, these decisions are regarded by the States as major forms of Central assistance, and often lead other States to clamour for them, even when the solution are *prima facie* unattractive on a techno-economic basis. The immediate interest of Kerala in a nuclear station illustrates the point. The Study Group might like to suggest that in a choice of schemes on a regional basis, and particularly for deciding on the scope of Central assistance to these projects, a set of financial principles which clearly put a premium on the most economic alternatives would have to be laid down and followed uniformally to avoid uneconomic solutions and avoidable friction.

8.6 *Collection and publication of data* :

The Study Group noted that the collection and publication of data, particularly of actual data regarding investment costs, operating performance of power stations and power systems of different categories is not being discharged. In fact, the information collected by Member (Comml.), CW&PC was found to be the only data regarding actual costs which is available to us on some acceptable and uniform basis. The great value of this data in introducing a sense of practical economies was accepted by members, who felt that collection and publication of relevant cost and economic data regarding generation and operation of power systems would go a long way towards introducing the necessary cost consciousness in the power supply industry and the country as a whole. This is a statutory function of CEA, which it has not been able to discharge so far. It should be organised to do so without delay.

8.7 *Economic factors for power development in each region* :

The main economic factors which must prevail in the choice of appropriate sources of power supply in *each region* in the country can now be considered. Future expansions of capacity must be planned not merely on a calculation of the deficit between maximum demands and the firm capacity of individual State systems as at present but after assessing the full energy potential of each Regional Grid and the firm capacity of the Regional Grid as a whole. The effect of diversities in demand in the Region must also be taken into account to arrive at the Regional maximum demand, and the regional energy requirements. The most economical paths for meeting the deficits in these two categories during the 5th Plan, for which options are still open, have then to be laid down on a long-term basis. Owing to shortage of time, schemes/sites of development are not being suggested in this paper in complete detail. Such details can easily be worked out once the approach indicated below is generally approved by the Study Group.

Northern Region :

In the Northern Region, at the end of the 4th Plan the aggregate installed capacity would be 6000 MW, of which 3000 MW will be hydro, 2600 MW thermal, and 400 MW nuclear. To reduce the cost of power in this region, the bulk of its power supply can and must be derived from the hydro electric resources, with initiation of large-scale nuclear generation to meet demands of the early eighties. That the main sources of hydro power in H.P. and J&K are not unfavourably located and are ample enough to meet the combined requirements of all these States and Punjab, Haryana, Delhi, Northern Rajasthan and perhaps the western most part of U.P. for the forseeable future is beyond doubt. Unfortunately U.P. does not have major economic hydel located within its boundaries and this is the main reason why during the past decade they have resorted, in increasing measures to high cost thermal alternatives. Consideration of development of the colossal hydro resources of the Sarda and Karnali rivers on the basis of international co-operation is, therefore, an urgent economic necessity and would provide very large blocks of power, at the lowest possible costs, and with an area of reticulation spreading up to Delhi, Rajasthan and stretching well into the Eastern Region of the country. The economic imperatives of hydel development in this region are so great that the setting up special "Indus Valley" and "Ghagra Valley" authorities, charged with full responsibilities for this work to be done on time-bound schedules, should be considered.

Eastern Region :

This is a region of large coal reserves, which has relied, almost exclusively, on thermal generation in the past. The aggregate capacity in the region by 1973-74 would be 4600 MW, of which only 900 MW is hydel, the balance being conventional steam units. The Region thus has ample "energy" potential for meeting even 5th Plan needs, and what it needs most urgently is low investment "peaking" hydro units which would enable fuller utilisation of these thermal installations, and bring them up to the levels of performance actually attained at Neyveli and Trombay. The 1000 MW Koel Karo project and pumped storage installations. *e.g* 200 MW Konar scheme are examples which must be considered for urgent implementation by the end of the Fourth Plan or early in the Fifth Plan. Others can be planned and worked out as required. Thereafter, the relative economics of developing the Himalayan hydro resources just beyond the Northern border of the region and conventional thermal/nuclear alternatives would need to be studied in the context of reducing costs of supply in the region.

In the southern part of the Region, Orissa, with its untapped hydel potential, can adequately provide all the low cost power it needs during the Fifth and Sixth Plan periods. There are attractive schemes like Upper Indravati 600 MW, Upper Lokab (180 MW), Tikkarpara etc. which the State has already investigated and can be taken up to meet the requirements of the State as well as the region.

Southern Region :

This region, with an aggregate capacity of 5000 MW by 1973-74 of which 3600 MW would be derived from hydro resources has a good mix of different sources. For meeting future demands, Kerala and Mysore have a number hydel sites which can adequately meet the requirements of the Fifth and Sixth Plans. Mysore State in particular, has a wealth of hydel resources, as yet untapped. which can not only meet its requirements during the Fifth and Sixth Plan periods but also leave adequate surpluses for meeting the requirements of Tamil Nadu in the most economic manner. The hydel resources of Andhra Pradesh are located to the far North of the Region on inter-State stretches of the Godavari and its tributaries and requires a comprehensive basin-wise approach for their implementation. It is unlikely that coal-based thermal generation at Singareni could provide an economic source of power supply to resource scarce Tamil Nadu, competitive either with local nuclear generation or imported hydro power from Kerala and Mysore. Development of the seasonal potentialities of the Cauveri river on the inter-State stretch between Sivasamudram and Mettur through installation of reversible pump-turbines, offers a spectacular possibility of large scale seasonal energy generation combined with firm peaking capacity located at the centre of gravity of the entire Southern Region, with major possibilities of all round economy. In the Southern Region, with the range of alternatives presented on a regional canvas, available resources can easily sustain a programme of predominant hydro generation to meet the total demand, through schemes involving the lowest investment and energy costs.

Western Region :

Gujarat and Maharashtra have little untapped water power potential and they are located far away from the collieries. The Narmada river, which has a limited potential of about 2000 MW at 3 or 4 sites below Punassa, is the source of importance in the western portion of the State. Madhya Pradesh has a number of hydel sites on its northern and southern peripheries—viz. the southern tributaries of Ganga, and the Induravati river (Godavari valley), which it could usefully exploit to bring down prevailing high costs of generation. The basic problem in the Western Region would be to provide energy at the lowest cost levels at the western fringe of this area viz. the coastal stretch between Bombay, Ahmedabad and Surat. Located as it is, the nuclear alternatives are prima facie the only answer for low cost energy supply in this area. However, to operate the nuclear stations at base load, it would be desirable to provide complementary hydro peaking alternatives, and intensive surveys would have to carried out to ensure that straight hydro peaking schemes and pumped storage developments are developed in time.

North-Eastern Region :

This is a region, where there is a natural abundance of hydro power. Demands even by 1980 would not utilise more than a small fraction of the firm power resources based largely on run-of-the-river developments. It can, without doubt, sustain all its industries on water power alone at the lowest cost levels. This region has such abundant resources of cheap power that special efforts would in fact be called for to utilise these hydel resources by relying on them for various electricity-intensive alternatives such as production of fertilizer and enrichment of uranium, if considered necessary.

ANNEXURE—I(A)

COST OF ENERGY FROM HYDRO POWER PLANTS

Sl. No.	Power Plant	Installed capacity (MW)	Firm annual energy potential million kWh	Estimated investment cost on generation (Rs. lakhs)	Investment cost/kW installed (Rs.)	Cost of firm energy generation (Paise/kWh)
1.	Bhakra Nangal	1084	3540	8571	790	2·06
2.	Kundah (stages I, II & III)	425	1745	6423	1510	2·76
3.	Sabarigiri	300	1335	4300	1430	2·42
4.	Koyna (stages I & II)	540	2150	5644	1040	1·97
5.	Rihand	300	900	3754	1250	3·12
6.	Ranapratapsagar	172	500	1328	770	1·99
7.	Sharavathi	890	4680	10096	1140	1·62
8.	Parambikulam-Alliyar	185	586	1746	940	2·24
9.	Kodiar	100	342	1482	1480	3·25
10.	Idikki Stage I	390	1865	6820	1750	2·74
11.	Kuttiadi	75	273	825	1100	2·26
12.	Yamuna Stage II	360	1140	7017	1950	4·62
13.	Koyna Stage III	320	590	3800	1190	4·82
14.	Pandiar-Punnapusha	100	415	1525	1525	2·76
15.	Jawaharsagar	99	316	1842	1860	4·37
16.	Beas-Sutlej Link (Dehar and 5th unit at Bhakra R. B.)	780	3900	13938	1790	2·68
17.	Baira Siul	200	950	1873	940	1·48
18.	Salal	270	1740	5225	1940	2·26
19.	Logtak	70	368	1006	1440	2·05

Note :

1. In working out cost of energy generation, interest has been assumed at 6% and depreciation on sinking fund basis.
2. As consumption by power station auxiliaries is very small in the hydro plants, the cost of energy sent out will be approximately the same as the cost of energy generation.
3. Power plants at Sl. Nos. 1—6 are completed. Power plants at Sl. Nos. 7 & 8 are partly completed. The rest of the plants are under construction.

