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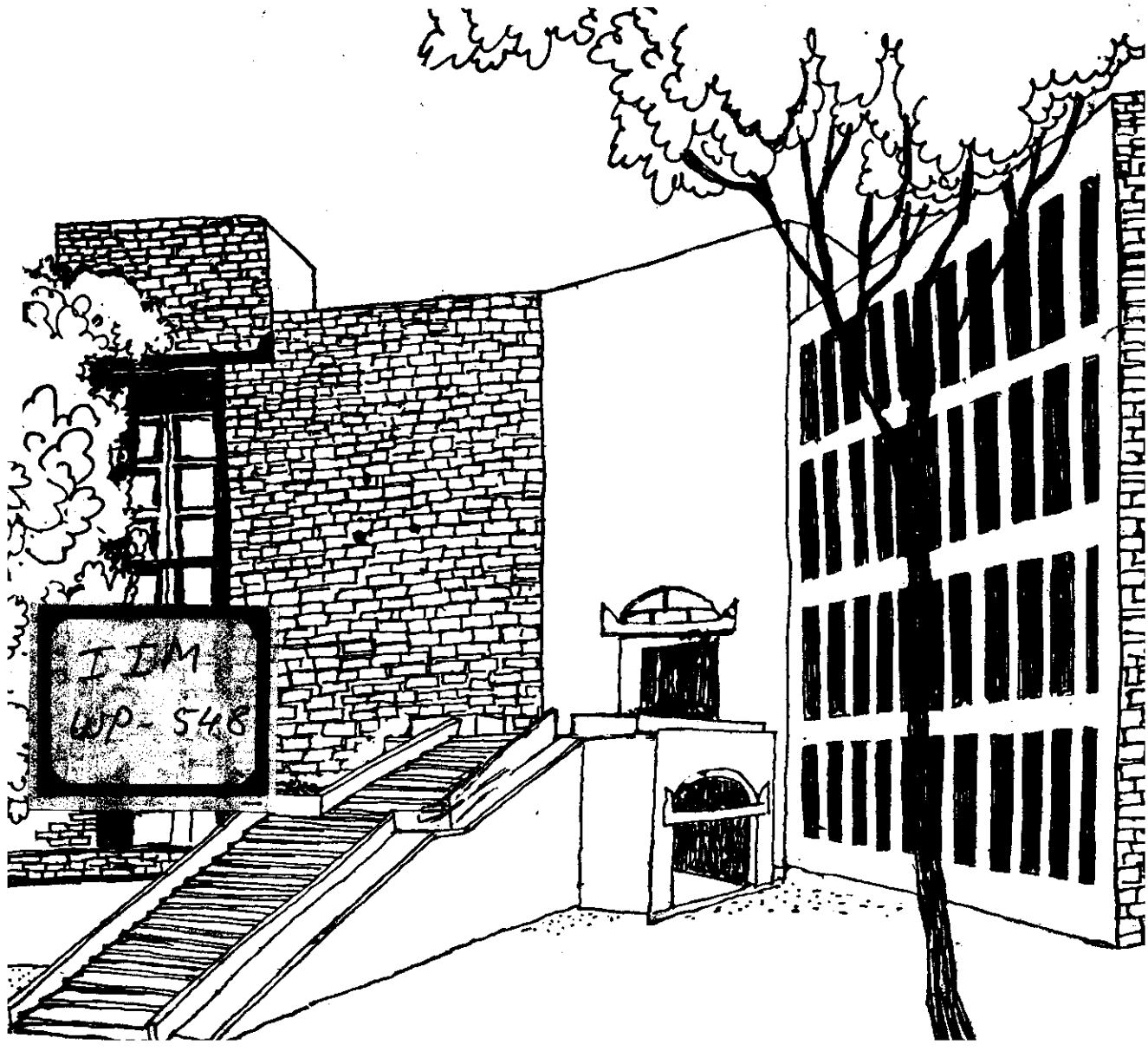

HOUSEHOLD ENERGY BEHAVIOUR AND URBAN DEVELOPMENT: THE CASE OF AHMEDABAD

By

R.S. Ganapathy
&
G. Padmanabhan

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Abstract

HOUSEHOLD ENERGY BEHAVIOUR AND URBAN DEVELOPMENT: THE CASE OF AHMEDABAD

RS Ganapathy
G Padmanabhan

Energy is a key input to meet the basic needs of human beings like food, clothing and shelter. Household energy behaviour needs to be understood for ensuring individual and social well being. The urban household energy use in India is critical because of the wide variations in the quantity of energy use among the socioeconomic and ethnic groups residing in a city. This paper develops a conceptual framework and describes a case study of household energy behaviour in Ahmedabad, a major Indian city. In the context of the energy profile of the city, household energy is assessed from the demand and supply sides. A survey of three hundred households and secondary data analysis was done. The results link energy consumption to cooking patterns, technology and source availability. Three scenarios for the household energy use in year 2001 are constructed and policy instruments and programmes to achieve a desirable scenario that is sustainable, equitable and efficient, are developed. Some general policy options are also discussed.

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Household Energy Behaviour and Urban Development: The Case of Ahmedabad

RS Ganapathy
G Padmanabhan

1. INTRODUCTION:

Energy has become a key input to meet the basic necessities of human beings like food, clothing and shelter. Individual life styles which are influenced by many factors are affected by the availability of energy in its various forms. With the increase in population, the demand for energy is also growing at an increasing rate. Domestic energy consumption is important because it relates directly to individual household behaviour as well as government policy making. The urban household sector energy use in a developing country is very critical because of the wide variations in the quality and quantity of energy use among the socio-economic and ethnic groups residing in rapidly growing urban centres.

This study was conducted in Ahmedabad mainly to identify the various sources of energy consumed in the city with emphasis on the household sector, where variations across income groups are studied. The first part of this study develops the conceptual framework and the limitations in conducting such a study in India. The methodology adopted is also explained. Then the energy profile of Ahmedabad from the supply side is analysed. After giving a brief account of the energy profile, demand from the household sector is estimated through a survey. Consumption pattern of various sources of energy are estimated for different income groups. End uses for each source for the income groups and the response to price increase or shortages by the income groups, the use of cooking appliances etc. are analysed.

Using the information gathered from the primary survey, an attempt to estimate the demand of various sources of energy by different income groups in the city for 2001 for three distinct scenarios are made. Finally programmes and policy measures that can be adopted to achieve a desirable scenario are developed in the paper.

2. A CONCEPTUAL AND METHODOLOGICAL FRAMEWORK:

The emergence of energy as a central issue of the seventies poses a serious challenge to the policy makers of India. While the crisis in urban domestic energy scene is obvious, few studies have been made of this problem. Hence an adequate understanding of the probelm and the policy options to deal with it do not exist.

A micro-sectoral approach to the energy policy and planning process is well suited to the Third World cities in comparison to the industrialised ones, as there is much greater reliance on non-commercial energy sources (New Combe 1980). The report No.4 of Papua New Guinea Human Ecology Programme emphasises on patterns of energy use in that city and alternative energy sources for the future. The report after reviewing the policies of the energy sector in urban setting, undertakes a sectoral analysis from the demand side through surveys conducted in Lae. For analysing the demand pattern in households four categories of households depending on the physical structure are selected and were surveyed daily for a period of 14 days. From this data, New Combe constructs an energy profile of households in Lae.

Factors affecting the domestic energy use in Australian cities were studied by Peter Newman (Newman 1982). Variations in urban domestic energy use were ascertained by taking into account a number of possible correlates. The impact of climatic change and the structure of buildings were identified by conducting studies regarding consumption in some selected Australian cities. Estimates were done using survey results in these cities and extrapolating them for the total city with the data acquired from dealers regarding the number of households using a particular source of energy. Correlation analysis to derive the relationships with other variables are done in the study.

In the present study for Ahmedabad, the methodologies adopted in the above studies cannot be applied fully. The main limitation is the lack of primary data. Energy consumption or demand information are very inadequate in India. None of the suppliers keep records for the end uses of the fuel they supply but some have sector-wise consumption data.

Eric Monnier (Monnier 1983) identified a few determinants of household behaviour in energy in France. His study reveals the influence of socio-economic variables such as the socio-professional category, the age or the income of the household etc. on energy consumption.

In India, the first and the only study done for a city level demand of energy was by NCAER (NCAER 1975), when they estimated the energy demand for the year 1978-79 for Greater Bombay. The estimation was done by conducting primary surveys in all the sectors on a sample basis and the results were projected for the city. Using the growth rate of energy consumption from 1958 to 1971, they have projected the demand for 1973-74 and 1978-79. Pattern of shift was also incorporated in the estimation. This study takes into account both primary and secondary sources of energy.

Naik (Naik 1983) in her paper "Energy in Urban Life" - a case study of Ahmedabad has estimated the energy supply in Ahmedabad for early eighties. The study looks at the energy profile from the supply side.

Most of the energy related studies from the demand side are done through primary surveys. The end uses of any of the sources are also not understood fully and there is hardly any study done on them. These seriouslimitations and the lack of data base make the studies related to energy very expensive and resource consuming. This is one of the reasons why studies related to consumption pattern of energy are not attempted in India. Suggestions are made by some institutions and organizations to improve the supply efficiency and production of various sources of energy. Demand estimation at a national level is also done which does not really help in conserving energy unless a micro sectoral analysis with the pattern and factors of consumption are done (Ganapathy, 1984).

In this study, the methodology adopted is similar to the one in the study by NCAER for Greater Bombay. To estimate the supply, data from the suppliers were used and for estimating the demand a primary survey was done in Ahmedabad. Various factors affecting consumption across income groups were captured through the survey. The sample survey results were extrapolated for the city to estimate the demand. Based on future scenario projections, the growth rate was determined and the demand for household energy in 2001 was estimated.

