















# Low Carbon Society Scenario Bhopal 2035





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### Foreword

Of all cities in India and, perhaps, of the world, Bhopal has a unique topographic configuration in which hills and lakes segment the city into sub-cities which, though linked to the core are yet almost self-sufficient in themselves. This is one metropolitan agglomeration which has inbuilt disaggregation in terms of population and activity distribution. In other words, this is a city which lends itself to decentralised growth and management.

The lakes of Bhopal, in particular the Upper Lake and the Lower Lake, together with the hills Manva Bhand, Idgah, Ahmedabad, Shyamla, Arera, Char Imli, Shahpura, MANIT and IIFM, provide huge open spaces which act as the lungs of the city. Because the hills have been brought under afforestation or low density public use we have in and around Bhopal almost 12,000 ha. (30, 000 acres) of land under tree growth. This is an enormous vegetation pool for absorption of carbon dioxide and particulate matter. Because the hills around the lakes are afforested there is root zone treatment of run-off and, therefore, this acts as a natural filter for keeping the water bodies relatively clean.

On the negative side is the frenetic building activity taking place in the southern sector of the city and along the Bhopal bypass which moves in an arc along the northern and eastern periphery of the city. These new developments are not ecology friendly and planners must immediately intervene to ensure that the basic green character of Bhopal is not disturbed.

A dispersed population is spread over a far wider area than the same numbers residing in an urban concentration. At the same time the transport system to move people around this segmented city does add pollutants to the atmosphere. The planners must find a balance in which public transport begins to dominate and the modes of transport are environment friendly. Coupled with this is the need to clear up waterways such as Banganga, Patranala, Kaliasote River and protect other rivers such as Kolans, Uljhavan, Halali and Betwa, some of which drain into the Upper Lake and others which carry the waste water of Bhopal towards the Betwa. If these waterways are cleaned up Bhopal would certainly contribute its mite and move towards being an eco-friendly city.

Reduction in the number of vehicles on the road, measures to prevent pollution of the lakes and the planting of trees would certainly help in reducing the carbon footprint of Bhopal. The bonus would be that there would be simultaneous improvement in the health of the citizens, cleaner air and water and a better quality of life for even the poorest citizens. This has to be our goal for 2035.

The faculty and students of the School of Planning and Architecture, Bhopal and Maulana Azad National Institute of Technology, Bhopal have worked on precisely the above mentioned issues and compiled a report on the action areas which need urgent attention. The report is comprehensive, the findings are of great public interest and solutions suggested are practical. These are the kinds of initiatives that we need if Bhopal is to really develop as a low carbon environment friendly city, a city whose micro climate has benefited by human intervention and a city which is bidding fair to becoming the most livable city in India.

M.N. Buch Chairman National Centre for Human Settlements and Environment

Bhopal June, 2011

### **Executive Summary**

All over the world, cities are major contributors to Greenhouse Gas (GHG) emissions and the same is true for the cities in India. In pursuit of environment friendly development, many cities in various parts of the world have attempted to design and implement climate change mitigation and adaptation strategies. Developing low carbon cities is a step in that direction.

Developing Low Carbon Society (LCS) studies at city level gives a platform where researchers interact with stakeholders and policymakers to integrate their knowledge and build relevant scenarios for transition towards LCS. The LCS roadmaps thus achieved will help in integration of development activities, prioritize investments in urban infrastructure, and provide incentives for use of innovative technologies to improve efficiency. Another important contribution will be to promote behavioral and lifestyle changes.

To define the pathways towards reaching the desired goal of LCS, methodologies to workout a broad framework would be needed. This framework should also look at the opportunities of cobenefits apart from the direct GHG emissions reduction. Such co-benefits, like improved local ambient air quality and health benefits work towards minimizing social costs.

To analyze the role that urban settlements can play in moving towards LCS, it would be necessary to take cases studies of cities that show diverse characteristics. It would be useful to take-up large number of studies before any generalizations can be drawn as the cities that have grown over the years have distinct individualities that cannot be easily generalized. More so, in case of a country like India, the diversity in terms of climate, topography, resource-potential, economic-base and socio-cultural practices has resulted in a variety of development patterns. To explore and analyze the role of rapidly urbanizing metropolitan cities in India, towards moving on low carbon pathways, a case study of Bhopal located in Central India has been taken up.

In the present study, simulations for two possible scenarios namely Business as Usual (BaU) and Low Carbon Society (LCS) for Bhopal in 2035 are developed and emission reduction potentials of various counter measures are quantified using the AIM/ExSS model. Action plan and policy measures are suggested for moving towards the LCS Bhopal 2035.

The simulations show that the GHG emission and energy consumption increase in both the scenarios. The GHG emissions of Bhopal in 2005 were around 2.5 million ton  $CO_2$  which rise by around 6 times to 14.2 million ton  $CO_2$  in the target year 2035 under the BaU. However, with energy efficiency improvements, development of renewable energy, and other policies to promote sustainable development across all sectors, Bhopal has about 40% GHG emission reduction potential over BaU level in the possible LCS Scenario.

The scenario assessment shows that, of the total emission reduction potential, 50% would be due to fuel switch which is prominent in residential, commercial and industrial sectors; about 40% would be due to energy efficiency improvements mostly from residential, commercial, and transport sectors; and remaining around 10% would come from reduction in energy service demand in residential and transport sectors.

The LCS approach demands greater efficiency of energy consumption as well as reduction in GHG emissions. Pursuit of these goals presents wide ranging issues in urban transportation, industrial, residential and commercial sectors. Many of the measures in these areas overlap with each other.

In pursuit of developing LCS Bhopal 2035, the menu of policies and measures fosters numerous objectives and these policy priorities change and evolve constantly with challenges of the day. The overall vision of the LCS approach is to make Bhopal a more livable entity to all its residents. Seven Actions have been suggested that can impact the existing energy consumption pattern as well as GHG emissions in future. These actions have been defined with an understanding of the inherent strengths and potential of Bhopal district which can be explored at this time of rapid development.

A sustainable path taken now can guide tomorrow's growth in a more holistic and inclusive manner with little need of post-action course correction. These actions, though, identified separately for the ease of communication, are inseparably linked in the LCS framework and can only work in conjunction towards achieving the vision.

#### Seven Actions Towards LCS Bhopal 2035

GREEN GOVERNANCE	
	Government Initiatives Towards LCS
HOLISTIC HABITAT	
	Energy Efficiency in Buildings
SUSTAINABLE STYLE	
	Low Carbon Lifestyle
CELLULAR CITY	
	Multi Nuclei Land Use Planning
FORM AND FLOW	
	Integrating Transport with City Structure
NURTURING NATURE	
	Leveraging on the Natural and Historic Assets
RURAL RICHES	

• Promoting a Better Lifestyle in the Rural Areas

		SECTORAL CONTRIBUTION				
	ACTIONS	Residential	Commercial	Industry	Passenger Transport	Freight Transport
1	GREEN GOVERNANCE					
2	HOLISTIC HABITAT					
3	SUSTAINABLE STYLE					
4	CELLULAR CITY					
5	FORM AND FLOW					
6	NURTURING NATURE					
7	RURAL RICHES					

#### Sectoral Contribution in Emission Reduction from Seven Actions

The present literature on sustainable development and LCS indicates that it would need a significant transformation in the world energy use pattern. High energy intensity is an area of major concern and quantification of emissions reductions from current policy baseline is necessary. The study outcome shows that, Bhopal has rising population and higher share of tertiary sector in occupational pattern. To transform it into LCS would require an aggressive portfolio of policy measures coupled with strong environmental awareness, conservationist values and environmental integrity. The key policy measures are improving energy intensity (attainable with reducing energy service demand, lifestyle changes) along with access to low carbon power (hydro, nuclear), fuel switch in industrial and transport sectors and measures promoting end-use device efficiency specifically in transport, industrial and residential sectors.

