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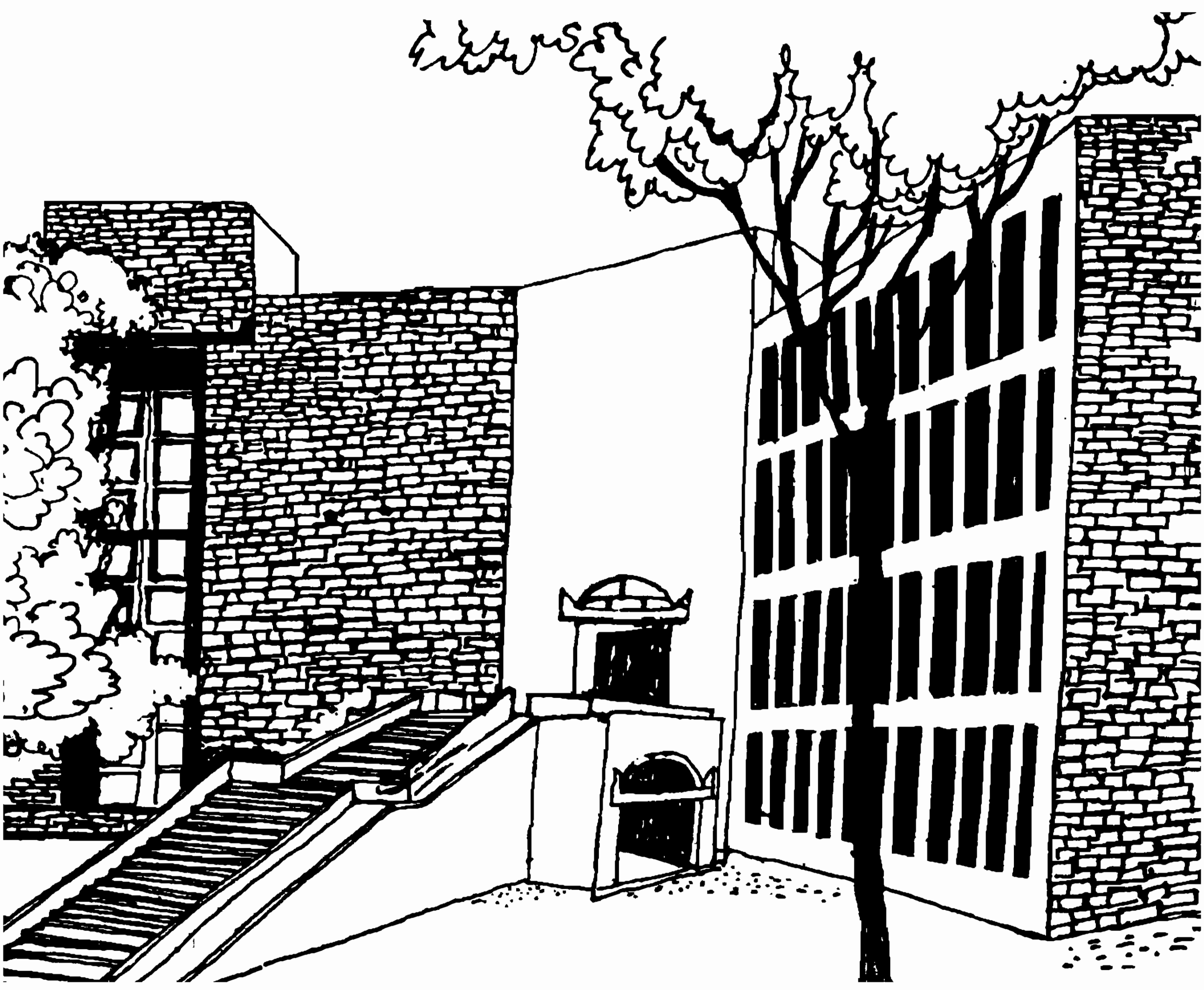

MANAGEMENT OF URBAN ENERGY AND AIR QUALITY: CASE OF AHMEDABAD CITY

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MANAGEMENT OF URBAN ENERGY AND AIR QUALITY :

Case of Ahmedabad City

by

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Abstract

This paper explores the synergistic relationship between energy and environment in an urban system through a case study of the city of Ahmedabad, India. The analytical framework is based on estimation of sectoral fuel consumption patterns, emissions inventory of major pollutants, and projections of future patterns of fuel consumption and emissions. The current and future patterns are then reassessed with the introduction of certain technical and policy interventions, which are both feasible and probable in the time horizon of five to ten years. These options are evaluated in terms of potential energy savings, reduction of fuel costs and potential emission reductions.

