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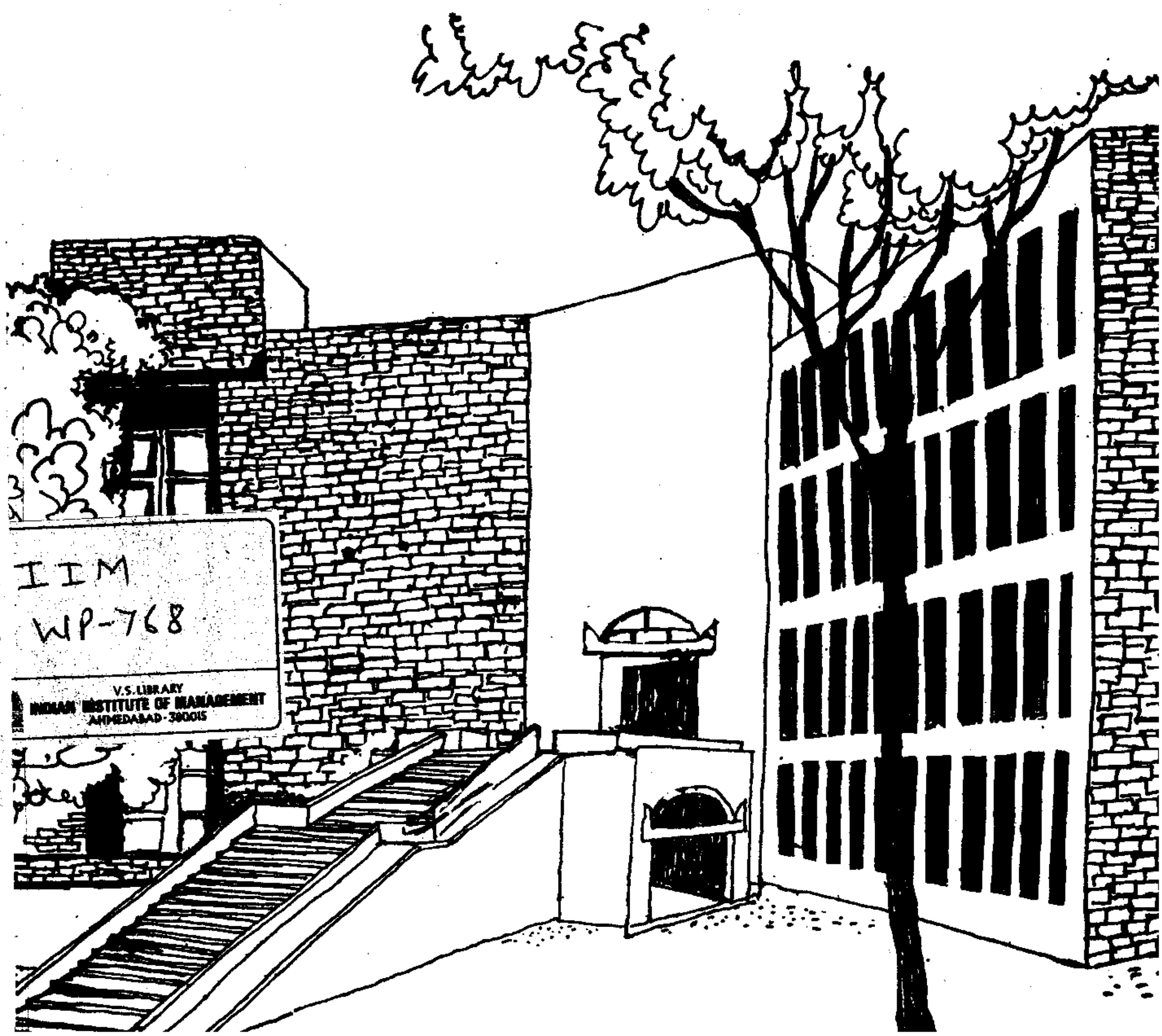

ENERGY PLANNING IN INDIA: RELEVANCE OF REGIONAL PLANNING FOR NATIONAL POLICY

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SYNOPSIS

This paper presents a macrolevel energy model and its application for energy planning for three states in India-namely Gujarat, Kerala and Rajasthan. In conjuntion with energy modelling at national level, the Advisory Board on Energy, Government of India, envisaged regional energy planning to capture regional specificities in energy demand-supply structure. Methodology for constructing reference energy system, expanded input-output table with disaggregated energy sectors and a linear programming model for analysis are presented. Scenario analysis approach is adapted and analysis and findings are presented for future reference years upto 2000 A.D.

1.0 INTRODUCTION

Given vastness of the country and wide diversity in the stages of development and resource-base, a national-level energy model for India should necessarily be supplemented by the regional(state) level models. Apart from an attempt for a decentralized planning exercise, regional study on energy planning is envisaged to become a part of necessary regional networking of capabilities and data-base and is expected to considerably aid the policy makers and planners at national as well as state level to frame realistic and meaningful policies. In conjuntion with national planning, regional analysis is done to capture regional specificities in energy supply-demand structure. This is essential since a large part of policy decisions on energy supply are presently being made centrally at the national level. Regional energy analysis integrated appropriately in the national energy planning would provide the necessary disaggregation for realistic planning and implementation. It was in response to this need of disaggregation and to capture the regional specificities in energy planning, the Advisory Board on Energy, Government of India, sponsored a study for developing regional energy model and analysis covering three states - Gujarat, Kerala and Rajasthan. The paper presents methodology used in this study for constructing input-output(I-O) transactions, reference energy system, disaggregation of I-O table, LP Model and analysis under different scenarios for several reference years. Detailed analysis is presented only for Gujarat state, however a comparitive anlysis of three states is given.

