A road map towards Low Carbon Ahmedabad 2050

Preface

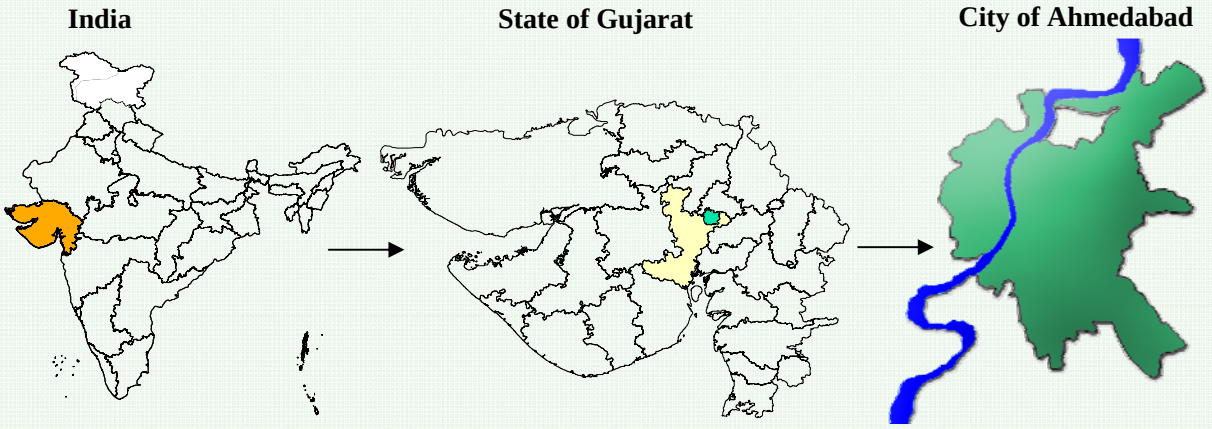
This roadmap is in continuation to our earlier study Ahmedabad LCS Vision 2035. This research has been supported by various government agencies (for discussions and data) and is a collaboration among various academic and research institutions, namely- Indian Institute of Management Ahmedabad, Kyoto University, National Institute for Environmental Studies Tsukuba and Mizuho Information and Research Institute Japan.

We felt the need for extending this study for a much longer period so as to coincide with the generally agreeable year of 2050 for implementing long-term measures. This timeline gives us an opportunity to rethink the development paradigm in the city considering the latest developments in the economy and other sectors.

This LCS roadmap document intends to communicate to city level policy makers - how to effectively integrate carbon mitigation actions in the development plans of the city. The actions outlined in the document, we believe, would guide effective transition towards a Low Carbon Ahmedabad. The proposed actions are in line with national position articulated in India's National Climate Change Action Plan and official Government position in various high level declarations such as the "Copenhagen Accord".

We sincerely hope that our research findings, we hope will contribute to towards a sustainable transition in Ahmedabad .

- P. R. Shukla



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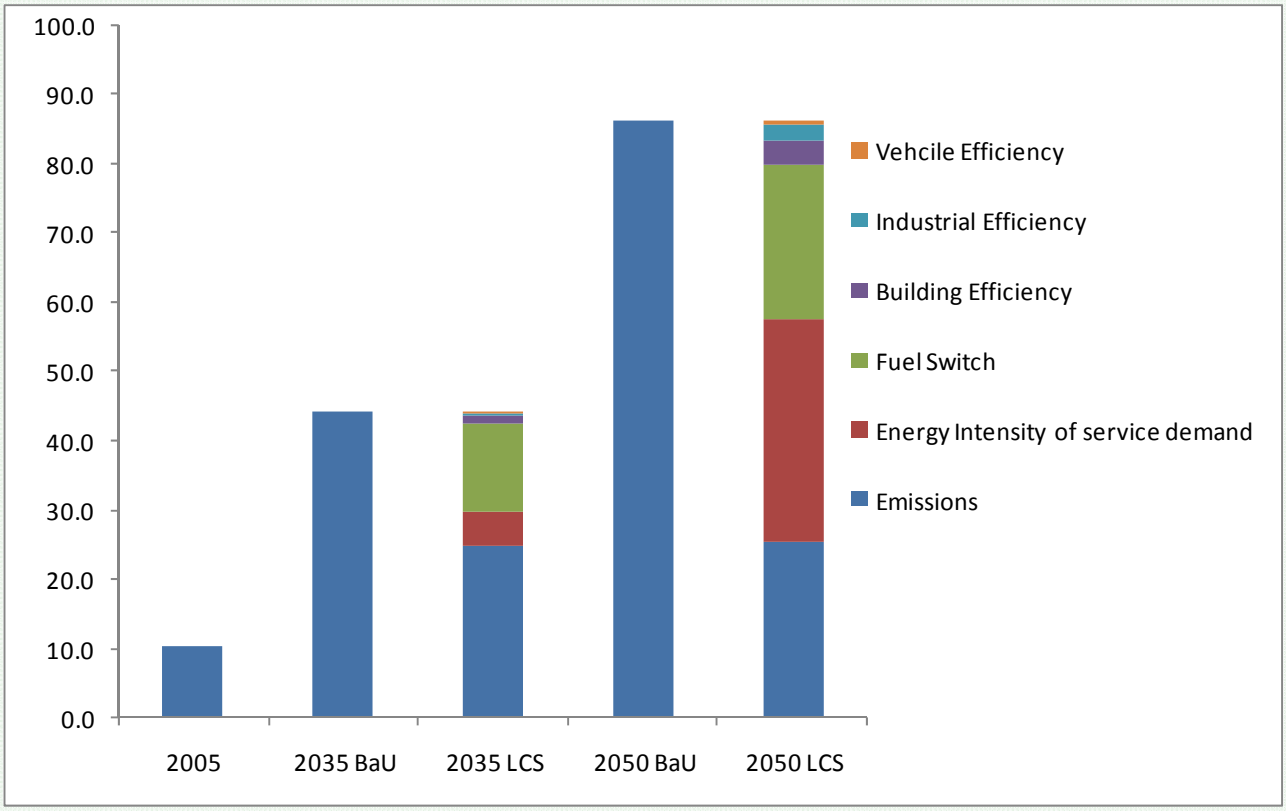
Executive summary

This report articulates a low carbon vision for the city of Ahmedabad. The methodology involves deducing current socio economic, energy and emission parameters for the city using the base year (2005) data. This data has been methodically prepared using various approaches as enunciated in literature for various sectors. These parameters are used in conjunction with the future energy service demands, energy technology assumptions, and socio economic assumptions for Ahmedabad (population, etc) from the City Development Plan (CDP) and expert opinion, to obtain the target years (2035, 2050) socio economic and other assumptions.

In order to transit to a low carbon society in Ahmedabad, several countermeasures are required. It is interestingly observed from the model output that for such a transition in Ahmedabad, decoupling of economic growth and energy use emerges as the highest mitigation potential as compared to decarbonisation of energy. Besides, there is a substantial mitigation potential from fuel switch and energy efficiency. Specifically, this would mean improvements in energy intensity of economic activities, like reduction in energy service demand for industrial, transport and commercial sector, cleaner and greener power (renewable like hydro, solar and biomass), and promoting end-use device efficiency in the transport sector, industrial and residential sector.

These countermeasures can be presented as a policy package for Ahmedabad, as described in the next page.

Figure 1: GHG emissions and mitigations by means (mt CO2)



Policy Package for Ahmedabad

For realizing the vision of a Low Carbon Society for Ahmedabad, a comprehensive list of policy options are required, focused at implementation of the different mitigation measures. The policy package suggested below is a menu of such actions, that is needed to be integrated in the city development plan of Ahmedabad. When pursued together, these set of actions would help in devising dedicated policies in the near term, thereby helping in the realization of low-carbon society vision for Ahmedabad.

1. **SUSTAINABLE TRANSPORT**
   - Bus rapid transit systems, metro rail, shift to electricity usage in vehicles, promotion of bikes & walks, better ICT usage for traffic management, appropriate infrastructure for bikes & walks
2. **LOW CARBON ELECTRICITY**
   - Promotion of transition towards green power, shift to gas in power sector, new power infrastructure which is renewable based
3. **ENERGY EFFICIENCY**
   - Energy labeling program promotion, building standards, vehicle & device efficiency measures
4. **MATERIAL EFFICIENCY**
   - Sustainable and less energy embedded building material and building design
5. **ENVIRONMENTAL INFRASTRUCTURE & MUNICIPAL SERVICES**
   - Water resource management, improving built environment, increasing green cover, standardization in municipal services like lighting, shift to energy efficient lamps
6. **REDUCE, REUSE AND RECYCLE**
   - Less energy intensive processes, waste management, waste recovery and recycling, fuel from waste
7. **GOVERNANCE**
   - Coordination, planning and implementation of LCS measures
8. **FINANCING**
   - Adequate fund availability, either through VGF or external aids

Background

In the developed world context, the concept of a low-carbon society has the following attributes:

(1) Actions should be compatible with the principles of sustainable development, however not at the cost of the development needs of all groups in the society.
(2) Make an equitable contribution towards global efforts in stabilizing CO_2 concentration in the atmosphere and other GHG gases, through deep emission cuts.
(3) Use low-carbon energy sources and technologies and demonstrate a high level of energy efficiency at all levels of energy usage.
(4) Adopt certain behavioral and consumption styles that are consistent with low levels of greenhouse gas emissions.

However, the concept of a low-carbon society has a different meaning for the developing world. Countries, like India, still have low per capita emissions, are on an increasing economic growth trajectory and have priorities in meeting the development needs, like education, healthcare.

But, the LCS opportunity for developing countries arrives with a window of opportunity, as it gives a chance for such countries to avoid critical lock-ins; particularly in long-lived infrastructure assets. From the perspective of a city, like Ahmedabad, the LCS opportunity is a window to decide about the future flow of energy through infrastructure and other behavioral and lifestyle related choices and therefore the importance of such a study.

For setting priorities within the overall framework of an LCS society, it is imperative to understand the long-term goals for such a society. At the Ahmedabad city level, the overall aim of implementing actions within the LCS framework should aim at improving the "Quality of Life" (QOL) of the local residents. 'Quality of Life' should be embodied within the broader deliverables of providing a safe, secure and a comfortable city. Such a society would not emerge in the immediate future but decisions regarding key choices have to be taken now.

Such choices would be either resource/sector based or hard/soft type. While the former controls key energy service demands in certain sectors like residential, building, commercial, etc but the latter, provides an alternative option through either physical type decisions or management decisions. It is important to recognize that the concept of LCS from a city-level perspective should be planned within the jurisdiction levels of the local government. Specifically, only those activities or actions should be considered which the local government is capable of influencing like operationalisation of standards in building sector, promoting the concept of 3R etc.

At the next level, the LCS framework at the city level should look at opportunities which create various kinds of co-benefits apart from direct GHG emission reductions. Such co-benefits, like improved local air quality, provide an opportunity to minimize social costs of such a transition. The other advantage of such an approach would be in achieving "multiple dividends", at minimum social cost. It also helps in achieving various developmental goals of the city and therefore, is in line with the concept of sustainable development.

