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Low carbon city: A guidebook for city planners and practitioners

Promoting low carbon transport in India

Dhar, Subash; Pathak, Minal; Shukla, P.R.

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

PROMOTING LOW CARBON TRANSPORT IN INDIA

Low Carbon City:

A Guidebook for City Planners and Practitioners

UNEP
UNEP RISØ CENTRE
ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT
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Authors

Subash Dhar
UNEP Risø Centre, Denmark

Minal Pathak
CEPT University, Ahmedabad

P. R. Shukla
Indian Institute of Management Ahmedabad

August 2013

UNEP Risø Centre on Energy, Climate and Sustainable Development
Technical University of Denmark

This publication is part of the 'Promoting Low Carbon Transport in India' project

Supported by:

Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

based on a decision of the Parliament
of the Federal Republic of Germany

ISBN: 978-87-92706-27-0

Design and production:

Magnum Custom Publishing
New Delhi, India
info@magnumbooks.org

Photo acknowledgement:
Front cover: Indian Institute of Management Ahmedabad
Back cover: Subash Dhar

Acknowledgements

We wish to thank Dr. Shobhakar Dhakal, Asian Institute of Technology (AIT) Thailand, and Mr. Vatsal Bhatt, Brookhaven National Laboratory, for reviewing this guidebook. The report has greatly benefitted from their critical and insightful comments and suggestions.

We are most grateful to policy makers and planners in several cities, and numerous researchers and practitioners who spared their valuable time for perceptive discussions.

We would like to acknowledge and express gratitude to Prof. Shuzo Nishioka and the LoCARNet team for insightful discussions and their continued support of our research. We also thank Prof. Yuzuru Matsuoka (Kyoto University) and Dr. Mikiko Kainuma, Dr. Toshihiko Masui and other researchers of the AIM (Asia-Pacific Integrated Model) team from NIES (Japan) for discussions on modelling methodologies and their applications.

Our special thanks go to Ms. Kamala Ernest from UNEP, for her support and valuable input in the preparation of this guidebook. Special thanks also to Ms. Josephine Baschiribod and Ms. Surabhi Goswami for providing valuable editorial inputs during the preparation of the final report.

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Abbreviations

BAU	Business-as-Usual
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CO_2e	Carbon Dioxide Equivalent
CoP	Conference of Parties
DFC	Dedicated Freight Corridor
EV	Electric Vehicles
FAR	Fourth Assessment Report of the IPCC
GDP	Gross Domestic Product
GEA	Global Energy Assessment
GHG	Greenhouse Gas
GSDP	Gross State Domestic Product
GoI	Government of India
Gt	Giga tonne
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IAV	Impacts Adaptation and Vulnerability
IAM	Integrated Assessment Models
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
LCS	Low Carbon Society

MTOE	Million Tonnes Oil Equivalent
MW	Megawatt
NAPCC	National Action Plan on Climate Change
RCP	Representative Concentration Pathways
SPM	Summary for Policy makers
SSP	Shared Socioeconomic Pathways
PFC	Perfluorinated Compounds
PPMV	Parts per Million Volume
PPP	Public Private Partnership
TAR	Third Assessment Report
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Varun Shiv Kapur, 2012

1. Introduction and Outline

1.1 Context

This guidebook is produced as part of a larger research project on "Promoting Low Carbon Transport in India", a major initiative of the United Nations Environment Programme (UNEP), hereafter referred to as the Low Carbon Transport (LCT) project in this document. The LCT project acknowledges the critical role of the transport sector in mitigating greenhouse gas (GHG) emissions. India is currently the fourth largest GHG emitter in the world, although the per capita emissions are less than half of the global average. India's transport sector accounts for 13% of the country's energy related CO_2 emissions (INCCA, 2010). Evidently, opportunities exist to make India's transport growth more sustainable and climate compatible by aligning development and climate change agendas. India's National Action Plan for Climate Change (NAPCC) recognises that GHG emissions from transport can be reduced by adopting a sustainability approach through a combination of measures, such as increased use of public transport, higher penetration of bio-fuels, and enhanced energy efficiency of transport vehicles.

The key objectives of the LCT project are as follows:

a) Delineating an enabling environment for coordinating policies at the national level to achieve a sustainable transport system.
b) Enhancing the capacity of cities to improve mobility with lower CO_2 emissions.

The LCT project has been endorsed by the Ministry of Environment and Forests (MoEF), Government of India. It is jointly implemented by the UNEP Risø Centre, Denmark (URC); Indian Institute of Technology, Delhi (IIT-D); Indian Institute of Management, Ahmedabad (IIMA); and CEPT University, Ahmedabad.

This guidebook is prepared to link the outputs from the national Low Carbon Transport assessment with the process of developing Low-carbon Comprehensive Mobility Plans (LCMP) within the cities. The primary audience for this guidebook are the city planners, transport division executives and consultants working with the cities for transport planning. Transport planning also requires inputs from other sectors – i.e., industrial, commercial, residential, municipal utilities, land-use, and waste. Land-use and location of industrial, commercial and residential areas are essential to estimating trip lengths. Similarly, health impacts from transport emissions cannot be estimated without knowing emissions of local pollutants from other sectors. The carbon emissions from transport, e.g., metro rail, depend on external inputs such as carbon content of electricity delivered to the city. Therefore, the guidebook also provides a judicious coverage of emissions, relevant information from other applicable sectors and activities.

1.2 Cities and climate change

Cities and climate change have a dual relationship. Cities, as major emitters of greenhouse gases, contribute to climate change. The changing climate would cause severe impacts on cities, as they house the increasing majority of the population and productive assets. The contemporary scientific understanding of climate change, however, is barely reflected in the conventional urban development policy making and planning. Nevertheless, globally, city planners are now increasingly paying attention to climate change for three key reasons. First, the participation of cities is vital to achieving national environment and development goals. Second, since the cities hold most of the financial, institutional and intellectual capital; their active participation is essential in formulating and implementing national climate change mitigation and adaptation policies. Finally, cities are where sizeable co-benefits of climate change, such as improvements in air quality and traffic congestion, and reduced heat island effects, would accrue by aligning climate change and development policies.

1.3 Aims and audience

The principal aim of the guidebook is to provide basic guidance to city level policy makers, urban planners, transport planners and consultants who are collectively referred to as “city planners”, on:

a) How to incorporate globally agreed upon climate change objectives, targets and policies in long-term city level development plans.

b) How to align national development and climate change agendas with city level development plans.

c) How to delineate win-win options that deliver multiple co-benefits, besides climate change benefits, such as air quality improvement, improved energy access, reduced congestion in the transport system, and improved national energy security.

Several key messages have been restated and highlighted in the guidebook.

1.4 Chapters

The guidebook comprises six chapters following the introduction. Chapter 2 provides a quick primer on the science of global climate change. Chapter 3 presents: i) a brief history of global climate negotiations, ii) the meaning of the term ‘low carbon’ within the context of the currently agreed on long-term global climate stabilisation target, iii) corresponding global emissions targets and carbon price trajectories, and iv) a basic understanding of low carbon scenarios and alternate development pathways (i.e., plans, policies and strategies) to achieve these scenarios. Chapter 4 explains what low carbon development means to India, with a clear focus on the cities. This chapter is based the methodology for a national level assessment of low carbon scenarios for India (Shukla and Dhar, 2011). Chapter 5 focuses on: i) what low carbon development at the national level means for the cities, and ii) how to align low carbon city planning with national low carbon development pathways. Chapter 6 links mitigation with adaptation, and presents framework for climate compatible development, and Chapter 7 provides the conclusion.

Photo credit: UNEP

2. The Science of Global Climate Change

Scientific assessments show that the global temperature has risen by 0.74°C (range 0.56°C to 0.92°C) from 1906 to 2005, and it is increasing rapidly. Eleven of the twelve years between 1995 and 2006 were the warmest years since the beginning of instrumental temperature measurements in 1850. Trends of other human influenced extreme events in the late 20th century include warmer and fewer cold days and nights, warmer and more frequent hot days, heat waves, heavy precipitation, increase in tropical cyclones, more intense and longer droughts (IPCC FAR WG I 2007).

The earth's climate is influenced by several factors: radiation from the sun, reflectivity of the earth, reflection of sunlight by clouds and fine particles, and concentration of greenhouse gases in the atmosphere. The six main greenhouse gases (GHGs) identified in the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydro fluorocarbons (HFCs) and per fluorinated compounds (PFCs). In addition, ozone, chlorofluorocarbons and aerosols also contribute to global warming. These gases come from various sources and differ in their potential to contribute to temperature rise (Table 1).

Table 1: Major Greenhouse Gases and their Global Warming Potentials (GWP)

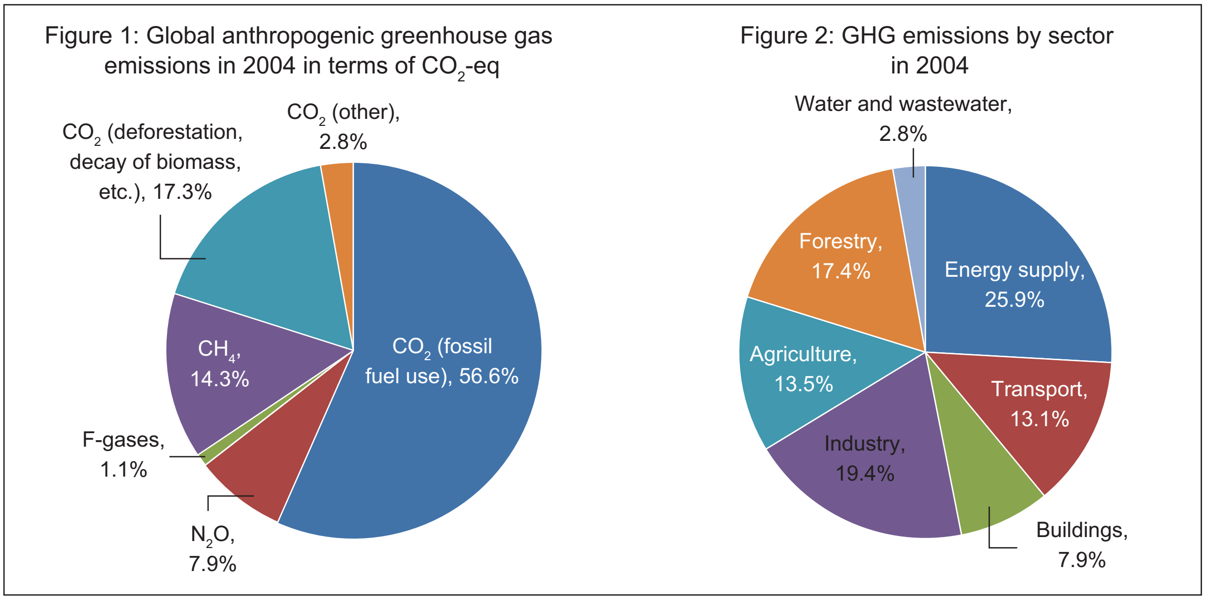
Greenhouse Gas	Global Warming Potential for 100-Year Time Horizon	Average Radiative Forcing (W m^{-2})
Carbon Dioxide (CO_2)	1	1.66
Methane (CH_4)	21	0.48
Nitrous Oxide (N_2O)	310	0.16
Per fluorocarbons (PFC)	6,500–9,200	0.34
Hydro fluorocarbons (HFC)	140–11,700	0.34
Sulphur hexafluoride (SF_6)	7,400–23,900	0.34

Source: IPCC Fourth Assessment Report, Working Group I, table 2.14 (2007)

GHGs vary in their warming influence (radiative forcing) on the global climate system due to their different radiative properties and lifetimes in the atmosphere (Table 1). These warming influences may be expressed through a common metric based on the radiative forcing of CO_2. Technically referred to as 'Global Warming Potential' (GWP), it refers to the potential of a greenhouse gas to generate warming. CO_2-equivalent emission is the amount of CO_2 emission that would cause the same level of radiative forcing, over a given time horizon, as an emitted amount of a long-lived GHG or mixture of GHGs. Radiative forcing, as a result of increases in atmospheric CO_2 concentrations caused by human activities since the preindustrial era, predominates over all other radiative forcing agents (IPCC, 2007a, SPM).

Emissions of greenhouse gases (Figures 1 and 2) mainly include those from energy use, as well as non-energy emissions. Energy related emissions include CO_2, which predominantly arise from energy supply, residential and commercial buildings, transport and industrial energy use, and methane (CH_4) that is emitted in the natural gas supply-chain. Non-energy sector emissions mainly include CH_4, N_2O and CO_2 from land-use change and forestry. CO_2 emissions primarily from fossil fuel use occupy the largest share of global anthropogenic GHG emissions. The CO_2 concentration in the atmosphere, which was 280 ppmv during the early industrial revolution period two centuries ago, has risen significantly, and in May 2013 passed the 400 ppmv level (UNFCCC, 2013).

Figures 1 and 2: Global Anthropogenic GHG Emissions in 2004 (by Type and Sector)



Source: IPCC Fourth Assessment Report, Working Group III

The IPCC Fourth Assessment Report (IPCC WGI AR4, 2007) noted that "changes in atmospheric concentrations of greenhouse gases and aerosols, land cover and solar radiation alter the energy balance of the climate system", and concluded that "most of the observed increase in globally averaged temperatures since the mid-20th century are very likely (greater than 90% probability) due to observed increase in anthropogenic greenhouse gas concentrations".

Information on future changes in the concentration of greenhouse gases, associated temperature rise and impacts on various systems are studied with the help of climate models. Climate models compute these future climatic changes by incorporating several complex scientific phenomena, including air circulation patterns, ocean atmospheric interactions, radiative forcing of different greenhouse gases and interactions with other climate influencing agents like aerosols. There is a level of uncertainty associated with the climate projections due to the complexity of the interactions within the climate system. Hence, for every given path of global emissions, there is an associated probability distribution of temperature changes (Table 2).

Table 2: Properties of Emissions Pathways for Alternative Ranges of CO_2 and CO_2e Stabilisation Targets

Anthropogenic addition to radiative forcing at stabilisation	Multi gas concentration level (CO_2e)	Global Mean Temperature increase*	Change in global emissions in 2050 (% of 2000 emissions)
2.5-3.0	445-490	2.0-2.4	-85 to -50
3.0-3.5	490-535	2.4-2.8	-60 to -30
3.5-4.0	535-590	2.8-3.2	-30 to +5
4.0-5.0	590-710	3.2-4.0	+10 to +60
5.0-6.0	710-855	4.0-4.9	+25 to +85
6.0-7.5	855-1,130	4.9-6.1	+90 to +140

*at equilibrium using the best estimate of climate sensitivity
Source: IPCC Fourth Assessment Report WG III Table 3.10

Table 2 shows the likely temperature increase with corresponding GHG stabilisation levels. If emissions continue to rise at their current pace and are allowed to double (i.e., reach 560 ppmv) from their pre-industrial level, the world will face an average temperature rise of 3.5°C. Serious impacts are associated with this scenario (IPCC FAR, WG II 2007), including rise in sea-levels, shifts in growing seasons, and an increasing frequency and intensity of extreme events such as storms, floods and droughts. According to the IPCC report: i) even a temperature rise to 2°C would exacerbate already observed impacts including human mortality, loss of glaciers, and increase in extreme events; ii) a warming of 2–4°C would lead to worsening impacts on all scales, such as a decrease in global agriculture production and the loss of biodiversity, and iii) a warming beyond 4°C would lead to a significant increase in vulnerability, and exceed the adaptive capacity of many systems.

Photo credit: McKay Savage, 2005

3. Global Agreements and Targets

The 1992 Earth Summit in Rio de Janeiro formally placed managing climate change on the global agenda. The United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon by countries in May 1992 and entered into force in March 1994. The ultimate objective of the convention (UNFCCC, 1992) was to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, while ensuring that economic development continues to proceed in a sustainable manner.

The subsequent Kyoto Protocol (KP), adopted in December 1997, cemented climate negotiations with a commitment by industrialised countries to reduce average annual CO_2 emissions between 2008 to 2012 by nearly 5% from the 1990 levels. The protocol entered into force in February 2005, though without the participation of some key nations. Nevertheless, the KP prompted countries to make advances towards mitigating their GHG emissions. Three notable areas spurred by the KP have been low carbon technology innovations, the emergence of climate finance, including the emissions trading market, and widespread participation of nations in emissions mitigation using the flexibility mechanisms under the Kyoto Protocol. The aggregate global emissions, however, continued to grow due to incomplete participation, insufficiency of the negotiated target, and rapid growth of emissions in major developing economies.

In recent years, the UNFCCC negotiating text has referred to aiming at a 2°C stabilisation target and exploration, as possible, for achieving a 1.5°C stabilisation target. The 2°C stabilisation target signifies the stabilisation of GHG emissions concentration at a level that would stabilise, in the long-run, the temperature rise to below 2 degrees centigrade over and above the pre-industrial period average global temperature. This target translates to stabilising the CO_2e concentration at 450 ppmv in the long-run. The recently concluded 18th Conference of Parties to the UNFCCC in Doha reaffirmed the 2°C target and the continuation of the Kyoto Protocol mechanisms till 2020.

3.1 Meaning of the term 'low carbon'

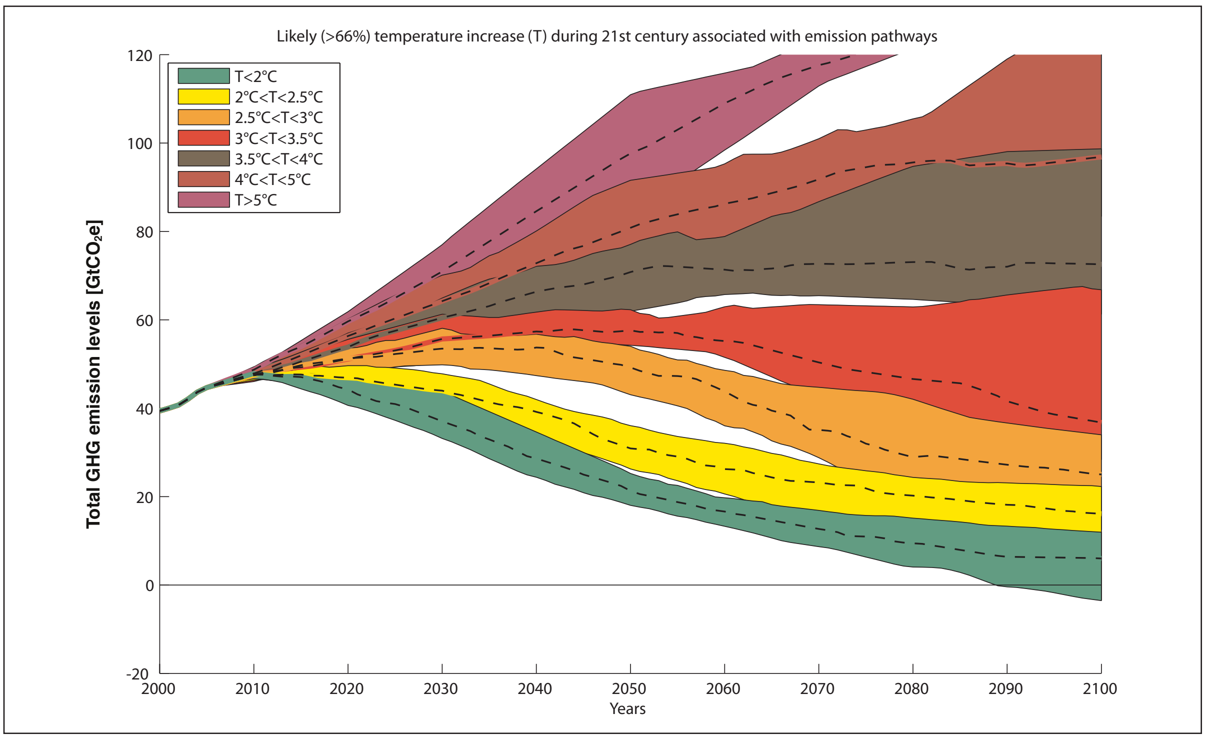
The term 'low carbon' ('carbon' here refers to the 'carbon dioxide equivalent') has evolved, historically. It has also changed with the growing evolving understanding and assessment of 'climate sensitivity' – e.g., the response of the global system to changes in temperature – following changes of atmospheric CO_2 concentration (see Table 2). Typically, 'low carbon' transformation refers to global GHG emissions pathways that stabilise GHG concentration in the atmosphere at levels considered not to be 'dangerous anthropogenic interference with the climate system'.

The climate change assessment literature has no unique benchmark for what can be considered 'dangerous'. It is left to policy makers to make informed choices (based on best available policy-relevant literature like IPCC Assessment Reports) regarding what could be considered 'dangerous'.