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1 Introduction

Conservation of energy and protection of the environment are two of the biggest challenges in managing the quality of life in cities throughout the world. Due to high population densities and intensive manufacturing activities urban settlements are constantly under the threat of environmental degradation, often caused by unsustainable patterns of resource consumption. When these problems are neglected for a period of time, the environmental changes and resource constraints tend to become irreversible or extremely costly to restore.

Cities in the developed countries have faced these problems of industrial development and urbanisation quite successfully by devising appropriate technological solutions, strict environmental laws, and effective policies for pollution control and management. Cities in the developing countries, on the other hand, lack the resources and political will to manage the quality of urban environment which is rapidly deteriorating due to the combined pressures of population and economic growth.

Along with water and land pollution, air pollution is one of the major contributors to declining quality of urban environment. Interestingly, the major sources of air pollution in an urban area are easily identifiable as these are closely related to patterns of energy consumption, particularly the specific fuel-mix and technologies in use. Thus, in the industrial sector of the urban economy the major causes of air pollution are usually power generation plants and industries using large amounts of fossil fuels. Motor vehicles and traditional cooking fuels are the other major contributors of air pollution in an urban area.

The fuels used in different sectors of the urban system emit various air pollutants, such as sulphur dioxide (SO_2), oxides of nitrogen (NO_x), suspended particulate matter (SPM), corbon monoxide (CO), hydro carbons (HC), lead (Pb) and ozone (O_3) which then disperse in the atmosphere. These are the major determinants of local air quality in conjunction with meteorological conditions prevailing in the area. Since population density of an urban area is generally high, the residents get exposed to significant doses of air pollutants before adequate dispersal can take place. Consequently, urban population may face serious health risks due to long term exposure to polluted air. It is unfortunate that policy makers in the developing countries have ignored the significant economic and health costs of polluted urban environment.

While energy is a crucial input for economic growth it is also a fact that our present patterns of energy consumption rely too heavily on non-renewable energy sources whose supply is limited. Energy conservation is increasingly becoming a dominant consideration in the energy policies of developing nations. That is certainly good news for urban environment since any strategy for energy conservation would necessarily lead to air quality improvement. It is logical to assume, therefore, that management strategies for energy conservation could also form the basis for management of air quality particularly in the urban context.

2. Status of Air Quality in Indian Cities

A number of indian metropolitan cities, such as Delhi, Bombay and Calcutta, are often singled out as having extremely high levels of air pollution. A subjective assessment of relative air quality situation in 20 megacities of the world, shows that in almost all of the megacities in developing countries SPM levels regularly exceed the WHO standard. Beijing, Mexico city and Seoul are the most polluted in terms of both SO_2 and SPM concentrations (Table 1). The report recommends that air quality "monitoring activities in India should be expanded to cover more pollutants and a wider geographical area" (UNEP - WHO, 1994).

Table 1. Air Quality in Mega Cities in Developing Countries

Cities	Pollutant				
	SO_2	SPM	Pb	CO	NO_x
Bangkok	o	xx	x	o	o
Beijing	xx	xx	o	-	o
Bombay	o	xx	o	o	o
Calcutta	o	xx	o	-	o
Delhi	o	xx	o	o	o
Jakarta	o	xx	x	x	o
Karanchi	o	xx	xx	-	-
Mexico City	xx	xx	x	xx	x
Seoul	xx	xx	o	o	o
Shanghai	x	xx	-	-	-

Note : xx Serious Problem
x Moderate to Heavy Pollution
o Low Pollution
\- Insufficient data
Source : UNEP & WHO, GEMS Air Report, 1992.

Since 1984, the Central Pollution Control Board (CPCB) has conducted a National Ambient Air Quality Management Program under which 175 monitoring stations have been establishedthroughout the country. Table 2, based on the CPCB reports, shows the ambient airquality for selected indian cities during 1991. Table 3 shows the National Air Quality standards of India and the corresponding World Health Organisation (WHO) standards for three major air pollutants SO_2, NO_x and SPM.