This study is of special significance because the pathways to achieve the LCS are open for the developing countries and a framework for a LCS from the perspective of developing countries is evolving. It could be said that fast growing Indian cities have an opportunity to contribute to the climate change mitigation by developing on a low carbon pathway.

Bhopal June, 2011 Aashish Deshpande Manmohan Kapshe Sheuli Mitra Kshama Puntambekar

### Background

#### Introduction

International discussions have lately been focused on how the world community must reduce Greenhouse Gas (GHG) emissions by 60 percent by year 2050, to prevent global average temperatures from rising above 2°C over preindustrial levels. As each individual country will take the development path on the basis of its local resource endowments, it becomes imperative to focus on the possible incentives, that can help the developing countries in moving towards a lower carbon future. Care needs to be taken to account for the barriers that can retard the process. This translates into formulation of an integrated approach to sustainable development and a Low Carbon Society (LCS) requiring re-aligning development and climate priorities.

The main characteristic of LCS approach is to imbibe societies in transition to address not only the environmental challenges of climate change but also social, economic and political challenges among others.

#### Low Carbon Society - Concept

LCS is a sustainably developed or developing society on the basis of close, reasonable and harmonious coordination of economic and social development and environmental protection. In this society, environmental protection will be given the same level of attention as other socioeconomic development issues.

LCS has the following attributes:

- 1. Take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met.
- 2. Make an equitable contribution towards the global effort to stabilize the atmospheric concentration of  $CO_2$  and other greenhouse

gases at a level that will avoid dangerous climate change, through deep cuts in global emissions.

- 3. Demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies.
- 4. Adopt patterns of consumption and behavior that are consistent with low levels of greenhouse gas emissions.

LCS framework is not merely an approach of reducing GHG emissions. It also helps to achieve national development targets especially those related to effective and sustainable development.

With rapid urbanization, in the coming years India faces the challenges in economic development which have to be met with the limited resources available, with minimal externalities and large uncertainties with regard to climate change. From this perspective, the LCS approach gives alternative options for the future flow of energy through infrastructure and other behavioral and life style choices.

#### LCS Study for Bhopal

The urban population of Bhopal has increased at an average decadal growth rate of over 70% in the last four decades. Bhopal, being a growing urban centre in India, is a prototype city and has hence been selected as a suitable case study for implementation of the LCS framework. The study area has been delineated to include the entire district of Bhopal, which has considerable areas in the rural urban fringe. The planning area of the city of Bhopal constitutes a large part of the district. The development of the district thus holds great opportunities at this juncture, standing at the crossroads of a rural-urban interface, which if explored in the right perspective, would lead to a more sustainable vision.



A view of old city Bhopal

### Time Horizon, Target and Vision

#### **Time Horizon and Target**

The time horizon for achieving LCS targets is set for the year 2035. The objective is to align city development plans and policies with national and global targets.

The target is 40% reduction in 2035 Business as usual (BaU) emissions. The BaU scenario of 2035 has been computed envisaging the continuation of present government policies, existing technologies, lifestyles and energy consumption patterns.

#### **Business as Usual Bhopal 2035**

The present trend in Bhopal has been extended to future with existing technology in residential, commercial, transport and industrial sectors with prevailing economic and demographic trends. The BaU scenario for future emission projection in Bhopal city envisages the continuation of present government policies, and capture forecast for various economic, demographic, land use and energy use indicators. In the BaU scenario the air pollution levels continue to grow over the three decades of projection period. Using historic trends, in the transport and residential sector the energy and emission scenario has been drawn for three decades, assuming that all the past growth rates will continue in the future. In this scenario no specific interventions are taken however all policy initiates are incorporated. The BaU scenario shows us the projected picture bringing out the extent of the problems in future.

#### Low Carbon Society Bhopal 2035

For analyzing the possibilities of reducing the GHG emissions in future a sustainable development future scenario is drawn here for Bhopal that is expected to take it towards Low Carbon Society. For managing energy emissions and driving the urban eco-system towards balance, the city has to work as an organic whole and the effects of all significant activities are made apparent. In this process the citizens and the policymakers make informed choices. The governance and management process is taken to be rooted in sustainability that takes decisions which not only address the interest of the present stakeholders but also of the future generations.

#### **Bhopal LCS Vision**

- To be sustainable and low carbon in line with national policies
- Ready for future and resilient to change
- Conservation and green orientation for quality of life
- Economic and social competitive clean and green industries
- Efficient transport system
- Community participation in city development

Time Horizon: Year 2035

**Reduction Target:** 40% of 2035 BaU Emissions



**Biomass Burning contributes to local pollution** 



Possibility of low rise green development

### The Profile

Bhopal, the capital city of the state of Madhya Pradesh, is one of the many cities in India, growing at a very fast pace. Historically, the identity of city of Bhopal is linked with the feudal State of Bhopal as its capital and the large man-made lakes. After the reorganization of states in 1956 Bhopal was declared to be the capital of Madhya Pradesh. By then, it had already acquired a complex urban structure. However, it was only after 1956 that the spectacular growth of Bhopal started and it began to sprawl across the adjoining areas.

#### **Climate and Geographic Settings**

Bhopal is situated on the Malwa Plateau spreading across the central part of India. It lies in hilly terrain, sloping towards the North and South East. It has an average elevation of 576 meters above MSL, which is higher than the north Indian plains with the land rising towards the Vindhya Range to the south. Bhopal has uneven elevation and has a number of small hillocks within its boundaries and also includes large water bodies and forest areas in close proximity to the urban area. The location, geographic and demographic characteristics of Bhopal are given in Table 1 and Figure 1 & 2.

Bhopal faces hot and dry summers and mild winters. The minimum temperature reaches 6°C for a few days in winter. The hot and dry summers are followed by rainy spells due to monsoonal winds. The rainfall is concentrated in the months of July and August; however there are isolated rains throughout the year.

Table 1: Geographic characteristics

Latituda	
Latitude	77.35 N
Longitude	23.25 E
Altitude	550-600 MSL
Max Temp.	45 degree Celsius
Min Temp.	06 degree Celsius
Av Rainfall	900-1220 mm
Planning Area	2772.4 Sq km (601 Sq km urban plan area)

Research and the second second

Figure 1: Location of Bhopal District- the study area



Source: BDP (2005)

Source: BDP (2021)\*

**Figure 2: Tracing the growth of Bhopal with development plans** \* *Bhopal draft development plan 2021 has been put on hold by the State government* 

#### **Demographic Characteristics**

Bhopal had a population of 85,000 in 1956 at the time of declaring it is as the State Capital. The city became a metropolis with 1.063 million population in 1991. The population of Bhopal city has increased at an average decadal growth rate of over 70% during the last 4 decades. As per the Census 2011 provisional estimates, the population of Bhopal district in 2011 is 2.36 million. Estimates indicate that the population of Bhopal district would grow to around 4.5 million by 2035. The population characteristics are indicated in Table 2.