3.2 Global targets

The current concentration of CO_2 in the atmosphere stands at 400 ppmv, and is continuing to rise. In order to remain within the global 2°C temperature target, the greenhouse gas concentration will need to stabilise at approximately 450 ppm CO_2e (Table 2). The stabilisation target could be achieved by following alternate emission pathways. A recent assessment (UNEP, 2012) shows that scenarios that meet the 2°C limit have global emissions in 2050 roughly 40% below 1990 emission levels and roughly 60% below 2010 emission levels. The medium range (50–66%) of probability of staying below the 2°C limit requires global emissions to peak before 2020 (Figure 3). One of the suggested pathways shows that emissions need to peak around 2020, and decline progressively to reach the target emissions reduction by 2050.

Figure 3: Range of Pathways Limiting Global Temperature Increases with a Likely (>66%) Chance of Staying Below Various Temperature Limits



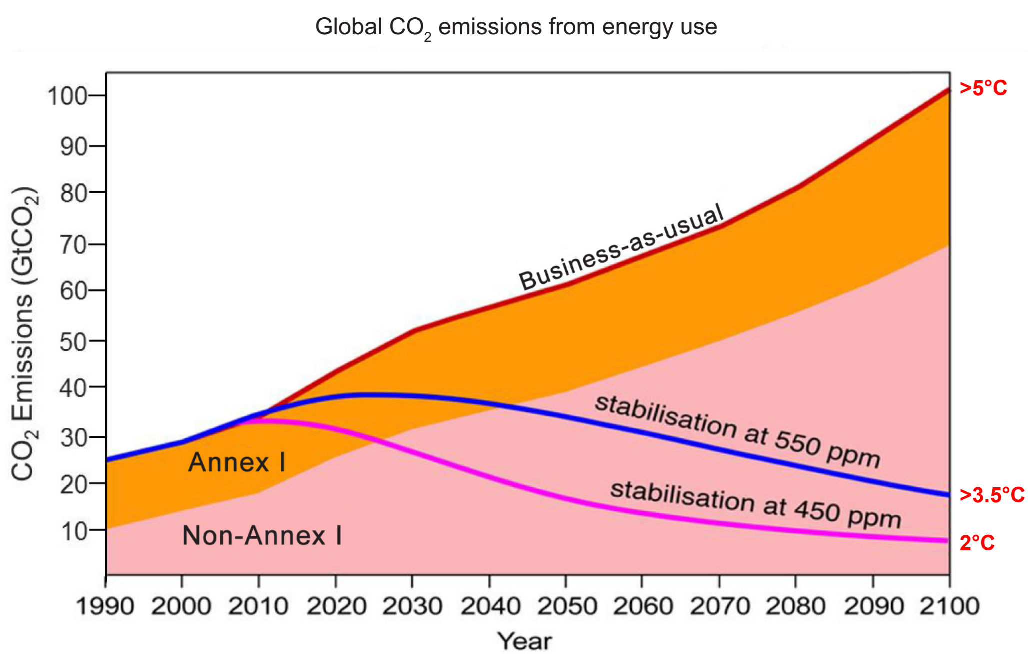
The coloured ranges show the 20 to 80 percentile ranges of the sets of emission pathways, assessed by Integrated Assessment Model, that have approximately the same "likely" avoided temperature increase in the 21st century. Dashed lines show the median transient emission pathways for each temperature level.

Source: UNEP 2012.

3.3 Emission paths for stabilising temperature at 2°C

The future projections are notable in showing the rapid rise in economic growth and emissions from developing countries. From a third of the global CO_2 emissions share in 1990, the emissions from developing countries are growing rapidly (Figure 4). The emerging economies, notably China and India, as per the OECD estimates, will have the combined GDP at 2005 prices (PPP) that will exceed the total of seven major OECD economies by 2025. By 2060, the per capita income in China and India is projected to see a seven-fold increase (OECD, 2012). This trend in economic growth has major implications on energy use and emissions from these countries (Figure 4).

Figure 4: Global Emission Pathways



In many developing countries, per capita emissions from fossil fuels and industry are still much lower compared to developed countries. In 2011, India's per capita emissions were 1.6 tonnes, compared to per capita 17.3 tonnes in U.S.A, 7.5 tonnes in EU-27, 9.8 tonnes in Japan, 7.2 tonnes in China, and 2 tonnes in Indonesia (PBL, 2012). However, future emission trends (Figure 4) show that the share, in the global emissions, of the emissions from developed (Annex I) countries shall decrease, while the share of emissions from developing (Non-Annex I) countries shall continue to rise. Therefore, achieving the global goal of stabilising climate change at 2°C, duly and cost-effectively (UNFCCC, Article 3.2),will require the participation of all nations (Satterthwaite, 2010). The universal participation, though necessary from an economic efficiency perspective, would require leadership of developed countries (UNFCCC Article 3.1), equitable sharing of the burden of climate change mitigation, adaptation and impacts (Shukla, 1999; Shukla, 2005) and suitable transfers of technology and financing from a fairness perspective.

3.4 Global carbon price

A market for trading carbon dioxide emissions rights was established during the past decade, following the Kyoto Protocol. The carbon price, i.e., the price of a tradable carbon dioxide emissions right, is similar to a tax on carbon emissions. The long-term carbon price signal is vital for making economically optimal choices in the public and private investments for cities, e.g., the level of investments in the mass transport infrastructures, which would deliver lower carbon emissions over a long-term period. Future carbon price trajectories are projected by the integrated assessment models. There is no single estimate for the global carbon price due to uncertainties associated with socioeconomic scenarios (GDP growth, population, etc.) and development of technologies (e.g., CCS, nuclear, solar, gasification, etc.). For example, an integrated assessment model (IAM) study (Rogelj et al., 2013) reports that a CO_2

price of 100 USD[1] has a 70% chance of achieving the 2°C target, and a 90% probability of achieving a 3°C target. For simplicity, a single CO_2 price trajectory is used for this study, based on a reputed published IAM study for a 2°C stabilisation scenario (see Table 3).

The global carbon price trajectory in Table 3 follows the results from a study using IMAGE and MESSAGE models (Rao et al., 2008) for such scenarios. This carbon price (or tax) trajectory applied over a 'conventional development scenario' would deliver an overall mitigation of 93.5 billion tonnes of CO_2 between 2010 and 2050 for India (Shukla and Dhar, 2011). Alternatively, a 'sustainable development scenario' wherein India's sustainable development goals are aligned with its mitigation actions, would deliver the same cumulative mitigation over the 2010–2050 period at a much lower carbon price trajectory (Shukla and Dhar, 2011). This lower trajectory represents the 'social value of carbon', which also represents the carbon price net of co-benefits (e.g., air quality and energy security improvements), co-costs and risks (e.g., food security risks from loss of food production due to additional land and water use for bio-energy production) arising from carbon mitigation actions.

Some national governments specify the 'social value of carbon' upfront which can be used to assess the carbon emissions contributions from the construction and operation of projects. A good practice would be to use the 'social value of carbon' announced by the national government as the default value by all projects. In absence of such information, the 'social value of carbon' can be computed by modelling assessments as a 'shadow price' of carbon mitigation in a sustainable world (Shukla et al., 2008). Table 3 provides carbon prices assessed by a modelling exercise for a sustainable development scenario for India, aligned to a 2°C global stabilisation target.

For uniformity across cities, sectors and projects, some national governments (https://www.gov.uk/carbon-valuation) specify the trajectory of the 'social cost of carbon', which is then used for assessing all investments. The cost trajectory is updated periodically, e.g., every three to five years.

Table 3: Carbon prices under conventional and sustainable low carbon scenarios (USD per tonne of CO_2)

Scenario	2020	2030	2040	2050
Conventional	46	86	135	200
Sustainable	26	56	100	117

Source: Adapted from Shukla and Dhar, 2011

3.5 Global energy system transitions (changes in LCS vis-à-vis BAU)

The energy system has multiple linkages with the environment, development, and human wellbeing. Transformation to a sustainable future requires radical improvements in end-use efficiency, increased share of renewable energy, smart grid, as well as nuclear energy, and carbon capture and storage as hedging options for the climate risk.

There are several options available for low carbon transformation. Some options that are already being implemented in the transport sector include: i) enhanced use of bio-fuels to substitute oil, ii) increased

[1] 2012 US$.

share of public transport, especially metro in the cities, and iii) enhanced penetration of electric cars and electric two-wheelers. Low carbon transition to electric vehicles and mass transport systems would require a supply of clean and low carbon electricity, as for example through an increased share of natural gas, renewables and emerging technologies like carbon capture and storage (CCS).

In the buildings sector, low carbon transition would first begin by reducing energy use through energy efficient end-use technologies – e.g., for heating and cooling, and increasing the implementation of current best practices in building construction, design operation and state of the art retrofits. High-end technologies for appliances, ICT and changes in lifestyle and behaviour could further reduce energy demand (GEA, 2012).

These measures will require sizeable investments in energy efficiency and clean energy supply. Cities may generate a part of the additional finance from the reallocation of funds from savings in energy costs, reduced energy subsidies and carbon finance instruments like CDM and NAMAs.

3.6 Emission scenarios

Greenhouse gases have long atmospheric life-times. For instance, CO_2 molecules have an average life exceeding nearly 100 years. Greenhouse gases, thus, accumulate in the atmosphere, by contrast to local air pollutants like sulphur dioxide or dust particles, which have a very short life lasting a few hours to a few weeks. The cumulative nature of greenhouse gases results in their influence on the climate – increasingly manifesting in the long-run. Managing climate change, therefore, requires shaping and assessing long-term emission pathways. This entails delineating and influencing long-term emissions of GHGs from human activities. However, since the future is uncertain, there could be numerous feasible emission pathways, each underlying the understanding and articulation of what would drive the future. Therefore, climate experts analyse different potential futures, each represented as an emissions scenario. A future emissions scenario, and its consequence on the climate and its feedback to the human and natural systems, is analysed using Integrated Assessment Models.

Scenarios offer a structured means of organising information and gleaning insight into the possibilities. They illuminate uncertainty, as they help in determining the possible ramifications of an issue along one or more plausible paths. A scenario is a plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Scenarios are neither predictions nor forecasts, but are useful in providing a view of the implications of developments and actions. Scenarios are useful tools for scientific assessments, learning about complex systems behaviour, and policy making.

Scenario building involves describing, in narrative and quantitative terms, the possible future pathways of development driven by economic, demographic, land-use, technological and energy drivers. Scenarios can be geographically down scaled, e.g., to a city level. A city scenario is a communication tool that describes the way the city may evolve in the future. It has both qualitative and quantitative elements. The qualitative part, which is the storyline, broadly describes how the city would evolve in terms of spatial changes, demographic changes, people's incomes, type of infrastructure, and behavioural patterns.

The global scientific community is currently developing new projections that analyse the interaction between socioeconomic development and climate change, through the use of narrative storytelling. These new projections, called Shared Socioeconomic Pathways (SSPs), define five possible paths that societies could follow over the next century. The SSPs comprise a set of narratives and quantitative information, which can be used to integrate the assessment of costs and benefits of mitigation, adaptation and residual climate impacts. The SSP scenarios aim to permit consistent down scaling of the qualitative and quantitative narrative from a global or regional scale to a local level.

The business-as-usual (BAU) scenario

The future representing the continuation of past trends, usually referred to as a business-as-usual (BAU) scenario, is often used as a counter factual reference or a benchmark for assessing the policy interventions for achieving any other scenario. A BAU scenario assumes the future economic development along the conventional path. For developing countries in a rapid growth phase, the scenario assumes the future socioeconomic development would mimic the resource intensive development path followed by currently developed countries. The scenario assumes improvements in energy intensity as well as improvements in labour productivity, similar to the dynamics-as-usual case and the achievement of national targets for commercial renewable energy, and is, therefore, different from a 'frozen technology' case, which is a scenario without improvement in energy and carbon intensities (Nakicenovic et al.,2006). A frozen technology scenario freezes the structure of the economy, the technological know-how, fuel quality, and plant efficiencies. The trajectory for emissions in this scenario is, thus, driven by the assumption that there will be no technology or policy interventions from the base case.

Changes in BAU will mainly include improvements across sectors in efficiency, dispersion of advanced technologies and end-use appliances. For instance, based on the continuation of present trends, the BAU scenario implies a greater increase and access to renewable energy production and use. The power sector will see more advanced power generation technologies, a higher share of cleaner fuels like natural gas, and an increase in the use of new technologies like CCS. In the industry sector, old and inefficient technologies will be phased out and substituted with more efficient technologies and devices. In the transport sector, there will be greater incorporation of biofuels and alternate vehicle technologies. On the end-use side, passenger transport will see a greater share of electric cars, battery operated vehicles and hybrid cars. Consequently, the share of biofuels and electricity will increase in public transport.

The BAU scenario extrapolates existing trends and does not assume any radical policy interventions for emission mitigation. However, it does incorporate major infrastructure or development plans in the near future – for instance the addition of a new MRT system or land-use changes in a new development plan.

The low carbon society (LCS) scenario

Low carbon society scenarios visualise social, economic and technological transitions through which societies respond to climate change. Generally, the concept of a low carbon society defines actions that are compatible with the principles of sustainable development allowing for deep emissions cuts using low carbon energy sources and technologies, at high levels of energy efficiencies, without imposing any cost to the developing needs. An LCS scenario also includes adoption of behavioural and consumption styles consistent with sustainable development. A simple scheme to understand the main driving forces of emissions reductions based on the Kaya Identity is given in Box 1.

Box 1: Decomposition of decarbonisation

Decarbonisation happens across scenarios as the energy intensities decline over time due to technological improvements and the changing structure of the economy, resulting in a decoupling of economic growth and energy consumption. The decline is faster in the case of sustainable scenarios, as the demand for intermediate goods and services reduces because of sustainable practices. An alternative way of looking at two pathways for achieving a low carbon society is simplified by the 'extended Kaya identity'. The change in CO_2 emissions from a base year is derived using the formula:

Change in CO_2 = Demand effect (D) + Energy intensity effect (E/D) + Carbon intensity effect (C/E) + Measures effect (C'/C)

Where D = driving forces (service demand of final and intermediate consumption), E = Energy consumption, C' = CO_2 emissions without measures in the energy transformation sector, and C = CO_2 emissions with measures in the transformation sector.

Achieving a low carbon society in Asia is a challenge, as the region consists of diverse and rapidly growing economies that are undergoing multiple transitions in income, demographics, infrastructures, and institutions (Kainuma et al., 2012). The challenges of meeting development goals, resource constraints, and climate change adaptation add to the complexity. Therefore, an exclusive, climate-centric vision could prove expensive, as it would create a large mitigation and adaptation 'burden'. Instead, the focus can move toward a 'development-centric' framework in order to reduce conflicts and deliver greater global and national benefits. There are several pathways to reaching a low carbon society. Each pathway has its own co-benefits. The challenge is to reach the objective with minimal costs.

In addition to being energy efficient, a sustainable low carbon development will need to integrate equity and quality of life. While the harder measures will involve controlling energy service demands in sectors, and enforcing stringent taxes, a more sustainability oriented approach that involves measures that integrate resource efficiency, environment improvements and social benefits will lead to better outcomes. The sustainable development pathway would reduce mitigation costs and create numerous opportunities to realise the co-benefits without having to sacrifice the original objective of enhancing economic and social development. Recent modelling exercises show that it is possible to realise low carbon scenarios consistent with a 2°C temperature rise. The LCS can be achieved in a more sustainable manner by enhancing investments in infrastructures and end-use efficiency improvements, which ensure development and other co-benefits along with improving competitiveness of national renewable energy options (Kainuma et al., 2012).

Transition to low carbon societies cannot be achieved overtime. Policy makers need to assess the future demands, and develop scenarios that look at the technological and behavioural changes likely to happen. Priority actions need to be identified for choices that deliver these local benefits in the next 5 to 10 years, and also lead to the long-term progressive decoupling of CO_2 with city growth.

Photo credit: Amcanada, 2009

4. What Does a 2°C Scenario Mean for India?

India has endorsed the long-term target of limiting the temperature rise to under 2°C,[2] and has also made a voluntary pledge to reduce its emissions intensity by 20–25% by 2020, from the 2005 levels. The 'National Action Plan on Climate Change (NAPCC)', released by the Prime Minister's office in June 2008, considers mitigation and adaptation actions, implemented through eight National Missions (Appendix 3).

The most relevant mission for achieving low carbon cities is the National Mission on Sustainable Habitat. This mission is led by the Ministry of Urban Development (MoUD), and the broad strategies proposed within the mission document for urban transport are in the following areas:

- Strengthening public transport through promotion, regulation of private vehicles, and fiscal measures to incentivise public transport
- Modal shift to non-motorised transport
- Planning, monitoring and coordination
    - o Improving access to goods and services through an integrated urban plan
    - o Multi modal integration through the setting up of a Unified Urban Metropolitan Transport Authority
    - o Comprehensive mobility planning and intelligent transport systems
    - o Central financial support
    - o Integrating intercity transport with urban transport
    - o Service level benchmarks
- Technology
    - o Shifting from fossil fuels to biofuels and alternative fuels (e.g., EVs)
    - o Improving and establishing fuel efficiency standards for vehicles
    - o Facilitating R&D
    - o Discouraging diesel propelled vehicles

The various policy actions taken in the last few years, which can be linked to this mission, have been listed in Appendix 2. However, JnNURM has mainly been the key driver of change with regard to the urban planning process, institutional capacities, and financing of urban infrastructures.

[2] The Prime Minister of India at the 2009 G8 summit in L'Aquila, Italy endorsed the 2°C target.

At the national level, scenario exercises have been undertaken to help understand the 2°C scenario for India; key scenario drivers and results are presented below. The aim is to help city level planners remain consistent with national goals and targets that are drivers of emissions in a city, but beyond the scope of city planning – e.g., fuel mix mandates like mandatory blending of ethanol with petrol, the carbon content of grid power, vehicle efficiency standards, etc. Simultaneously, actions within the scope of the cities in the areas of urban design and spatial planning, promotion of public transport and non-motorised transport are discussed to convey the importance of these actions, at the national level.

4.1 Demographic transition

Urban population

Presently, 31% of India's population live in urban areas (Census of India, 2011)[3]. Between 2001 and 2011, the urban population grew by nearly 32%, as compared to 12.2% for the rural population. The three largest urban agglomerations in India are Delhi, Greater Mumbai and Kolkata, with populations of 16.3, 18.4 and 14.1 million, respectively (Census of India, 2011). In addition, there are five cities with populations between 5 and 10 million. In total, 44 cities with populations exceeding 1 million accommodate over 40% of the total urban population of India (Appendix 1). However, the larger part of India's urban population still live in small and medium-sized towns with populations below 1 million (Table 4).

Table 4: Urbanisation status and trends in India

Size Category (population)	No. of cities (% of urban population)		
	1975	2000	2025
>10 million	0 (0)	3 (15.5)	6 (21.4)
5-10 million	2 (11.3)	3 (6)	3 (4.5)
1-5 million	8 (13.7)	25 (14.7)	54 (19.5)
0.5-1 million	17 (8.3)	38 (9.4)	75 (9.6)
<0.5 million	≈ 3,000(66.8)*	≈ 4,000 (54.5)	≈ 6,000 (45)

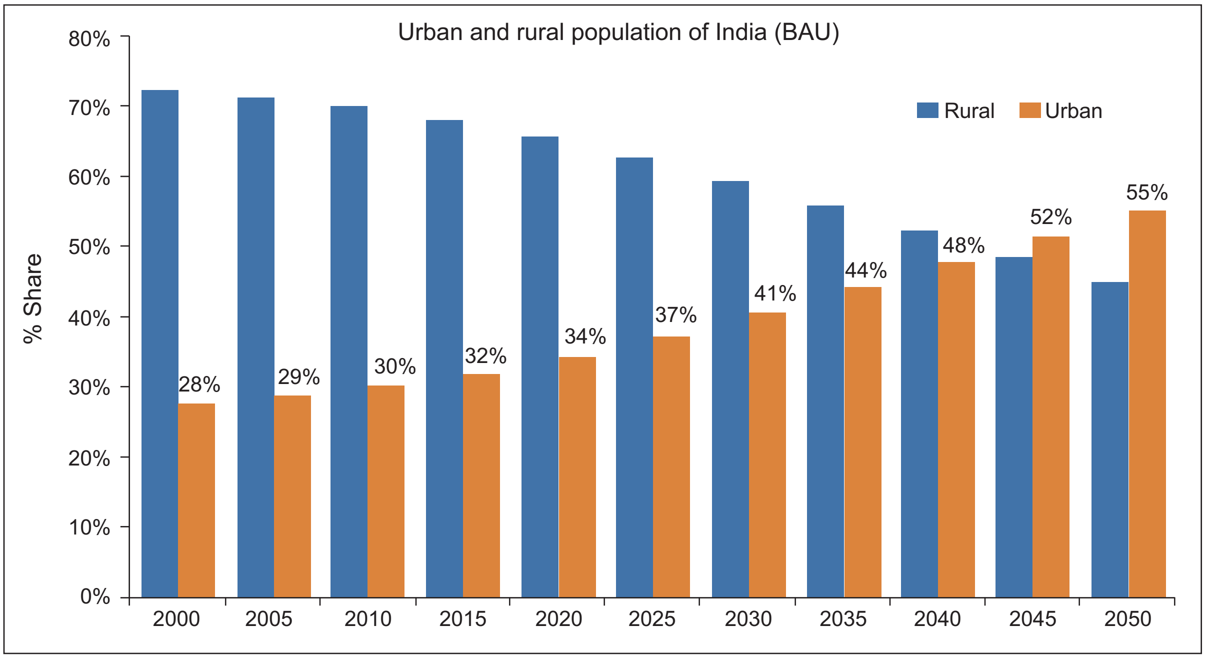
Source: World Urbanization Prospects 2011 revision, UN Population Division

City planners require population scenarios to plan for future urban needs. The UN Population Division provides population projections for major cities in India (Appendix 1 contains latest projections), which city planners can refer to when making projections for cities.