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ANNEXURE—I(B)

COST OF ENERGY FROM THERMAL POWER PLANTS

Sl. No.	Power Plant	Installed capacity (MW)	Estimated investment cost on generation (Rs. lakhs)	Investment cost/kW installed (Rs.)	Cost of energy Generation (paise/kWh) 45% P.F.	50% P.F.	60% P.F.	70% P.F.	75% P.F.
1	2	3	4	5	6	7	8	9	10
1.	Bandel	330	3362	1020	4·88	4·62	4·22	3·94	3·82
2.	Chandrapura 3rd Unit .	140	1261	900	4·29	4·05	3·70	3·45	3·35
3.	Indraprastha (Delhi) .	187·5	2533	1350	7·70	7·35	6·83	6·45	6·30
4.	Harduaganj Stage III .	100	2000	2000	9·12	8·60	7·83	7·29	7·05
5.	Korba-Stage II . .	200	3028	1510	6·03	5·63	5·04	4·62	4·45
6.	Kothagudam—Stage II .	120	1333	1110	6·09	5·80	5·38	5·07	4·94
7.	Talcher	250	2967	1190	5·11	4·80	4·34	4·01	3·87
8.	Satpura	312·5	3925	1260	5·34	5·02	4·54	4·19	4·05
9.	Pathrathu	400	5271	1320	5·65	5·31	4·80	4·43	4·29
10.	Santaldih	280	7500	1560	5·99	5·60	4·99	4·56	4·38
11.	Pathrathu extension . .	220	3698	1680	6·46	6·02	5·36	4·90	4·71
12.	Obra extension . .	300	5334	1780	7·18	6·71	6·02	5·53	5·33
13.	Harduaganj—Stage IV .	110	2156	1960	9·03	8·52	7·76	7·22	7·00
14.	Nasik	280	4785	1710	7·28	6·84	6·17	5·69	5·51
15.	Ennore	340	5814	1710	8·09	7·65	6·98	6·50	6·32
16.	Badarpur	300	5600	1870	9·02	8·53	7·82	7·30	7·10
17.	Bhatinda	220	4090	1860	8·79	8·30	7·59	7·07	6·87
18.	Ukai	480	6800	1420	7·09	6·72	6·17	5·78	5·62
19.	Kothagudam—Stage III .	220	4400	2000	8·24	7·72	6·95	6·39	6·17

ANNEXURE—I(B)

Sl. No.		Cost of energy				
		Sent out (paisc/kWh)				
		45% P.F.	50% P.F.	60% P.F.	70% P.F.	75% P.F.
1		11	12	13	14	15
1.	Bandel	5·31	5·02	4·58	4·28	4·14
2.	Chandrapura 3rd Unit .	4·66	4·40	4·20	3·74	3·64
3.	Indraprastha (Delhi) .	8·36	8·00	7·43	7·02	6·85
4.	Harduaganj State III .	9·93	9·36	8·51	7·93	7·66
5.	Korba—Stage II . .	6·56	6·13	5·48	5·03	4·84
6.	Kothagudam—Stage II .	6·63	6·31	5·86	5·51	5·37
7.	Talcher . . .	5·56	5·22	4·72	4·36	4·21
8.	Satpura	5·80	5·46	4·94	4·56	4·41
9.	Pathrathu . . .	6·14	5·78	5·22	4·82	4·66
10.	Santaldih . . .	6·52	6·09	5·43	4·96	4·77
11.	Pathrathu extension . .	7·04	6·55	5·83	5·33	5·11
12.	Obra extension . .	7·82	7·30	6·55	6·02	5·81
13.	Harduaganj—Stage IV .	9·83	9·27	8·44	7·86	7·62
14.	Nasik	7·92	7·45	6·71	6·19	5·99
15.	Ennore	8·80	8·32	7·60	7·07	6·88
16.	Badarpur	9·81	9·29	8·51	7·94	7·73
17.	Bhatinda	9·56	9·04	8·26	7·69	7·48
18.	Ukai	7·70	7·30	6·71	6·28	6·11
19.	Kothagudam—Stage III .	8·96	8·41	7·56	6·96	6·77

1. In working out cost of energy, interest has been assumed at 6% and depreciation on sinking fund basis.
2. Consumption by power station auxiliaries has been assumed at 8%.
3. The cost of energy at 75% P. F. has been indicated to enable comparison with nuclear plants whose economics are being considered on this basis. It has to be noted that it would not be possible to operate thermal power plants at such high plant factors.
4. Power plants at Sl. Nos. 1 to 8 are completed. Power plant at Sl. No. 9 is partly completed. The rest are under construction.
5. Power plants at Sl. Nos. 1 to 9 were either completed (fully or partly) or under advanced stage of construction at the time of devaluation and this is reflected in their capital outlay.
6. The cost of Ukai power plant (Sl. No. 18) is based on the indications given during the Annual Plan discussions (1970-71). It appears to be on the low side. On the basis of Rs. 1800/- per kW installed obtaining at plants under construction at present, the costs of energy generation/sent out at 60% P. F. would be 6·90 paise and 7·50 paise per kWh.

ANNEXURE—II

COMPARISONS OF COSTS OF ELECTRICITY GENERATION IN TYPICAL THERMAL AND NUCLEAR STATIONS

I. *Capital Costs*

(Approximate plant size 300—700 MW)

Rs. per kW of capacity

	Storage Hydel Plant designed for 75% Plant Factor	Storage Hydel Plant designed for 60% Plant Factor	Storage Hydel Plant designed for 30% Plant Factor	Thermal Plant	Nuclear Plant
	1	2	3	4	5
	Period 1965-66 to 1970-71				
Indigenous Investment	905	776	516	380	750
Imported equipment	201	194	180	570	750
Assumed tax on imported equipment . . .	66	64	59	188	248
Interest during period of construction . . .	387	341	249	205	474
Total investment per kW Capacity	1559	1375	1004	1343	2222
	Period 1970-71 to 1975-76				
Indigenous Investment	956	824	561	595	1110
Imported equipment	152	146	135	255	300
Assumed tax on imported equipment . . .	50	48	45	84	99
Interest during period of construction . . .	382	336	344	168	405
Total Investment per kW Capacity	1540	1354	985	1102	1904

ANNEXURE II—*Contd.*

II. *Operation Costs*

Stations Constructed during 1965-66 to 1970-71

paise per kWh.

