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Indian power sector: Achievements and failures

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Abstract

The paper deals with the growth of India's power sector over the last 50 years since independence, touching upon some developments that followed. It also highlights the power crisis that presently faces the nation, projecting into the next decade. The role played by the Indian Institute of Science in the development of India's power sector and is now playing to help mitigate the present and future shortages is briefly discussed.

Keywords: India's power sector, role of IISc.

1. Introduction

Those who recall the power situation of the 50s in India often are nostalgic of the 'good old days' when load shedding, power shortage, and energy crisis, common expressions in contemporary India, were unknown and had not entered the general vocabulary. This is despite the fact that the installed capacity (1,700 MW) for power generation has grown 50 times over the last fifty years (Table I). Electricity was used only in major cities and hardly 3,000 out of the 5,60,000 villages were electrified.

Industrial load was minimal and domestic use mainly comprised lighting load. Fans were rare, and refrigerators and air conditioners were virtually unknown. The energy crisis faced today clearly indicates a steep rise in demand which outstrips the generating capacity of nearly 90,000 MW. Almost five lakh villages have been electrified. Pumpsets energized exceed 12 million. Industries have grown significantly. Fans, refrigerators and television sets are used widely in cities, towns and even in a number of affluent villages. The widespread growth in energy demand may be viewed as an achievement. Our inability to meet the demand is a failure.

The Indian Institute of Science (IISc) played a major role in the early years of power development in India by providing technical support in the form of training, design and testing that was lacking in the power sector those days. While the Institute continues to provide training and technical know-how for the power sector, its contributions to renewable energy resources and energy conservation have assumed significance.

2. Technical support from IISc

It may be of historical interest to know that India's first hydroelectric generator (130 kW) was set up in Darjeeling in 1897. Two 100 kW units were set up in Simla in 1908, followed by three units of 250 kW in Chaba (60 km from Simla) between 1912 and 1918. Simla was the

FIG. 1. Major power projects in India. (source: TERI Energy Data Directory and Yearbook (TEDDY) 1996/97).

some major studies carried out by EE to assist the power sector and utilities over decades, in addition to training manpower for them. The dynamic relay testing bench at EE for testing relays was the only one of its kind in India and relays were extensively tested in the Department.

The use of network analyser was discontinued in late 60s and digital computer programmes were developed to study steady state and transient problems for systems at various voltage levels including 400 and 800 kV. The Institute's High Voltage Engineering Department

Table I
Installed capacity (in megawatts) of utilities (1970/71 to 1994/95)

Type	Year								
	1970/71	1975/76	1980/81	1985/86	1990/91	1991/92	1992/93	1993/94	1994/95
Hydel	6,383	8,464	11,791	15,472	18,753	19,194	19,576	20,374	20,829
Thermal†	7,906	11,013	17,563	29,967	45,768	48,086	50,749	54,375	58,110
Nuclear	420	640	860	1,330	1,565	1,785	2,005	2,005	2,222
Total	14,709	20,117	30,214	46,769	66,086	69,065	72,330	76,753	81,161

Source: Central Electricity Authority (CEA), 1995.
† includes diesel, wind, gas, etc.

summer capital of the British and Darjeeling boasted of tea estates. The hydel units in Sivanasamudram were commissioned to meet the power requirement of the Kolar Gold Fields. There has been more than 9% cumulative growth since the British left India with about 1,700 MW of generating capacity. Figure 1 represents some of the major power projects in India today.

The mode of power generation in India at present is approximately:

Thermal*	–	61 GW = 72%
Hydroelectric	–	21 GW = 25%
Nuclear	–	2.3 GW = 3%

*includes diesel, gas, wind, etc.

The share of hydroelectric power has steadily declined from 43.4% in 1970–71 to 25% at present (Table I and Fig. 2). Barely 25% of the available hydroelectric capacity has been harnessed so far. The long gestation is due to interstate water disputes, opposition on environmental grounds and site specificity of hydel projects. It is, however, desirable that it should be augmented to 35% over the next 15 years. On the contrary, the trends indicate further decline.

During the early years of power development in the country, IISc offerred significant services in training engineers and in designing power systems.