Table 2: Popul	lation characteristics
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Population Bhopal District (2001)	18,43,510
Population Bhopal Municipal Limit (2001)	14,33,875
Urban Population %	80.53
Growth rate (1991-2001)	36.85
Literacy rate	79.99
Sex ratio	1000:898

Source: Census (2001 a)

#### Land use

The land use in Bhopal is represented in seven broad categories of Residential, Commercial, Industrial, Public and Semipublic, Public utilities, Recreational and Transportation. The maximum share of land allocations in the Bhopal Development Plan (BDP) 1991, was under the residential category having 45% followed by recreational (15%) and transportation (13%) (Figure 3).



Figure 3: Land use allocation in development plans

#### **Economic Development**

On the economic front the city is growing as a multifunctional capital city. In a recent assessment, Bhopal has ranked 77<sup>th</sup> in the list of fastest growing cities in the world with an estimated annual average growth of 2.69% for the period 2006-2020 (citymayor.com). Figures from the Census of India 2001 show Bhopal as the 17th largest city in India.

In recent years, Bhopal has seen a decline of industries, traditional especially the engineering support and component manufactures that originally grew up around the Bharat Heavy Electricals Limited (BHEL). The service sector is becoming dominant and provides the majority of employment in Bhopal. The District Gross Domestic Product (DGDP) has grown from 45 billion INR in 2001-02 to 70 billion INR in 2005-06 at an annualized short term growth rate of 2.59% (Figure 4).



Figure 4: Bhopal district GDP (at current prices)

For the year 2005-06, the tertiary sector contribution to DGDP was more than 75% in the domestic economy (Figure 5). The occupation in tertiary sector has been continuously increasing over last four decades and percentage of workers in secondary sector has declined substantially whereas the primary sector share has declined marginally.



Figure 5: Sectoral distribution of DGDP (2005-06)

Source: Indicus Analytics



Vallabh Bhavan: The Secretariat

#### **Residential Sector**

As per the Census 2001, (Table 3) 97% of the households in Bhopal district have access to electricity as source of lighting. 443 households also use the solar energy for lighting.

Table 3:	Households	by source	e of lighting
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S. No	Source of lighting	Number of households
1	Electricity	323,091
2	Kerosene	11,152
3	Solar energy	443
4	Other oil	200
5	Any other	158
6	No lighting	332
	Total	335,376

Source: Census (2001 b)

The type of fuel used for cooking is an important determinant of the strategies that would be needed to address the emission concerns in Bhopal. Table 4 summarizes the distribution of households by the type of fuel used for cooking.

#### Table 4: Households by type of cooking fuel

S. No.	Type of fuel used for cooking	Number of households
1	Firewood	81,146
2	Crop residue	3,850
3	Cow dung	8,805
4	Coal, Lignite	1,133
5	Kerosene	86,470
6	LPG	150,636
7	Electricity	526
8	Biogas	706
9	Any other	647
10	No cooking	1,457
	Total	335,376

Source: Census (2001 b)



**BRTS work in progress** 

#### **Transport Sector**

Like all the major cities in India, Bhopal has also witnessed a very high vehicular growth. In the last two decades, the total motor vehicles have grown more than three times, and this growth is driven by two wheelers which have grown by more than three times followed by the large vehicles (buses, trucks, etc.) that have grown more than five times during the period. Of the total vehicles registered every year in Bhopal, two wheelers accounted for 79% in 1987-88 which increased to 94% in 2003-04. However, since 2003-04, with rising income and prosperity, the share of four wheelers plying on roads is growing rapidly (Figure 6).



Figure 6: Vehicles registered in Bhopal

#### Source: RTO Bhopal (2006-07)

The transport infrastructure in Bhopal is being transformed with widening of roads, over bridges on railway crossings, flyovers for fast transit, multistory parking at various locations, and pedestrian subways at major traffic points. Bhopal Municipal Corporation (BMC) under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) scheme has initiated Bus Rapid Transport System (BRTS) plan for Bhopal in phased manner (Figure 7).



Source: BCDP (2005)

#### **Energy Consumption and Emissions**

The energy consumption in Bhopal is growing rapidly. The electricity consumption for the year 2007-08 in Bhopal was about 940.83 million kWh (District Development Report 2007-08) of which Bhopal urban has been consuming more than 580 million kWh.

The share of residential sector has been highest with 58% of the total electricity consumption, followed by commercial 19% and others 18% and industrial sector accounting for 5%. Different sectors consume different forms of energy. However, in the total energy consumption, fuel wood, LPG and kerosene constitute more than 70% and the balance is distributed amongst Coal, Petroleum, and Electricity, etc. Table 5 shows the sector wise

Sector	Energy/Fuel	Quantity
	1. Electricity (M kWh)	340.1
I Decidential	2. LPG (MT)	49,240
1. Residential	3. Fuel wood (MT)	1,275.30
	4. Kerosene (kL)	11,941
	1. Electricity (M kWh)	112.9
II. Commercial	2. LPG (MT)	2,184
	3. Kerosene (kL)	2,388
III. Industrial	1. Electricity (M kWh)	29.5
N. Transportation	1. Diesel (kL)	59,369.80
iv. mansportation	2. Petrol (kL)	48,842.50
V. Waste	MSW (tpd)	550
VI. Others	Electricity (M kWh)	103.8

Table 5: Sector wise energy use (2007-08)

Source: ICLEI (2008)

energy consumption distribution in Bhopal urban for the year 2007-08.

A study carried out by ICLEI - Local Governments for Sustainability, in association with City Mayors Association, Bhopal shows that for the year 2007-08 the annual emission contribution from various activities in Bhopal Municipal Corporation area was about 0.74 Million TeCO<sub>2</sub>.

It can be also be observed that contribution of Industrial sector in  $CO_2$  emissions is very little (3%) whereas the residential, commercial and transport sector contribute more than 80% of  $CO_2$  emissions (Table 6).

It can be observed that for emission reduction primarily residential and transport sector needs to be targeted. The waste management and other sectors though their emission contribution is around 10%, can also contribute as there are, right now, no practices which are addressing emission reduction concerns.

#### Table 6: Carbon emissions in urban area (2007-08)

S. No.	Sector	CO <sub>2</sub> Emissions
I.	Residential	36%
II.	Industrial	3%
III.	Commercial	11%
IV.	Transportation	39%
V.	Waste	2%
VI.	Others	9%

Source: ICLEI (2008)



**Fuel Station** 



**Transportation of LPG Cylinders** 

### Socio-economic Scenario

### Socio-Economic Assumptions and Estimates for the Future

The energy consumption and emissions in a city are dependent on the demographic characteristics and economic development of the region. With rapid population increase Bhopal has grown from a small town to a hub of many economic activities. Development has touched every aspect of life in the city, from potable water and sewage systems to roads and the vehicles that ply on them. Using the growth rates from United Nation (UN) medium term population projections for India, UN World Urbanization Prospects 2009 and Census of India future estimates for Madhya Pradesh, it is assumed that the population of Bhopal district would grow from 1.8 million to 4.5 million by 2035. With the changing life style and growing nucleated family system the household size is assumed to reduce to 4 from the 5.1 (Census, 2001 a). Using these assumptions about population, household size and other assumptions (Table 7), future socio-economic indicators in 2035 are estimated by the AIM/ ExSS model. A summary of model estimates for the economy, the households and transportation sector are given in Table 8.