Extending the LCS framework further, the city would therefore be in conformance with a climate friendly regime. However at the same time the city would also be resilient to climatic variability. The LCS opportunity should therefore be looked at in terms of a platform for planning for climatic exigencies and therefore, minimize operational and other losses.

Target Setting and Timeline

The current selection of target years: 2035 and 2050 is done by keeping in mind the three time periods:

(1) Period up to 2020 (the terminal year of Post-Kyoto global carbon architecture period), by which many developing nations (including India) have promised voluntary emission reductions.

(2) Intermediate year of 2035, which gives an opportunity to check the progress made towards the long-term global commitments of GHG emission reduction by 2050.

(3) Period terminating in 2050, the year by which most of emission cuts are pledged by the developed as well as the developing world alike.

Figure 2: "*Ellis Bridge*" connecting east and west Ahmedabad

The time period is typically situated so as to assess the progress towards meeting GHG emission targets. Therefore actions taken now could be assessed by 2035 so as to get a realistic estimate about achieving deep cuts in GHG emissions by 2050; as envisaged by global leaders at (G8+5) summit in 2009. The targets in this study are in line with such global commitments, as city level planning is a part of the larger national policy making in India. The immediate future, 2020 (terminal year of post-Kyoto period) and the long-term future, 2050; coincides well with the target years chosen for this study.

In the recent G8+5 summit, deep global reduction target of GHG emissions were agreed upon by nations, with a concern towards stabilizing mean global temperature rise at 2º Celsius above the pre industrial level. The present LCS study is in line with the same targets. This scenario has also been endorsed at the 2009 declaration by the leaders of the "Major Economies Forum". However, India has particularly acknowledged, that it would, at no point in time, exceed the current emission levels (i.e at 2005 levels) of the Annex 1 countries.

The idea of LCS is not committing to the 2 deg C target, but an aspirational attempt being made by India. However this target is subject to adequate financial and technological commitment as agreed upon under the Framework Convention on Climate Change and also by the declaration of world leaders of the major economies. A city like Ahmedabad is also participatory to these global efforts but would need financial, technical and other (carbon finance) instruments, as agreed upon under the framework convention on climate change, to achieve these aspirational targets. These efforts do not under any circumstance undermine the importance of various bilateral efforts in achieving the LCS targets.

Figure 3: A glimpse of land use planning scenario in Ahmedabad

About Ahmedabad

Ahmedabad is the seventh largest urban agglomeration (UA*) in India, and the largest city in the state of Gujarat. The city plays a significant role in the economy of the state of Gujarat, accounting for almost 19 percent of main urban workers in the state.

The city was founded in the year 1411 AD and is located on the banks of River Sabarmati. Ahmedabad gets its name from Sultan Ahmed Shah, who founded the city. Over the last 600 years, the city of Ahmedabad has come a long way, from what was developed as a cluster enclosed by a wall in 1456 AD. In the late 19th century, development started spilling over towards the northeast and southeast of the walled city.

Figure 4: East and West Ahmedabad separated by the Sabarmati River

Historically Ahmedabad has been one of the most important centers of trade and commerce in western India. It was once known as the "Manchester of India" owing to its textile industry. With the establishment of the first textile mill in 1861, residences also developed across the western side of the Sabarmati river.

Today some of the industrial activities that have flourished in the city over the last few decades include chemicals, pharmaceuticals, electronics, dyes and paints. Ahmedabad's status as an important centre of trade and commerce remains unchanged. The city also has a large market for consumer goods in the retailing sector.

Several key high-growth industries such as textiles, pharmaceuticals and natural gas are already firmly anchored in Ahmedabad. The industrial centers around Ahmedabad are continuously experiencing expansion on account of economic growth. The economic base of the city is now shifting towards tertiary (service) sectors, which now account for more than 50% of total employment. Ahmedabad is also a major financial centre contributing about 14% of the total investments in stock exchanges in India.

Ahmedabad and its surroundings are currently under the jurisdictional authority of two local bodies, namely the Ahmedabad Municipal Corporation (AMC) and the Ahmedabad Urban Development Authority (AUDA). Beyond the municipal limits; the development is managed by the AUDA.

Table 1: Ahmedabad Demographics

Parameter	AMC	Urban Agglomeration
Population (Million)		
- 1991	2.8	3.3
- 2001	3.5	4.5
- 2006(estimated)	4.9	5.1
Population Growth		
- 1991-2001	2.03%	2.74%
Area (Km2)		
- 2001	190.8	485
- 2006	464.1	485
Density (per sq. km.)		
2001	18,445#	9,290
2006		10,609

 # In 2006, the jurisdictional limit of AMC was increased to 464.16 sq. km. This new limit coincides with the limits of the Ahmedabad Urban Agglomeration. The density of AMC in 2006 has not been calculated since the area of AMC in 2006 was almost equal to the UA area and the new AMC limits now included the population formerly housed in UA limits.

* Urban Agglomeration: It is a continuous urban spread constituting a town and its adjoining urban outgrowths.

Some Initiatives Underway

Many initiatives are being undertaken currently by the city and the state. The recently announced township policy promotes townships to come up at growth nodes emerging around various industrial clusters. The policy sees the government as a facilitator providing 'trunk infrastructure' like access roads, bulk water supply and bulk power (electricity and gas). This would facilitate effective planning for city level infrastructure for anticipated expansion and growth in the future. Besides, there are various initiatives underway in the urban transport infrastructure sector, with the Bus Rapid Transit System (BRTS) under execution and the Mass Rapid Transit System (Metro) being planned. These initiatives would also play a significant role in the energy flows and related emissions from the city.

Figure 5: "*Janmarg*" - The BRTS Corridor under development

The new regional plan submitted to the government envisages Ahmedabad into a much bigger Ahmedabad Metropolitan Area. It plans for a multi-modal transportation hub with Metro rail, BRTS, regional rail and the mass rapid transit systems in the next 7-10 years. This regional plan has been prepared for an area of 10,000 Km^2, which also comprises of 5 air strips within 65 km radius from the city and four multi-modal transport stations in the vicinity.

Reforms in the public transportation system includes low-floored CNG buses fitted with vehicle tracking system (GPS) and bus conductors with hand-held electronic ticketing machine. This has resulted in an increase of bus patronage, and improved collection. This has also resulted in an enhanced quality of service for passengers, mapping out loss making routes, reduces overlapping of routes and maximizing fleet usage by efficient management through constant monitoring of buses on various routes. The local government has also taken an initiative to develop the Sabarmati riverfront (Figure 6). This project also demonstrates governance initiative, since it is being managed by a special purpose vehicle (SPV), which is coordinating all the activities pertaining to this project.

Figure 6: Sabarmati River Front , being developed at Ahmedabad

Among the latest technological innovations, AMC has developed Asia's largest landfill site, developed over a total area of 2.77 Km^2, to dispose 1.15 Million tonnes of waste. It has been designed to meet city's requirements for the next 30 years. Solid waste will be segregated into biodegradable and non-biodegradable categories and dumped in a systematic manner, adhering to environmental standards. The waste would then be used to make pellets and fluff, to be used as fuel in local industries. This initiative of recycling waste to useful energy form by generation of methane (CH_4) is currently running successfully under pilot phase for other existing solid waste management (SWM) treatment plant. The area around the newly created SWM site has been planned to be developed as a "Green Zone", which would contribute in improving the ambient environment. Thus, the creation of such an environmental infrastructure leads to multiple dividends.

Land Use Planning

The Land use of Ahmedabad is diverse and strongly contrasting on either side of the river (East and West Ahmedabad, or as it is called locally- *Old* and *New* city). The contrast is not only in terms of resources but also in economic profitability and environmental sustainability. Ahmedabad shows differing trends in spatial development. It is spilling over towards the northeast and southeast of the walled city. While residences also developed across the western side of the Sabarmati river to meet the rising demand for housing, changing household pattern and structural changes in the city economy. People everywhere are moving from in--city areas into the outer, a development for which growing car ownership and the modal shift from public transport to car act simultaneously as both causes and effects. In addition to land area, the amount of floor-space per person is also growing, This, too, can be seen as both a cause and an effect of urban sprawl.

After the establishment of Land Administration Bureau in 1986, China carried out national land use planning twice. One of which was focused on "serving for social and economic development" and second one was to "protect arable land". They also aim to achieve higher in their ongoing project for land use planning in the near term horizon of 2005-2020 .

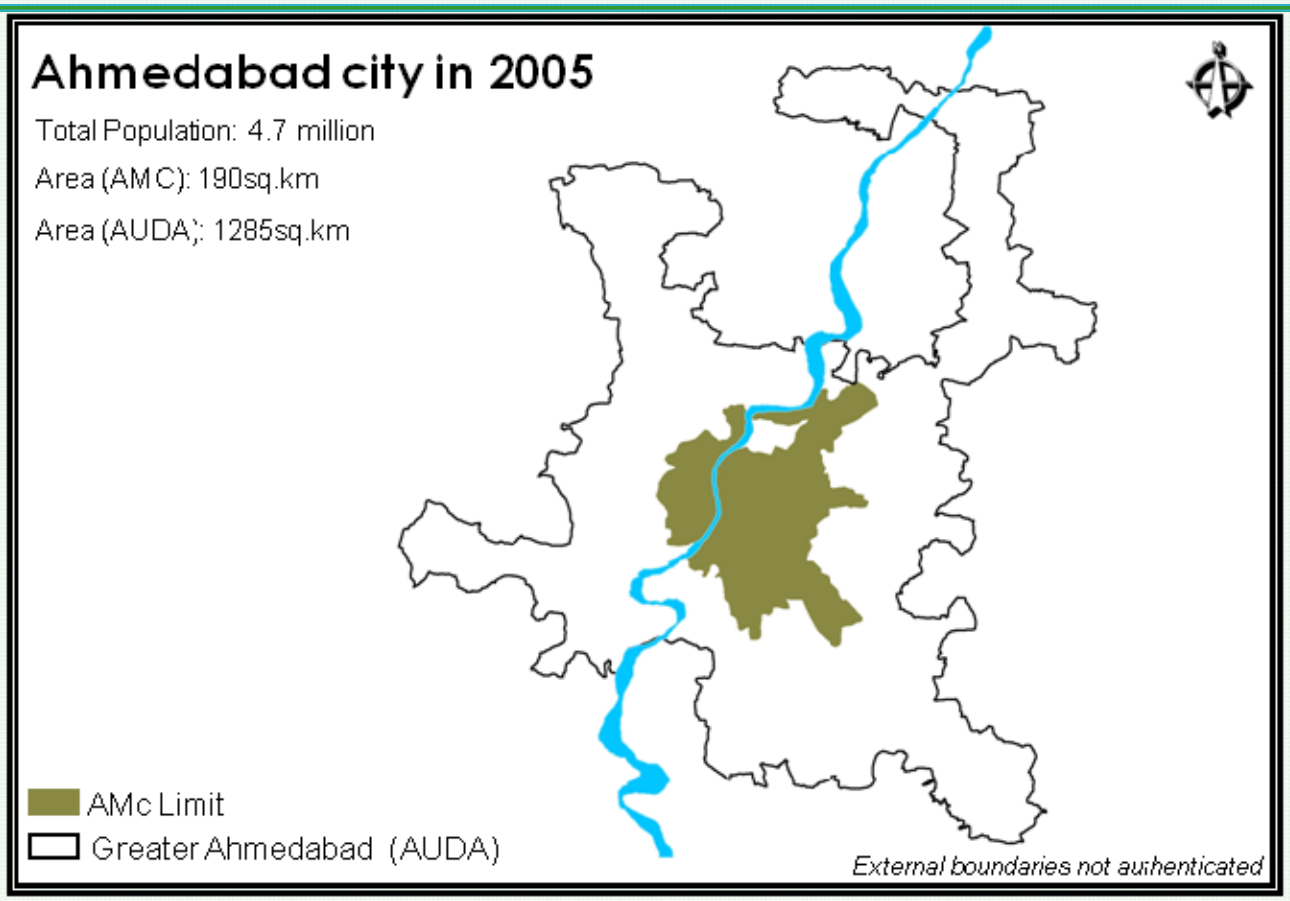
It is widely acknowledged that avoiding urban sprawl through high density and mixed-use settlement patterns offers environmental advantages pertaining to land use, transport and heating, thereby contributing to reduce the resource use per capita. In a developing city like Ahmedabad, Urban planning and its effective implementation requires proper Land Use (LU) planning to create curative LU Patterns that provide maximum mobility without the loss of natural habitats and biodiversity. Thus at the city level, it is necessary to have proactive response from local government to carry out an integrated land use planning to comprehensively address the adverse impacts of urbanization including heat island effect. Zoning techniques which may be applied to implement the master plan and to guide urban development to spatially appropriate areas include designation of sensitive land resources and areas, establishment of buffer zones, management of hazard-prone lands, protection of cultural resources, setting up of recycling schemes, conservation of open spaces and guiding and discouraging of excessive urban sprawl.