Projections show that India will continue to urbanise through 2050, however, the rate will slow down after 2030. By 2050, India's urbanisation level will reach 55% (Figure 5), and its urban population of 0.9 billion will be the second largest in the world, after China (UN, 2012). A large part of this growth will take place in cities with populations over 1 million. Many of these cities are expected to grow rapidly between 2000 and 2030 (Table 4), so that by 2025, there would be 63 cities with populations over 1 million, of which 6 cities would have populations exceeding 10 million.

[3] www.censusindia.gov.in Accessed 18 March, 2013.

Figure 5: Urban and rural population transition 2000–2050



Source: World Urbanization Prospects 2011 revision, UN Population Division

Working population

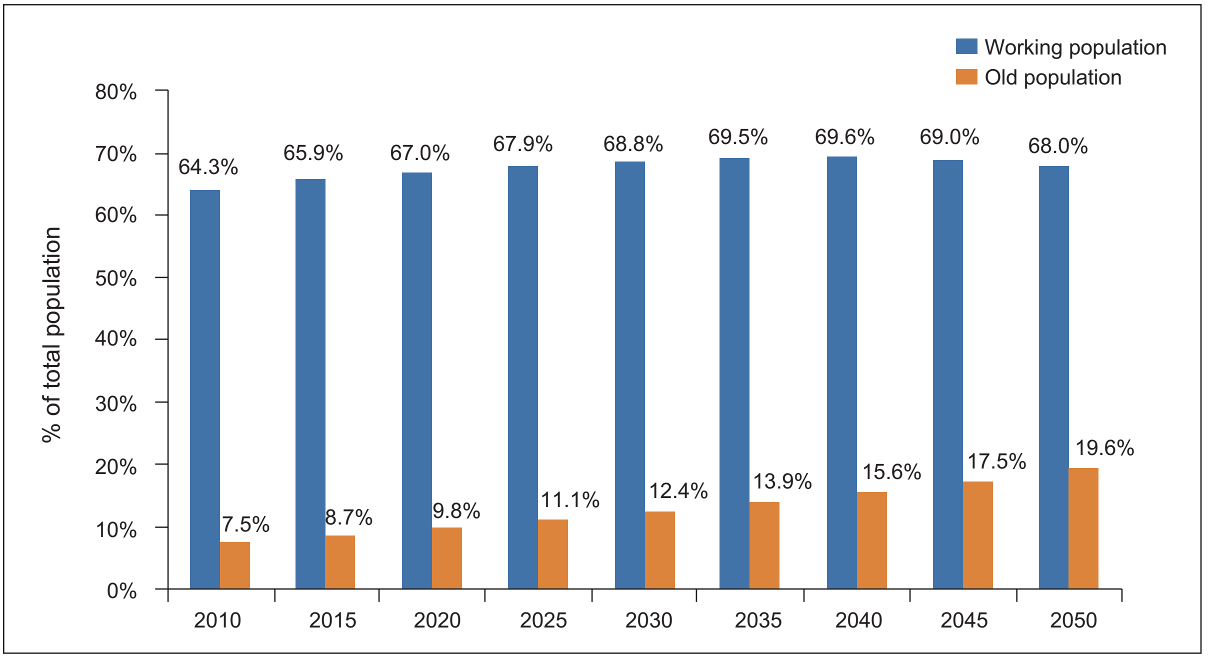
Despite the decline in the total fertility rate in India, the population will continue to grow in the coming decades. Based on the Census and UNPD's medium variant projections, India's population will grow at a compounded average growth rate of 1.0% between 2010 and 2030, resulting in a population of 1.5 billion. By 2030, 69% of the total population will comprise of men and women in the working-age group of 15–64 years (Figure 6). Moreover, the elderly population is also increasing rapidly, and by 2030 there will be 12.4% old people (Figure 6). These two trends, along with the changing share of primary, secondary and tertiary employment, will have implication for cities. Cities will be providing greater employment to the working population, and will need to build additional health care facilities for the elderly.

Large workforce will be a driver for growth of cities and a growing old population will need a different planning approach. City planners may refer to Figure 6, for the percentage share of the working and old age population. The figures are based on UN population projections, which are revised every 2 years.

Household size

The household size has been becoming smaller in both rural and urban households; however, the trend is more evident in urban areas due to the growing nuclearisation of families (Census of India, 2001). The trend has been extrapolated (Table 5) by considering an asymptotic value of 2.5 per household. The asymptotic value is based on the average household sizes in developed countries.

Figure 6: Population transitions for working and old people



Source: World Urbanization Prospects 2011 revision, UN Population Division

City planners can base the household size for their cities on published sources e.g., NSSO or undertake household surveys to understand the same. The projections for the future can then follow the trend of decreasing household size, using Table 5.

Table 5: Transitions with respect to household size in BAU

Year	Average Size of Household	
	Rural	Urban
2000*	5.40	5.10
2005	5.23	4.80
2010	5.06	4.52
2015	4.90	4.25
2020	4.75	4.00
2025	4.60	3.76
2030	4.45	3.54
2035	4.31	3.33
2040	4.18	3.13
2045	4.04	2.95
2050	3.90	2.76

‘* Size of household in 2000, based on NSSO

4.2 Economic growth

Economic growth will be an important parameter influencing the use of energy in developing countries. A common way of measuring economic growth is the Gross Domestic Product (GDP). Rising GDP in an equitable society will lead to improved standard of living, and increasing ownership, as well as use of home appliances, demand for travel, waste generation, and greater energy use for heating and cooling in domestic and commercial buildings. The overall economic growth and break up amongst various sectors of the economy for the BAU scenario are provided in Table 6. Cities could have the presence of certain industries, with plans for attracting other industries in the future and, therefore, city planners could use the growth rates for planning land requirements for respective industries.

Table 6: Projected GDP growth and break up by sector for BAU (values in %)

	2010–2030	2030–2050
Overall GDP	8.03	6.27
Industrial Output		
Steel	7.10	4.00
Aluminium	6.60	4.40
Cement	4.70	2.80
Paper	5.60	3.70
Brick	5.30	3.10
Caustic Soda	5.10	3.70
Soda Ash	5.10	3.70
Nitro Fertilizer	1.80	0.90
Cotton Textile	4.70	3.10
Sugar	3.50	1.80
Other Industry	5.10	3.70
Household Energy Demand (Urban)		
Cooking	4.30	4.08
Lighting	3.16	3.58
Appliances	4.45	5.85

Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

City planners need to project future industrial growth, and for short-term projections references can be made to the plan documents from the Planning Commission. For relatively longer term projections, planners can refer to Table 6.

The overall economic growth for the BAU scenario has been pegged with the GoI's 8% growth scenario. The Twelfth Five-Year Plan (2012–2017) announced by the Government of India projects three alternate scenarios for GDP growth during the years 2012–2017: 1) A strong, inclusive growth scenario characterised by a GDP growth rate of 8.2%, and strong institutional and governance structures, 2) Insufficient action characterised by a growth rate between 6–6.5%, with poor policy implementation and low emphasis on inclusiveness, 3) A policy logjam scenario characterised by a very low GDP growth rate of 5–5.5%, mainly due to failure at several levels. The BAU scenario is considered to be closer to the strong inclusive growth scenario.

4.3 Infrastructure choices

Infrastructure is one of the key elements determining growth. Also referred to as man-made capital, infrastructure choices generally entail huge costs and have a long life. Infrastructure choices have a major influence on national emissions, as they affect the overall energy system in a country. The way investments into infrastructures are made can, for example, transform smaller cities in India (cities with a population less than 1 million, Table 4) into either cities with a high share of public and non-motorised transport, or cities with a high dependence on personal automobiles. Smaller Indian cities are characterised by high density (more than 150 persons per hectare) and mixed land-use, with a high share of walking and cycle trips (Jain and Tiwari, 2013). As these smaller cities grow in size, due to increasing trip lengths the share of motorised transport will increase as well. In the case of mixed land-use, if densities are maintained at more than 50 persons per hectare and adequate investments into public transport are made (Barter, 1999), these cities can be transformed into transit cities[4], which have a high share of public and non-motorised transport. Otherwise, there is a high likelihood that these cities can transform into automobile cities[4], with long trip lengths and low share of public transport.

High growth adds pressure to existing infrastructure, and necessitates capacity augmentation. The total infrastructure investment in India increased from 5.7% of the GDP in 2007, to nearly 8.0% in 2011 (GoI, 2011). Recognising infrastructure as one of the key requirements for sustaining and accelerating growth, the Twelfth Five-Year plan targets 10% of the GDP to be used for infrastructure investment. In the case of urban infrastructure, the financing is provided by centre and state governments under JnNURM (see Appendix 2). The program had a budget of 20 billion USD for the seven year period ending in 2012. The program has a focus on creating urban infrastructures for public transport, however, institutional weakness at the city level, and lack of integration with NMT infrastructures are expected to limit the role of public transport. Accordingly, in the BAU scenario, a larger share of oncoming demand is apportioned to private motorised transport (Figure 7), while the Low Carbon Scenario considers that institutional weakness at the city level would be overcome, leading to a strong focus on public and non-motorised transport, which limits the growth of private transport modes.

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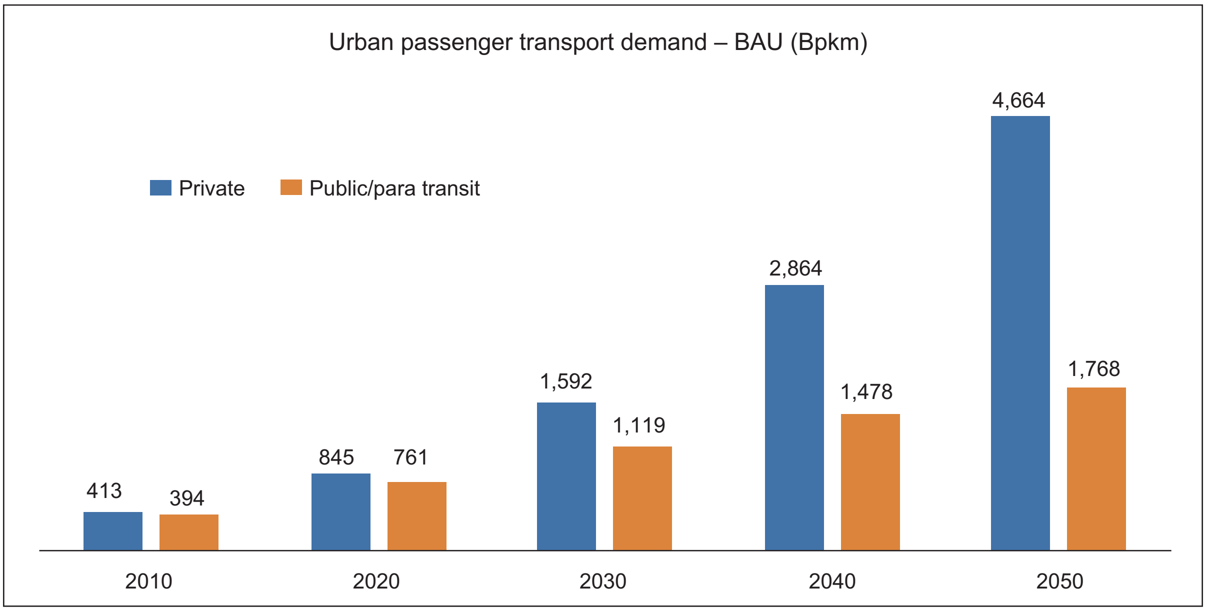
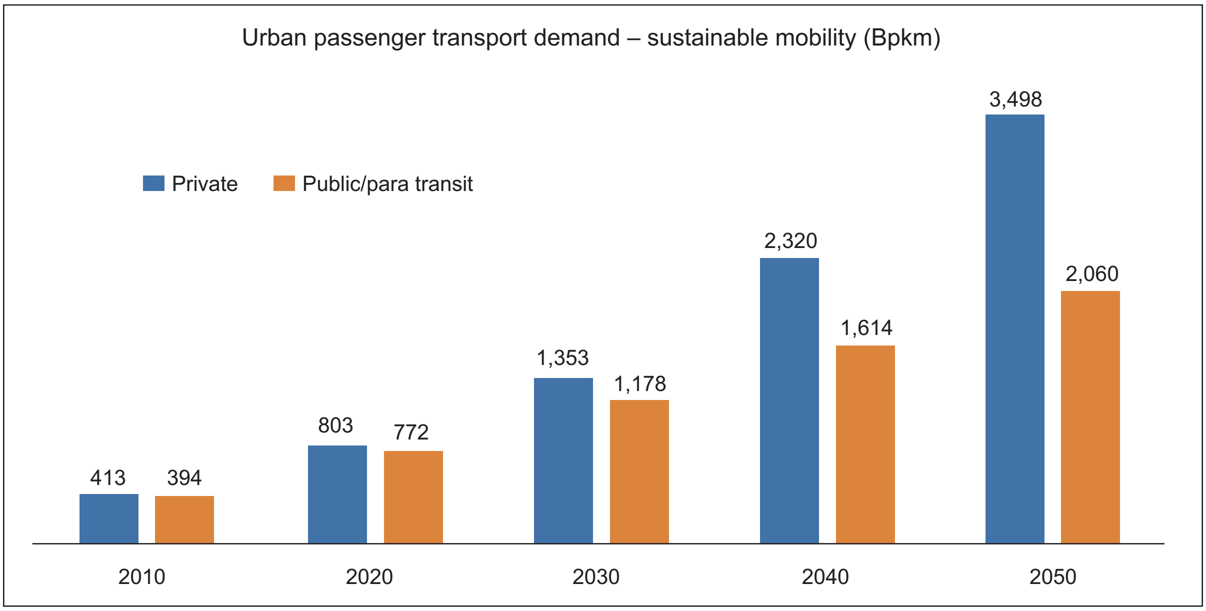
[4] Newman has classified cities into walking cities, transit cities, and automobile cities. Each city, as it grows, will generally have a mix of the three pure forms. Historically, smaller towns that have a high population density transform into transit or automobile cities. Transit cities are characterised by higher population densities and mixed land-use, coupled with an investment in public transit (Barter, 1999).

Figure 7: Projections for urban passenger travel demand in BAU and LCS scenario





Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

Investments in public transport will slow the growth of private transport, but will not be able to reverse it. Therefore, planning for mitigating the impacts of private transport should also be thought out by city planners.

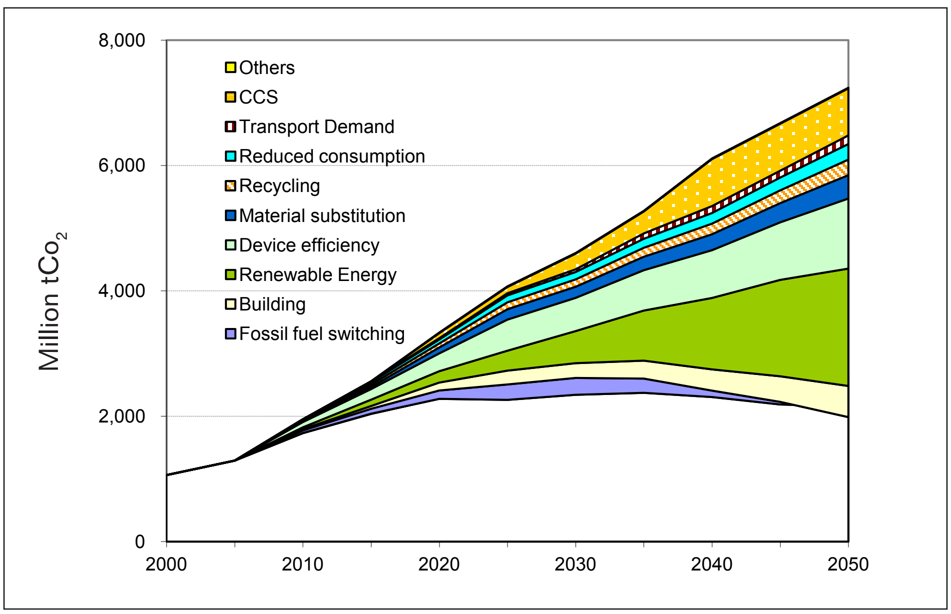
4.4 National emissions pathways

There can be alternative scenarios at the national level for transitioning to a low carbon future. The low carbon scenario is considered as the global 2°C stabilisation target. Analysis of scenarios requires an integrated modelling framework. For example, Shukla et al., 2008 and Shukla and Dhar, 2011 use a softlinked integrated modelling framework comprising of a bottom up energy system model and a top down macro-economic model. The modelling assessment translates a global price signal (Table 3) consistent with the 2°C global stabilisation target into mitigation actions (e.g., Figure 8), CO_2 emission trajectories (e.g., Figure 9), and per capita emission levels (e.g., Figure 13) for India. The modelling assessment identifies an optimal emissions pathway corresponding to each scenario for India. This emissions pathway is the most cost-effective for India, from a global standpoint, and does not represent an allocation of emissions for the country. The national mitigation action roadmap to achieve this pathway would require climate financing and transfer of technology, as per the global agreements.

The aim of the city level low carbon planning would be to develop a 'low carbon city roadmap' which: i) is consistent with the national mitigation roadmap and programs like 'mission on sustainable habitats' (see Appendix 3), ii) aligns the city's sustainable development objectives with the cost-effective mitigation responses in the city, and iii) delivers co-benefits, such as improved local air quality, and reduces risks (e.g., to national energy security).

The results for a national level BAU and a low carbon scenario, based on the sustainability paradigm, are presented below. The emissions pathway based on sustainable development pattern is caricatured by diverse response measures involving a combination of initiatives, on both the supply and demand sides. On the supply side, renewable technologies play a crucial role, while on the demand side, measures like dematerialisation, sustainable consumption, and end-use device efficiency play a key role (Figure 8).

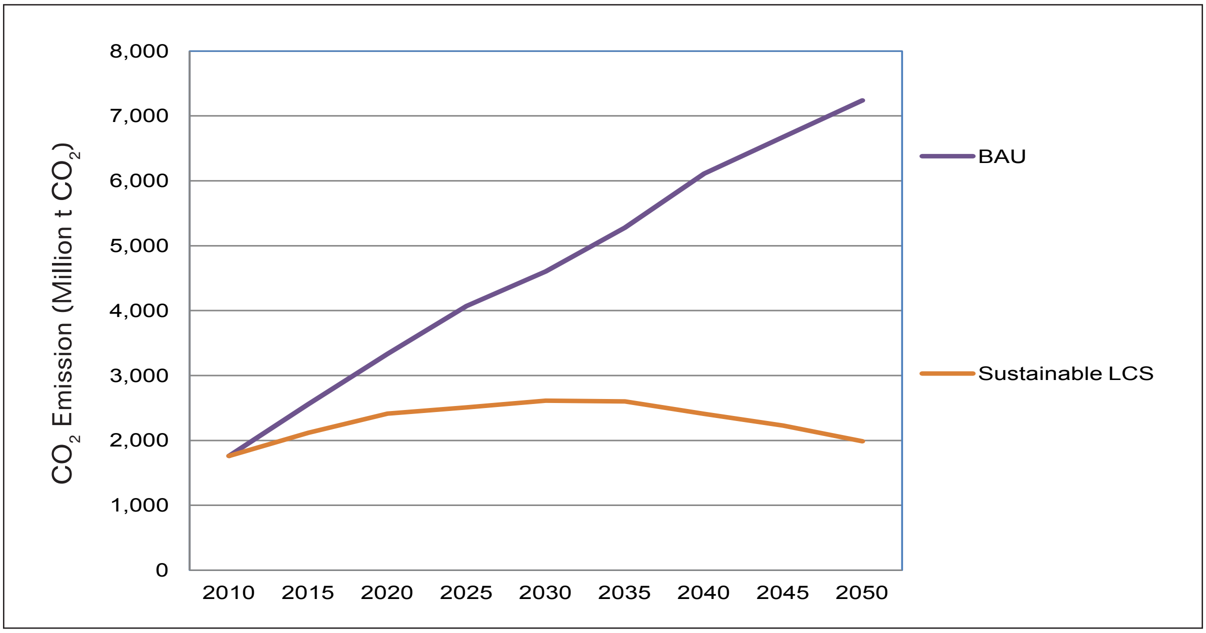
Figure 8: Mitigation wedges in the sustainable LC scenario



Source: Adapted from Shukla and Dhar, 2011

In the BAU scenario, CO_2 emissions will increase to 7.24 billion tCO_2 in 2050 (Figure 9), as the energy sector remains dependent on fossil fuels (Figure 10). In the low carbon sustainable scenario, a significant decoupling in CO_2 emissions is achieved (Figure 16), and the emissions start declining after 2030.