One of the notable training centres was the 'Thermal Power Station' in the Department of Mechanical Engineering which was set up in the 40s and had a 900 kVA generator which was driven by a steam turbine and could be synchronized to the grid. Electrical, mechanical and also civil engineering students had extensive training at this power station. The Department of Atomic Energy used to depute students to IISc for training in thermal power generation. The Thermal Power Station was operated for more than three decades and a very large number of power engineers of the country had been trained at this centre. The major transmission systems of the country were designed at IISc until the 80s. The Department of Electrical Engineering (EE) had procured a Network Analyser which was invaluable when digital computer was still in the rudimentary stage of development. In designing a transmission system, it is essential that generators and their interconnecting network are suitably simulated in order to ascertain the flow of power, check voltages at various buses, or in essence carry out 'load flow' study. The network analyser was very useful in these studies. Electrification of railways and mines, distribution network, supply restoration following faults, stability studies, system protection are

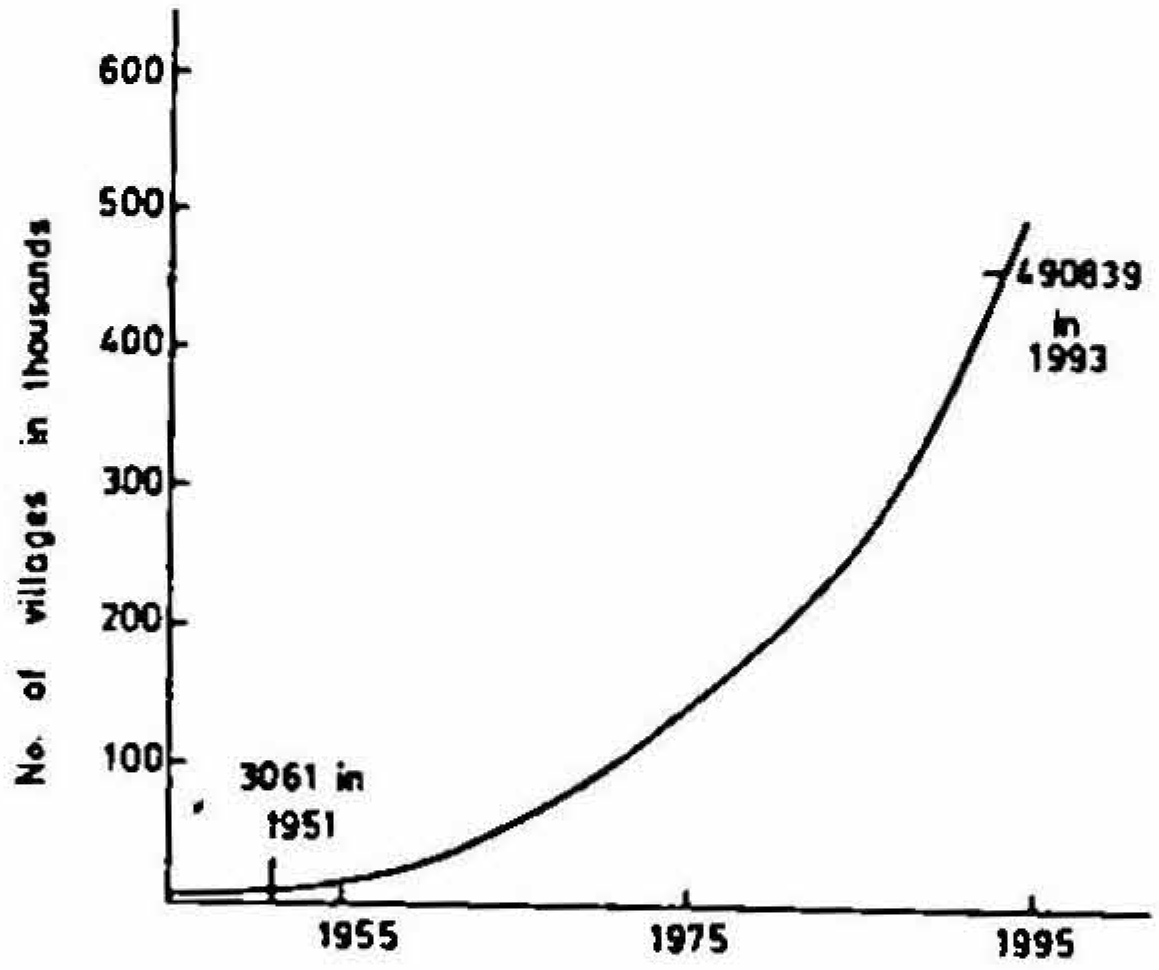

FIG. 4. Villages electrified.

