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Ashok V. Desai

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Introductory Note

The countries of the developing world are important to the evolving energy future. Their contribution to the demand for world oil and other energy sources is at present small, but its rate of growth is high. Indeed, as development continues the nations of the Third World may provide most of the growth in oil use for the rest of this century.

Because of the importance of developing countries to global energy outcomes, and of energy outcomes to the prospects for development, we have undertaken a series of studies designed to illuminate the dynamics of demand changes and the opportunities for (and barriers against) supply enhancement. One major portion of this effort is funded by the Agency for International Development under the ARDEN (A.I.D.-RFF Development and ENergy) Cooperative Agreement No. AID/DSAN-CA-0179.

The ARDEN program is divided into three main subprogram areas: 1) rural electrification, 2) biomass, and 3) energy demand and conservation. This discussion paper, "Interfuel Substitution in the Indian Economy" by Ashok V. Desai of the National Council of Applied Economic Research, New Delhi, India, belongs to the third category. Although conservation of energy of all forms is important, reduced petroleum use has the highest priority for most oil importing developing countries. Oil imports pre-empt limited supplies of foreign exchange and supplies are to some extent uncertain.

Dr. Desai's study analyzes evidence on interfuel substitution in the Indian economy, a case of particular interest. Alone among the developing countries India has managed to develop and sustain a major industrial

sector based on coal despite the challenge of cheap petroleum in the 1950s and 1960s. Coal accounts for over 60 percent of total energy consumption in India whereas it rarely exceeds 20 percent in other developing countries.

The India experience, while not typical of other countries, is helpful in two ways. First, it illustrates the feasibility and the difficulties of major dependence on coal, and second, it indicates the actions which had to be taken at a time of falling oil prices to retain a major role for coal in the economy.

Desai describes historical trends in energy consumption in the aggregate and in each of the main consuming sectors--industry and power, transportation, (where coal still accounts for one half of total energy consumed), agriculture, and residential. He concludes that during the era when petroleum came to dominate the world energy picture, in India the shift from coal to oil was slowed only in the industrial sector. Here, price was the key determinant of fuel choice (because convenience, etc. was of less importance) and the price of refined petroleum products was kept high by taxation. In contrast, policy since the oil price rise of 1973-74 has been to shield consumers from the full increase by lowering tax rates on petroleum products, encouraging thereby greater petroleum consumption.

Interfuel substitution is a topic which we believe deserves widespread attention and--in both the developing and industrial country context--further research. We issue this report on work in progress with the multiple purposes of informing the policy community of the state of knowledge, of stimulating research elsewhere, and of eliciting comments on our own efforts.

The research for this discussion paper was carried out by Dr. Ashok V. Desai as a consultant for the ARDEN project.

Milton Russell
Director, Center for
Energy Policy Research

Introduction

In the postwar period, oil rapidly replaced coal in most economies of the world. Apart from its physical advantages (for instance, higher energy content per ton and ease of storage and transport), oil was cheap. As a result, even economies well endowed with other fuel resources became heavily dependent on oil, mostly imported, and ran into serious difficulties when oil prices rose after 1972.

The difficulties were no less serious in India, which also imported the major proportion of the oil it consumed, but they were surmounted relatively more quickly. While the rise in oil prices led immediately to large payments deficits, they were wiped out by 1976, and since then the balance of payments has been comfortable.

This resilience was partly due to the fact that the replacement of other fuels by oil and gas up until the oil crisis had been a much slower process in India than in most other major countries. The slower substitution rate was not the only factor: restraint on consumption of oil products, substitution for major importables by increased domestic production, and a rise in exports were other important factors that played a role in India's recovery.[1] Nevertheless, the country's lesser dependence on imported hydrocarbons played a significant role in cushioning the effects of the rise in oil prices.

It is the object of this paper to review the process of interfuel substitution in the Indian economy from the fifties onward. The discussion will cover all forms of energy, including biofuels and animal power, although the paucity of data must limit the conclusions that can be reached on the last two.

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[1] For an analysis of India's experience, see Desai (1979a).

Trends in Aggregate Energy Consumption

Final commercial energy consumption, for which we have relatively reliable information, shows a progressive fall from the fifties to the early seventies in the proportion contributed by coal. This fall was not steady (until 1960 it was barely noticeable), nor was it entirely accounted for by the rise in oil consumption. Electricity consumption increased even more rapidly. Immediately after the oil crisis, the share of coal consumption began to rise but it declined again after 1975 (table 1).

We cannot construct time series of the consumption of noncommercial energy with any degree of credence, but two benchmark surveys permit us to estimate the consumption of biofuels in 1963 and 1973. A consistency exercise, presented in the appendix to this paper, indicates their weakness, but suggests that they are of more or less the right order, though an error of, say, 20 percent, cannot be considered improbable. We earlier made estimates of animate power in 1970 (Desai, 1978b); the same method has been extended to make estimates for 1963 and 1973. It should be stressed that the estimates are based on extremely tentative physiological reasoning, which will undoubtedly be revised in the coming years, as the yet sparse evidence expands on the relationship between nutrition and work capacity.

With the help of these estimates, aggregate energy consumption in the Indian economy in 1963 and 1973 is presented in tables 2 and 3. The comparison shows a fall in the proportion of all forms of energy over the ten years except for oil, gas, electricity, and bagasse. Bagasse is consumed in the sugar mills where it is produced, and is not an energy source for the rest of the economy. The inclusion of noncommercial and animate forms of energy thus confirms the impression given in table 1, that over the years, oil and electricity have gained ground in the overall energy picture.

But the replacement of solid fuels by hydrocarbons and electricity has been a slower process in India than in other comparable economies. The fossil fuel resources of OECD Europe, for instance, are similar to those of India--both have relatively large reserves of coal and are deficient in hydrocarbons. In 1955 Europe got three times as much energy

Table 1. Final Commercial Energy Consumption for Selected Fiscal Years

	1955	1960	1965	1970	1975	1977
Coal, million tons	28.8	40.4	51.8	51.4	71.4	74.5
Oil products, million tons	4.7	6.7	9.9	14.8	18.8	21.3
Light fractions	0.9	1.0	1.1	1.5	1.5	1.5
Middle fractions	2.4	4.1	6.1	8.9	11.6	13.7
Heavy fractions	1.4	1.6	2.7	4.4	5.9	6.1
Gas, billion cubic meters	--	--	--	0.2	0.3	0.4
Electricity, billion kWh	7.1	14.0	26.7	43.7	66.4	77.7
Thermal	4.9	9.1	17.8	28.2	49.6	58.6
Nuclear	--	--	--	2.4	2.6	2.3
Hydro	3.7	7.9	15.2	25.2	33.3	38.0
Less losses	-1.5	-3.0	-6.3	-12.1	-19.1	-21.2
			000 terajoules			
Coal	788	1,091	1,399	1,388	1,928	2,012
Oil	200	286	421	629	807	905
Gas	--	--	--	3	5	5
Electricity	26	50	96	157	239	280
Total	1,014	1,427	1,916	2,177	2,979	3,203
			Percentages			
Coal	77.5	76.5	73.0	63.8	64.7	62.8
Oil	19.9	20.0	22.0	28.9	27.1	28.3
Gas	--	--	--	0.1	0.2	0.2
Electricity	2.6	3.5	5.0	7.2	8.0	8.7
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note: Dash indicates figure is zero or negligible.

Sources: Ashok V. Desai, "Development and Energy Consumption," Oxford Bulletin of Economics and Statistics vol. 40, no. 3 (1978) p. 244; Central Electricity Authority, Public Electricity Supply: in All-India Statistics, 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics, 1977-78 (New Delhi, 1979), and Coal India memorandum submitted to the Committee on Controls and Subsidies, (New Delhi, 1978).

Table 2. Aggregate Primary and Final Energy Consumption, 1963 and 1973

Type of Energy	Primary 1963	Primary 1973	Final 1963	Final 1973
Commercial energy				
Coal, million tons	64.0	84.9	57.9	71.8
Oil, million tons	11.0[a]	24.5[b]	9.9[c]	22.5[c]
Gas, billion cubic meters	0.2	0.9	--	0.4
Electricity, billion kWh	14.0	31.3	21.4	55.7
Noncommercial fuels, million tons				
Wood	121.0	133.2	118.0	132.0
Dung	n.a.	n.a.	41.7	35.9
Charcoal	n.a.	n.a.	0.6	0.3
Bagasse	18.4	24.5	18.4	24.5
Animate energy, million tons				
Human food	82.0	112.0	n.a.	n.a.
Animal fodder	361.0	412.0	n.a.	n.a.

Notes: Dash indicates figure is zero or negligible.

n.a. = not applicable.

Sources: Coal: Central Statistical Organization, Basic Statistics Relating to the Indian Economy 1950-61 to 1975-76 (New Delhi, 1977); Oil and Gas: Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics, 1976 (New Delhi, 1977); Electricity: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1963-64 (New Delhi, 1965); Noncommercial fuels: see appendix A and Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1973-74 (New Delhi, 1975); Animate energy: Ashok V. Desai, Energy Output and Consumption in India: A Methodological Review, Working Paper no. 97 (Trivandrum, Centre for Development Studies, 1979). (The 1974 figures in the source are adjusted to 1973 in proportion to the population change.)

[a] Includes 2.9 million tons of imported refined products.
[b] Includes 4 million tons of imported refined products.
[c] Excludes refinery boiler fuel.

Table 3. Composition of Final Energy Consumption, 1963 and 1973

Type of Energy	Energy content (kTJ) 1963	Energy content (kTJ) 1973	Proportion (%) 1963	Proportion (%) 1973
Commercial energy				
Coal	1,563	1,939	31.2	30.6
Oil	421	956	8.4	15.1
Gas	--	6	--	0.1
Electricity	77	201	1.5	3.2
Total	2,061	3,102	41.1	49.0
Noncommercial energy				
Wood	1,770	1,980	35.3	31.3
Dung	417	359	8.3	5.7
Charcoal	18	9	0.3	0.1
Bagasse	275	367	5.5	5.8
Total	2,480	2,715	49.4	42.9
Animate energy				
Human workers	73	89	1.5	1.4
Working animals	402	429	8.0	6.9
Total	475	518	9.5	8.1
TOTAL	5,016	6,335	100.0	100.0

Note: Dash indicates figure is zero or negligible.

Sources: Calculated from table 2. Energy coefficients have been taken from Ashok V. Desai, "India's Energy Consumption: Composition and Trends," Energy Policy vol. 6, no. 3 (1978) pp. 217-34; Ashok V. Desai, Energy Output and Consumption in India: A Methodological Review, Working Paper no. 97 (Trivandrum, Centre for Development Studies, 1979).

from coal as from oil, while India got four times as much. By 1970, the proportions were reversed in Europe; in India, however, oil supplied only half as much energy as coal (Desai 1979a, p. 14). This occurred despite the faster growth of energy consumption in India, which should have facilitated a switch in fuels by reducing the need for converting coal-using equipment to oil.

The answer, as it emerges from table 4, is that by 1975 European industry and transport had made a faster changeover to oil. While only 10 percent of the Indian industrial energy consumption in 1975 was contributed by oil, the proportion in Europe as a whole was 45 percent. European railways had almost entirely given up coal, and 98 percent of the energy used for transport came from oil; whereas in India, coal still supplied about half. In the "other" sector, 29 percent of the commercial energy in India came from oil, against 52 percent in Europe; but commercial energy usage in the agricultural and the domestic sectors of India was so small that it made little overall difference.

The chief reason for the slower decline in the use of solid fuels in India was to be found in the government's energy pricing and tax policies. In the next four sections we shall review interfuel shifts in four sectors --industry, transport, agriculture, and domestic consumption--and the forces that have determined them. A final section will bring together the conclusions of this study.

Industry and Power

As was shown in the last section, Indian industry is much more dependent on coal as a primary fuel source than is European industry. The worldwide trend to oil in the postwar period has left the Indian industrial sector largely untouched.

There was, however, a time when oil replaced coal to a certain extent. As table 5 shows, the share of coal rose till 1960. This was at least partly because of the change in the industry mix; there was rapid expansion in such coal-using industries as steel and cement in the late fifties. In the sixties, however, there was a small but distinct shift to oil. This was the period when an expansion of domestic oil refining made available

Table 4. Final Commercial Energy Consumption in Major Sectors in India and Western Europe, 1975

	Coal		Oil		Gas		Electricity		Total	
	kTJ	%	kTJ	%	kTJ	%	kTJ	%	kTJ	%
India										
Industry	1,328	80.0	172	10.4	--	--	159	9.6	1,659	100.0
Transport	354	50.1	345	48.9	--	--	7	1.0	706	100.0
Agriculture	--	--	73	70.2	--	--	31	29.8	104	100.0
Other	275	60.7	130	28.7	5	1.1	43	9.5	453	100.0
Nonenergy	5	3.3	145	94.8	3	1.9	--	--	153	100.0
Total	1,962	63.8	865	28.1	8	0.3	240	7.8	3,075	100.0
Western Europe										
Industry	2,808	20.5	6,131	44.7	2,570	18.7	2,214	16.1	13,723	100.0
Transport	55	0.6	8,837	98.0	11	0.1	119	1.3	9,022	100.0
Agriculture	2	0.3	647	89.7	--	--	72	10.0	721	100.0
Other	1,665	13.6	6,308	51.7	2,307	18.9	1,923	15.8	12,203	100.0
Nonenergy	--	--	1,573	100.0	--	--	--	--	1,573	100.0
Total	4,530	12.2	23,496	63.1	4,888	13.1	4,328	11.6	37,242	100.0

Note: Dash indicates figure is zero or negligible.

Sources: Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1975-76 (New Delhi, 1977); Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics, 1976 (New Delhi, 1977); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1975-76 (New Delhi, 1977); Central Statistical Organization, Basic Statistics Relating to the Indian Economy 1950-61 to 1975-76 (New Delhi, 1977a.); Organisation for Economic Co-operation and Development, Energy Balances of OECD Countries 1973-1975 (Paris, 1977).

Table 5. Energy Consumption in Industry and Mining, Fiscal 1955-77

	1955	1960	1965	1970	1975	1977
Coal, million tons	10.1	20.9	30.1	31.1	48.5	45.8
Oil products, million tons	0.9	1.4	2.6	3.2	4.1	4.5
Electricity, billion kWh	6.3	11.6	22.6	34.4	44.3	50.2
Energy input, kTJ	334	665	1,003	1,098	1,641	1,607
Coal	273	564	813	840	1,310	1,237
Oil products	38	59	109	134	172	189
Electricity	23	42	81	124	159	181
Proportion of energy input, %	100.0	100.0	100.0	100.0	100.0	100.0
Coal	81.7	84.8	81.0	76.5	79.8	77.0
Oil products	11.4	8.9	10.9	12.2	10.5	11.8
Electricity	6.9	6.3	8.1	11.3	9.7	11.3

Sources: Petroleum Information Service, The Indian Petroleum Handbook 1967-68 (New Delhi, 1968); Energy Survey of India Committee, Report of the Energy Survey of India Committee (New Dehli, 1965); Ministry of Petroleum, Indian Petroleum and Chemicals Statistics 1972 (New Delhi, 1973); Fuel Policy Committee, Report of the Fuel Policy Committee (New Delhi, 1974); Ministry of Petroleum, Indian Petroleum and Petrochemical Statistics 1976 (New Delhi, 1977); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979).

increasing quantities of furnace oil that were absorbed by industry as well as by power plants.

The furnace oil surplus disappeared as increasing demand caught up with supply in the late sixties. A shortage of oil-refining capacity developed as a result of a hiatus in investment. The shortage affected furnace oil output more because, with the erection of naptha-based fertilizer plants, the demand for light distillates went up, and the proportions of the middle and heavy fractions were cut. The share of fuel oils in refined products went down from 28.4 to 24.7 percent between 1966 and 1970. The demand for them, however, had gathered momentum and could only be met with imports, which rose from virtually zero to over 2 million tons in 1973.

These imports could no longer be afforded when oil prices began to rise in 1973, and the government considered industry as a sector where it was particularly easy to cut down on oil consumption by substituting coal. By and large, the government relied on the rises in product prices resulting from the rise in the crude oil price, and reinforced by taxes, to restrain consumption. Oil costs of industries, however, constituted only a small proportion of their total costs, and it was feared that the industrial demand for furnace oil would be inelastic. Hence physical allocation was resorted to. Initially, users were given quotas equal to their 1973 consumption; then cuts were imposed based on a judgment regarding substitution possibilities. A firm could get its allocation increased if it proved that it needed more oil for export production, for import substitution, or to cater to defense demand. New firms had to be recommended by one of the designated sponsoring authorities before their allocation application could be considered.

Apart from making across-the board cuts, fuel-efficiency advisory service was also set up. The base for the service was provided by the National Productivity Council, which had operated such a service of its own since 1964. To its staff were added engineers from Indian Oil and the Directorate-General of Technical Development. Teams from this pool of thirty engineers began to visit firms from September 1974 onward, working out a phased fuel-saving program for each. By the end of 1975, they had visited three hundred firms consuming a million tons; in 1976 they surveyed another two hundred firms consuming 600,000 tons (Srinivasan, 1977). The possible oil savings were substantial--about 17 percent of consumption--but the

savings immediately achieved came only to about 2 to 3 percent. The rest required additional financial investment or modifications in equipment.

More effective were the committee's efforts to replace oil by coal, backed as they were by powers of oil rationing and coal allocation. Large savings were achieved immediately by switching a small number of power plants from oil to coal. As individual firms adjusted to oil rationing, their savings mounted as well. According to official figures, the gross savings were running at the annual rate of 800,000 tons by the end of 1977--with savings of 500,000 tons by power plants and 300,000 tons by industry. The comparison of oil input coefficients in 1973 and 1977 suggests larger savings. The 1973 input coefficients as applied to 1977 output figures for the industries covered in table 6 indicate net savings of 1,068,000 tons in industry alone--30 percent of their 1973 oil consumption.

After 1976, however, efforts to replace oil with coal ran aground. There was inadequate coal supply. The small boilers used by most industries require high-quality steam coal that comes almost entirely from the Raniganj-Jharia coalfields. These coalfields, the oldest in India, are difficult to develop owing to the haphazard small-scale workings that crisscross them. In the past three years they have been subject to frequent industrial disputes. Transport from these highly concentrated coal mines to the rest of India, especially the south and the west, also poses difficult problems. Hence, although the current relative prices make the substitution of coal for oil highly remunerative, the campaign to effect this change has virtually ceased.