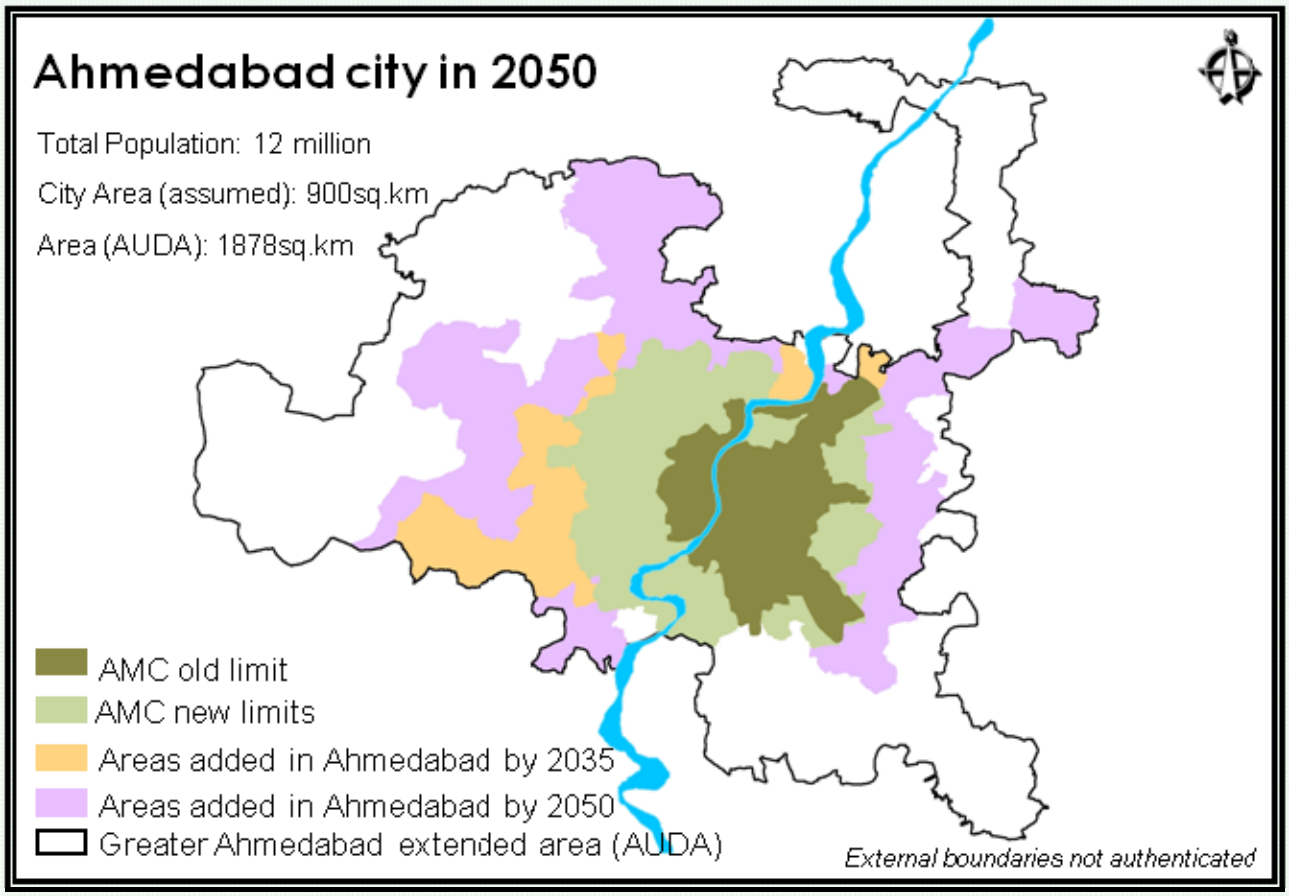
Land use Planning and Transport:

Land use and transport are strongly interlinked. Land use patterns such as location, scale, density, mix , clustering and connectivity may not automatically cause a shift towards sustainable travel behavior, however it can definitely provide an option and support to facilitate the transition towards such behavior. Also, under the growing threat of climate change and the strict global stabilization targets, there is an increased need to limit the GHG emissions from transport. Appropriate land use planning in growing cities like Ahmedabad can substantially limit the increasing travel demand, thereby leading to various spill over benefits like reduced congestions and improved air quality. Besides, there is an improvement in the overall quality of life, by making it easier for people to access the appropriate transport as per their need.

Thus, the government should encourage an efficient use of urban land by setting targets for the percentage of development occurring on brown fields, the promotion of "town centre first" policies, setting housing density targets, and reforming business rate relief for empty property and also consider introducing a charge on vacant and derelict land. Preservation of open space near town and cities, and redevelopment of vacant land not only reduces transport cost but also reduces the cost of providing and operating public services and utilities. Green belt is also equally important to check unrestricted sprawl of large built up area. All such policy initiatives are crucial for a developing city like Ahmedabad, which is projected to grow substantially over the next 40 years.

Spatial growth





Socio Economic Assumptions

The population of Ahmedabad has increased from 2.8 million in 1991 to 3.5 million in 2001. In response to rapid increase in population and development on the fringes, the jurisdictional limit of AMC was increased to 464.16 sq. km in 2006. The major portion of this extension of municipal borders has taken place on the western side of Ahmedabad. The western region is actually seen as the modern, dynamic and well -planned part of the city, offering world-famous educational institutions, most recent malls and entertainment facilities, and high-income residential areas. The new outgrowths have been in the western parts of the city, within the AUDA jurisdiction.

Using expert opinion, published references and our own estimates, it is projected that the population of Ahmedabad would increase to 7.8 million in 2035, and would further rise to 12 million in 2050. Using this assumption about population and other assumptions (see Table 2) about 2035 & 2050 Ahmedabad, future socio-economic indicators in 2035 & 2050 are estimated exogenously (see Table 3), which will be used as inputs in running the model for the target years. Following are the important assumptions for target years:

Economy: An input-output framework has been used to determine the future structure of the economy, where the future economic parameters (GDP, etc) are obtained using certain exogenous assumptions on the expected structure of the Ahmedabad economy in target years. In order to estimate GDP projections for Ahmedabad, a top-down approach was followed. This approach uses the current GDP and future projections of India's GDP (based on growth rate projections) as a starting point. Further, the GDP growth rate for Gujarat were pegged at 2% above India's GDP growth figures i.e. 10% from 2004-2032 and 8% from the successive period till 2050. Gujarat GDP was pegged at 7 % of India GDP, and Ahmedabad GDP was pegged at 17% of Gujarat GDP for the base year. Similarly, the target year GDP of Ahmedabad and Gujarat was determined using the GDP of India, keeping macro-economic consistency. Thus, on the basis of these assumptions, the modeling results show that the real GDP of Ahmedabad in 2050 is expected to be approximately INR 3673 billion (12.0 times the 2005 level).

The specific inputs to the model about the transitions in the structure of the economy are: share of the primary sector changes from 3.03% in 2005 to 1.3% in 2035 and 1.1% in 2050, while the share of secondary sector reduces from 69.2% in 2005 to 59.0% in 2035 and further to 49.5% in 2050 BAU. The tertiary sector gains from 27.8% in 2005 to 39.7% in 2035 and further to 49.4% in 2050. Considering the trends, it is obvious that the structure of the economy is moving towards more tertiary and secondary sector activities at the cost of primary. Thus there is a structural shift in the economy of the city, which is in line with the experiences and trends worldwide.

Further, to determine the structure of the economy in future, PFCE and other numbers regarding investments and government consumption have been estimated based on best available references and expert judgment. For the intermediate year of 2035, it is assumed that that import of agriculture commodities further increases (in line with the decrease in share of primary activities) and the share of electricity import also reduces, due to some localized generation in terms of solar and biomass. On the private consumption side, there will be a reduction in the share agriculture consumption, which will be complemented by an increase in consumption of manufacturing sector goods and a minor increase in service consumption.
There will be an increased share of private investment in electricity and water services, whereas the share of investment in manufacturing and construction sector will reduce, as

compared to the base year. A similar trend is assumed for government investments, where the share of investment in electricity and water will increase, with a reduction in the share of investment in construction. The share of government investment in services, the distribution of government consumption, and the distribution of exports has been kept the same. It is worthwhile to mention, that in spite of decrease in the relative shares, the absolute number will still be rising for all the sectors, due to an overall expansion of the economy from 2005 to 2035. For example, the private consumption in 2035 will be increased from more than the factor of population rise, on account of an assumed increase in consumerism.

For target year of 2050, it is assumed that agriculture import will increase to almost 100%. At the same time, the increased requirement of electricity in the city will largely be imported from outside (from the state /national grid). There will be a further reduction in the share of agriculture in private consumption side, whereas there will be a continuous increase in the consumption of services. For the private investment, the trend between 2005-2035 will be furthered, which will have an increased investment in electricity and water services, and a reduced share of investments in manufacturing and construction sector. The government investment will also follow a similar trend. For the exports, there will be a reduction in the share of manufacturing, giving way to the export of specialized services from the city like real estate, banking, insurance, IT and ITeS. In fact, exports and imports are both assumed to be increasing, on account of a more integrated economy with high degree of economic activities with outside.