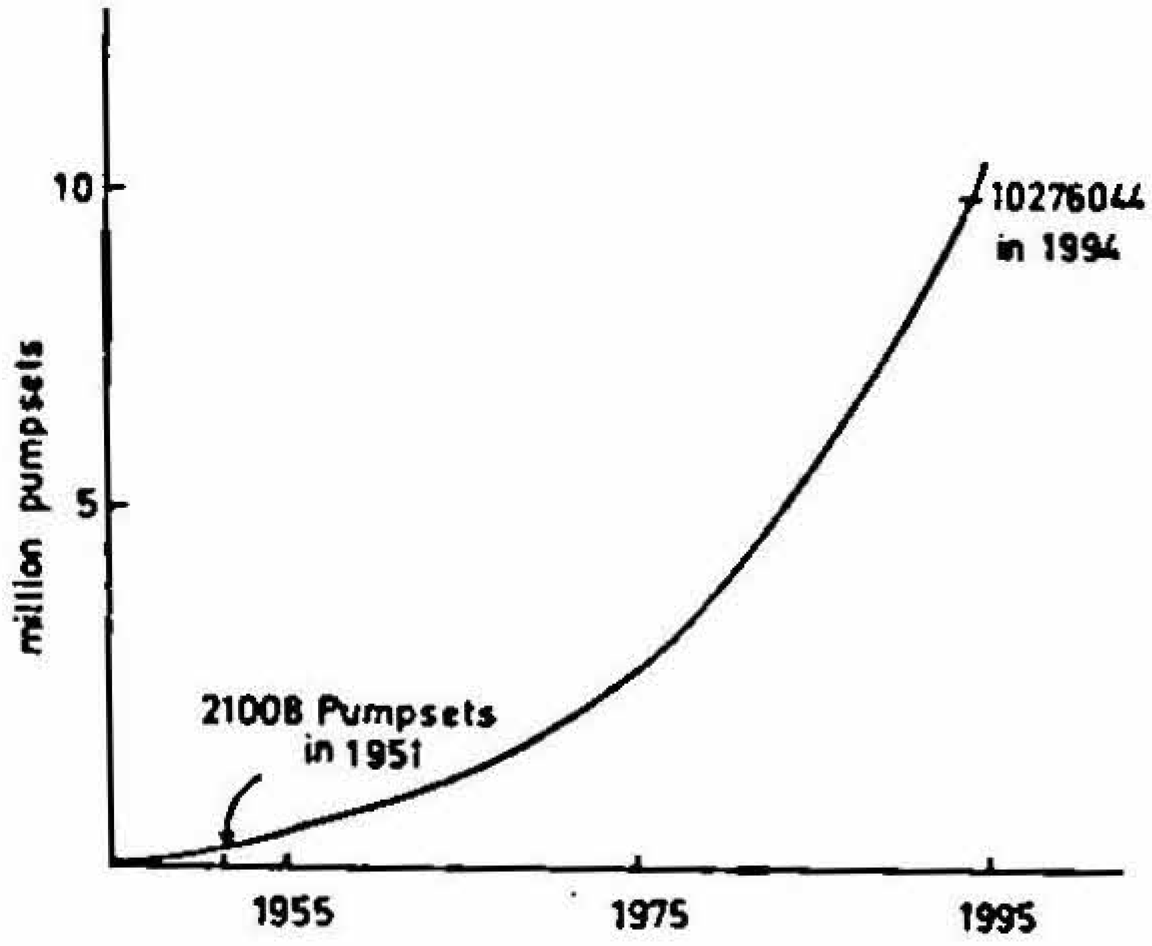

FIG. 5. Irrigation pumpsets energized.