Table 5 suggests that there was some substitution of electricity for coal as well, at any rate until 1970. We have tried to include both electricity purchased and generated for itself by industry, but it is possible that some self-generated electricity had been excluded in the earlier years, and that this is partly responsible for the rise of electricity use in total energy input. This can be investigated for one industry which has always generated a significant part of the electricity it consumed, namely, the cement industry. To this industry we now turn.

Cement

Cement production is a heat-consuming process, and its equipment can, within limits, burn coal and oil with equal ease. It was therefore one of

Table 6. Industrial Consumption of Fuel Oil, 1972-77

	Fuel oil consumption (thousand tons)						Output of industry							Oil input per unit of output						
	1972	1973	1974	1975	1976	1977	Unit	1972	1973	1974	1975	1976	1977	Unit	1972	1973	1974	1975	1976	1977
Iron and steel	449	439	488	324	482	471	1,000 tons	5,174	4,810	4,872	5,314	6,359	6,492	Tons of	87	91	92	58	76	73
Cement	171	204	141	74	43	38	1,000 tons	17,652	15,812	14,316	16,236	18,684	19,176	fuel per	10	14	10	5	2	2
Fertilizer	181	266	287	356	436	546	1,000 tons	1,020	1,056	1,326	1,188	1,992	1,824	1,000 tons	178	252	216	300	219	199
Aluminum	123	110	96	115	141	122	1,000 tons	179	154	129	167	210	185	of output	687	714	744	689	671	660
Sugar	60	59	52	46	52	48	1,000 tons	3,173	3,820	3,965	4,646	4,804	4,842		19	15	13	10	11	10
Textiles	606	650	560	590	585	523	Index	100.7	104	104.1	101	105.1	101	1970 = 100	97	106	91	89	94	87
Chemicals	702	795	715	796	778	799	Index	126.1	128	125.3	132	155.5	171	1970 = 100	113	126	116	123	101	94
Engineering	292	361	320	295	277	229	Index	105.7	122	129.4	127	141.6	180	1970 = 100	67	93	78	73	62	40
Other	846	726	769	848	681	752														
	3,410	3,610	3,388	3,444	3,475	3,528														

Sources: Ministry of Petroleum, Indian Petroleum and Chemicals Statistics 1974 (New Delhi, 1975); Ministry of Petroleum, Report 1974-75 (New Delhi, 1975); Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics 1976 (New Delhi, 1977); Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics 1977 (New Delhi, 1978); Central Statistical Organization, Monthly Abstract of Statistics vol. 30, no. 10 (New Delhi, 1977); Central Statistical Organization, Monthly Abstract of Statistics vol. 32, no. 12 (1979); Planning Commission, Non-Commercial Energy Consumption - A Modified Methodology, Paper WGEP/M-3/7 (New Delhi, 1978); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979).

the industries that partially changed over to oil when the furnace oil supply increased during the sixties; it was also a prime target of the government's efforts to reduce furnace oil consumption in the seventies.

As table 7 shows, the proportion of oil in the energy input to cement rose from virtually zero in 1960 to 11 percent in 1965. Then it began to decline, and fell to 1 percent in 1977. Fuel efficiency in the industry improved throughout, but there is no indication that it improved more rapidly with the use of oil or vice versa.

The consumption of purchased electricity rose faster than cement output throughout 1955-77, but this was caused by the purchase of an increasing proportion of the power consumed. When purchased and self-generated electricity are added together, their ratio to cement output shows no trend.

These results can be confirmed by looking at two states (table 8). Cement plants in both Tamil Nadu and Gujarat shifted substantially to oil in 1960-65, and partially reversed the shift in 1965-70. The energy coefficient increased in both states while the proportion of oil was increasing. Hence oil does not appear to have been more fuel-efficient than coal in this industry and, in fact, it is quite the reverse.

Cement plants in Tamil Nadu generated virtually no electricity for themselves; those in Gujarat generated a substantial but decreasing proportion. In neither state does the power coefficient show any trend. Thus electricity did not replace coal, which remained the main fuel input.

In cement, therefore, there was progressive improvement in fuel efficiency. Oil replaced coal to some extent in the sixties, but the shift had no clear effect on fuel efficiency. In the seventies, when oil became expensive and was rationed, it virtually disappeared as a fuel input to the cement industry. It appears that the uses of electricity were specific and distinct from the use of coal and oil as fuel.

Power

The composition of fuels in the electric power industry can vary in either of two ways: first, as a result of changes in the relative importance of plants designed to use particular fuels, and second, through variation in the fuel mix of steam plants which can burn a variety of fuels.

The plant composition of the Indian power industry has not undergone significant change in the last twenty-two years (table 9). In the early

Table 7. Energy Consumption in Cement, 1955-77

	1955	1960	1965	1970	1977
Cement output, million tons	4.0	7.5	10.7	14.0	19.2
Energy inputs					
Coal, thousand tons	1,377	2,451	3,016	3,868	5,000
Oil products (thousand kiloliters)	2	10	266	142	38
Purchased electricity, GWh	167	431	823	1,346	1,945
Total energy, kTJ	37.9	68.1	94.8	114.9	143.5
Energy coefficient, MJ/t	9,505	9,056	8,835	8,213	7,478
Proportions in energy input, %					
Coal	98.2	97.1	85.9	90.0	94.1
Oil products	--	0.6	10.9	4.8	1.0
Purchased electricity	1.8	2.3	3.2	4.2	4.9
Power coefficient, kWh/t[a]	130	124	114	117	122

Note: Dash indicates figure is zero or negligible.

Sources: Directorate of Industrial Statistics, Census of Manufacturing Industries 1955 (Calcutta,1957); Central Statistical Organization, Annual Survey of Industries, 1960 (Calcutta, 1964); Energy Survey of India Committee, Report of the Energy Survey of India Committee (New Delhi, 1965);Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics 1976 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi,1979); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979).

[a]Includes self-generated as well as purchased electricity.

Table 8. Energy Consumption in Cement in Gujarat and Tamil Nadu, for Selected Years

	Tamil Nadu				Gujarat[a]		
	1955	1960	1965	1970	1960	1965	1970
Cement output, thousand tons	693	1,127	1,630	2,550	899	1,198	1,800
Energy consumption							
Coal, thousand tons	176	297	253	615	293	236	443
Oil products, thousand kl	--	--	137	54	4	116	136
Purchased electricity, GWh	74	122	177	283	45	79	136
Total energy, TJ	5,018	8,458	12,815	19,730	8,299	11,180	15,220
Energy coefficient, Mj/t	7,242	7,505	7,862	7,737	9,154	9,330	8,455
Proportions in energy input, %	94.7	94.8	533	84.2	96.1	57.0	78.6
Coal	94.7	94.8	553	84.2	96.1	57.0	78.6
Oil products	--	--	42.7	10.7	1.9	40.5	18.2
Purchased electricity	5.3	5.2	5.0	5.1	2.1	2.5	3.2
Power coefficient,[b] kWh/t	107	108	109	111	91	118	98

Note: Dash indicates figure is zero or negligible.

Sources: Calculated from table 7. Energy coefficients have been taken from the following works of Ashok V. Desai, "Development and Energy Consumption," Oxford Bulletin of Economics and Statistics vol. 40 no. 3, (1978) pp. 263-272; Ashok V. Desai, "India's Energy Consumption: Composition and Trends," Energy Policy vol. 6 no. 3, (1978) pp. 217-234; Ashok V. Desai, Energy Output and Consumption in India: A Methodological Review, Working paper no. 83 (Trivandrum, Centre for Development Studies, 1979).

[a]Gujarat State came into existence in 1956.

[b]Electricity generated within the industry was negligible.

Table 9. Utility Power Generation by Source of Energy, For Selected Years

	1955	1960	1965	1970	1975	1977
Power output, GWh	8,592	16,937	32,990	55,828	79,231	91,369
Steam	4,619	8,732	17,372	27,796	42,760	50,557
Hydroelectric	3,742	7,837	15,223	25,248	33,301	38,007
Diesel and gas turbines	231	368	393	365	543	553
Nuclear	--	--	--	2,417	2,626	2,272
Proportion of output, %	100.0	100.0	100.0	100.0	100.0	100.0
Steam	53.8	51.5	52.7	49.8	54.0	55.3
Hydroelectric	43.5	46.3	46.1	45.2	42.0	41.6
Diesel and gas turbines	2.7	2.2	1.2	0.7	0.7	0.6
Nuclear	--	--	--	4.3	3.3	2.5

Notes: Apart from utilities, captive plants of industries and railways generated 7,556 GWh in 1977 composed of steam, 7,113 GWh, hydro, 11 GWh, diesel and gas, 433 GWh.

Dash indicates figure is zero or negligible.

Sources: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1955 (Simla, 1956); Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1960-61 (Simla, 1962); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1965-66 (New Delhi, 1968); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi, 1979); Central Statistical Organization, Statistical Abstract India, 1972 (New Delhi, 1973).

years when the Indian power industry was smaller and more fragmented, a number of towns got their electricity from local diesel generators. About 3 percent of the utility power supply came from diesel plants. Isolated, material-based industries, like steel and cement, also generated a substantial proportion of their power requirements.

As the power grids of the states grew, they reached an increasing number of towns, and local diesel stations were phased out. Diesel generation has become somewhat more competitive in the seventies with the advent of more efficient gas turbines, which also have the advantage of much shorter commissioning periods than steam thermal plants. Still, diesel's proportion of the utility power supply continues to decline, and was only 0.6 percent in 1977.

Self-generation of power has continued to hold some attraction for industry because many parts of the country suffer from a chronic excess demand for power, industries do not get all the power they need, and the methods of rationing available--such as unscheduled and unannounced power cuts, voltage reductions, and abrupt directives to reduce power consumption by a certain percentage--can severely dislocate industry. The handicap is particularly serious for continuous-process industries. Hence such large-scale, power-intensive industries as aluminium and steel have continued to build captive power plants as they have expanded. But for most industries, captive power turns out to be far more expensive than utility power. Thus, the proportion of power generated by captive plants of industries and railways to power produced by utilities has declined from 18.8 percent in 1960 to 8.3 percent in 1977.

The Tarapur nuclear power plant, commissioned in 1968, made a substantial addition to utility power supply; in 1970 nuclear power supplied 4.3 percent of the total. Since then, however, its proportion has declined. The Tarapur plant was built with U.S. assistance. It has become increasingly difficult to get enriched uranium from the United States, since India refused to sign the nuclear nonproliferation treaty. Further, the stocks of spent fuel have grown progressively, and have strained storage capacity. Hence the Tarapur plant's capacity utilization has come down. The Rana Pratapsagar plant in Rajasthan was built with Canadian assistance, which was terminated when India detonated a nuclear device in

1974. It was then put on line with largely indigenous expertise, but continues to limp owing to a shortage of heavy water. A third plant now being built near Madras has been greatly delayed because the Indian industrial sector has no experience in manufacturing the kind of equipment that it requires. Thus, after a big start in the sixties, nuclear power has come to a halt, at least for the present.

The Indian power system therefore continues to rely largely on thermal and hydroelectricity. Hydroelectric power has been important in India since the beginning because it was cheap in the early years when the more favorable sites were developed, and because the railway system, despite its early development, was not geared to carry coal to distant parts from the coalfields concentrated in the Bengal-Bihar belt. Hydroelectric schemes figured prominently in the first two five-year plans--the proportion of hydroelectricity in utility power generation rose to a peak of 50.8 percent in 1963. But the emphasis on hydroelectricity had a number of disadvantages which soon became evident. For one thing, hydroelectric power supply depended on the inflow of water into reservoirs, and varied from year to year according to the state of rainfall and snowfall. Second, many hydroelectric power schemes were also designed for irrigation, and the time pattern of irrigation requirements differed from that of power demand. The only way to deal with these problems was to balance hydroelectric capacity with thermal power.

An impetus was given to thermal power generation in the early sixties by the expansion of the steel industry. The steel industry required high-quality, low-ash coking coal which could only be obtained by washing coal and screening out high-ash coal. High-ash coal had no use except in power generation. Thus a certain expansion of thermal capacity was dictated by the development of the steel industry. In addition, the commissioning periods of thermal plants were shorter than those of hydroelectric power stations; in times of sudden power shortages thermal stations were favored. For these reasons, steam power generation has gained ground in the seventies. Now, however, it is likely that there will be a shift again toward hydroelectricity in the eighties.

Let us now consider the composition of fuels in the steam-powered plants (table 10). Here solid fuels, and coal among them, have been the mainstay. There is one power station in Tamil Nadu that runs on local

Table 10. Fuel Consumption in Thermal Power Plants, for Selected Years

	1955	1960	1965	1970	1975	1977
Solid fuels, thousand tons						
Coal	3,691	6,410	10,276	14,569	24,293	28,857
Lignite	--	--	2,184	2,543	2,388	2,734
Wood	n.a.	n.a.	14	15	16	8
Liquid fuels, thousand kiloliters						
Diesel oil	--	--	--	--	38	153
Furnace oil	24	280	388	891	1,723	1,165
Heavy stock	--	--	--	392	85	543
Gas						
Refinery Gas, thousand tons	--	--	--	5	--	--
Natural gas, million cubic meters	--	--	139	152	143	175
Electricity						
Power output, GWh	4,618	8,720	17,372	27,853	42,760	50,557
Heat input, kTJ	91	160	277	403	608	690
Efficiency	18.3	19.6	22.6	24.9	25.3	26.2
Proportion of fuels in heat input, %	100.0	100.0	100.0	100.0	100.0	100.0
Solid fuels	99.0	93.2	93.7	86.9	87.8	89.1
Oil products	1.0	6.8	5.5	12.5	11.8	10.5
Natural gas	-	-	0.8	0.6	0.4	0.4

Note: Dash indicates figure is zero or negligible. n.a. = not available.

Sources: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1955 (Simla, 1956); Central Water and Power Supply, Public Electricity Supply: in All-India Statistics 1960-61 (Simla, 1962); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1965-66 (New Delhi, 1968); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi, 1979); Central Statistical Organization, Statistical Abstract India, 1972 (New Delhi, 1973).

lignite, and a small plant in the Andaman Islands that burns wood. The rest of the system relies on coal.

The steam-powered plants began using furnace oil as a supplementary fuel when it became available in the sixties. Initially, it was used mainly by plants situated near oil refineries, but gradually the power plant engineers discovered a specific use for furnace oil. Being a more concentrated fuel, furnace oil makes it easier to keep a plant running when the load factor is low; it also makes it easier to deal with fluctuations in load. Such fluctuations increased in the seventies when the proportion of agricultural demand--which was highly seasonal and considerably varied from day to day--increased. As a result, there was a rapid rise in fuel oil consumption.

From 1974 onward, the government forced the public utility power system to cut down on its consumption of oil products. It did so in two ways. First, a number of towns (particularly in Kashmir, Punjab, Haryana, and Uttar Pradesh) were connected to the power grid and their diesel generators closed down. Second, the steam-powered plants reduced their oil product consumption from 49 to 40 kiloliters per gigawatt-hour thereby saving 430,000 kiloliters. The substitute fuel was coal. The replacement coefficient of coal for oil cannot be precisely worked out for lack of homogeneity in both, but somewhere between 1.9 and 2.3 million tons more coal and lignite were used in 1976 than would have been necessary with 1972 coefficients; about 5 or 6 tons of coal replaced each ton of oil products. (Incidentally, this replacement was not entirely a sequel to the rise in oil prices; nearly half of it took place in FY1972-74.)

In the reshuffling of refined product prices in 1973 and 1974 the differential between the price of furnace oil and other oil products was greatly narrowed. The subsequent official squeeze on furnace oil consumption appears to have been accompanied by the substitution of diesel oil and kerosine (whose prices had not risen so drastically) for furnace oil. Thus the net oil product savings of the power sector were appreciably lower than the large absolute fall in its furnace oil consumption between FY1974-76 would suggest.

The replacement of furnace oil by other oil products was not caused by a deliberate evasion of official policy. But big savings in furnace

oil consumption would best be achieved by switching large oil-fired power stations--Trombay in Maharashtra, Ahmedabad and Dhuvaran in Gujarat, and Barauni in Bihar--to coal. These plants were originally designed to use oil because they were near refineries; the locational advantage could not be changed by the rise in oil prices. The plants in Gujarat and Maharashtra were far from coalfields. As a consequence, whenever there was a break in coal supplies to them, use of oil was the best alternative available; and if furnace oil was not available, other oils could be used equally well. While, therefore, substitution of coal for oil made good sense for the economy, geography and logistics reduced the scope for substitution.

The fuel efficiency of steam plants has steadily improved from 18.3 percent in 1955 to 26.2 percent in 1977. There is no evidence that it was affected by interfuel shifts. The improvement in efficiency in 1965-70, when the proportion of oil rose rapidly, was not much more than it had been in other five-year periods. It is known that the gas-burning plants at Uttaran and Dhuvaran in Gujarat are almost twice as efficient as coal- or oil-burning plants, but the proportion of gas is too small to affect the picture.

These conclusions are confirmed, as in the case of the cement industry, by data for individual states (table 11). Fuel oil use was more substantial in Gujarat and Maharashtra, both of which have refineries. Fuel efficiency in Gujarat improved from 17.5 percent in 1960 to 27 percent in 1977. There was considerable replacement of coal by oil, whose share rose from 7.1 percent to 69.2 percent in 1965-70; fuel efficiency, however, improved very little in that period. The experience in Tamil Nadu confirms this. The lignite-burning plant in Tamil Nadu (not included in the figures in table 11 because it is owned by the central government) closed down in 1974 when the lignite seam ran out. Output of coal-burning plants was then stepped up, and more furnace oil was used in them. With it, the fuel efficiency fell slightly. Fuel efficiency in Uttar Pradesh and West Bengal, where furnace oil was little used, was lower than in the other three states, but this was related to factors other than the composition of fuel input, such as scale of plants and quality of management.

Table 11. Interfuel Shifts in Thermal Power Generation in Selected States, 1960-77

State and year	Power output (GWh)	Thermal efficiency (%)	Shares in fuel input (%) Solid fuels	Oil products	Natural gas
Gujarat					
1960	1,209	17.5	100.0	--	--
1965	2,155	23.4	86.6	7.1	6.3
1970	2,959	23.3	25.8	69.2	5.0
1975	4,611	25.8	42.9	53.8	3.3
1977	5,710	27.0	58.5	38.9	2.6
Maharashtra					
1960	1,835	18.8	100.0	--	--
1965	2,416	23.2	73.3	26.7	--
1970	3,392	26.4	66.0	34.0	--
1975	6,034	28.2	76.7	23.3	--
1977	8,198	30.3	80.6	19.4	--
Uttar Pradesh					
1960	786	14.0	100.0	--	--
1965	1,451	15.9	100.0	--	--
1970	3,758	19.4	98.9	1.1	--
1975	5,356	21.5	96.2	3.8	--
1977	6,111	22.5	96.3	3.7	--
West Bengal					
1960	2,150	18.8	100.0	--	--
1965	3,310	22.4	99.3	0.7	--
1970	3,992	23.8	98.0	2.0	--
1975	4,686	22.8	97.6	2.4	--
1977	5,046	23.6	96.9	3.1	--
Tamil Nadu					
1960	416	15.5	100.0	--	--
1965	2,230	26.6	96.9	3.1	--
1970	2,595	27.1	96.9	3.1	--
1975	1,317	25.9	97.9	2.1	--
1977	1,852	25.0	90.4	9.6	--

Note: Dash indicates figure is zero or negligible.