Table 2: Quantitative Assumptions of socio-economic indicators (2035 and 2050)

Parameter	**2035 BAU**	**2050 BAU**
Demographic composition	0-6 : 33% 7-64: 62% >65 : 5%	0-6 : 20% 7-64: 65% >65 : 15%
Primary Industry Exports	7.1% CAGR (2005-2035)	7.4% CAGR (2005-2050)
Secondary Industry Exports	6.1% CAGR (2005-2035)	5.8% CAGR (2005-2050)
Tertiary Industry Exports	10.4% CAGR (2005-2035)	10.8% CAGR (2005-2050)
Private consumption	8.0% CAGR (2005-2035)	8.1% CAGR (2005-2050)
Government consumption	9.7% CAGR (2005-2035)	8.4% CAGR (2005-2050)
Fixed capital formation	3.4% CAGR (2005-2035)	9.23% CAGR (2005-2050)
Modal share	2W :24% SV : 15% LV : 1.1% Bus : 15.9% Train: 8% Bike : 11% Walk: 25%	2W : 7% SV : 15% LV : 3.4% Bus : 36.6% Train: 8% Bike : 8% Walk: 22%

Sectoral Assumptions

Industry: The energy consumption by the industrial sector in the city has shown an increasing trend, and our estimates indicate that the energy demand CAGR for the 4 year period between 2003 and 2007 has been a robust 7.5 %. This is also the period that experienced heavy investments in natural gas supply infrastructure in the city, and the corresponding supply linkages from sources. Thus, this increase can be attributed to growing industrialization during the period and also due to the easy availability of natural gas as a fuel.

Two largest consumers of energy products in Ahmedabad are the textiles and chemicals industry. Textile sector is the largest consumer of energy, primarily in the form of steam and electricity. The last few years have seen a major substitution of oil usage in Textile sector with other energy carriers like coal and lignite. Although natural gas does provide a price advantage, however it is still not used much for steam generation because of the availability of cheaper substitutes like coal, lignite, and biomass (non commercial, for smaller industries). The other major industrial sector is the chemicals sector. Nearly 1200 chemical units operate in Ahmedabad, majority of which are clustered in three major industrial estates. Steam is the main requirement for these units, and therefore coal/lignite has historically been used in boiler applications and other heating activities (such as brick kilns, etc). However, the chemical industry has shown a robust increase in the demand for natural gas in the recent years, replacing coal and lignite. The primary reason is the quality requirements of the industrial processes (for example, ceramics), where the flame to be produced has specific technical requirements, and thus it is imperative to use a superior fuel like natural gas.

The future demand for energy in the industrial sector at Ahmedabad is driven by two important parameters: the growth of industrial sector (driven by the growth in economy), and the energy intensity of the industrial output (processes). As discussed above, the economy of the city will undergo a structural shift in the future, where the share of industrial sector will be reduced from the current levels. However, there will still be a wide increase in the industrial outputs, in terms of absolute numbers. At the same time, the energy intensity of the various industrial process will also experience a change, partly on account of fuel shift (from oil to gas, and subsequently from gas to electricity), and also due to the reduction of energy use per unit of output, due to energy efficiency and process level improvements. Thus, the future energy demand from the industrial sector in Ahmedabad is driven by an interplay of these factors.

Households: The model structure provides the possibility of classifying the households in two broad categories, based on the type of housing facility. This classification broadly links to the economic status of the residents, and hence differentiates between the usage of different services and appliances in the household, and also the energy usage per capita and the energy source being utilized. Household type hht1 refers to the high income housing, and hht2 refers to the lower income houses. We have assumed that the share of household (hht1:hht2) amongst these two types is 40:60 in 2005 (base year, based on actual data). However, because of the rising economic affluence and income effects, the share changes to 50:50 in 2035, and further improving to 60:40 in 2050.

Commercial: As highlighted in the description of future economic structure of Ahmedabad (above), the tertiary sector will have a rapidly rising share in the economy. This will happen due to the growth of service related activities (banking, insurance, real estate, IT, ITeS, education, consulting, etc) to the city, and the shifting out of manufacturing related activities

to other cities in the state or maybe even outside. Also, as the real estate sector in the city/ country develops, it is anticipated that it will be kept pace by policy reforms aimed at increasing the FSI. Hence, combining all these effects, our best estimates indicate that the total floor space for commercial activities will increase from a base of 21 sq. km in 2005 to 103 sq. km in 2035 and further to 156 sq. km in 2050 in line with tertiary sector growth.

Transport: The main drivers of passenger transport demand are population, per capita trip rate (PCTR) and the average trip distance (ATD). It is commonly understood that economic activities have a high correlation with mobility, and thus an increase in overall travel demand is expected as the economic activities rise in the city. This increase can be explained on account of the increase in the above mentioned parameters: population, PCTR and ATD. Thus, with rising incomes, the future resident of Ahmedabad will undergo a change in pattern of travel, wherein the average number of trips will be increased in future, on account of some additional leisure and work trips, and also increase in average trips per capita due to more women being moving to the job market. Also, due to an expansion in city limits, the average trip length will also undergo an increase, accounting for the increased distances between work, home and other travel destinations. Thus, accounting for the increase in population, per capita trip rate, and the increases average trip length, passenger transport demand will increase from 14.89 Billion passenger-km in 2005 to 53.3 Bn mil p-km level in 2035 and further increase to 129.6 in 2050.

The quantitative assumptions that relate to these storylines can be summarized in Table 2 and 3.

Table 3: Estimation result of scenario quantification in 2035 and 2050

Indicator	**2005**	**2035**	**2050**	**2050/2005**
Population (millions)	4.7	7.8	12.0	2.55
No. of households (millions)	1.1	2.1	3.4	3.1
Average persons/household	4.3	3.7	3.5	0.8
GDP (billion INR)	305	3673	9884	32.4
GDP per capita ('000 INR)	65	471	824	12.7
Gross output (billion INR)	727	7695	19024	26.2
-Primary industry	*22*	*99*	*210*	*9.5*
-Secondary	*503*	*4538*	*9424*	*18.7*
-Tertiary	*202*	*3058*	*9390*	*46.5*
Commercial Floor space (square km)	21	103	156	7.4
Passenger Transport Demand (Million passenger-km)	14.9	53.3	129.6	8.7
Freight Transport Demand (Million ton-km)	3.1	21.7	92.5	30
BAU Energy Demand (Million toe)	1.8	11.3	23.0	12
BAU CO2 Emissions (Million ton -CO2)	10.2	44.1	86.3	8.5
BAU Emissions per capita (ton-CO2)	2.16	5.66	7.19	3.3

LCS Scenario: Qualitative Storylines

In order to achieve the target of transitioning to a low carbon economy, we need to develop the low carbon scenarios for a future Ahmedabad. Hence, it was important to collect a set of counter measures, which will help us to alter the energy emission profile in the target year. However, these counter measures needs to be consistent with a storyline that defines how we visualize the Ahmedabad city in future. This section presents the storylines for a future articulation of low carbon Ahmedabad, enlisting a collection of several low carbon measures.

The qualitative storyline that help us articulate low carbon measures and actions can be presented as under, classified into few broad categories, for the ease of understanding:

Transport Sector: The actions on sustainable transport comprises of improvement in vehicle efficiency, fuel switch from oil to electricity (for private vehicles, buses and train), modal shift from private vehicles to public transport (bus and train), and better traffic management. However to achieve such a scenario, certain indirect actions would be required. Some of these actions will be standardization electricity supply infrastructure and appropriate institutional mechanisms to ensure transition to mass based transit systems. All these actions would lead to a strong decoupling between economic growth, mobility and transport energy use.

Urban Sector: The actions aimed at the urban sector focus on few broad areas, including the building design, land use & urban planning, and on environmental infrastructure for the cities. The low carbon measures focusing on the Building Design are crucial for controlling the energy flows in the established assets. Use of appropriate building technologies, energy audits and associated standardization across building types, materials and devices would go a long way in controlling flow of energy across these stocks. The actions are also aimed at promoting dematerialization, directing towards a more towards sustainable lifestyle by using energy efficient materials and local materials. This will also provide significant co-benefits in terms of promoting a sustainable lifestyle, better control of energy service flows and resource conservation. Similarly, the actions focusing on land Use & urban planning are targeted at increasing the green cover and improving the built environment so as to reduce the urban heat island effect. At the same time, it is also crucial to focus actions on planning various environmental infrastructures, such as solid waste management facilities and sewage treatment plants. Apart from direct mitigation benefits, these are important in realizing other co-benefits such as resource utilization and enhancing the quality of life. For example, a modern landfill can also be a source of fuels in the form of land fill gas (LFG), pellets and fluff, which can be used in the local industries. Similarly, significant improvements can be realized in the energy consumption of public services, by shifting to energy efficient sources like street lamps.

Energy Sector (Demand Side): The actions focused on demand side are aimed at efficiency improvements achieved through device improvements. These efficiency impacts are realized in residential, commercial, industrial and transport sectors. It is believed that due to technological innovations and improvements, such high efficiency factors are realizable. These efficiency improvements can be consistently achieved through implementation of uniform building codes (efficiency in residential sector), standardization in device & vehicle efficiency, promotion of local and less carbon intensive material for construction and designing an appropriate institutional mechanism to facilitate such a transition.

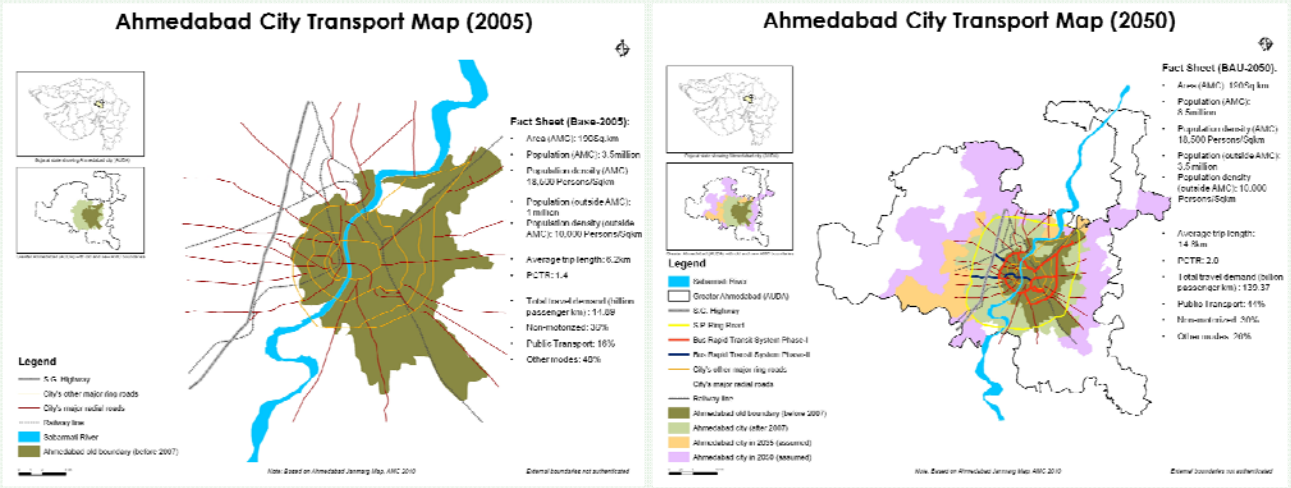
Energy Sector (Supply Side): The actions focused on energy sector aim at fuel switch, decoupling economic growth and energy re-

quirement, and decoupling the carbon intensity of power sector. The action on Fuel Switch refers to switching from coal to gas and other renewable resources of energy like biomass, wind and solar. This switch can happen across sectors, like increased use of gas in industries, piped natural gas for domestic usage and gas-based power production technologies. The measures for decoupling economic growth and energy requirement are aimed at process level improvements in various sectors, especially industry. De-carbonizing the electricity sector aims at using more renewable sources of energy for power generation or by using coal with CCS option. Another aspect in low carbon electricity is generating electricity from waste (solid waste management). Such possibilities have already been explored for Ahmedabad, and are realistic.