The total number of pumpsets energized in the early 50s was less than 20,000. At 12 millions now, it has grown 600 times in about 50 years. The increase in artificial irrigation has relieved India from the vagaries of monsoons to a great extent and has turned a perennially food-deficit country, plagued by famines, to a self-sufficient one. Energy consumption in rural areas which was less than 12% in the 70s now exceeds 30%. This highly desirable aspect is marred by poor distribution network and distorted tariff system which contributes significantly to India's present power crisis.

The percentage of consumption of electrical energy in the industrial sector has reduced over the years since agricultural and domestic consumption has increased. Table II shows how the consumption of electrical energy has changed over the last 15 years. Although it increased over the years, per capita consumption of electrical energy (Table III) in India presently at 320 units, is still very low compared to developed countries which is in excess of 14,000 units/year in the US, and about 8,000 units in West European countries.

4. Rural electrification

Extensive work since independence has helped most states attain 100% rural electrification which has helped significantly in augmenting food production.

Transmission and distribution (T&D) losses in India are very large indeed, averaging 25% of the electrical energy generated. This should normally not exceed 10% (China and Korea have reduced T&D losses to less than 10%). The bulk of the losses takes place in the 11 kV and the 415 V sectors.

A computer-aided power system improvement (CAPSI) package was developed at the Department of Electrical Engineering to redesign the distribution network using interactive graphics facilities. The software provides a highly cost-effective design and has been used by a number of state electricity boards.

Extensive studies conducted by the Department on the cost-effectiveness of rural electrification in Karnataka state revealed that although rural electrification has led to a large-scale

Table II
Sectoral share (in percentage) of power consumption—utilities only (1980/81 to 1993/94)

Sector	Year					
	1980/81	1985/86	1990/91	1991/92	1992/93	1993/94
Domestic	11.2	14.0	16.5	17.3	18.0	18.2
Commercial	5.7	5.9	5.9	5.8	5.7	5.9
Industrial	58.4	54.5	44.2	42.0	40.9	39.6
Railways	2.7	2.5	2.2	2.2	2.3	2.4
Agriculture	17.8	19.1	26.4	28.2	28.7	29.6
Others	4.4	4.0	4.5	4.5	4.4	4.3

Source: Central Electricity Authority (CEA), 1995. Public Electricity Supply, All India Statistics, General Review, 1993/94, pp. 183–185, CEA, New Delhi, p. 214

provided exclusive testing facilities for almost all manufacturers of high-voltage equipment in addition to help in designing the HV system. A 2-km long, 400-kV transmission system was set up in the department for carrying out tests relating to high-voltage transmission of electricity until the late 70s.

It may be claimed without exaggeration that the Indian power sector owes a great deal to IISc for the technical support and training provided by the Institute for over eight decades.

3. Impact of the growth of power sector

The most significant impact of the growth of the power sector in India has been on agriculture and industry. Figure 3 gives an approximate breakdown of electrical energy in different sectors. Figures 4 and 5 show how rural electrification and energization of pumpsets have grown over the years .