Sources: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1955 (Simla, 1956); Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1960-61 (Simla, 1962); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1965-66 (New Delhi, 1968); Central Electricity Authority, Public Electricity Supply: in All-India Statistics, 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi, 1979); Central Statistical Organization, Statistical Abstract India, 1972 (New Delhi, 1973).

Conclusion

If the evidence from Indian power and cement industries is any guide, the use of oil in steam generation and for other purely thermal uses was not associated with a higher fuel efficiency than was the use of coal. Hence the substitution between the two fuels should have depended on their relative costs per unit of energy. Fuel oil prices, like all other oil product prices, was determined until 1976 on the basis of equivalent import costs plus customs duty. According to the formula developed for the purpose (Ministry of Petroleum, Chemicals, Mines, and Metals, 1969) the retail price in Bombay in the early seventies was Rs144 per kiloliter (3.03 RS/Million Btu)--nearly twice the import cost of Rs75. At this price, the furnace oil was three times as costly per unit of energy as coal, whose price at minehead was only Rs34.69 per ton, or 1.27 Rs/million Btu (Director of Mine Safety, 1976). This was the situation when the relative price of oil was lowest in the post-war period.

Thus there was no general cost incentive to use furnace oil. Furnace oil found markets near refineries, away from coalfields, and in industries where it offered some nonprice advantages over coal, for example, greater production capacity, greater controllability of process, no ash disposal problem, ready availability, and so forth.

The failure of furnace oil to make substantial inroads into the industrial fuel market must therefore be related to the high tax rates on it, which gave considerable protection to coal. This handicap was reinforced by the rise in oil prices after 1973. Subsequently, coal prices rose as well. In June 1979 the prices of furnace oil and low-grade coal were Rs389.06 per kiloliter and Rs58.55 per ton, respectively (Ministry of Industry, 1979). Between 1973 and 1979 the relative price of furnace oil to coal price rose by 60 percent. Thus, the government's tax and price policies have restrained the type of rapid shift from coal to oil that occurred in most industrial economies after World War II.

Transport

It was observed in the section entitled "Trends in Aggregate Energy Consumption" that transport in India was less dependent on oil than it was in Western Europe. In this section we will discuss why the changeover to

oil occurred less rapidly in India. We shall confine ourselves to land transport.

In India as elsewhere, there was a steady shift from coal to oil products, as is shown by table 12, but, into the late seventies, coal continued to supply over half the final energy consumed. However, this picture is misleading in two respects. For one thing, diesel and electric traction were many times more efficient on the railways than steam traction; thus final energy consumption overestimates the contribution of coal. For another, the fuel efficiency of diesel traction on railways was considerably greater than on the road transport; therefore, the estimates in table 12 overstate the role of the latter. We shall try to correct these biases in the sections which follow.

Railways

One of India's quaint sights is the thousands of steam engines which continue to serve the railways long after the time they have become relics in most other railway systems. Their persistence, which seems appropriate in the context of the oil crisis, was the result of what came to be viewed as a miscalculation.

As a first step in the postindependence industrialization, a factory with an annual capacity of 168 steam engines was built in 1950 (Railway Board, 1971, p. 27). By then, European systems were switching to diesel engines, which had the advantages of greater speed, longer range, and more controllable fuel consumption. The need for faster and more powerful engines became evident in India by the late fifties when the growth of heavy industries generated substantial bulk traffic. The steam engine works at Chittaranjan began to make electric engines in 1955. But electric engines required extensive track facilities for power transmission, which were capital-intensive. They were economical only when traffic density had crossed a certain threshold level. Further, electrification took time. The only short-term solution was to introduce diesel engines, which could replace steam engines at all traffic levels and with little additional investment on the track (in fact, it made unnecessary many facilities required by steam engines, such as watering points, coal dumps, and coal hoists). Hence about 400 diesel engines were imported, and finally, in

Table 12. Energy Consumption in Land Transport, for Selected Years

	1955	1960	1965	1970	1975
Road vehicle consumption, thousand tons					
Gasoline	850	842	1,093	1,400	1,259
Diesel oil	310	890	1,925	4,109	5,356
Railway consumption[a]					
Coal, thousand tons	11,192	14,801	15,940	14,341	13,137
Diesel oil, thousand tons	--	63	311	569	789
Electricity, GWh	590	780	1,160[b]	1,401[b]	1,296
Total consumption, kTJ	354	481	578	654	679
Gasoline	37	37	48	61	55
Diesel oil (on road)	13	38	83	177	230
Diesel oil (on rail)	--	3	13	24	34
Coal	302	400	430	387	355
Electricity	2	3	4	5	5
Proportion of total consumption, %					
Rail	85.9	84.4	77.3	63.6	58.0
Road	14.1	15.6	22.7	36.4	42.0
Coal	85.3	83.2	74.4	59.2	52.3
Oil products	14.1	16.2	24.9	40.0	47.0
Electricity	0.6	0.6	0.7	0.8	0.7

Sources: Ashok V. Desai, The Impact of the Rise in Oil Prices on India, Working paper no. 83 (Trivandrum, Centre for Development Studies, 1979); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts (New Delhi, 1956); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts (New Delhi, 1962); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1970-71 (New Delhi, 1972); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1975-76 (New Delhi, 1977); Energy Survey of India Committee, Report of the Energy Survey of India Committee (New Delhi, 1965); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1965-66 (New Delhi, 1968); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1970-71 (New Delhi, 1973); Indian Oil Corporation, Estimated Demand of POL Products During 1968 Thru 1975 (New Delhi, 1968).

[a]Locomotive use only.

[b]Includes the small quantity consumed by Calcutta Tramways.

1963, a new diesel engine factory was built with a capacity of 150 engines per year.

By the sixties it was doubtful whether steam engines were economical for any role except shunting; but to utilize capacity and labor, the railways continued to make steam engines till 1971. The stock of steam engines went down slowly through attrition; but neither the rate of attrition nor the growth of traffic could accommodate all the diesel and electric engines that could be produced, and their production capacity was underutilized.

Diesel engines, with their greater speed and load capacity, were first used on the lines where bulk traffic of heavy commodities, such as coal, ores, and steel, strained line capacity. Hence the penetration of diesel traction was faster into goods than into passenger traffic (table 13). In passenger traffic, conversion to diesel engines began with long-distance, limited-stop trains. Slow, short-distance trains with frequent stops continue even now to be hauled by steam engines. Consequently, the fuel efficiency of steam traction has steadily worsened (table 14).

The capital costs of electric traction were higher than those for diesel traction; hence it required greater traffic density to break even with the former than the latter. According to a study by the National Council of Applied Economic Research (1971), a cost comparison of diesel and electric traction--based on actual prices except for diesel oil whose price was taken net of taxes--favored diesel up to the highest traffic densities reached on Indian railways. If diesel oil was priced inclusive of taxes, which more than tripled its cost, the traffic density where the costs of diesel and electric traction were equal was about 15 to 20 million gross ton-kilometers per year, a density reached only on a few tracks in particularly heavy use. The NCAER took the rate of interest to be 6 percent but a more realistic interest rate would have favored diesel. The railways preferred assumptions that favored electric traction and came to a lower break-even point of 8 to 9 million gross ton-kilometers (Railway Board, 1971, p. 15).

Investment in electric traction is lumpy. Its full benefits cannot be realized by electrifying short stretches of track; on the contrary,

Table 13. Interfuel Shifts in the Railways, for Selected Years

	Fiscal Year				
	1960	1965	1970	1975	1976
Passenger traffic, million gross ton-kilometers	65,958	80,592	90,755	101,498	110,788
Steam	63,934	75,814	70,252	63,904	62,693
Diesel	32	1,334	11,635	23,700	30,712
Electric	1,992	3,443	8,868	13,893	17,384
Goods traffic, million gross ton-kilometers	159,071	211,619	233,329	270,025	286,431
Steam	143,222	104,979	70,487	52,213	45,216
Diesel	13,492	75,294	113,990	149,424	163,970
Electric	2,355	31,145	48,852	68,387	77,245
Passenger traffic, %	100.0	100.0	100.0	100.0	100.0
Steam	96.9	94.1	77.4	63.0	56.6
Diesel	--	1.7	12.8	23.4	27.7
Electric	3.1	4.2	9.8	13.6	15.7
Goods traffic, %	100.0	100.0	100.0	100.0	100.0
Steam	90.0	49.6	30.2	19.3	15.8
Diesel	8.5	35.6	48.9	55.3	57.2
Electric	1.5	14.8	20.9	25.4	27.0
All traffic, %	100.0	100.0	100.0	100.0	100.0
Steam	92.1	61.9	43.4	31.3	27.2
Diesel	6.0	26.2	38.8	46.6	49.0
Electric	1.9	11.9	17.8	22.1	23.8

Sources: Central Water and Power Commission, Public Electricity Supply: in All India Statistics 1960-61 (Simla, 1962); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1965-66 (New Delhi, 1966); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1970-71 (New Delhi, 1972); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1975-76 (New Delhi, 1977); Ministry of Railways, Indian Railways. Annual Statistical Statements 1976-77 (New Delhi, 1978).

Table 14. Fuel Consumption by Railways per Thou. and Gross Ton-kilometers for Selected Years

	1960		1965		1970		1975	
	Kg	MJ	Kg	MJ	Kg	MJ	Kg	MJ
Coal[a]	47.1	1,272	52.0	1,404	59.7	1,612	64.3	1,736
Passenger traffic	54.8	1,480	56.2	1,517	59.0	1,593	63.2	1,706
Goods traffic	43.6	1,177	48.9	1,320	60.3	1,628	65.7	1,774
	liters	MJ	liters	MJ	liters	MJ	liters	MJ
Oil[a]	3.9	141	4.6	166	4.0	144	4.1	148
Passenger traffic	9.3	336	3.0	108	5.3	191	5.6	202
Goods traffic	3.9	141	4.8	141	3.9	141	3.9	141
	kWh	MJ	kWh	MJ	kWh	MJ	kWh	MJ
Electricity	179	644	34	122	24	86	16	58
Relative fuel efficiency (coal = 1)								
Oil	9.0		8.5		11.2		11.7	
Electricity	2.0		11.5		18.7		29.9	

Sources: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1960-61 (Simla, 1962); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1965-66 (New Delhi, 1966); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1970-71 (New Delhi, 1972); Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1975-76 (New Delhi, 1977); Ministry of Railways, Indian Railways, Annual Statistical Statements 1976-77 (New Delhi, 1978).

[a]Combined totals calculated using total tonnage kilometers and total fuel consumption summed over passengers and goods. The specific gravity of high-speed diesel oil is taken to be 0.84.

the frequent change of engines it would entail would reduce efficiency. Hence electrification has to be undertaken for entire track systems that generate a good deal of self-contained traffic.

In the sixties electric traction was introduced on suburban lines, where heavy passenger traffic required an increase in track capacity, and in the coal-steel belt of Bengal, Bihar, and Orissa, where traffic density was high. Like diesel, electric traction has made greater inroads into goods traffic than into passenger traffic.

Following the oil crisis, the Fuel Policy Committee recommended accelerated electrification (Fuel Policy Committee, 1974, p. 91). While electric traction has not replaced diesel at the rate envisaged by the committee, the long trunk routes--Delhi-Calcutta, Delhi-Bombay, and so forth--are now being electrified. Once this has been completed, traffic hauled by electric power should show a rapid rise.

Electrification would lead to a considerable rise in fuel efficiency, for, in 1977, electric traction was thirty times as efficient as steam traction in energetic terms (table 14). Even after discounting for the low efficiency of power generation (26 percent in 1977), electric traction remains seven times as efficient as steam. Diesel traction is twelve times as efficient as steam traction. Thus, although coal accounts for 90 percent of the railways' final energy consumption, this high figure reflects the inefficiency of steam traction rather than its importance, for by 1977, steam engines hauled less than 20 percent of the traffic.

Road-Rail Competition

At the outset of this section, we set out the trends in energy consumption in road and rail transport. It would be interesting to compare them with indicators of transport output. However, reliable figures of transport output can be worked out only for 1965 (table 15). According to the estimates, road transport carried 63 percent of the passengers and 37 percent of the goods. Its overall share would depend on the relative weights used. If we treated a passenger as being equivalent to 1.2 gross tons as the railways do,[2] the share of road transport would work out to

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[2] Including the weight of the carriage per passenger.

Table 15. Composition of Passenger and Goods Traffic, 1965

	Number (1,000)	Average Number passengers or load (tons)[a]	Average Annual mileage (1,000 kilometers)	Annual passenger- or ton-kilometers	billion passenger- ton-kilometers %
Passengers					
Motorcycles	71.3	1.5	13.6	1.45	0.6
Scooters	126.8	1.5	11.2	2.13	0.8
Scooter-rickshaws	14.1	1.5	37.1	0.78	0.3
Cars	346.6	2.0	18.2	12.62	4.8
Jeeps	56.1	2.5	21.4	3.00	1.1
Taxis	32.5	2.5	42.8	3.48	1.3
Petrol buses	11.0	30.0	28.2	9.31	3.6
Diesel buses	60.1	40.0	55.2	132.70	50.6
All road transport				165.47	63.1
Railways[b]				96.76	36.9
All mechanized transport				262.23	100.0
Goods					
Light petrol trucks	32.0	3.0	27.9	2.68	1.4
Heavy petrol trucks	14.4	4.0	30.0	1.73	0.9
Other petrol vehicles	46.0	2.0	18.5	1.70	0.9
Diesel trucks	199.9	5.0	61.0	60.97	32.8
Other diesel vehicles	19.1	3.0	30.7	1.76	1.0
All road transport				68.84	37.0
Railways[c]				117.00	63.0
All mechanized transport				185.84	100.0

Note: This table covers mechanized transport only.

Sources: Central Statistical Organization, Statistical Abstract India, 1974 (new Delhi, 1975); National Council of Applied Economic Research, Consumption Pattern of Selected Petroleum Products (New Delhi, 1971).

[a]Assumed. Supporting figures for goods are available in Ministry of Food and Agriculture (1966). For buses and trucks, the figures are of capacity rather than average load, but the two may not be too far apart since both buses and trucks are com overloaded.

[b]Fiscal years.

[c]Net ton-kilometers; that is, excluding tare weight (weight of empty car).

be 53 percent. The gross weight per passenger is much lower for a bus, so weights based on road transport would lower its share. Depending on weights, therefore, road transport carried between 37 and 53 percent of the traffic in 1965, while it accounted for 23 percent of the energy consumption. Very approximately it was twice as fuel-efficient as the railways.

This relative inefficiency of the railways was caused by their use of coal, for their diesel engines achieved 25 ton-kilometers per liter of fuel against a mere 4 ton-kilometers for trucks (Railroad Board, 1971).

Table 15 gives a point estimate for 1965. It is impossible to make similar estimates over a period of time, for surveys of vehicle-kilometers comparable to estimates of the National Council of Applied Economic Research(1971) are not available, and the number of kilometers traveled has been changing over the years. In particular, the average annual distance traveled by automobiles almost certainly fell considerably after oil prices began to rise in 1973. While the number of all gasoline-driven vehicles (excluding the small number of buses) went up, gasoline consumption in 1977 was 14 percent lower than it was in 1972. This does not necessarily imply that there was a decline in the number of passenger-kilometers traveled. Commuters driving to work in cities (for example, Bombay and Delhi) began to pool cars. More important, there was a restructuring of the stock of passenger vehicles toward greater fuel efficiency.

The number of automobile purchases declined after 1973. Even in 1972, the new-car purchases came to only 7 percent of the existing stock. Hence the increase in the number of cars on the road in 1974-77, net of scrapped vehicles, could have been only negligible, possibly negative. Until 1973 new cars were in excess demand, and until this time that demand seemed to be unending. In 1974, however, the excess demand suddenly disappeared, and the manufacturers of a relatively less fuel-efficient model, who used to charge a registration fee, had to reduce their price and begin giving installment credit. But the difference in fuel efficiency was not large enough, nor was the supply of models elastic enough to restructure the market toward smaller or more efficient cars. The demand for motorcycles and scooters, on the other hand, shot up, and

their output doubled between 1972 and 1976. (The imports and exports of both cars and scooters were negligible.)

There was also a movement away from individual to mass transportation. The period after 1973 saw the advent of minibuses in many cities. In some cities (for instance, Delhi) employees began to charter buses. The capacity utilization of such buses, used only to transport commuters and school children at specified times, is low, and their costs are higher than for public buses. But for people who earlier traveled by car or scooter, chartered buses nevertheless reduced costs, and a shift to them reduced gasoline consumption. The annual sales of new buses came to 16 percent of the stock in 1972-74 and left room for a considerable net expansion of the fleet.

There was also a considerable increase in the fuel efficiency of railway services (see tables 13 and 14) arising from the substitution of diesel oil and electricity for coal. The fuel efficiency of trucks also increased as a result of an increase in their average size; but it could not have been nearly as rapid as that for railways. Overall, it is likely that the railways' share fell after 1965, though not as rapidly as the energy consumption figures in table 12 imply.

It is clear that this shift to roads continued in passenger transport after 1972 (Desai, 1979b). The gross additions to the bus fleet reached 17 percent per year in 1972-74 and probably were not much less afterwards; even after scrappings, the bus fleet would have continued to grow at about 10 percent. Additions to the passenger coach fleet of the railways rose by only 3 percent 1972-74 (Ministry of Railways, 1977, p. 258), while passenger-kilometers on the railways actually fell by 6 percent. Railway passenger traffic rose after fiscal year 1974 and was 22 percent above the fiscal year 1972 level in fiscal year 1976. We have no comparable figure for bus passengers, but the high-speed diesel consumption of state bus lines rose by 42 percent in the same period. Thus all indicators point toward a faster growth in long-distance bus transport than in passenger rail traffic.

The evidence on goods transport is weaker but points in the same direction. The gross additions to the truck fleet were about 6 percent per year; but the net increase was probably only 2 to 3 percent a year.