	Storage Hydel			Thermal					
				Zero Cost Coal			Medium Cost Coal		
Assumed Plant Factor	75%	60%	30%	75%	60%	30%	75%	60%	30%
Financial Charge	2·4	2·7	4·0	2·3	2·8	5·6	2·3	2·8	5·6
Fuel costs	..	..	..	0·1	0·1	0·1	1·5	1·5	1·5
Operation & Maintenance	0·2	0·2	0·3	0·2	0·3	0·5	0·2	0·3	0·5
Special Insurance	..	..	..	..	..	..	..	..	..
Total cost per kWh.	2·6	2·9	4·3	2·6	3·2	6·2	4·0	4·6	7·6
Stations Constructed during period 1970-71 to 1975-76									
Financial charges	2·4	2·6	3·9	1·9	2·3	4·6	1·9	2·3	4·6
Fuel costs	..	..	..	0·1	0·1	0·1	1·4	1·4	1·4
Operation & Maintenance	0·2	0·2	0·3	0·2	0·3	0·5	0·2	0·3	0·5
Special Insurance	..	..	..	..	..	..	..	..	..
Total cost per kWh.	2·6	2·8	4·2	2·2	2·7	5·2	3·5	4·0	6·5

ANNEXURE II—*Contd.*

II. *Operation Costs*

Stations Constructed during 1965-66 to 1970-71

paise per kWh

	Thermal			Nuclear		
	High Cost Coal					
Assumed Plant Factor	75%	60%	30%	75%	60%	30%
Financial Charges	2·3	2·8	5·6	3·7	1·7	9·3
Fuel costs	3·2	3·2	3·2	0·6	0·6	0·6
operation & Maintenance	0·2	0·3	0·5	0·3	0·4	0·7
Special Insurance	..	..	..	0·1	0·1	0·2
Total cost per kWh.	5·7	6·3	9·3	4·7	5·8	10·8
Stations Constructed during period 1970-71 to 1975-76						
Financial charges	1·9	2·3	4·6	3·2	4·0	8·0
Fuel costs	3·0	3·0	3·0	0·5	0·5	0·5
Operation & Maintenance	0·2	0·3	0·5	0·4	0·5	0·7
Special Insurance	..	..	..	0·1	0·1	0·2
Total cost per kWh.	5·1	5·6	8·1	4·1	5·0	9·4

Extracted from report of the energy survey of India Committee (1965).

ANNEXURE—III

TYPICAL COST OF ENERGY GENERATION IN MIXED HYDRO-THERMAL SYSTEMS

CASE—A.

Assume that thermal and hydro installed capacities are approximately equal *i.e.* for 1 kW of thermal capacity, there is 1 kW of hydro capacity for complementary operation.

(*i*) With 2 kW of installed capacity, a total load of 1·5 kW at bus bars can be met .

(*ii*) Annual energy corresponding to 1·5 kW of load at 60% annual system load factor . . . . 7900 kWh.

(*iii*) Annual energy generation corresponding to (ii) above assuming 6% for auxiliary consumption and transformer loss on the average . . . . 8500 kWh.

(*iv*) Annual energy generation from thermal stations . . . . . . 5500 kWh.
hydro station 3000 kWh.

(*v*) **Annual charges for energy generation**

Thermal

(*a*) Interest @ 6% of capital outlay at Rs. 1800/- per kW	Rs.	108·00
(*b*) Depreciation	Rs.	29·60
(*c*) Operation and maintenance	Rs.	45·00
(*d*) Fuel charges (at pit head rates)	Rs.	90·00
TOTAL	Rs.	272·60

Hydro

(*a*) Interest charges @ 6% of capital outlay of Rs. 1200/- per kW installed (*i.e.* corresponding to Rs. 2000/- per kW of firm power at system load factor	Rs.	72·00
(*b*) Depreciation	Rs.	3·40
(*c*) Operation and Maintenance	Rs.	14·00
TOTAL	Rs.	89·40

Total annual charges Rs. 272.60+Rs. 89.40=Rs. 362·00

(*vi*) Cost of energy generation =Rs. $\frac{362}{8500}$

= 4·26 P/kWh

(*vii*) Cost of energy at power station bus bars : Rs. $\frac{362}{7900}$

= 4·58 P/kWh

CASE—B

Assume that thermal and hydro installed capacities are approximately in the ratio 2 : 1 *i.e.* for 2 kW of thermal capacity there is 1 kW of hydro capacity for complementary operation.

(*i*) With 3 kW of installed capacity, a total load of 2·5 kW at bus bars can be met.

(*ii*) Annual energy corresponding to 2·5 kW of load at 60% annual system load factor . . . . 11,800 kWh.

(*iii*) Annual energy generation corresponding to (ii) above assuming 6% for auxiliary consumption and transformer loss on the average . . . . 12,600 kWh.

(*iv*) Annual energy generation from thermal station . . . . 9,600 kWh.
Hydro Station . . . . 3,000 kWh.

ANNEXURE III—*Contd.*

(*v*) Annual charges for energy generation

Thermal

(*a*) Interest @ 6% of capital outlay at Rs. 1800/- per kW	Rs.	216·00
(*b*) Depreciation	Rs.	59·20
(*c*) Operation and Maintenance	Rs.	90·00
(*d*) Fuel charges (at pit head rates)	Rs.	157·00
TOTAL	Rs.	522·20

Hydro

(*a*) Interest charges at 6% of capital outlay of Rs. 1200/- per kW installed (*i.e.* corresponding to Rs. 2000/- per kW of firm power at system load factor)	Rs.	72·00
(*b*) Depreciation	Rs.	3·40
(*c*) Operation and Maintenance	Rs.	14·00
TOTAL	Rs.	89·40
Total annual charges—Rs. 522·20+Rs. 89·40	Rs.	611·60
(*vi*) Cost of energy generation	Rs.	611·60 / 12600
		4·85 P/kWh
(*vii*) Cost of energy at power station bus bars	Rs.	611·60 / 18100
		5.18 P/kWh.

NOTE : 1. Depreciation has been worked out on sinking fund basis assuming an interest rate of 6%. In the case of hydro projects, it has been assumed that (i) 2/3 of the total capital outlay will be on Civil Works and the balance in electrical works and (ii) the civil works have a life of 100 years and the electrical works have a life of 35 years. In the case of thermal plants, the life has been assumed at 25 years.

2. The cost of coal for thermal stations has been assumed at Rs. 30/- per tonne and specific consumption at 0·35 per kWh.