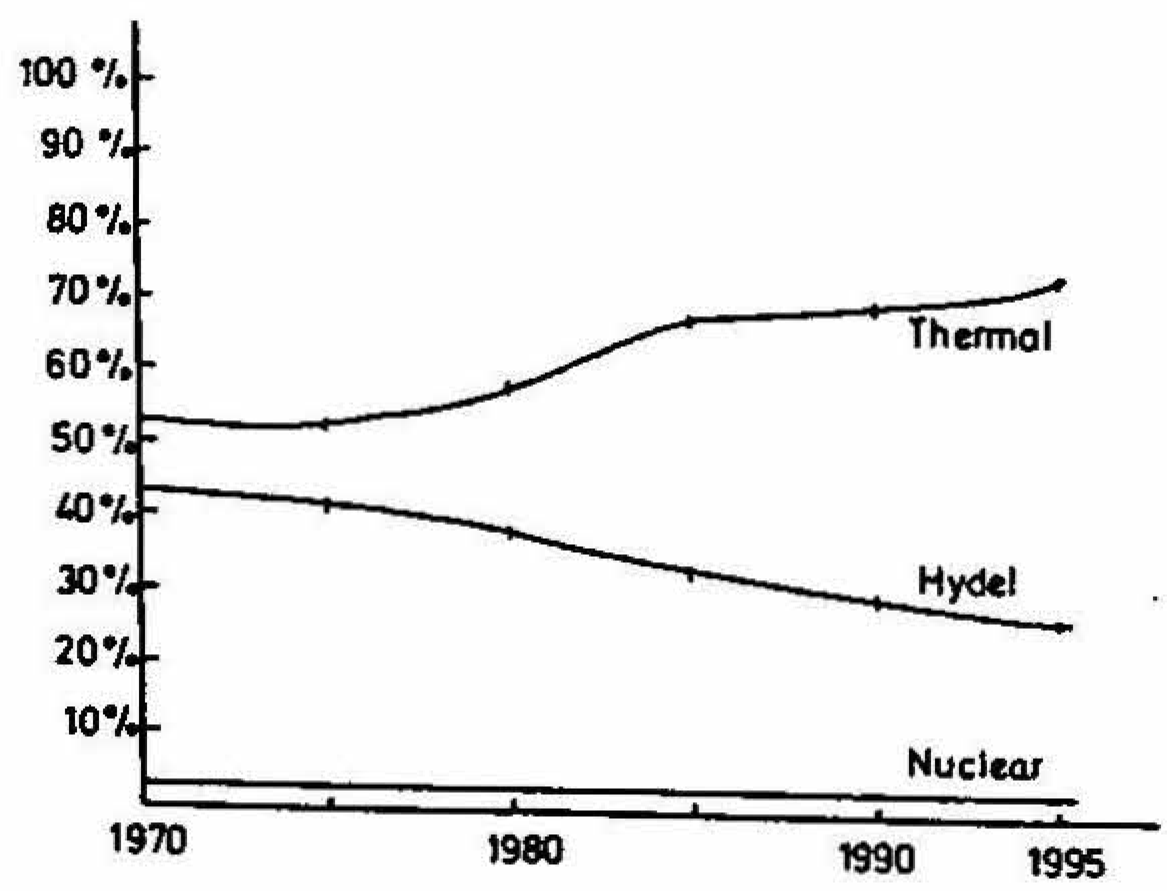

FIG. 2. Percentage change in thermal, hydel and nuclear power generation in India.