3.0 Regional Input-Output Transactions

Regional Input-Output table captures the sectoral inter-dependence, basic structure and broad technology in the economy. Since the level of technology, production structure and their rates of change vary considerably across regions in India [1], it is imperative to incorporate the spatial dimension explicitly into the planning model. This can be done most effectively only when regional I-O tables consistent and compatible with the national I-O table are estimated. I-O tables were constructed for all three States. Since methodology followed was nearly the same, I-O transactions for only Gujarat are presented below.

The estimates of regional input-output transactions are made by following the survey based method to generate first the I-O coefficient matrix. The whole regional economy of Gujarat State is classified into four broad categories: (A) Industry including electricity (30 sectors), (B) Agriculture and animal husbandry (8 sectors), (C) Fishing, Forestry and Mining (7 sectors), and (D) Supra-regional transactors and services (5 sectors). The classification of sectors into these four categories is based on the nature of data availability at the State level and the nature of the activity. For the industrial sector, the basic source of data is the Annual Survey of Industries carried out by the CSO with the help of State Statistical Bureau. It may be noted here that although the national matrix for the year 1984-85 is based on the detailed tabulation of the ASI 1973-74, we have used the latest available detailed tabulation of ASI which is for the year 1978-79. Thus, our estimates are based on more recent data base than the national I-O table implicit in the 7th Plan. For the agriculture and animal husbandry sectors, the basic source material is the cost of cultivation surveys conducted from time to time by the State governments and the State income accounts maintained by the State Statistical Bureau. For fishing, forestry and mining sectors, the national input-use coefficients adjusted for the State-sector-specific value added proportions and the survey results are used. In the case of supra-regional transactors and services, the national input-use coefficients are adopted like most other studies. With the help of the estimated gross output in each of the 50 sectors for the Gujarat State, we generate the input-output transactions in Gujarat for the year 1984-85 at current prices consistent and compatible with the national matrix.

When we compare the regional input use coefficients with the corresponding national coefficients, it is evident that regional input-use coefficients differ on the whole from the national ones. Although most of the coefficients of the Gujarat State are not different from the national coefficients in the first three decimal places, about 11% to 12% of the total coefficients in Gujarat differ from the national coefficients by 0.01 or more in absolute terms. In specific sectors or activities, therefore, there appears to be considerable regional differences in technology as reflected by input use coefficients.

In order to forecast the optimal energy requirements for the years 1989-90, 1994-95 and 1999-2000, we need to forecast final demand and gross output for each sector of the regional economy for each forecast year. Given the I-O matrix for the base year

1984-85, projections of regional inter- industry transactions for the forecast period are derived by projecting the final demand and corresponding estimates of gross output by sectors. Sector-wise final demand in the State economy are projected by using (a) sector-wise trends in final demand implicit in the Planning Commission's estimates relating to then national I-O transaction matrices for 1984-85 and 1989-90; and (b) time-trends in State domestic product by industry of originaly over the period 1960-61 to 1984-85.

3.0 REFERENCE ENERGY SYSTEM (RES)

3.1 RES Representation

An RES is a way of representing the activities and relationship of an energy system. It depicts energy flows from energy sources through energy conversion technologies to the end-use demand sectors [2],[3],[4]. The RES network has three basic components - energy sources, energy products and energy end-use demand. Energy demand for each sector is independently assessed based on present use pattern, demographic data, sectoral development plans and targets. Conversion efficiencies of technologies at various stages of production, transmission, distribution and end-use system and energy resources availability are considered. Since energy resources are individually emphasised, the approach requires disaggregation of energy sectors from the existing level of representation in the usual input-output tables.

3.2 Disaggregated Sectors Defination

Energy sources energy product and energy (end-use) demand sectors are broadly classified as follows :

Energy Sources(S):

1. Electricity - hydel , thermal, nuclear, diesel and natural gas.

2. Coal and lignite - coking coal, noncoking coal, hard coke, soft coke, lignite.

3. Crude and petroleum products - Crude, MS, LPG, NAPTHA, ATF, SKO, HSD, LDO, FO, LSHS, and other petroleum peoducts

4 . Natural gas

5. Non commercial energy sources - firewood, cropwaste, charcoal, dung, biogas, solar, wind, and animal power

Energy Products(P):

1. Demestic sector - lighting, cooking and other uses.

2. Municipal sector - street lighting, public water works

3. Industry sector - process heating, electric drive ore reduction, and ind.lighting

4. Transportion sector- road, rail and air Person Kilometers (PKMS) and Tonne Kilometers(TKMS)

5. Agricultural sector- irrigation, harvesting , thrashing and land preparation

Energy Demand(I):

Energy demand(end-use) sectors are taken directly from the I-O matrix used by the Planning Commission. The expanded matrix with emphasis on energy sectors represents a departure from the conventional input-output analysis. First, energy sector outputs are expressed in terms of physical units. Second, outputs of energy supply and conversion sectors are distributed to energy demand sectors via "dummy" energy product sectors.