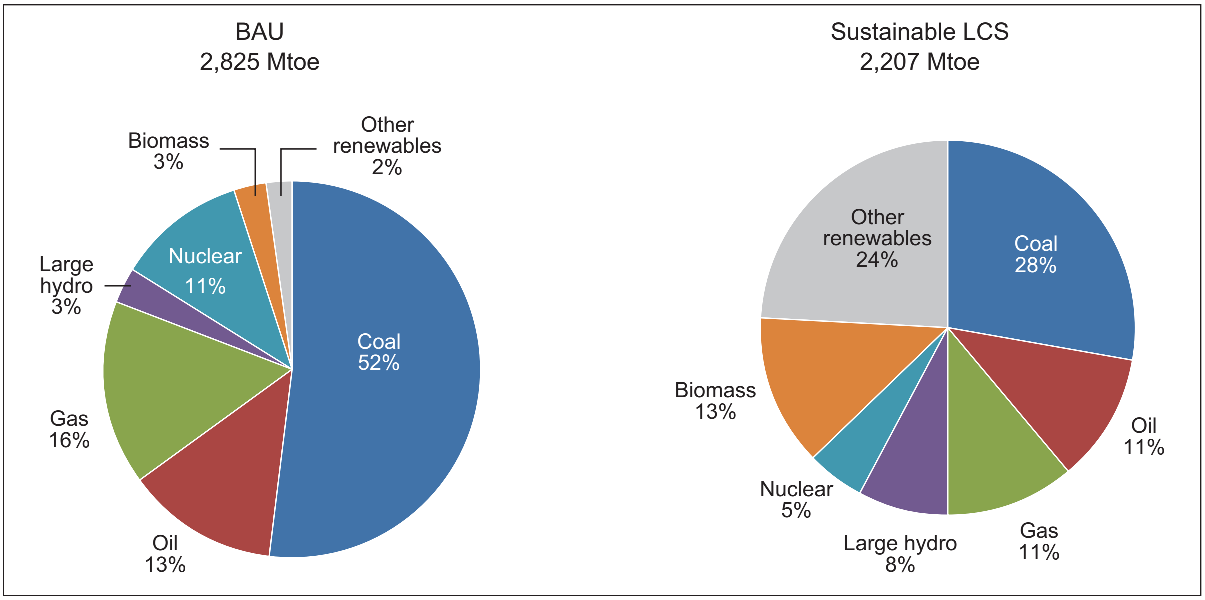
Figure 9: CO_2 Emission: BAU and sustainable LCS



Source: Adapted from Shukla and Dhar, 2011

The energy demand in BAU increases to 2,825 Mtoe (Shukla and Dhar, 2011), which is more than 4.2 times the primary energy demand of 669 Mtoe in 2009 (IEA, 2011). The energy system is, however, dominated by conventional fossil energy sources, which will contribute nearly three fourths of the total energy mix in 2050 (Figure 10). Together, nuclear and large hydro will contribute another 14%, leaving a mere 5% for renewables.

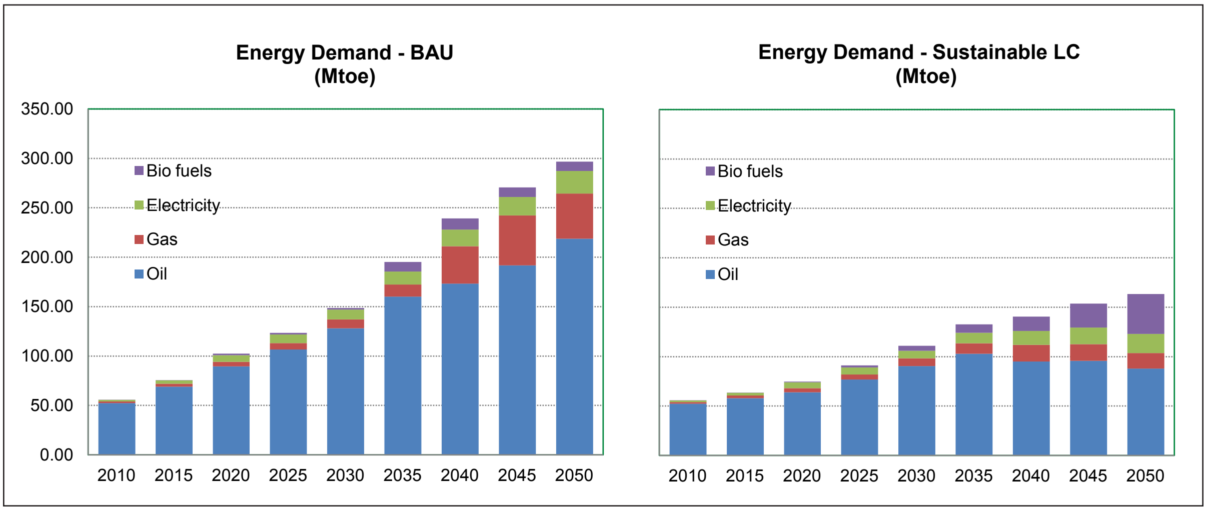
Figure 10: Primary energy demand in 2050 – BAU and sustainable LCS



Source: Adapted from Shukla and Dhar, 2011

In the sustainable LCS, the overall demand for energy is much lower than in BAU (Figure 10), due to sustainable demographic transitions, dematerialisation, demand substitution, sustainable urban planning, etc. In the case of transport, improvements to urban design and spatial planning, promotion of public transport and non-motorised transport, shift to rail for freight and passenger transport, use of more efficient vehicle technologies, shift to pipelines for liquid transportation, etc., can, in themselves, reduce the demand for energy from transport by nearly half (Figure 11). This demand reduction can deliver substantial co-benefits in terms of energy security, local environment quality, and health.

Figure 11: Energy demand from transport sector in BAU and sustainable LCS



Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

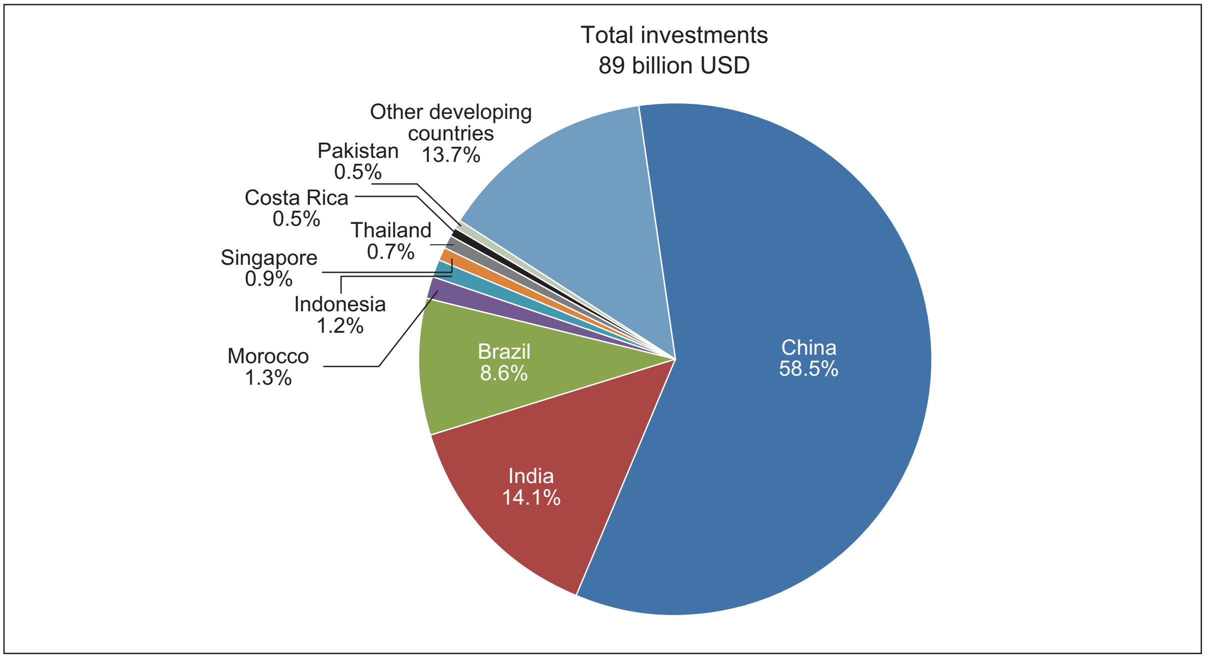
4.5 National energy and emission indicators

The energy mix is expected to diversify in the future, shifting many countries from being highly dependent on coal, oil and traditional biomass, to ones with significant shares of renewable, natural gas, nuclear and commercial biomass. This can be confirmed by the trend in current investments – e.g., 89 billion USD was invested in renewable energy within the developing countries, alone (Figure 12). The share of renewables is projected to increase substantially in the future, depending on investments in technology and infrastructure (IPCC, 2011).

In the future, technologies like carbon capture and storage[5] offer possibilities of taking up a significant amount of emitted CO_2. According to WEO (2012), the share of low carbon energy (nuclear, biomass, hydro, and renewables) and fossil fuel-based power plants with CCS will comprise 25% of the world's primary energy mix in 2030.

[5] Carbon capture and storage (CCS) is a technology that involves capturing carbon dioxide (CO_2) from large point sources, such as fossil fuel power plants, and storing it underground, thus, preventing it from entering the atmosphere.

Figure 12: Investments in renewable energy in developing countries in 2011

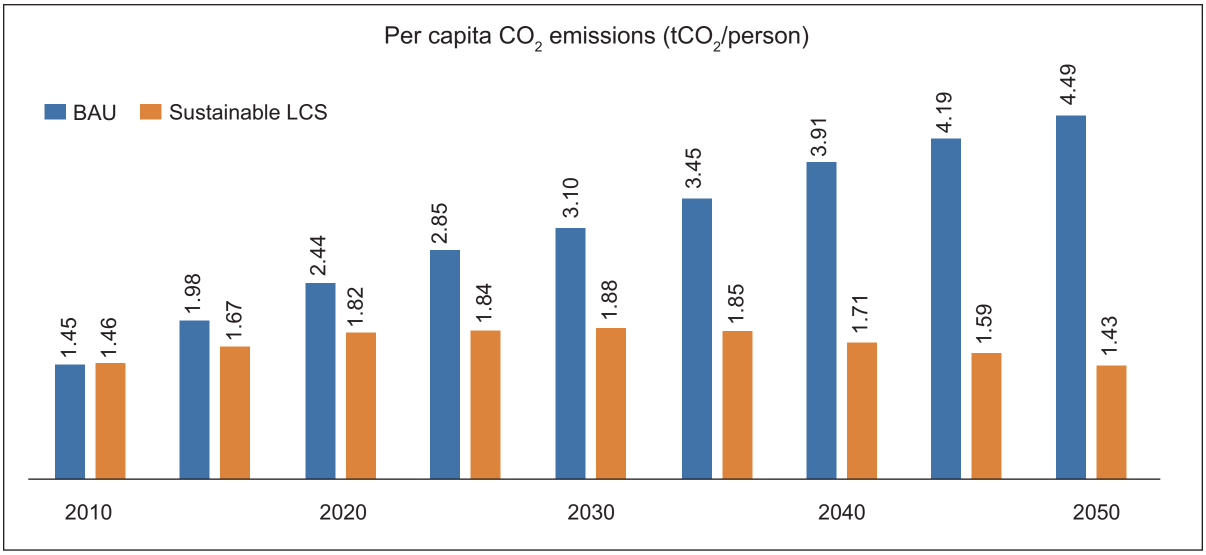


Source: IRENA, 2012

Per capita energy consumption and CO_2 emissions

India's historical and current per capita CO_2 emissions are among the lowest in the world. However, per capita CO_2 emissions are expected to grow rapidly as a result of economic growth, and to reach approximately 4.49 tCO_2 per capita in 2050 (Figure 13), which is more than the current global average. In the sustainable low carbon scenarios, the per capita emissions increase and peak in 2030 (Figure 13).

Figure 13: Per capita CO_2 emissions at the national level

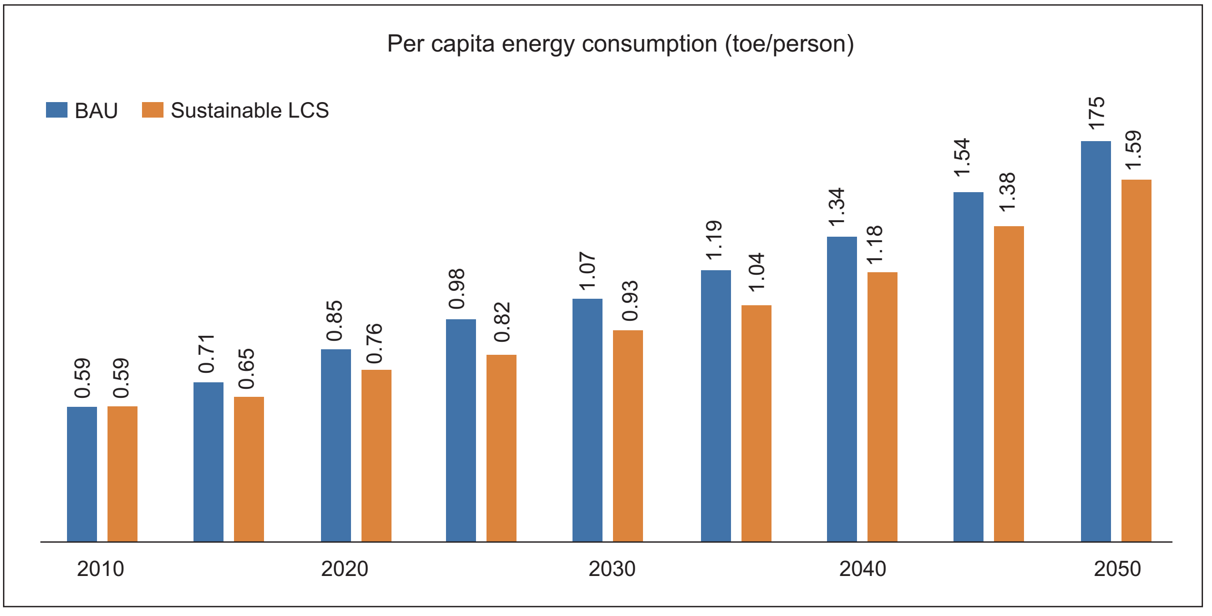


Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

The per capita energy consumption, however, shows an increasing trend across both the scenarios, though the increase is slower in the low carbon scenario (LCS), based on the sustainable path (Figure 14).

Cities will vary in terms of their per capita emissions – i.e., cities with a high concentration of energy intensive industries will have higher per capita emissions. Figure 13 provides the national average, which can be used to decide a per capita emission level for each city, for the future, by city planners – in consultation with stakeholders.

Figure 14: Per capita energy consumption at the national level



Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

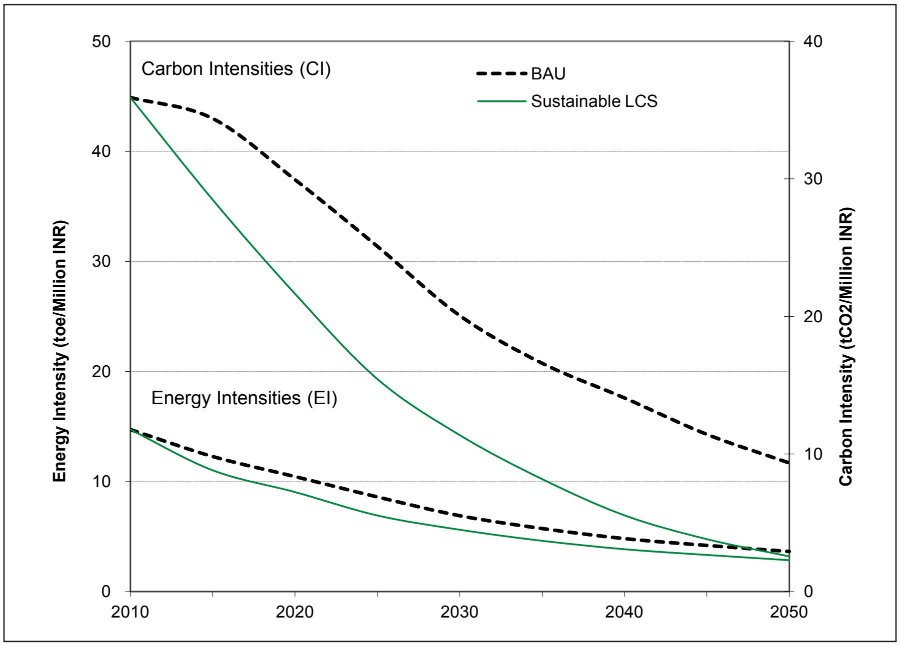
Energy intensity and carbon intensity

The elasticity of energy demand with respect to GDP has been falling over time and is currently around 0.80 (Planning Commission, 2012). In the future, the decoupling of energy demand and economic growth is expected to continue (Figure 15) due to changes in the structure of the economy, and overall improvements in technologies. The improvements in energy intensity also help in decoupling economic growth from CO_2 emissions (Figure 15), although, a stronger decoupling of economic growth and CO_2 emissions can be seen in the low carbon scenario where transformations in both the supply side (greater diffusion of renewables) and demand side decarbonise the economy.

Renewable share

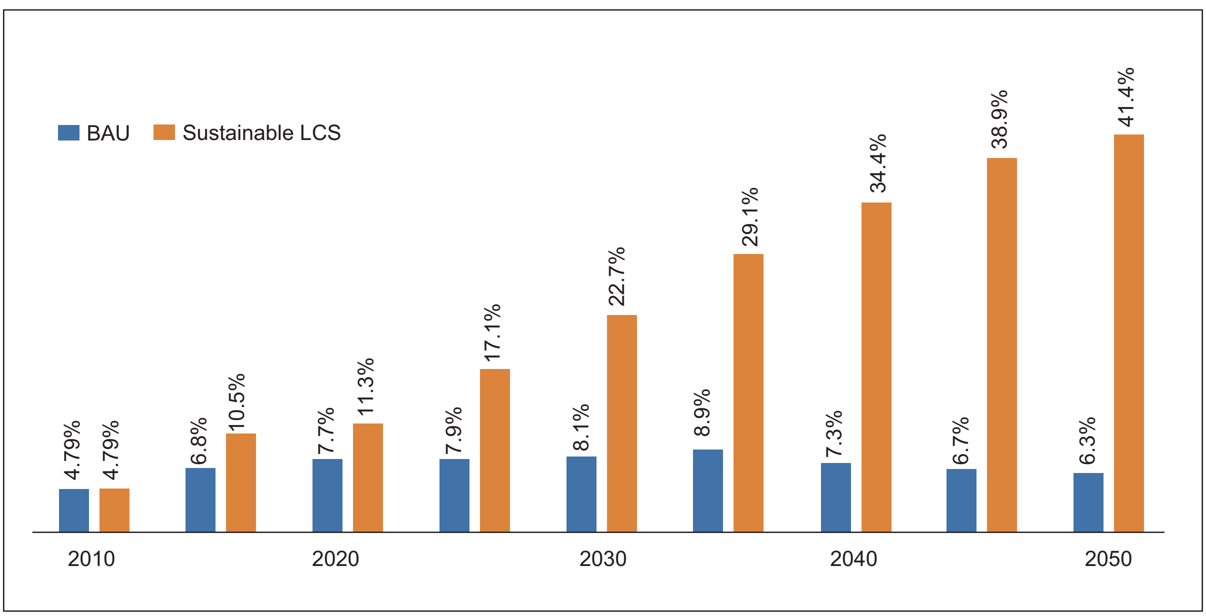
Globally, renewable energy accounted for nearly 13% of the total primary energy supply in 2008, and deployment has been increasing rapidly in recent years. Currently, developing countries host 53% of the total global renewable energy generation capacity. The share of biofuels in the transport sector has also been rising steadily, having accounted for 3% of the global road transport fuel demand in 2009 (IPCC, 2011). Following global trends, in India the share of renewable energy has also risen rapidly. The renewable energy share is expected to increase 8 times in the sustainable LCS scenario by 2050. This is much higher compared to a small increase of 1.5 times in the BAU scenario (Figure 16).