The increase in the goods wagon fleet of the railways was even slower. Further, it is our impression that a rising proportion of goods on the road was being carried by vehicles other than trucks, particularly tractor-trailers and vans. Total ton-kilometers of goods moved by rail fell slightly between fiscal year 1972 and fiscal year 1974, then rose 16 percent by 1976. The recorded high-speed diesel consumption by trucks rose by 58 percent during the four years, but the figure is misleading. Until 1973, the market price of high-speed diesel was much above that of kerosine, which led to the clandestine mixing of gasoline with high-speed diesel for cheaper fuel.

In early 1974 the prices of both were nearly equalized to remove the incentive for adulteration. As a result, the recorded consumption of kerosine fell by 600,000 tons between 1973 and 1974. If we add kerosine consumption to high-speed diesel consumption in road transport, there was a total increase of 23 percent in 1972-76; and this is probably a low estimate of the growth of fuel consumption in road transport. Hence road transport of goods probably expanded faster than railways goods traffic, though perhaps not much faster.

The question as to why the rise in oil prices did not dampen the growth of road transport or favor rail transport raises a number of complex issues relating to rail capacity, speed and quality of service, taxation, and so forth, but the basic answer is simple. First, fuel costs make up a fairly small percentage of road transport costs varying between 15 and 20 percent in state bus and truck operations in 1971 (Ministry of Shipping and Transport, 1971, pp. 220-225). Second, the rise in the price of high-speed diesel, the prime fuel of road transport, was the lowest among major oil products--only 50 percent between early 1973 and 1978--somewhat less than the general rise in prices. Third, the railways themselves were increasing their consumption of high-speed diesel even more rapidly than road transport because of the rise in traffic intensity that could be achieved by replacement of steam engines by faster diesel engines. Thus, railroad competition was little affected by the relative costs of oil products and other fuels.

Agriculture

Even now Indian agriculture consumes only small quantities of conventional energy forms; hence there is little scope for substitution among them, except insofar as the spread of electricity into rural areas has recently led to some replacement of diesel by electric irrigation pumps. However, the commercial energy--oil and electricity--that is used in agriculture powers equipment designed to replace human and animal labor. It is this substitution that we shall focus on here.

Indian agricultural practice differs considerably, not only from that of developed countries, but also from that of the less-developed countries of Africa, South America, and the Pacific, and also from that of East Asia. It may be useful to begin with a discussion of its characteristic patterns of energy consumption before we consider the changes brought about by commercial energy.

Except in small pockets in the hills of Orissa and the northeast, shifting cultivation and the digging-stick culture have long disappeared in India. Now, the dominant form is the ploughing of more or less permanently cultivated land. About 10 percent of the land under cultivation is fallow at any one time, but fallowing in rotation is rare, and most land is cultivated year after year.

Virtually all ploughed land is worked by bullocks, a smaller proportion by buffaloes. The use of horses is unknown. Ploughing generates the peak demand for animal labor. The plough is almost invariably drawn by two animals and guided by one human worker. The peak demand for manual labor is in reaping.

The fodder of working animals is straw obtained from cultivation, but in virtually no part of India does all the fodder come from agriculture. According to calculations given in appendix A, the agricultural sector supplies only about half the total animal fodder. Of the rest, perhaps a third comes from fallows and pasture, but the remainder--a crucial proportion--must come from outside the agricultural system. In effect, therefore, agriculture obtained an energy subsidy from nonagricultural land in the form of fodder grazed by animals. But a considerable part of the energy obtained by animals is consumed in the activity of grazing itself, so that the net efficiency of animal labor is low. It is in-

creased by reserving most of the grown fodder for working or milch animals, but even then the productivity of animals in terms of work, as well as of milk, is low.

This system, which relies on the availability of uncultivated land for grazing, comes under strain in two types of areas. First, in the arid areas of the northwest and the peninsula (in Rajasthan, Gujarat, Maharashtra, Andhra, Madhya Pradesh, and once Punjab and Haryana), the rainfall is too low and the isolation too great to provide fodder from nonagricultural land in summer. Here the practice for centuries has been to grow tall crops like sorghum, millet, and pulses, which give more straw per unit of grain than wheat or rice. Second, there are areas in the Gangetic valley and along the southern coast (in West Bengal and Tamil Nadu), where a dense population has encroached upon nonagricultural land and the available grazing land is inadequate. These areas mainly grow rice owing to its high yield and climatic suitability, but its straw-grain ratio is low. Fodder supply in these areas is also low, and fodder is economized by increasing the proportion of human to animal labor (by means of high yields per hectare, which reduce ploughing labor input per ton of grain), and by increasing the proportion of working to nonworking animals. The ratio is increased partly by having fewer buffaloes, which are better as milch animals than working animals, and partly by varying the sex ratio of cattle. This may sound impossible in a country where slaughter of cattle is rare, but mortality among young stock is high and is related to their eventual economic utility.

While ploughing is the prime task of working animals, they are--or were--also used for irrigation in areas where underground water is available but is too deep to raise with human labor. Animal-operated water lifts were most common in the upper Gangetic plain--Punjab, Haryana, and Uttar Pradesh--but were also used in the arid northwest and the peninsula wherever water was available. Rice-growing areas used little animal labor for irrigation because there was a shortage of animals and because rice required too much water to be economically cultivable with animal-drawn water. But rice was extensively irrigated in Tamil Nadu from shallow lakes impounded by low dams, and water was often lifted over the low heads--rarely more than six feet in height--by human labor.

The above description applies to Indian agriculture in the unmechanized state that substantially prevailed till the 1950s. By 1972, however, there were five times as many mechanical pumps, with a much higher average capacity, as animal-operated lifts (table 16). There were about 3.2 million pumps in 1972, and by 1977 this number had roughly doubled, with a matching increase in output. The spread of tractors was much more limited. Their numbers were significant only in Punjab and Haryana; and there, too, bullocks continued to be extensively used for ploughing. We shall next inquire how far pumps and tractors replaced animal labor (and thereby the human labor involved in supervising animals).

Irrigation

Figures for the number of animal-operated water lifts are not available before 1961, but at that time there were few pumps except in Tamil Nadu, and hence little possibility for substitution. The animal-operated devices were of two types. The Persian wheel, operated by a single bullock, was used principally in the canal-irrigated areas of Punjab and Uttar Pradesh where the water table is high. Elsewhere, where water had to be drawn from deeper down, two bullocks walking down an incline pulled up a leather bucket from a well over a pulley. The bucket was emptied on reaching the top, after which the bullocks walked backwards up the incline.

As table 16 shows, animal-operated devices were used most extensively in Punjab (which then included Haryana) and Uttar Pradesh in 1961. Even there, however, they could not have been very important in terms of irrigated area or the amount of animal labor engaged. In Punjab where they were most prevalent, they would have engaged 6 to 7 percent of the animals if all the devices were being worked simultaneously; and even if each had irrigated 5 hectares--which would be a high figure--they would have irrigated less than 10 percent of the cropped area.

In the next decade so many pumps were installed that, by 1972, their number far exceeded that of animal-operated water lifts. But the number of water lifts actually rose. Pumps were installed most extensively in Tamil Nadu, where earlier low-head man-operated devices were prevalent; and next in Punjab, where the number of animal-operated devices fell.

Table 16. Density of Working Animals and Competing Machines on Gross Cultivated Area, for Selected Years (number per 1,000 hectares)

	Working animals				Tractors			Pumps			Water lifts		
	1956	1961	1966	1972	1961	1966	1972	1961	1966	1972	1961	1966	1972
Punjab[a] (including Haryana)	272.0	283.5	255.2	249.6	0.8	1.8	5.6	1.8	6.3	40.6	18.5	20.3	7.2
Punjab (excluding Haryana)			300.1	294.7	--	2.3	7.4	--	8.9	67.0	--	29.6	8.9
Haryana			204.6	198.5	--	1.3	3.6	--	3.5	22.8	--	9.8	5.3
Uttar Pradesh	616.1	642.0	657.2	659.1	0.3	0.5	1.6	0.5	1.7	13.4	6.6	11.0	10.0
Bihar	795.9	730.1	724.5	769.7	0.1	0.2	0.5	0.5	1.0	8.9	2.0	3.1	5.0
West Bengal	808.9	782.9	797.4	706.2	--	0.2	0.1	0.6	0.8	1.0	2.3	2.3	--
Assam	873.5	991.0	1335.9	884.2	--	[illegible]	0.2	--	--	--	--	--	--
Orissa	657.8	827.0	673.7	762.3	--	--	0.3	0.2	0.1	0.9	--	--	--
Rajasthan	268.6	297.7	277.7	239.1	0.2	0.3	0.6	0.2	0.8	4.8	2.8	1.9	4.1
Gujarat[b]		316.0	305.8	294.9	0.2	0.3	0.9	5.4	12.5	39.6	2.5	1.8	0.6
Maharashtra[b]		353.4	360.3	338.3	0.1	0.1	0.3	3.9	9.8	18.9	0.9	0.5	0.2
Madhya Pradesh	520.6	568.4	585.9	515.3	0.1	0.1	0.2	0.7	1.3	5.4	5.0	4.7	4.8
Andhra	476.8	544.5	561.2	536.8	0.2	0.2	0.5	4.4	8.6	20.2	2.3	1.7	3.0
Karnataka	317.3	386.1	386.3	371.0	0.1	1.3	0.5	2.1	5.0	10.3	2.5	1.5	3.1
Tamil Nadu	701.3	726.6	813.5	703.7	0.1	0.4	0.9	19.0	35.5	116.2	0.1	0.3	0.1
Kerala	379.6	350.5	296.7	208.6			0.1	2.6	4.7	9.5	10.5	4.3	1.7
India	488.7	526.5	522.0	500.1	0.2	0.4	1.0	2.6	5.7	19.2	4.1	4.4	3.9

Sources: Ministry of Food and Agriculture, India Livestock Census 1956, vol 1, Summary Tables (Delhi, 1960); Ministry of Food and Agriculture, Haryana, Punjab, Chandigarh, and Himachal Pradesh: Agricultural Statistics (New Delhi, 1966); Ministry of Food and Agriculture, India Livestock Census 1961, vol. 1, Summary Tables (New Delhi, 1966); Ministry of Food and Agriculture, Agricultural Situation in India 1975 (New Delhi, 1976) Ministry of Food and Agriculture, Indian Livestock Census 1972, vol. 1, Summary Tables (New Delhi, 1976); and Ministry of Agriculture, Indian Livestock Cen[illegible] 1966, vol. 1, Summary Tables (New Delhi, 1971).

[a]The erstwhile (East) Punjab was divided into two states, Punjab and Haryana, after 1961.

[b]Bombay was divided into Gujarat and Maharashtra in the course of the comprehensive reorganization of states in 1956.

However, the number of animal-operated devices rose in Uttar Pradesh and fell only slightly in Nadhya Pradesh, the two other states where the density of pumps was high. On the other hand, the use of pumps spread widely in Gujarat, Maharashtra, and Andhra Pradesh, all relatively low rainfall states with low water tables. Thus pumps did replace human workers and animals to some extent; but for the most part they exploited deep water resources that were earlier too expensive to utilize with animal labor.

The peak power requirement of lift irrigation is an increasing function of depth. The peak power capacity of men as well as of animals limits the maximum depth from which they can lift water to about 5 meters and 10 meters and their output to 1 to kiloliters per hour and 4 to 5 kiloliters per hour respectively (Dhawan, 1975, p. 433). A 2-horsepower pump, about the smallest in common use, would lift about 30 kiloliters per hour from a depth of 8 meters (Bhatia, 1978, pp. 12-13). Pumps of higher capacity would lift proportionately more water with a lower fuel input per kiloliter and could also pump from a greater depth. A number of high-capacity pumps in India tap water down to 300 meters. Thus pumps can achieve a higher output per hour than human or animal power at depths accessible to the latter and they also can exploit depths that would otherwise remain unexploited.

Further, there is evidence that pumps are installed for their scale effect and not simply because they are cheaper. In Gujarat, small-diameter suction pumps were not popular because they could be replaced by two animal-drawn devices; and among reasons given by farmers for buying a pump, intensification of cropping and augmentation of bullock power were prominent (Patel and coauthors, 1969, pp. 107, 122). A pump not only raises more water, but, by depleting the water faster in the well or around the screenpipe, it also accelerates recharge and makes more water available to the individual farmer--but does not, of course, increase the underground water supply (Dhawan, 1975, p. A 35). Since the returns to timely water supply are extremely high, the choice of water-raising technology is governed in the long run by the corditions of underground water supply.

If this explanation is correct, the areas of competition between

mechanical and nonmechanical devices are limited to those where the water table is high enough for exploitation by traditional devices, and where the demand for water is low enough to be met by them--principally high-rainfall areas in the lower Gangetic plain; here, too, as cultivation is intensified and second and third crops become commonplace, mechanical pumps may be expected to gain in popularity.

There are numerous studies which come to very similar conclusions on the economics of diesel oil and electricity as alternative fuels for pumping. All of them conclude that the irrigation requirements of an individual farm are best met by electric pumps if calculations are made at market costs. For instance, Patel and Patel (1969) calculated the relative costs of exploiting a well with discharge of 0.3 cubic meters per second in Gujarat, and found electric pumping to be appreciable cheaper. In a study done after the rise in oil prices, Bhatia and Mehta (1975) considered a large number of technical alternatives in drilling, screens, pumps, depth, and water requirements in the context of a Punjab farm and concluded that diesel power was almost invariably cheaper. But their conclusion followed entirely from the fact that they included the capital costs of electricity transmission, which tend to be extremely high for rural irrigation pumps. In a later benefit-cost analysis for a representative Bihar farm, Bhatia (1978) found electric pumps cheapest at market costs among a number of existing and potentially available technologies as long as power connection costs were held below Rs5,835.

These studies of fuel choice under controlled conditions suggest that where both diesel oil and power are available, farmers would choose electric pumps for irrigation. This is generally true of most of the country. After 1966, the emphasis of rural electrification shifted from lighting to irrigation and, as a result, the number of electric pumps rose from 513,000 in 1966 to 1.1 million in 1969 and 3 million in 1977 (Central Electricity Authority, 1978). This subsidized electrification of irrigation is the chief explanation of the relative decline in the number of diesel pumps.

However, the market for diesel pumps is not confined to nonelectrified areas. As Patel and Patel (1971) found in Uttar Pradesh, the average costs of irrigation for small farmers using less than 40,000 cubic meters of water per year were lowest with small portable 5 to 6.5 horsepower

diesel pumps whose capital costs were low. In Bihar, Appu (1974) observed that small farmers share or hire portable diesel pumps, which are carried around from one bamboo tubewell to another in carts or tractor-trailers. It is their mobility that affords small diesel engines a market among peasants with small land-holdings that electricity cannot penetrate.

Ploughing

The mechanization of ploughing made some headway only in Punjab and Haryana, so we shall concentrate on these two states. In table 17, we present their land area, output, and livestock statistics for 1961, 1966, and 1972.

It should be noted that 1965-66 was a time of exceptional drought; therefore, area under cultivation and crop yields were depressed in that year. Even so, it is clear that agriculture in Punjab and Haryana was relatively static till 1966 but that it took a big leap forward in the next six years. They were also the years in which the number of tractors increased from 16,000 to 60,000. If we assume that each tractor replaced five pairs of bullocks, their contribution to draught power rose from 6 to 18 percent. This displacement effect is borne out by the fact that cropped area per working animal rose by 12 percent.

The amount of cropped area increased by 20 percent in 1966-72, while the number of working animals rose by 8 percent. It cannot be argued, however, that there was a shortage of working stock for there was an active market in livestock, and animals could have been brought from outside the area. The number of livestock other than working animals went up by 21 percent. Whether it did so by natural increases or by stock imports, it is clear that there was no constraint on the growth of working stock.

Neither did fodder output restrain the work capacity of animals, for straw output per animal rose from 1.26 tons in 1966 to 2.27 tons in 1972. The amount of grazing area was reduced by more than 50 percent. But even in 1966, only 14 percent of cultivable land was available for grazing. Hence the fall in grazing area could not have led to a reduction in fodder supply; on the contrary, the rise in fodder available from agriculture

Table 17. Agricultural Land Area and Number of Livestock in Punjab and Haryana, for 1961, 1966, and 1972

	1961	1966	1972
Land area, thousand hectares			
Reported area	9,410	9,428	9,433
Forest, built-up and uncultivable land	1,290	1,313	1,330
Pastures, groves, fallow, and cultivable land	970	982	460
Net sown area	7,165	7,133	7,643
Double-cropped area	2,156	1,815	3,129
Gross cropped area	9,307	8,948	10,772
Output, million tons			
Foodgrains	6.16	5.37	12.47
Straw[a]	12.08	11.50	23.58
Livestock, thousand			
Working animals	2,354	2,493	2,689
Milch cows	888	834	953
Milch buffaloes	1,191	1,443	2,049
Other	5,978	5,537	6,952
Equipment, thousand			
Tractors	8	16	60
Pumps	17	62	441
Carts	539	615	667
Ploughs	1,950	2,064	2,221

Sources: Ministry of Food and Agriculture, India Livestock Census 1961, vol. 1, Summary Tables (New Delhi, 1966); Ministry of Food and Agriculture, Indian Agricultural Statistics 1965-66 (New Delhi, 1971); Ministry of Food and Agriculture, Indian Livestock Census 1972, vol. 1, Summary Tables (New Delhi, 1976); Economic and Statistical Organization, Statistical Abstract of Punjab 1969 (Chandigarh, 1970).

[a]Calculated with straw-grain ratios taken from table A-8.

reduced the need for grazing areas.

Tractors were not introduced because of any constraint on working animals or fodder, and must have been acquired solely because of their cost advantage. While no valid general comparison of their relative costs can be made with existing data, table 17 suggests that fodder must be considered as an important factor among the costs of animals. When the livestock of Punjab and Haryana was restructured between 1966 and 1972, the percentage of working animals fell from 27 to 22 percent, while that of milch animals rose from 22 to 25 percent.