Table 7:	Socio-economic	assumptions
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Indicators	Assumptions for Year 2035
Population	4.5 Million
Household size	4
Demographic composition	0-14 [26%], 15-64 [67%], 65+ [7%]
Primary Industry Exports	CAGR 3.0%
Secondary Industry Exports	CAGR 5.8%
Tertiary Industry Exports	CAGR 5.9%
Private Consumption	CAGR 1.1%
Government Consumption	CAGR 5.9%
Fixed Capital Formation	CAGR 5.9%
Exports	CAGR 5.9%
Transport Passenger	Increase 17% Decadal [Modal share NMT (29%), Public Transport (17%), Four wheelers (Pvt+IPT) 14%, Two Wheelers (40%)
Transport Freight	Increase 2% Decadal

**Economy:** The AIM/ExSS model estimates that the Bhopal economy will grow rapidly with district GDP rising from INR 70 billion in 2005 to 400 billion in 2035 where tertiary sector contribution will grow at about 6% CAGR followed by secondary sector at 5.8% and primary sector at 3% CAGR. Using an Input-Output framework, the model estimates changes in the structure of the economy with shift towards service sector from 57% in 2005 to 61% in 2035. This shift is attributed to decline in the secondary sector share from 38% to 35% in the same period. The primary sector share remains almost same with about 1% increase in three decades.

**Households:** Along with rapid rise in population the number of households is expected to grow from present 386 thousands to 1136 thousands.

**Commercial sector:** The total floor space for commercial activities has been estimated to grow from 61 sq. km in 2005 to 431 sq. km in 2035 as per the rise in tertiary sector's contribution in the domestic economy.

**Transport sector:** The motor vehicle density is expected to rise with increase in motor vehicle fleets and population growth. The passenger transport demand would grow from 5 billion passenger-km in 2005 to 25 billion passenger-km level in 2035 and the freight transport demand would grow to 3.5 billion ton -km in 2035 from 0.6 billion ton-km in 2005.

Table 8:	Estimates	of socio-econ	omic in	dicators

Parameter	2005	2035 BaU
Household	0.4 Million	1.1 Million
GDP	70 Billion INR	403 Billion INR
GDP per capita	33 Thousand INR	94 Thousand INR
Gross Output	125 Billion INR	754 Billion INR
Primary Sector	5 Billion INR	16 Billion INR
Secondary Sector	45 Billion INR	257 Billion INR
Tertiary Sector	75 Billion INR	481 Billion INR
Floor Area	61 Sq. Km	431 Sq. Km
Passenger Transport	5 Billion P Km	25 Billion T Km
Freight Transport	0.6 Billion T Km	3.5 Billion T Km

### Energy and Emissions: 2035

Based on scenario quantification using the macro economic data, future energy demand and corresponding GHG emission in 2035 are estimated. The final energy demand in Bhopal is projected to rise more than three times to 3 million toe in 2035 where the share of residential sector would be 43% followed by industry with 28% and transport sector with 21% (Figure 8).

About 80% of the energy demand will be met by coal and oil resources in the year 2035. Gas follows with 8%, more than half of which is going to transport sector and almost equal share of the remaining to residential and industrial sectors. The renewable energy sources, specifically hydro power, nuclear and solar energy shows a growing contribution in the energy mix.

In the year 2035, for the low carbon society scenario, the energy mix will shift towards cleaner fuel with almost doubling of renewables share from 12% in BaU to 22% (Figure 9).

In this scenario the coal and oil will decline by half in quantity whereas the natural gas would grow with renewable energy sources. With this energy demand mix, the GHG emissions for Bhopal would rise from 2.5 million  $tCO_2$  in 2005 to 12.0 million  $tCO_2$  in 2035 BaU scenario and would decline to 7.0 million  $tCO_2$  in 2035 LCS scenario (Figure 10). A sectoral analysis of GHG emissions shows that the contributions from building sector for Bhopal would rise more than 5 times compared to year 2005 in BaU scenario.

Similar rise in GHG emissions contribution would also come from the passenger and freight transport sector in the same period. The per capita GHG emissions contribution would be more than two times from 1.2 tCO<sub>2</sub> in base year 2005 to 2.6 tCO<sub>2</sub> in the 2035 BaU scenario and would decline to 1.5 tCO<sub>2</sub> in 2035 LCS scenario (Figure 11).



Figure 8: Final energy demand by sector



Figure 9: Energy demand by primary energy



Figure 10: GHG emissions by sector



Figure 11: Per capita GHG emissions

### Mitigation Potential: 2035

In low carbon society development scenario for the projection year 2035, the model estimates that the total GHG emissions in Bhopal is to be reduced to 7 million  $tCO_2$  from 12 million tCO<sub>2</sub> in BaU scenario. This accounts for more than 40% GHG emissions reductions (Figure 12).

The largest reduction of 2.4 million tCO<sub>2</sub> would come from fuel switch. The energy efficiency improvements in buildings from residential and commercial sectors would provide 33% of the total emission reduction potential with 1.6 million  $tCO_2$  in the LCS scenario followed by reduction in energy service demand (9%) and energy efficiency improvements in transport (5%) and industrial (3%) sector.

Bhopal being an administrative capital with rising population and having higher share of tertiary sector in occupational pattern, in pursuit of a low carbon society development, would require an aggressive portfolio of policy measures.

Key policy measures for improving energy intensity (attainable with reducing energy service demand, lifestyle changes) along with access to low carbon power (hydro, nuclear), fuel switch in industrial and transport sectors and measures promoting end-use device efficiency specifically in transport, industrial and residential sectors, would be needed.





Developing walkways along the roads



**Encouraging non-motorised transport** 

#### **Residential Sector**

Energy use by households depends on the level and specific mix of energy services used and the energy required to deliver those services. In growing cities like Bhopal average per capita energy services will rise significantly with change in life style, augmentation of household equipment coupled with increase in per capita income.

The number of households in Bhopal is estimated to rise from 0.4 million in 2005 to 1.1 million in 2035 (Figure 13). This rise is attributed to increase in population and rapid urbanization leading to reduction of household size from 5.1 (census 2001) to 4 persons per household. Rise in number of households is the major driver for energy requirement. In the residential sector the final energy demand rises from 429 ktoe in 2005 to 1305 ktoe in 2035 BaU scenario, which is reduced to 892 kote in 2035 LCS scenario, correspondingly the GHG emissions changes from 1.0 million tCO<sub>2</sub> in year 2005 to 5.6 million tCO<sub>2</sub> in 2035 BaU scenario (Figure 14).

The GHG emissions in 2035 LCS scenario is estimated to be 49.9% lower than the 2035 BaU scenario. The reduction of 2.8 million  $tCO_2$ emission in the 2035 LCS scenario would mainly come from energy efficiency improvements end-use devices and shift towards cleaner fuel.