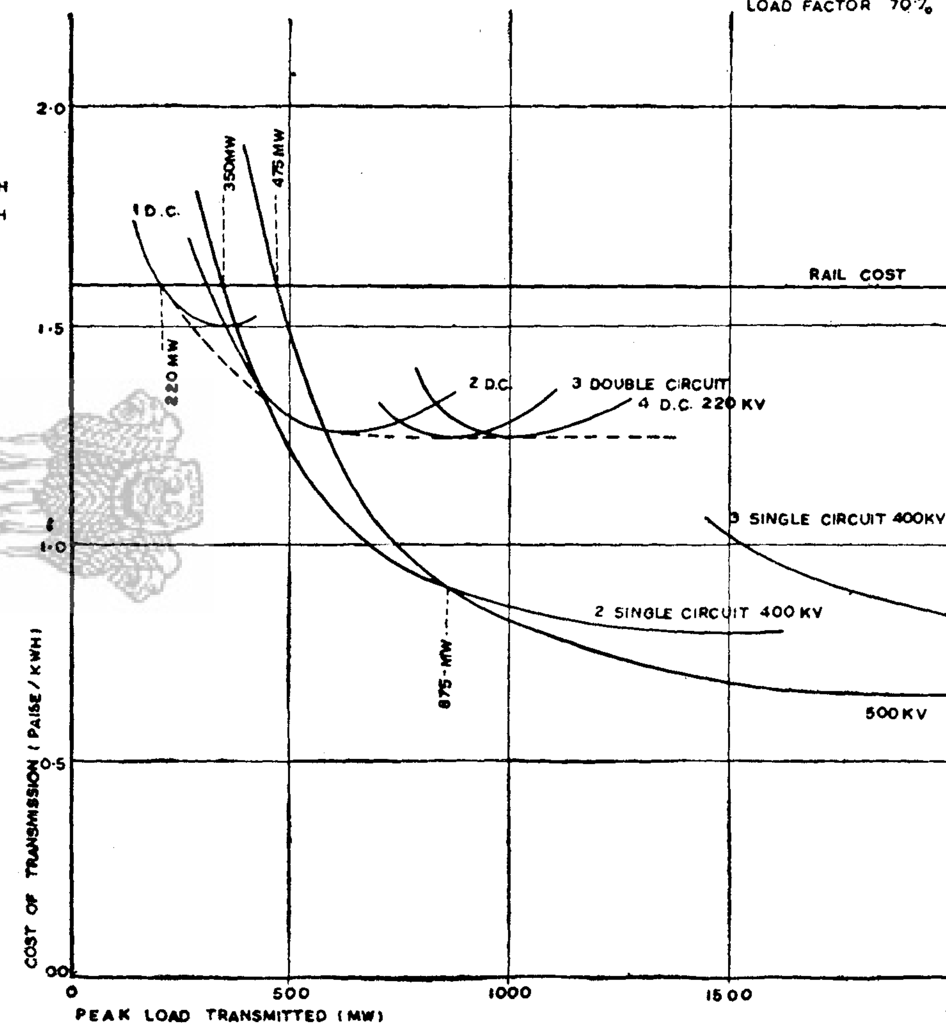
ANNEXURE IV

VARIATION OF TRANSMISSION COSTS WITH LOAD

LOAD FACTOR 70%

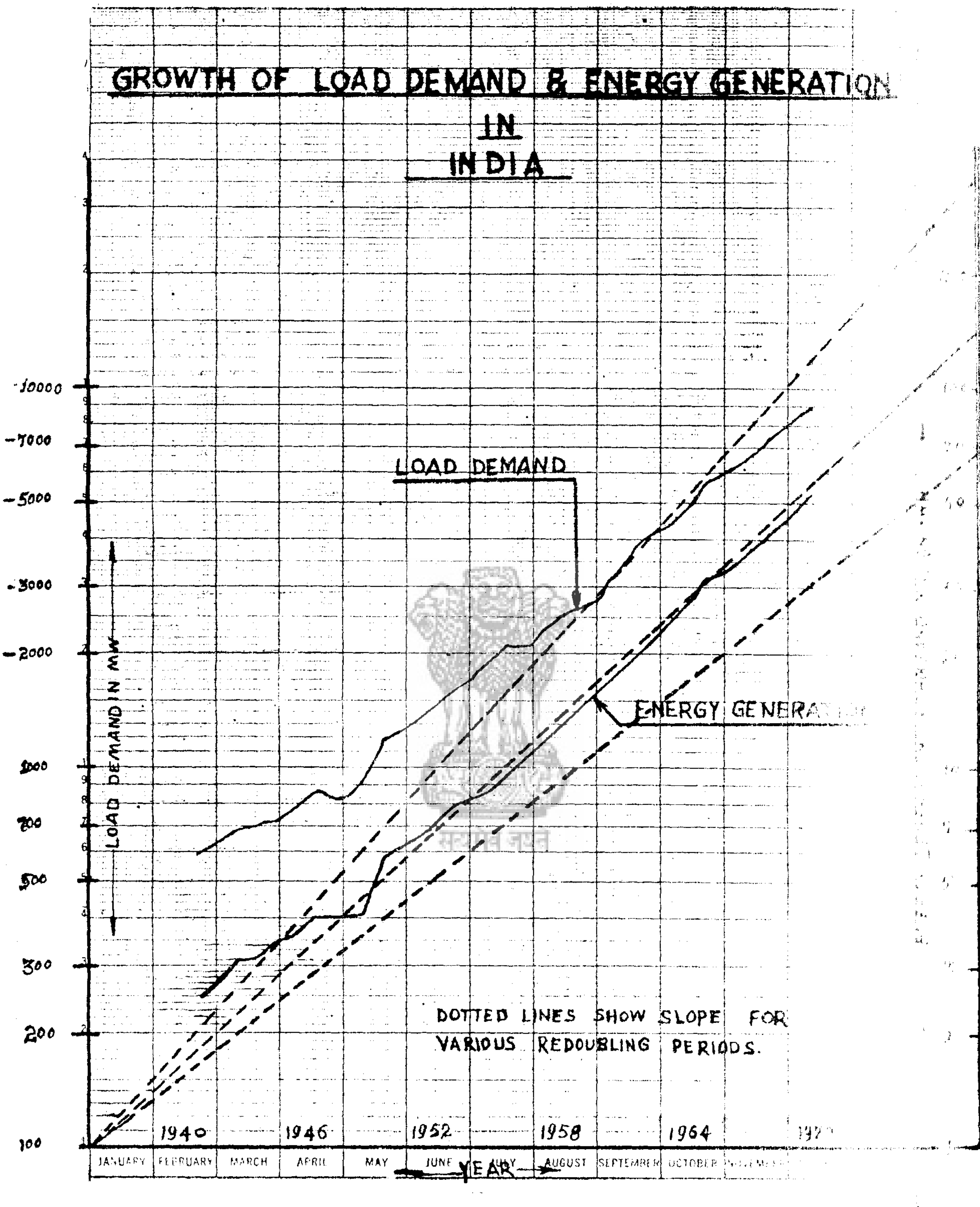
ASSUMPTIONS:-

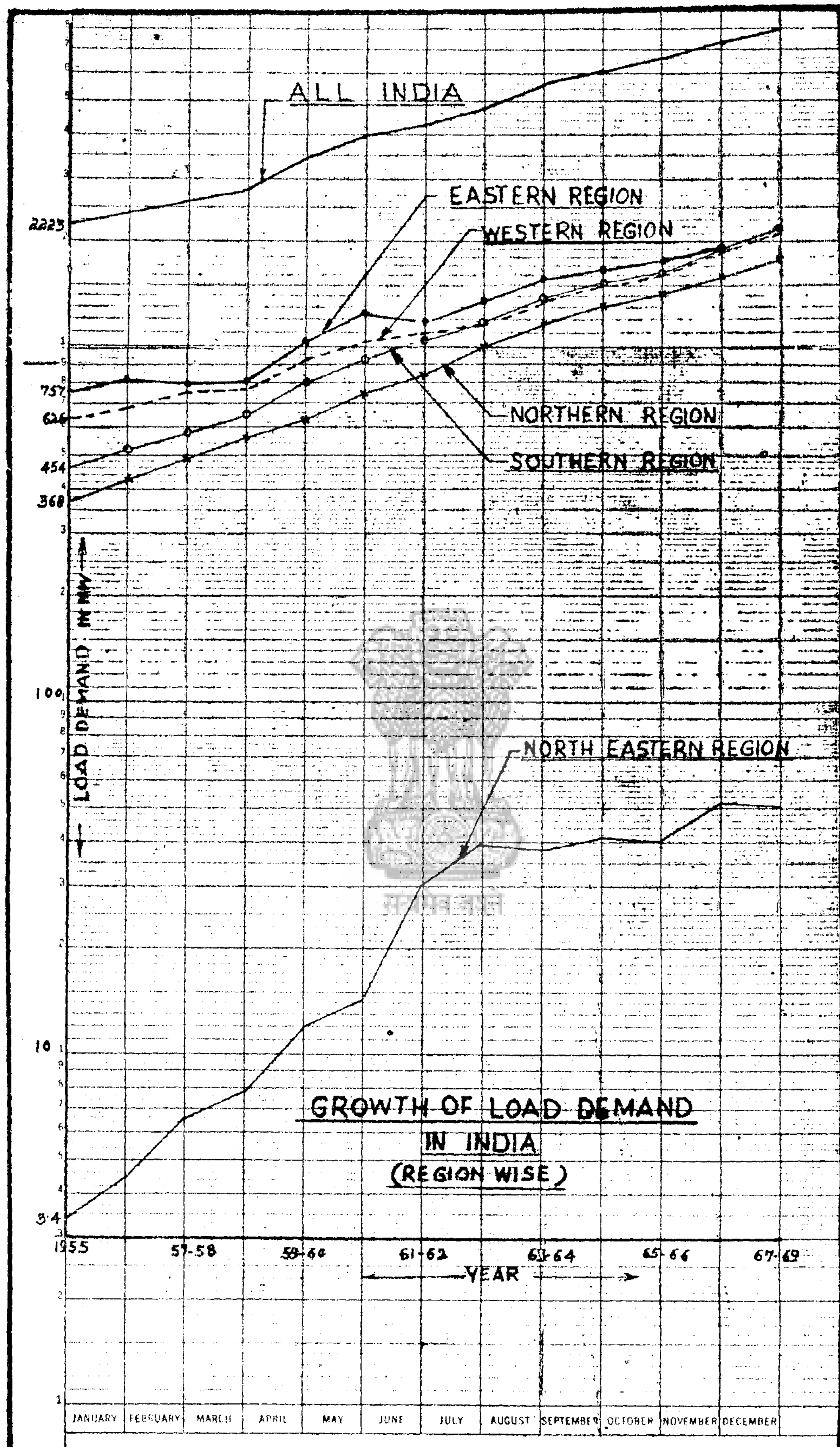
1. CALORIFIC VALUE OF COAL.....4900 K CAL / KG
2. COST OF COAL AT MINE MOUTH...RS. 35 62/ TONNE
3. COST OF COAL AT BOMBAY BY RAIL..RS. 69 12 / TONNE
4. NET HEAT RATES FOR THERMAL UNITS....2300 K CAL/ KWH.
5. FUEL COST AT MINE MOUTH....1·67 PAISA /KWH
6. FUEL COST AT BOMBAY FOR RAIL TRANSPORT....3·25 PAISA / KWH
7. DIFFERENTIAL COST FOR RAIL TRANSPORT......1·58 PAISA / KWH
8. COST OF TRANSMISSION IS FOR A DISTANCE OF 700 KM AND INCLUDES.
   - i INTEREST ON CAPITAL....... 6%
   - ii DEPRECIATION WITH 35 YEARS LIFE AND 10% SALVAGE VALUE...... 2·6%
   - iii O & M CHARGES......... 1·4%