Table 2. Ambient Air Quality in Selected Indian Cities (1991)

City	Pollutant levels Annual Average (in microgram/cum)		
	SO_2	NO_x	SPM
DELHI	33	46	543
BOMBAY	27	26	226
CALCUTTA	62	39	394
MADRAS	8	13	101
KANPUR	7	13	380
AHMEDABAD	16	7	285

Source: Annual report, CPCB, 1992-93

Table 3. Ambient Air Quality Standards
(Annual average cocentrations in microgram/cum)

Pollutant	SO_2	NO_x	SPM
INDIA *	60-80	60-80	140-360
WHO**	40-60	150 *	60-90

Notes :
* The lower range values are for residential and rural area while the higher range values are for Industrial and mix use area.
** The NOx standard is 24 hourly average.

Source :
1. Central Pollution Control Board, New Delhi, India.
2. World Health Organization and United Nations Environment Programme, Urban Air Pollution in the Megacities of the World (Backwell Oxford, U.K., 1992).
3. World Resource Institute, 1994-95.

Comparison of the two tables shows that, based on the aggregate average of available monitoring stations, none of the listed cities experience ambient concentrations higher than the permissible levels for SO_2 and NO_x However, SPM concentrations in these cities greatly exceed the specified standard of 140-360 micrograms/cum for industrial and residential land uses with the exception of Madras. The WHO annual average standard of 60 to 90 micrograms/cum for SPM exceeded in all of the cities many times over.

3 Energy and Environment Status : Ahmedabad City

In 1993, a comprehensive research study was undertaken to estimate patterns of energy consumption and associated environmental impacts in the city of Ahmedabad, India. This study was confined to the area within the limits of Ahmedabad Municipal Corporation (AMC) limits (Goswamy P., 1994). The information obtained in that study forms the core of the analysis carried out in this paper.

With a population of over 28.8 million in 1991, and total area of 191 sq.km, the city of Ahmedabad (AMC limits) is the largest city of Gujarat state and also its major energy consumer. Founded in the year 1411 AD, as a settlement of merchants, weavers and craftsmen, Ahmedabad grew into a major centre of textile industries. Even after the decline of the textile sector, the city continues to have a strong base of other industries dealing in chemicals, metals and manufacturing of engineering goods, with textiles still retaining the top spot.

The river Sabarmati flows through the middle of the city. The areas to the West of the river are predominantly residential, mixed with commercial establishments. The old city, on the eastern bank of the river, comprises high density residential and commercial land uses enclosed within the fort wall built more than a century ago. East Ahmedabad, which now includes three major industrial estates of the Gujarat Industrial Development Corporation (GIDC), is predominantly industrial with supporting residential and commercial landuses.

The public transportation is provided by Ahmedabad Municipal Transport Service (AMTS), which has a fleet of about 750 buses plying on 250 routes. The service capacity is clearly inadequate and personal motor vehicles are increasing at a tremendous rate causing congestion and air pollution. The other important component of the city's transport system is the large number of three-wheeler autorickshaws. What is most worrisome about them is that most of these vehicles illegally use a 70:30 mixture of kerosene and petrol which emits about four times the pollutants emitted when only petrol is used. Kerosene is a subsidised fuel targeted for low income households and officially channelised through the public distribution system. This subsidy, instead of benefitting the target group, now poses a serious health risk for the entire population.

Electricity supply in the city is managed by the Ahmedabad Electricity Company (AEC) which has an installed capacity of 550

MW. The plant is located on the bank of the Sabarmati river and adjoins a fairly dense residential zone. Coal India Ltd. and various major oil companies supply the city with coal and petro-fuels, such as petrol, diesel, and fuel oils. Traditional fuels, namely firewood, charcoal and dried cow dung, also play an important role for meeting energy needs of residential and commercial sectors.

Pattern of Energy Consumption (1992):

The final estimates of energy consumption for Ahmedabad city are summarised in Table 4. Thus, in 1992, total energy consumption in the study area was 18686 Billion Kilo Calories (BKCal). Nearly 40 percent of this was consumed by the industrial sectors. That does not including the AEC's power plant whose consumption nearly equalled the energy consumed in all the industries put together.