Figure 15: Trends in carbon intensities and energy intensities w.r.t GDP 2010–2050



Source: Adapted from Shukla and Dhar, 2011

Figure 16: Share of renewable energy 2010–2050



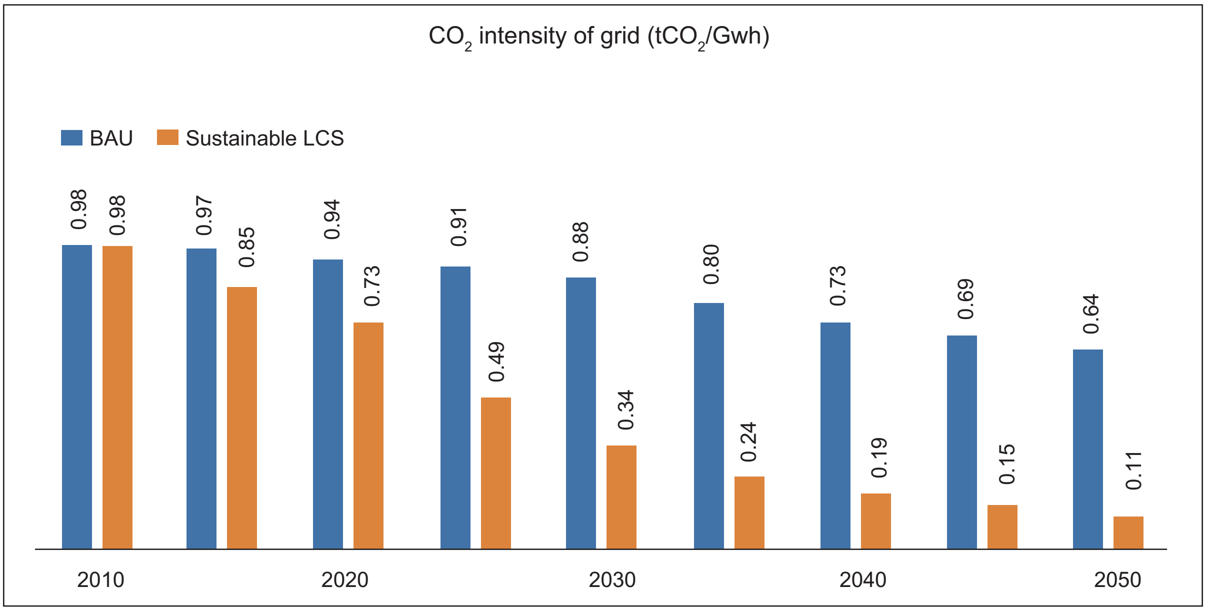
Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

4.6 CO_2 intensity of electricity

Major electricity consuming sectors in cities are industry, residential and commercial buildings. Municipal services including street lighting and water pumping also consume electricity. Although generation is sometimes outside city boundaries, electricity emissions are considered within a city's emission inventory[6]. Electricity demand is expected to rise in BAU, with increasing demand coming from residential and commercial buildings. Demand for electricity will, nevertheless, be higher in LCS due to increasing demand for the transport sector. Decarbonisation of electricity will, therefore, be a major intervention in an LCS scenario.

Electricity generation in India is highly reliant on coal and the government continues to see coal as the mainstay of power generation, therefore, the CO_2 intensity of electricity would decline due to efficiency improvements, but will remain high in BAU (Figure 17). In the sustainable low carbon scenario, the CO_2 intensity would reduce sharply, as renewables play a greater role (Figure 16); the coal-based power generation happens in combination with CCS.

Figure 17: CO_2 intensity of electricity from grid connected power 2010–2050



Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

Cities are major users of electricity, and in many cases the demand comes from outside the city boundaries. According to Scope 2 guidelines for emission inventories, cities need to account for this. City planners can, therefore, refer to Figure 17 for the future CO2 intensity of the grid.

4.7 Fuels for transport

The transport sector relies mainly on fossil fuels. Electricity is generally used in cases of rail-based transport modes, in addition to fossil fuels. In India, the low share of electrified routes ensures a low demand for electricity, even from railways. The dependence on fossil fuels is linked to the domination of internal combustion engine drivetrain technology, globally. Advancements in battery technology and environmental concerns have led to a diffusion of electric and hybrid drivetrain technologies in the US, Japan and China, while in India there is a negligible presence of these technologies. In order to improve air quality in Indian cities, natural gas has been used as an option, and as a result fuelling infrastructures for compressed natural gas (CNG) have been built in many cities. Therefore, in the BAU scenario, a greater

[6] As per scope 2 emission guidelines from IPCC emissions from electricity are included within city emissions

diffusion of CNG-based vehicles is expected, and gas emerges as a substantial fuel option (Figure 11). Electricity demand from transport also grows substantially as a result of construction of rail-based public transport systems (metro) within cities, construction of dedicated freight corridors, electrification of rail routes, and diffusion of electric vehicles for passenger transport.

The transport sector, at present, is heavily dependent on oil (petrol and diesel), however, in the future there will be diversification towards electricity, biofuels and natural gas. The level of diversification is even greater in an LCS scenario. City planners can refer to Figure 11 to decide on the fuel mix for their BAU and LCS scenarios.

Biofuels are expected to play an increasing role, however, the national targets of 10% by 2017 of biofuels for transport are difficult to achieve in the BAU scenario, due to land constraints and the high costs of production on marginal lands. In the sustainable LCS scenario, the overall demand for energy reduces substantially (Figure 11); moreover, a higher carbon price ensures greater diffusion of advanced biofuel technologies (e.g., using crop waste), giving biofuels a large role in transportation.

Photo credit: virgodad (Richard Bettles), 2007

5. What Does a 2°C Stabilisation Mean for Cities?

Cities and climate change have a dual relationship. Cities, as major emitters of greenhouse gases, contribute significantly to climate change. Consequently, the changing climate leads to severe impacts on cities as they house an increasing majority of the population and productive assets. Climate change is only marginally considered in the conventional urban development policy making and planning. However, globally, city planners are now increasingly paying attention to climate change for three key reasons. First, the participation of cities is vital to achieving national environment and development goals. Second, since cities hold most of the financial, institutional and intellectual capital, their active participation is essential in formulating and implementing national climate change mitigation and adaptation policies. Finally, cities are where sizeable co-benefits of climate change, such as improvement in air quality and traffic congestion, and reduced heat island effect, would accrue the integration of climate change and development policies.

There is a great deal of interest in looking for mitigation solutions at local levels, as the density and concentration of people in cities offer several opportunities to optimise energy use and consequent emissions. Looking at the population growth expected in urban areas in the future, it is clear that cities will play a significant role in climate change mitigation.

With the projected growth of the national GDP, and increase in the number of metropolitan areas, cities will become key economic drivers in the future. This will require significant investments in the urban sector. The estimated urban infrastructure investment requirement for the 20-year period from 2012–13 to 2031–32 is 66 billion USD (GoI, 2012). Since many of these infrastructures will remain for the next few decades, it is important to direct these decisions with a long-term view of impending problems such as climate change.

Per capita emissions in Indian cities have a huge diversity, ranging from less than 0.5 tonnes CO_2e to more than 2.7 tonnes CO_2e (ICLEI, 2009), with per capita emissions higher in metropolitan areas. In addition to activity levels, emissions also depend on the scope of the inventory, the geographical boundary of the city considered, and the emission factors. Though emissions in Indian cities are lower than those of developed countries, these cities are on an increasing economic growth trajectory, which will have significant implications on future carbon emissions.

The LCS approach is an opportunity, as it gives the means for such countries to avoid critical lock-ins. From the perspective of a city, the LCS opportunity is a window to decide on the future flow of energy, through infrastructure and other behavioural and lifestyle related choices. Therefore, it is important to look at alternative trajectories of development in order to make informed choices.

5.1 Vertical and horizontal integration to align national and city-level climate actions

A low carbon city plan can only work if well integrated with global and national scenarios. Integration with global scenarios is essential for cities, since technology innovations and transfer of technology depend on developments on a global scale. Cities also need to consider global scenarios that project aggregate mitigation targets, as well as local climate impacts and adaptation requirements, and integrate these into city level plans.

The success of urban climate governance, beyond the local level, requires various forms of vertical and horizontal coordination (OECD, 2008). Integration with national policies, in cities, is an important enabling condition for the success of green growth plans, including climate change mitigation and adaptation plans. The national government can govern through regulatory measures, and provide support for public investments aimed at cleaner and climate-friendly production, raising consumer awareness and catalysing R&D. Moreover, the national government could support green and climate-friendly investments within cities through technical assistance, signals for carbon price, funding and knowledge sharing for large-scale infrastructure projects such as smart grids, mass transit systems, and appropriate urban finance provision (Hammer et al., 2011).

It is also important to recognise that cities have certain limitations in exercising choices. For instance, the electricity mix, and, therefore, the carbon content of electricity, may not be under the direct control of the cities. The carbon content of grid electricity is largely influenced by national policies and programs. Therefore, several important inputs for low carbon city planning come from parameters influenced by national level socio-economic dynamics, which decide technology choices, financing, and national urban development policies.

Green or low carbon actions such as local solid waste processing plants or the addition of efficient buses, which can be implemented in the short-term and also have sizeable co-benefits other than direct carbon mitigation benefits, are being successfully executed by several cities. However, the implementation of a long-term action plan requires a comprehensive multi-sectoral approach, as well as a good vertical coherence between the local and national governments, and between local-state governments. Solutions implemented with purposive and effective engagement at different levels of the government can help remove several barriers, and can better facilitate implementation.

Just as a city is vertically integrated with global and national actions, it is simultaneously horizontally linked to the region it is a part of. A city is, in fact, a bioregion that interacts with its surroundings by utilising resources, generating employment, creating opportunities for entrepreneurship, learning, and providing services to surrounding towns and villages. The process of city development is fluid, as the whole system undergoes changes in terms of area, land-use and infrastructure. In addition to climate governance within its region, horizontal coordination also involves city networks. Emerging city networks such as C40 and ICLEI have played a significant role in facilitating the implementation of sustainable climate related actions in cities. These organisations facilitate learning among cities, and showcase local examples at the national and international levels. The size and impact of these networking activities confirms the role of cities as entities that have global impact and the need for a multilevel governance approach in policy and research (Gustavvson et al., 2007).

The multilevel governance approach emphasises the two-way relationship between the national and local government, and the need to bridge the policy gaps between the two levels. It works on the premise that the national government needs the local governments to implement climate strategies, while local actions are embedded in national, legal and institutional settings (Corfee-Morlot et al., 2009).

A low carbon city plan can only work if well integrated with global, national and regional plans. Therefore, inputs from global and national levels are important considerations for city scenarios. Inputs from the global level include global scenarios, mitigation targets and technology developments. Information from the national and regional levels include national low carbon policies, regional development, and changes in the carbon content of energy supply options.

5.2 City indicators for energy and emissions

Indicators are useful for policy makers in the communication of the impact of strategies, and are most helpful when specific and measurable. In India, the MoUD has prepared indicators and benchmarks for measuring urban services[7]. Similarly, under the LCT, city level indicators for urban transport have been prepared[8].

A low carbon strategy requires a focus on energy, as its use is the major contributor to emissions of local pollutants and CO2. Therefore, in this section, indicators for energy use based on the national assessment for India are provided for the residential, transport and commercial sectors (Table 7). This is done in order to help policy makers and experts working in the cities to formulate benchmarks at the city level for energy use.

Table 7: Energy indicators for residential, transport and commercial sectors for BAU

Indicators	Unit	2010	2020	2030	2050
Residential: Urban					
Annual Energy consumption per household	(toe/hh)	0.44	0.43	0.40	0.38
Electricity consumption per household	(kwh/hh)	1,085.76	1,445.12	1,914.02	3,016.40
Transport: Urban					
Annual Energy consumption per person	litres eq. petrol/ person	34.1	50.7	50.6	65.9
Energy consumption per '000 pkm	kgoe/'000 pkm	12.41	11.97	9.17	8.44
Commercial					
Energy used per unit service GDP	toe/million INR	0.62	0.40	0.25	0.11

Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

[7] http://www.urbanindia.nic.in/programme/uwss/slb/slb.htm

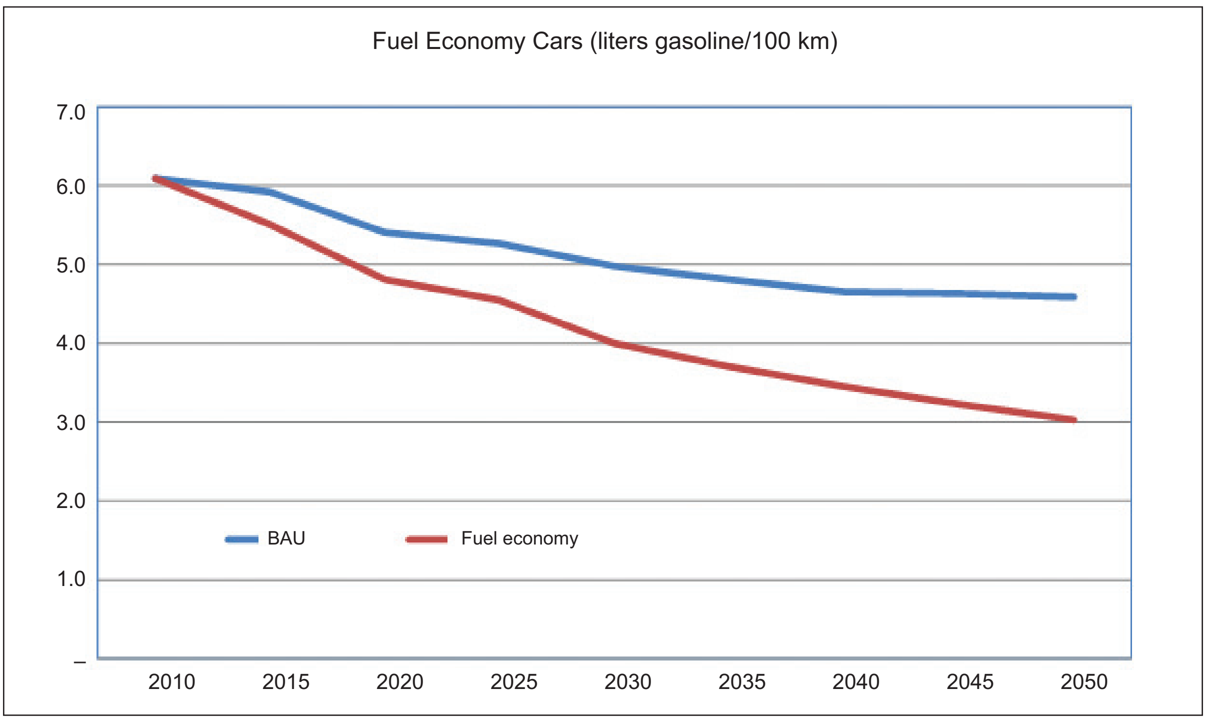
[8] http://www.unep.org/transport/lowcarbon/newsletter/pdf/ANNEX%202%20City%20level%20Indicators_%204oct.pdf

City planners would need a system of measuring energy consumption within the city to estimate these indicators. A top down approach for this would require information from electricity utilities and oil companies. A bottom up approach would involve estimating underlying activity information from surveys for households and commercial establishments.

5.3 Technology transitions

Cities are influenced by technology advancements at a global level, however, policies at the national level are required to create an enabling environment for diffusion of efficient technologies. For example, hybrid cars have diffused more in the US and Japanese markets due to favourable national policies. Energy efficiency is one of the strategic levers for reducing emissions (Socolow et al., 2006) and the energy efficiency of global technology stocks is expected to improve significantly in the future (Fulton et al., 2013; Plotkin et al., 2009). At a national level, actions altering the energy profile have a great bearing on cities, e.g., fuel economy standards could shape a significant shift in vehicle efficiencies in India (Figure 18).

Figure 18: Fuel efficiency improvements in gasoline cars



Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

City level planners should consider suitable improvements in the efficiency of vehicles. Figure 18 provides efficiency improvements for cars for a BAU scenario and a fuel economy scenario.

City gas distribution networks are being developed in many Indian cities, leading to a shift towards gas for transportation (Dhar and Shukla, 2010) in place of petroleum oil. The spread of natural gas networks within cities, and the greater availability of electricity can create enabling conditions for the introduction of new and more efficient technologies in households. For instance, solid fuels constitute 25% of fuel use within households (NSSO, 2012), and the same can be replaced by natural gas and LPG in urban households. Increasing incomes will, however, lead to greater penetration of appliances in households and result in energy intensive lifestyles.

Table 8: Appliance ownership for urban households (per 1,000 households)

Residential	2000	2010	2020	2030	2040	2050
Fan	1,393	1,501	1,645	1,779	1,870	2,000
AC/ Cooler	152	200	279	371	446	570
Refrigerator	237	319	459	627	765	1,000
TV	607	670	757	839	897	980
Washing m/c	92	142	240	376	501	740

Source: Adapted from "Low Carbon Transport Scenarios for India" (Dhar and Shukla, 2013, forthcoming)

City planners can undertake household surveys, or make use of NSSO data, to understand current appliance ownership. Future appliance ownership is expected to increase in line with income; Table 8 is a projection for the BAU scenario at the national level, and serves as one of the references for this.

5.4 Urban form and structure

The urban form includes population density, open spaces, extent of impervious surfaces, road networks, trip distances, civic infrastructure, etc. Together with the structures (built forces) and natural parameters, the city morphology has a great bearing on energy use and, therefore, on emissions.

The density and diversity of the urban form influences a city's energy use. Urban sprawl is a major challenge for cities. As cities spread out, work related trip distances and other travel activities increase. This often leads to a higher reliance on personal motorised transport. It is observed that compact cities emit less CO_2 emissions, on a per capita basis, from passenger transportation than sprawled cities (Makido, Yamagata and Dhakal, 2010, Newman and Kenworthy, 2011).This can be explained in three ways: i) compact cities enable shorter trips, which can be taken by walking and cycling, ii) compact cities offer scale and viability for public transport, and iii) a sprawled development is expensive, as it uses infrastructure less intensively than dense urban areas (World Bank, 2012).

Urban forms and structures will be important for influencing future emissions from cities in India. In rapidly developing cities, urban planning and its effective implementation requires land-use planning that creates land-use patterns within cities that can provide services without the loss or degradation of natural habitats. Local governments can proactively carry out integrated land-use planning to address adverse impacts from urban sprawl, including increased private motorised transport, air pollution and urban heat island effect. Zoning techniques may be applied to implement master plans, and guide urban development to spatially organise activities and infrastructure provision that can reduce energy use, conserve open spaces and restrict private motorised transport. Simultaneously, densifying development may not always be the solution, as most Indian cities already have high densities. Urban planning needs to be tailored to city types, depending on the city typology and the spatial organisation of activities. Governments can set targets for the percentage of development occurring in 'brownfields' – setting housing density targets –

introduce taxes on vacant land, preserve open spaces near towns and cities, and encourage development of green belts.

Urban form also affects the vulnerability of a city to climate impacts; for example, the extent of impervious surfaces can influence flooding and heat island effect (Blanco et al., 2011). Indian cities are growing rapidly, in terms of both population and area, and are expected to continue. The density of many Indian cities is very high, however, historically, many high density cities have sprawled (Angel et al., 2010). It is therefore, important to see how these densities will be transformed in the future. Climate change mitigation and adaptation bring to the table additional issues and aspects to be integrated into the city's planning of urban form and structure.

Due to the diversity of Indian cities, solutions for urban planning and development will need to be tailored to the particular city. This can be achieved by following a bottom up approach, which relies on studying the city form (e.g., by mapping building footprints), city plans (through collection of all information on all plans from authorities, and interaction with stakeholders), and preferences of inhabitants (e.g., by undertaking survey of households). A few alternative scenarios should be analysed and presented to the stakeholders.

City planners should run various land-use scenarios to explore density and diversity for the future. Land-use planning also needs to better integrate the NMT modes with public transport. Decisions regarding urban forms and structures can deliver multiple co-benefits, reduce climate-related risks, and, in general, enhance quality of life in the immediate future as well as in the long-term.

5.5 City emissions pathways

Low carbon city planning builds upon the on-going planning processes within the respective sectors. Conventional planning processes, however, do not analyse the energy flows, which are rather important for CO_2 emissions accounting. Therefore, the accounting of energy and, from it, emissions for the base year and horizon years is the first step. Next, it is necessary to define an emission level for the low carbon scenario, for which it is helpful to refer to the per capita national benchmarks (see Figure 13). It is generally good practice to engage stakeholders at the city level for this. The low carbon scenario target can be achieved through alternative pathways and frameworks.