SOURCE:- EHV TRANSMISSION STUDY BY TATA CONSULTING ENGINEERS, BOMBAY.

P.P.GUPTA S.LAL


GROWTH OF LOAD DEMAND & ENERGY GENERATION
IN
INDIA
LOAD DEMAND
ENERGY GENERA
LOAD DEMAND IN MW
10000
7000
5000
3000
2000
1000
700
500
300
200
100
DOTTED LINES SHOW SLOPE FOR
VARIOUS REDOUBLING PERIODS.
1940
1946
1952
1958
1964
YEAR


ALL INDIA
EASTERN REGION
WESTERN REGION
NORTHERN REGION
SOUTHERN REGION
NORTH EASTERN REGION
2223
757
626
454
368
100
10
3·4
LOAD DEMAND IN MW
1955
57-58
59-60
61-62
63-64
65-66
67-69
YEAR
GROWTH OF LOAD DEMAND
IN INDIA
(REGION WISE)

ANNEXURE—VII(A)

CONSTRUCTION PERIOD OF RECENTLY COMPLETED HYDRO PROJECTS IN INDIA

Sl. No.	Name of Project	State	Installed capacity [no. and size of Unit (MW)	Date of commencement of investigation	Date of submission of first proposal	Date of sanction of project by Planning Commission	Date of commencement of active construction work	Date of commissioning of first Unit	Date of Completion of Project	[illegible]
1	2	3	4	5	6	7	8	9	10	11
1.	Kundah Stage I & II . .	Tamil Nadu	PH I-2×20 PH II-4×25	1947	1952	Sept., 1955	June 1956	March, 1960	June 1961	
2.	Kundah Stage III	Tamil Nadu	PH I-1×20 PH II-1×35 PH III-2×60 PH IV-1×50 PH V-1×20	*	Oct., 1959	Sept., 1960	Jan., 1961	Feb., 1964	Feb., 1966	
3.	Mettur Tunnel	Tamil Nadu	4×50	**	Nov., 1957	Jan., 1960	Aug., 1960	Aug., 1965	July, 1966	
4.	Panniar . .	Kerala	2×15	1953 (Approx.)	1954	Aug., 1956	1956	Dec., 1963	Jan., 1964	
5.	Sholayar . .	Kerala	3×18	1953 (Approx.)	1954	Aug., 1960	Nov., 1960	May, 1966	May, 1968	
6.	Sabarigiri . .	Kerala	6×50	1953	1955	Aug., 1960	Feb., 1961	April 1966	Nov., 1967	
7.	Sharavathi Stage I	Mysore	2×89	1952	1954	June 1956	Oct., 1959	Dec., 1964	June, 1965	
8.	Sharavathi Stage II	Mysore	6×89	1952	1954	June 1956	1963	Oct., 1967	March 1967	
9.	Koyna Stage I .	Maharashtra	4×60	1946	1950	1953	March 1956	May 1962	Feb., 1963	
10.	Koyna Stage II .	Do.	4×75			1953	June, 1964	March, 1966	June, 1967	
11.	Upper Sileru .	Andhra Pradesh	2×60	1954-55	1957	Sept., 1959	April, 1961	Oct., 1967	March, 1968	
12.	Gandhi Sagar .	M.P./ Rajasthan	5×23	..	1949@	..	Jan., 1953	Nov., 1960	3 Units March, 1961 (Aug., 1963 4th Unit) March, 1967 (5th Unit)	
13.	Ranapratap Sagar	M.P./ Rajasthan	4×43		1949@	May, 1960	April, 1962	Jan., 1968	May, 1969	
14.	Bhakra Nangal .	Punjab/ Haryana/. Rajasthan								

ANNEXURE VII (A)—*contd.*

1	2	3	4	5	6	7	8	9	10	11	12
	(*a*) Ganguwal .		2×24 1×29	1945***	1945	..	1948	Jan., 1955	Jan., 1955 Dec., 1961 (3rd Unit)	7	
	(*b*) Kotla . .		2×24 1×29					July, 1956	July, 1956 Dec., 1961 (3rd Unit)	8	
	(*c*) Left Bank (Bhakra) .		5×90				1948 (Bhakra Dam)	Nov., 1960	Dec., 1961 (All 5 Unit) commissioned)	12	
	(*d*) Right Bank (Bhakra) .		5×120					May, 1966	Dec., 1968		
15.	Yamuna Stage I	U. P.	3×11·25 *3×17	1947	1948	Mar£, 1967	1960/ 1961	Nov., 1965	Not yet		
16.	Rihand . .	U. P.	6×50	1945 Prel. investigation 1951-52 detailed investigations	1952 1957		££Apr., 1957	1961/ 1962	Mar., 1966	4½	
17.	Hirakud . .	Orissa	4×37·5	1945	June 1947		@@1951	1956	1958/59%	7	

*The Stage III development had been envisaged while revising the proposals for Stages I & II in 1953-54, and the project has been implemented on this basis.

**As this is a development at the existing Mettur Dam, no major investigations were involved.

@The proposal was for a unified development of the Chembal Valley, the construction of which was taken up in stages.

***Some investigations had been carried out during 1916 to 1919.

£ Stage I was aproved by U. P. Government in 1949 but work was postponed due to paucity of funds. The work was restarted in 1956-57 but again stopped till the investigation of Koch Dam was completed. Active construction started in 1960-61.

££Global Tenders were invited and work awarded to M/s. Hindustan Construction in April, 1955, but the work started in April, 1957.

@@In 1948, the Government of Orissa accorded administrative approval to the construction of Hirakud Dam. Preliminary work started in May, 1948 and completed by September, 1950. The Dam was completed in 1957.

%Hirakud Stage I completed in 1958-59 while Stage II in September, 1963.