Resource Efficiency: The actions focused on resource efficiency aims at material efficiency and resource management. The action on material efficiency aims at promoting dematerialization and is directed more towards sustainable lifestyle by using energy efficient materials and local materials. It also aims at efficiency improvements achieved from device improvements and reducing energy consumption in intensive industrial processes. It needs implementation of energy efficiency codes and promotion of local and less carbon intensive material for construction. The action on resource management aims at better management of natural resources for a substantial GHG mitigation. Reduced dependence on groundwater for irrigation and a shift to surface water significantly alters the energy consumption patterns in the agriculture sector. It also comprises of creating various infrastructures such as solid waste management facilities and sewage treatment plants. Thus, all these actions primarily target at reducing the energy intensity of the output from the local economy. By constructing common facilities at the city level, one can actually reduce, reuse and recycle many resources and thereby move on to the sustainable style of living. This would give an added incentive of energy reduction.

Apart from sectoral measures, there are certain overarching actions that have been considered separately. Although such actions, like governance and financing, do not facilitate any carbon mitigation directly, they do provide support to other low carbon measures. While well designed governance structures ensure that the actions are implemented in the most non-conflicting manner, appropriate financing facilitates that the actions are able to attract innovative funding mechanisms so that the actions are self sustaining.

Figure 7: Low carbon transitions in transport sector



Energy & Emissions : 2035 & 2050

The macroeconomic data is used to estimate future energy demand and the corresponding GHG emissions in 2035 and 2050, based on scenario quantification. The estimated results about energy demand and GHG emissions are shown in Figures 8-11 below.

Final energy demand in Ahmedabad is projected to increase from 1.8 million toe in 2005 to 11.3 million toe in 2035 (BAU scenario), and further to 23 mtoe under 2050 BAU scenario. Industry remains as the bigger consumer of energy, maintaining a share of around 60% in the final energy demand, under various scenarios. The second biggest demand for energy comes from the household sector, where the share in final energy use increases from around 18 % to 30 %, because of the increased household services demand on account of increases economic affluence and the associated penetration of consumer durables.

As can be seen from Figure 4 above, the share of electricity increases gradually, and a major portion of the final energy demand is met by electricity in 2050 (in this case, gas based thermal power generation), closely followed by gas. The relative shares of electricity and gas are further enhanced, under the low carbon scenarios. Thus, in terms of infrastructure choices, it clearly outlines the need for extensive investments in power sector infrastructure, including generation, transmission and distribution.

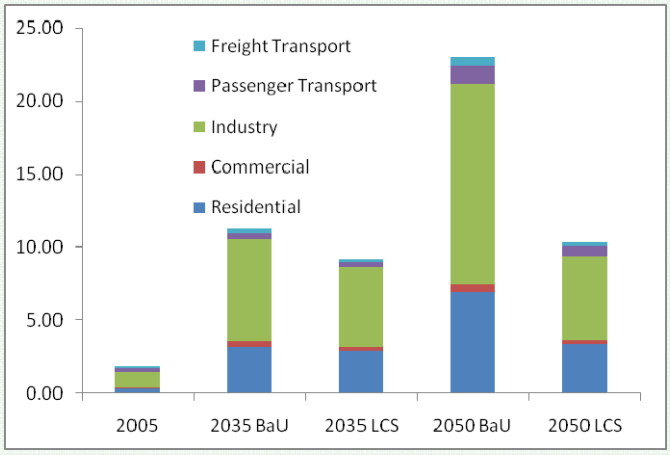


Figure 8: Final energy demand by sector (mtoe)

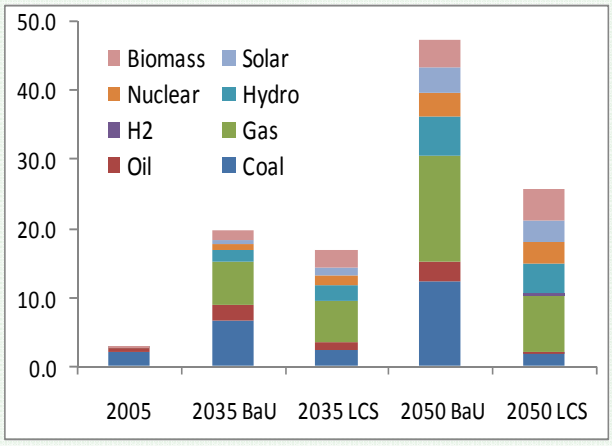


Figure 9: Total primary energy supply (mtoe)

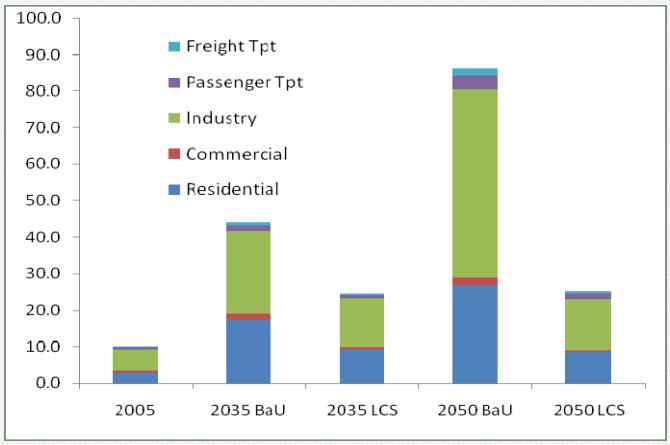


Figure 10: Sectoral GHG emissions (mt CO_2)

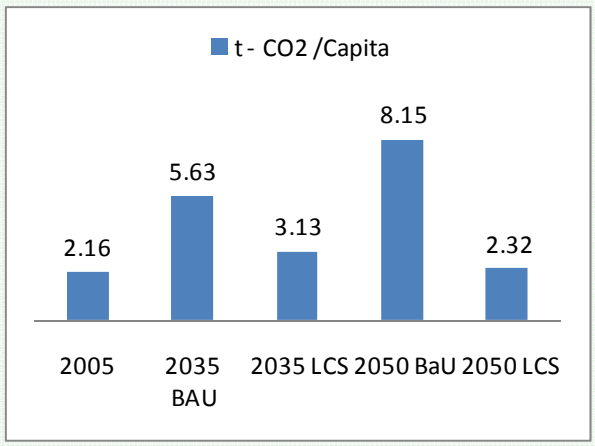


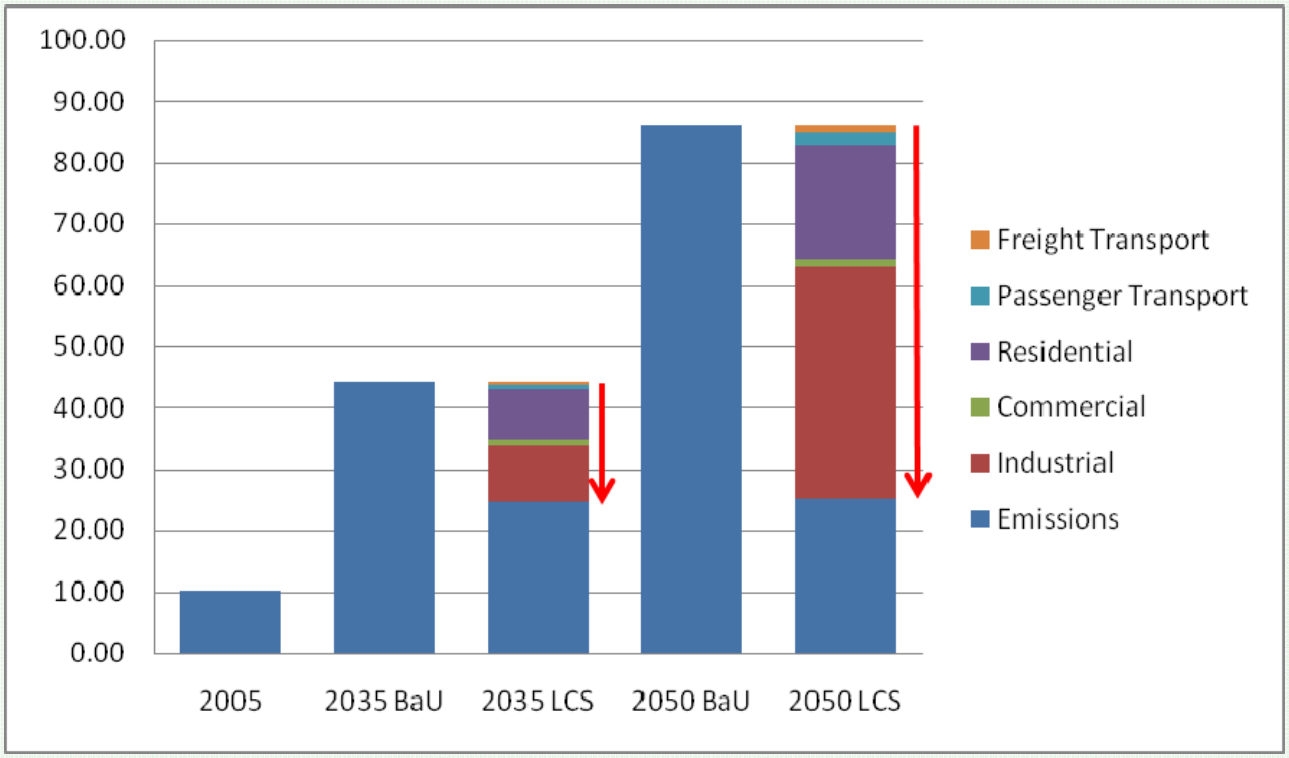
Figure 11: Per capita GHG emissions

As can be seen from Figure 9 that the primary energy supply is primarily met by gas, although various other sources like nuclear, solar, and hydro play a crucial rle. Hence, the power infrastructure development will have to follow a portfolio approach, wherein simultaneous investments have to be made in acquiring power generation capacity from all these sources, and the associated transmission infrastructure to haul the generated power to the city. Besides, there is a large share of gas in the final energy use in the city, and hence in order to supply this gas for final energy use, there will be investment requirements for gas supply infrastructure, which would mean city gas distribution grid for household and retail customers, and also gas retail outlets for transport sector customers. Also, in order to support the electricity driven vehicles on the roads, especially under the 2050 LCS scenario, there will be a need to develop the charging infrastructure for these electric cars.