City emissions inventory

Greenhouse gas accounting is the first step towards planning for mitigation actions. Cities need to have a reliable inventory of emissions at a sectoral level (Hoornweg, Sugar and Trejor Gomez, 2011). The emission inventory should be clear on emission factors and coefficients, scope and system boundaries, measurement methods, and consistency and clarity of definitions. Emission scenarios can then be developed by using a bottom up approach for individual sectors (see frameworks for transport and building sectors – Figures 20 and 22) using models that allow a consistent accounting of emissions.

GHG emissions in cities come from energy use activities – predominantly transport, industry, and buildings. Non-energy sources of greenhouse gases in cities come from solid waste and wastewater. Emissions are strongly influenced by the type of economic activities carried out in the city, its morphology and growth pattern, fuel mix, and technology choices[9]. People's lifestyle choices and behaviour also have a significant

[9] For example choice of options for mass transit – metro, bus rapid transit, etc., or the share of different fuels among cities – for instance, CNG penetration is higher in some cities than in others.

influence on the energy footprint. Generally, per capita emissions tend to increase with income, mainly driven by high consumption choices of its citizens.

Emissions arising from energy use activities, mainly electricity and fuel consumption in buildings and industries, transport, and waste, are usually considered direct emissions, and form an important part of the inventory. Indirect emissions include those emissions that come from outside city boundaries, for instance those embodied in materials consumed within the city, intercity transport, etc., and are more difficult to estimate. Electricity has embedded emissions, which are considered Scope 2 emissions. Data can be obtained from local utilities for power produced locally, however, for electricity purchased from the grid, emission coefficients need to be considered. Grid emission coefficients for the future are provided in Figure 17.

There are issues regarding attribution of sectors such as aviation, rail and marine transport. Globally, these emissions are considered outside the national boundary. The international aviation emissions are not accounted for in the national emissions inventory. This is based on the principle that 'molecules carry the flag'. It is, therefore, better to keep aviation out of the city accounting. The same is true for intercity transport for passenger and freight (by road or rail). Most importantly, a policy maker (e.g., local government head) will be interested in emissions they can influence. As intercity emissions are, to a great extent, not in this category, there is little purpose in including them in the city accounting process.

Setting a time frame and mitigation actions

When setting a time frame, there are two things to consider. In the event that the low carbon scenarios are analysed using economic models, it is important to set a longer time frame since several infrastructures and technology interventions have high capital costs and long life spans and, therefore, may not come up if the time frame is one or two decades. However, if the model framework is based on a non-economic framework (see framework for transport sector), then the time frames can be aligned with city level planning horizons.

For the LCS scenario, cities can use a back casting approach to identify the various mitigation actions, and link the city level per capita emissions to those for the national LCS scenarios (Figure 13). Current emissions for several million-plus Indian cities are about 2 tonne per capita. Recent studies show that despite the numerous energy efficiency improvements – infrastructures and fuel switch in BAU – CO_2 emissions will continue to increase, and the results from the national assessment show that per capita emissions of carbon dioxide equivalent from India will be approximately 4.5 tonnes by 2030 (Figure 13). Emissions may be higher for urban areas. However, for the LCS scenarios, the per capita emissions need to be brought down to the current emission levels (Figure 13).

The per capita emission targets, which cities decide on, can be apportioned to sectors depending on the type of city, share of various sectors in emissions, and flexibility of sectors to achieve emission cuts. The share of individual sectors will depend on the type, economy, and location of the city. Cities vary widely in terms of composition of emissions. For instance, the share of transport in the total emissions in Indian cities is currently much lower than that of cities in developed countries, however, these will increase in the future.

City scenarios

City scenarios are developed to look at alternatives for achieving the targets. These scenario assumptions are driven by bottom up and top down information. Top down information includes global and national scenarios, risks and uncertainties, climate parameters, and information on future technologies and innovations. This must be tied in with bottom up information, which includes elements of the city, like demographic characteristics including population and income growth, changes in city form and structure, and the share of sectors contributing to the city's GDP. A city's potential to act, i.e., mitigation and adaptation, and the behavioural characteristics of its population are also important to consider when developing city scenarios. Once the city establishes priorities – mitigation goals and adaptation priorities – these can be spread out to have a short, medium and long-term action plan.

The Tyndall Centre for Climate Change Research has developed an integrated assessment model for cities that simultaneously looks at emissions accounting and climate impacts assessment. Global climate and economic models drive scenarios of regional economy and land-use change, ensuring that while they are influenced by local policy, these scenarios are also globally consistent. It is at the level of land-use modelling that the analysis becomes spatially explicit. Scenarios of land-use and city-scale climate and socioeconomic change inform the emissions accounting and climate impacts modules (Dawson et al., 2009).

The success of these scenarios also depends on the extent of stakeholder buy-in, which includes local businesses, industry, and citizens. The capacity of local governments to implement these is necessary, yet the process is slow. Therefore, it is important to have a low carbon strategy that looks at measures that can be implemented in the short-term while initiating more long-term measures like green electricity (Deshpande et al., 2011).

Low Carbon City Planning can build on the conventional planning process. City planners, however, need to do energy and emissions accounting for the city. Emission levels can thereafter be set in consultation with stakeholders, and scenarios are then developed for achieving the target.

5.6 Transport sector – scenarios, framework and options

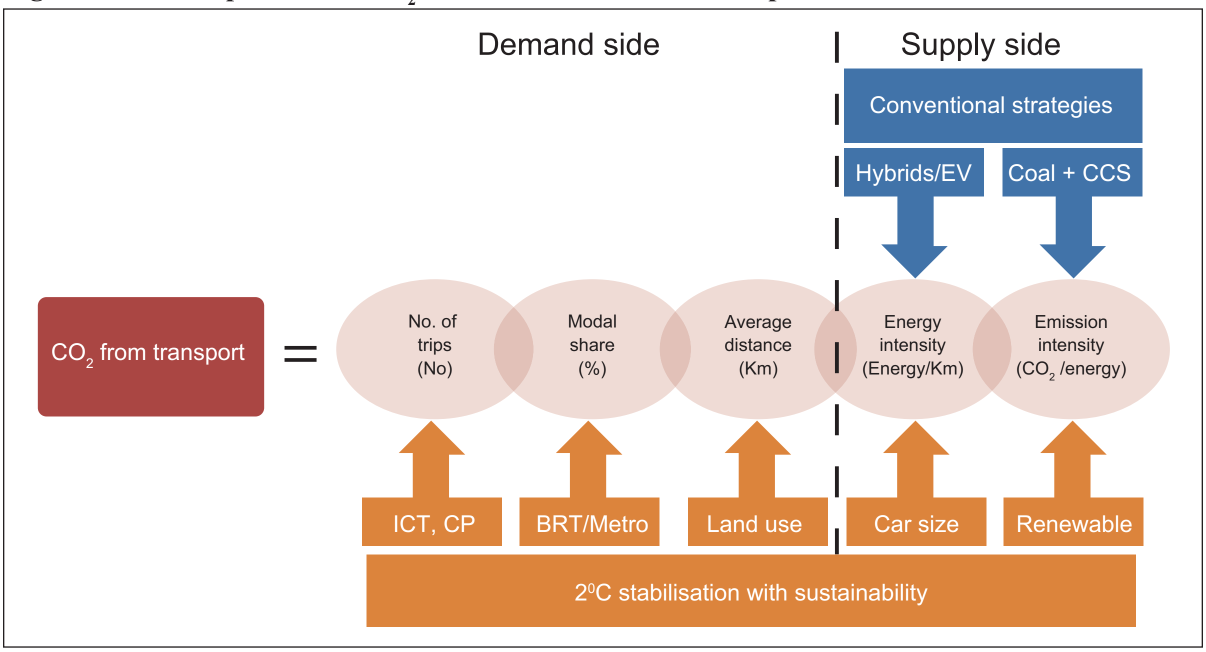
The transport sector, overall, is responsible for about 10% of the total final energy demand, especially dominating the growing demand for oil in India. The sector has serious implications for local emissions and energy security, currently being responsible for 8% of India's CO_2 emissions. Between 2002 and 2007, the CO_2 emission load from cars increased by 73%, and from two-wheelers by 61% (Roychowdhury, 2009).The energy demand, and therefore, GHG emissions, from transport is expected to grow in the BAU scenario (see Figure 11), and a greater share of this demand will be for private motorised modes (Figure 7), which will lead to a high share from transport in urban emissions.

Cities in developing countries like India, China and Brazil are faced with high levels of air pollution. The present levels of PM10 in many Indian cities exceed the National Ambient Air Quality Standards on several days. Cities in developed countries have been able to limit PM10 levels despite high car ownership. Therefore, it is possible to address the problem through stringent emission norms for vehicles, although influencing private car ownership and car use, and shifting demand to NMT and public transport modes may be more economical options. In India, million-plus cities which have a relatively higher car ownership than smaller cities occupy a sizeable share of the energy consumption and CO_2 emissions from the total on-road passenger transport activities in the country (Ghate and Sundar, 2010),and these cities could be taken as priority for low carbon interventions.

Transport Scenario

Transport emissions can be reduced through demand and supply side interventions (Figure 19).The demand side interventions rely on reducing the trips, retaining[10] modal shares of non-motorised transport, and shifting demand from private vehicles to public transport. The demand side strategies can be achieved by creating an urban form, which integrates non-motorised and public transport to make public transport more accessible. However, building and maintaining good quality infrastructures for NMT, and providing reliable public transport are necessary to manage the demand for passenger transport. The supply side strategies essentially rely on policies that affect the technology choices for consumers (e.g., for more efficient cars, cleaner fuels, etc.), as well as decarbonising the electricity.

Figure 19: Decomposition of CO_2 emissions from urban transport

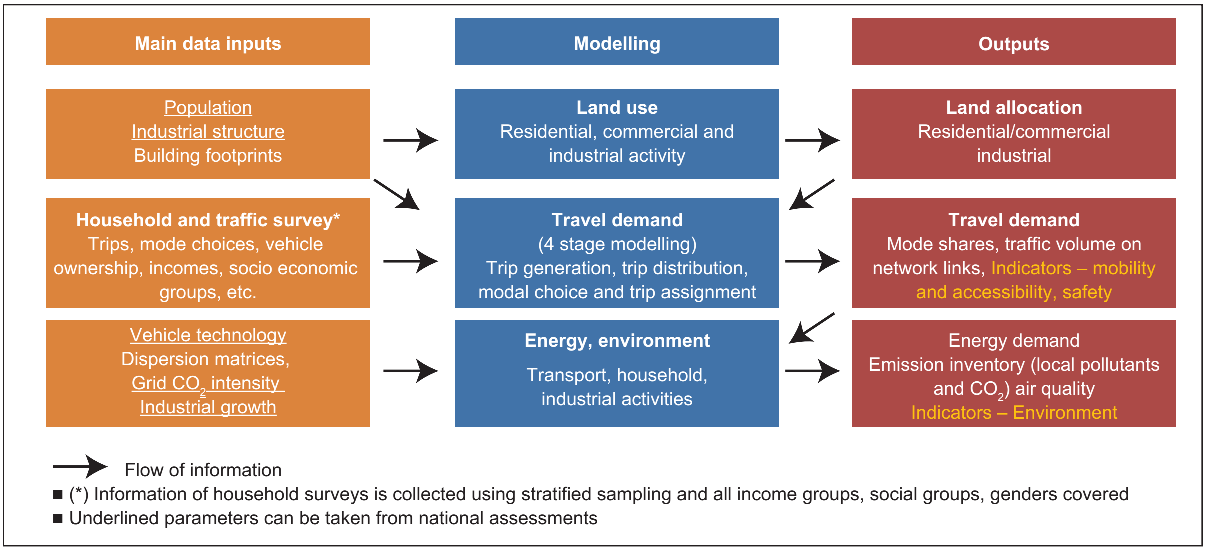


Framework for low carbon transport

The framework for low carbon mobility needs to utilise the four strategic levers of urban form, NMT, public transport and technology. The framework should be able to study impacts of alternative strategies on key indicators of mobility, safety, and local environment (see Tiwari et al., 2012) in addition to more aggregate indicators like CO_2 and energy use. It is difficult to find a single model that can estimate all these indicators. One approach is to have a model framework (Figure 20) that combines a GIS based transport planning model – which has a detailed description of transport activities – with an emission inventory and air diffusion model (e.g., SIM AIR) – which can analyse the impact of activities from different sectors, including transport, on the local environment, energy use and CO_2 emissions.

[10] The NMT share is high in most Indian cities (Jain and Tiwari, forthcoming); it is, therefore, important to retain the NMT shares.

Figure 20: Transport modelling framework for low carbon planning



The modelling follows a sequential approach where, first, a land-use scenario is created for BAU. This scenario for BAU can be simply based on land-use plans for a city[11], or created and discussed with stakeholders within the city. The next step is to understand the current travel patterns within the city, which are analysed from a survey of households[12] and traffic surveys. The surveys are helpful in developing a travel demand model for the city, which can estimate travel demand, mode shares, and traffic volumes on various roads. The travel demand model can then be used to analyse alternative strategies for urban form, NMT and public transport. The outputs for travel activity (disaggregated geospatially) are introduced into the Energy and Air dispersion model, which has a description of different transportation technologies. The activity level information is used to calculate emission loads on various road networks. The model also has a characterisation of emission loads from other sectors (residential, commercial, industry and waste). These emission loads are then transformed into emission concentrations by using dispersion matrices[13]; CO_2 being a GHG does not require any dispersion modelling.

Policies required for low carbon transport

A wide array of policies can be used for managing transport demands, improving the energy intensity of transport, and reducing the carbon intensity of transport to achieve a Low Carbon Transport system (Figure 21 and Appendix 4). The policies can be broadly classified as those leading to supply of infrastructures, regulations and institutions, which lay down the rules and regulations, and market instruments.

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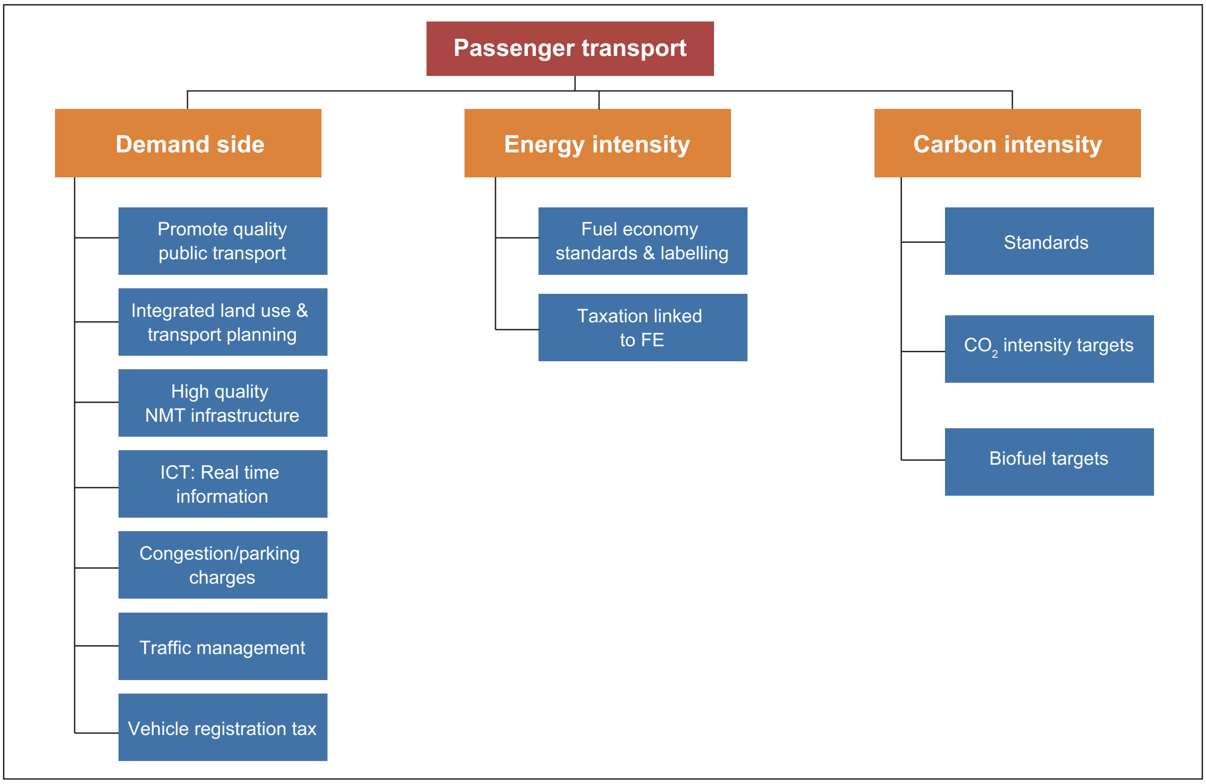
[11] Cities in India prepare a land-use plan for the area falling under the domain of municipal boundaries (generally smaller) and under the urban development authority (generally bigger). These land-use plans are for long-term planning purposes, and span about 20 years.

[12] Details on the household survey required are provided in the LCMP toolkit used for UNEP promoting Low Carbon Transport Project. The survey generally covers 0.5% of households within a city.

[13] Dispersion matrices are extracted from dispersion modelling.

Figure 21: Low carbon options for passenger transport



Transport infrastructure

A low carbon mobility strategy will require major changes in infrastructures and urban design. Transport infrastructures have long lives, a 'public goods' character, and are usually provided by the government. Government infrastructure policies can change the advantage of alternative modes, e.g., investments in roads only, can spur the growth of private vehicles. Several Asian cities have initiated investments in mass transit systems. The choices for mass rapid transit systems include various options ranging from bus systems and light rail transit systems, to rail-based options like metros. The selection of the transport system depends on a variety of factors, the most important ones being the travel pattern of a city and the cost of setting up infrastructure. A broad overview of public transit options is provided in Table 9.

Table 9: Overview of mass transit options

	Bus rapid transit	Light rail system	Metro
Capacity (Passengers per line in one hour)	10,000 to 20,000 (Sometimes going up to 40,000 Bogota BRT)	10,000 to 20,000	12,000 to 45,000 (Sometimes going up to 80,000 Hong Kong Metro)
Costs (Million USD per km of length)**	5 to 27	13 to 40	27 to 330
Existing Networks in 2011(km) **	2,139	15,000	10,000
CO_2 per passenger (gCO_2/pkm) **	14 to 22	4 to 22	3 to 21
Typical Fuel	Diesel	Electricity	Electricity

Source: ** Data from IEA, 2012 Energy Technology Perspectives 2012, rest from Newman and Salter, 2011

Metro systems have been criticised for their high capital costs (Goel and Tiwari, 2013, forthcoming), however, BRT systems have been generally advanced as a solution to meet the mobility needs of developing countries. The BRT design philosophy has provision for both cyclists and pedestrian modes and, therefore, by design, it tries to achieve intermodal integration. BRT systems have been implemented in a number of cities in Latin America and Asia, with Curitiba and Bogota being two widely cited models for BRT. In India, a number of cities have implemented BRT systems, though concerns have been raised regarding a lack of focus on NMT and pedestrian facilities (Mahadevia et al., 2012).

The choice of modes for public transport varies – in some cases, bus systems are preferred over metro; there is no 'one size fits all' model. The decision to set up transport infrastructure should take into consideration a city's growth pattern, population, travel demand (both present and future), resources and environmental considerations. Economies of scale govern the choice of technology. It is not easy for a single city to become sustainable. For example, if a large number of cities adopt BRTS, costs can come down significantly.

In addition to infrastructure upgradation, it will be necessary for cities to facilitate a shift towards public transport. This can be done by facilitating better integration of different transport modes. Instruments to discourage private automobile use can also facilitate the shift to public transport. Some innovative sub-actions include having car parks near major metro stations and bus stops, electronic ticketing, and improved frequency of public transport.

Pricing is a key determinant in encouraging people to use public transport. In developing countries, pricing is important from an equity perspective, as a large proportion of people do not have access to personal vehicles, have low incomes, and rely only on public transport to commute (Mahadevia et al., 2012). Fare strategies for transit systems, therefore, should balance needs for financial sustainability and affordability for low-income groups.

Regulations and institutions

A variety of institutions are involved in regulating transport activities at the national and local level. Vehicle registrations are handled by local transportation authorities, which could play an important role in regulating the supply of vehicles and the withdrawal of inefficient vehicles. In India, fuel policies are decided by the Ministry of Petroleum and Natural Resources, while fuel efficiency norms and standards are decided by the Bureau of Energy Efficiency.