Since the unit of measurement of different sources of energy are not the same, it creates a problem in aggregating. Generally there are three measurement systems used to aggregate different types of energy consumption. The simplest of these is the heat content system. This measure is formed by converting energy sources into heat units based on their energy content. This system does not take into account differences in efficiency of utilisation among various energy sources. Coal equivalent method commonly used internationally uses heat content for energy sources in terms of equivalent amount of coal. In India, the most commonly used measure is coal replacement system. This is the amount of coal required to replace other energy sources in use. Here we also take into account the relative efficiency of the fuel with reference to coal. Because of different degrees of thermal efficiency with which the alternative energy sources are used in India and since coal is the major source of energy in India, coal replacement measure is considered to be more appropriate.

Table 1

Coal Replacement Value for Selected Energy Sources

Source of Energy	Unit	Coal replacement unit (Kg.)
Coal	1 Kg.	1.0
Kerosene	1 Litre	6.98
LPG	1 Kg.	10.25
HSDO	1 Litre	7.44
LDO	1 Litre	7.68
Furnace oil	1 Litre	2.0
Electricity	1 KWH	0.70
Firewood & Agricultural waste	1 Kg.	0.70
Dry Dung	1 Kg.	0.30
Charcoal	1 Kg.	0.90

Source: NCAER, 1973.

The analysis done in this paper includes two parts. The first part looks at the energy supply profile of the city. Data for this section is from secondary sources, mainly the sales estimates of the suppliers of various sources of energy. Electricity consumption figures for various purposes were supplied by Ahmedabad Electricity Company Lt.(AEC), the utility which is in charge of electricity supply in the city. Coal consumption figures are based on the sales estimates of coal India Ltd. Petroleum

product, sales estimates were collected from the oil companies. Charcoal and firewood consumption figures were updated from previous studies (Naik 1983) using the information collected from Octroi Department of the Municipal Corporation which provided the information regarding the quantity of firewood and charcoal that were transported into the city through road and rail. Thus, for electricity, kerosene, diesel and petrol, sectro-wise consumption figures were available. For LPG the consumption by commercial sector was not available hence the whole consumption is included in the residential sector. The Octroi Department could not provide the proportionate consumption of charcoal and firewood by commercial and residential sector. This was assumed to be the same as a previous survey conducted in the city in late seventies. Animal energy consumption (mainly used for transport of goods and people) is calculated from some assumptions based on the findings of an earlier study (Ramaswamy 1981). The findings of this study confirm that a bullocak can produce 0.7 HP which is equivalent to 750 KW of electrical energy, i.e. 12.5 KWH. Here it is assumed that a camel is three times powerful than a bullock thus 4500 camels in the city can produce 0.7 x 3 x 4500 = 9450 HP which is equal to 118125 KWH. Unofficial estimates shows that there are 10,000 donkeys within the city. Assuming that two donkeys have the same power of a bullock, 10,000 donkeys can produce 43750 KWH of energy. From the above, an energy supply profile of the city is constructed.

Demand estimate of households is done through a primary survey conducted in the city in 1984. Here a sample of 300 households were selected from all over the city. To avoid any spatial bias of energy consumption, the sample households were selected in such a way that all parts of the city are equally represented. For this the city was divided into three parts: Walled city (the oldest), eastern side of river Sabarmati excluding walled city and western side of river Sabarmati. Since 30 per cent of people in Ahmedabad reside within the walled city 1/3 of households were selected from this area. The remaining households were divided equally among the western side and eastern side, excluding the walled city.

In order to capture the demand patterns by various income groups the sample within each of these three parts were again proportionately divided according to the income distribution of population. However, the income group-wise population residing in each of these parts were not available but the distribution for the city as a whole was available. Here this proportion was taken, while selecting the households.

The respondents were not able to give the actual consumption of various sources of energy, but could provide the amount they spend, on an average

month, on each source. Using the present market price of per unit of each of these sources the quantity of fuels were worked out. With this information and the total number of households in each income group the consumption of various sources of energy in 1984 was extrapolated for the city.

Estimation of energy demand for 2001 is based on the survey results. The three future scenarios constructed are distinct from each other in nature. The assumptions made in the first scenario are statusquo in nature. It assumes the trend in consumption pattern of energy, the population growth etc. will all continue with the same intensity. Due to the increase in demand and population there will not be any shift in the demand pattern. Here the population growth rate for the last decade is taken for projection of population for 2001. Assuming the same household size the number of households were worked out and using the same proportion of income-wise, the households under each category were calculated. Demand for each source of energy by each income group was calculated using the present per household demand pattern.

The assumptions for the second scenario are pessimistic in nature. Here the scenario assumes some changes in growth rate of population, life style of the people, and pattern of energy consumption. The income groupwise number of households are calculated using the same method but with different growth rate of population. Demand estimation is done by incorporating the natural increase due to the increase in households and the changes and shifts that are likely to takeplace as per the assumptions.

The third scenario makes assumptions which are desirable in terms of energy consumption. To accomplish this the government will have to intervene and this would result in shifts in the present energy demand pattern. The demand for 2001 is first estimated using the same method as in the other two scenarios and corrections are made by incorporating the changes that would take place due to the government intervention. Results of survey, for example, the response to supply shortage or price increase are used in determining the shift in demand.

3. THE ENERGY SUPPLY PROFILE OF AHMEDABAD:

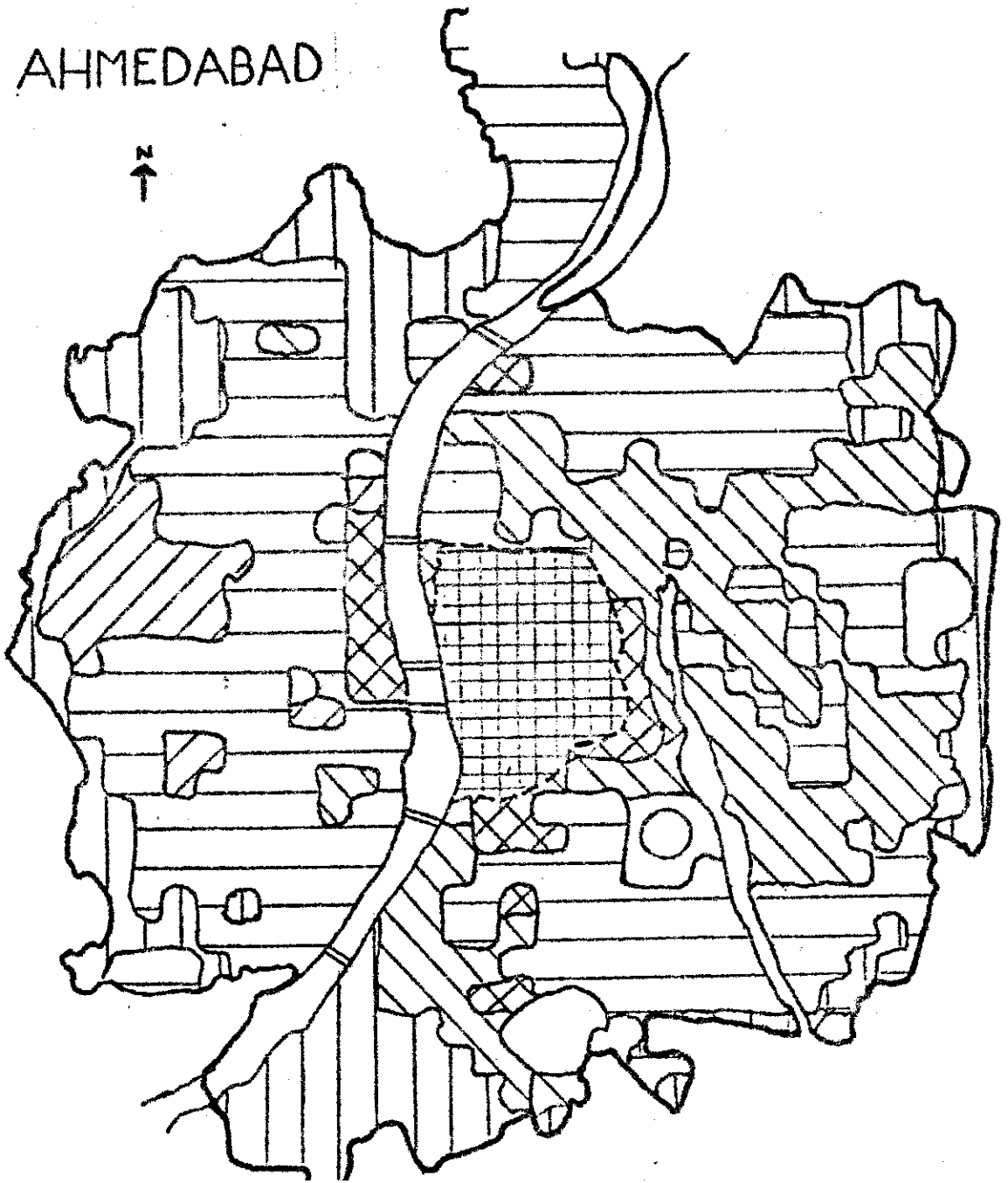
Origin and Growth of Ahmedabad

Since its foundation in 1411, Ahmedabad has undergone two phases of development which can be classified into pre-industrial phase (1411-1859) and industrial phase (1859 onwards). In order to give the city a good economic base, the settlement of merchants, weavers and craftsmen were encouraged by the founding king, Ahmed Shah in the fifteenth century. Since then the population of the city had increased enormously and a local body was formed in 1857. Gradually the institutional facilities (education, cultural and recreational) improved and the city entered an industrial phase.