Based on the energy demand by source, the CO2 emissions in Ahmedabad are projected to increase from 10 million ton CO2 in 2005 to 44 million ton CO2 in 2035 BAU scenario, and further to 86.3 million ton CO2 under the 2050 BAU scenario. However, by making cross sectoral infrastructural investments over the planning horizon extending upto 2050, there is a possibility to limit the overall emissions from the city, as has been shown under the 2035 LCS and 2050 LCS scenario (Figure 10 & 12).

As discussed earlier, the biggest consumption of final energy happens in the industrial and household sector, and correspondingly, the two sectors are also the biggest contributors to overall emissions (Figure 10 and Figure 12).

Figure 12: Sectoral Mitigation Potential (million ton CO2)



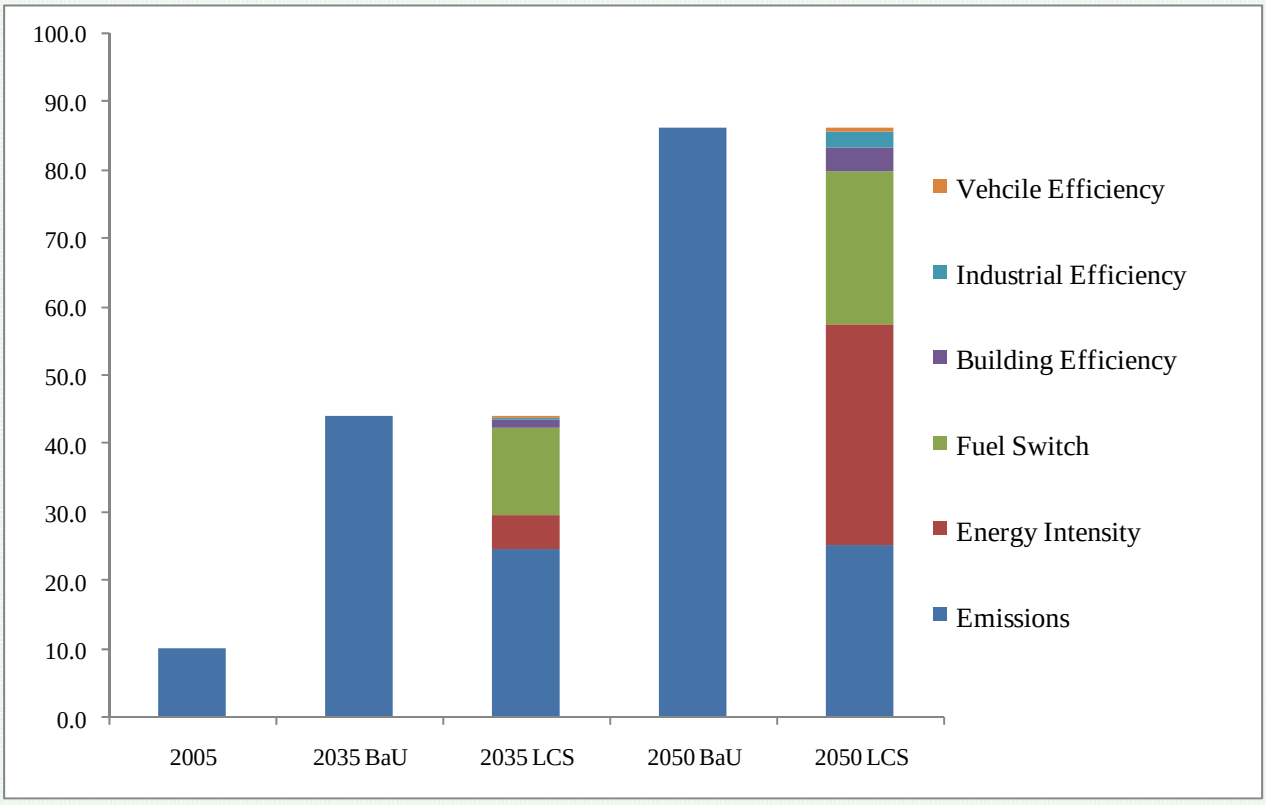
Mitigation potential in 2035 & 2050

In order to transit to a low carbon society in Ahmedabad, several countermeasures are required. It is interestingly observed from the output that for a LCS transition in Ahmedabad the major contribution is from reduction of energy intensity. The major emission reduction potential is from improvements in energy intensity of economic activities, low carbon power (more renewable like hydro, solar and biomass), reduction in energy service demand (for industrial and commercial sector), fuel switch in power, transport and industrial sector; and measures promoting end-use device efficiency (particularly, in the transport sector, industrial and residential sector).

Thus with these measures, our target of at least matching the base level emission figures or reducing further is achieved and we are situated at less than the base year emission level. The overall reduction from the base year emission of per capita is 6.6%. It is important to highlight that there is a significant energy and emission decoupling of GDP which is happening in Ahmedabad over the entire modeling period upto 2050.

As can be seen from Figure 13, that the major emission reduction potential is from improvements in reduction in service demand and energy intensity of service demand, fuel switch (both at end use level, as well as using low carbon electricity i.e. gas or renewable like hydro, solar and biomass), and investments promoting end-use device efficiency (particularly, in the transport sector, industrial and residential sector). Thus, the sectoral infrastructure developments have to be aligned in the long term, to address these emission concerns.

Figure 13 : Breakdown of emissions reduction potential



Low Carbon Infrastructures

Low carbon transition arrives with a window of opportunity for developing countries, as it gives us a chance to avoid critical lock-ins; particularly in long-lived infrastructure assets. From the perspective of a city, like Ahmedabad, it facilitates the decision about the future flow of energy through infrastructure and other behavioral and lifestyle related choices. As can be seen in the analysis above, several infrastructure choices, which could be either resource/sector based or hard/soft type, determine the future energy and emission dynamics of the city. Thus, a BRTS corridor being implemented in the city or a Metro under planning will have a long term implication on the energy demand of the transport sector in the city. However, the decision for such infrastructure investment choices has to be taken now, to avoid economic and behavioral lock-ins and inertia.

The possibility of aligning long term infrastructure choices so as to simultaneously achieve the possible sectoral mitigation of CO2 can be better understood as under:

Transport Infrastructures: There is a need for sustainable transitions in the transport sector, which would mean a focus on public transport investments so as to shift from private vehicles to public vehicles (bus and train), appropriate city gas distribution grid to facilitate transition from oil to gas (private vehicles and buses), and also the availability of appropriate infrastructures (reticulated electric corridors for buses, and charging infrastructure for cars), so as to facilitate a further transition to electric vehicles in the long run.

Power Infrastructure: In order to facilitate a transitions to electricity, from coal and gas in the case of industrial sector, oil and gas in the case of transport sector, and coal, kerosene and LPG in the case of residential sector, there is a need to make investments in power generation as well as transmission and distribution infrastructure. However, the transition to a low carbon economy provides us with this opportunity to make investments in low carbon electricity, thereby aiming at decoupling the carbon intensity of power sector by using greener and cleaner energy sources like renewable, nuclear, gas and biomass based generation.

Building and other urban infrastructure: Ahmedabad is a growing city, and hence lot of developments in urban infrastructure is yet to take place. This provides us an opportunity to better control our energy flows in the building sector (residential and commercial). With an appropriate land use planning, multiple benefits are possible, which can impact the overall emissions and also the quality of life. The city planning can account for a transit oriented development to reduce the mobility needs (and hence the transport energy use), an increased green cover can be targeted, thereby improving the built environment so as to reduce the urban heat island effect. Similarly, uniform building codes, and promotion of local and less carbon intensive material for construction can promote efficiency in the residential sector.

Actions toward LCS

General introduction of actions

Broadly, the actions are enumerated in the following table. The actions can be broadly categorized into those that promotes improvements in efficiency, to those that encourages sustainable mode of transportation ,to clean forms of energy and chiefly, that promotes efficient use of energy resources through promotion of measures like 3R. However within these actions, the overarching action of governance and financing has been separately considered. While the governance aspect ensures that the actions are implemented in the most non-conflicting manner and the financing action ensures that the actions are able to attract innovative financing mechanisms so that the actions are sustainable by itself. However it must be noted that all the actions yield multiple co-benefits and build adaptive capacities of the local population.

Description of "Actions"

The action on **Sustainable transport** comprises of focus fuel switch from oil to electricty (private vehicles, buses and train), better traffic management and shift from private vehicles to public vehicles (bus and train). However to achieve such a scenario, certain indirect actions would be required. Some of these actions will be standardization electricity supply infrastructure and appropriate institutional mechanisms to ensure transition to mass based transit systems. From the developing countries view-point, such an action would yield multiple benefits. On the co-benefits side, there would be improvement in local air quality due to reduced pollution and reduction in use of natural resources. Sustainable transport will lead to various adaptation benefits as well, by enhancing health security (owing to improved air quality) and energy security (due to reduced energy usage, specially oil). This action gives the added benefit of controlling the energy usage, as electricity is used at the end use.

The action on **Energy Efficiency (EE)** is focused on efficiency improvements achieved through device improvements. These efficiency impacts are realized in residential, commercial, industrial and transport sectors. It is believed that due to technological innovations and improvements, such high efficiency factors are realizable. These efficiency improvements can be consistently achieved through implementation of uniform building codes (efficiency in residential sector), standardization in device & vehicle efficiency norms and its strict implementation & designing an appropriate institutional mechanism to facilitate such a transition.

The action on **Low Carbon Electricity** aims at decoupling the carbon intensity of power sector by using more renewable sources of energy for power generation. Another aspect in low carbon electricity is generating electricity from waste (solid waste management). Such possibilities have already been explored for Ahmedabad, and are realistic. Such shifts in energy technology would yield multiple benefits, such as improvement in local air quality and effective waste management. On the adaptation side, investments in low carbon electricity would generate livelihood and build capacity in low carbon energy technologies. Besides, there would also enhance health security (owing to improved air quality) and energy security (due to reduced usage of fossil fuels, specially coal).

The action on **Material Efficiency** aims at promoting dematerialization and is directed more towards sustainable lifestyle by using energy efficient materials and local materials. This will also provide significant co-benefits in terms of promoting a sustainable lifestyle, better control of energy service flows and resource conservation. These measures would also result in improving livelihood security (generation of employment through local industries) and enhance energy security by the overall reduction in energy demand.

The action on **Environmental Infrastructure & Municipal Services** comprises of creating various infrastructures such as solid waste management facilities and sewage treatment plants. Apart from direct mitigation benefits, these are important in realizing other co-benefits such as promotion of 3R and enhancing the quality of life. For example, a modern landfill can also be a source of fuels in the form of land fill gas (LFG), pellets and fluff, which can be used in the local industries. Significant improvements can be realized in the public services domain by standardization of consumption and shifting to energy efficient lamps.

The action on **3R,** targets primarily at reducing the energy intensity of the output from the local economy. By constructing common facilities at the city level, one can actually reduce, reuse and recycle many resources and thereby move on to the sustainable style of living. This would give an added incentive of energy reduction.