Figure 13: Number of households



Figure 14: Change in residential sector



**Construction activities** 



**Construction activities** 



New residential and commercial developments



**Government housing** 

#### **Commercial Sector**

The commercial floor space area is estimated to rise from 61 sq. km in 2005 to 431 sq. km in the year 2035 (Figure 15). This can be attributed to increased commercial activities as Bhopal being an educational hub and administrative city has a higher tertiary sector occupational share in the economy.

The commercial floor space is also a major driver for energy demand. By inducing change in the energy mix of the power supply and end use device efficiency, the final energy demand changes from 0.06 million toe in 2005 to 0.24 million toe in 2035 BaU scenario, which reduces to 0.19 million toe in 2035 LCS scenario (Figure 16). The corresponding GHG emission reduces from 1.4 million tCO<sub>2</sub> in 2035 BaU to 0.76 million tCO<sub>2</sub> in 2035 LCS scenario.









**Existing Commercial Areas** 

#### Freight Transport

Fright transport is needed to develop the commerce and industry base. A six fold rise in freight transport demand is expected in the BaU scenario where small and medium trucks have largest modal share (Figure 17). This rise in freight transport service demand leads to fivefold rise in energy demand and GHG emissions. In the 2035 BaU scenario the energy demand rises to 131 ktoe and declines to 110 ktoe in the LCS scenario. Correspondingly the GHG emissions declines from 0.4 million tCO<sub>2</sub> in 2035 BaU scenario to 0.3 million tCO2 in LCS scenario (Figure 18). This 24% GHG emission reduction can be attributed to the policy measures for energy efficiency improvements, fuel shift and travel demand management.







New Commercial Development

#### **Passenger Transport**

Every city's pulse is its transport. The passenger transportation provides the mobility necessary for social development. The passenger transport sector in Bhopal is characterized by the higher number of two wheeler vehicles and large distances they are driven with its spatial distribution. The passenger transport demand is expected to grow by about 5 times from 5.2 billion P-km in 2005 to 25 billion P-km in 2035 BaU scenario and with integrated transport management measures this marginally declines to 24.1 billion P-km in LCS scenario (Figure 19). This spurt in demand results in 5 times rise in the energy demand to 510 ktoe which in LCS scenario declines to 287 ktoe. Correspondingly the GHG emission reduces from 1.4 million  $tCO_2$  in 2035 BaU scenario to 0.9 million  $tCO_2$ in LCS scenario (Figure 20), accounting towards the 40% emission reduction. Most of the mitigation can be achieved with enhanced vehicle efficiency, modal shift, increasing use of public transport and improved transport system.



Figure 19: Passenger transport demand



Figure 20: Change in transport (Passenger)



Use of bicycle: an alternative



**City public transport** 



**Redesigning the rotaries** 

#### **Industrial Sector**

In this study, the industrial sector as energy consuming sector consists of both primary and secondary industries of Bhopal and comprises of agriculture, fisheries, mining, forestry, manufacturing and construction activities. Assuming an average annual GDP increase of 5.8%, the output of industrial sector will rise more than five times from 50 billion INR in 2005 to 265 billion INR in the year 2035 (Figure 21). The composition of industry in Bhopal remains same with change in structure. With existing policies and end-use device efficiency improvements, the energy demand and GHG emissions would rise around four times from the base year 2005, as in the span of thirty years competitiveness in the industrial sector will foster relatively higher technology shifts compared to other sectors.

With enhanced mitigation measures in 2035 LCS scenario, the GHG emission reduces to 3 million  $tCO_2$  from 3.6 million  $tCO_2$  in the 2035 BaU scenario (Figure 22). This reduction can be achieved by promotion of energy efficiency improvements in end-use devices both in electrical and non-electrical equipment, boilers and furnaces, fuel switch from coal and oil to gas and clean electricity.

For mitigation in industrial sector, fiscal incentives from the government would be necessary to promote the substitution. Further initiatives would also be required to inform industries on energy saving measures through the development of norms, reports and audits. With new developments and awareness, industries will also augment opportunities to spur energy conservation at the plant level. Though the energy consumption is expected to rise over the period, with the gain in productivity and energy efficiency, a small increase in energy will be required compared to the large amount of output that will be produced per unit of energy consumed.

Thus, from the above discussion we can see that for transforming Bhopal towards a low carbon society, several measures would be needed. The major focus should be on diffusion of low carbon technologies in residential and commercial sectors with energy efficient buildings and retrofits.

The shift towards cleaner fuel in industrial and transport sectors would provide higher emission reductions. Along with strong environmental awareness, conservationist values with energy service demand reduction to environmental integrity, low carbon electricity supply with increased share of renewables like hydro, solar to promotion of end-use device efficiency, specifically in industrial, transport and building sectors, would yield substantial emissions reduction.



Figure 21: Composition of industrial sector output



Figure 22: Change in industrial sector



**Industries near Bhopal** 



Bharat Heavy Electricals Ltd.

### **Seven Actions Towards LCS**

In pursuit of developing low carbon society 2035 Bhopal, the menu of policies and measures fosters numerous objectives and these policy priorities change and evolve constantly with challenges of the day.

The LCS approach demands greater efficiency of energy consumption as well as reduction in GHG emissions. Pursuit of these goals presents wide ranging issues in urban transportation, industrial, residential and commercial sectors. Many of the measures in these areas overlap with each other.

The overall vision of the LCS approach is to make Bhopal a more livable entity to all its residents. Seven Actions are the key steps that can influence the existing energy consumption pattern and GHG emissions in future. These actions have been defined with an understanding of the inherent strengths and potential of Bhopal district which can be explored at this time of rapid development. A sustainable path taken now can guide tomorrow's growth in a more holistic and inclusive manner with little need of post-action course correction.

These actions, though, identified separately for the ease of communication, are inseparably linked in the LCS framework and can only work in conjunction towards achieving the vision.



#### **Action 1: Green Governance**

#### Government Initiatives Towards LCS

The success of the LCS vision lies first and foremost in the Government's will to embrace sustainability as an intrinsic focus in all its future plans and policies. This would mean incorporation of various measures at policy level and in the implementation mechanisms. Few of them are:

- Taxation and subsidy on various commodities and services which would result in promoting sustainable technologies.
- Regulated pricing of solar power, alternative fuels, differential taxing on vehicles switching to alternative fuel technologies.
- Introduction of Government programmes and schemes to take alternative technologies to the masses. (Solar cookers, solar heaters already developed and sold by various government agencies at subsidized rates are examples in this direction.)
- Financial assistance in the form of loans and grants to switch over to alternative energy or fuel sources in the initial stages of transition and development.
- Enforcement of regulatory and development guidelines to enforce sustainable methods of development—compulsory rain water harvesting for all premises, zero discharge and recycling of grey water proposals, mandatory requirements of quantifying energy usage in buildings, etc.
- Adoption of green technologies in all its own civic service provisions- use of solar energy for street lighting, rainwater harvesting, recycled gray water for urban landscaping and recycling of garbage collected to convert to compost or bio-energy.

#### **Action 2: Holistic Habitat**

#### Energy Efficiency in Buildings

Holistic Habitat would encompass all measures affecting the building and construction industry.