Regulatory reforms may include mandatory emission norms for vehicles, or a complete ban on certain kinds of vehicles. In order to promote new technologies in the market, the government can enforce certain regulations – e.g., CNG vehicles were introduced due to mandates on city bus fleets in Delhi.

Cities in developing countries have to make a choice, as problems of development goals, energy, local air pollution and climate change exist simultaneously. Therefore, transportation must be aligned with energy policies, and these, in turn, must be integrated into the development strategy. While it may not be possible for cities to decide on certain policies, for example enforcing emission standards, individual cities can enforce congestion tax or other local policies. Urban policies such as provision of basic services, like schools and hospitals in every neighbourhood, can be effectively implemented for reducing travel demand.

Economic instruments

Economic instruments can include emission taxes, congestion charges, or subsidies on the use of cleaner fuels. The use of congestion charging in London, Singapore, Seoul and many other cities has achieved remarkable success in relieving congestion, reducing CO_2 emissions and improving local air quality. The London Congestion Charging Scheme, introduced in 2003, calls for a charge for motor vehicles entering a specified zone at specified times. Since it was introduced, the policy has reduced congestion, improved traffic circulation and generated substantial revenue (Litman, 2011). The reduced congestion has resulted in decreased GHG and air pollution emissions.

Climate finance for transport projects

Carbon finance instruments are expected to become an additional source of financing for low carbon infrastructure projects in the future. The Clean Development Mechanism (CDM) was used to finance transport projects with limited success. The Delhi Metro Rail Project has been notable among urban transport projects. It has received financing under the CDM for two projects: 1) Regenerative braking, which is estimated to save 411 KT CO_2e of cumulative emissions by 2017, and 2) A modal shift where metro trips replace conventional modes, which is estimated to save 3.7 million tCO_2e by 2018.

In the post-Kyoto climate regime, transport projects are now eligible to receive financial support under the NAMA framework (Box 2). NAMAs for the transport sector could include actions pertaining to: 1) Avoiding or reducing trips, e.g., through the integration of land-use and transportation planning, 2) Shifting to, and maintaining, the use of "green" modes, such as public transport and non-motorised transport, and 3) Improving the vehicle and fuel technology of all modes of transport to improve the environmental efficiency of each kilometre travelled (Binsted, Wayman and Allen, 2012).

Box 2: What are NAMAs?

Nationally Appropriate Mitigation Actions (NAMAs) are climate change mitigation actions, mainly GHG emission reduction policies and actions, implemented by developing countries (Ninomiya, 2012). NAMAs were first reported in the Conference of Parties in Bali in 2007, and were further strengthened in subsequent agreements. One of the decisions in the Cancun agreement was that "developing country Parties will take nationally appropriate mitigation actions in the context of sustainable development, supported and enabled by technology, financing and capacity-building, aimed at achieving a deviation in emissions relative to 'business as usual' emissions in 2020"; as of 2010, countries are to provide details of mitigation actions through National Communications.

NAMAs have two main components: they must be deemed 'nationally appropriate' (for instance, address national development and environment goals), and they must reduce GHG emissions from a 'business as usual' scenario (Binstead, Wayman and Allen, 2012). There are three kinds of NAMAs: unilateral (mostly voluntary, initiated by the country), supported (including financial, technology or capacity building support), and credited (including those supported by the carbon market).

The NAMA Pipeline Analysis and Database contains information on submissions to the UNFCCC from developing countries and countries in transition for NAMAs (UNEP Risø 2013). The number of NAMAs under development increased significantly, from 30 initiatives in November 2011 to a total of 52 in May 2012 (Van Tilburg, 2012). More than half of the total submissions made by developing country parties pertain to the land transport sector (Binsted A, 2011). Table 10 shows some examples of NAMAs and their stages of development.

Table 10: NAMAs in urban transport

Country	Type	Type of Action
Submitted to UNFCCC		
Ethiopia	Shifting Freight to Electric Rail	Project
Indonesia	Sustainable Urban Transport Initiative	Policy/Program
Under Development		
Columbia	Electric Vehicles Transit oriented development	Strategy/Plan
Mexico	Optimisation of the conventional bus system in Mexico City	Strategy/Plan
Chile	Low emission vehicles (taxis and Transantiago), bicycle promotion, transit management	Strategy/Plan
Brazil	Comprehensive Mobility Plan for Bello Horizonte	Strategy/Plan

Sources: Ecofys (2013)

A number of cities in developing countries have expressed a willingness to take local transportation projects forward using the NAMA framework. This is supported by the realisation that there are financial resources, and several opportunities on the way. Cities can share ideas and best practices, and develop bankable transport projects, which will also help reap early mover advantage (Sakomoto, 2012).

Under recent global negotiations, new frameworks and instruments have now become available to finance mitigation actions. These include NAMAs, which are mitigation actions in developing countries that can receive financial support from the global carbon market. By designing mitigation actions that are measurable, reportable and verifiable (MRV), cities can leverage finance under NAMAs for a low carbon future.

5.7 Industries

Industrial sector emissions of greenhouse gases (GHGs) include carbon dioxide (CO_2) from energy use, from non-energy uses of fossil fuels, and from non-fossil fuel sources (e.g., cement manufacturing), as well as non-CO_2 gases (IPCC AR4). Globally, industrial energy consumption is expected to grow from 191 quadrillion Btu in 2008 to 288 quadrillion Btu in 2035, in the reference case. Nearly 89% of this increase will come from non-OECD countries, mainly due to economic growth and increase in total industrial energy consumption (IEO, 2011).

Key mitigation options for the industry sector involve measures across scales from those that can be implemented at the sectoral level to industry-specific measures. Certain interventions can also pertain to specific industrial operations. Industry-specific measures include more efficient electric motors and motor-driven systems; high efficiency boilers and process heaters; fuel switching, including the use of waste materials; and recycling. Process-specifc options could include the use of bio-energy contained in food and pulp and paper industry wastes, recovery of pressurised blast furnace gas, or the reduction of emissions from specific manufacturing processes. Emissions can also be reduced from specific operations such as controlling steam or air leaks, insulation, higher capacity utilisation, etc. (IPCC AR4).

Greenhouse gas emissions from the industry sector in cities are mainly driven by growing levels of production to meet demands, increase in energy intensity in what is produced, and by the importance of industries producing goods, for which the fabrication entails large greenhouse gas emissions, such as motor vehicles (Satterthwaite, 2010).

It is beyond the scope of this guidebook to go into detail regarding emission reduction strategies for the various industries, however, city administrators need to consider industries as job providers, whose location would dictate trip lengths for the workforce and, therefore, would have implications for emissions from the transport sector.

5.8 Buildings sector: framework and options

The buildings sector includes residential buildings, commercial buildings, retail spaces, and institutional and public buildings. Buildings account for 30% of the total final energy consumption. The residential sector consumes 18% of the total energy use, globally, while the share of the commercial sector is 12%[14]. Buildings are responsible for 8% of global GHG emissions and a third of energy related emissions (UNEP 2012).

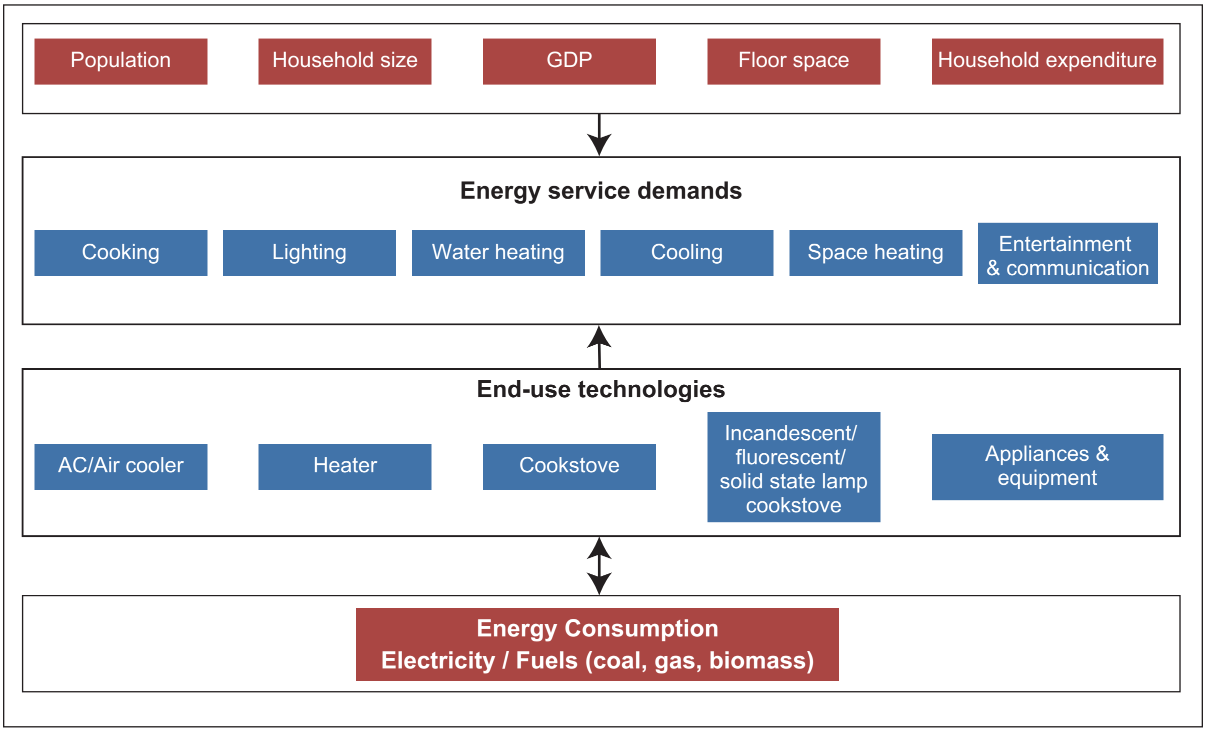
[14] www.eia.gov/tools/faqs/faq.cfm?id=447&t=1. Accessed 26 March, 2013.

Construction of new buildings is expected in the future, for both residential and commercial spaces. More than 60% of the buildings that will exist in 2050 have yet to be constructed in developing countries. This offers a huge opportunity for cities to plan, in advance, the reduction of CO_2 emissions from buildings.

Framework for buildings sector

Energy consumption in buildings varies across cities, depending on climate, development status, and socio-cultural factors. Million-plus cities have higher consumption than Class I cities (urban agglomerations/ towns which have at least 100,000 persons). Key drivers for energy consumption in residential buildings include population, number of households, GDP, household expenditure and increase in floor area (Figure 22). In BAU, increase in income and the desire for a more comfortable lifestyle can result in a higher ownership and use of lighting, cooling and other appliances (Table 8) in buildings, leading to greater energy consumption per capita. It is projected that final energy demand from the buildings sector in India will grow five times by the end of the century, with a high demand for floor space and building energy services coming mainly from urban centres (Chaturvedi et al., 2012).Furthermore, the demand for space cooling and appliances will grow substantially.

Figure 22: Building energy consumption framework



Source: Based on Chaturvedi et al., 2012; van Ruijven et al., 2011

Temperature is also an important factor, since the need for space heating or air-conditioning is much higher in cities that experience extreme weather. Building form, orientation, materials, and technology also influence a building's energy consumption. A study in Bhopal showed that the highest energy consumption in buildings was due to space cooling. A high correlation between temperature and building energy use was observed, indicating that energy consumption was at its highest during summer months (Deshpande et al., 2011).

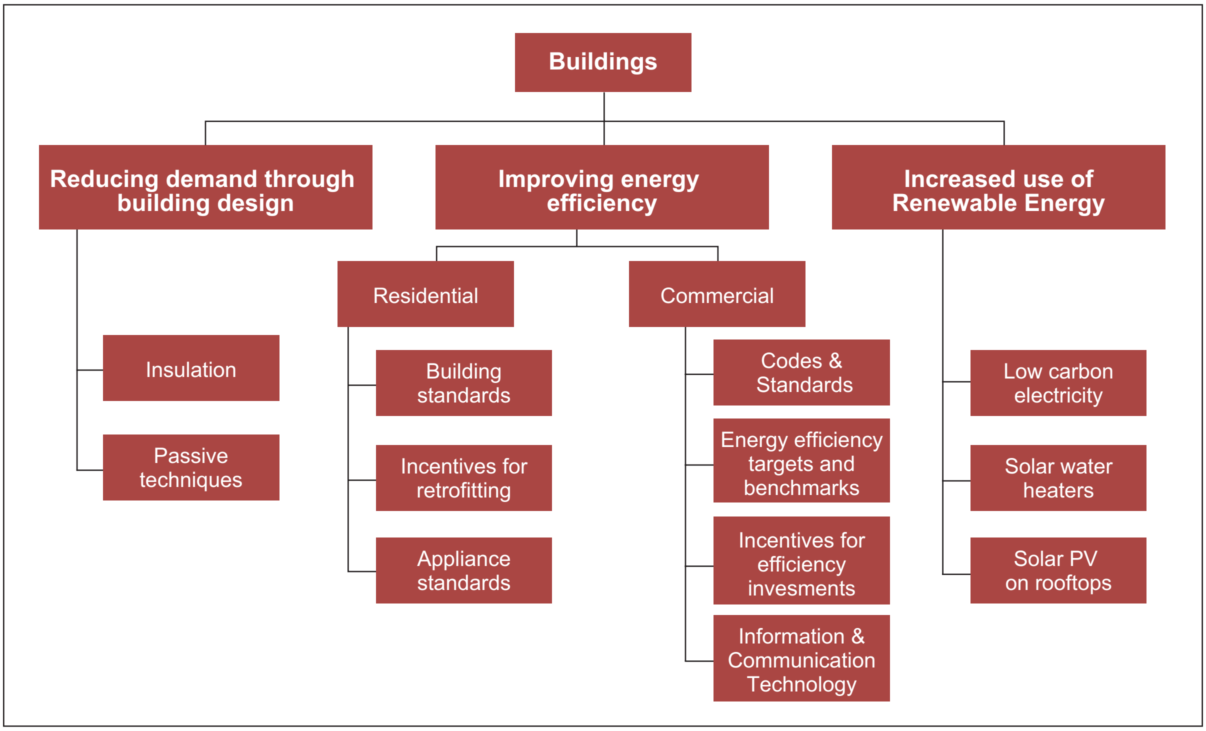
Currently, the residential sector in India has a higher share of final energy consumption, mainly due to a higher share of solid fuels in cooking, which are commonly combusted inefficiently. More than half of the urban households use LPG for cooking, while about a third depend on traditional sources.

Buildings generate emissions during both the construction and the operations phases. The use of construction materials often has a huge volume of embedded CO_2, which comes from the raw material, and from the processing and transport of these materials. The significance of embedded emissions is now gaining importance and, globally, many cities have started accounting for emissions from building construction materials. This accounting will help cities move towards further dematerialisation and low carbon building construction. Sourcing locally available materials offers a good opportunity for cities to reduce emissions from construction materials.

Low carbon options for the buildings sector

There are three types of policies that address energy consumption in buildings: 1) Regulatory instruments, which mainly involve building energy codes that specify the minimum energy performance of a building, 2) Information instruments, such as labelling, and 3) Incentives that include fiscal, financial and economic measures for energy efficiency (IEA, 2013).Mitigation options for the buildings sector include reducing energy demand, improving energy efficiency, and increasing use of low carbon energy sources (Figure 23).

Figure 23: Mitigation options for the buildings sector



The commercial sector includes business and other commercial establishments, hotels, hospitals, educational institutions, government and public buildings. Major drivers for commercial energy consumption are floor areas of commercial buildings, and energy intensity per unit areas. The expanding service sector will lead to an increased demand for commercial spaces in cities. There will also be a higher demand for comfortable offices and retail establishments. This will increase the use of air conditioners, office appliances and lighting, causing a significant increase in the energy use per unit area. Simultaneously, the ratio of floor area per output would decrease, as commercial spaces would be used more efficiently.

CO_2 reduction in the BAU scenario would come from a modification of building design, energy efficiency, fuel switch and cleaner electricity. Some CO_2 reduction in commercial buildings would also come from the use of Information and Communication Technology (ICT), which can reduce demand for office spaces by promoting increased online interaction between consumers and suppliers.

Many studies have analysed the emission reduction potential of energy efficiency for the buildings sector. Good building policies implemented now can deliver high gains, as buildings have a long life. Significant energy savings can be achieved in the buildings sector, cost effectively. Lack of awareness/information, financial reasons, and split incentives are some important barriers to energy efficiency improvement in buildings.

Building codes that mandate minimum energy requirements have proven to be very effective in GHG mitigation. According to the Bureau of Energy Efficiency, Government of India, 1.7 billion kWh of energy savings are achievable annually through mandatory Energy Conservation Building Code (ECBC) compliance (BEE, 2009). Additional savings would come from improvement in lighting systems and cooling technology[15].

Energy efficient lighting will reduce energy demand by a fraction of current levels (between 10–50%). Developments are underway to phase out incandescent light bulbs. The initial transition involves the switch to CFLs. Technologies in the near future include LEDs, light sensitive switches, and further improvements in solid state lighting. Similarly, efficiency in household appliances could save between 30–60% of the total energy demand.

In addition to energy efficiency and demand reduction, cities are also experimenting with alternative forms of renewable and low carbon energy supply (UN Habitat, 2011). The initiatives have primarily focused on the use of simple devices like solar water heaters and, to some extent, photovoltaic cells. Solar water heaters have been widely accepted in cities in several countries, including China, due to their longer lifespan and simplicity of installation.

The Planning Commission of India has outlined two scenarios for the buildings sector: the determined effort scenario, and the aggressive effort scenario. A higher imposition of rating systems, ECBC compliance, retrofitting old buildings, and construction of energy efficient buildings in the aggressive effort scenario could save 122 million tonnes of CO_2 from commercial buildings by 2020, as compared to the determined effort scenario (Planning Commission, 2011).

5.9. Waste sector

The waste sector mainly contributes to methane emitted from solid waste in landfills and wastewater. Landfill waste generates methane, that has a global warming potential 21 times that of CO_2, which means that every tonne of waste kept from going to the landfill saves 21 equivalent tonnes of CO_2 (CO_2e). This makes waste management an important parameter for low carbon development. Globally,

[15] These included LED lighting systems, efficient air conditioners, efficient appliances with low standby power and automated sensors that regulate lighting and cooling intensity.

water and wastewater generate 3% of the total GHG emissions. The emissions for different cities vary depending on the consumption patterns, waste generation, management and disposal of waste. Though the contribution of this sector is small to the total emissions in a city, it is growing rapidly.

The increasing volume of waste has become a major concern for local governments in a large number of Indian cities, threatening to cause irreversible damage to the environment and quality of life. The average per capita waste generation in most developed countries exceeds 800 grams/day. In comparison, the average per capita waste generation in Indian cities is 670 grams/day, with landfills being the most prevalent way of disposing of waste, raising important social and environmental concerns. Waste generation in Indian cities is increasing at a rate of 1.33% per year. This is mainly driven by population growth, rising incomes, consumption driven lifestyles, and preference for packaged goods.

Options for mitigation from waste

Cities will have to look at alternate means of waste management, as available landfill space within the city would be constrained in the future. Emission reductions could come from waste management measures such as energy recovery from waste, greater recycling, composting and improved recovery of useful products, with the help of highly advanced technologies.

Low carbon initiatives can include measures at the generation stage, processing and final disposal. Reduction in waste generation in BAU would be a slow process, as the effect of rising incomes and consumption will offset minor gains achieved from sustainable behaviour of few citizens. In LCS, city corporations will make aggressive efforts for waste segregation and recycling. This will be facilitated by awareness drives and setting up of community recycling centres. Decentralised waste management options can reduce the amount of waste treated by the local municipal body, which can also reduce the amount of waste going to the landfill. Large commercial establishments including hotels, restaurants and institutions will be encouraged to manage waste within their premises, thus, reducing the amount of waste going to the landfill.

Some waste-to-energy and waste to compost activities will continue in BAU. In LCS, the proportion of waste going to landfills will be less than 50%, due to aggressive efforts towards becoming zero waste cities. Methane recovery factor has a big influence on a city's emissions. Cities will invest in landfills with methane recovery options to bring down emissions in LCS. Apart from direct mitigation benefits, waste management can help realise other co-benefits such as resource utilisation and enhancing quality of life. For example, a modern landfill can also be a source of fuels in the form of landfill gas (LFG), pellets and fluff, which can be used in the local industries.

In India, some Urban Local Bodies (ULBs) have initiated successful reform initiatives in the waste sector. These integrated waste management solutions incorporate initiatives ranging from door-to-door collection, improved technologies in waste processing and disposal methods, to successful public-private partnerships in these areas.