Ahmedabad lies between 23°50'N latitudes and 72°3'E and 72°41'E longitudes covering an area of 98.15 Sq.kms. dissected by river Sabarmati flowing from north to south. The city is built on a more or less flat land with a few hillocks towards south west and west and the main water bodies are river Sabarmati and Kankaria lake. The average height of the city is 48.77 meters above mean sea level, Ahmedabad experiences extreme climate situations with temperature varying from an all time peak of 45°C in summer to 4°C in winter and receives an average rainfall of about 730 mm from south-west monsoon (refer to the map of the city for its location and landuse).

There are two distinct types of built forms in the city: one within the walled city which is old or rather traditional and organic in terms of development and the outside part which is relatively recent in development. Since the triggering of development occured within the walled city over four hundred years, the increase in population and activities have resulted in congestion. Conversion of land use from residential to commercial and service use became intense and the narrow roads could not accommodate the rising vehicular traffic. The regulations regarding open spaces are not observed and at present it is a cluster of buildings accommodating various activities with overcrowded, narrow roads, highly polluted due to the lack of space coupled with the emission from automobiles. People from low income and middle income groups live here. In the western side, live the more affluent section of the society. The land under industrial use starts from the eastern end of the Ellisbridge in the

AHMEDABAD



LEGEND-LANDUSES

- RESIDENTIAL
- INDUSTRIAL
- COMMERCIAL
- INSTITUTIONAL
- MIXED LANDUSE
- AGRICULTURAL
- OPEN SPACES

SCALE 1CM = 732 MT.

South to Vadej level bridge in the north. The north eastern and south-eastern strip of industrial belt consists of textile mills. Functionally the city is classified industrial.

At present the city accommodates 2.1 million people out of which more than 40 per cent are migrants (1981 census data). With the construction of bridges across the river the movement of people towards the western part increased mainly for residing in places with better quality of life. On the western side almost parallel to the river, a commercial district was developed along the Ashram Road. The peripherial areas of the old fort wall have large scale wholesale activities dealing with wide range of goods which has become one of the major traffic generating nodal points. The interstate bus stand and Railway station are two other nodal points on the eastern side. All these have led to large scale east-west and west-east movements especially in the morning and evening peak hours.

With the increase in population and employment, the demand for housing also increased and this has led to a large scale construction of houses both by private developers as well as government agencies. With addition of every house there is an increase in demand for energy. The magnitude and type of demand is decided by the people living in households. Migrant population from rural areas carry along with them the life styles and cooking habits that were moulded in a subsistence village economy. 50 per cent of population in Ahmedabad live in slums, chawls and pols (different types of low income housing). The consumption of non-commercial sources of energy is high mainly because of larger proportion of people in the lower income group. Rapid industrialisation also has led to an increase in demand of various sources of energy. Rapid urbanisation coupled with industrialisation led to an increase in demand for transportation. All these put together resulted in a heavy energy demand of various sources by various sectors of the urban economy.

Growth of activities in Ahmedabad

Population of Ahmedabad grew from 1.8 lakhs in 1901 to 21 lakhs in 1981. The city expanded in its area from 14.93 Sq.km. in 1901 to 92.98 Sq.km. in 1971.

Table 2

Population Growth in Ahmedabad

Census year	Population	Annual Growth Rate
1901	1,85,889	-
1911	2,16,777	1.54
1921	2,74,007	2.37
1931	3,10,000	1.24
1941	5,91,267	6.67
1951	8,37,163	3.53
1961	11,49,918	6.88
1971	15,85,544	3.26
1981	21,23,831	2.97

Source: Statistical Outline of Ahmedabad City. Ahmedabad Municipal Corporation. Ahmedabad, 1983.

Rapid industrial growth in Ahmedabad is one of the major reasons for this manifold increase in population. There is a wide variation in spatial density of population in the city. The walled city has got a very high density of 83,544 persons per km. The eastern side excluding the walled city has got a density of 13096 persons per km. whereas on the western side the density is only 3414 persons. However, during day time the density is much higher in many parts depending on the activities they accommodate. The overall density of the city is 12,363 persons per km.

The number of industries in 1970-71 was only 1187 but it rose to 1981 in 1979-80. Among the industries the textile industries marked the highest growth rate followed by chemicals. At the same time the number of transport industries decreased considerably from 62 in 1970-71 to 14 in 1979-80. The main reason is that due to the lack of space many of these have shifted outside the city to the urban peripherial areas.

Table 3

Industrial Growth in Ahmedabad

Industry	1970-71	1974-75	1979-80
Textiles	249	262	420
Engineering	310	290	362
Printing	92	115	139
Chemical	42	82	141
Transport	62	16	14
Others	433	676	905
Total ...	1187	1441	1981

Haphazard and fast growth of industries in Ahmedabad has led to serious pollution problems and congestion. Textile mills within the city and other activities they generate together have made the traffic on roads, leading to railway station and warehouses and from mills very congested.

Within the last 20 years the length of surfaced roads in Ahmedabad has doubled. Scooters, motorcycles and mopeds together constitute 53 per cernt of the total vehicles registered in Ahmedabad. Private vehicles are much more than public vehicles. Autorickshaws, taxis and pedal rickshaws serve as the main intermediary public transport mode. Ahmedabad Municipal Transport Service (AMTS) operates buses for public transport in the city. The utility at present operates 217 routes and carries 829,589 people daily. AMTS has got a bus to population ratio of 1:5141.

Present Energy Profile:

The energy profile is from the supply side which looks at the various sources of energy consumed by different sector in the city. Data for this section is collected from secondary sources of sales information of utilities and resource supply companies for 1982-83. From this data, we have computed the total consumption of energy in standard units.

Ahmedabad consumed 4157109 coal replacement units (tonnes) of energy in the year 1982-83. This 42 lakhs of CR units include electricity, coal, kerosene, diesel, petrol, LPG, charcoal and firewood used for various purposes. Out of the total consumption, 28 per cent was in the form of electricity, 18 per cent coal, 17 per cent kerosene, 11 per cent diesel, 9 per cent petrol, 4 per cent LPG, 4 per cent furnace oil, 4 per cent firewood, 3 per cent in the form of animal energy, 1 per cent charcoal and 1 per cent other (Figure 1).

Industry is the maximum energy consuming sector (47 per cent). Industrial consumption of energy is met mainly by electricity, coal, kerosene and furnace oil. The second major energy consuming sector is households which amounts to 25 per cent of total energy consumption. Here the commercial sources like electricity, kerosene, LPG and noncommercial sources like charcoal and firewood are the major sources. Transport sector consumes 20 per cent of the total energy, mainly diesel and petrol. Commercial sector consumes 5 per cent, public amenities 2 per cent and others 1 per cent.

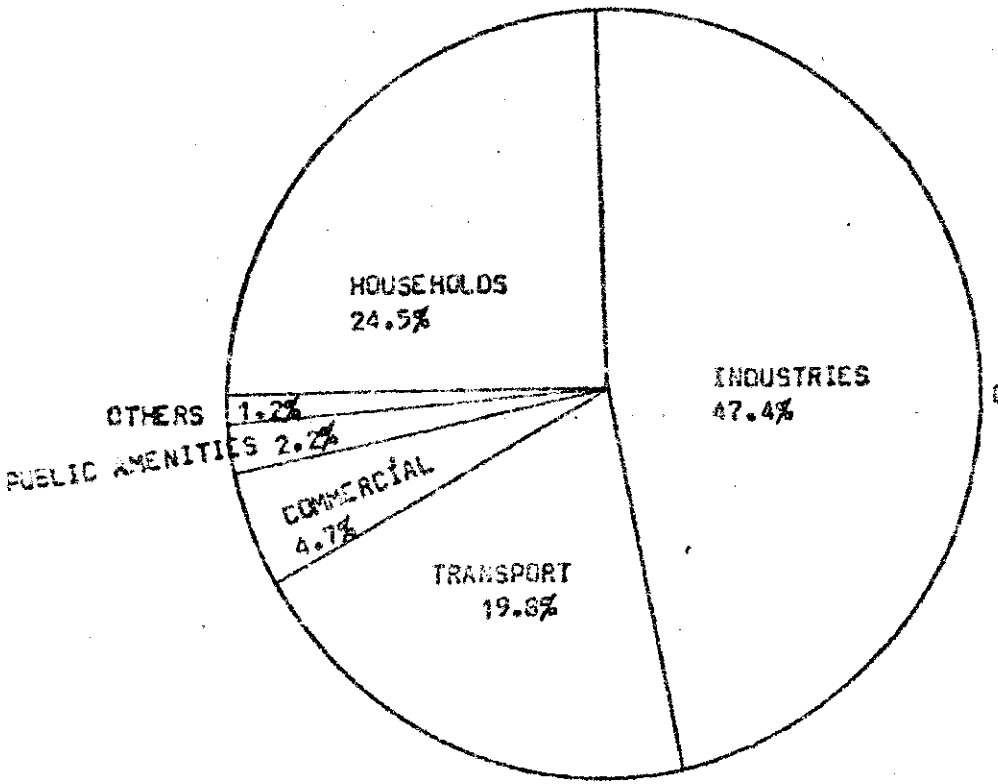
Source-wise consumption of Energy:

Electricity is consumed by all the sectors except transport and is consumed by industries in a major way followed by households, public amenities and commercial. The city consumed 1664215335 KWH of electricity in 1982-83. 74 per cent of this goes for industrial use, 11.9 per cent for households, 5.9 per cent commercial sector and 7.65 per cent for public amenities. Public amenities include the consumption by Ahmedabad Municipal Corporation which uses electricity for street lighting and for traffic signals. Electricity is supplied in the city by Ahmedabad Electricity Company Ltd. (AEC) a regulated utility.