The coefficients matrix A is artificially partitioned as:

	Energy Supply (S)	Energy Product (P)	Energy Demand (I)	
	Ass	Asp	0	Energy Supply
A =	Aps	0	Api	Energy Product
	Ais	0	Aii	Energy Demand

Where,

Ass: input-output coefficients describing sales of the output of one energy supply sector to another energy supply sector. Conversion losses are excluded since all coefficients are calculated on the basis of delivered energy.

Asp: input-output coefficients describing how distributed energy products are converted to end-use forms. They contain end-use conversion efficiencies embodied in the RES.

Asi: 0 implying that energy supplies are not used directly by energy demand sectors; energy is distributed to the energy demand sectors via energy product sectors.

Aps: Input-output coefficients describing how energy products are used by the energy supplying industries. Auxillary consumptions are accounted for in Ass.

App: 0 implying that energy products are not used to produce energy products.

Api: input-output coefficients describing how energy products - final energy forms - are used by energy demand sectors. This submatrix describes the ways end-use energy forms are used in the energy demand sectors.

Ais: input-output coefficients describing the uses of non-energy materials and services by the energy industry. An example of this would be requirements for machinery for oil drilling or coal mining.

Aip: 0 implying that energy product-sectors equipment require no material or service inputs. This is because they are pseudo-sectors and not real producing sectors.

Aii: input-output coefficients describing how non-energy products are used in the energy demand sectors. Coefficients in this submatrix are enumerated in purely monetary terms. Aii is equivalent to the A matrix of the conventional input-output framework.

Note that input - output coefficients in the S and P sectors are in physical units . For example, electricity is expressed in MU(million units), petroleum products are expressed in MT(metric tons), etc. Only the input-output coefficients in the I sector are in monetary values.

3.3 CONSTRUCTING RES FOR A BASE YEAR (1984-85)

Construction of RES primarily require detailed data about energy supply, demand and the energy flow relationship for a year for which data are largely available. For the present study 1984-85 is taken as base year. For conventional energy sources such as coal, petroleum, electricity etc., data is available from appropriate state and central agencies [5],[6],[7].[8],[9],[10]. For non-conventional sources, data is obtained from state energy development agencies and other published sources [11],[12],[13]. Base year energy demand for each product sector is derived from several sources, major source for the industry sector data is the data on quantity of fuel as input to various industry sectors collected by Central Statistical Organisation(CSO). For non-commercial energy sectors energy estimates are made using NCAER survey data[11] and other information collected from state agencies. Energy demand for the product sector is is independently estimated based on the fuel use pattern for every product sector and taking into account conversion efficiencies of devices. Energy demand for domestic, municipal, agriculture, industry and transportation sectors are thus assessed. In fact, for each of these product sectors, energy demand is estimated independently. Using the energy flows from different energy sources to energy product sectors, RES for base year (1984-85) is constructed.

3.4 RES Projections For 1989-90,1994-95 & 1999-2000.

After validating the demand for energy products for base year 1984-85, the projections of demand for energy product sectors for 1989-90 , 1994-95 and 2000-2001 are made from base year demand. The projections in different sectors are based on the appropriate sectoral growth rates, demographic data, etc. Since 1984-85 demand is validated with actual consumptions, the procedure can be expected to give good demand forecast. In the case of 1989-90, actual growth rates in key sectors are checked and actual demand upto the recent time is considered for validation of demand projections. For example, consumption of electricity and petroleum products in different sectors is obtained for 1986-87 and the projections are validated with actual growth in consumption pattern. For 1994-95, and 1999-2000 projections are made from the 1989-90 energy demands. Growth rates used for industry, agriculture, transportation etc. are in correspondance with the growth rates suggested by input-output tables for these periods. Demand projections are made for various scenarios to understand policy implications.

Construction of RES for base year is the key to a meaningful analysis. Considerable and diverse data sources are used. Requisite data for the purpose do exist with the appropriate state agencies. Besides considerable published mertarial is available. However, certain assumptions are required where data gaps prevail and this must be done with utmost care so as to keep the data realistic. In case of state (regional) models, transportation data pose difficulties since inter and intra state movements have to be considered. In some other sectors too, national level data is easier to obtain than state level data and sometimes disaggregation from national level data has to be done. with approprriate assumptions. This apart, appropriate cost data is most difficult to obtain especially for future scenarios. However, our experience is that meaningful RES can be constucted at regional level which can capture regional specificities.

4.0 A LINEAR PROGRAMMING(LP) MODEL

4.1 RES - LP Model Linkage

The RES is viewed as a network optimization problem in which energy flows are routed through a linear network in order to minimise the total energy cost subject to the requirement that all end-use demands are met. The problem formulation résults in Linear Programming model. The model is similar to the Brookhaven model [3],[4],[14],[15]. However in our model, additional bounding constraints are incorporated to limit the extent of substistution.

4.2 Energy Variables

There are 175 Decision variables.