ANNEXURE VII(B)

PERIOD OF CONSTRUCTION OF SOME HYDRO PROJECTS IN FOREIGN COUNTRIES

Sl. No.	Name of Project	Country	Installed capacity (MW)	No. and Unit size (MW)	Date of commencement of construction	Date of completion of project	Period of construction (Years)
1	2	3	4	5	6	7	8
1.	Glen Canyon	U.S.A.	896	8×112	May, 1957	1964	7
2.	Palisades	U.S.A.	116	4×29	1951	1957	6
3.	Melton Hilladam—TVA	U.S.A.	72	2×36	Sept., 1960	Nov., 1964	4½
4.	Serrabonoon	France	920	4×80	1955	1961	6
5.	La Bathic Power Project	France	528MVA	6×88MVA	1956	1962	6
6.	Fessenheim	France	180MVA	4×45MVA	1952	1957	5
7.	Vogelgrum	France	156MVA	4×39MVA	1955	1959	4
8.	Marocolsheim	France	168MVA	4×42MVA	1956	1961	5
9.	Phcnau	France	168MVA	4×42MVA	1960	1963	3
10.	Harrsele	Sweden	225MVA	3×75MVA	June 1963	Sept., 1957 (2 Units commissioned)	4½
11.	Kaunerta Development	Austria	385	5×77	1961	1965	4
12.	Upper Tuloma	U.S.S.R	225	4×56·25	1961	Sept., 1965	4
13.	Mauvoism	Switzerland	252·5		1949	1958	9
14.	The River Caroni Project—Macagua No. I	Venezeula	370	6×61·5	1954	1962	8
15.	Pullinque	Chile	48	3×16	1954	1961	7
16.	Volta River Project—Akosombo Dam	Ghana	512	4×128	May, 1961	1966	5
17.	Mangla Dam	Pakistan	1000	10×100	July, 1962	July, 1967 (2 Units commissioned)	5

सत्यमेव जयते

ANNEXURE—IX

COAL WASHERIES PROGRAMME

(Quantities in million tonnes per annum)

Sl. No.	Name	Owner	Present/rated Capacity Raw coal input	Present/rated Capacity Clean coal output	Estimated availability of washery by-product fuel 1970-71	1971-72	1972-73	1973-74	Remarks
1	2	3	4	5	6	7	8	9	10
			Two Product						
1.	Lodna	Turner Morrison	0·50	0·30	0·07	0·08	0·08	0·08	Rated capacities is expected to be expanded during the Fourth Plan period.
2.	Durgapur . . .	West Bengal (DCOP)	1·20	0·60	0·14	0·14	0·22	0·30	
3.	Dugda II . . .	H.S.L.	2·40	1·20	0·29	0·29	0·29	0·40	
4.	Bhojudih . . .	H.S.L.	2·00	1·40	0·54	0·54	0·54	0·55	
5.	Kathara . . .	N.C.D.C.	3·00	1·50	1·05	1·08	1·08	1·44	
6.	Sawang	N.C.D.C.	0·75	0·50	0·18	0·18	0·18	0·24	
7.	Gidi (Blendable)	N.C.D.C.	2·84	1·80	0·09	0·13	0·26	0·80	
			12·69	7·30	2·36	2·44	2·65	3·81	
			Three Product						
1.	West Bokaro . . .	TISCO	0·45	0·30	0·07	0·07	0·07	0·08	Rated capacities are expected to be expanded during the Fourth Plan period.
2.	Jamadoba . . .	TISCO	1·44	1·00	0·24	0·24	0·27	0·35	
3.	Durgapur . . .	H.S.L.	1·50	1·90	0·16	0·16	0·16	0·16	
4.	Dugda I	H.S.L.	2·40	1·44	0·24	0·25	0·25	0·41	
5.	Patherdih . . .	H.S.L.	2·00	1·30	0·30	0·30	0·30	0·30	
6.	Kargali . . .	N.C.D.C.	2·72	1·80	0·27	0·27	0·40	0·40	
7.	Chasnalla . . .	IISCO	2·70	1·90	0·05	0·05	0·19	0·34	
	TOTAL . .		13·21	8·64	1·33	1·34	1·67	2·04	

ANNEXURE—X

Extract from "Uranium Resources—Revised Estimates December, 1967—A joint Report by the European Nuclear Energy Agency and the International Atomic Energy Agency.

Uranium Resource Estimates—India :

The greatest effort in the development of uranium resources in India continues to be focussed on the Singhbhum thrust belt in Bihar, where lately a few new deposits have been located. Exploration including substantial core drilling, is also underway, however, in several areas.

The bulk of the evaluated reserves of 72,500 short tons U308 in the Singhbhum thrust belt is of low grade, ranging between 0.02 to 0.49% U308, out of which 15,000 short tons U308 are contained in the ore averaging 0.05% U308 and above. The latter includes the reserves of Jaduguda with an average overall grade of 0.07% U308, even after taking into account 0.1% U308 ore locally met at depth in a few bore holes. The exact price category is uncertain and only some 3,000 short tons of Reasonably assured Resources and Estimated Additional Resources of about 1,000 short tons U308 expected below 600 metres depth may be classified in the $ 10 to 15 per pound range (the cost of extraction being near the maximum of this range. (The balance of 11,000 short tons of U308 contained in the ore averaging 0.05% U308 and above is considered to be marginal, due to lack of by-products, remoteness from the established mill at Jaduguda and consequent haulage involved etc. Hence they may be tentatively classified under $ 15—30 per pound price range.

The extensive (37,500 short tons) low grade material between 0.02 and 0.049% U308 can be economically worked only if large scale open-cast operations are undertaken and high percentage of recovery achieved by low cost methods of treatment. Besides this, there are 3,000 short tons of Reasonably Assured and 17,000 short tons of estimated Additional Resources obtainable as by-product of mining for copper in the extensive Roam-Rakha-Tamapahar deposit with reserves of 98 million tons of copper ore containing on an average 0.02% U308. The lower grade uraniferous copper ores of the Mosabani Mine, from the tailings of which averaging 0.012% U308 the uranium could not be extracted economically due to poor recovery, have, however, been left out of consideration. As the percentage recovery of uranium for the Roam-Rakha-Tamaphar ore achievable under full scale conditions is not known, the 20,000 short tons of resources available from this source have been tentatively included in the $ 15—30 category.

The monazite deposits of India contain about one part uranium to 25-30 parts thorium. Out of total resources of 16,500 short tons available from this source, the reasonably assured 10,000 short tons U308 are mainly in the States of Kerala and Madras where detailed exploration has been carried out. In this case also the price category is uncertain because it would depend upon the market for thorium and rare earth chlorides produced. Hence, the entire resources may be provisionally placed in over $15 per pound category.

The possiblities for additional resources are considered good, although data are still inadequate for estimation in this category. The large deposits in the Singhbhum belt have good possibilities of extensions below the persent explored depth of 600 metres and grade may continue to improve with depth. It is learnt that in the major deposits at Jaduguda and Narwapahar exploration below 600 metres will be undertaken shortly. Furthermore, untested parts of the Singhbhum belt which are covered with alluvium are favourable for additional near-surface deposits.

Uranium mineralisation has been found in the Himalaya mountains at several localities in the form of uraninite veinlets along joints and fractures in quartzites intermittently over a strike distance of 150 kilometres and also as disseminations in chlorite schists. Assessments of reserves are however not yet possible, as the exploration is in early stages. Lately uranium-bearing phosphorites have been located in the Krol series (Permo-carboniferous to Trias) and in the carbonaceous shales underlying it, which are being investigated.

Potential, but unestimated, low grade uranium resources also exist in carbonaceous clays associated with lignite deposits in South India, in uranium-bearing argillaceous sediments of several areas, in phosphatic nodules in Madras, etc.

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× × × ×

Thorium Resource Estimates :

The almost total absence of a commercial market for thorium as a nuclear fuel at present, and the uncertainty regarding its future has relegated this mineral to a comparatively minor position in the present report.

Total known resources of thorium, the availability of thorium, the availability of which is considered to be reasonably assured , are still estimated at more than half a million short tons of thorium oxide. This figure only includes tonnages which may be exploited under present technology at prices less than $10 per pound of THO2. It is not considered realistic to include a further estimate of resources above this price, artly because current indications are that such market might never exist, and partly because he data available on higher cost thorium resources is totally inadequate.

More than half of the presently known 500,000 (or more) tons of low-cost TH02 is to be found in placer deposits in India and other parts of the world. Most of the remainder is in veins in the United States and in the uranium ores of the Elliot Lake district of Canada. The economic availability of the thorium in placer deposits is presently contingent on the marketing of rare earths and other co-products, and although the demand for these products has recently shown an increase, the resultant production of thorium is still relatively small. Similarly, there has been no incentive for large-scale production from the vein deposits of thorium in the United States. Thus the majority of these resources are likely to be preserved during the forseeable future until the utilisation of thorium for nuclear power becomes feasible on a large scale.