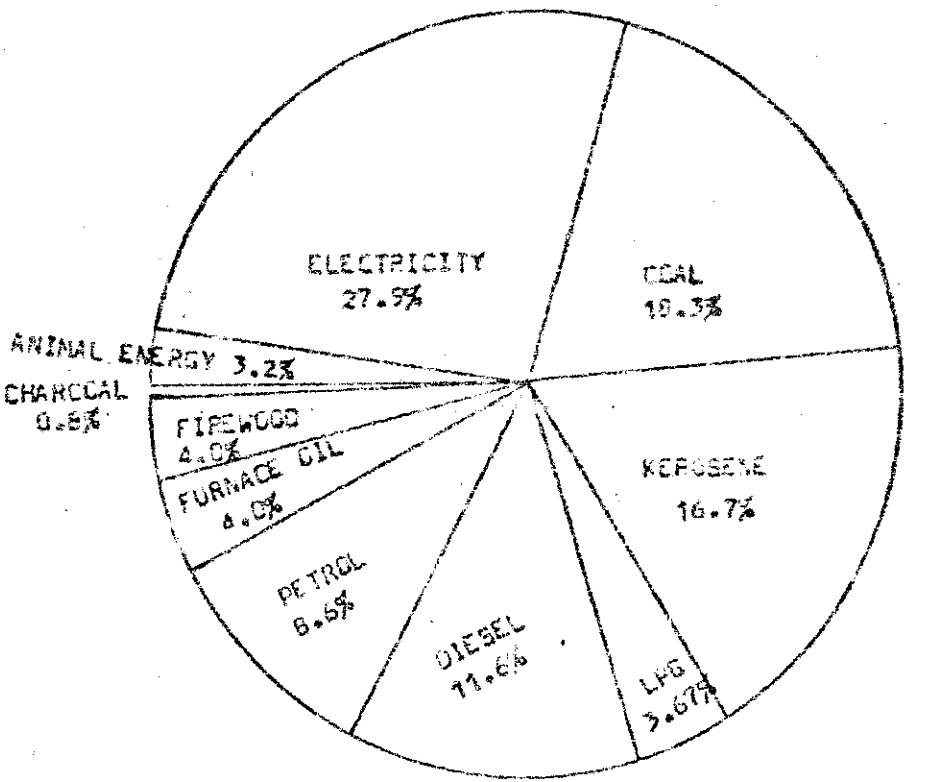
Coal in the city is consumed by Industries and the Ahmedabad Electricity Company for power generation (consumption by AEC is not taken into account to avoid double counting). Consumption of coal by industries in 1982-83 was 767270 M Tons. However, there are some low income households which consume coal collected from railway yards which could not be estimated from supply sources.

ENERGY CONSUMPTION IN AHMEDABAD 1982-83

SECTORWISE CONSUMPTION OF ENERGY



SOURCE WISE ENERGY CONSUMPTION



Households consumed 83 per cent out of total kerosene consumption of 100333.5 kilolitres in 1982-83. Industrial consumption of kerosene amounts to 15 per cent and the remaining was consumed by commercial sector mainly by hotels and restaurants. Both commercial and residential sectors consume LPG. However, the proportion consumed by commercial sector is not available from the supply side. Hence it is included in the residential sector. Consumption of LPG for 1982-83 was 15,000 M Tons.

Out of 54000 kilo litres of diesel oil sold in Ahmedabad 90 per cent was consumed by transport sector. Remaining 10 per cent was consumed by thermal plants and for agricultural purposes. Petrol consumption was 48000 kilo litres consumed only by the transport sector.

Firewood and charcoal sales data in the city were not available due to the absence of any formal organization dealing with this fuel source. Here, for the study purpose, the toal quantityof firewood and charcoal that were transported into the city through rail and road were collected from the Octroi Department. The proportional share of these fuels for commercial and residential sectors were taken from the previous estimates: 60 per cent of firewood was consumed by commercial sector and the remaining by households out of total consumption of 245252 M Tons. In 1982-83 the city consumed 52412 M Tons of charcoal. This is taken to be used only in residential sector.

Animal Energy:

In addition to the above mentioned sources of energy in Ahmedabad there is a substantial use of animal energy utilised mainly for transporting goods from factories to godowns, godowns to wholesale depots and from wholesale to retailers. It is roughly estimated that there are 5000 camel drawn carts in the city and about 15000 hand carts. Unofficially it is estimated that there are 10000 donkeys in the city used for carrying construction materials. Thus the total animal energy alone if converted into coalreplacement units would came to 135975 MTCR. This is estimated based on some assumptions made in the use of animals in the city. It is assumed that a camel is three time more powerful than a bull. Thus 4500 camels in the city (again an unofficial estimate) can produce

0.7x3x4500 = 9450 HP which is equal to 118125 KWH. If one camel works for 5 hours for 20 days in a month then annual camel energy in the city will be 118125 x 5 x 20 x 12 = 141750000 KWH or 99225 M Tons of coal replacement. Similarly it is assumed that 2 donkeys are powerful as a bull, and the energy produced by 10,000 donkeys for 5 hours in a day for 20 days in a month is equal to 52500000 KWH/year at 36750 MTCR/year. Thus the total animal energy used in the city from camels and donkeys equals 135,975 MTCR.

Table 4

Sector-wise consumption of various sources of energy in Ahmedabad - 1982-83

Sources of Energy	Residential (%)	Commercial (%)	Industrial (%)	Transport (%)	Public Administration (%)	Others (%)	Total (in actual units
Electricity	11.91	5.9	74.2	-	7.6	0.3	1664215335(KWH)
Coal			100				767270 (M Tons)
LPG	100						15000 (M Tons)
Kerosene	82	2.5	14.9				100333.5(K.Ltrs.)
Diesel Oil				90		10.0	54000 (K. Ltrs.)
Petrol				100			48000 (K. Ltrs.)
Furnace Oil			100				84924 (Litres)
Charcoal	100						52412 (M. Tons)
Firewood	39.8	60.2					245452 (M. Tons)
Animal Energy			100				135975 (MTCR)
Total (in MTCR)	9859704	189689.48	1906813.63	933375	89167.4	52192	4157109.77

4. ENERGY DEMAND PATTERN AND NEEDS ASSESSMENT:

Energy Demand in the household sector

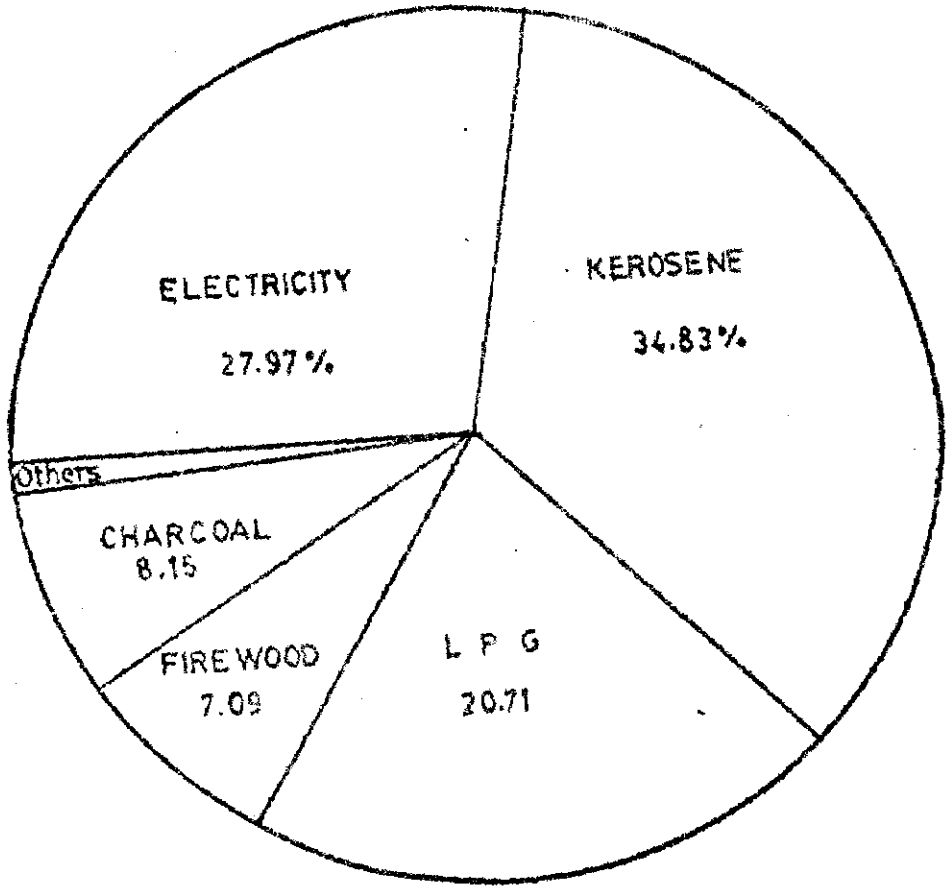
Households in Ahmedabad consume various sources of energy like electricity, kerosene, LPG, firewood, charcoal, dried cowdung and agricultural waste. The end uses for which these sources are put into depend mainly upon the income of the household. There is a shift from non-commercial to commercial sources as the income goes up. To study the pattern of consumption of various sources of energy by household a primary survey of three hundred households was conducted. This primary survey attempted to capture the variations in terms of pattern of energy consumption across income groups, hence the sample was proportionatly divided according to the income-wise proportion of households. To avoid spatial bias in the consumption of various sources, the households were chosen from all over the city.