- X_s - Energy Source : 30 Variables
- X_p - Energy product : 19 Variables
- X_i - Energy Demand : 47 Variables
- d^+_s - Energy Export : 12 Variables
- d^-_s - Energy Import : 12 Variables
- X_{sp} - Energy flow : 55 Variables

4.3 Energy Costs

Objective function is to minimize total energy system costs while satisfying the demand for energy products and non-energy sectors. Costs for energy sources(Cs) considered include the production costs [16][17](in case of materials produced in the state), production and transportation costs for materials imported in the state and existing prices in case of non-commercial materials. For new capacities of energy sources (eg. electric power stations), fixed cost is appropriately allocated. Cost for energy products(Csp) include both fixed costs and variable costs. Import and export of fuels is considered by incorporating import and export prices Pis and Pes.

4.4 LP Formulation

The LP formulation (175 variables and 255 constraints) for energy demand alalysis is as follows:

$$\text{Min}: \quad CsXs + CspXsp - Pes(ds\ ) + Pis(ds\ )$$

$$\text{S.T.}: \quad AssXs + IspXsp + ds^{-} - ds^{+} = Xs \le Gs \quad \text{(60 constraints)}$$

$$ApsXs + ApiXi + Yp = Xp \quad \text{(19 constraints)}$$

$$AisXs + AiiXi + Yi = Xi \quad \text{(47 constraints)}$$

$$EspXsp = Xp \quad \text{(19 constraints)}$$

$$Lsp \le EspXsp \le Usp \quad ; \quad \text{(110 constraints)}$$

$$X,\ ds^{-},\ ds^{+} \ge 0$$

where

Isp = Matrix (PxS) denoting 1 if sector S can supply P, else 0.

Gs = Annual Availability of Source.

Lsp & Usp = Lower & Upper bounds respectively on the end-use energy of sector p that can be provided by a source s.

Esp = Efficiency of the device using a source s to convert potential energy of the source into end-use energy for product sector p.

5.0 ANALYSIS FOR GUJARAT STATE

5.1 Scenario Approach

In the present study, RES is constructed for three States Gujarat, Rajasthan and Kerala. Energy analysis for these states is carried out. Analysis and results for all reference years for Gujarat State are presented here in details. Since analysis for other two states is similar, it is not detailed here. However a comparision of the results for three states is presented later. The time frame used is upto 2000 AD, which is not too far a future, and thus allows for construction of reasonable future scenarios and at the same time, this time horizon is far enough for meaningful planning and concrete policy interventions.

5.2 Analysis of Results

5.2.1 Base Year : 1984-85

Optimal cost(annual) for the Base Scenario was found to be Rs 2363 crores. This cost includes cost of energy sources(i.e. fuels) and end-use devices(annualised). For this base run structural bounds were kept almost same as existing proportion. Thus fuel substitution is restricted , however the costs of substitution of fuels is available from the dual solution. The shadow prices associated with bound constraints can be interpreted as marginal cost of fuel substitution. For example, the marginal cost of substitution by LPG of firewood is found to be Rs. 4286 per tonne.

From summary Tables 1, 2 and 3, following conclusions can be drawn.

(i) Gujarat imports 18 percent of its electricity consumption from neighbouring states. The power deficit is about 1852 MKWH(450 mw). Large quantity of non-coking coal is purchased from outside the state. In terms of petroleum products and natural gas, Gujarat is surplus since the state has a refinery and is endowed with crude and natural gas. More than four million tonnes of firewood is consumed annually, essentially for cooking and heating needs.

(ii) Electricity provides for 98 percent of domestic lighting needs and kerosene 2 percent. Since as kerosene is very

TABLE : 1

STATE : GUJARAT

ELECTRICITY GENERATION & CONSUMPTION - 1984-85 TO 1999-2000

ELECTRICITY

	1984-85	1989-90	1994-95	1999-2000
CAPACITY(MW)	3054	3891	7550	9532
GENARATION(MKWH)*	8049	11963	22697	28952
CONSUMPTION(MKWH)	9438	13724	19824	28483
EXPORT(IMPORT)(MKWH)	(1852)	(2298)	2873	469

AFTER T&D AND AUXILLIARY CONSUMPTION LOSSES

TABLE : 2

STATE : GUJARAT

CONSUMPTION OF MAJOR FUELS - 1984-85 TO 1999-2000

MAJOR FUELS*	1984-85	1989-90	1994-95	1999-2000
COAL(MT)	8980236	13585544	22184734	26298787
LIGNITE(MT)	1047467	1350000	3000000	4000000
NATURAL GAS(M.CU.M.)	673	884	1731	2676
HSD(MT)	981098	1187060	1301897	1526417
FO/LSHS(MT)	882311	1041548	1444096	1800730
NAPHTHA(MT)	585747	768758	888090	1133010