If relative costs led to the acquisition of tractors, it may be asked why tractors became commonplace only in Punjab and Haryana; for the relative costs in these two states could hardly have been so different from those in the rest of India. The answer, which at this stage must be tentative, is threefold. First, while the fodder costs of draught power were probably equally high in other parts of India, they were less visible to the farmer because a larger part of fodder supply came from communal grazing lands.[3] If a farmer saved fodder by buying a tractor, the savings accrued to the village, and not to him. In Punjab and Haryana, where commons formed a very small proportion of cultivable area, farmers fed their animals almost entirely from their own hay, and savings in hay from tractorization accrued largely to them. Second, the Green Revolution, which was largely confined to Punjab, Haryana, and western Uttar Pradesh, raised farmers' incomes so rapidly that their investment capacity rose much faster than it did for farmers in other parts of the country. Not only was the rise in incomes more rapid, but the rise in marketed surplus also was greater, as was the increase in purchasing power (as distinct from subsistence consumption). Third, the rise in marketed surplus also raised the ratio of gross ton-kilometers to ton-kilometers of the sold output; the transport requirements so generated were met by tractors. It is notable that while the grain output in Punjab and Haryana more than doubled between 1966 and 1972, the number of bullock-carts rose

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[3]The custom in most parts of India is that grazing is open to all animals, not only on grazing lands, but also on private farmland when crops are not growing.

only from 615,000 to 669,000. Tractors contributed as much to the mechanization of rural transport as to ploughing.

Conclusion

We have looked at two aspects of agricultural mechanization, namely, mechanization of irrigation and of ploughing. The use of mechanical pumps spread more widely, though not more rapidly, than tractors, whose introduction was highly localized. This may be because the economic advantage of pumps over animal draught power was greater than that of tractors. More important, however, pumps made it economical to tap aquifers that were too deep to exploit with animal power, while tractors largely replaced animal power and did not bring new area under cultivation.

While we are not here concerned with the employment of human labor, our results throw an interesting sidelight on it. It is commonly believed that pumps increase employment. The effect of tractors is more controversial, but the weight of evidence seems to support the view that they reduce employment (Binswanger, 1978).

We need here to distinguish between the primary and secondary effects of mechanization. Insofar as the productivity of a machine is higher than that of an animal (or a pair of them), mechanization will lower the number of hours required to do a certain task; and since a machine requires supervision, as does an animal, the primary effect of mechanization must be to increase the productivity and to reduce the employment per task of the supervisor--it must therefore reduce employment per unit of output. This is as true of pumps as of tractors. But two features distinguish the product of pumps--namely, water--from the product of tractors--namely, draught power.

First, the introduction of pumps has been associated with a massive rise in the quantity of water. The draught-power applications have also risen rapidly in those areas where tractors have been introduced in significant numbers; but, by and large, tractors are not associated in India with the extension of the margin of cultivation. Second, the returns to water inputs have been spectacularly positive in the arid parts

of India--and pumps have prevailed only in those areas--whereas the returns to marginal increases in draught power on already cultivated land are not known to be remarkable.

Hence the primary fall in employment arising from the use of pumps is overshadowed by the secondary labor employed in harvesting and processing the additional agricultural output, while secondary employment generated by tractors goes unnoticed. This is so partly because it has not been looked for. For instance, the increase in employment on milch animals has not been estimated in any study of tractors. Partly, the studies have used the wrong techniques by trying to isolate statistically the impact of tractors on output from that of irrigation, fertilizers, and so forth; since there is a high degree of cross-correlation, nothing definite emerges.

The questions to be asked--and answered--are, Does an increase in the amount of draught power applied raise output under Indian conditions? And is the introduction of tractors associated with greater application of draught power per hectare? The answer to the first question is that it probably does raise output, for otherwise the normal Indian practice of ploughing a field four or five times before it is sown would not make sense. Ploughing reduces weed growth and increases rainwater percolation, both of which increase output, and both effects are increased by deeper ploughing that the greater horsepower of a tractor permits; but, obviously, returns to more or deeper ploughing must diminish. The answer to the second question is not known, and rather than speculate on this, we would leave it for future enquiry.

Domestic Consumption

Trends in domestic fuel consumption are difficult to read. As shown in appendix A, the available estimates of noncommercial fuel consumption are too approximate to yield any reliable trends. Therefore, we shall start with the more definite statistics of commercial energy consumption and draw inferences about noncommercial energy.

Lighting

For lighting the only alternatives that count are kerosine and elec-

tricity. Vegetable oils, extensively used for lighting at one time, went out of use when cheap Russian kerosine became available at the turn of the century (Dasgupta, 1971). Electricity was the urban illuminant, for virtually all towns had it by the fifties (though a large proportion of the slum and shifting population in cities must have continued to use kerosine). Kerosine, on the other hand, was the rural illuminant, at any rate until the mid-sixties when electricity had reached barely 8 percent of the villages.

This picture has since changed. By the end of March 1978, electricity had reached 38 percent of the villages having 60 percent of the rural population. This does not, of course, mean that 60 percent of rural homes were electrically lighted; the proportion of households having electricity is much lower. We do not have nationwide information on this proportion, but a recent survey of rural energy consumption in northern India (National Council of Applied Economic Research, 1978), offers an interesting insight into the question.

According to the 1971 data, the area surveyed by the NCAER had 188,204 villages, of which 55,589 were supposed to be electrified, according to official sources, by the end of March 1975. The survey found that 45,974 had domestic connections. This does not mean that the rest were electrified only on paper, for the thrust of the rural electrification program was to supply power for productive uses, mainly for irrigation; and it is likely that in the remaining villages power was available only to pumps and workshops. Thus 29.5 percent of the villages in the surveyed area had electricity, about the same as the percentage for the country as a whole.

Of the villages, 24.4 percent had domestic connections; however, they were among the larger villages, and contained 40.7 percent of the households. Of the 9.3 million households in those villages, 2.4 million, or 25.8 percent, had domestic connections. Thus, the households with connections, comprised 10.5 percent of the rural population.

The NCAER study found that 82.7 percent of the villages with electricity had domestic connections, and that a quarter of their population received electricity. The percentage of electrified villages in northern India was very similar to that for the whole of India. If we assumed

the percentages established by the NCAER would apply also to later years, the percentage of the rural population having electricity in March 1978 would work out to be 12.8 percent.

The percentage of kerosine consumed by these households would be greater, because they would be the better-off households. How much greater, it is difficult to say. The 1963-64 National Sample Survey did not show the per-capita consumption of better-off households to be much above the national average, but they were already by then receiving some electricity. The NCAER survey shows that households receiving electricity continued to consume kerosine, but that their consumption peaked off at about 25 liters a year per household. Evidently, households receiving electricity used kerosine for cooking. The total evidence seems to point toward the conclusion that the kerosine consumption of better-off households in the absence of electricity was above the rural average but not greatly so. If we assume it to be 20 percent greater, the 12.8 percent better-off households must have consumed 15.3 percent of the kerosine, which is therefore the proportion by which electrification should have reduced the demand for kerosine. The increase in national per capita kerosine consumption in 1970-77 is probably due to its growing use in cooking (table 18).

There is also other evidence that electricity had made a dent in the demand for kerosine. Hurricane lanterns, among the brightest of unpressurized kerosine lamps, have a high rate of kerosine consumption and are generally used by better-off households. However, in 1977 their output fell 25 percent below the 1971 output of 3 million; and in the early sixties, it had been 5 million. On the other hand, in 1977 the output of light bulbs and tubes was almost 50 percent higher than that of 1971.

There is a further process of substitution that has perhaps been working against kerosine lighting. In villages, a kerosine lantern is put to two uses: to light a home and to light one's way in the dark. For the second use a better substitute became available in the 1950s, namely, the battery torch (flashlight), which costs less initially, and has a lower operating cost because it can be switched on and off. While we have no figures on the production of torches, the output of battery cells gives some idea of their use. At 600 million per year, the output of

Table 18. Domestic Consumption of Commercial Energy, 1955-77

	1955	1960	1965	1970	1975	1977
Kerosine, thousand tons						
Official estimate	1,404	1,948	2,528	3,262	3,031	3,525
Minus estimated diversion to high-speed diesel oil[a]	--	400	700	1,250	--	--
Actual consumption	1,404	1,548	1,828	2,012	3,031	3,525
Electricity, GWh	850	1,492	2,355	3,840	5,821	6,821
LP gas, thousand tons	--	--	--	163	257	310
Population	391	432	487	539	598	622
Per capita consumption						
Kerosine , kg	3.59	3.58	3.75	3.72	5.07	5.67
Electricity, kWh	2.17	3.45	4.84	7.12	9.73	10.97
Gas, kg	--	--	--	0.30	0.43	0.50
Villages electrified, %	1.5	4.2	8.4	18.5	32.3	37.7
Proportion of rural population in electrified villages, %	n.a.	n.a.	n.a.	n.a.	54.4	59.8

Notes: Dash indicates figure is zero or negligible.

n.a. = not available

Sources: Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1955 (Simla, 1956); Central Water and Power Commission, Public Electricity Supply: in All-India Statistics 1960-61 (Simla, 1962); Central Statistical Organization, Statistical Abstract of the Indian Union 1963 and 1964 (New Delhi, 1965); Central Statistical Organization, Statistical Abstract India, 1974 (New Delhi, 1975); Central Statistical Organization, Statistical Abstract India 1977 (New Delhi, 1978); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1965-66 (New Delhi, 1968); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1970-71 (New Delhi, 1973); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1975-76 (New Delhi, 1977); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi, 1979); Ministry of Petroleum, Indian Petroleum and Chemicals Statistics 1972 (New Delhi, 1973); Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics, 1976 (New Delhi, 1977); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979); Indian Oil Corporation, Estimated Demand of POL Products During 1968 Thru 1975 (New Delhi, 1968).

[a]The National Council of Applied Economic Research (1971) estimated that kerosine used as adulterant came to 34 percent of officially estimated HSD consumption in 1968. We have applied the same ratio to other years. HSD prices were raised above those of kerosine in 1957, and again equalized in 1974.

cells in the seventies was three times its level in the early sixties. Much of the increase can be explained by the rise in the number of transistor radios. But considering their cumulative output to date, the number of transistor radios must be of the order of 20 million; consumption of 30 cells a year per radio would obviously be too high. Very approximately, 200 to 300 million cells a year are used to power 40 to 50 million torches, perhaps not many fewer than the number of hurricane lanterns. While torches have not replaced hurricane lanterns, they certainly would reduce kerosine consumption (Desai, 1979b).

Cooking

In the discussion of cooking we can no longer avoid noncommercial fuels, for they constituted the predominant cooking fuels in rural India. In table 19 figures for rural domestic energy consumption in various states in 1963-64 are presented, as estimated by the NSS. As stressed in appendix A, the figures are extremely inaccurate, but some of their features stand out so clearly that they will withstand the inaccuracy.

According to table 19, firewood and dungcakes were virtually the only cooking fuels that mattered in rural India. Of them, firewood provided almost all the fuel in the sparsely populated states of Assam and Orissa, and also in the southern states. Dungcakes were important in the Gangetic plain, but the farther one traveled southward from the plain, the less important they became. This regional variation is confirmed by estimates of the use of dung as manure (see table A-6). The reason for it is not clear, but must be related to the number of trees for firewood,[4] for the northern plains are visibly denuded of trees.[5]

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[4] As far as rural firewood consumption is concerned, it is not the forest area that matters but the number of trees within walking distance of a village. The rural population in most parts of India is too far from forests to get much fuel from them. They do, however, probably yield a goodly amount of fuelwood for urban areas located nearby.

[5] According to Sleeman (1844), it was the practice in India for villages to have a grove of shady mango, tamarind, and neem trees on their outskirts, where strangers could camp in summer. Such groves were cut down in the north during the depredations of the eighteenth century, and laws of private property subsequently introduced by the British made their replanting by public-spirited citizens unfeasible.

Table 19. Monthly Rural Per Capita Domestic Consumption of Energy by States, 1963-64

State	Fire-wood (kg)	Dung (kg)	Other solid fuels (kg)	Kero-sine (liters)	Elec-tri-city (kWH)	Energy consump-tion (MJ)	Fire-wood (%)	Dung (%)	Other solid fuels (%)	Kero-sine (%)	Elec-tri-city (%)
Punjab	18.35	17.04	0.10	0.42	0.07	464.02	59.32	36.72	0.65	3.26	0.05
Uttar Pradesh	17.19	14.00	0.07	0.34	0.01	412.23	62.55	33.96	0.51	2.97	0.01
Bihar	14.79	10.84	1.49	0.46	0.01	391.55	56.66	27.68	11.42	4.23	0.01
West Bengal	15.46	18.74	2.72	0.54	0.02	520.41	44.56	36.01	15.68	2.81	0.01
Assam	45.24	0.02	0.13	0.67	--	706.82	96.01	0.03	0.55	3.41	--
Orissa	34.92	2.79	0.07	0.43	0.01	569.32	92.00	4.90	0.37	2.72	0.01
Rajasthan	20.40	10.38	0.55	0.27	--	436.02	70.18	23.81	3.78	2.23	--
Gujarat	16.70	4.78	0.06	0.64	0.03	323.25	77.49	14.79	0.56	7.13	0.03
Maharashtra	21.63	2.94	0.17	0.65	0.05	382.53	84.82	7.69	1.33	6.12	0.05
Madhya Pradesh	31.09	11.41	0.08	0.50	--	600.85	77.62	18.99	0.40	3.00	--
Andhra	21.07	1.35	0.07	0.50	0.02	349.72	90.37	3.86	0.60	5.15	0.02
Karnataka	29.59	0.71	0.27	0.56	0.06	479.43	92.58	1.48	1.69	4.20	0.05
Tamil Nadu	22.35	0.85	0.04	0.51	0.09	363.63	92.20	2.34	0.33	5.05	0.09
Kerala	28.28	0.04	0.06	0.44	0.11	442.64	95.83	0.09	0.41	3.58	0.09
Jamu and Kashmir	47.81	11.95	0.07	0.23	0.05	847.21	84.65	14.11	0.25	0.98	0.02
India	22.20	8.28	0.48	0.47	0.03	447.23	74.46	18.51	3.22	3.78	0.02

Note: Dash indicates figure is zero or negligible.

Source: National Sample Survey, Tables with Notes on Household Consumption of Fuel and Light (New Delhi, 1969).

How significantly could this pattern of fuel-off-the-ground have been changed by the incursion of commercial fuels? The NSS estimates, shown in table A-1, suggest a substantial fall in per-capita consumption of wood and dung, while we have seen previously that a considerable proportion of kerosine was being used in the 1970s for cooking. There also was a rise in the use of gas for this purpose. We need to know whether kerosine and gas could account for a great decline in the use of wood and cowdung.

Observations on the efficiency of domestic fuel use made in the course of a recent energy survey of the National Council of Applied Economic Research are summarized in table 20. They are obviously approximate and, it should be emphasized, they ignore the economies of scale in household fuel consumption which have been found very significant. They suggest that kerosine replaces by seven to thirteen times and gas by eleven to fifteen times its weight in terms of firewood, and even greater quantities of twigs and dung. Hence the fall in the consumption of firewood and dung between 1963-64 and 1973-74 shown by NSS is more than accounted for by the rise in kerosine and gas consumption (table A-1).

Substitution of kerosine and especially gas for solid fuels must have been largely an urban phenomenon. It occurred in Bombay between 1958 and 1972 (table A-1) and it is possible from this example to gain some idea of how it worked. As table 21 shows, most households owned a number of cooking devices. Although solid fuels supplied only 8 percent of the energy in 1972, 31 percent of the households had equipment to use it. Apparently, they did not switch overnight from one fuel to another; rather, they bought a new stove, kept the old one, and used one or the other as supply and prices dictated.

There is however, another factor, namely, the changeover from earthenware to aluminum cooking vessels. No production statistics exist for either, but the current production of aluminum is about 200,000 tons, of which about half is commercial grade. Perhaps 30,000 to 40,000 tons is being used for utensils, sustaining an output of 60 to 80 million utensils. It can therefore support a very rapid rise in the stock of aluminum utensils, and a concomitant rise in cooking efficiency. However, given the extreme vagueness of domestic fuel statistics, we should desist at this point from reading any further trends into them.

Table 20. Average Efficiency of Utilization of Cooking Fuels

	Energy content (MJ/kg)	Utilized energy (MJ/Kg)	Efficiency (%)
LP gas	44	27.7	63
Kerosine			
in pressure stove	43	24.3	56
in wick stove	43	18.0	42
Soft coke	40	4.0	10
Coal	27	2.7	10
Charcoal	30	4.8	16
Firewood			
closed hearth	15	2.6	16
open hearth	15	1.9	13
Twigs and straw			
closed hearth	10	1.6	16
open hearth	10	1.3	13
Dungcake	10	0.8	8

Source: National Council of Applied Economic Research, Energy Demand in Greater Bombay (New Delhi, 1975) p. 82.

Table 21. Cooking Devices and Energy Use in Bombay, 1972

Monthly income (in rupees)	Percentage of households owning				Percentage of useful energy from				
	Gas stove	Kerosine stove	Sigri[a] or chula[b]	Total	Electricity	Gas	Kerosine	Solid fuels	Total
200 or less	1.9	25.9	12.2	26.7	1.6	0.9	16.7	3.4	22.6
201-300	2.8	24.4	8.5	24.4	2.1	1.4	16.3	2.3	22.1
301-500	10.6	25.8	7.1	25.8	3.9	6.7	14.3	1.4	26.3
501-800	5.9	9.4	1.4	9.5	2.2	3.9	4.7	0.4	11.2
801-1,200	6.9	7.7	1.6	8.7	3.1	4.5	2.8	0.3	10.7
1,201-1,800	2.9	2.5	0.5	3.1	1.6	1.8	0.8	0.2	4.4
1,801-2,400	1.1	0.8	0.1	1.2	0.8	0.7	0.2	0.1	1.8
Over 2,400	0.5	0.4	--	0.5	0.5	0.3	0.1	--	0.9
All groups	32.6	96.9	31.4	100.0	15.8	20.2	55.9	8.1	100.0

Note: Dash indicates figure is zero or negligible.

Sources: Calculated from National Council of Applied Economic Research, Energy Demand in Greater Bombay (New Delhi, 1975) pp. 69, 70, 73, and 80.

[a] Coal-burning stove.

[b] Hearth for burning firewood.

Conclusion

We began this study with the observation that the worldwide shift to oil in the postwar period occurred in India as well, but at a much slower rate than in Western Europe, which had a similar resource endowment. Looking more closely into sectoral energy consumption trends, we found that the shift from coal to oil had been slow only in industry; there, the relative fuel efficiency of the two fuels was not very different, and their relative prices determined the rate of substitution. The price of furnace oil was always kept considerably higher than that of coal per unit of energy, which is why its substitution was so slow. In transport, consumption figures overstate coal's contribution since it was used very inefficiently in the railways. In agriculture, as well as domestic consumption, coal was hardly in the picture. Insofar as competition existed, it was between oil and electricity, and electricity gained ground in both sectors.

Now we shall try to look behind the relative prices which appear to have strongly affected the rates of substitution. As table 22 shows, there have been considerable changes in relative prices over the 22 years. Electricity prices rose least throughout the period. Oil product prices rose more slowly than coal prices until the late sixties, and then they increased at a faster rate.