Here in this survey the respondents could not give the actual consumption of energy but could give the approximate amount that they spent in a month for various energy sources. By taking the average expenses of each source under six income groups separately, the total energy and expenditure for the city is extrapolated by multiplying with the number of households in each group. From this estimate, the actual units of consumption is derived by dividing with the current price/unit. From the survey the total annual consumption by households for the city is estimated to be 836704.08 M Tons of coal replacement and this costs Rs.3484.21 lakhs. The supply estimate of various sources of energy to household sector shows that the total consumption by household sector for 1982-83 was 985870.4 MTCR. The difference between the demand and supply estimates (149166.32 MTCR) is mainly because the survey sample used here is not truly a representative one, and there could be some errors in the method of estimation for the city. In the case of LPG, since the consumption by commercial sector is not available, it is included along with the household sector. This would also make some difference. The supply figures are for the whole year computed by the dealers whereas in the case of demand survey the respondents could give only the consumption in an average month. This difference is not taken into account while making the estimation mainly because this could not be done in a one point of time survey. Among the various resources, kerosene is the maximum consumed,

Figure 2.

SOURCEWISE CONSUMPTION OF ENERGY BY

HOUSE HOLD SECTOR (in %)



83 per cent of the total household energy consumption is met by commercial sources of energy. All India Urban consumption of commercial sources of energy is only 49 per cent. Among the non-commercial sources of energy is charcoal is the maximum consumed (8.1%), firewood 7.1 per cent. Consumption of agricultural waste and dried cowdung together is only 1.3 per cent.

Expenditure-wise the city spends maximum on electricity. From the city households total expenditure on energy 34 per cent is for electricity, 24 per cent for kerosene and 16 per cent for LPG. Thus 74 per cent expenditure on energy brings in 83 per cent of the total energy consumption. Expenditure on non-commercial sources of energy is 26 per cent. Firewood and charcoal consuming 10 per cent each and cowdung 4 per cent (Refer to Figure 2).

Figure 5

Source-wise consumption of energy by household sector in Ahmedabad (%)

Source	Consumption	Expenditure
Electricity	27.97	34
Kerosene	34.83	24
LPG	20.71	16
Charcoal	8.15	10
Firewood	7.09	10
Cowdung and Agricultural waste	1.30	4

Variations across income groups:

By examining the consumption of various sources of energy by income groups, we can find alarge scale variation. It is found that as the income increases the percentage consumption of electricity also increases, i.e. the share of electricity consumed out of total electricity consumption is high in the case of higher income groups in spite of less households in that group. Thus about 34 per cent of the total consumption of electricity is by households having a monthly income of more than Rs.2000 whereas the total number of households in this category are only 14 per cent. At the same time 69 per cent of the households below Rs.1000 as income consume only 39 per cent of electricity, use.

The same trend is observed in the share of electricity out of the total energy consumption. This is due to the tasks associated with electricity is more in the case of higher income groups. This is evident from 48 per cent of the energy consumption is met by electricity, in the case of households having an income of more than Rs.3000 per month. At the same time in the case of households with a monthly income of Rs.1000-2000 this share varies from 32 per cent to 43 per cent and in the case of households with an income of less than Rs.500 p.m., the share is only 16 per cent.

Table 6

Consumption Pattern of Electricity

Income Group	% of households	% share of electricity out of total energy consumption	% share out of total electricity consumption
Less than Rs.500	38.13	16.11	12.28
Rs.500 - 1000	33.52	24.7	27.73
Rs.1000-1500	9.84	32.35	11.89
Rs.1500-2000	5.24	46.46	11.61
Rs.2000-3000	8.07	39.50	16.03
Rs.3000 and above	5.81	48.50	20.85

In the case of kerosene consumption the pattern among income groups is not skewed as in the case of electricity. Here out of total kerosene consumed by households 68 per cent goes into the households with an income less than Rs.1000; the percentage of households in this category is also 68. 13 per cent of households in the city have an income more than Rs.2000 and they consume 15 per cent of kerosene consumed by households. The dependence on kerosene in the case of lower income households is very high. Kerosene in these households is used for almost all purposes. This proportion steadily declines as the income increases. The end uses of kerosene is more in the case of lower income groups.

Table 7

Consumption Pattern of Kerosene

Income Group	% share out of total energy consumption	% share out of total kerosene consumption
Less than Rs.500	48.20	12.28
Rs.500 - 1000	36.99	27.32
Rs.1000 - 1500	34.80	11.89
Rs.1500 - 2000	22.50	11.61
Rs.2000 - 3000	22.78	16.03
	18.08	20.85

None of the households with an income less than Rs.500 use LPG. As the income goes up the percentage of households using LPG also goes up. The proportion of LPG usage by income groups out of total LPG consumption does not show any steady increase or decrease. Households having an income between Rs.500 - 1000 consume 30 per cent of total LPG consumption by households. If we compare the percentage consumption with the proportion of households then it seems to be high among the households having an income above Rs.1500.

The extent of use of LPG in an household can be understood from the share of LPG in total energy consumption. This shows an increase as the income goes up except in the case of households having an income more than Rs.3000. Households with an income less than Rs.1000 use 18 per cent of energy in the form of LPG. This share is as high as 30 per cent in the case of households having an income between Rs.2000 - 3000.

Table 8

Consumption Pattern of LPG

Income groups	% share out of total energy consumption	Proportion out of total LPG consumption
Less than Rs.500	-	-
Rs.500 - 1000	18.5	30.25
Rs.1000 - 1500	29.83	16.21
Rs.1500 - 2000	32.31	12.76
Rs.2000 - 3000	36.10	21.67
Rs.3000 and above	38.08	19.10

Firewood consumption like any other non-commercial sources also decreases as the income goes up. Out of the total firewood consumption by households 57 per cent is consumed by households having an income less than Rs.500 which constitute 38 per cent of the total households in Ahmedabad with an income between Rs.500-1000 consume 38 per cent of firewood. This shows a large scale reliance on firewood by lower income people. Firewood consumption in households having an increase above Rs.3000 is only 0.72 per cent. Intensity of firewood is not much even in low income groups. It is found that even in households with an income less than Rs.500 consume only 16 per cent of energy in the form of firewood. In high income groups the share is less than 1 per cent.

Table 9

Consumption Pattern of Firewood

Income Group	% share out of total energy consumption	Proportion out of total firewood consumption
Less than Rs.500	15.9	59.90
Rs.500 - 1000	7.46	38.70
Rs.1000 - 1500	0.879	1.50
Rs.1500 - 2000	0.93	1.16
Rs.2000 - 3000	0.50	0.96
Rs.3000 and above	0.36	0.72

Charcoal is another non-commercial source which is consumed mainly by lower income households. 91 per cent of charcoal is consumed by households with anmonthly income less than Rs.1000. The intensity of charcoal consumption in households is very low which is evident from even households with a monthly income less than Rs.500 consuming only 16 per cent of the total energy in the form of charcoal. Least consumption is by households having an income between Rs.1500 - 2000.where only 0.87 per cent of the total energy is consumed in the form of charcoal.

Table 10

Consumption Pattern of Charcoal

Income Groups	% share out of total energy consumption	Proportion out of total charcoal consumption
Less than Rs.500	15.6	44.16
Rs 500 - 1000	11.5	47.18
Rs.1000 - 1500	2.05	2.78
Rs.1500 - 2000	0.78	0.77
Rs.2000 - 3000	1.05	1.61
Rs.3000 and above	2.20	3.56

Dried cowdung and agricultural waste usage in Ahmedabad is very insignificant in the sense these together contribute only 1.2 per cent of total energy consumption by households that too only by households with an income less than Rs.1000. Low intensity of use of these two sources is reflected in households with an income less than Rs.500 per month consuming only 4 per cent and households with an income between Rs.500-1000 consuming only 0.8 per cent of total energy in the form of these two sources of energy.

Summary:

Various sources of energy consumed by households include kerosene, electricity, LPG, Charcoal, firewood, cowdung and agricultural waste in order of their importance. Major part of consumption comes from commercial sources. Except cowdung and agricultural waste all other sources of energy are used by households in all income groups. Electricity and LPG

consumption increases with income whereas kerosene, firewood and charcoal consumption decreases as the household income increases. Kerosene is maximally used in households andis consumed by almost all households in all income groups. In the case of electricity all households with an income more than Rs.1000 per month use it. High income households tend to consume all commercial sources of energy like electricity, kerosene and LPG. Except in the case of very low income, charcoal is consumed by more number of households than which consume firewood. In the case of kerosene and LPG there exists a large and efficient network of distribution system whereas in the case of charcoal and firewood it does not exist. Firewood in slums are collected from the road side and from other public spaces.

Table 11

Percentage of households consuming various sources of energy

Income Group	Electricity	Kerosene	LPG	Firewood	Charcoal	Cowdung	Agri. waste.
Less than Rs.500	50	100	-	70	54	41	9
Rs.500 - 1000	62	100	28	34	50	20	10
Rs.1000-1500	100	100	70	40	12.5	-	-
Rs.1500 - 2000	100	100	83.3	5.0	11.0	-	-
Rs.2000 - 3000	100	100	87.5	4.1	8.3	-	-
Rs.3000 and above	100	100	100	7.0	2.10	-	-

End Uses of Various Sources of Energy:

Various sources of energy consumed in an household are put to differen end uses. The sources and end use are determined by a number of factors. One of the major factors which determines the end use of a particular source of energy is the income of the household. Total expenditure on energy is highly correlated with the income of the household. The purpose for which each source is utilized also depends on other factors like the type of house they live in and their lifestyle and convenience. For

example, a higher income family living in a flat would use electricity for heating water at the same time a family living in a bunglow may use firewood. This again depends on the availability of those sources.