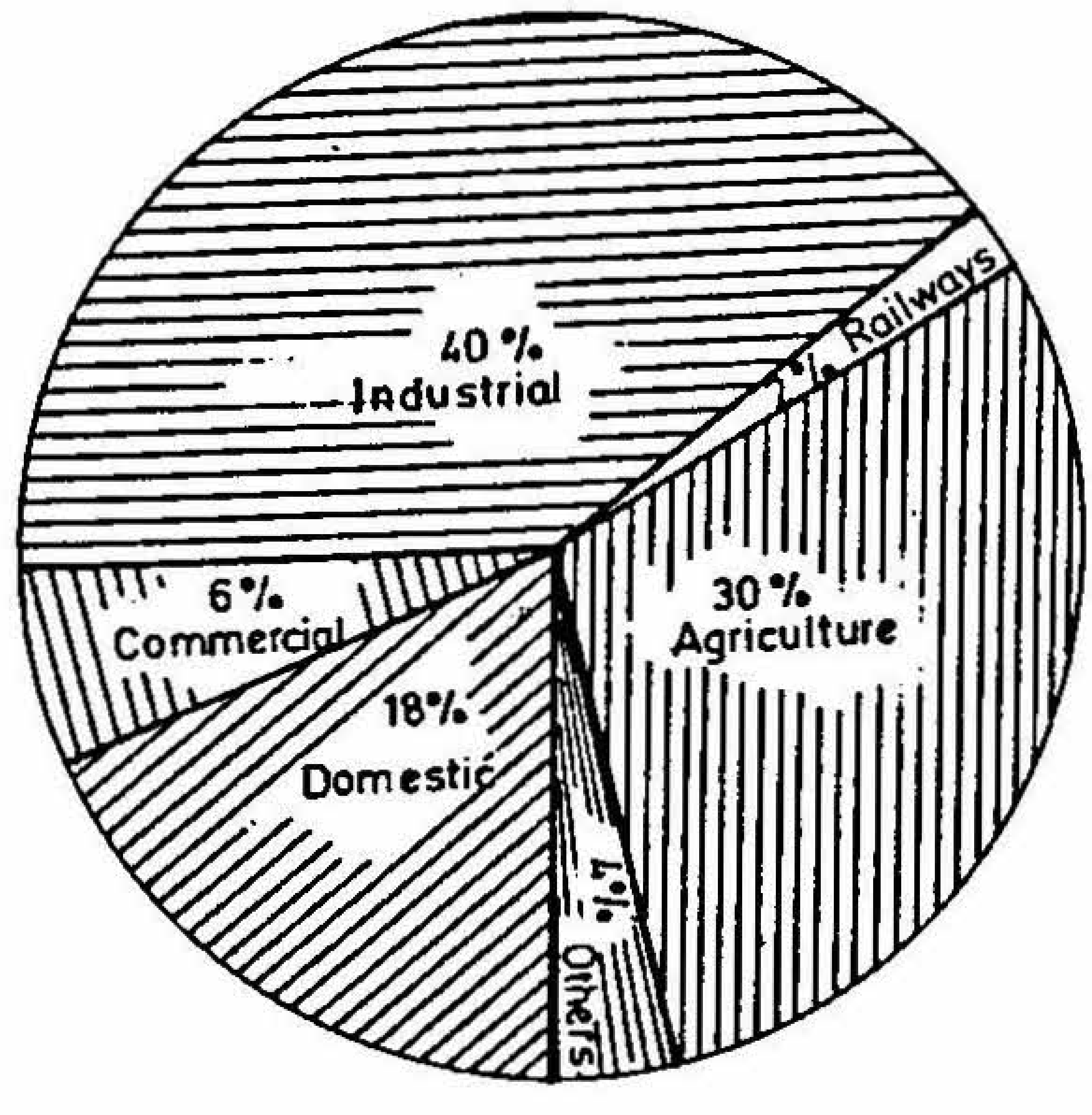

FIG. 3. Electrical energy used in various sectors (1995).

Table IV
Targets and achievements in installing additional capacity (in MW): 1980/81 to 1994/95

	Year						
	1980/81	1985/86	1990/91	1991/92	1992/93	1993/94	1994/95
Target	2687	4460	4212	3811	4458	4439	4818
Actual	1823	4223	2777	3027	3537	4539	4598
Shortfall	−864	−237	−1435	−784	−921	+100	−220
Per cent	−32.2	−5.3	−34.1	−20.6	−20.7	+2.3	−4.6

Source: Centre for Monitoring Indian Economy (CMIE), June 1995.

average overall efficiency of power generation (coal-based thermal plants), i.e. coal to electricity from generation to utilization is barely 14%. The average efficiency from coal to electricity conversion is about 30%, the plant load factor (units generated as a ratio of the number of units of electricity that a generator is capable of generating in a year) is about 68%. The efficiency of transmission and distribution is less than 75%. The product of efficiencies of all these stages comes to about 14%]. The efficiency of utilization in general is very poor as old motors are in vogue (electric motors account for more than 70% of electricity used in India). Primarily, as a result of inefficient generation, transmission, distribution and utilization, there is a perpetual power crisis in India. Add to this, slippages in project execution (Table IV) have left with considerably less installed capacity than was planned for. As such, funds are meagre, and when diverted from future projects to complete ongoing ones, there is further slippage.

Table V
Commercial profit/loss with subsidy (Rs. million): 1992/93 to 1995/96

State electricity boards	Year			
	1992/93	1993/94	1994/95*	1995/96†
Andhra Pradesh	−42	−226	−2,062	−4,687
Assam	−2,054	−2,227	−2,243	−1,469
Bihar	−2,796	−1,897	−2,775	−3,150
Delhi Electricity Supply Undertaking	−2,073	−2,636	−2,522	−2,677
Gujarat	1,080	920	−6,430	−5,280
Haryana	−3,684	−4,383	912	−1,614
Himachal Pradesh	−409	−387	−221	−65
Jammu and Kashmir	−2,245	−2,932	−3,154	−3,508
Karnataka	323	340	431	457
Kerala	−654	−621	−770	−1,123
Madhya Pradesh	298	−211	−1,870	−2,566
Maharashtra	1,616	1,890	1,917	1,597
Meghalaya	−57	−57	−143	−107
Orissa	259	243	243	890
Punjab	−6,263	−6,807	−9,456	−10,498
Rajasthan	651	292	−1,121	−4,234
Tamil Nadu	925	967	−316	−3,397
Uttar Pradesh	−8,124	−10,483	−13,510	−11,345
West Bengal	−1,214	−1,061	−1,924	−1,591
Average	−24,463	−29,276	−45,014	−54,367