More important, the import price of crude oil per unit of energy continued to fall until, in 1965, it was only 55 percent higher than that of coal. At such a price, crude oil or its heavier distillates would have been competitive with coal in uses where their special advantages (higher energy intensity, ease of transport, storage and handling, and absence of residue) counted. But--unlike in Japan--crude oil was never directly used as fuel in India, and heavy distillates were priced considerably above crude oil. Furnace oil cost 2.4 times as much as crude in 1970. The question is, Why were prices of refined products kept so high?

The prices of refined products were raised primarily by means of taxes. The prices received by refineries were fixed on the principle of import parity and were generally similar to prices ruling in the Persian Gulf. They were raised severalfold by taxes. As table 23 shows, the posted prices in the Persian Gulf in 1961 were similar for gasoline, kerosine, and diesel fuel. Taxes, however, amounted to more than 300 percent

Table 22. Relative Prices of Commercial Forms of Energy, for Selected Years

Price	1955	1960	1965	1970	1975	1977
Price indices (1970-71=100)						
Coal	42.2	53.6	71.7	100.0	170.7	197.6
Gasoline	50.9	56.8	74.4	98.3	281.3	285.6
Kerosine	50.3	53.8	80.3	98.8	200.4	229.6
Light diesel oil	63.5	81.2	97.0	100.4	201.9	213.9
Furnace oil	n.a.	n.a.	n.a.	100.0	346.3	429.7
Crude oil[a]	90.6	80.0	67.6	100.0	830.9	987.2
Electricity	62.9	70.5	76.0	99.0	153.6	179.5
Price per energy unit (Rs/GJ)						
Coal	0.53	0.68	0.91	1.26	2.16	2.49
Gasoline	12.87	14.37	18.81	24.86	71.15	72.23
Kerosine	5.81	6.22	9.28	11.42	23.16	26.53
Light diesel oil	4.89	6.26	7.48	7.74	15.56	16.48
Furnace oil	n.a.	n.a.	n.a.	5.01	17.36	21.54
Crude oil[a]	1.89	1.69	1.41	2.09	17.36	20.63
Price relative to crude oil						
Coal	0.28	0.40	0.65	0.60	0.12	0.12
Gasoline	6.81	8.50	13.34	11.89	4.11	3.50
Kerosine	3.07	3.68	6.58	5.46	1.33	1.29
Light diesel oil	2.59	3.70	5.30	3.70	0.90	0.80
Furnace oil [a]	n.a.	n.a.	n.a.	2.40	1.00	1.04

Note: n.a. = not available.

Sources: H. L. Chandok, Wholesale Price Statistics: India 1947-1978 (New Delhi, Economic and Scientific Research Foundation, 1978); Central Statistical Organization, Statistical Abstract India, 1968 (New Delhi, 1969); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979).

[a] Import price.

Table 23. Build-up of Retail Prices of Certain Oil Products in Calcutta, for Selected Years

Product and year	Posted price[a]	Central taxes	Other taxes[b]	Refiner's margin	Distribution costs	Total
Gasoline (Rs/kl)						
1961	92	326	--	63	92	573
1973	176	1,063	25	139	57	1,460
1975	792	2,144	21	229	84	3,270
1979	1,009	2,703	392	-151	79	4,032
Kerosine (Rs/kl)						
1961	101	91	--	33	24	249
1973	214	329	--	40	67	650
1975	778	428	--	-226	70	1,050
1979	1,052	493	61	-315	89	1,380
High-speed diesel (Rs/kl)						
1961	91	308	--	51	53	503
1973	165	512	25	144	54	900
1975	718	413	21	-90	38	1,100
1979	989	1,209	129	-917	72	1,482
Furnace oil (Rs/kl)						
1961	50	49	--	14	30	143
1973	105	108	20	51	16	300
1975	556	137	20	20	27	760
1979	650	126	20	184	51	1,031

Note: Dash indicates figure is zero or negligible.

Prices as of May 31, 1961, but as of March 31 for 1973, 1975, 1979.

Sources: Ministry of Steel, Mines, and Fuel, Report of the Oil Price Enquiry Committee (New Delhi, 1961); Ministry of Petroleum and Petrochemicals, Indian Petroleum and Petrochemicals Statistics 1978-79 (New Delhi, 1979).

[a] Minimum posted price at Bandar Mahshahr.

[b] State and municipal taxes.

on gasoline and diesel fuel, but only about 100 percent on kerosine. As a result, the domestic prices of gasoline and diesel fuel were twice as high as the price of kerosine. Not only taxes but the refiners' and distributors' margins differed greatly among products. By reading table 22 together with table 23 we can see that the import price of furnace oil per unit of energy must not have differed too much from that of coal in the sixties and early seventies. It is thus likely that the heavy taxation substantially retarded the shift to furnace oil.

The tax rates on individual products were determined by a number of considerations. Kerosine was a mass consumption good, and furnace oil was an industrial input, so they bore relatively low taxes. High-speed diesel oil was used by road transport which, since it competed with government-owned railways, was more heavily taxed. Gasoline was supposed to be the fuel of wealthy automobile owners, so it was taxed at the highest rate. The tax on gasoline rose until it reached six times the posted price in 1970.

When oil prices rose after 1973, the tax rates were brought down to moderate the rise in refined product prices; the specific rates (per kiloliter) were raised much less than the posted price. More important, the price of Indian crude supplied to refineries was pegged at the 1973 import parity price till 1976 and Rs45 per barrel after that (Ministry of Petroleum, 1976). Thus there was massive cross-subsidization of imported oil by local crude, which is reflected in the negative refiners' margins in 1975 and 1979. Since all refineries except the small, 500,000-ton British Petroleum refinery in Digboi were nationalized in 1975 and 1976, the separation of central taxes from the refiner's margin is largely an accounting artifact. In general, the government prefers to realize its returns in the form of taxes rather than enterprise profits since it fears that high profits generate wage claims and encourage inefficiency.

It may seem paradoxical that the government should begin to subsidize imported oil precisely when its foreign exchange costs rose to unprecedented levels. As shown by table 24, the ratio of oil imports to exports rarely exceeded 10 percent until 1970; in that period, the taxes on oil products were progressively raised until they contributed almost

Table 24. Oil and Refinery Products in Foreign Trade and Central Budget, for Selected Years

	1955	1960	1965	1970	1975	1977
Imports of oil and products, Rs million	556	695	684	1,370	14,165	15,610
Exports, Rs million	5,963	6,602	8,096	15,350	39,416	54,040
Proportion of oil imports to exports, %	9.3	10.5	8.4	8.9	35.9	28.9
Central taxes on oil products, Rs million	269	1,239	3,442	6,379	11,550	12,790
Central revenue, Rs million	5,017	10,029	23,444	33,419	80,228	97,787
NNP, Rs billion	100	133	206	344	616	732
Percentage of oil taxes to central revenues, %	5.3	12.4	14.7	19.1	14.4	13.1
Percentage of oil taxes to NNP	0.3	0.8	1.3	1.8	1.7	1.6

Sources: Central Statistical Organization, Statistical Abstract India, 1958-59 (New Delhi, 1960); Central Statistical Organization, Basic Statistics Relating to the Indian Economy 1950-61 to 1975-76 (New Delhi, 1977); Ministry of Finance, Budget 1956-57. Explanatory Memorandum (New Delhi, 1957); Ministry of Finance, Budget at a Glance (1978-79) (New Delhi, 1978); Central Electricity Authority, Public Electricity Supply: in All-India Statistics 1977-78 (New Delhi, 1979).

20 percent of the central government's revenues. After 1973, the cost of oil imports absorbed about one-third of export earnings; just then the contribution of oil taxes to revenue was brought down more or less to what it was in 1960. The tax policy was obviously not calculated to help the balance of payments.

The fact is that the oil taxation policy was based on largely domestic considerations before as well as after the oil crisis. The strongest among those was the taxation of goods with a high income-elasticity, which was expected to increase the income-elasticity of tax revenues. Supporting grounds were easily found for this policy. For one thing, goods with high income-elasticity were also generally goods consumed by those who were better off; their taxation thus served the goal of progressivity. This was the rationale behind the high tax on gasoline. For another, income elastic goods were often cheaper or more efficient substitutes for old, established goods; industries producing the latter were larger and politically more powerful, and influenced taxes for their own protection. Thus, taxation of road transport evidently gave protection to railways.

But unless the tax-paying groups are unmistakably distinct, strongly differential taxes lead to their merger for tax evasion. Thus, the lower taxation of kerosine led to its partial substitution for diesel oil. The high taxes on gasoline led to a boom in scooters and motorcycles until their owners became too strong a lobby to ignore. The low price of kerosine encouraged its use in cooking. When the Finance Minister lowered duty on light diesel oil in March 1979 in order to help farmers, it was discovered that most of the benefit went to nonfarmers. To put it more generally, although the penetration of oil into the Indian economy was slowed down by taxation, it was nevertheless so pervasive by the seventies that the government had to subsidize oil users. A rich source for the subsidies was discovered in the rapidly growing output of local crude.

A note should be added on the pricing of coal and electricity. The coal industry used to consist of a large number of small mine-owners who depended on a few large buyers like railways, steel plants, and power plants for the bulk of their demand. The mine-owners had little bargaining power; consequently they received low prices and had little surplus

to invest. The competition of oil made the industry even more impecunious, and, by the end of the sixties, it was in dire straits. Concerned about coal supplies, the government took over the industry in 1970. Since then miners' wages have risen much more rapidly than before, and have pushed up prices. But the power of the major purchasers--most of whom are government-owned--together with the government's belief that low profits keep the public sector industry on its toes and help it resist wage demands has ensured enormous losses for the coal industry. In effect, therefore, the government continues to subsidize coal users; but the subsidy is small compared with that received by oil users from local crude production.

Most of the electricity is produced by state governments. Power is one of the few industries they own (passenger transport is another), and they are keen to expand it as rapidly as possible. They also try to use the availability of power supply as a magnet for industries; in view of widespread power rationing, the promise of unrationed or less rationed power offers a powerful attraction to industry. The limit to the expansion of power generation is determined by the money that the states can save or borrow from the central government for investment. The states have to limit the losses of the power industry because their capacity to bear losses is limited and because their ability to obtain financing from the government depends on the financial viability of their electricity boards. So the power industry has always earned a low but positive rate of return on its investment.

Thus the prices of coal and electricity have tended to be low and unresponsive to demand variations. The prices of oil products, on the other hand, used to be high owing to their taxation by the central government; the tax policy was the primary reason for the slow penetration of oil. Since the oil crisis, however, the consumer forces that kept coal and power prices down have also overtaken oil. Central tax revenues, as well as the windfall profits that the state-owned oil drilling industry would otherwise have made, have been squeezed to keep oil prices down. The result has been a continuing rise in the consumption of oil products. In a sense, India has continued its process of catching up with the world oil culture after the oil crisis.

Appendix A

Noncommercial Fuel Consumption

A consistency exercise made in our 1978 survey of Indian energy consumption (Desai, 1978b) to check dung consumption gave implausible results. A later revision revealed that both fodder consumption and dung output had been overestimated. In the present exercise, consistency checks have been attempted on all items of domestic consumption.

We have four surveys of domestic fuel consumption--surveys done by the National Council of Applied Economic Research (1959, 1965) for metropolitan cities in 1958 and for rural areas in 1962; and National Sample Surveys for rural and urban areas in 1963-64 (NSS, 1969 a and b) and 1973-74 (Planning Commission, 1978). Their results are summarized in table A-1.

All the surveys have a major shortcoming, namely, that none of them involved the actual measurement of the fuels consumed. What they reflect is the household's impression of the quantities that were consumed. The households may have some idea of their consumption of purchased gas, kerosine, or electricity, but their estimates for firewood or dungcakes can be only highly approximate.

Other peculiarities of the surveys should be noted. The NCAER surveys covered a few months only (for example, the 1972 Bombay survey covered only a month) and could be biased because of seasonal variations and stock changes. The NSS surveys covered one year, but the sample changed every month; so here again, it is impossible to be sure that the seasonal variations were accurately reflected. Finally, the 1972 Bombay survey by the NCAER extrapolated fuel consumption figures for those households that could not give good estimates. The households were asked for their food consumption estimates, to which were applied norms of fuel requirement per kilogram of food, based on data for those households that could give both food and fuel consumption estimates.

The NCAER urban figures are for large cities only and hence not comparable with the NSS figures. The former show a much greater consumption of kerosine and electricity and less of firewood and dungcakes

Table A-1. Estimates of Domestic Per Capita Energy Consumption

Fuel	Urban						Rural		
	Delhi 1958	Calcutta[a] 1958	Bombay[a] 1958	Bombay[b] 1972	NSS 1963-64	NSS 1973-74	NCAER 1962	NSS 1963-64	NSS 1973-74
Coal, kg	--	0.6	21.0	--	12.9	17.8	--	3.5	3.7
Coke, kg	54.6	83.4	5.7	3.0	16.9	15.6	3.8	1.7	3.1
Charcoal, kg	10.9	2.4	72.7	6.0	4.4	2.6	0.6	0.7	0.1
Dungcakes, kg	14.4	6.7	0.6	c	33.3	25.2	126.8	100.8	72.7
Wood, kg	18.7	28.8	28.7	9.7	169.3	148.6	234.7	270.1	251.9
Other solid fuels, kg	--	8.9	0.8	7.0	3.5	4.9	72.3[d]	9.8	12.4
Kerosine, liter	8.9	8.6	31.1	34.3	10.2	14.0	5.8	4.4	8.8
For lighting	2.5	4.5	2.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
For cooking	6.4	4.1	28.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Gas, cbm									
LPG	--	--	--	8.8	--	--	--	--	--
Piped gas	--	--	1.0	4.4	--	--	--	--	--
Electricity, kWh	52.3	53.7	37.9	108.5	9.0	18.2	0.5	0.3	2.2
For lights & fans	29.0	41.3	29.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other	23.3	12.4	8.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Notes: n.a. = not available. Dash indicates figure is zero or negligible. The following conversion factors have been used: 1 kg = 1.1 seer; 1 liter = 0.22 gallons; 1 maund = 40 seer; 1 cbm = 115.86 cubic feet.

Sources: National Sample Survey, Tables with Notes on Household Consumption of Fuel and Light (New Delhi, 1969) pp. 45 and 85; Planning Commission, Non-Commercial Energy Consumption - A Modified Methodology, paper WGEP/M-3/7 (New Delhi, 1978); National Council of Applied Economic Research, Domestic Fuels in India 1960-75 (Bombay, Asia Publishing House, 1959) pp. 5, 6, 136, 138, 171, and 203; National Council of Applied Economic Research, Energy Demand in Greater Bombay (New Delhi, 1975) pp. 69, 70.

[a] Survey done during summer. [b] Survey done in an unspecified month. [c] Included in other solid fuels.

[d] "Vegetable wastes;" straw, twigs, leaves, and so forth.

than the NSS figures. The consumption in urban areas in the early sixties was closer to the rural pattern than to that of the metropolitan centers.

The two NCAER surveys of 1958 and 1972 for Bombay make an interesting comparison. They appear to show that the per-capita consumption of wood and charcoal fell drastically. The compensatory rise was largely in the consumption of gas, whose share in cooking fuels (excluding electricity) was 25 percent in 1972 (National Council of Applied Economic Research, 1975, p. 74). If this picture is correct--and we cannot be sure that it is because of the change in estimation methods--gas would seem to replace about ten times its weight in firewood and dung.

In contrast, the NSS urban surveys of 1963-64 and 1973-74 do not show a great change. They suggest that the per-capita consumption of biofuels fell by about 27 kg, and kerosine consumption rose by about 4 kg. If the additional kerosine had been used for cooking only, which is not certain, it would seem to have replaced about seven times its weight. Rural consumption of biofuels shows a much larger fall--about 60kg--while kerosine consumption rose by 4.4 kg. Here the replacement ratio would appear to be impossibly large, and other reasons for this can be suggested--for instance, a rise in the cooking efficiency could be caused by the replacement of earthenware by aluminum cooking vessels. However, these speculations should not be taken too seriously, for the NSS estimates are of dubious validity, a point to which we shall turn now.

Let us first compare the 1963-64 NSS and 1962 NCAER rural estimates in greater detail (table A-2). Firewood consumption figures from the two sources are comparatively close if other fuels are included also; there is scope for overlapping between firewood, twigs, and leaves. For the latter, the NCAER estimate is so high that it looks unrealistic. The dungcake figures differ considerably, and there is no pattern in the differences. The charcoal figures differ as well. Taking all the figures together, the impression we get is that both estimates are highly approximate, that individual figures are probably extremely inaccurate, and that there is no presumption that one set of estimates is any better than another. Thus, this comparison does not furnish a check on either.

Another possible check is a comparison of aggregate consumption calculated from a survey with official consumption statistics for

Table A-2. Rural Per Capita Noncommercial Energy Consumption: A Comparison of Estimates

	(Kg/ year)							
	Firewood		Vegetable wastes		Dungcake		Charcoal	
Zone[a]	NSS	NCAER	NSS[b]	NCAER	NSS	NCAER	NSS	NCAER
Northwest	349.16	236.61	5.60	27.98	157.11	169.06	2.21	0.27
West	275.47	314.64	8.64	19.26	33.71	108.67	0.19	0.16
South	281.37	241.88	4.14	184.68	10.71	98.22	0.17	0.74
East	308.42	237.20	17.37	79.56	98.82	103.13	0.44	1.17
North	277.72	171.11	3.89	34.93	157.60	168.11	0.51	0.23
Total India	270.17	234.69	9.84	72.34	100.77	126.76	0.66	0.57

Sources: National Sample Survey Tables with Notes on Household Consumption of Fuel and Light (New Delhi, 1969, p. 45); National Council of Applied Economic Research, Domestic Fuel Consumption in Rural India (New Delhi, 1965) p. 81.

[a]The zones are defined as follows: Northwest-Punjab, Rajasthan, Jammu and Kashmir, Delhi and Himachal Pradesh; West-Gujarat, Maharashtra, and Karnataka; South-Kerala, Tamil Nadu, and Andhra Pradesh; East-Orissa, Bihar, West Bengal, Assam, Manipur, and Tripura; and North-Uttar Pradesh and Madhya Pradesh.