TABLE : 3 STATE : GUJARAT

CONSUMPTION OF MAJOR ENERGY SOURCE BY ENERGY PRODUCT SECTORS

DOMESTIC SECTOR				
ENERGY SORUCE	1984-85	1989-90	1994-95	1999-2000
ELECTRICITY(MKWH)	1098	1775	2923	4887
SKO(MT)	553705	647553	727163	862098
FIREWOOD(MT)	4142000	4142000	4142000	4142000
CROPWASTE(MT)	385440	462526	631000	808000
LPG(MT)	80467	110542	127000	140892
INDUSTRY SECTOR				
ELECTRICITY(MKWH)	6319	8811	12723	17438
COAL(MT)	3700415	4787263	5283334	6752472
LIGNITE(MT)	1047657	1350000	2947000	2947000
FO/LSHS(MT)	835647	1136330	1444096	1800730
ROAD TRANSPORT				
MS(MT)	246134	292995	337789	406883
HSD(MT)	616139	731110	890385	1032890
RAIL TRANSPORT				
HSD(MT)	69564	75504	88557	101164
ELECTRICITY(MKWH)	140	168	209	305
COAL(MT)	415601	443621	333318	166358
AGRICULTURE SECTOR				
ELECTRICITY(MKWH)	1619	2257	3226	4505
HSD(MT)	154926	200204	269955	330363
MUNICIPAL SECTOR				
ELECTRICITY(MKWH)	300	411	743	1348
ELECTRIC POWER SECTOR				
COAL(MT)	4656288	8123000	16314600	19100400
LIGNITE(MT)			1053000	1053000
NATURAL GAS(M.CU.M.)	273	319	735	1432
HSD(MT)	34200	46000	53000	62000

inefficient lighting fuel, it constitutes 63 percent of potential energy.

(iii) For domestic cooking, kerosene and firewood each provides for about 40 percent of needs; however, as firewood stoves are relatively inefficient, firewood constitutes 63 percent of potential energy in cooking.

(iv) Coal is the major fuel (59%) for industrial process heating.

(v) 65% of road passenger movement is met by HSD and rest by MS. HSD meets 95% of goods movement.

(vi) For rail passenger movement, electricity, coal and HSD provide for about 34, 39, and 26 percent of needs. For goods movement, HSD provides for the bulk (66%) of the needs.

(vii) Electricity provides for 68 percent of irrigation requirement whereas diesal pumps provide for about 28 percent.

(viii) For fertilizer production, FO/LSHS (60%), natural gas (27%) and Naphtha (12%) are the basic fuels/ feedstocks.

(ix) About 52 percent of coal is used for thermal power stations and 41 percent for industrial process heating requirements.

(x) More than 65 (61 percent for industrial drive)percent electricity is consumed for industrial uses.

(xi) Of the total of electricity consumed in the state, irrigation, domestic sector and municipal sector account for 17, 11 and 3 percent respectively.

(xii) 52 percent of HSD is consumed for goods movement and 23 percent for passenger movement.

(xiii) 76 percent of kerosene is used for cooking and 22 percent for lighting.

(xiv) About 28 percent dung is used for cooking and 67 percent as manure.

5.3 Base Secnario Analysis for 1989-90, 1994-95, 1999-2000

Base Scenario for the reference years were created by assuming :

(a) Energy product demand (over 1984-85) for domestic sector and passenger transport is projected to grow in proportion to population growth rate and a small obsolute per capita increase.

(b) Energy product demand for agriculture and industrial sector is increased in a proporation higher than the proportionate increase in gross output of these sectors by taking into account forecasts on fuel and electricity consumption by other agencies.

(c) For goods movement, the increase is proportionate to the increase in gross output of industry and agriculture.

(d) Increase in 10 percent efficienty (over 1984-85) in road transport, diesel locos and air travel is assumed.

(e) Power generation capability is projected based on actual plans of state electricity board and expected additional MW capacity to be made available. Same power load factor, T & D losses and auxilliary consumption (%) as in 1984-85 are assumed.

(f) Availability of firewood, charcoal, dung and animal power is assumed at the same level as in 1984-85. Cropwaste availability is increased in proportion to the increase in gross output of the agriculture sectors. For non-coventional energy sectors, output is assumed as per the state plans.

(g) For Base Scenario of each reference year, it is assumed that the proportion of energy product demand met by different fuels will remain nearly the same as in 1984-85.

5.4 A COMPARATIVE ANALYSIS OF BASE SCENARIOS FOR FOUR REFERENCE YEARS

Tables 1 to 3 summarise consumption of major fuels and electricity and consumption of major fuels by energy product sectors for four reference years. From these tables it can be seen that :

(i) Electricity generation is planned to increase rapidy (94% increase) during 8th Plan (1989-90 to 1994-95) period. If the power plants come up as per the GEB plans, then by 1994-95, Gujarat will have surplus power (880 MW surplus) However, due to considerable increases in thermal power plant capacity during 8th plan period, coal and natural gas consumption in the state is increasing substantially. In 1999-2000 AD, the State is expected to have nearly same consumption of electricity as the planned capacity. Electricity consumption in fifteen year period (1985-2000) is expected to triple.

(ii) Consumption of petroleum based fuels is expected to increase steadily, nearly doubling for Naphtha, FO and LSHS and increasing by 60 owexwhr for HSD in fifteen years.

(iii) In domestic sector consumption of electricity is increasing by four fold and kerosene consumption by about fifty percent in fifteen years.

(iv) Industry will remain to be the major consumer of electricity consuming about 60 percent of total in 2000 AD. Coal will be the major fuel for process heating but lignite will replace coal to some extent by 1995.