Table 4. Estimated Energy Consumption: Ahmedabad (1992)

Sector	RESID	COMM	INDUST	TRANSP	POWER	TOTAL
Fuel	Billion KCal					(%)
Electricity	290	277	1196	0	0	1763 **(9.4)**
Coal & Lig.	0	0	4284	0	5916	10200 **(54.6)**
Natural Gas	0	0	471	0	1214	1685 **(9.0)**
Petro-Fuels	1325	359	1116	1301	0	4101 **(22.0)**
Bio-Fuels	385	177	375	0	0	937 **(5.0)**
All Fuels (%)	2000 (10.7)	813 (4.3)	7442 (39.8)	1301 (7.0)	7130 (38.1)	18686 (100.0)

Note : RESID = Residential INDUST = Industry
TRANSP = Transport POWER = Power Generation
COMM = Commercial establishments and Public amenities.
Lig. = Lignite,
Petro-Fuels = Petrol, Diesel, Kerosene, Furnace oil and others.
Bio-Fuels = Firewood, Dry cowdung, Charcoal.

Domestic energy consumption accounted for 10.7 percent of the total consumption. Maximum energy, nearly 55 percent of the total, was derived from coal and lignite. Petro-fuels provided about 22 percent of the city's energy requirements, while share of electricity was only about nine percent (Table 4).

Table 5 shows the relative shares of different fuels in each of the major consuming sectors. The residential and commercial sectors depend primarily on petro-fuels, electricity and bio-fuels. The industries use all types of fuels with maximum use of coal and lignite, which are also the main fuels for power generation.

Table 5. Pattern of Energy Use: Ahmedabad (1992)					
Sectorwise where the energy came from ... Column %					
	RESID	COMM	INDUST	TRANSP	POWER
Electricity	14.5	34.1	16.1	0	0
Coal & Lignite	0	0	57.6	0	83.0
Natural Gas	0	0	6.3	0	17.0
Petro Fuels	66.3	44.1	15.0	100.0	0
Bio Fuels	19.2	21.8	5.0	0	0

The conversion factors to convert quantities of fuels to energy values are listed in Appendix-D.

Emission Inventory (1992)

Under the national network of the CPCB, there are five air quality monitoring stations in the study area which provides only available information on the overall ambient air quality in the city. An analysis of the data for the year 1992-93 indicates that while the concentration of SO_2 and NO_x in Ahmedabad's air are far below the National Ambient Air Quality Standards (NAAQS), those of SPM exceed these standards at almost all places.

The sector-wise fuel-wise pattern of energy consumption was transposed into estimates of total annual emissions of three major pollutants (SO_2, NO_x, SPM). The fuel emission factors of different fuels are listed in Appendix E. The resulting pattern of emissions inventory for the city of Ahmedabad is shown in Table 6.

Table 6. Emissions Inventory: Ahmedabad (1992)							
Sector / Pollutant		RESID	COMM	INDUST	TRANSP	POWER	TOTAL
SO2	t/yr.	926	420	14552	1450	13921	31269
	%	3.0	1.4	46.5	4.6	44.5	100.0
NOX	t/yr.	1566	431	8773	9754	11030	31554
	%	4.9	1.4	27.8	30.9	35.0	100.0
SPM	t/yr.	1496	609	61822	1031	11895	76853
	%	2.0	0.8	80.4	1.3	15.5	100.0

The major finding is that the industrial sector and power plant together contributed 96 percent of total SPM emissions in the city, indicating that any solution to the city's pollution problem must be found in these two sectors. The industries and the power plant also account for more than 90 percent of SO_2 emissions. The NO_x emissions are attributed roughly equally to three sectors, namely power, transport, and industries.

4 Future Projections: Ahmedabad (2002)

This research was probably the first attempt to study the pattern of energy consumption in the city of Ahmedabad. As no other local data were available, future projections of energy use could not be based on past trends. Consequently, indirect estimates have been made here on the basis of population projections for the study area and certain assumptions regarding growth rates of energy consumption in different sectors of the urban system.

During the period 1981-1991, the urban population of Gujarat grew at an annual compound growth rate of 2.9 percent. The corresponding growth rate for the period 1971-1991 was 3.2 percent per annum (NIUA, 1993). The city of Ahmedabad has also experienced high population growth. However, the growth in the Western periphery outside the AMC limits, is faster compared to growth within the city limits. The current trends suggest that the city's population within the study area of AMC may reasonably be projected to grow by 15 percent during the 10 year period from 1992-2002.