*Revised estimates †Annual Plan
Source: TEDDY (1996/97)

Table III
Per capita consumption of electricity (in kilowatt hours) between 1985/86 and 1993/94

Region, state, and union territory	Year 1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94
Northern region	**173**	**192**	**202**	**217**	**241**	**249**	**265**	**282**	**288**
Haryana	247	272	306	328	365	400	455	507	487
Himachal Pradesh	123	145	162	167	180	209	210	208	217
Jammu and Kashmir	116	140	163	172	178	193	189	188	197
Punjab	423	481	515	660	639	606	616	684	703
Rajasthan	140	155	162	182	201	201	231	246	254
Uttar Pradesh	118	131	135	143	159	166	174	179	186
Chandigarh	443	478	483	532	584	708	755	715	665
Delhi	543	560	567	576	651	704	758	823	779
Western region	**259**	**275**	**297**	**314**	**334**	**367**	**391**	**406**	**437**
Gujarat	299	320	373	397	399	469	504	538	590
Madhya Pradesh	168	182	187	188	205	247	267	281	310
Maharashtra	313	327	347	372	405	411	434	439	459
Goa	328	339	357	382	396	452	495	541	593
Dadra and Nagar Haveli	141	228	420	876	879	905	980	1175	1392
Southern region	**186**	**202**	**205**	**229**	**249**	**272**	**288**	**312**	**335**
Andhra Pradesh	183	205	197	218	227	245	191	312	344
Karnataka	187	197	207	233	273	296	296	303	323
Kerala	140	135	130	148	164	188	196	200	217
Tamil Nadu	213	238	249	277	295	323	335	369	387
Pondicherry	249	345	439	527	618	720	782	856	843
Lakshadweep	93	118	137	155	171	154	172	183	207
Eastern region	**115**	**119**	**125**	**135**	**129**	**150**	**156**	**162**	**172**
Bihar	95	95	104	110	102	110	108	117	125
Orissa	130	146	165	201	181	271	295	297	319
West Bengal	135	137	135	137	139	148	151	158	164
Andaman and Nicobar islands	83	89	112	121	105	117	118	162	168
Sikkim	55	57	65	68	96	119	20	114	116
North-eastern region	**50**	**50**	**62**	**63**	**76**	**89**	**88**	**93**	**94**
Assam	53	51	64	63	78	94	90	97	96
Manipur	32	48	60	57	80	97	107	104	111
Meghalaya	76	83	88	98	108	115	125	129	135
Nagaland	68	56	62	67	70	75	78	73	68
Tripura	28	29	35	41	51	47	53	59	60
Arunachal Pradesh	32	34	47	55	58	68	58	54	67
Mizoram	28	26	41	49	57	69	69	91	101
All India	**178**	**191**	**201**	**217**	**236**	**253**	**268**	**283**	**299**

Source: TEDDY 96/97

energization of pumpsets, the very poor in the villages have not benefited from it. It recommended one bulb connection per dwelling at a flat charge of Rs. 5 per month to recover partially the cost of providing the connection and for energy consumption. The state government implemented this suggestion and launched the *Bhagyajyothi* scheme of one bulb per hut. Over 15 lakh huts have been electrified since then. This proposal was later adopted by the Government of India which launched the *Kutirjyothi* scheme.

5. Problems of the power sector

The Indian power sector is grossly inefficient resulting in perennial power shortage and energy crisis in the country despite an impressive growth. The performance of states is uneven. [The through and can be used for small-scale power production. The contributions of the Institute in T&D loss minimization have already been mentioned. Demand side management is presently an important area of research at the Institute. A major project from Karnataka State Electricity Board (KEB) for energy auditing and demand side management (DSM) in industrial and agricultural sector has been undertaken in the Department of Electrical Engineering. The project also involves a critical study of data acquisition, storage, transmission and utilization.