(v) More than two-thirds of HSD consumption in the state in 2000 AD will be for road transport sector. Goods transport sector will consume about 55 percent. HSD consumption for road transport will increase by 65 percent in fifteen years.

(vi) For rail passenger transport, electricity will contribute 56 and HSD about 31 percent of needs. For rail goods transport, HSD will contribute to two-thirds of the movement. Contribution of coal in rail sector will decline to 13 for passenger and 5 percent for goods movement. Electricity consumption will more than double and HSD consumption will increase by about 70 percent during the fifteen.

(vii) For agriculture sector, electricity consumption will nearly triple and HSD consumption will double in fifteen year period.

(viii) Consumption of coal for electricity is increasing by nearly four fold and natural gas about five fold during fifteen year period.

(ix) For municipal sector, i.e. public water works and street lighting, electricity consumption will increase by more than four fold during the 1985-2000 period.

Above observations clearly suggest that coal will be the major source of energy as per the existing projections for electricity generation. As coal is brought from far distance (average lead of about 1000 km), load on railways will increases substantially. Projection for electrical power capacity are made as per the State electicity board plans, however in reality power projects are expected to be delayed at least for about two to three years. Uncertainty still prevails over the timely implementation of four 500 MW Narmada(coal) Thermal Power Projects. Similarly Gas availability for power is uncertain. Hence, for electrical power sector available capacity shall be lower than planned capacity. The results also suggest a major electrification of railway system.

Optimal energy cost for the Base Scenario for the four reference years at 1984-85 constant prices are as follows:

REFERENCE YEAR	1984-85	1989-90	1994-95	1999-2000
COST(Rs million)	23630	31980	50550	67810

As can be seen, energy costs are increasing rapidly and are tripling in fifteen years.

5.5 Scenario Analysis

Major scenarios are consturcted for reference years 1994-95 and 1999-2000. Some short term possibilities and interventions are considered for 1989-90. In all scenario runs, cost structure is considered same as in 1984-85.

5.5.1 A SHORT-TERM SCENARIO

In 1989-90, a possible short term scenario (Scenario (S.T.)) is considered which may result due to (a) use of excess LSHS production of Gujarat Refinery for process heating by industry up to twentyfive percent more than the Base Scenario (b) increase in lignite production in the state to about 2.5 million tonnes per annum and (c) increase in natural gas consumption for industrial process heating such that all natural gas produced in the state is consumed in the state.

TABLE 4

CONSUMPTION OF FUELS AND EXPORT (IMPORT) - 1089-90

STATE : GUJARAT

	SCENARIO (S.T.)		BASE SCENARIO	
FUELS	CONSUMPTION	EXPORT (IMPORT)	CONSUMPTION	EXPORT (IMPORT)
FO/LSHS (MT)	2783065	484935	2226452	1041548
LIGNITE (MT)	2500000	NIL	1350000	NIL
NAT.GAS (MCUM)	950	NIL	884	66
COAL (MT)	11526550	(11526550)	13585544	(13585544)

As can be seen, coal consumption and import are reduced by about two million tonnes, i.e. a reduction of fifteen percent. LSHS production will reduce after 1992-93 on completion of hydrocracker unit of Gujarat Refinery, however there after to natural gas may be provided for industrial process heating.

5.5.2 Scenario II - Electric Power Sector Situation

In the base scenario, we assumed that the electric power plants will be available as per the present projections[4] of State Electricity Boards and Central Electricity Authority (CEA). However, in reality, power plants are delayed in implementation. Two scenarios, II(a) and II(b) are constructed for electric power sector situation. A basic assumptions for scenario II are :

(i) New power plants will be available three years later (three year delay) than the projected target dates.

(ii) Electricity import from other States is possible to the extent of 50 percent of the deficit.

This means that electricity shortage in certain sectors will have to be conpensated by substitute fuels.

The bounds on the proportion of an energy source meeting demand of an energy product as obtained from 1984-85 base runs are relaxed to some extent to allow for substitution of fuels, especially to replace electricity shortage. Energy product demand is assumed to be the same as for the Base Scenario.

For Scenario II(a) Table 5 gives comparative figures of electricity generation and consumption. Power deficit is expected to be 320 MW (1994-95) and 925 MW(1999-2000). In Base Scenario, power was surplus for both reference years. Thus we find that optimistic situation for power sector as projected by GEB plans and CEA may alter significantly if implementation of power plants is delayed by three years even if half the electricity deficit is substuted by other fuels.

Table 6 gives the substitution of electricity by other fuels in various sectors. HSD consumption increases significantly (26 percent for 1994-95 and 47 percent for 1900-2000) in Scenario II(a) compared to Base Scenario since electricity shortage in agriculture sector has to be met by HSD for irrigation. SKO consumption is higher (53 percent for 1994-95 and 78 percent for 1999-2000) since SKO substitutes electricity in domestic lighting sector.