[b]Other fuels in the case of the NSS.

commercial fuels (table A-3). The figures for coke agree fairly well; and considering the possibility of stock changes, the figures could match. Kerosine figures for 1963 are not too far apart, but, for 1973, the NSS figure is far larger than that of the Petroleum Ministry. A possible explanation for this is that NSS investigators were required to record consumption in kilograms, but actually recorded it in liters. Such a mistake would bring down the NSS estimate to 3.65 million tons, not too far from the Ministry's 3.45 million tons, but the Ministry figure included about a million tons of kerosine used to adulterate high-speed diesel (compare with the National Council of Applied Economic Research, 1971, pp. 51-53) and therefore not used as kerosine. Finally, the NSS estimates for electricity consistently fall short of those compiled from Electricity Boards' sales statistics. For all three commodities, the government statistics are more directly estimated and more reliable. Therefore, it is not impossible that the NSS estimates may embody errors up to 40 or 50 percent.

We are basically interested in statistics for noncommercial fuels; here the NSS estimates cannot be compared with an alternative source. But it is possible to attempt a consistency exercise of the sort that was done in the appendix to our paper on Indian energy consumption (Desai, 1978b).

We begin with estimates of total biofuel consumption in 1963-64 and 1973-74 based on NSS statistics (table A-4). The earlier paper made estimates for 1970(the 1973-74 NSS results were not then available); now we shall stick close to the NSS surveys, and assume for the present that their results are correct. We shall ignore the small quantities of wood that are used to make charcoal.

We may remark that the estimates of firewood consumption per head are by no means high. A recent study based on actual measurement found per capita firewood consumption in four Karnataka villages to vary between 579 kg and 1156 kg per year (Somasekhara, 1978). Another study of fourteen households in Nepal found per capita consumption of 1.9 tons per year (Bajracharya, 1979). Thus, the NSS figures of firewood and dungcake consumption are conservative by the standards of less-developed countries.

Table A-3. Domestic Consumption of Coke, Kerosine and Electricity: A Statistical Comparison Based on Production Estimates and NSS Consumption Surveys

	1963[a]	1973[b]
Population, million		
Rural Urban	381	461
Urban	84	120
NSS rural per capita consumption		
Coke, kg/yr	1.680	3.098
Kerosine, kg/yr	4.486	7.217
Electricity, kWh/yr	0.360	2.281
NSS urban per capita consumption		
Coke, kg/yr	17.155	15.480
Kerosine, kg/yr	8.095	11.218
Electricity, kWh/yr	8.881	17.640
NSS-based aggregate consumption		
Coke, thousand tons	2,081	3,285
Kerosine, thousand tons	2,389	4,674
Electricity, GWh	883	3,167
Output-based aggregate consumption		
Coke, thousand tons[c]	2,279	2,911
Kerosine, thousand tons	2,437	3,451
Electricity, GWh	2,062	4,645

Sources: NSS estimates: Planning Commission, Non-commercial Energy Consumption--A Modified Methodology, Paper WGEP/M-3/7 (New Delhi, 1978); Coke output: Director-General of Mine Safety, Statistics of Mines in India, 1973, vol. 1, Coal (Dhanbad, 1976); Kerosine: Ministry of Petroleum, Indian Petroleum and Petrochemicals Statistics, 1976 (New Delhi, 1977); Indian Oil Corporation, Estimated Demand of POL Products During 1968 Thru 1975 (New Delhi, 1968); Electricity: Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1970-71 (New Delhi, 1972) p. 166; Ministry of Railways, Supplement to Indian Railways Annual Report and Accounts 1975-76 (New Delhi, 1977) p. 136.

[a] 1963-64 for NSS.

[b] 1973-74 for NSS.

[c] Output of soft coke.

Table A-4. NSS-Based Estimates of Noncommercial Fuel Consumption for 1963-64 and 1973-74

Consumption	1963-64		1973-74	
	Firewood	Dungcake	Firewood	Dungcake
Per capita consumption, kg/yr				
Rural	273.48	102.00	248.04	71.28
Urban	171.48	33.71	146.52	24.96
Aggregate consumption, metric tons				
Rural	104.20	38.86	114.42	32.88
Urban	14.40	2.83	17.57	2.99
Total	118.60	41.69	131.99	35.87

Source: Planning Commission, Non-Commercial Energy Consumption - A Modified Methodology, Paper WGEP/M-3/7 (New Delhi, 1978).

Next, we estimate the dung consumption in its other major use, namely, as manure (table A-5). Here we have only some NSS surveys of the 1950s; for all the detailed statistics of fertilizer consumption that have become available, there is no national survey of manure consumption in the last twenty years.

In our last study (Desai,1978b), we used the results of the eleventh round (1956-57) of the NSS. Actually, manure-consumption figures were collected in the fifth, sixth, and seventh rounds also, and were generally higher than for the eleventh round. All the figures suffer from the general weakness of the NSS estimates: that is, they are based on verbal responses and not on actual measurements. The responses could well be inaccurate since farmers in this country think of manure in terms of cartloads and not in terms of maunds, which was the unit of the NSS. Further, if--as we hope will be clear from what follows--manure consumption is limited by supply, and if the supply depends on the availabilty of animal fodder, which varies widely from year to year, then manure consumption is also highly variable. For these reasons, we have calculated manure consumption in 1963-64 and 1973-74 on the basis of both the average and the lowest applications in the NSS rounds. The figures do not pretend to be good estimates, but the two figures give an idea of the limits of variation.

Two further reservations are necessary, which we shall mention now but subsequently ignore for convenience. First, farmyard manure is not composed entirely of dung; it contains an indeterminate amount of vegetable matter. But manure in India is believed to consist almost entirely of dung. Second, all manure is not composted; a great deal of it is relatively fresh, unfermented dung. This is also clear from the fact that the proportion of dung used as manure goes up in the rainy season. Hence manure is not completely dry, and its dry weight may well be something less than the quantities shown in table A-4. This is a point worth noting, for our checks below are done in terms of dry weight.

A further check on the quantities of dung used as fuel and as manure can be made on the basis of their proportions, on which we have some state data (table A-6). Our earlier figures suggested that about 80 to 85 percent of the dung was used as manure for the whole country. This proportion is roughly correct for peninsular India; in the Gangetic

Table A-5. Aggregate Farmyard Manure Consumption 1963-64 and 1973-74 (million tons)

Crop	Manure applied (kg/ha)			Area (m ha)		Manure used (million tons) average		Manure used (million tons) low	
	high	low	average	1963-1964	1973-1974	1963-1964	1973-1974	1963-1964	1973-1974
Rice	2,476	1,505	1,955	35.8	38.3	70.0	74.9	53.9	57.6
Wheat	2,036	1,060	1,619	13.5	18.6	21.9	30.1	14.3	19.7
Jowar	893	497	647	17.4	16.7	11.3	10.8	8.6	8.3
Bajra	996	710	814	11.1	13.9	9.0	11.3	7.9	9.9
Barley	1,582	1,423	1,489	2.8	2.7	4.2	4.0	4.0	3.8
Maize	3,814	3,545	3,720	4.6	6.0	17.1	22.3	16.3	21.3
Ragi	4,254	2,937	3,688	2.5	2.4	9.2	8.9	7.3	7.0
Small millets	6,745	510	573	4.6	4.6	2.6	2.6	2.3	2.3
Gram	336	150	270	9.4	7.8	2.5	2.1	1.4	1.2
Tur	393	104	223	2.5	2.6	0.6	0.6	0.3	0.3
Urd	393	140	245						
Moong	218	22	107	12.3[a]	13.1[a]	3.3[b]	3.5[b]	2.1[b]	2.3[b]
Masur	506	321	422						
Other pulses	417	209	307						
Groundnut	986	520	720	6.9	7.0	5.0	5.0	3.6	3.6
Rape and mustard	502	245	380	3.0	3.5	1.1	1.3	0.7	0.9
Sesamum	381	143	303	2.4	2.4	0.7	0.7	0.3	0.3
Linseed	n.a.	n.a.	97	2.0	2.0	0.2	0.2	0.2	0.2
Castor	350	60	221	0.5	0.5	0.1	0.1	--	--
Other oil seeds	303	66	134	--	1.2	--	0.2	--	--
Cotton	1,134	573	848	8.2	7.6	7.0	6.4	4.7	4.4
Jute	3,092	1,529	2,517	1.3	1.2	3.3	3.0	2.0	1.8
Potatoes	6,852	4,845	5,471	0.1	0.5	2.2	2.7	0.5	2.4
Spices	4,335	2,554	3,280	0.9	1.5	3.0	4.9	2.3	3.8
Tobacco	3,549	2,116	2,701	0.4	0.5	1.1	1.4	0.8	1.1
Sugarcane	6,217	5,712	6,043	2.2	2.8	13.3	16.9	12.6	16.0

Notes: Dash indicates figure is zero or negligible. n.a. = not available. It is assumed that manure consumption per hectare in these years was as estimated by NSS surveys in 1950s.

Sources: Manure application: National Sample Survey, Tables with Notes on Some Aspects of Agriculture in India (New Delhi, 1969) p. 75; Cultivated area, 1963-64: Central Statistical Organization, Statistical Abstract India, 1968 (New Delhi, 1969) pp. 57-62; 1973-74: Ministry of Food and Agriculture, Agricultural Situation in India 1975 (New Delhi, 1976) pp. 367-368.

[a]Total area for urd, moong, masur, and other pulses.

[b]Manure applications per hectare are assumed to be equal to the simple average for urd, moong, masur, and other pulses.

Table A-6. Percentage of Dung Used as Manure

India[a]	
1963-64	78-82
1973-74	82-86
Bihar, 1965-66	42
Karnataka, 1965-66	80
Maharashtra, 1964-65	86
Tamil Nadu, 1965-66	79
Punjab, 1961-62	47
Uttar Pradesh, 1962-63[b]	45
Gujarat, 1963-64	76

Sources: Bihar: D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Western Madhya Pradesh during 1965-66) (New Delhi, Institute of Agricultural Research Statistics, no date) p. 24; Karnataka: D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Karnataka State during 1965-66)(New Delhi, Institute of Agricultural Research Statistics, no date) p. 35; Maharashtra: D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Maharashtra State during 1964-65) (New Delhi, Institute of Agricultural Research Statistics, no date) p. 35; Tamil Nadu: D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Tamil Nadu State during 1965-66) (New Delhi, Institute of Agricultural Research Statistics, no date) p. 34; Punjab, Uttar Pradesh, and Gujarat: Institute of Agricultural Research Statistics, Final Report of Repeat Surveys on Milk Production and Bovine Practices in the States of Punjab (1961-62), Eastern Uttar Pradesh (1962-63), and Gujarat (1963-64) (New Delhi, 1969) pp. 30, 55, and 86.

[a]Implied in tables A-3 and A-4.

[b]Cultivators only.

plain, however, the proportion is only 40 to 50 percent. Since the plain contains about one-third of the cattle, the overall proportion suggested by the Indian Council of Agricultural Research (ICAR) surveys is 65 to 75 percent. Thus our figures for manure consumption could be high, or estimates of dungcake consumption could be too low. In view of our subsequent calculations we shall be inclined toward the first possibility.

The dung is produced as a by-product of fodder intake by animals, and there must be a relationship between the two quantities. Let us suppose the relationship is a proportional one, since no workers in the field have worked on any other hypothesis.

Dung output can be measured in terms of its wet weight, its dry weight, or its energy content. Fodder intake poses a problem since green fodder has a higher water content than does dry fodder. It is convenient to convert all fodder in terms of its dry weight. Robinson (1974, p. 489) gives a moisture content of 82 percent for green fodder and 13 percent for dry fodder, which would give the air-dry weight of green fodder as 31 percent of its gross weight. The dry weight of dung is commonly taken to be 20 percent of its wet weight. Odend'hal (1972,p.9), following Hafez (1968, p. 271), gives ratios of 20 percent for mature animals and 30 percent for cattle less than three years of age. We shall use a ratio of 20 percent for simplicity. On the basis of Odend'hal (1972, pp. 9-13) and the National Council of Applied Economic Research (1965, p. 114), we calculated the energy content per gram of dung to be 64 percent of that of dry fodder. This means that the proportion of fodder energy passed in the form of dung is 64 percent of the dry-weight ratio of dung to fodder.

Odend'hal (1972, pp. 13-14) estimated the energy ratio of dung to fodder at 19.8 percent for the cattle in a West Bengal village, which implies a dry-weight ratio of 31 percent. We had earlier questioned this as being inconsistent with energy ratios of 35 to 40 percent for cattle in Europe, Japan, and the United States (Desai, 1978b, p. 230). But Odend'hal's estimates are based on observation, and must be taken seriously, even if they imply that West Bengal cattle are significantly more efficient users of energy than cattle in industrial countries. We

have been convinced of the correctness of Odend'hal's estimates by some calculations done on ICAR's estimates of feed consumption and dung collection for a number of regions. One should expect dung output to be underestimated in uncontrolled Indian studies since a large proportion is not collected at all; this danger cannot be discounted, even in ICAR surveys. But it is likely to be least in the northern Gangetic plain where dung is a scarce commodity, and especially in Punjab where a very high proportion of animals are fenced in. For Punjab, as well as east Uttar Pradesh, we get a ratio of dung (wet weight) to fodder (dry weight) of 1.47, or a dry-weight ratio of 0.29 (table A-7), which is not very different from Odend'hal's 0.31. Henceforward we shall use a dry-weight ratio of dung to fodder of 30 percent. If it is lower than the ratio observed in industrial countries, the suggestion is that dung throughput increases more than proportionally as an animal is fed more.

With a dung-fodder ratio of 30 percent, the manure and dungcake-consumption estimates of tables A-4 and A-5 imply fodder consumption of about 700 million tons. Let us now look at the supply side. First, we will consider the output of straw.

In our previous study (Desai, 1978b), we had used straw-grain ratios from NSS to estimate straw output. They have since proved to be gross underestimates so, for our purposes here, we have used ratios estimated from ICAR experiments and based on actual measurements (table A-8). Here again, there is considerable variation, so we have given the standard deviation wherever it can be calculated. Further, two estimates are made of the straw output--one based on the average straw-grain ratios and another on the ratios plus one standard deviation. The latter calculation tells us about the possible limits of variation--for instance, if the straw-grain ratios were normally distributed around the average, there is a less than 5 percent chance that the straw output was greater than 266 million tons in 1963-64, or greater than 333 million tons in 1973-74.

Four comments on the estimates in table A-8 are called for. First, the "straw output" includes certain things which are not strictly straw, for example, cotton and jute sticks which are used for fuel. Second,

Table A-7. Feed Consumption and Dung Collection in Punjab and Uttar Pradesh

	Punjab		Uttar Pradesh	
	No. of animals observed[a]	Feed and dung per head[b] (kg/day)	No. of animals observed[a]	Feed and dung per head[b] (kg/day)
Feed				
Cows in milk	3,391	6.091	7,680	5.185
Dry cows	3,572	4.547	3,887	3.908
Bullocks	11,649	9.311	16,325	7.085
Young cattle	9,997	2.084	9,186	1.897
Buffaloes in milk	5,377	9.982	6,072	8.241
Dry buffaloes	4,587	6.617	1,764	5.073
Male buffaloes	2,004	7.171	522	6.982
Young buffaloes	9,862	2.034	3,748	2.043
Average feed per day		5.643		5.260
Dung collected				
Wet weight		8.300		7.700
Dry weight		1.660		1.540

Source: Institute of Agricultural Research Statistics, Final Report of Repeat Surveys on Milk Production and Bovine Practices in the States of Punjab (1961-62), Eastern Uttar Pradesh (1962-63), and Gujarat (1963-64) (New Delhi, 1969).

[a]Numbers added for all three seasons, summer, winter and monsoon.

[b]Dry weight.

Table A-8. Straw Output for 1963-64 and 1973-74 (million tons)

Crop	Crop output					Straw output			
						Average		High	
	NSS SGR[a]	SGR[a]	SD[b]	1963-1964	1973-1974	1963-1964	1973-1974	1963-1964	1973-1974
Rice	0.92	1.50	0.39	37.0	44.1	55.5	66.2	69.9	83.3
Wheat	1.09	1.48	0.38	9.9	21.8	14.7	32.3	18.4	40.3
Jowar	2.55	2.26	0.73	9.2	9.1	20.8	20.6	27.5	27.2
Bajra	2.15	2.19	0.57	3.9	7.5	8.5	16.4	10.8	20.7
Barley	1.11	1.58	--[c]	2.0	2.4	3.2	3.8	3.2	3.8
Maize	1.45	2.08	0.44	4.6	5.8	9.6	12.1	11.6	14.6
Ragi	1.18	1.85[d]	0.66	2.0	2.1	3.7	3.9	5.0	5.3
Millets	0.83	2.10[d]	--	2.0	2.0	4.2	4.2	4.2	4.2
Gram	0.77	1.98	0.53	4.5	4.1	8.9	8.1	11.3	10.3
Tur	0.88	1.13	--[c]	1.4	1.4	1.6	1.6	1.6	1.6
Other pulses	0.93	1.80	0.40	4.2	4.5	7.6	8.1	9.2	9.9
Groundnut	0.83	3.55	1.77	5.3	5.9	18.8	20.9	28.2	31.4
Sesame	0.15	3.55[e]	--	0.4	0.5	1.4	1.8	1.4	1.8
Rape & Mustard	0.24	3.55[e]	--	0.9	1.7	3.2	6.0	3.2	6.0
Linseed	0.21	1.83	--[c]	0.4	0.5	0.9	0.9	0.9	0.9
Castor	0.18	3.55[e]	--	0.1	0.2	0.4	0.7	0.4	0.7
Potatoes	0.05	0.30	--[c]	2.4	4.9	0.7	1.5	0.7	1.5
Cotton	0.49	7.55	2.67	1.0	1.0	7.6	7.6	10.2	10.2
Jute	0.80	1.37	--[c]	1.1	1.1	1.5	1.5	1.5	1.5
Total output				98.9	120.6	172.8	218.2	219.5	275.4

Sources: Straw grain ratios: National Sample Survey, Tables with Notes on Some Aspects of Agriculture in India (New Delhi, 1969) pp. 25 and 30; Indian Council of Agricultural Research, All-India Coordinated Agronomic Research Project. Annual Report 1974-75 (New Delhi, 1977) pp. 58-77; Crop output, 1963-64: Central Statistical Organization, Statistical Abstract India, 1968 (New Delhi, 1969) pp. 63-69; Crop output 1973-74: Ministry of Food and Agriculture, Agricultural Situation in India 1975 (New Delhi, 1976) pp. 367-368.