6. Conclusion

India has made significant progress in power sector and the Indian Institute of Science has played a major role, particularly in helping to plan transmission and distribution of power. However, the future appears bleak and power happens to be the most crucial infrastructural requirement to industrial, agricultural and general economic development of a country.

Whereas increasing efficiency in generation, transmission, distribution and utilization is going to alleviate power/energy problem significantly, it is misleading to say that savings from these sources will meet our demand and addition to installed capacity can be delayed. It is, however, necessary to have a suitable combination of decentralized and large-scale power generation. In certain areas, nuclear power plant may be the only option, but it is crucial that decentralized small-scale power plants (from biomass, wind energy, small hydel plants, etc.) be set up where possible. Self-sufficiency in electrical energy, wherever feasible, has to be achieved in rural areas. The Indian Institute of Science, will, no doubt, continue to provide the necessary design, hardware and software support and provide innovative ideas that are suitable to the Indian situation.

One of the main reasons for paucity of funds in the Indian power sector is that almost all electricity boards run at a loss and are under the control of the state governments (Table V). Agricultural consumption is virtually free, domestic consumption is subsidized and in general the tariff structure is highly ad hoc. Attempts to privatize the power sector (e.g. Orissa State Electricity Board) are prompted by belated realization that the state electricity boards, as they are now, are no longer viable. The inefficient financial and technical management of the power sector has left India in a power crisis which is likely to turn more acute during the next few years.

Table VI gives a projection of the peak demand and energy in the country and the expected deficits. Unless some drastic measures are taken, it may not be possible to come out of the vicious circle in which the country is placed now where the deficit of power/energy lowers GDP growth and low growth does not permit adequate investment in the power sector.

The power crisis has already hit the industries hard and is clearly one of the major deterrents to foreign investment in the country. It has been stated earlier that the rural sector accounts for more than 30% of the electrical energy consumption which is virtually free. Add to this the large distribution losses in transmission and distribution. It is unfortunate that we should generate bulk energy at a certain place and transmit it wastefully over long distances to use inefficiently. It makes sense to turn the villages self-sufficient in energy production. The experiments carried out by ASTRA (Application of Science and Technology to Rural Areas) of the Institute at Ungra and Pura villages in Karnataka have shown the way. IISc's Sustainable Transformation of Rural Areas (SUTRA) encompasses a large scope for rural self-sufficiency for energy and water management. The biomass gasifier, developed by the Combustion Gasification Propulsion Laboratory (CGPL) of the Institute has been a major break-

Table VI
Peak demand and energy requirement for India (1995–2015)

Characteristic	Year				
	1995	2000	2005	2010	2015
Peak demand (MW)	63,542	91,190	1,27,401	1,72,262	2,26,542
Plant load factor (%)	60	62	64	66	68
Energy generation (GWh)	4,66,526	6,70,005	9,16,096	1,22,977	16,18,157
Auxiliary consumption (%)	10	10	9	9	8
Electricity transmitted (GWh)	4,19,873	6,03,005	8,33,647	11,19,097	14,88,704
T&D losses (%)	21.5	21	20.5	20	19.5
Saleable units (GWh)	3,29,601	4,76,374	6,62,750	8,95,278	11,98,407
Energy requirement (GWh)	3,56,970	5,17,005	7,26,096	9,86,780	12,85,696
Residential	58,977	82,718	1,16,056	1,52,054	2,03,006
Commercial	23,043	33,858	50,748	73,096	98,245
Industrial LT	28,118	42,315	60,705	89,195	1,13,235
Industrial HT	1,26,723	1,81,736	2,49,283	3,40,633	4,50,362
Agriculture	78,402	1,09,963	1,55,229	2,11,788	2,67,805
Others	41,707	66,415	94,075	1,20,011	1,53,043
Surplus/deficit (%)	–7.67	–7.86	–8.72	–9.27	–9.27

Source: Centre for Monitoring Indian Economy (CMIE), 1994–95, and 14th Electric Power Survey of India, Central Electricity Authority (CEA), New Delhi, 1991.