Electricity is used for lighting, cooling, water heating and recreation. (Under cooling, use of refrigerators and fans are also included). However from the survey, the use of electricity for cooking and washing clothes were not found. The major use of electricity in an average household is for lighting and cooling. It was observed that there is a large scale variation in the use of electricity among households of different income. In households with a monthly income of less than Rs.1000, electricity is used by 47 per cent of the households only for lighting. Their expenditure on electricity is Rs.18.60/month. Only 5 per cent of them use electricity for recreation. All the households with an income more than Rs.1500/month use electricity for recreation. From the analysis it was found that some households spend about Rs.300/month for electricity.

Kerosene is used by almost all households in all income groups and is consumed mainly for lighting, cooking and water heating. The use of kerosene for lighting is confined to only lower income households. They consume about 4.8 litres of kerosene for lighting. Kerosene is principally used for cooking in households with an income between Rs.1000-1500 (90 per cent). Households with an income more than Rs.3000 also uses kerosene for cooking (about 80 per cent) but the extent of use is very limited which is evident from the expenditure on kerosene is least in this category. At the same time highest expenditure is by households in the group of Rs.1000-1500 which shows the extensive use of kerosene.

Liquid Petroleum Gas (LPG) is used both for cooking and for water heating. However, the use of LPG for water heating is very limited. Monthly expenditure on LPG for cooking is minimum in households within the income group of Rs.1000-1500. This is because of the higher use of kerosene in these households for cooking. Maximum expenditure on LPG is by households with an income more than Rs.3000, where the expenditure on kerosene is minimum.

Firewood, a non-commercial renewable source of energy is extensively used among lower income group households for heating water and for cooking. As the income goes up the use of firewood is only for water heating. The expenditure on firewood for cooking also decreases. This again explains the shift to other sources with the increase of income. An household in less than Rs.500 category spends Rs.20/month on firewood for cooking alone. More than 50 per cent of the households in this category consume firewood for cooking.

Charcoal is more extensively used than firewood. The use of charcoal is maximum in Rs.500-1000 income group. Households above Rs.3000 group uses charcoal only for water heating. Expenditurewise, maximum use of charcoal for cooking is by households in less than Rs.500 group. They spend Rs.29 per household/month on charcoal for cooking. Maximum expenditure on water heating by charcoal is by households within the income group of Rs.1000-1500/month.

Agricultural waste and dried cowdung are used mainly by lower income groups for cooking. Expenditure on cowdung for cooking is maximum in households with an income below Rs.500, same is the case with agricultural waste. Cowdung is used for water heating only by households with an income between Rs.500-1000/month.

Consumer Response to Price Increase and/Shortage in Supply of Energy:

People respond to price increase or supply shortages in energy is different ways. These two are the major uncertainties facing energy consumers in India. This response is determined by many factors like the affordability and availability of other sources of energy. An household in the higher income group might continue to use the same sources of energy even if there is an increase in price; at the same time a household in the lower income might look for cheaper source or would even cut down their consumption. Some households will adopt some technological measures to save energy, for example, using pressure cookers for boiling vegetables and grains, thereby saving time and fuel. Another means of reacting to price increase is by changing the end use like eating in hotels or buying prepared food items. From the survey it was found that the response for different sources of energy are different for different income groups.

50 per cent of the households in less than Rs.500 category use electricity. 40 per cent of them continue to use the same amount even if there is a price increase whereas the remaining households decrease their consumption. Among the households in Rs.500-1000 income group 63 per cent of the households consume electricity. More than 50 per cent of them use the same amount and the remaining decrease their consumption. 58 per cent of households with an income between Rs.1000-1500 use the same amount of electricity even with a price increase. Households with an income between 1500-2000 use the same amount to the extent of 78 per cent. In the case of households with an income between Rs.2000-3000, 50 per cent use the same amount and in the case of households above Rs.3000, 72 per cent use the same amount of electricity even with a price increase. Out of all the households which consume electricity, there is no change in consumption in the case of 55 per cent of the households and the remaining decrease their consumption. However the extent of decrease in consumption could not be gathered. Decrease is mainly through reduction in operating time.

In the case of kerosene which is used by almost all the households the consumption is reduced if there is a price increase or supply shortage. The percentage of households within each income group which continue to use the same amount even with a price increases as the income increases. This could be due to the affordability of higher income groups. Thus only 18 per cent of the households below Rs.500 remained without any change. Whereas in the case of households with an income above Rs.3000 this proportion is 64 per cent. About half of the households consuming kerosene substitute with some other source of energy when there is a price increase. In the case of very low income groups the main substitution source is firewood and charcoal. 20 per cent of households in Rs.500-1000 income group have responded to price increase with substitution. Here the substituting source is mainly LPG, charcoal and firewood. 33 per cent of households in Rs.1000-1500 group and 25 per cent in 1500-2000 group have responded to price increase by substitution. This group also have opted LPG, charcoal and firewood.

In Ahmedabad there is a shortage in supply of LPG for the last several years. Consumers have to wait for more than a month in certain cases to get a refill cylinder. Hence the customers usually bribe the distribution company employees to get orders filled in advance which again worsens the situation. To meet this problem of shortage households have responded by substitution or by reduction in consumption. 42 per cent of the total households within city use LPG. As observed in the case of electricity the price increase has not affected the consumption in higher income groups. In some cases supply shortage is met with substitution by kerosene and in some case by either firewood or charcoal. Some households within an income range of Rs.500-1500 have responded to price increases through change in technology, which mainly includes the use of efficient cooking appliances like pressure cookers.

33 per cent of the households concentrated mainly among lower income groups consume firewood. 50 per cent of the households with an income less than Rs.500 consume the same amount even if there is an increase in price. This is mainly because of the reasons: (i) there are no affordable alternatives and (ii) they gather a substantial proportion of firewood from private and public spaces for which they really do not pay much other than the time spent in gathering, 23 per cent of the households decrease their consumption. Substitution is mainly done with charcoal and kerosene.

In the case of charcoal which is used by 30 per cent of the households mainly concentrated among low income groups responded to price increase by cutting down their consumption. Substitution in this category is mainly with firewood, kerosene, dried cowdung and agricultural waste.

Dried crowdung and agricultural waste consumption is very low. The users of these sources of energy prefer to use the same amount even if there is an increase in price. This is due to the fact that they really do not spend much on these sources but gather them from road sides, farms etc.

Cooking appliances and operating time:

The efficiency of energy utilisation in a household for cooking depends on the cooking appliances in use. According to the second law of thermodynamics energy gets lost in the process of conversion. The extent of loss depends on the conversion process and the technology in

use. Likewise in the process of cooking, energy is lost, the magnitude of loss determined by the cooking appliance in use. Most of the appliances in use in India are not efficient. However, efficient means available are not affordable by most of the people. For example the chulahs (cooking stove) using firewood or charcoal are extensively used in India both in urban and rural areas by low and middle income people, are very inefficient. The energy efficiency of firewood open chulah is estimated to be less than 7 per cent. From the survey it was found that every household with an income less than Rs.500/month owns a chulah. The average operating time of chulah/day in an household in this income group is 2 hours 30 minutes. The time of operation of chulah declines as the income increases. This is due to the shift to other sources of energy by higher income groups. Kerosene stove is another commonly used appliance in India. Stoves with 70 per cent efficiency are available in India but are not affordable by most of the people. The operating time varies from 44 minutes in an household with an income less than Rs.500/month to 1 hour 40 minutes in an household with an income more than Rs.3000/month. With the increase in income there is an increase in operating time of LPG stoves. This varies from the household with an income between Rs.500-1000/month (40 mts.) to an household with an income more than Rs.3000/month (more than 4 hours).

Table 12
Operating Time of Cooking Stoves

Income Group	Chulah		Kero. Stove		LPG Stove		Hot Plates		Cooking range	
	Hr.	Mts.	Hr.	Mts.	Hr.	Mts.	Hr.	Mts.	Hr.	Mts.
Below Rs.500	2	32	0	44	-	-	-	-		
Rs.500 - 1000	1	36	1	44	0	42	-	-		
Rs.1000 - 1500	-	19	1	36	2	22	-	-		
Rs.1500 - 2000	-	40	1	26	2	53	-	-		
Rs.2000 - 3000	-	06	1	43	4	00	0	03		
Rs.3000 and above	-	04	1	40	4	04	-	-	0	09

Cooking energy consumption is also determined by the food habits of the people. However, from the survey the extent of variation of this based on food habits, could not be ascertained. Since the time taken for cooking different food items vary, the energy consumed also varies. Non poor families in urban areas would eat outside at weekends and on holidays which would again reduce their energy consumption. To capture these variations, *an extensive survey is needed.*

5. LOOKING AT THE FUTURE: SCENARIO CONSTRUCTION :

Every institution in modern society and the life styles are moulded by the availability of energy in its various forms and its social, political and economic costs. Energy decisions are to be made with the future of society in mind. Some see a threat in the excessive consumption of fuels and other resources and some see a threat in not meeting these demands. The social, political and environmental costs of energy use both direct and indirect are proving to be very high. It has become clear by now that planning according to old rules had resulted in decisions that are costly both socially and environmentally and have become a threat to the rights and welfare of future generations. The list of problems and limitations of forecasting provides ample motivation to search for a new approach in thinking about our urban energy future. The most promising such approach is that of elaborating a representative set of alternative future scenarios based on differing assumptions about energy use. In this method alternative feasible energy futures are constructed and then a choice among them is made to shape the future. Here three scenarios are constructed with certain assumptions made about some of the important factors that affect the energy use.