A detailed study of pattern of development in East Ahmedabad, which includes the 3 large industrial estates set up by the GIDC, projects growth of industries in the area by 10 percent in the same decade (Mehta T., 1995). Thus, it is reasonable to assume that total industrial activity in the city of Ahmedabad would grow by 10 percent from 1992 to 2002.

To relate the projected population growth to future energy consumption, additional assumptions must be made regarding expected increases in per capita energy consumption due to changes in availability of consumer products, affordability and lifestyles. Generally it would be expected that per capita energy consumption in cities would continue to rise over time due to the above factors. This is specially likely in the case of developing countries where the current consumption levels are rather low.

Thus the benchmark projections of energy consumption for Ahmedabad in the year 2002 are based on the forecast that the study area would experience population growth of 15 percent from 1992 to 2002. Correspondingly, it is assumed that energy consumption would increase by 20 percent in the residential and commercial sectors and, with industrial growth expected to be around 10 percent, energy consumption in the industrial sector would also grew by 10 percent during the same period.

This may be characterised as **`business as usual'** scenario, as all other factors related to fuel-mix, energy conversion efficiencies, and end-use systems are assumed to remain constant. Table 7 depicts the projected pattern of energy consumption. Total energy consumption in the year 2002 is estimated to be 21525 BKCal, which represents an increase of about 15 percent over the 1992 consumption. Among various fuels, the maximum increase is expected in the consumption of petro-fuels which could increase by more than 40 percent during the ten year period.

Table 7. Energy Consumption: Ahmedabad - 2002

	RESID	COMM	INDUST	TRANSP	POWER	TOTAL
	Billion KCal					(%)
Electricity	347	333	1316	0	0	1996 (9.3)
Coal & Lignite	0	0	4713	0	6109	10822 (50.3)
Natural Gas	0	0	518	0	1253	1771 (8.2)
Petro Fuels	1590	430	1228	2602	0	5850 (27.2)
Bio Fuels	461	213	412	0	0	1086 (5.0)
All Fuels	2398 (11.1)	976 (4.5)	8187 (38.0)	2602 (12.1)	7362 (34.2)	21525 (100.0)

An emissions inventory for the city in the year 2002, based on emission loads of the three major pollutants are shown in Table 8. These are derived from projections of energy consumption with appropriate fuel emission factors. Projected changes in the consumption of fuels would result in 36 percent increase in NO_x emissions during the 10 year period. The SO_2 and SPM emissions, on the other hand, would be expected to increase by 10 to 11 percent.

Table 8. Emissions Inventory: Ahmedabad (2002)

Sector / Pollutant		RESID	COMM	INDUST	TRANSP	POWER	TOTAL
SO2	t/yr.	1111	504	16007	2900	14375	34897
	%	3.2	1.4	45.9	8.3	41.2	100.0
NOX	t/yr.	1879	517	9650	19508	11388	42942
	%	4.4	1.2	22.5	45.4	26.5	100.0
SPM	t/yr.	1795	731	68004	2062	12275	84867
	%	2.1	0.9	80.1	2.5	14.4	100.0

5 Possible Energy Solutions

The ten year projection period used in this study represents a medium-term horizon for energy planning and policies. Obviously, the micro changes in energy supplies and demand as well as national policies for the energy sector would determine the types of interventions that might be appropriate for energy management at the local level. However, it is difficult to predict these changes. On the other hand, it is not difficult to identify feasible and viable options which improve the air quality at the city level. After examining the potential of improved energy technologies, energy management techniques, fuel substitution and availability of efficient enduse devices, certain interventions in the urban energy sector are considered to be quite attainable by the year 2002.

Table 9. ALTERNATIVE SCENARIOS: Option Considered

S.No.	**Indutrial Sector**
1.	Energy Audits and Housekeeping
2.	Technology Upgradation
3.	Natural Gas replaces Coal and Lignite
	Residential & Commercial Sectors
4.	Flourescent Tubelights replaces Bulbs
5.	Efficiency improvements in Cooling Devices
6.	LPG & Kerosene replaces Bio-fuels
	Transport Sector
7.	No Kerosene use allowed in Autorickshaws
8.	Vehicle fuel consumption improvements

Accordingly, eight alternative scenarios have been constructed (Table 9). In the city's industrial sector, energy audits and house-keeping measures have enormous scope for energy savings. **Scenario 1** assumes that atleast 10 percent reduction in fuel consumption can be achieved by implementing these measures. **Scenario 2** assumes that 10 percent reduction in the consumption of diesel, coal and lignite can be attained through technology upgradation of solid fuel boilers and prime movers using diesel fuel.