- The application of sustainable technologies at the pre-construction, construction and postconstruction stages becomes necessary for achieving this action.
- Beginning with EIA studies of the site, choice of site in the context of the city's vulnerability map, the pre-construction decisions become important in achieving sustainability.
- The construction phase would have to incorporate measures related to technologies used during construction, lead lengths of various materials used, energy involved in transportation of materials, energy consumption during production of construction materials, etc., and suggest alternatives which would contribute in emission reduction in all the stages.
- Post construction stages would include the energy consumption parameters and the reduction methods used throughout the life of the building by use of efficient layout and design and energy efficient appliances.
- Buildings of all uses, including residential, commercial, retail, public and semi public, would need to develop individual energy manuals quantifying their energy usage and chalk out means of consumption reduction, specific to building type and use. Technology upgrades of existing traditional methods of building construction to enhance their performance are encouraged through building research centres helping adapt indigenous technologies to changing scenarios, instead of replacing them altogether with ubiquitous global means.



Vidhan Sabha Bhavan



View of old city across lower lake

#### Action 3: Sustainable Style

#### Low Carbon Lifestyle

Adopting sustainability as the way of life and not an alternative path is imperative for the success of the LCS vision.

- Incorporation of the basics of sustainable living at the primary education level to sensitize children from an early age.
- Value education to children to internalize the concepts of a more sustainable living in their daily lifestyle. Avoiding wastage of water, walking or cycling to school, living in naturally lit and ventilated surroundings, etc.
- Educating the present urban adult population, who are increasingly distanced from more natural ways of rural life and incorporating energy saving techniques in day to day operations.
- Reducing dependence on energy driven gadgets and automated transport .
- Reduce, Reuse and Recycle
- Awareness drives and subsequent checks on impact.

#### Action 4: Cellular City

#### Multi Nuclei Land Use Planning

The city of Bhopal by virtue of its topography and natural settings has historically developed as a city with multiple nuclei with natural barriers separating various zones (Figure 23). This natural formation can be used to the best advantage to develop a cellular city form and structure. This would imply developing compact multi functional districts or townships (depending on the scale of the settlement) within an overall cohesive framework.

- Development of a number of mixed land use compact zones which are economically robust and support large populations. The old fortified city area which continues to be the business hub of the city is the most prominent example of this format. With its high densities and mixed land use, it offers multiple occupational opportunities to its residents who often live and work in quarters in close proximity to each other. This format can be translated in the present planning context as self contained planning units each having a mix of uses and supporting a residential population employed in the same zone. The benefits of reduced travel, efficiency of time management would be promoted, while improving on servicing of the area with basic infrastructure, which often remains neglected.
- The definition of the different cells (area, population, density, predominant activity) would depend on the location of cells in the context of the city's overall structure and the natural elements delineating them. The underlying bases of delineation would remain the principles of sustainability in attempting to create self contained, mixed use zones with the benefits of reduced transport, each focusing on activities specific to them, reducing on inter zone travel.



Solar water heating system



Figure 23: Proposed Sub Cities in Bhopal Source: Adapted from BDP (2005)

#### Action 5: Form and Flow

#### Integrating Transport with City Structure

In keeping with the multi nuclei land use planning, the integration of transport systems connecting the cells as well as intra cell transport is critical for reduction in emissions in the LCS scenario. Three key strategies for this action would include the following:

#### Connecting the Cells

- Consideration in land use planning to account for reduction in travel demand, by reducing inter zonal travel requirement.
- Systematic optimization of travel routes and laying hierarchy of roads connecting the cells reducing road lengths and consequently travel distances between zones wherever required.
- Developing an efficient public transit system. The necessity of planning a public transport system with optimum route distribution to capture maximum riders would depend on the proposed land use distribution as well as the densities of the areas which would form the catchment of these zones.
- Having good connectivity in all parts of the district of Bhopal would ensure boosting of the economy as well as help remove disparities within regions thereby promoting holistic development.

#### Walkable Cells

• Efficient micro-level connectivity within the defined cells. The target of the land use

planning within the zone would be to reduce vehicular travel to the extent possible and encourage walking and cycling.

- Design of pedestrian friendly roads and walkways with grade separation at vehicular interchanges for safe cross-overs.
- Provision of dedicated bicycle tracks along major arteries.
- Good signage and street texture details at neighbourhood level to make roads accessible to all, including children, elders and physically and mentally challenged persons.

Migration to Sustainable Transport Technology

- Switch over to sustainable fuel and transport technology.
- Involvement of the Government in enforcing strict emission control norms for all motorized vehicles.
- Policy measures in the form of fuel subsidies for promoting alternative fuel.
- Market availability of vehicles with green technology using alternative fuels or solar power.
- Creation of public parking lots at the edge of core city areas freeing the congested core from motorized traffic and encouraging pedestrian movement, not only impacting emission reduction, but also giving back vital public realms to the pedestrian and recreating the historic magic of such spaces.



The VIP Road

#### **Action 6: Nurturing Nature**

Leveraging on the Natural and Historic Assets

Bhopal is fortunate to be endowed with large natural resources in the form of its many lakes and wooded hills, which give it a unique identity and define its many zones as well. It also has an old fortified city area as a historic resource. Protecting and leveraging this natural advantage is the next important step.

- Bhopal having a composite climate with only three to four months of concentrated rainfall needs to have a holistic water management system in place (quality and quantity).
- Conservation of the Upper Lake and all the other lakes in the district.
- Rainwater harvesting to recharge ground water reserves at the district level by effective mapping of watersheds and potential reservoir areas. Also at the community and individual premise level in open receptacles or underground reservoirs, thus reducing energy and cost requirements of long distance pipeline laying and network design.
- Encouraging social forestry in urban areas helping prevent erosion of valuable top soil and providing green cover within the concrete jungles. Plantation of indigenous species which thrive in the local climatic conditions with little requirement of additional watering or maintenance for public area plantations.
- Creation of a hierarchy of open spaces at all levels- the city, city cells and neighbourhoods and clusters leveraging on the natural assets.
- Reviving the cultural heritage by promoting traditional art forms (moti work, zardosi, etc.), medicinal systems (unani and hamams, etc.) along with preservation of its historic

built fabric to make the city economy more robust.

• Promotion of tourism activities related to its natural and historical assets.

#### **Action 7: Rural Riches**

#### Promoting a better life in the rural areas

A considerable part of Bhopal district is still rural in nature and would be transforming to urban areas in the near future. At this juncture, it is important and carry forward the good practices of rural living even in the transition to urbanization.

- Inclusion of agro based industries (food processing, agricultural produce marketing etc.) in the economic activities of the district, concentrated in the 'cells' on the ru-urban fringes. This would curb migration of population to the core city areas, where a population largely equipped with agricultural work skills, become misfits in a predominantly secondary and tertiary sector economy.
- Technological inputs to upgrade existing occupations to enhance their productivity.
- Increase in agricultural yield and agro based industries would help in creating food reserves in the hinterland of city areas and reduce dependence on food imports from other regions.
- Adopting building planning principles applied in rural housing typologies which are in the Indian context considerably energy efficient and based on passive methods of insulation.
- Improve lifestyles in rural areas through Government policies on supply of basic infrastructure.