The larger framework of **Governance** comprises of how to govern the city. Local government executes at the interface of the state and the centre and therefore has to plan, implement and coordinate a host of activities. To facilitate a smooth transition to a low carbon city, the local government of Ahmedabad would need an effective governance and institutional mechanism. Governance initiatives will have an overlapping influence in ensuring sustained sectoral emission reductions. In the residential and commercial sector, effective governance would comprise of implementing uniform building codes, ensuring faster penetration of energy labeling programs and greater public awareness about reducing energy consumption. In the transport sector, governance initiatives should focus on better city planning (to reduce congestion, and encourage shorter movements) and standardizing vehicle efficiency norms. And in the industry and power sector, it comprises of implementing energy efficiency standards and ensuring mandatory fuel switch to cleaner fuels.

In the context of developing nations, **Financing** plays a key role in any low carbon initiative over and above the business as usual transition. Thus, the deep emission cuts would involve substantial investments in low-carbon infrastructure. Besides, these infrastructure and technology choices would also lead to some economic losses (GDP), which would translate into developmental loss and would have to be compensated through either international investments and technology transfer. For ensuring a transition to a low carbon society, various financial initiatives would be necessary at the local level. In the building sector, financial incentives are needed for energy efficiency improvements (advance technologies in end use devices), and initiatives like green buildings. In the transport sector, financial support is needed for huge investments in public transport infrastructure, modern transport technology (traffic management), and incentives to promote efficient vehicles. Industry sector needs to be supported with financial initiatives such as tax benefits for investments in efficient and low carbon technology equipments. For the power sector, investments in CCS and renewable energy technologies need to be appropriately supported financially.

Municipal Services from LCS perspective

From the perspective of electricity usage for municipal services, the major forms of energy usage comes from street lighting and electricity for water pumping, treatment and distribution. From the government estimates, it is found that in the base year of 2005 21.89 ktoe energy was used in such services. This is projected to increase to 46.97 ktoe in 2035 BAU and 80.77 ktoe in 2050 BAU. This is mainly due to the expansion of the city limits, and therefore more energy used for street lighting and energy for water. There are significant electricity saving opportunities that exist in this sector, chiefly due to energy efficiency measures, automation of street lighting, automation in water plants, and implementing demand side measures for curtailing the water requirements in the domestic and commercial sector.

Governance & Financing

At the outset, governance structure is a hierarchical web of interactions at various levels. These interactions, popularly termed as organization structure, help in delineating responsibilities and setting up jurisdictional boundaries. For e.g., AMC is divided into various zones and each zone has Deputy Municipal Commissioner with the overall responsibility of the zone. However many common and overlapping functions are aggregated at the AMC level, like water supply and production. These departments have to ensure coordination at all levels to facilitate implementation of any initiative. This becomes an onerous task for a large area, and therefore manifests itself in various inefficiencies. The local government has thus embarked upon various initiatives so as to solve this problem. One of the initiative is the Continuous Monitoring System – to bring more accountability and transparency (at all levels of governance).

Another aspect in the governance structure is the form of governing arrangement. AMC has come up with innovative forms of local governance, like Public-Private Partnership (implemented in Solid Waste Management Projects), Special Purpose Vehicle (like the BRTS project, and the Sabarmati Riverfront Development Project), among others. These forms help in managing policy implementation in a viable and effective framework.

Key function of the local government lies in coordinating, planning and implementing policies. However with a number of policy initiatives, and with overlapping governance structures; it becomes extremely difficult in achieving the desired results. For example, BRTS (bus rapid system) project is implemented via a Special Purpose Vehicle (SPV), a typical project structure which is run on commercial principles, but local implementation overlaps with jurisdictional responsibilities of various state departments like the traffic police, regional transport office. These offices come under the control of the state government and therefore, it is a challenge for the local authorities to remove the multifarious effects of coordination failure.

On Financing side, the options at the local level comprise of innovative mechanisms, like 'municipal bonds' and other innovative institutional arrangements. On the institutional front, for example; the Sabarmati River Front Project is a Special Purpose Vehicle, aimed at reclaiming land on the sides of the river Sabarmati. Not only improving the built environment through this initiative of an environmentally initiated infrastructure, this initiative aims to sell a part of the land claimed back on commercial basis. This improves the viability of the project and ensures speedy pay-back.

Thus in the overall framework of governance and financing, the set of activities like form, finance and structure; help in connecting with the framework of sustainability for the LCS society (from the resources side as well as from the consumption side). It also looks at the redistribution justice aspect, as people participate at the lowest levels and concern about the common citizen in the policy making process helps in ensuring equity in the decision making progress.

Most of the cities in the current context exhibit voluntary participation in various activities. These voluntary participations predicate upon the various sources like information. However most of the initiatives are achieved through private channels only and are in isolation. Therefore, one has to keep in mind that uniform sustainability frameworks can only be implemented through effective governance structures backed by policies, laws and regulations. And therefore, effective governance structures is a fundamental aspect in ensuring implementation of various LCS actions.

Snapshot of solid waste management

As a part of the 3R action, Ahmedabad is already doing a lot of activities pertaining to recycling and managing the waste system effectively. Apart from maintaining an efficient built environment, it also helps in providing opportunities for recycling some of the treated waste, particularly with regards to waste water.

The local government has taken many initiatives to improve the system of waste management. Among them the primary ones are : mechanized collection and transfer, door-to-door collection, privatization in collection and transportation, composting of 500 MT solid waste/day, construction of new sanitary landfill, palletization and methane recovery. Generation of electricity from waste (PSP) is also in planning stage.

The following table gives a snap shot of the progress made in the domain of solid waste management and the issues on which the local government is currently focusing. This is important to mention because in the sustainable scenario of LCS, this is a key initiative.

Operation	Unit	Issues / Remarks
Generation:	2100 MT/ day	Approx 500/capita/day
Collection: - % of total - Population covered: - Number of sweepers	 98% 100% 7358	 Lot of waste is thrown in open dumps No segregation at source.
Transportation - Total vehicles deployed	 127	Partially privatized
Storage - Waste storage pits	 708	
Disposal Two landfill sites	 770 Hectares	One landfill site is a non sanitary landfill. Hazard of groundwater contamination from leachate
Recycling	Largely informal through rag pickers	Rag pickers are exposed to a number of health hazards.
Composting (MT/day)	500	Outsourced to private company. 150 tonnes compost produced in a day
Pelletization (MT/day)	500	Still in planning stage.AMC has tied up with a private company. AMC will supply these pellets to industries as raw fuel to substitute conventional fuels.
Hazardous Waste	Disposed off at Secured facility	Two sites for Common Hazardous Waste TSDF (Treatment, Stabilization & Disposal Facilities) in the city

Energy and Environment Policies in India

There have been numerous policy initiatives, legislations and acts enacted and introduced in the environment and energy domain in India. These policies, legislations and acts have focused either individually on an environmental sector like water, air or they have targeted broadly the entire value chain of the energy sector. For example, the latest policy document adopted by the Government of India - the Integrated Energy Policy Roadmap, 2006. This policy road-map has been accepted by the Government of India (GoI) in 2009, and which broadly links energy sector to the goals of Sustainable Development by developing policies that promote 'efficiency' and reflect externalities associated with energy consumption.

Further in June, 2008; the Prime Minister of India released India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The plan identifies eight core "national missions" running through 2017 and directed ministries to submit detailed implementation plans to the Prime Minister's Council on Climate Change by December 2008.Emphasizing the importance of high economic growth rates, the plan "identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively." It says "these national measures would be more successful with assistance from developed countries", and pledges that India's per capita greenhouse gas emissions "will at no point exceed that of developed countries even as we pursue our development objectives."

The eight National Missions and their related targets are elucidated below in the table. These targets are in line with the mitigation of GHG emissions across many sectors, and therefore are important from the perspective of an LCS study.

No.	National Mission	Targets
1	National Solar Mission	Specific targets for increasing use of solar thermal technologies in urban areas, industry, and commercial establishments
2	National Mission for Enhanced Energy Efficiency	Building on the Energy Conservation Act 2001
3	National Mission on Sustainable Habitat	Extending the existing Energy Conservation Building Code; Emphasis on urban waste management and recycling, including power production from waste (3R)
4	National Water Mission	20% improvement in water use efficiency through pricing and other measures
5	National Mission for Sustaining the Himalayan Ecosystem	Conservation of biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers are projected to recede
6	National Mission for a "Green India"	Expanding forest cover from 23% to 33%
7	National Mission for Sustainable Agriculture	Promotion of sustainable agricultural practices
8	National Mission on Strategic Knowledge for Climate Change:	The plan envisions a new Climate Science Research Fund that supports activities like climate modeling, and increased international collaboration; It also encourage private sector initiatives to develop adaptation and mitigation technologies

Moreover, there are other specific programs identified for implementation, within the National Action Plan from the mitigation perspective. It mandates the retirement of old inefficient coal -fired power plants and supports R&D in making IGCC and super-critical technologies to be used as power plant technology. It also envisages initiatives like renewable portfolio standard for all states and mandatory energy audits for energy intensive industries. The plan also advocates for aggressive implementation of the energy labeling program.

Data Preparation

Further to the identification of qualitative storylines that bind the low carbon measures, it is also important to identify a large set of technical data and parameter values that are needed to estimate the effect of these measures on reducing GHG emissions. For example, technological parameters in the base year related to energy efficiencies are defined with respect to current efficiency levels, however, for future estimates, on account of reduced costs and several other developments, a higher penetration of better technologies is supposed to be taken. Similarly, for various sectors, there are specific quantitative parameters that would change, as we transit from the base year towards the intermediate year, and finally the target year of the modeling. Some of the important sectoral quantitative assumptions can be summarized as under:

Building Sector: Following a Top-Down approach, and using current electricity consumption data , per capita electricity usage was projected based on references for other similar income cities in the world. In order to corroborate the results, a Bottom-Up method, comprising of appliance ownership level was also used for base year. For the commercial sector, property tax collection information and commercial property tax rate was used as information base for calculating the commercial floor space area.

Transport Sector: The methodology of demand estimation follows the estimation of passenger demand by the Per Capita Trip Rate (PCTR) method. Hence, Passenger travel demand = PCTR x Population X Distance x Modal share. Based on this methodology, passenger travel demand is estimated for the various BAU and CM scenarios. These demand estimates are represented in the table on the next page.