Some micro-initiatives include 'door or gate to dump' projects to improve coverage of services in the city. These initiatives are supplemented with information and education campaigns that raise awareness with the help of public events, use of mass communication tools, etc. In Ahmedabad City, an effective solid waste management department, in addition to managing the above activities, develops solid waste Master Plans that serve as guiding documents – not only for the city to manage municipal waste, but to align this with other national and international best practices toward zero waste cities (AMC, 2012).

These initiatives have resulted in positive environmental benefits, including climate change mitigation, and improved overall quality of life in these cities. The above sections show how sectoral interventions in cities can help to achieve the overall mitigation target for the city. However, it is recognised that due to a city's connection to its hinterland, surrounding cities and other remote areas, there is a constant exchange of goods and services within these boundaries. These exchanges pack in emissions that are not necessarily generated within the city but do make a sizeable contribution to the total greenhouse gas emissions of the city. Information on these can be extracted through direct and indirect methods such as surveys of urban income and expenditure, cross boundary supply chains and data on material flows. Eventually, cities will need to find ways of accounting these embedded emissions, and work on reorienting these flows toward low carbon pathways.

Taking these into consideration, the definition of a low carbon city needs to be expanded to a city that promotes a low carbon and sustainable lifestyle choice, local consumption to avoid products with high-embedded carbon, and optimises energy consumption through innovative design and planning solutions. Finally, by enhancing green cover and water bodies, it promotes environmental conservation to achieve larger environment and climate benefits.

Photo credit: Thomas Locke Hobbs, 2011

6. Towards an Integrated Approach

A global survey of local governments in 90 cities found road congestion, lack of affordable housing, urban sprawl, air pollution, storms and flooding as the key challenges faced by a majority of cities. Cities in middle and low-income countries reported additional issues of water, sewage, informal land development, inadequate infrastructure and public services (LSE Cities, 2012). Some of the above mentioned challenges like storms, flooding and water would become further aggravated due to climate change.

The question is whether it is possible for Indian cities to develop in a way that can minimise energy use, optimise resource consumption, reduce environmental externalities, and enhance social and economic objectives. Can urban development effectively integrate climate objectives?

It is emphasised here that the mainstreaming of climate change actions requires going beyond strategies for mitigation, alone. Mitigation actions help in reducing the climate change risks but, going by the precautionary principle, countries also need to prepare for the worst and, therefore, build their adaptive capacity. Developing countries must pursue these mitigation and adaptation actions within an overall framework of development, looking at other developmental challenges like poverty reduction, employment creation, health, environment, etc. Therefore, the following sections delve into the adaptation issue, frameworks for adaptation, aligning development and climate change, climate compatible development, and co-benefits of mitigation and adaptation.

6.1 Adaptation

A 2°C scenario is, in itself, associated with some climate change and inability to achieve this global target can lead to serious climate changes. Cities in India are quite vulnerable to the impacts of climate change due to their limited ability to cope with extreme events. It is predicted that climate change will lead to temperature changes, changes in frequency, intensity and location of precipitation and storms, sea-level rise, flooding and environmental health risks.

Climate risks also vary among cities. For cities located in coastal regions, challenges of sea-level rise, and increase in frequency and intensity of cyclones will impact infrastructures. Conversely, cities inland will be affected by temperature increases and rainfall variability, which can have severe health impacts for the vulnerable populations, and affect the operationality of various infrastructures. Cities across India need to make significant investments in transport infrastructures, which have a long life span. In the past, large infrastructure projects have been mandated to go through environmental impact assessments, however, with a changing climate it is necessary to study the impacts of climate on infrastructure projects. There is some generic guidance on these topics[16]; for a deeper understanding of LCT projects, a case study of a transport infrastructure with a framework for adaptation is also available (Garg et al., 2013).

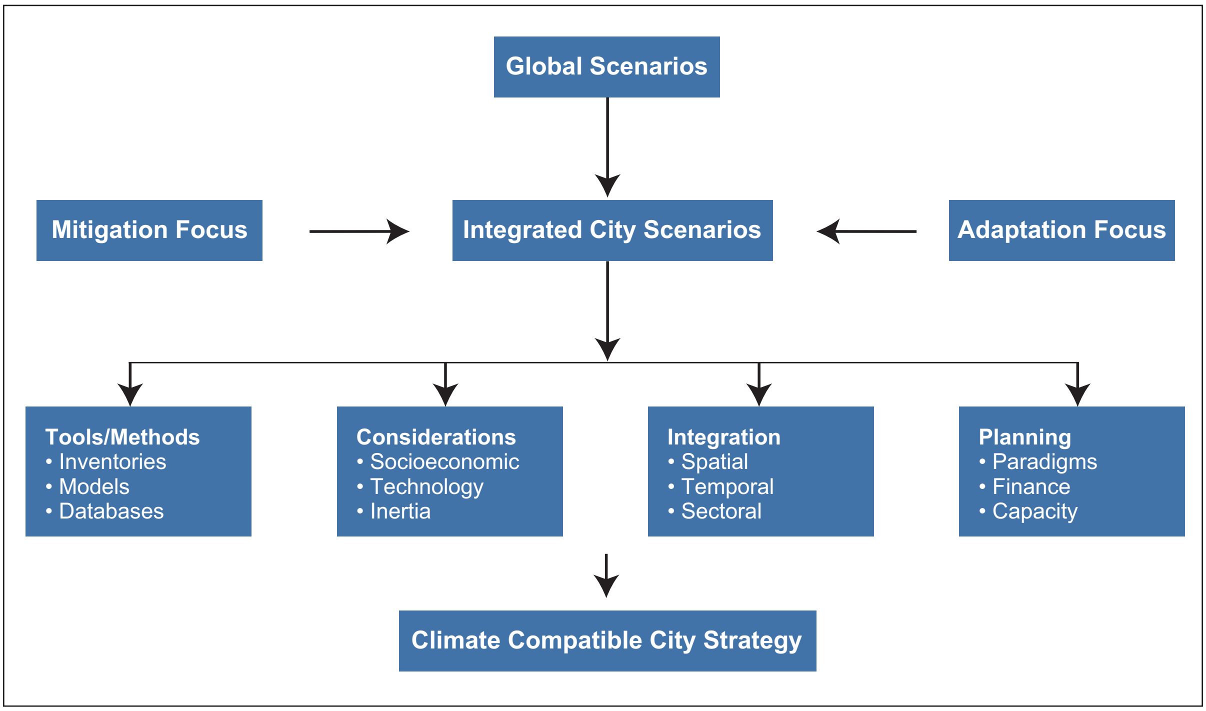
Existing regulations make the study of impacts from large infrastructure projects on the environment mandatory. With growing evidence of climate change, a reverse analysis to understand the impacts of climate change on large infrastructure projects is becoming necessary.

[16] For an example, refer to GiZ guidance Module 5f "Adapting Urban Transport to Climate Change"

6.2 Aligning climate and development

The relationship between climate change and sustainable development is two sided. Climate change influences social and economic development through its influence on humans and natural systems. Similarly, policies that promote sustainable development can influence emissions and vulnerability (Halsnæs et al., 2007). For developing countries, a development policy may not necessarily help achieve climate objective. Furthermore, a climate centric policy focus will not deliver the necessary development benefits. The International Research Network for Low Carbon Societies (LCS-RNet) recognises that climate policies could find more traction for the low carbon transition if they also address immediate social and economic goals such as poverty reduction, job creation and protection of welfare benefits (LCS-RNet, 2011). The Indian approach recognises that climate change is not an environmental issue, but a manifestation of style and mode of development (Heller and Shukla, 2003; Sathaye et al.,2006; GoI, 2008).

Figure 24: Framework for climate compatible urban development



The emerging concept of Climate Compatible Urban Development (CCUD) emphasises that it is vital to make urban development plans compatible with the changing climate mitigation and adaptation response actions. The framework for a climate compatible urban development plan (Figure 24) is based on the integrated assessment paradigm, which aligns global climate change concerns and issues with the urban development agenda. It is a three-step process. The first step starts with the identification of a city's future goals (e.g., in the year 2050) and related targets based on its development stage, climate risks profile, energy use, emissions and local environmental and social objectives. The second step is to incorporate climate risks into major policies and actions, e.g., explicitly integrating climate risks into cost-benefit assessments of large infrastructure projects, building codes, energy policy, or converting the city's mobility plan into a low carbon mobility plan. The action identified through this process will be compatible with development and climate goals, and, hence, would improve resilience to climate change as well as deliver multiple co-benefits (GEA, 2013) associated with greenhouse gas mitigation. The third step will translate the city-wide action plan into a detailed roadmap that includes cross-sectoral strategy, governance architecture, finance, and local and project-specific implementation strategy.

6.3 The co-benefits approach

The three main factors for successful preparation and implementation of adaptation and mitigation plans in local areas are: 1) Identification of the secondary benefits associated with climate actions, e.g., employment, energy savings, and improved quality of life, 2) Strong political, professional and technical support for the agenda from elected representatives and higher authorities, and 3) Successful partnerships with utilities, private, public and voluntary groups to raise financial support for mitigation and adaptation (Allman, 2004).

Plans have a higher chance of succeeding if mitigation measures offer other secondary benefits in addition to meeting climate goals. The secondary benefits, in general, accrue directly to the cities and can, therefore, help in ensuring greater support from cities. For example, cities that have dense development, better linkages to transport systems, and greater accessibility to local employment, are more energy efficient and have lower impacts on the environment. They also contribute to social benefits by providing better access to services, jobs, and social networks (OECD, 2012). Similarly, investments in mass transit can deliver benefits of enhanced mobility, clean air, and climate change mitigation.

Evidence and analysis suggest that investments in sustainable multifunctional cities, and greening of the buildings and construction sectors offer high returns, as well as multiple economic, social, and environmental benefits for governments, businesses, and society at large. Several investment opportunities exist in the following areas: retrofitting of existing building stock; energy efficiency and use of renewable energies in buildings; energy efficient lighting; investment in passive and low energy strategies; investment in alternative and green building materials and construction technologies, and BRT systems (UNEP, 2009).

Photo credit: Micky lakshya at en.wikipedia, 2007

7. Conclusions

Local governments are making efforts to balance social, economic and environmental objectives in order to enhance the quality of life of its citizens. Addressing climate change, i.e., development transformation towards a low carbon society, is a relatively new issue, which is added to the city planners' long list of challenges. Climate change brings in a vital global dimension to city planning in terms of its origin and reach. While conventionally climate change is viewed as an environmental issue, it is increasingly recognised that its origin and the extent of its impact arise from the socioeconomic development pathways followed by countries collectively and in the long-term. Thus, low carbon transformation is more an issue of addressing the 'style' of development, i.e., shaping the socioeconomic development pathway, which simultaneously delivers social, economic and environmental goals.

Addressing climate change requires a perspective that is global and integrated in terms of space (global to local), time (long-term and short-term) and sectors. Cities are the key human settlements wherein the relationship among these dimensions manifests most dynamically, extensively and intricately. Low carbon development in cities,therefore, must be aligned with national and global sustainability targets, including those related to reducing energy and the carbon intensity of energy, and the economy.

This guide book focuses on the role of cities in achieving global climate mitigation targets, and stresses the fact that as rapidly growing urban centres, the cities in emerging countries like India will play a significant role in the coming future. The aim of the guide book is to inform local governments, planners and practitioners about how to integrate low carbon objectives into the city planning process. The local governments and planners have the mandate, perspective, will, and expertise to deliver – within the in situ conditions – the quality of life that citizens best deserve. The guidebook does not attempt to teach the city policy makers and planners how to do planning. At best, it is a modest attempt to inform the city policy makers, planners and practitioners on how to integrate the 'low carbon development' objectives into city planning.

This guidebook provides relevant and useful information about articulating alternate development scenarios, delineating and quantifying activities which are vital drivers of carbon emissions, computing energy and materials, balancing and relating emissions for each scenario, and developing this information as the roadmap for actions which can most effectively deliver low carbon development. It also touches upon low carbon interventions for key sectors like transport, buildings and waste. An integrated approach is presented to guide cities in developing actions that can deliver co-benefits vis-à-vis multiple socioeconomic and environmental indicators, including low carbon emissions pathways and high climate resilience. Such a transformation pathway towards climate compatible urban development could generate a wealth of opportunities for cities – mainly to move away from resource-intensive high emission development towards building a prosperous and more liveable, efficient and climate resilient society.

Low carbon city plans in most nations are still at a nascent stage. Local governments, in both developed and developing countries, are working towards building a low carbon and climate resilient future. In developed countries, the challenge is to unlock from the preexisting lock-ins such as carbon intensive infrastructures, prevalent land-use arrangements, service delivery systems and policies. In developing countries, the policy makers and planners have opportunities to build low carbon infrastructures, land-use plans and efficient service delivery systems,e.g., for waste management, but may need additional finances to implement the low carbon plans. In the short-run, carbon finance instruments like NAMAs are available for the incremental finance. In the long-run, however, the low carbon transition will have to arise on the back of a vibrant carbon market, which the UNFCCC negotiations are aiming to deliver.

Many local governments have developed low carbon action plans and initiated pilot projects. The findings from the guidebook will be useful for policy makers, planners, consultants and other practitioners engaged in developing low carbon city plans. The idea for this originated from discussions with national policy makers, local policy makers, urban planners, practitioners and stakeholders during the implementation of the UNEP sponsored project on ‘Low Carbon Transport in India’. The response to the initial draft of this guidebook from policy makers, researchers and practitioners, during various project workshops, has been encouraging. The suggestions for the guidebook required us to look at all the sectors at the city level, though the transport sector at the national level remained the key focus of the project. The guidebook is a step in the direction of providing helpful guidance to city planners and practitioners to integrate the ‘low carbon’ aspect in their imminent work. The use of the guidebook and the feedback, we believe, will help to improve it further in the future.

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Appendix

Appendix 1: Current population and projections for top 50 Indian cities and their rate of change

City	Population (in thousands)		Average rate of change (%)		
	2011	2025	2011-2015	2015-2020	2020-2025
Delhi	22 654	32 935	3.19	2.66	2.36
Mumbai	19 744	26 557	1.68	2.18	2.31
Kolkata	14 402	18 711	0.9	1.98	2.34
Bangalore	8 614	13 193	3.96	3.01	2.5
Chennai	8 784	12 814	3.01	2.71	2.48
Hyderabad	7 837	11 647	3.34	2.83	2.51
Ahmedabad	6 425	9 599	3.38	2.86	2.54
Pune	5 100	7 487	2.95	2.76	2.58
Surat	4 661	7 530	4.81	3.35	2.64
Jaipur	3 102	4 557	2.8	2.78	2.67
Kanpur	2 928	3 910	0.9	2.2	2.64
Lucknow	2 926	4 234	2.48	2.69	2.67
Nagpur	2 511	3 498	1.68	2.46	2.68
Indore	2 188	3 233	2.8	2.83	2.73
Coimbatore	2 180	3 413	3.93	3.18	2.76
Patna	2 059	2 904	1.86	2.54	2.72
Bhopal	1 900	2 786	2.6	2.78	2.76
Vadodara	1 829	2 605	2.01	2.6	2.75
Agra	1 763	2 615	2.8	2.85	2.77
Visakhapatnam	1 746	2 570	2.65	2.81	2.77
Ludhiana	1 622	2 257	1.52	2.47	2.76
Kochi	1 620	2 285	1.78	2.55	2.77
Nashik	1 579	2 376	3.05	2.95	2.8
Vijayawada	1 511	2 370	3.85	3.2	2.83

City	Population (in thousands)		Average rate of change (%)		
	2011	2025	2011-2015	2015-2020	2020-2025
Madurai	1 472	2 110	2.06	2.65	2.79
Varanasi	1 443	2 036	1.74	2.55	2.79
Meerut	1 434	2 054	2.03	2.64	2.8
Rajkot	1 406	2 145	3.27	3.03	2.83
Jamshedpur	1 346	1 924	1.98	2.64	2.81
Srinagar	1 285	1 909	2.72	2.87	2.83
Jabalpur	1 273	1 763	1.33	2.44	2.8
Asansol	1 248	1 733	1.38	2.46	2.81
Allahabad	1 223	1 712	1.54	2.51	2.81
Aurangabad	1 201	1 801	2.89	2.93	2.85
Dhanbad	1 200	1 655	1.24	2.42	2.81
Amritsar	1 190	1 675	1.63	2.54	2.82
Jodhpur	1 149	1 721	2.85	2.93	2.86
Raipur	1 140	1 874	4.67	3.5	2.9
Ranchi	1 137	1 689	2.68	2.88	2.85
Gwalior	1 111	1 631	2.44	2.8	2.85
Durg-Bhilainagar	1 069	1 496	1.48	2.51	2.84
Chandigarh	1 034	1 517	2.4	2.8	2.87
Tiruchirappalli	1 028	1 472	1.92	2.65	2.86
Kota	1 013	1 572	3.5	3.15	2.89
Mysore	991	1 447	2.28	2.77	2.87
Bareilly	990	1 494	2.95	2.98	2.89
Tiruppur	982	1 698	5.63	3.82	2.95
Guwahati	974	1 387	1.79	2.62	2.86
Kozhikode	970	1 328	1.03	2.38	2.85
Thiruvananthapuram	959	1 301	0.83	2.32	2.84

Source: UN Population Division, 2011

Appendix 2: Indian government's initiatives that address urban transport

Policy	Key Interventions	Implementing Institution
JnNURM (2007-2012)	• Establishment of linkages between asset-creation and asset-management through a slew of reforms for long-term project sustainability; adequate funds for urban infrastructural services; • Planned development of identified cities including peri-urban areas, outgrowths, and urban corridors leading to dispersed urbanisation; • Scale-up delivery of civic amenities and provision of utilities (water supply, sanitation, etc.) with emphasis on universal access for the urban poor; urban renewal of the old city areas to reduce congestion; and security of tenure at affordable prices, improved housing, and ensuring delivery of other existing universal services of the government for education, health and social security.	Ministry of Urban Development, GOI
National Urban Transport Policy (2010)	• Incorporating public transport in urban planning; • Prioritising non-motorised and public transport; • Integrated multimodal transport; • Intelligent transport systems; • Clean technologies; • Equitable road space allocation; • Innovative financing.	Ministry of Urban Development
Standards and Labelling of Fuel Consumption in Cars (2012)	• Setting efficiency targets for passenger vehicles; • Certification of vehicles based on efficiency.	Bureau of Energy Efficiency
National Biofuel Policy (2009)	• Research and development; • Purchase policy and registration for enabling biofuel use; • Targets for blending biofuels in petrol and diesel e.g., 10% by 2017 for bioethanol in petrol and 10% biodiesel in diesel.	Ministry of New and Renewable Energy

Appendix 3: Eight national missions under national action plan on climate change

Sr. 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, integrated land-use planning, achieving modal shifts from private to public transport, improving fuel efficiency of vehicles, alternative fuels, emphasis on urban waste management and recycling, including power production from waste
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 23–33%
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 modelling, and increased international collaboration; it also encourages private sector initiatives to develop adaptation and mitigation technologies

Appendix 4: Detailed actions towards low carbon transport

Desired Intervention	Actions	Detailed Actions	Good Practice Examples
Urban Planning	1. Integrating land-use and transportation planning	• Transport modelling • Activity and land-use mapping for identifying transport strategy • Detailed design	Curitiba
Demand Management	1. Reducing travel demand 2. Reducing average trip distance 3. Reducing no. of trips	• Urban planning • Designing mixed-use neighbourhoods • Allowing high-density development • Integrated transport and land-use planning • ICT • Other instruments • Congestion pricing • Parking charges • Fuel taxes	Congestion Charging Scheme London
Modal Shift to Low Carbon Transport	1. Increasing share of public transport 2. Retaining share of NMT	• Improving access • Car parks near stations/bus stops • Feeder systems • Frequency • Integration • Electronic ticketing • Subsidies • Adding footpaths • Dedicated bicycle lanes • Park and ride facilities • Incentivise NMT	Delhi Metro Ahmedabad BRTS
Energy Intensity Reduction	1. Improve vehicle efficiency 2. Emission standards	• Vehicle I/M systems • Higher occupancy	Tokyo's Operations No Diesel

Desired Intervention	Actions	Detailed Actions	Good Practice Examples
Emission Intensity Reduction	1. Alternate fuels 2. Petrol electric hybrid vehicles 3. Cleaner diesel cars 4. Zero emission vehicles (fuel cells, new technologies)	• Subsidies for electric two-wheelers and cars • Biofuel-based transport • Infrastructure for electric cars • Fuel tax; Vehicle excise tax • Awareness • Incentives for alternate fuel vehicles	China's Electric Vehicle Policy

FOR MORE INFORMATION, CONTACT:

United Nations Environment Programme (UNEP)
Division of Technology, Industry and Economics (DTIE)
Transport Unit
P.O Box 30552
Nairobi, Kenya
Tel : +254 20 762 4184
Email : lowcarbon@unep.org
www.unep.org/transport/lowcarbon

DTU