Stupa at Sanchi



Museum of Man

### **Policy Challenges and Future**

#### **Policy challenges and Measures**

Solution to environmental problems requires many changes in the current practices, and technological, institutional and human factors are often resistant to change. Further, the environmental policies involve multiple stakeholders with multiple, conflicting interests and concerns that have a range of implications for the present and for future generations. The concerns about the environmental costs of economic development are now both widespread and intense.

To attain the status of low carbon city, Bhopal will have to make efforts for emissions reduction in future. Measures will be needed in every walk of life for harnessing renewable materials and energy sources and also to reduce the use of natural resources by using them more efficiently and productively, cut or eliminate pollution and toxic wastes and deliver equal or superior performance compared with conventional offerings. Following are the policy challenges for different sectors -

	<ul> <li>⇒ Fuel use varies from wood, biomass, charcoal to kerosene, electricity and LPG depending on the income level.</li> <li>⇒ Emissions from common fuel use.</li> </ul>						
Residential and Commercial Sector	Use of inefficient fuel and technologies is the primary cause for high GHG and local emissions causing indoor as well as outdoor pollution.						
	<ul> <li>⇒ Lower rate of conversion to new technologies, as the alternative inefficient fuel is freely and easily available and low preference for energy efficient technologies over consumer durables.</li> <li>⇒ Inefficient building designs</li> </ul>						
Transport Sector	<ul> <li>⇒ Limited network of roads,</li> <li>⇒ High traffic density,</li> <li>⇒ Increasing number of private vehicles,</li> <li>⇒ Inadequate provisions for non-motorized transport</li> </ul>						
Industrial Sector	<ul> <li>⇒ Large share of unorganised industrial activities</li> <li>⇒ Use of inefficient fuel and technologies</li> <li>⇒ Low rate of conversion to new technologies</li> </ul>						

Bhopal has grown from a small town to a hub of many economic activities. It is a synthesis of the old and the new with bustling bazaars in the old city area and modern industrial centers. Development has touched every aspect of life in the city, from potable water and sewage systems to roads and the vehicles that ply on them. At present the land use planning, the pattern of development and appropriate infrastructure provision have not kept pace with the economic growth of the city. Due to rapid rate of urbanization, the city fabric is being stressed with growing transport concentration and rising energy consumption.

Bhopal with its development planning proposals and efforts of the civic society along with host of government and non government agencies is well poised to become a role model for central India with its clean and green surroundings, tourist friendly transport system, green pathways and energy efficient and environment friendly industry and good governance.

Based on the results of the present study, it can be envisaged that a city like Bhopal can move on to the path of becoming a low carbon society city to be able to address the issues of increasing energy consumption and emissions. This would be possible only if needful steps and planning measures are taken in coming years to address the infrastructure bottlenecks and by adoption of cleaner technologies. It is expected that the policymakers will be able to accommodate these requirements addressing the environmental concerns and Bhopal will emerge as the first low carbon society state capital in India.



### Appendix-A: Methodology and Framework

#### The LCS Study Methodology

The LCS studies commonly use problem formulation methodology where the socioeconomic assumptions of the target year, environmental load emissions, and measures for reduction are collectively called 'future society image'. Suitable actions for the study area are then identified that are needed to transform the present condition to the identified 'future society image' (Figure 24).



Figure 24. Procedure to create a local LCS scenario

To create a local low-carbon society scenario. concept of 'back casting' is used, which first sets a desirable goal, and then seeks the ways to achieve it. In this process, to formulate the framework of LCS scenario for a region, a problem outline is drawn that establishes the coverage areas, base and target year, targeted activities, environmental targets and number of scenarios. This is followed by description of socio-economic assumptions for developing qualitative future image and quantification of the parameters (Figure 25). The parameters of socio-economic assumptions, economic growth rate of the region, export value by industry and population characteristics, considered to have large influence on GHG emissions, are then used as exogenous variables for AIM/ExSS model.



**Figure 25: Low carbon society study framework** (*Adapted from Gomi et al. 2010*)

#### **Modeling framework**

For the present research the study area as stated above is Bhopal district with urbanrural mix. Major urban areas have high concentration of population, high density of vehicles on road, high volume of traffic, concentration of commercial and industrial activities contributing a greater share in the economy and rural hinterland local characterized by low population, low density of vehicles, poor infrastructure facilities and livelihood agrarian in nature having potential for growth with increasing influence of the urban area. Commensurate with rapid growth of Indian economy, Bhopal is witnessing a spurt in economic activities leading to faster land development, population growth and increase in residential, commercial and transport requirements. These increasing economic activities coupled with growing demand have led to rise in emissions and infrastructure bottlenecks

These characteristics of Bhopal district having different growth rates, diverse levels of infrastructure facilities, difference in energy consumption levels, fast changing economic activity, occupational pattern and land use, are the drivers for strategy formulation for various emission mitigation options leading to development of low carbon pathway for Bhopal in coming years.

the next step, the interventions In considered feasible to be introduced for a target year are collected. These include, but are not limited to, energy-saving technology, change of traffic structure, increasing use of renewable energy, energy-saving actions, the source of absorption, etc. To ascertain the suitable combination of interventions and measures, standards, expenses minimization, stakeholders' receptiveness, and technical feasibility is considered. Applying possible values of technical parameters (energy efficiency, technology share, etc.), GHG emissions are estimated in a reiterative process till the set targets are achieved. Based on these conforming measures, actions and policy recommendations are formulated and suggested.

The estimation system of Extended Snapshot (AIM/ExSS) Model is shown in Figure 26. The AIM/ExSS model can capture the emission reductions of each counter measure thereby can show the reduction potential of specific policy prescription and identify potential high emission reduction countermeasures.



Figure 26: Estimation system of AIM/ExSS Model (Adapted from Gomi et al. 2010)



The Upper Lake

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	r	-	-		-	-	-	-	-		
Import	(11.03)	(8.42)	(0.73)	(2.31)	(11.28)		(00.0)	(00.0)	(2.98)		
Export		00.00	00.00	0.49	2.06	6.57		31.59	0.01		
Fix	0.25				5.00	8.95		0.02			
Government Investment	0.00	0.00		0.00	1.57	0.01	0.00	10.35	0.35		
Private Consumption	11.21	8.43	0.72	0.00	4.82	0.00	1.19	12.53	0.62	68.33	1.67
Banking & Insurance					0.07	0.01	0.02	0.14	0.19	1.47	0.00
Rest of Tertiary	1.34	0.01	00.0	0.03	8.17	0.94	0.82	7.32	1.76	48.62	(0.13)
Elec Gas Water	0.01	0.00	0.00	0.52	0.66	0.08	1.14	0.56	0.23	1.62	(0.39)
Construction	0.15	0.07	0.00	0.71	5.40	0.42	0.39	2.32	0.77	7.02	0.03
Manufacturing	1.81	0.09	0.06	2.41	8.77	0.23	0.76	3.62	06.0	5.10	2.05
Mining	0.00	0.00		0.01	0.22	0.04	0.05	0.09	0.04	1.04	0.37
Fisheries	0.00		0.00		0.01	0.00	0.00	0.00	0.00	0.05	(00.0)
Forest	0.00	0.00		0.00	0.00	0.00	0.00	0.01	0.00	0.17	0.00
Agriculture	96.0	0.00	0.00	0.00	0.33	0.03	0.06	0.33	0.03	3.23	(0.25)
2005		Forest	Fisheries	Mining	Manufacturing	Construction	Elec Gas Water	Rest of Tertiary	Banking & Insurance	Gross Value Added	Tax