Table 4: Appliance penetration in residential & commercial sector

End Use	CAGR	Diffusion (number per 100 household)	
		2005	2050
Air conditioners	4.06	10	60
Refrigerators	2.5	47	70
Washing Machine	4.58	8	54
Computers	4.06	10	60
CFL	5.68	5	60

End Use	2050 BAU		2050 LCS	
	Reduction Potential	Penetration	Reduction Potential	Penetration
Lighting	66%	50%	66%	70%
Cooling	20%	40%	25%	50%
Computers	20%	50%	25%	70%
Water Heaters	50%	50%	50%	60%
Refrigerators	20%	50%	25%	60%

Table 5: Travel demand in various scenarios

S.no.	Scenario	Mode	Modal Share	Passenger Travel Demand (million km/year)
			All Modes	All Modes
1	Base 2005	tptw	25.00%	3722.64
		tpsv	23.00%	3424.82
		tplv	1.60%	238.25
		tpbs	14.40%	2144.24
		tptr	0.00%	0.00
		Bike	14.00%	2084.68
		Walk	22.00%	3275.92
	Total in Base Year	**(All Motorized)**	**100.00%**	**14890.54**
2	BAU-2035	tptw	24.00%	12922.19
		tpsv	15.00%	8076.37
		tplv	1.10%	592.27
		tpbs	15.90%	8560.95
		tptr	8.00%	4307.40
		Bike	11.00%	5922.67
		Walk	25.00%	13460.62
	Total in BAU-2035	**(All Motorized)**	**100.00%**	**53842.46**
3	CM-2035	tptw	16.00%	8614.79
		tpsv	9.00%	4845.82
		tplv	2.50%	1346.06
		tpbs	28.50%	15345.10
		tptr	8.00%	4307.40
		Bike	11.00%	5922.67
		Walk	25.00%	13460.62
	Total in CM-2035	**(All Motorized)**	**100.00%**	**53842.46**
4	BAU-2050	tptw	7.00%	9756.01
		tpsv	15.00%	20905.74
		tplv	3.40%	4738.63
		tpbs	36.60%	51010.01
		tptr	8.00%	11149.73
		Bike	8.00%	11149.73
		Walk	22.00%	30661.75
	Total in BAU-2050	**(All Motorized)**	**100.00%**	**139371.60**
5	CM-2050	tptw	2.00%	2229.95
		tpsv	5.50%	6132.35
		tplv	2.85%	3177.67
		tpbs	31.65%	35288.89
		tptr	8.00%	8919.78
		Bike	15.00%	16724.59
		Walk	35.00%	39024.05
	Total in CM-2050	**(All Motorized)**	**100.00%**	**111497.28**

A Procedure to create local LCS scenario

In order to create a local low-carbon society scenario, we developed a method based on the idea of "back casting", which sets a desirable goal first, and then seek the way to achieve it. Figure 27 shows overview of the method.

(1) Setting framework

Framework of an LCS scenario includes; target area, base year, target year, environmental target, number of scenarios. Among them, the base year is compared with target year. The target year should be far enough to realize required change, and near enough to image the vision for the people in the region. In this study, we set the target year of Ahmedabad as 2035. This is also a suitable time span for an LCS study for the reasons above and also, in line with the explanation given earlier (p 8). As an environmental target, we targeted CO_2 from energy use because it will be a main source of GHG emissions from Ahmedabad in 2035.

(2)Assumptions of socio-economic situations

Before conducting quantitative estimation, qualitative future image should be written. It is an image of lifestyle, economy and industry, land use and so on. For this, we made assumptions about the future in Ahmedabad on various dimensions; such as economy, population, land use, etc. These assumptions were either based on the city CDP, or other government estimates about socio-economic conditions.

(3)Quantification of socio-economic assumptions

To estimate Snapshot based on future image of (2), values of exogenous variables and parameters are set. Using those input, ExSS calculates socio-economic indices of the target year such as GDP, output by industry, transport demand, and so on.

(4)Collection of low-carbon measures

To collect counter measures which are thought to be available in the target year. For example, high energy-efficiency devices, transport structure change such as public transport, use of renewable energy, energy saving behavior and carbon sink. Technical data is required to estimate their effect to reduce GHG emissions. In this research we employed those assumptions which are in line with a developing economy and also, considering the fact that in 2035 quite a number of advanced technologies and systems would penetrate into India, and thus Ahmedabad.

(5)Setting introduction of counter measures

Technological parameters related to energy efficiencies are defined with respect to current efficiency levels and also, its acceptance. In future estimates, such consideration as more penetration due to cost decrease is taken into account in specifying estimates about certain technologies.

(6)Estimation of GHG emission in the target year

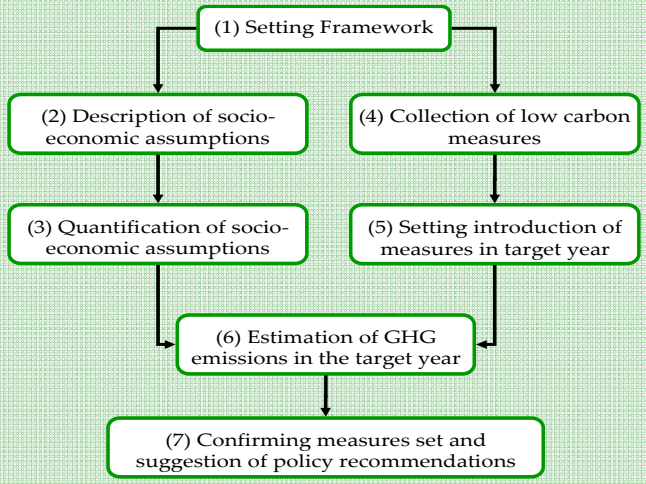
Based on socio-economic indices and assumption of measures' introduction, GHG emissions are calculated.

(7)Proposal of policies

Propose policy set to introduce the measures defined. Available policies depend on the local situation of Ahmedabad. ExSS can calculate emission reduction of each counter measure.

Therefore, it can show reduction potential of measures which especially needs local policy. It can also identify measures which have high reduction potential and therefore important.

Figure 23. Procedure to create a local LCS scenario



"Extended Snapshot Tool"

Figure 28 shows the structure of the Extended Snapshot Tool (ExSS); seven blocks with input parameters, exogenous variables and variables between modules. ExSS is a system of simultaneous equations. Given a set of exogenous variables and parameters, solution is uniquely defined. In this simulation model, only CO_2 emission from energy consumption is calculated, even though, ESS can be used to estimate other GHG and environmental loads such as air quality. In many LCS scenarios, exogenously fixed population data are used. However, people migrate more easily, when the target region is relatively a smaller area such as a state, district, city or town. Population is decided by demand from outside of the region, labor participation ratio, demographic composition and relationship of commuting with outside of the region. To determine output of industries, input-output approach with "export-base approach" is combined in line with the theory of regional economics.

Industries producing export goods are called "basic industry". Production of basic industries induces other industries i.e. non-basic industries, through demand of intermediate input and consumption of their employees. Number of workers must fulfill labor demand of those productions. Given assumptions of where those workers live and labor participation ratio, population living in the region is computed. This model enables us to consider viewpoints of regional economic development to estimate energy demand and CO2 emissions. For future estimation, assumption of export value is especially important if the target region is thought to (or, desired to) develop led by particular industry.

Passenger transport demand is estimated from the population and freight transport demand is a function of output by industries. Floor area of commerce is determined as the driving force for com-

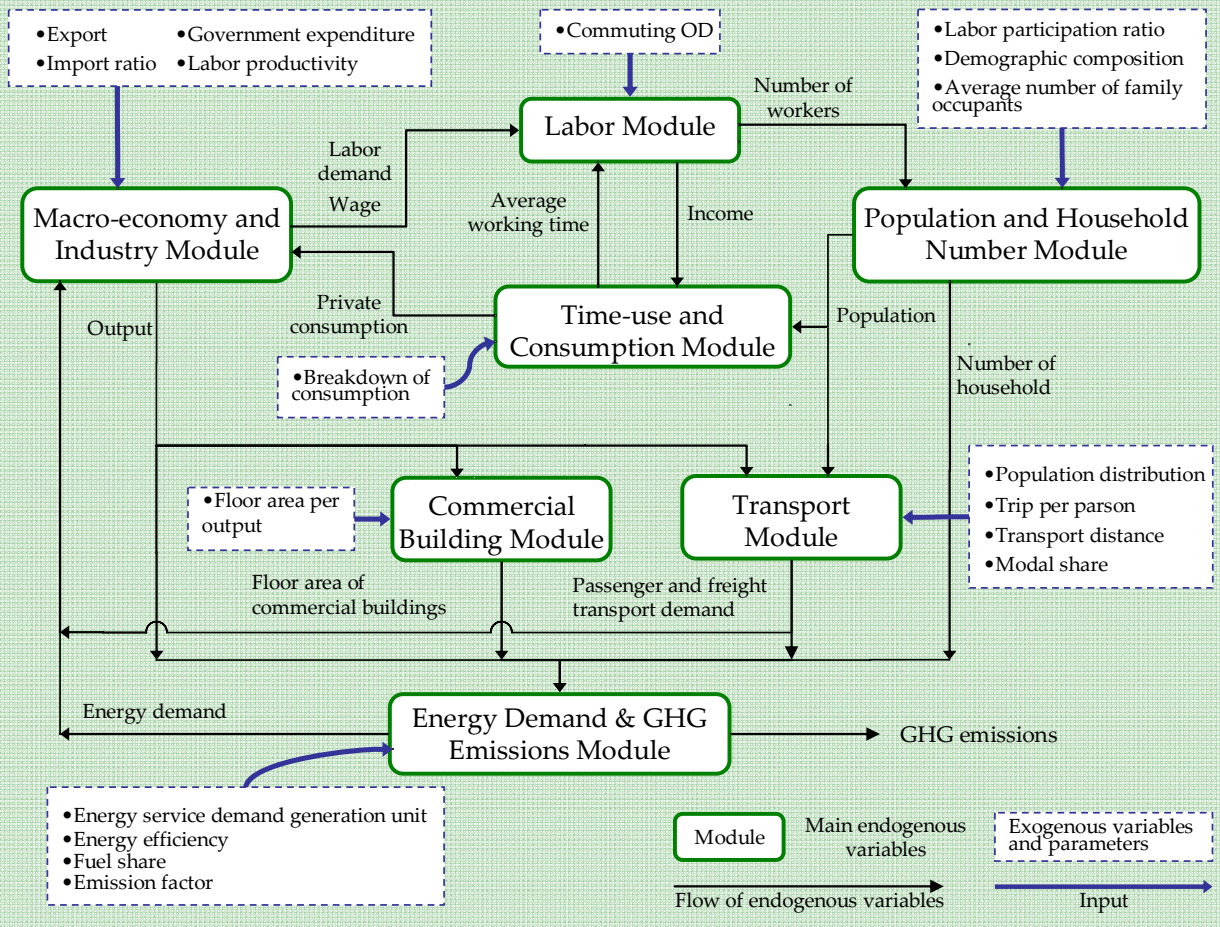
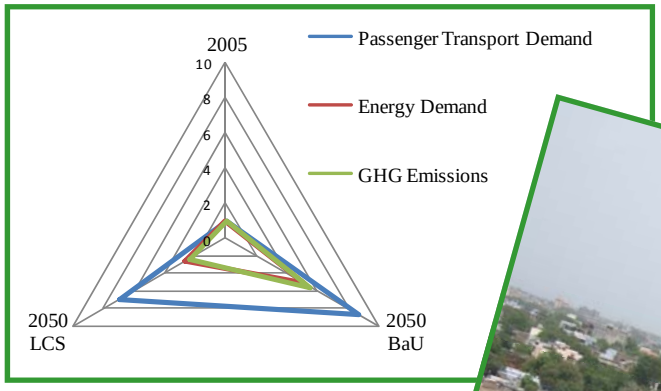


Figure 24. Overview of calculation system of Extended Snapshot Tool



Japanese partner institute Logo

< To be added by the Japanese team)

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