Scenario 3 is based on the expectations that 50 percent of coal and lignite used in industries would be replaced by natural gas by the year 2002. Although there have been some bottlenecks in the availability of natural gas recently, yet this region is strategically located to have easier access to this fuel in the future. Scenarios 1,2, and 3 reflect the energy conservation possibilities in the industrial sector.

In the residential and commercial sectors also there are promising possibilities for energy conservation. Significant savings of electricity can be obtained by replacing ordinary bulbs with flourescent tubes which are nearly 40 percent more energy efficient. It is estimatedthat in 1992 nearly 33 percent of the households and 20 percent of commercial establishments in the city were using bulbs for lighting. **Scenario 4** assumes that by the year 2002, all commercial establishments would be using fluorescent tubes and only the poorest 20 percent of households would continue to use electric bulbs.

Cooling devices such as refrigerators, coolers and air conditioners offer significant opportunities for energy efficiency improvements. **Scenario 5** assumes that efficiency of all such devices would increase by 3 percent by the year 2002.

In urban areas it is a common phenomenon that as household income increases there is a shift from traditional bio-fuels to kerosene and LPG. This shift was also observed in the household survey conducted in 1992 in Ahmedabad (Goswamy, P., 1994). **Scenario 6** assumes that 50 percent of households using fuelwood and charcoal in 1992, would switch to kerosene in the year 2002. Similarly, 50 percent of those using kerosene in 1992 would switch to LPG.

As indicated earlier, illegal kerosene used in autorickshaws poses a serious health risk to citizens of Ahmedabad. **Scenario 7**, assumes that using suitable `carrot and stick' approach, this practice would be totally eliminated by the year 2002.

The **Scenario 8** envisages continuing improvements of fuel consumption in all motor vehicles, which would be sold in the city of Ahmedabad. The specific fuel consumption of new vehicles is expected to be 50 percent lower than the older vehicles. Assuming a 50:50 mix of old and new vehicles, this would amount to a net reduction of 25 percent in total fuel consumption in the transport sector in the year 2002.

6 Impact Assessment

Each of the scenario developed in the previous section could possibly generate two types of important benefits for the city of Ahmedabad. the first is the direct benefit of energy conservation. That 'energy saved' is same as more 'energy produced' is a well understood fact. Given that most of our current energy sources are nonrenewable in nature it is imperative that all possibilities for energy conservation should be explored. the indirect benefit of conserving energy result from the reduction in emission of pollutants automatically result from reduced burning of fuels from the perspective of an urban community this indirect benefit is just as important as direct benefit of energy savings.

The impact of energy conservation options described in the eight scenarios were simulated to estimate the potential energy savings which may be expected when the indicated interventions have been implemented. The results are shown in Table 10.

Table 10. Potential Energy Conservation Impacts

S. No.	Type of Interventions	Energy Reduction (BKcal)	Fuel Cost Savings (million Rs @ 1992 price)
	Industrial Sector		
1.	Energy Audits and Housekeeping	132	340
2.	Technology Upgradation	556	200
3.	Natural Gas replaces Coal and Lignite	636	520
	Residential & Commercial Sectors		
4.	Flourescent Tubelights replaces Bulbs	5	10
5.	Efficiency improvements in Cooling Devices	8	20
6.	LPG & Kerosene replaces Bio fuels	76	-30 *
	Transport Sector		
7.	No Kerosene use allowed in Autorickshaws	24	-700 *
8.	Vehicle fuel consumption improvements	651	1120
	Total (All Options Combined)	2088	1480

Note : * Additional Fuel cost

Fuel Costs : Appendix C

The three most promising options for the city Ahmedabad are: Vehicle fuel consumption improvements (Scenario 8); Replacement of coal and lignite by natural gas in industries (Scenario 3) and upgradation of technologies of solid fuel boilers and diesel engines in industrial units (Scenario 2). If these three options were implemented simultaneously the total energy consumption of Ahmedabad city in the year 2002 can be reduce by 1843 BKCal compare to the benchmark - 'business as usual'- scenario.