However, thorium resources in Canada are intimately associated with uranium reserves. As the present demand for thorium is so limited, most of the thorium produced as a result of uranuim production ends up in the tailings dumps. Reserves in the dumps are estimated to contain 35,000 tons TH02.

It is considered that the total estimated Additional Resources of thorium at less than $10 per pound is just under one million tons THO2, on the basis of exploration experience in known areas of mineralisation.

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×× ×× ×× ××

Definitions :

1. In view of current trends in the marketing of uranium resources, it appears no longer realistic to consider $ 5 per pound U308 as attainable lower limit for bulk purchase.

The three original price ranges are therefore retained in the following modified form :

Less than $ 10 per pound U 308 }
$ 10 to $ 15 per pound U 308 } *
$ 15 to 30 per pound U 308 }

The form of the tables has been modified in order to emphasize the difference in reliability of the estimates of low-cost resources as compared with those in the medium to high price, brackets.

A distinction has also been made between by-product and main-product uranium.

2. Once again each price range is subdivided into two categories.

The term Reasonably Assured Resources as employed in the previous report, has been retained for the first category, and refers to material which occurs in known ore deposits of such grade, quantity and configuration that it can, within the given price range, be profitably removed from the earth and processed with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of ore-body habit. Reasonably Assured Resources in the less than $ 10 per pound category are equivalent to reserves in the mining sense.

A slight change in terminology has been introduced for the second category which is now called *Estimated Additional Resources* rather than "possible additional resources" as in the previous report, which might have been interpreted as a maximum. Furthermore, in the presentation of the figures, an attempt has been made to distinguish between estimates of resources attributed to unexplored extensions to known ore bodies and those which are postulated to exist in geologically favourable areas.

A further qualification of the total deposits estimated in the three price ranges of the two categories, is provided by the chart supplementing Table 1 which indicates the geological nature of the resources.

3. Figures for uranium resources, reserves and production refer to U308, and the basic unit adopted for commercial transactions is the pound of U308 contained in chemical concentrate.

*On the basis of 1967 Costs.

ANNEXURE—XI

Installed hydro, thermal and nuclear capacities as recommended in the CW&PC's perspective plan by the Energy Survey of India Committee and the Working Group on Power during the Fourth Plan and as per present programme.

Year	Installed capacity (MW)			
	Hydro	Thermal	Nuclear	Total
1	2	3	4	5
As per CW & PC's Perspective Plan :				
1965-66 .	5394	7832	150	13376
1970-71 .	11299	10702	975	22976
1975-76 .	18854	13802	2325	34981
1980-81 .	28144	17012	4825	49981
As per Energy Survey of India Committee (Corresponding to the growth of overall economy at an annual average rate of 6%)				
1970-71 .	9830	8830	580	19240
1975-76 .	14800	12400	1500	28700
1980-81 .	23900	18300	4000	46200
As per Working Group on Power during the IV Plan :				
1973-74 .	11262	13875	1000	26137
1978-79 .	21588	17730	2100	41418
As per actuals/planned during the Fourth Plan :				
1965-66 .	4094	6080		10174
1969-70 .	6131	8948	400	15479
1973-74 .	9097	13038	1000	23135

ANNEXURE—XII

Savings that could have been effected during the Fourth Plan if the economic path of development suggested in the .CW&PC's .Perspective Plan (1962) had been adopted.

The CW&PC's Perspective Plan (1962) had recommended a higher proportion of hydro-electric development in the country and envisaged that in 1970-71, 50% of the total installed capacity would be in hydro-electric installations and in 1975-76 hydro-electric installations would constitute about 54% of total installed capacity.

The hydro-thermal distribution in the country at present and as anticipated in 1973-74 as per Fourth Plan is as under :—

	1969-70	1973-74
	MW	MW
Hydro	6100	9100
Thermal	8900	13000
Nuclear	400	1000
TOTAL	15040	23100

If the Perspective Plan of CW&PC had been followed, for the same total installed capacities at present and in 1973-74, the hydro-thermal distribution would have been approximately as under :—

	1969-70	1973-74
	MW	MW
Hydro	7700	12500
Thermal/Nuclear	7700	10600
TOTAL	15400	23100

Higher hydro capacity affords savings on two accounts (i) savings on fuel cost due to lower energy generation from thermal sources and (ii) savings on other annual charges due to lower depreciation and operation and maintenance charges at hydro-electric plants.

Savings in Fuel Costs during the Fourth Plan :

(a) Energy generation as per actuals/ estimates in 1969-70 and anticipated in 1973-74 as per present Programme :—

	1969-70	1973-74
	MW	MW
Thermal/Nuclear	33,340	58,000
Hydro	22,850	37,000
TOTAL	56,190	95,000

(b) Energy generation in 1969-70 a 1973-74 if the Perspective Plan h been followed :

	1969-70	1973-74
	MU	Mu
Thermal/Nuclear	29,000	46,00(
Hydro	27,300	49,00C
TOTAL	56,300	95,00C

(c) Additional Thermal Generation in (a above :

1969-70	4,340	million units
1973-74	12,000	million units

(d) Total additional thermal generatior during the 5-year period (1969-70 t 1973-74) due to not following th(Perspective Plan=40,000 MU.

(e) Cost of fuel for additional thermal generation during the 5-year period at the fuel cost of 3p/unit.

$$= \frac{\text{Rs. } 40{,}000 \times 10^6 \times 3}{100}$$

=Rs. 120 crores

Note : If Perspective Plan had been followed, the installation of thermal power plants at locations far away from collieries would have been avoided. At these locations, the cost of fuel is more than 3p/unit).

II. *Saving in annual Depreciation and O & M Charges during the Fourth Plan.*

(a) Additional thermal capacity during the Fourth Plan due to non-adherence to the CW&PC's Perspective Plan :

1969-70	1600 MW
1970-71	2000 MW
1971-72	2400 MW
1972-73	2900 MW
1973-74	3400 MW

(b) Assume that the capital outlays per kW of installed capacity are the same in both the alternatives and it is Rs. 1800 per kW installed. Saving in depreciation charges if the hydro alternative is adopted is about 1.2% of capital outlay and saving in O&M charges is about 1.5% of capital outlay. Thus, the total saving if hydro alternative is adopted is 2.7% of capital outlay.