TABLE 5 STATE:GUJARAT

GENERATION AND CONSUMPTION OF ELECTRICITY

ELECTRICITY	1994-95		1999-2000	
	SCENARIO II(a)	BASE SCENARIO	SCENARIO II(a)	BASE SCENARIO
CAPACITY (MW)	5675	7550	7550	9532
GENERATION (MKWH)*	16997	22697	22697	28952
CONSUMPTION(MKWH)	17998	19824	25590	28483
EXPORT(IMPORT)/(MKWH)	(1317)+	2873	(3807)@	469

* After T & D and Auxilliary Losses + Power Deficit of 320 MW @ Power Deficit of 925 MW

TABLE 6 STATE:GUJARAT

CONSUMPTION OF MAJOR ENERGY SOURCES BY ENERGY PRODUCT SECTORS

	1994-95			1999-2000		
	BASE SCENARIO	SCENARIO II(a)	SCENARIO III	BASE SCENARIO	SCENARIO II(a)	SCENARIO III
ESTIC SECTOR						
CTRICITY (MKWH)	2923	2948	2950	4587	4762	491
(MT)	727163	1110333	461214	362398	1536292	32353
MT)	127000	127000	296333	140892	140892	56949
EWOOD(MT)	4142000	4142000	3000178	4142000	4142000	197208
USTRY SECTOR						
CTRICITY (MKWH)	12723	12673	12699	17438	17375	1737
L (MT)	5283324	5292564	5227797	6752472	6764586	668206
LSHS(MT)	1444096	128545	1419188	1800730	1805989	170216
GAS(M.CU.M)	270	270	324	356	356	49
D TRANSPORT SECTOR						
MT)	337789	337789	304010	406883	406883	36619
(MT)	890385	890385	919197	1032690	1032890	107908
L TRANSPORT SECTOR						
CTRICITY (MKWH)	209	188	110586	305	275	10116
L (MT)	333318	333318	209	166358	166358	30
(MT)	88557	94332	299986	101164	109414	16635
ICULTURE SECTOR						
CTRICITY (MKWH)	3226	1946	3628	[illegible]	1830	45
(MT)	269955	609708	197478	330363	1040394	16635

Scenario II(b) :

This scenario considers fuel substitution within electric power sector. In Gujarat power generation is largely through thermal power stations. Basic alternate fuels for thermal power generation are coal, lignite and natural gas. Since coal based plants have long implementation period compared to gas based plants, in Scenario II(b) the possibility of building power capacity at a faster rate using gas based power plants is considered. As HBJ pipeline is passing through Gujarat, using natural gas for electric power generation is feasible. The scenario is created only for reference year 1994-95 since for 1999-2000, there is sufficient time to build capacity based on alternative fuels.

In Scenario II(b), besides assumption (i) of scenario II(a) above, other assumption is that the deficit in the target capacity of Base Scenario, caused by delayed projects(three years delay) during the eighth plan period, will be entirely compensated by new gas based thermal power plants. Thus in this scenario generation of electricity will be same as in the Base Scenario with only difference that the fuel substitution will take place between coal and natural gas. Table 7 shows that natural gas requirement for power sector would double (additional natural gas consumption of 1741 MCUM) while coal consumption will reduce by nearly 5 million tonnes compared to Base Scenario.

TABLE 7 STATE:GUJARAT

POWER SECTOR : ELECTRIC POWER CAPACITY AND FUEL CONSUMPTION

FUELS	1994-95	
	SCENARIO II(b)	BASE SCENARIO
COAL/LIG ELEC.(MW)	4252	6067
NAT. GAS ELEC. (MW)	2665	790
COAL CONS. (MT)	11258591	16314600
NAT. GAS CONS. (MCUM)	3472	1731

5.2.3 Scenario III : Structural Change in Energy Supply - Demand Relations

This scenario considers change in the proportions of energy product demand supplied by various energy sources over the actual proportions obtained in 1984-85. This allows for substitution of corresponding fuels and is achieved by relaxing bounds on the proportion of an energy product which can be supplied by an energy source. The original proportions(bounds) existed in the economy due to various techno-economic realities and constraints. Relaxation of bounds for constructing this scenario has been done while considering the possible limits on the bounds which will exist even in extreme situations. The assumptions for reference years 1994-95 and 1999-2000 are different with respect to the extent of relaxation on bounds. These assumptions are broadly outlined below :

Scenario III assumptions :

(1) Bound on domestic lighting sector is totally relaxed.

(2) For urban and rural cooking needs,LPG is available for upto 60 and 20 percent needs respectively by 1994-95 and 80 and 40 percent respectively by 2000 AD.

(3) For industrial process heating, lower bound on coal relaxed by 20 percent, bounds on FO/LSHS and natural gas are relaxed to plus or minus 20 percent of original bounds for 1994-95 and plus or minus 40 percent for 1999-2000.

(4) Bounds on the transport sector are relaxed by plus or minus 10 percent.

(5) For agriculture sector, bounds on electricity and HSD for irrigation are relaxed by plus or minus 30 percent for 1994-95 and 70 percent for 1999-2000.

(6) Upper bound on animal power for agriculture is reduced by 50 percent for 1994-95 and fully for 1999-2000.

(7) Structure of fuel supply to thermal power plants is maintained as in the base case.

(8) Cost for all reference years are considered at 1984-84 constant prices.

Comparing the base scenario with scenario III(Table 6), It can be seen that :

(i) In domestic sector, LPG consumption is increasing very rapidly since LPG is the main fuel substituting firewood and SKO. LPG consumption in 2000 AD increases by four fold while SKO and firewood consumption reduces by 61 percent and 52 percent respectively.