Energy audit and housekeeping measures in the industrial sector have potential of further reducing energy consumption be 132 BKCal. Replacement of bio-fuels by LPG and Kerosene in residential and commercial sectors would result in significant energy savings.

In this study it was not possible to conduct a thorough of each of the suggested interventions. Instead a rough estimate of fuel cost savings were made (Table 10). It was found that scenario 6 and 7 involving replacement of fuel of bio-fuel and a ban on Kerosene use in Autorickshaws would impose additional fuel costs on the affected users. All other scenarios produce significant monetary benefits in the terms of reduced fuel costs.

The impacts of different scenario options on the city's pollutant emission load are shown in Table 11.

Table 11. Simulated Impacts on Pollution Emission

S. No.	Type of Intervention	Change in Total Emission		
		SO_2 (t/a)	NO_x (t/a)	SPM (t/a)
	Industrial Sector			
1.	Energy Audits and Housekeeping	-309	-212	-264
2.	Technology Upgradation	-1843	-901	-4690
3.	Natural Gas replaces Coal and Lignite	-8400	-4582	-36126
	Residential & Commercial Sectors			
4.	Flourescent Tubelights replaces Bulbs	-11	-7	-9
5.	Efficiency improvements in Cooling Devices	-20	-14	-17
6.	LPG & Kerosene replaces Bio fuels	-350	+185	-631
	Transport Sector			
7.	No Kerosene use allowed in Autorickshaws	-275	-4430	-344
8.	Vehicle fuel consumption improvements	-977	-3320	-456
	Total (All Options Combined)	-12185	-13281	-42537

It was found that the maximum potential for reduction of emission would result from replacement of coal and lignite by natural gas in industries. The expected decrease would be of the order of 25 percent of total SO_2, 11 percent of total NO_x emissions and 43 percent of total SPM emissions in the city.

Infact, all of these scenarios for the industrial and transport sectors produce significant emission reduction and thereby improve the city;a air quality. If all eight scenarios could be successfully implemented by the year 2002, total emission reduction amounts to 35 percent of total SO_2, 31 percent of total NO_x and 50 percent of SPM emission.

7 Conclusions

The main conclusion of this study is that improvement of urban air quality depends crucially on state of the technology, fuel mix and operating practices in the industrial and transport sectors. The scope for energy conservation in the residential and commercial sectors of an urban system is smaller in comparison. However certain improvements of device efficiencies may produce significant energy savings and fuel costs savings for average consumers. Replacement of certain traditional fuels by cleaner fuels is also important because of the health hazards of indoor pollution to which large numbers of people are exposed. This study has also established usefulness of methodologies based on the concepts of Reference Energy System for simulating energy - environment dynamics of an Urban areas.

Various policy options may have to be evaluated to determine the types of actions needed for implementing those measures which have the maximum potential for energy savings and emissions reductions. Primafacie, it appears that the desired changes could be better induced by offering suitable incentives and disincentives through market mechanisms rather than through over restrictive regulations.

Appendix A : Energy Consumption: Ahmedabad (1992)							
Sectors / Fuels	Resi /Dom	Comm	Indust	Transp	Power	Total	
Electricity	289.80	277	1196.02			1762.82	9.4
Coal			3129.19		5915.75	9044.94	48.1
Kerosene	602.16	351.42	32.08	149.38		1135.04	6.0
LPG	722.90	7.30	1.74			731.94	3.9
Petrol				750.26		750.26	4.0
Disel				401.79		401.79	2.1
Lignite			1155.00			1155.00	6.1
FO+LSHS			311.04			311.04	1.7
Otherpetro			771.38			771.38	4.1
Firewood	250.88	118.06	236.50			605.44	3.2
Cowdung	83.14					83.14	0.4
Charcoal	50.64	59.45	138.32			248.40	1.3
Natural Gas			470.97		1213.74	1684.71	9.0
Animal				99.33		99.33	0.5
Total	1999.5	813.23	7442.23	1400.7	7129.49	18785.2	100

Appendix B : Pattern of Energy Use: Ahmedabad (1992)

Sectorwise wherre the energy came from ... Column %

	RESID	COMM	INDUST	TRANSP	POWER
Electricity	14.5	34.1	16.1	0	0
Coal & Lignite	0	0	57.6	0	83.0
Natural Gas	0	0	6.3	0	17.0
Petro Fuels	66.3	44.1	15.0	100.0	0
Bio Fuels	19.2	21.8	5.0	0	0