Re-

Energy Balance Table in the Base Year

2005	Coal	Oil	Gas	Solar	Biomass	Electricity
Residential	2.6	148.4	1.2	0.5	125.2	21.7
Commercial	1.6	12.8			6.7	16.8
Industry	38.6	30.9	5.8		64.5	39.7
Passenger		96.3	3.8			0.7
Freight		22.8				0.5
Total	49.9	311.1	10.9	0.5	199.4	79.4

### Appendix-B: Data Tables

2035 BaU	Coal	Oil	Gas	Solar	Biomass	Electricity
Residential	104.5	748.4	21.2	45.9	96.8	288.2
Commercial	4.7	125.6	0.8	2.6	11.7	96.5
Industry	92.7	230.1	126.4		245.2	161.4
Passenger		487.4	19.6			3.5
Freight		128.3				3.0
Total	201.8	1719.8	168.0	48.5	353.7	552.6

## Appendix-C: Sources of Data

Purpose	Data use	Source
		1. Economic Parameters
	Input Output Table	<ul> <li>CSO (2007). Central Statistical Organisation, INPUT-OUTPUT TRANSACTIONS TABLE 2003-04.</li> <li>CSO (2009). Central Statistical Organisation, INPUT-OUTPUT TRANSACTIONS TABLE 2006-07.</li> </ul>
SAM Estimation	Estimates for Base Year 2005	<ul> <li>GoMP (2007-08). Economic Survey of Madhya Pradesh (in Hindi) 2007-08, Directorate of Economics and Statistics, Madhya Pradesh.</li> <li>Indicus Analytics. District GDP Estimates (2006-07), http://www.indicus.net, 2009.</li> <li>DDR(2008). District Development Report, Divisional Planning and Statistics Office, Bhopal Division Publication (In Hindi), Bhopal, Madhya Pradesh</li> </ul>
Projections for changes in economic structure	Future Projections for Year 2035	<ul> <li>Economy Watch. India Economic Indicators for Years 2011- 2015 (Forecast) (2010), http:// www.economywatch.com.</li> <li>Long term DGDP projection using a combination of exponential and logistic curves till 2035.</li> <li>Expert opinion is used to validate the GDP growth rates in future periods.</li> <li>The sectoral shares in DGDP of used sectors are determined using past series CAGR and projections for India in those sectors.</li> <li>Expert opinion is used to validate the DGDP growth rates and sectoral share projections in 2035.</li> <li>From future share projections, the absolute values for DGVA by the different sectors are estimated.</li> <li>Gomi, Kei, Kouji Shimada and Yuzuru Matsuoka, (2010), A low-carbon scenario creation method for a local-scale economy and its application in Kyoto city, Energy Policy, Elsevier, vol. 38(9), pages 4783-4796.</li> </ul>
		2. Demographic Parameters
Population	Estimates for Base year 2005	<ul> <li>Census (2001 a). Census of India: Primary Census Abstract, Office of the Registrar General &amp; Census Commissioner, Ministry of Home Affairs, Government of India.</li> <li>DDR (2008). District Development Report, Divisional Planning and Statistics Office, Bhopal Division Publication (In Hindi), Bhopal, Madhya Pradesh</li> <li>BCDP (2005). Bhopal City Development Plan, (2005), Jawaharlal Nehru National Urban Renewal Mission (JNURM).</li> </ul>
ropulation	Future Projections for Year 2035	<ul> <li>Population projections for India and States 2001-2026, (2006), Report of the Technical Group on Population Projections, National Commission on Population, Census of India.</li> <li>District Level Population Projections in Eight Selected States of India 2006-2016, (2009), United Nations Population Fund (UNFPA) – India Publication.</li> <li>World Population Prospects: The 2008 Revision. (2009), Population Division, Department of Economic and Social Affairs, United Nations.</li> </ul>
		3. Transport Parameters
Transport sector composition (Passenger and Freight)	Estimates for Base year 2005	<ul> <li>BRTS (2006). Bus Rapid Transport - Detailed Planning Report (Bhopal), (2006), prepared by BCECOM, Bhopal Municipal Corporation, Bhopal.</li> <li>Comprehensive Traffic and Transportation Study for Bhopal Urban Area, (2005), Ministry of Urban Development, Government of India.</li> <li>RTO Bhopal (2006-07). Annual Report 2006-07, Road Transport Office (RTO), Bhopal, Ministry of Road Transport, Government of Madhya Pradesh</li> <li>Traffic &amp; Transportation Policies &amp; Strategies, Wilbur Smith Associates South Asia Pvt. Ltd., 2008, Ministry of Urban Development, Government of India.</li> <li>Barter, P., Kenworthy, J. and Laube, F. (2003) Lessons from Asia on Sustainable Urban Transport (CST) Asia.</li> <li>(BCDP, 2005). Bhopal City Development Plan, Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Bhopal Municipal Corporation, Bhopal.</li> <li>Road Transport Year Book (2006-07). Ministry of Road Transport &amp; Highways, Government of India.</li> </ul>
	Future Projections for year 2035	<ul> <li>Bus Rapid Transport - Detailed Planning Report (Bhopal), (2006), prepared by BCECOM, Bhopal Municipal Corporation, Bhopal.</li> <li>Comprehensive Traffic and Transportation Study for Bhopal Urban Area, (2005), Ministry of Urban Development, Government of India.</li> <li>Traffic &amp; Transportation Policies &amp; Strategies, Wilbur Smith Associates South Asia Pvt. Ltd., 2008, Ministry of Urban Development, Government of India.</li> </ul>
		4. Floor Area Parameters
Land use and floor area	Estimates for Base year 2005	<ul> <li>BDP (1991). Bhopal Development Plan 1991, Government of Madhya Pradesh</li> <li>BDP (2005). Bhopal Development Plan 2005, Government of Madhya Pradesh</li> <li>BDP (2021). Bhopal Development Plan (Proposed) 2021, Government of Madhya Pradesh.</li> </ul>
		5. Energy Use Parameters
Energy Balance Table Estimation (Energy consumption and use)	Estimates for Base year 2005	<ul> <li>Annual Report (2006-07), Department of Food &amp; Civil Supplies, Government of Madhya Pradesh.</li> <li>Energy Balances of Non-OECD Countries: Beyond 2020 Documentation, 2007 Edition</li> <li>ICLEI (2008). Energy and Carbon Emission Profile of 53 South Asian Cities, 2007-08, ICLEI South Asia</li> <li>Census (2001 b). Housing Census of India 2001, H-7, Office of the Registrar General &amp; Census Commissioner, Ministry of Home Affairs, Government of India.</li> <li>DDR (2008). District Development Report, Divisional Planning and Statistics Office, Bhopal Division Publication (In Hindi), Bhopal, Madhya Pradesh</li> <li>NSSO, (2006). National Sample Survey, 62nd Round: July 2005 – June 2006. National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India.</li> </ul>

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