Scenario - 1

This scenarios is status quo in nature. It assumes that the past trend will continue in such a way that the changes are not going to affect the pattern of energy consumption. Within the last 8 decades population of Ahmedabad grow at the rate of 3.09% annually. In the last decade the city experienced a growth rate of 2.95%. Population growth is influenced by a number of factors which vary in intensity over time. Death rate per thousand in the city has declined from 15.51 in 1961 to 12.07 in 1971. Similarly, the birth rate also showed a decline from 38.96 in 1961 to 29.51 in 1971. This is mainly due to better medical facilities and family planning measures. The percentage of migrants in the city decreased from 50.82% to 42.9% in 1961-71. These three major

factors contribute to the growth of population. Here this scenario assumes the same trend for the next 20 years. The assumptions are as follows :

1. The population will continue to grow at the same rate as experienced in 1971-81.
2. Drastic changes in life styles so as to affect the present trends in energy consumption are not likely.
3. Energy consumption will not change due to the change in food and cooking habits of the people.
4. Within the next 20 years technological changes will not have an impact on energy consumption.
5. The proportion of population under each income group is not going to change within the next two decades.
6. Since the above factors are going to follow the same trend the intensity of energy consumption in households is not going to change considerably.
7. Due to the increase in population the number of households are going to increase and this will certainly lead to an increase in demand. But the city will meet this demand by increasing the supply but major substitutions are not going to take place.

Energy Demand :

To estimate the demand for 2001 based on Scenario-1, the methodology adopted is the following. Firstly the present consumption of various sources of energy per household was calculated. Then the demand of various sources with the increase in households were worked out using the same per household consumption. To find out the number of households in each income group the same household size of 5.4 is taken and the projected population in 2001 is divided by this 5.4 and the present proportion under each income group is taken.

Thus growth rate for 1971-81, $r = \sqrt[10]{\frac{\text{pop.1981}}{\text{pop.1971}}} - 1$

i.e. $\sqrt[10]{\frac{2123831}{1585544}} - 1 = \underline{\underline{0.0296}}$

assuming the same rate of growth, projected population for 2001 = $(r+1)^n \times$ Pop. 1981.

i.e. $(.0296 + 1)^{20} \times 2123831 = \underline{\underline{3806191}}$

No.of households in 2001 (assuming an average household size of 5.4)

$$\frac{3806191}{5.4} = \underline{704850}$$

Table 13

Projected Number of Households

Income Groups	Number of households
Less than Rs.500	265296
Rs.500 - 1000	237370
Rs.1000 - 1500	68697
Rs.1500 - 2000	36582
Rs.2000 - 3000	56340
Rs.3000 and above	40561

For Project Demand see Table 14 in the next page

Scenario - 2 :

This scenario is more pessimistic. Here some changes in economy and technology are assumed which will affect the present pattern of energ consumption. The basic assumptions are :

1. In Ahmedabad the government freezes the industrial and economic growth inside the city. This will affect the migration into the city. At the same time the city has already established a number of activities which will continue attracting people to the city. Population growth for the last 4-5 years show that it has decreased considerably. With the new policy the decrease in growth rate is going to reduce the proportion of low income people.

2. With the change in technology, efficient chulahs and kerosene stoves will be available, in market at a price which most of the people will not be able to afford unless the government intervenes through subsidies.

3. Life styles of the people are going to change whereby the use of electrical gadgets in middle class families will be much more than at present. Some of these will be due to convenience for example, washing machines, wet grinder, refrigerator etc. Moreover, the use of electricity for entertainment will also increase.

4. Increase in prices of grocery and provision goods will result in price hike of food stuffs in hotels and restaurants. This would result in more number of people preferring to eat food at home which would result in an increase of cooking energy.

Table - 14

Projected Energy Demand for 2001 by Household sector based on Scenario - 1
Coal Replacement units/year

Income Group	Electricity	Kerosene	LPG	Firewood	Charcoal	Cowdung	Agrl.Waste
Less than 500	65010.59	194532.81	-	64216.19	63182.27	12706.31	3909.57
Rs.500 - 1000	149021.88	223119.60	111627.01	45021.21	69560.15	4320.08	395.60
Rs.1000 - 1500	68833.01	74083.53	63475.08	1870.43	4352.06	156.32	-
Rs.1500 - 2000	61943.51	32086.98	46051.50	1327.99	1103.52	-	-
Rs.2000 - 3000	85579.12	49352.54	78303.54	1095.68	2294.39	-	-
Rs.3000 and above	46965.27	42951.09	68563.33	787.67	5033.36	-	-
Total:::	459738.64	554728.63	371568.10	115440.63	146923.18	17347.68	4346.50

Total energy demand under this scenario is 1670093.36 MTCR.

5. There will be a shift in the income of the people. Income of poor people is likely to rise with better emoluments from industries.

6. The present shortage in supply of LPG coupled with increase in demand would result in households going for substitute sources of energy for cooking. From the survey it is found that LPG users, when faced with shortage, go for kerosene and firewood as substitute sources. Hence the demand for kerosene and firewood as likely to increase.

With these assumptions, one can visualise the situation in 2001 based on this scenario. If the population growth rate decreased from 2.96% to 2.5% annually within the next two decades the city will have a population of 3480144. Assuming an average household size of 5.4 persons the city will have 644471 households. With the increase in density and lack of space the construction activity will not increase much, which indirectly can affect the growth of lower income people. Developmental activities in the metro area outside its limits would attract these low income people and hence the proportion of them will decrease in total population. However, there is no method available to estimate the decrease with the available data. Hence, this proportion can only be estimated approximately. Between 1961-71, the proportion of one roomed houses in Ahmedabad has decreased from 65.3 to 57.5. The proportion of members staying in these houses also decreased from 57.2 to 53.7 within 1961-1971. This again strengthens the above assumption as the probability of people with an income below Rs.500 staying more in one roomed houses falling (AMC, 1981). At present, 38.13% of households are having an income less than Rs.500 per month. This is assumed to decrease to 30% by 2001. With these proportion of households in 2001 in different income groups are estimated.

Table - 15

Incomewise Distribution of Households

Income Groups	Number of Households
Less than Rs.500	193341
Rs.500 - 1000	238453
Rs.1000- 1500	77335
Rs.1500 - 2000	45111
Rs.2000 - 3000	52201
Rs.3000 and above	38024

Table - 16

Demand for Household Energy for 2001 based on Scenario-2

Income Group	Electricity	Kerosene	L P G	Firewood	Charcoal	Cowdung	Agricultural Waste
Below Rs.500	41373	156809	-	60004	65219	10751	3005
Rs.500 - 1000	130728	143033	112146	33456	57102	2907	242
Rs.1000 - 1500	67666	53219	71453	1557	4004	118	
Rs.1500 - 2000	66705	25418	56789	1121	1112		
Rs.2000 - 3000	69242	29180	72551	750	1736		
Rs.3000 and above	90502	25694	64275	562	3856		
Total	533884	43356	377216	97542	129027	13776	3246

Total Demand for Scenario 2 is 1665535.4 MTCR

This demand estimated is applicable when there is no disruption in supply. Out of the total electricity demand 50 per cent goes for lighting. Due to increase in use of electrical gagets the demand for electricity is going to increase. This will be more in the middle income groups. Hence the demand for electricity in households with an income between 1000-3000 per month will be higher than our estimated figure. Taking into consideration the present supply shortage of LPG, the possibilities of substitution of this source can be anticipated. From the survey it was found that people prefer using kerosene or firewood in times f shortage of LPG. Hence the demand of these two sources is likely to go up. Thus this scenario constructed with given assumptions would lead to a serious energy crisis in household sector.

Scenario - 3:

This scenario is more optimistic. Here the assumptions made are not likely to happen under normal circumstances but the intervention of government can help in achieving a situation which is more desirable.

Assumptions for Scenario -3

1) Population growth of the city for the next two decades will decrease as the developmental activities in the fringes are very rapid due to the rising labour costs and land value within the city. With the metro development plans proposal to develop growth centres around the city. developmental activities will be more active there. People who seek employment in these areas would prefer staying close to these centres.

2) Keeping in view the energy crisis, technological innovations for more efficient usage of energy will be introduced. Use of solar energy for heating water and for cooking will be more extensive. Within the next 20 years the use of charcoal and firewood for heating water in the higher income groups will stop due to solar cookers. Technological innovations in kerosene stoves and firewood chulahs would help in reducing the consumption of kerosene for cooking in higher income households by 30%, the consumption of firewood in lower income groups by 25 to 50%.

3) There will be a change in lifestyle where the use of electrical gadgets like TV, Radio, Refrigerators, food blenders etc. will be more extensive and will increase electricity consumption in middle income groups. Electricity will replace kerosene in low income households for lighting. Overall consumption of electricity will increase by 5% among low income households.

4) The use of LPG will be more due to the easy availability and its efficiency.

5) The wages of the workers will increase and hence there will be an overall increase in the income of all groups. The proportion of lower income people will decrease.

6) Fuel substitution will take place in case of certain sources like kerosene, firewood and charcoal.

7) Energy utilisation will be more efficient. Loss of energy in the process of conversion will be minimised.

These assumptions are optimistic and can be achieved only through significant intervention of the government and other organizations. In the former two scenarios we are not assuming any change in the use of technology affecting the consumption of energy. This scenario assumes

the changes in the population growth, economy etc. to be the same as in Scenario-2, but takes into account the changes that are desirable in the energy sector. The efficiency of firewood will be increased to double the present level. Use of solar cookers would reduce the consumption of cooking energy by 30%. Efficient kerosene stoves can save 30% of kerosene. Considering these two factors kerosene use for cooking will be minimised by 30%. Due to inefficient use of energy, the consumption in Scenario-2, kcal/person/day is 2216.59 which is more than three times the norms given by the NCAER fuel survey conducted in 78-79.