Fuelwise where the energy went ... Row %

	RESID	COMM	INDUST	TRANSP	POWER
Electricity	16.4	15.7	67.9	0.0	0.0
Coal & Lignite	0.0	0.0	42.0	0.0	58.0
Natural Gas	0.0	0.0	28.0	0.0	72.0
Petro Fuels	32.3	8.8	27.2	31.7	0.0
Bio Fuels	41.0	19.0	40.0	0.0	0.0

Appendix C : Costs of different Fuels under use in Ahmedabad (1992)

S. No.	Fuel	Rate in Rs	Units
1	Electricity	2.2	Unit or Kwh
2	Coal	1650	Tonnes
3	Kerosene	3.00	Litre
4	LPG	6.60	Kg.
5	Petrol	18.7	Litre
6	Diesel	7.50	Litre
7	Lignite	800	Tonnes
8	FO+LSHS	7.00	Litre
9	Diesel/ Petrol	9.00	Litre
10	Fire Wood Domestic	2.00	Kg
11	Fire Wood Indst.	1500	Tonnes
12	Cowdung	1500	Tonnes
13	Charcoal	1300	Tonnes
14	Ntural Gas	1700	MCum.
Source : Goswamy P., 1994			

Appendix D : Energy Conversion Factors and Efficiencies of Different Devices

Fuel	Enduse	Energy Conversion Factors	Unit of Conversion	Efficiency of Device
Elect.	All Applainces	860	KCal/Kwh	22 to 90
Coal	Power Gen.	5.1	MKCal/t	31
	Industrial	4.5	MKCal/t	47.5
	Cooking	6.9	MKCal/t	18
Charcoal	Cooking	6.9	MKCal/t	18
	Industrial	6.9	MKCal/t	47.5
Kerosene	Cooking	11	MKCal/t	50
	Lighting	11	MKCal/t	31.4
	Autorickshaws	11	MKCal/t	20
LPG	Cooking	11.95	MKCal/t	55
Petrol	Transport	10.5	MKCal/t	28
	Power Gen.	10.5	MKCal/t	68
Disel	Transport	10.8	MKCal/t	40
	Power Gen.	10.8	MKCal/t	68
Lignite	Industrial	2.3	MKCal/t	47.5
Firewood	Cooking	4.73	MKCal/t	14
	Industrial	4.73	MKCal/t	47.5
Cowdung	Cooking	2.13	MKCal/t	12
Natural Gas	Power Gen.	9000	KCal/Cum	70

Note : MKCal/t = Million Kcal per tonne of fuel
KCal/Kwh = KCal per Kilowatt hour
KCal/cum = KCal per cubic meter

Source : Goswami P., 1994.
NCAER, 1966
TEDDY, 1994-95

Appendix E : Pollution Emmisions Factors for different Fuels

S. No	Fuel	EndUse	Unit of factor	Emission Factors		
				SO_2	NO_x	SPM
1	Elect.	All Type		0	0	0
2	Coal	Power	Kg/t	12	8.2	10.25
		Industries	Kg/t	12	8.2	57.4
		Domestic	Kg/t	3.9	4.3	44.4
3	Charcoal	Domestic	Kg/t	3.9	4.3	44.4
		Industries	Kg/t	3.9	4.3	44.4
4	Kerosene	Domestic	Kg/t	12.93	10.77	0
		Transportation	g/km	0.112	4.48	0.462
5	LPG	Domestic	Kg/t	0	14.3	0.02
6	Petrol	Transportation	g/km	0.02 - 0.2	0.113 - 3.2	.033 - .33
7	Disel	Transportation	g/km	0.45-15	.99-21	0-.75
8	Lignite	Industries	Kg/t	11.3	3.87	40.6
9	Firewood	Domestic	Kg/t	0.79	0.48	9.06
		Industries	Kg/t	0.79	0.48	9.06
10	Cowdung	Domestic	Kg/t	6.63	0.13	20.7
11	Natural Gas	Power	Kg/th cum	0.01	11.26	0.04
		Industries	Kg/th cum	0.01	11.26	0.04

Note : Kg/t = Kilogram/Tonnes, g/km = Grams/Kilometer

Source : Goswami P, 1994

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