(ii) In industry sector, fuel substitution is largely among coal, FO/LSHS and natural gas. For both reference years, natural gas is preferred for industrial process heating to substitute coal and LSHS within bound relaxation.

(iii) In transportation sector, for road passenger movement HSD replaces MS and for rail transport,HSD replaces coal to the extent allowed by bound relaxation.

(iv) In agriculture sector, electricity replaces HSD to the extent allowed by bounds relaxation.

In Scenario III, availability of electricity is assumed, and hence net result is the increase in the electricity consumption, largely due to increase in the agriculture sector.

Optimal Cost (annual) for Scenario III is Rs. 4886 crores for 1994-95 which is 189 crores (3.33 percent) less compared to Base Scenario Cost. For reference year 1999-2000, optimal Cost (annual) is Rs. 6532 crores which is 249 crores (3.67 percent) less than the Base Scenario Cost.

6.0 Comparision of Energy Demand-Supply Structure in Three States.

For Kerala and Rajasthan analysis similar to the analysis for Gujarat presented in Section 5 was carried out. From the analysis of three states, we find that the structure of energy demand-supply relationship (coefficients of expanded I-O matrix) differs for each state significantly.

A comparision of the actual energy demand-supply relationship for the year 1984-85 described in earlier sections for the three states shows that :

(i) In Kerala and Rajasthan, SKO is consumed largely for domestic lighting (73 and 54 percent respectively) and rest for cooking. For Gujarat only 23 percent SKO is consumed in domestic lighting and 77 percent for cooking

(ii) In Kerala, firewood and agriculture waste provide for 92 percent of energy demand in cooking sector and petroleum based fuels provide for only 7 percent of cooking needs. In Gujarat, petroleum based fuels and natural gas provide for 51 percent of cooking energy demand. In Rajasthan, petroleum based fuels meet only

11 percent of cooking energy demand where as firewood alone provides for 68 percent of cooking energy needs.

(iii) In Gujarat most of the electric power generation is through coal based thermal power plants (92 percent) whereas in Kerala almost all electricity generation (1984-85) is through hydel plants. In Rajasthan coal based, nuclear and hydel power plants supply electricity. None of the three states produce coal. Gujarat has very high consumption and import of coal. In Kerala, coal import is very little. Gujarat and Rajasthan have electricity deficit, whereas Kerala has surplus electricity.

(iv) Coal provides for 92 percent of industrial process heating needs for Rajasthan, whereas in Gujarat and Kerala, coal provides for only 50 and 18 percent of industrial process heating needs respectively.

(v) For road passenger transport, in Gujarat MS provides for about 35 percent of movement whereas for Rajasthan and Kerala MS provides for only 7 percent and 19 percent of needs respectively.

(vi) For Gujarat, about 71 percent of total HSD consumption is used for road and rail transport whereas for Kerala and Rajasthan figures are 76 and 93 percent respectively.

(vii) For Rail transport in Gujarat HSD, coal and electricity are all used, whereas in Kerala only HSD is used.

(viii) In irrigation, HSD provides for 69 percent, 40 percent and 6 percent needs of Gujarat, Kerala and Rajasthan respectively. Electricity provides for 94 and 28 percent of irrigaton needs respectively for Rajasthan and Gujarat.

(ix) Gujarat consumes huge quantity of petroleum based fuels and natural gas in fertilizer sector since several large fertilizer plant are located in the state. In Rajasthan there is little fertilizer production.

(x) Gujarat produces large quantity of natual gas whereas there is no natural gas production in other two states.

(xi) Due to high industrialisation, Gujarat consumes considerable fuel in industrial sector compared to Karela, where industrial sector consumes little fuel.

From these observations and discussion in earlier section, it is apparant that the energy demand supply structure is quite different in the three states. National Energy Planning therfore will benifit significantly if regional specificities are considered both in making aggregate estimates and for disaggregating the national level plan. Since fuel availabilities in future for three states are quite different, different fuel substitution posibilities exist in various energy product sectors. For example, in Gujarat, natural gas can be considered as a major fuel alternative for future energy scenarios which is not the case for the other two states. Thus, for long term energy planning and policy making exercises, consideration of regional specificities and analysis at regional level will be essential to strengthen the national planning exercise.

7.0 Policy Implications

The results of our study suggests following implications for policy analysis. Regional level planning should be done for all regionas to capture the regional specificities and integrated with the national energy planning. National level energy supply-demand structure is inadequate to incorporate regional specificities and hence integration of regional planning with national planning shall help in appropriately disaggregating the national plan for realistic regional implemantation. Since in India, location decisions such as for major plants, refineries, gas pipelines etc. are made centrally(nationally), regional and national planning has to be integrated for deciding the appropriate allocations, pricing etc.. National planning based on aggregate I-O table can be refined by disaggregating I-O table for specific major sectors. Since the energy demand is independetly assesed for end-use sectors, energy demand growth may be considered independently, especially under various futuristic scenario to asses the efficacy of various interventions. Since the results are sensitive to present and future costs, resource availabilities, technological efficiencies and demand levels; appropriate assesment of these parameters both at national level and at disaggregated regional level need to be made for optimal overall plan formulation and efficient implemantation at regional level.

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