[a]Straw grain ratio. [b]Standard deviation. [c]Only one observation. [d]Average of ratios for bajra, jowar, and ragi. [e]Groundnut ratio has been repeated for lack of data.

the straw output for 1963-64 is probably underestimated, for between that year and 1973-74, dwarf varieties of wheat and bajra were introduced which would have reduced the straw-grain ratios. Our guess is, however, that such underestimation would not much exceed 10 million tons. Third, all the straw is not for animal consumption; some is used for thatch, and some probably as fuel. Finally, however, a number of agricultural products are excluded. For instance, the 6.4 million tons of tapioca produced in 1973-74 would have yielded at least 12 million tons of sticks for fodder and fuel. Sugarcane would have yielded over 15 million tons of tops for green fodder. The 6-million hectares under fodder crops produced 10 to 12 million tons of green or dry fodder. Very approximately, agriculture produced about 25 million tons in 1963-64 and about 40 million tons in 1973-74 of biomass above that shown in table A-8. The total biomass was distributed between food, dry fodder, green fodder, and fuel.

The straw supply must match consumption. In our earlier study the straw consumption of cattle was estimated at 364 million tons, more than twice the straw supply of 149 million tons. The error arose from the assumption that the fodder consumption per animal, as estimated by ICAR, referred to all animals. Actually, as the detailed surveys of ICAR (Singh and coauthors, n.d.) make clear, their feed consumption figures refer only to stall-fed animals, and a significant proportion of animals were not stall-fed. Even among the stall-fed animals there were many which were not fed all year-round. The ICAR surveys give the proportion of animals that were not stall-fed at all, but not of animals that were partially stall-fed. In table A-9 we have adjusted the ICAR proportions; that is, we more or less doubled the proportion of non-stall-fed animals so as to get rough equality between supply and consumption of straw fodder. The straw supply per animal was higher in 1973-74 than in 1963-64; we have correspondingly increased straw consumption by raising the proportion of animals that are stall-fed. The assumption, as well as the figures, are arbitrary: there could equally well have been a rise in the straw consumption per stall-fed animal, or in the number of days in the year that an average animal was stall-fed.

The animal numbers for 1963-64 and 1973-74 are assumed to be the same as those for the census years of 1961 and 1972. The figures for 1963-64

Table A-9. Aggregate Fodder Consumption, for 1963-64 and 1973-74

Animal	Number of animals (million)			Fully grazed (%)	Assumed stalled (%)		Consumption per head (kg/yr)				Aggregate stall consumption (million tons)							
											1963-64				1973-74[a]			
	1961	1966	1972		1961	1972	Con.	Green	Dry	Equally Dry	Con.	Green	Dry	Equally Dry	Con.	Green	Dry	Equally Dry
Cattle																		
Cows in milk	20.7	21.0	22.0	20.0	50.0	60.0	105	1,622	1,292	1,900	1.09	16.79	13.37	19.67	1.39	21.41	17.05	25.08
Dry cows	33.5	34.7	34.4	37.5	30.0	45.0	46	1,055	1,031	1,404	0.46	10.60	10.36	14.11	0.71	16.33	15.96	21.73
Bullocks	72.5	73.4	74.5	15.0	60.0	70.0	112	1,811	2,063	2,736	4.87	78.78	89.74	119.02	5.84	94.44	107.58	142.70
Young stock	48.8	48.1	47.5	37.5	40.0	50.0	17	577	538	734	0.33	11.26	10.50	14.33	0.40	13.70	12.78	17.43
Buffaloes																		
Buffaloes in milk	12.5	12.9	15.1	12.5	65.0	75.0	291	2,476	2,153	3.212	2.36	20.12	17.49	26.10	3.30	28.04	24.38	36.37
Dry buffaloes	12.5	13.3	14.1	25.0	60.0	65.0	38	1,575	1,464	1,990	0.29	11.81	10.98	14.93	0.35	14.43	13.42	18.24
Male buffaloes	7.7	8.2	8.1	15.0	60.0	70.0	64	2,376	1,985	2,786	0.30	10.98	9.17	12.87	0.36	13.47	11.25	15.79
Young stock	18.5	18.6	20.1	37.5	50.0	55.0	5	581	605	790	0.05	5.37	5.60	7.31	0.06	6.42	6.69	8.74
Total	226.7	230.2	235.8								9.75	165.71	167.21	228.34	12.41	208.24	209.11	286.08

Sources: Livestock numbers 1961: Ministry of Food and Agriculture, India Livestock Census 1961, vol. 1, Summary Tables (New Delhi, 1966) pp. 2-6; 1966 and 1972: Ministry of Food and Agriculture, Agricultural Situation in India 1975 (New Delhi, 1976) pp. 141-142; Fodder consumption: V. N. Amble, "Feed Requirements of Bovines and Possibilities of Meeting Them," Indian Journal of Agricultural Economics vol. 20, no. 1 (1965) p. 72; Proportion of animals grazed estimated from D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Western Madhya Pradesh during 1965-66) (New Delhi, Institute of Agricultural Research Statistics, no date); D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Karnataka State during 1965-66) (New Delhi, Institute of Agricultural Research Statistics, no date); D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Maharashtra State during 1964-65) (New Delhi, Institute of Agricultural Research Statistics, no date); D. Singh et al., "Sample Survey for Estimation of Milk Production and Study of Bovine Practices" (Report of the survey conducted in Tamil Nadu State during 1965-66) (New Delhi, Institute of Agricultural Research Statistics, no date): Institute of Agricultural Research Statistics, Final Report of Repeat Surveys on Milk Production and Bovine Practices in the States of Punjab (1961-62), Eastern Uttar Pradesh (1962-63), and Gujarat (1963-64) (New Delhi, 1969).

[a]The livestock numbers in 1963-64 and 1973-74 are assumed to be the same as those for 1961 and 1972, respectively. Since the numbers changed slowly, the resulting inaccuracy is negligible.

could have been derived by linear interpolation from 1961 and 1966 figures, but the results would have been misleading, for the drought in 1965-66 caused considerable mortality among livestock, and the rise in numbers between 1961 and 1966 was not smooth. In any case, a difference in the method of estimation would have made little difference to livestock numbers, which changed very slowly over the years.

As stated, the proportions of stall-fed animals shown in table A-9 were chosen so as to keep their straw consumption roughly equal to the straw fodder supply calculated from table A-8. As a by-product, table A-9 also yields stall consumption of concentrate and green fodder. The concentrate figures are well below the supply of bran, oilcake, and so forth. They therefore pose no problem, and we shall do no further calculations in their respect.

Green fodder consumption is, however, substantial, amounting to almost a quarter of the total consumption in terms of dry fodder equivalent. The question must be asked, What is the source of supply? The source can be either fodder crops grown on agricultural land, or grass cut from nonagricultural land. The area under fodder crops is officially estimated at about 6 million hectares, and does not vary greatly from year to year. In addition, about 14 million hectares is under permanent pastures, and 20 million hectares under fallow. This 40 million hectares is perfectly capable of growing the 50 to 70 million tons (dry-weight) of green fodder consumed. Fodder collection is extremely labor-intensive, and the sparser the growth the greater the labor-intensity. Hence it is likely that green fodder is by preference collected from land devoted to it and protected as far as possible fron uncontrolled grazing. So we can assume that the entire stall-fodder consumption is met from the produce of farms and pastures.

Fodder consumption of grazing animals must come from pasture, wasteland, and forestland. No estimates of their consumption exist, but we can set two upper limits to it. First, the consumption per head of grazing animals cannot be better than that of stall-fed animals. Second, the yield of biomass--grass, wood, leaves, and so forth--from nonagricultural land must be no higher than that from agricultural land. The two limits are about the same for 1963-64: if pastures, wasteland and forestland had

yielded as much biomass as agricultural land, it would have been sufficient to give grazing animals as much fodder as was given stall-fed animals. For 1973-74 the first limit is lower than the second.

How far the biomass yield of nonagricultural land is below that of agricultural land is anybody's guess. Table A-10 gives one estimate, placing the yield at 84 percent of that from agricultural land, and fodder consumption of grazing animals at 70 percent of that by stall-fed animals. If grazing animals consumed as much fodder (in terms of dry weight) as stalled animals, a further 58 million tons of fodder would have been required. And if it had all come from forestland, wasteland, pastureland, and fallows, the yield would have had to increase to 2.03 tons, or almost as much as that of the agricultural land.

Table A-10 also gives a comparable exercise for 1973-74. Here again, there is a statistical basis only for the yield of agricultural land; the rest of the yields are calculated on the assumption that grazed animals got 70 percent as much fodder as stall-fed animals. The results are striking: the required biomass yield of nonagricultural land is the same as it was in 1963-64, and its ratio to agricultural biomass yield falls from 84 percent to 69 percent. It may be recalled that we have already assumed a rise in the proportion of stall-fed animals, which is equivalent to a rise in the average fodder intake of all animals. What emerges therefore is that the 22 percent increase in agricultural biomass yields was sufficient to meet the higher fuel requirements and to raise the standards of animal nutrition without raising the biomass offtake from nonagricultural land. Further, if the latter had risen in the same proportion as had the yield of agricultural land, it would have been more than sufficient to feed grazing animals as much as stall-fed animals, which would have required a further 47 million tons of fodder.

It should be stressed that there is much guesswork behind the figures in table A-10, and that the figures are for individual years and ignore year-to-year variations. However, they are based on consistency exercises and suggest limits of probability which cannot be ignored. They also suggest that while the absolute level of exploitation of forestland may be too high, it is not rising. At least between 1963-64 and 1973-74 the agricultural system met the rising biomass--food, fodder, and fuel--requirements and left some room for improvement of animal-fodder intake. For

Table A-10. Biomass Consumption for 1963-64 and 1973-74

	1963-64				1973-74			
	Forestland and wasteland[a]	Pasture and fallow	Farms and plantations	Total	Forestland and wasteland[a]	Pasture and fallow	Farms and plantations	Total
Reporting area million ha	129	36	160[b]	325	124	33	174	330
Yield, tons/ha	1.68[c]	1.68[c]	2.01	1.84	1.68[c]	1.68[c]	2.45	2.09
Output or offtake, metric tons								
Food, drink & tobacco	--	--	82	82	--	--	112	112
Concentrates[d]	--	--	14	14	--	--	17	17
Dry fodder	--	--	167	167	--	--	207	207
Green fodder[e]	105	60	17	182	100	55	20	175
Domestic fuel	100	--	18	118	93	--	38	131
Industrial fuel[f]	--	--	22	22	--	--	30	30
Industrial raw materials[g]	--	--	2	2	--	--	2	2
Timber[h]	12	--	--	12	15	--	--	15
Total	217	60	322	599	208	55	426	689

Note: Dash indicates figure is zero or negligible.

Sources: Reporting area: 1963-64, Ministry of Food and Agriculture, Indian Agricultural Statistics 1965-66 (New Delhi, 1971) pp. 5-6; 1973-1974, Central Statistical Organization, Monthly Abstract of Statistics, vol. 31, no. 12 (New Delhi, 1978) pp. 43-44; Central Statistical Organization, Statistical Abstract India 1978 (New Delhi, 1979) pp. 44-45; Crop output: as in table A-8; Domestic fuel: as in table A-4; Dry fodder: as in table A-9.

[a] Includes forests culturable and unculturable wastelands.

[b] Gross cropped area.

[c] Offtake per hectare from forestland and pastureland is assumed to be equal in the absence of separate data.

[d] Calculated at the rate of 10 percent husk for foodgrains and 75 percent cake for oil seeds.

[e] Calculated on the assumption that grazed animals get 70 percent as much fodder as stall-fed ones, entirely as green fodder, which is added to green fodder consumption in stalls (from table A-9). Air-dry weight taken to be 31 percent of green weight (Desai, "India's Energy Consumption: Composition and Trends," Energy Policy, vol. 6, no. 3 (1978) pp. 217-234.

[f] Bagasse burnt in sugar mills and gur pans. Fresh bagasse with 48 percent moisture calculated at 32 percent of sugar cane output (Indian Sugar Manufacturers' Association, Indian Sugar Handbook 1965-66, (Calcutta 1967) p. 57) and reduced to air-dry bagasse with 25 percent moisture.

[g] Includes cotton, jute, and other commercial crops, but excludes crops included under food, drink, and tobacco.

[h] Assumed.

those who choose to make different assumptions about the level of grazing-fodder output, table A-11 gives the relationship between the ratio of fodder intake of stall-fed animals (which we have called the fodder ratio) and the ratio of biomass output of nonagricultural land to the output of agricultural land (called the yield ratio).

Let us now come to the supply of dung which, according to our earlier estimate, would be 30 percent of fodder intake. However, not all the dung produced is used; only the dung collected is useful. Here we may assert without much risk that all the dung of stall-fed animals would be collected. The proportion of fodder fed in stalls thus gives us a lower limit to the proportion of dung collected, and the former proportion in our foregoing analysis depends on the ratio of fodder intake of grazing and stall-fed animals. The actual proportion of total dung collected will depend on the proportion of dung of the grazing animals that is collected. Thus the proportion of dung collected will be a function of (1) the proportion of fodder fed in stalls, and (2) the proportion of dung collected from grazing animals. The values of the function for selected values of these two proportions are given in table A-12.

According to table A-12, the overall collection efficiency varies less than the collection efficiency of dung from grazed fodder; this is to be expected based on our assumption that all dung from stall-fed fodder is collected. Further, at lower levels of fodder intake for grazing animals, the collection efficiency is higher. At the level we consider likely--70 percent--and with collection efficiencies of dung from grazed fodder over 40 percent, the overall collection efficiency is over 77 percent. We shall adopt 90 percent as the most likely overall collection efficiency for both years, ignoring the fact that the figures for 1973-74 are higher.

We now have all the evidence necessary to calculate the dung available for manure; and this is done in table A-13. Minor uses of dung, such as binder for floors and walls, are ignored. At the fodder ratio of 70 percent, the proportion of collected dung available for manure comes to 57 percent in 1963-64 and to 66 percent in 1973-74. These figures are

Table A-11. Fodder Intake and Required Biomass Yield

Percentage ratio of fodder intake of grazing and stall-fed animals	Biomass yield of nonagricultural land (tons/ha)		Percentage ratio of biomass yield of non-agricultural land	
	1963-64	1973-74	1963-64	1973-74
50	1.45	1.42	70.4	58.9
60	1.56	1.52	76.0	59.8
70	1.68	1.62	81.6	63.8
80	1.80	1.72	87.3	67.7
90	1.91	1.82	92.9	71.1
100	2.03	1.92	98.5	75.6

Sources: Fodder consumption: V.N. Amble, "Feed Requirements of Bovines and Possibilities of Meeting Them," Indian Journal of Agricultural Economics vol. 20, no. 1 (1965) p. 72; Proportion of animals grazed estimated from D. Singh et al. (See complete reference in table A-9); Reporting area 1963-64: Ministry of Food and Agriculture, Indian Agricultural Statistics 1965-66 (New Delhi, 1971, pp. 5-6); 1973-74: Central Statistical Organization, Monthly Abstract of Statistics (1978, pp. 43-44). Crop output: As in table A-8.

Table A-12. Dung Collection Efficiency, Fodder Intake of Grazing Animals and Collection Efficiency of Dung from Grazed Fodder

Percentage ratio of fodder intake by grazing animals to that of stall-fed animals	Collection efficiency of dung from grazed fodder							
	1963-64 (%)				1973-74 (%)			
	20	40	60	80	20	40	60	80
50	76	82	88	94	82	87	91	96
60	73	79	87	93	80	85	90	95
70	70	77	85	93	77	83	89	95
80	68	75	84	92	75	81	88	94
90	65	73	83	91	73	80	87	93
100	63	71	82	91	71	78	86	93

Sources: Fodder consumption: V. N. Amble, "Feed Requirements of Bovines and Possibilities of Meeting Them," Indian Journal of Agricultural Economics vol. 20, no. 1 (1965) p. 72; Proportion of animals grazed estimated from Singh et al. (See complete reference in table A-9).

Table A-13. Maximum Dung Supply Available for Manuring (million tons)

	Percentage ratio of fodder intake of grazed animals to that of stall-fed animals					
	1963-64			1973-74		
	60	70	85	60	70	80
Total fodder intake	344	364	385	380	396	412
Total dung output	103	109	116	114	119	124
Dung collected	93	98	104	103	107	111
Minus dung burnt	-42	-42	-42	-36	-36	-36
Supply of manure	51	56	62	67	71	75

Source: Fodder consumption: V. N. Amble, "Feed requirements of Bovines and Possibilities of Meeting Them," Indian Journal of Agricultural Economics vol. 20, no. 1 (1965) pp. 70-78; Proportion of animals grazed estimated from Singh et al. (See complete reference in table A-9).

low as compared with the ratio of 65 to 75 percent that was obtained earlier from the ICAR Surveys, but not grievously so. In view of the fact that the fuel-consumption figures are from an NSS survey and could easily be off by 10 million tons, we consider this a good enough consistency check.

If our new results are correct, it follows that the figures of farmyard manure consumption given in table A-5 are gross overestimates. We have also found the NSS to have overestimated fodder consumption and underestimated straw-grain ratios, overestimated kerosine consumption and underestimated domestic power consumption.

This extended analysis leads to the following conclusions:

1. Comparisons with NCAER surveys as well as with aggregate consumption statistics suggest that the results of the 1963-64 NSS survey were reasonably accurate, and could be within 20 to 30 percent of the actual figures.

2. Similar comparisons show the 1973-74 NSS results in poor light. In view of the rise in agricultural biomass, the supply of dung almost certainly went up in the intervening ten years, and there was room for an increase in its consumption as fuel. The 1973-74 survey grossly overestimates kerosine consumption, whose per capita supply did not go up. Hence, kerosine could not have replaced dungcakes or wood. But it is possible that electricity, whose consumption rose considerably, replaced kerosine as an illuminant and that kerosine at the same time partially replaced wood and dung as cooking fuels.

3. The spreading use of aluminum utensils and their substitution for earthenware vessels could have increased the fuel efficiency of cooking, and could account for the fall in the per capita consumption of traditional fuels, wood, and dung. The statistical basis of the fall, however, remains weak.

Appendix B

Table of Energy Equivalents

	Units	Value
Coal	MJ/Kg	27.0
Hard Coke	MJ/Kg	25.5
Soft Coke	MJ/Kg	20.9
Oil -light fractions (gasoline, naptha, LPG, etc.)	MJ/Kg	44.0
-middle fractions (kerosine, jet fuel, diesel oil, etc.)	MJ/Kg	43.0
-heavy fractions (fuel oil)	MJ/Kg	41.0
-crude	MJ/Kg	42.0
Natural Gas	MJ/Cbm	15.0
Firewood	MJ/Kg	15.0
Charcoal	MJ/Kg	30.0
Dung	MJ/Kg	10.0
Plant Residues	MJ/Kg	15.0
Electricity	MJ/KWh	3.6

Source: Ashok V. Desai, India's Energy Economy: Facts and Their Interpretation (Bombay, Centre for Monitoring Indian Economy, 1980).

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