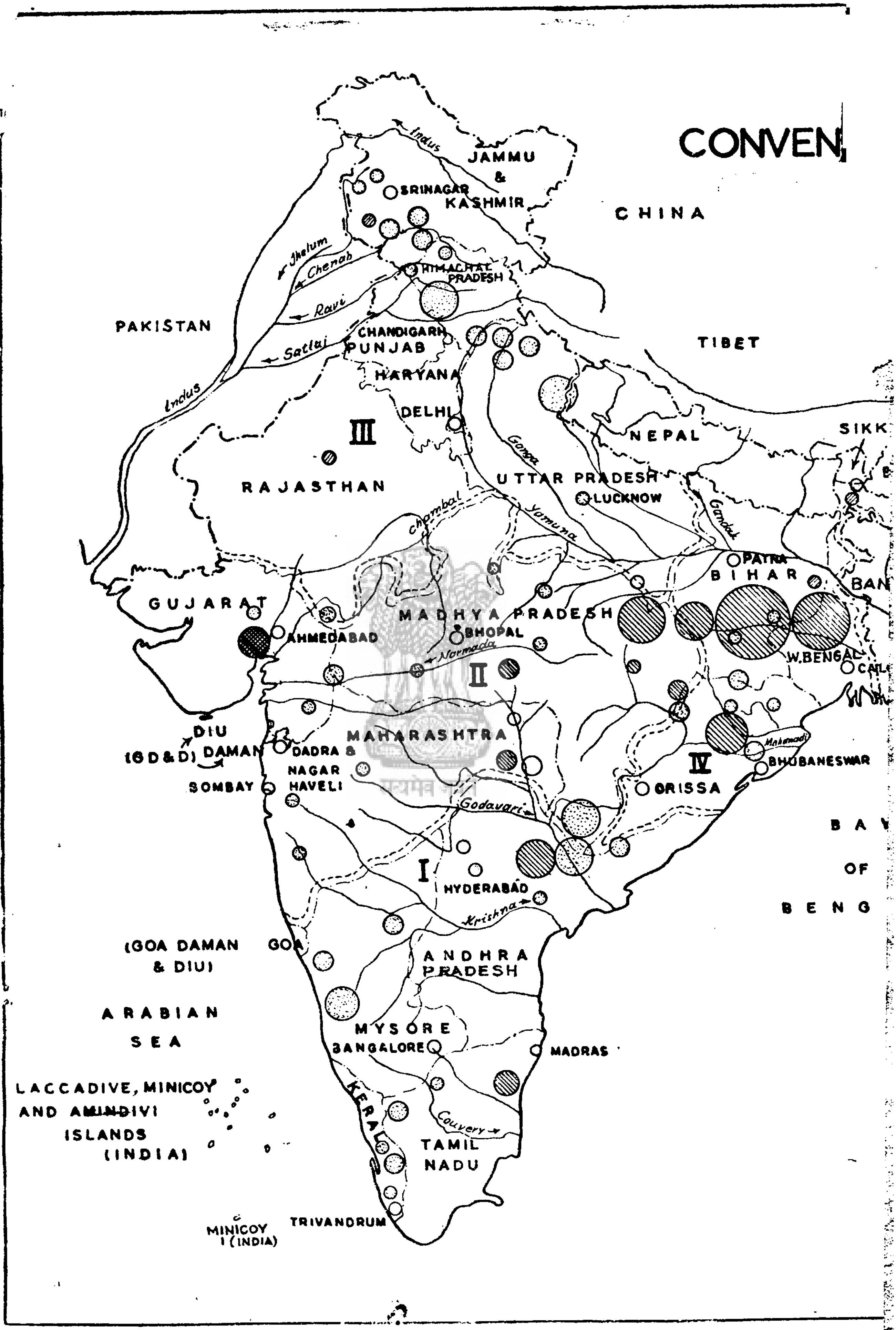
i.e. $\text{Rs.} \frac{2\cdot7}{100} \times 1800\,(1600+2000+2400+2900+3400) \times 10^6$

=Rs. 59 crores.

III. *Total Savings during the Fourth Plan* :

Savings in fuel cost	Rs. 120 crores
Savings in annual charges	Rs. 59 crores
TOTAL	Rs. 179 crores

7—782I&P/71—GIPP


CONVEN
JAMMU & KASHMIR
SRINAGAR
CHINA
Indus
Jhelum
Chenab
Ravi
Satlaj
HIMACHAL PRADESH
PAKISTAN
CHANDIGARH
PUNJAB
HARYANA
TIBET
DELHI
NEPAL
SIKK
III
RAJASTHAN
Ganga
UTTAR PRADESH
LUCKNOW
Chambal
Yamuna
Gandak
PATNA
BIHAR
BAN
GUJARAT
MADHYA PRADESH
BHOPAL
AHMEDABAD
Narmada
W.BENGAL
CAL
II
DIU
(GD&D) DAMAN
DADRA & NAGAR HAVELI
MAHARASHTRA
Mahanadi
IV
BHUBANESWAR
BOMBAY
ORISSA
Godavari
BAY OF BENG
I
HYDERABAD
Krishna
(GOA DAMAN & DIU)
GOA
ANDHRA PRADESH
ARABIAN SEA
MYSORE
BANGALORE
MADRAS
LACCADIVE, MINICOY AND AMINDIVI ISLANDS (INDIA)
KERALA
Cauvery
TAMIL NADU
MINICOY I (INDIA)
TRIVANDRUM

A

INDIA

IONAL ENERGY. RESOURCES

Scale :-

0 50 100 200 300 400 MILES

LEGEND

TOWN

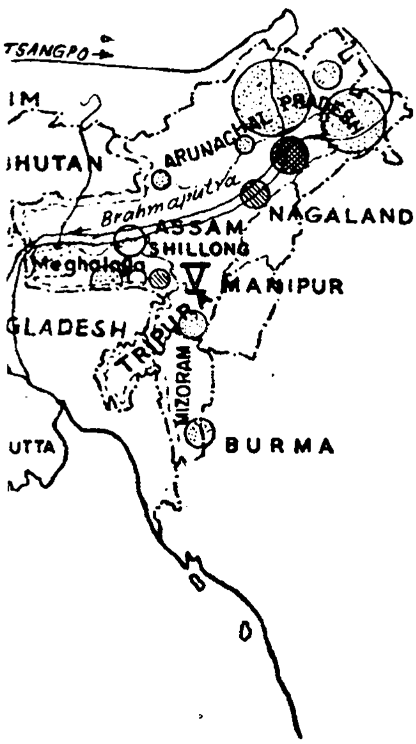
INTER STATE BOUNDARY

INTERNATIONAL BOUNDARY

HYDRO CONCENTRATION

COAL & LIGNITE RESERVE CONCENTRATION

OIL & GAS RESERVE CONCENTRATION



NOTES

1. THE TERRITORIAL WATERS OF INDIA EXTEND INTO THE SEA TO A DISTANCE OF TWELVE NAUTICAL MILES MEASURED FROM THE APPROPRIATE BASE LINE.

2. THE BOUNDARY OF MEGHALAYA SHOWN ON THIS MAP IS AS INTERPRETED FROM THE NORTH-EASTERN AREAS (REORGANISATION) ACT, 1971, BUT HAS YET TO BE VERIFIED.

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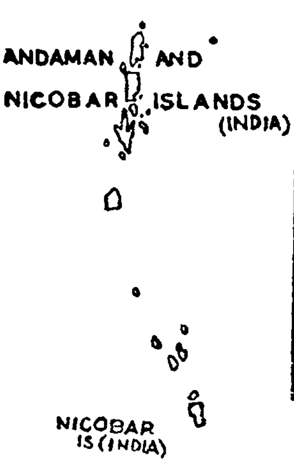

REF NO.	REGION	TOTAL COAL RESERVES 10 METRIC TONS	TOTAL LIGNITE RESERVES 10 M.TON	HYDRO RESOURCES (MW) AT 60% L.F.		TOTAL OI[L] RESERVES 10 M.TONS
				TOTAL	DEVELOPED AND UNDER DEVELOPMENT	
I	SOUTHERN	5515.50	2032.00	8097.0	3220.5 (39.80%)	
II	WESTERN		11.10	7168.9	941.5 (13.12%)	
III	NORTHERN	22887.00	20.30	10731.5	2450.7 (22.60%)	153.87
IV	EASTERN	74227.30	—	2693.7	574.0 (21.30%)	
V	NORTHEASTERN	3629.60	—	12464.4	37.5 (0.30%)	
	TOTAL :-	106,259.40	2063.40	41155.5	7224.2 (17.60%	153.87

TOD-9452

ANNEX-VIII

N

LEGEND

TOWN ------------------ ○

INTER STATE BOUNDARY-----

INTERNATIONAL BOUNDARY----

HYDRO CONCENTRATION ------

COAL & LIGNITE RESERVE CONCENTRATION -----------

OIL & GAS RESERVE CONCENTRATION ---------

:RS OF INDIA EXTEND INTO THE SEA TO A
AUTICAL MILES MEASURED FROM THE APP-

3HALAYA SHOWN ON THIS MAP IS AS
THE NORTH-EASTERN AREAS (REORGANISATION)
:T TO BE VERIFIED.

HYDRO RESOURCES (MW) AT 60% L.F.		TOTAL OIL RESERVES 10 M. TONS	TOTAL NATURAL GAS RESERVES 10 CU. METRES
TOTAL	DEVELOPED AND UNDER DEVELOPMENT		
8097.0	3220.5 (39.80%)	153.87	63,000
7168.9	941.5 (13.12%)		
10731.5	2450.7 (22.60%)		
2693.7	574.0 (21.30%)		
12464.4	37.5 (0.30%)		
41155.5	7224.2 (17.60%	153.87	63,000