By taking into consideration the above assumptions demand for 2001 based on Scenario-3 is estimated. For this, demand by Scenario-2 is taken as a base and from that demand changes are made in each income group's demand for each source of energy. Electricity demand in households below Rs.2000 as monthly income will increase by 5%. Kerosene consumption in these households will decrease by 50% due to the replacement of kerosene by electricity for lighting and due to efficient stoves. In the case of firewood, charcoal, cowdung and agricultural wastes also, the demand will decrease by 50% due to efficient chulahs. LPG consumption in households with a monthly income less than Rs.1500 will increase by 5% due to increased supply. In higher income groups kerosene consumption will be reduced by 30% as use of solar cooker will reduce the cooking energy consumption by 30%. Based on these, the demand is projected for 2001.

Table - 17

Energy Demand for 2001 Based on Scenario-3

Income Groups	Electri-city	Kero-sene	L P G	Fire-wood	Char-coal	Cow-dung	Agrl. Wastes	Solar Energy
Below Rs.500	43441	59643	28036	30002	32609	5375.5	1502.5	
Rs.500-1000	137264	98094	5607	16728	28551	1450	141	
Rs.1000-1500	67666	37253	75025	1557	2002	90		
Rs.1500-2000	70040	17792	56789	510	560			
Rs.2000-3000	69242	14590	68923	320	816			
Rs.3000& above	90502	12847	44925	280	1923			
Total	478155	240219	279305	49397	66461	6915	1643	22000

Total Demand : 1164095 MTCR

It is assumed that by 2001, due to the subsidized price of solar cookers, some of the households will use them for heating water and for cooking. Here the consumption of solar energy is assumed to be 22000 MTCR. It is only an arbitrary figure and the extent of use by each income group is not calculated, as at present the use of solar energy is very small. Total demand for 2001 under the Third Scenario is 1.32 times of present consumption and the per/person/day K.cal of consumption is 1125.6 which is 1.6 times of the NCAER norm whereas in the second scenario it is 3.2 times of the norm. At present, the per person K.cal/day is 3 times higher than the norm, proposed by NCAER from its 78-79 study. Table 18 compares the three scenarios for Ahmedabad.

Table - 18

Energy Demand for 2001 - Scenario Comparison in MTCR

	Scenario - 1	Scenario - 2	Scenario - 3
Electricity	459738.6	533884	478155
Kerosene	554728.03	433356	240219
LPG	371568.10	377216	279305
Firewood	115440.63	97542	49397
Charcoal	146923.18	129027	66461
Cowdung	17347.68	13776	6915
Agricultural Waste	4346.50	3246	1643
Total	1670093.36	1665535.4	1164095

6. PLANNING FOR HOUSEHOLD ENERGY SECTOR FOR 2001:

This approach of planning through the scenarios requires some ethical value judgements. Energy future is to be planned by defining a feasible set of alternatives and then chosing from them the most desirable. Again the 'desirable' is subjective but maximum emphasis should be given to the most efficient usage with minimum use of non-renewable resources and maximum utilisation of renewable resources. Once the desirable scenarios is identified, then the means of achieving it become important. The micro decisions of households to plan rationally the energy mix should be encouraged by the local government. Here the third Scenario is selected as the most desirable one. It is postulated that the policy measures suggested here can result in achieving this scenario.

Required Policy Decisions:

Electricity supply to the households should be increased. For this the generation capacity has to be raised either by setting up new plants or increasing the existing capacity. This is essential to decrease the consumption of kerosene for lighting in lower income households and also to meet the increase in demand. The use of electrical gadgets is going to increase and it is not possible to curb this by increasing the price of electricity as it is a part of the change in lifestyle. With the central government's decision of reducing the price of TV, the use of electricity for recreational purpose will increase.

Among other fuels used for cooking LPG is considered to be the most efficient but the lower income households are not in a position to afford this due to high initial investments. If the supply is increased by 1.7 times then 25 per cent of the households with an income less than Rs.500 also can be provided with LPG connections. For this the government should give some subsidies thereby helping the poor people to purchase the stoves etc.

Solar cookers are available now for Rs.550. The use of this can reduce cooking energy consumption by 30 per cent. If arrangements to pay the cost in instalments are made or the present subsidy increased, then the use of this can be promoted to a great extent. Likewise there are efficient kerosene stoves fabricated by Indian Oil Corporation which has got 70 per cent efficiency. Subsidies can also promote the sales of these which would help in reducing kerosene consumption by 30 per cent.

Firewood chulahs in use at present are very inefficient (below 10 per cent). Some of the new chulahs developed have an efficiency upto 30 per cent. These cost Rs.100 each, which is also beyond reach for many families. Large scale production of these can bring down the cost andthe government can give incentives to the people to make these chulahs in slums by slum dwellers themselves. Even if the efficiency increases by 10 per cent, the demand of firewood after two decades can be met with the present supply.

Programmes:

For conventional fuels the initial investment is made by the suppliers (in India largely public sector) and the user has to pay only the service charges, whereas in the case of renewable energy sources like bio-gas and solar energy the user has to incur the initial investment. But once this is made then there is no more expenditure. It is essential that a general awareness must be created among the people regarding the newer techniques which offer more efficient ways of utilising the renewable sources. Only an organised programme or publicity and promotion can make it popular among the people. This can help in removing certain superstitions and beliefs attached to the reluctance in using certain renewable ources. Mass media can be used as a major means to create an awareness mong people.

A new organization which can look into the various factors that ffect energy consumption, develop new technology for efficient cooking ppliances, conduct seminars and workshops in collaboration with other nstitutions and organisations will be helpful for developing energy

conservation measures and for efficient utilisation of energy. The newly created Department of Nonconventional Sources of Energy in the Central Government and the Gujarat Energy Department Agency in the Gujarat State can play these roles. However, at the Ahmedabad Municipal Corporation level there is no organization or budget for energy. A Municipal Department of Energy Planning and conservation complemented by a voluntary citizen groups are vitally needed to achieve the Third Scenario.

Generation of bio-gas from sewage disposal is another renewable energy which can be developed in an urban setting. In Ahmedabad already there is a large scale plant set up in sewage farm to generate bio-gas but this is not functioning effectively. Studies conducted to supply bio-gas through pipes reveal that the cost involved will be too high. Hence feasibility of bottling this gas have to be studied. Experience in villages show that most of the community bio-gas plants set up are not working properly. This is mainly because of the lifestyles and cultural superstitions prevailing among the people. Awareness among people to remove these superstitions is essential to promote the use of bio-gas. A recently prepared plan for 1985-90 includes projects to utilise urban wastes to recover energy, fertiliser and material. Hopefully, a plant of this nature in Ahmedabad can be useful for households. In this analysis, however, we have not included this as a source for households.

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7. SUMMARY AND CONCLUSIONS:

Among the urban sectors, indistrial sector consumes 54 per cent of the energy supplied in the city followed by household sector 21 per cent, transport sector 21 per cent and commercial sector 4 per cent. 25 per cent of the energy sold in the city is in the form of electricity, 16 per cent of coal, 15 per cent kerosene, 10 per cent diesel, 7 per cent petrol, 3 per cent LPG and 4.5 per cent firewood and charcoal. Household sector energy consumption is met by electricity, kerosene, LPG, charcoal, firewood, dried cowdung and agricultural waste.

As the income increases, there is a shift from noncommercial to commercial sources of energy. Commercial sources contribute to 84 per cent of energy consumption by households. Low income households use kerosene for lighting. As the income increases there is a large-scale reliance on electricity for lighting. LPG consumption for cooking also increases with the rise in income.

As the income of the families increases, they tend to depend more on fuels which are less smoke omitting for cooking. Firewood and charcoal consumption in higher income group is limited to water heating. It was found from the survey that middle income groups depend more on electricity for water heating. This is mainly due to the fact that many of the middle income groups stay in flats where the use of firewood and charcoal become inconvenient. At the same time, higher income groups residing in independent bunglaws use firewood, twigs and leaves for heating water.

Higher income group households continue to use the same amount of energy even if there is a price increase. In this group shortage of LPG results in substitution with kerosene or firewood. Shortage of kerosene results in substitution by firewood and charcoal. Expenditure on cooking energy increases with increase in income.

From the Scenarios constructed we find that in the first two Scenarios, the demand for energy sources by household sector is going to increase 1.7 times. With the present supply deficiency, this will only result in further worsening the problems. The Third Scenario suggests that the intervention of government can result in meeting the demand for 2001 with the efficient energy supply.

Suggestions made in the Third Scenario if implemented, can save a good amount of energy which is at present wasted. If the excess gas burnt in refineries are bottled, the LPG supply can be increased without any effort. To provide access to the poor it is essential to provide efficient cooking stoves with subsidy. Large scale production of those can be encouraged to bring down the cost of production. To promote the use of renewable sources of energy like solar energy, it is essential to have large scale extension, provision of subsidies and production.

Further work in this direction to understand urban household energy behaviour can be done through a more detailed study. In this paper we have not estimated the investment and efforts needed for implementing various programmes. In the Scenarios price change effects are also not included as the extent of decrease in fuel consumption and/or substitution due to the change in price was not captured from the survey. Similarly, decrease in cooking energy due to the use of solar cookers are only assumed, whereas further studies are needed on the heat generated by solar cookers and the corresponding decrease in the cooking energy consumption.

It is possible, as we have shown to achieve a more efficient (in energy terms), equitable and environmentally sustainable energy in future for the households of Ahmedabad. What is needed is clear government policy, financial allocation, programme design and management and active citizens participation.

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