Chapter 8
Integrating Climate Change in City Planning: Framework and Case Studies

Minal Pathak, P.R. Shukla, Amit Garg, and Hem Dholakia

Abstract The relationship between cities and climate change has been under discussion by researchers and policy makers. It is an accepted fact that cities have a very important role to play in mitigating greenhouse gas emissions. This is especially true for rapidly growing cities in developing countries like India where urban population growth, spatial expansion, and economic development have resulted in increasing demand for energy. Future per capita CO_2 emissions are expected to increase by four times between now and 2050. At the same time, like many other cities in developing countries, Indian cities are experiencing simultaneous challenges including infrastructure scarcity, air quality deterioration, and inadequate water resources. Large populations, high densities, presence of informal settlements, and industries within these cities have made them vulnerable to climate extremes. Urban infrastructure also will be at risk from climate change events including intense precipitation, flooding, and heat events. Future growth in urban areas will exacerbate existing issues of infrastructure provision and environmental issues of air quality, water, and waste. Climate change will be an added dimension to these urban challenges. Current urban planning process does not mainstream climate concerns and therefore necessitates the search for alternate approaches. Using case studies of selected cities, the chapter briefly highlights mitigation and adaptation challenges for these selected Indian cities and suggests a framework for integrating climate change concerns in urban planning and management.

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8.1 Introduction

Globally, urban areas are expected to absorb the entire population growth in the next four decades and at the same time draw people from rural areas. Currently, over 3.6 billion people live in urban areas and by 2050 this number will be 6.3 billion. Nearly half of this population growth will happen in Asian cities (UN 2012). Within the next decade, there will be nearly 500 cities of more than a million people, including several megacities with a population exceeding 20 million. The role of the cities for global carbon mitigation is now increasingly being realized by research and policy communities (Dhakal 2010). Urban activities including transport, industry, solid waste disposal, domestic fuel use and power generation contribute to significant GHG emissions (Dhakal 2004, 2009). Cities also account for an estimated 67 % of global energy use and 71 % of global energy-related CO_2 emissions (OECD 2013).

In 2011, average per capita CO_2 emissions in EU-27 were 7 tons and 16.9 tons in United States. In the same year, India's per capita CO_2 emissions were 1.4 tons which are much lower than the 2011 global average of 4.5 tons and China's 5.9 tons (IEA 2013). However, India's total CO_2 emissions are the fourth largest globally (Oliver et al. 2012). Also, past trends show a significant increase in demand. For instance, between 1994 and 2007, emissions from electricity grew at a CAGR of 5.6 %, transport emissions increased at 4.5 %, and residential sector emissions increased by 4.4 % (GoI 2011). Population growth and economic development are important drivers of energy consumption and CO_2 emissions (Li et al. 2010). With increasing urban population and income, energy demand is expected to increase. It is now also clear that meeting global targets will require cooperation of large developing economies like India and China (Satterthwaite 2010).

Vulnerability to climate events presents a special challenge for these cities. With a large part of the population still residing in informal settlements, the damage from extreme events in the future can be significant for these city residents, particularly in large densely populated cities in India. Cities also face some other challenges related to climate change. These include air pollution, urban heat island effects, vulnerability from increasing population in coastal areas, high population density, and diversity (Rosenzweig et al. 2011).

Managing the future expansion of urban areas in India is already a significant challenge. The problem of climate change is an added dimension. The business-as-usual scenario will lead to highly populated cities with poor air quality, high GHG emissions, income disparities, and poor quality of life. Therefore, planning for the future will require consideration of the implications of economic growth while considering resource constraints and climate change impacts.

Three main reasons for Indian cities to look at climate change include the following: (1) A significant share of national population and high contribution to economic growth in the future will make these major energy consumers and therefore key players in national and global climate change mitigation, (2) inaction to integrate climate concerns could pose significant threats including high potential economic losses for cities, and (3) sectoral interventions in urban areas have significant potential to mitigate GHG emissions, minimize risk from climate change as well as generate a number of ancillary benefits.

The World Development Report (2009) emphasized the idea of harnessing the growth and development benefits of urbanization while proactively managing its negative effects (World Bank 2009). Cities have a key role to play in the global green economy transition, since they are centers of economic growth, job creation, and innovation as well as major contributors to global warming and environmental problems (Hammer et al. 2011). At the same time, these are also faced with environment and infrastructure issues. While emissions are rising rapidly, vulnerability to climate change is a more pressing issue. The long-term problems of climate change further compound the problem. Literature in the past decade converges on the fact that cities now need to look for solutions that address both mitigation and adaptation challenges simultaneously.

Indian cities need a vision that can align both development and climate change. City plans are usually made for short-term about 10–15 years. The idea of climate responsive urban development in this paper highlights the necessity to look at urban development that is low carbon and climate resilient. However, looking at the long-term vision of the city can be useful to align climate change into city development and receive both short-term environment benefits and achieve climate objectives.

The chapter is divided into five sections including the introduction. The second section looks at India's urbanization profile and the environmental issues in Indian cities. Sections 8.3 and 8.4 highlight the mitigation and adaptation challenges using case studies of selected Indian cities. The following section highlights the adaptation issues for Indian cities. Section 8.5 suggests an integrated framework for cities to deal with climate change. The framework presents all the considerations that cities need to develop a scenario both to reduce emissions and increase resilience. Finally, the paper addresses the core issue of making the city development more sustainable by integrating local environment, climate change, and social sustainability.

8.2 India's Urbanization Profile and Challenges

Presently, 377 million people live in the urban areas of the country, constituting 31.16 % of the total population (Census of India 2011). Between 2001 and 2011, the urban population grew by nearly 32 %, as compared to 12.3 % for the rural population. Delhi, Greater Mumbai and Kolkata are the three largest urban agglomerations in India with populations over 10 million. In the next category, there are five cities with populations between 5 and 10 million. In total, 53 cities with populations exceeding one million accommodate over 40 % of the total urban population of India (Census of India 2011). However, the larger part of India's urban population still live in small- and medium-sized towns with populations below one million. Figure 8.1 shows the population of major Indian cities.

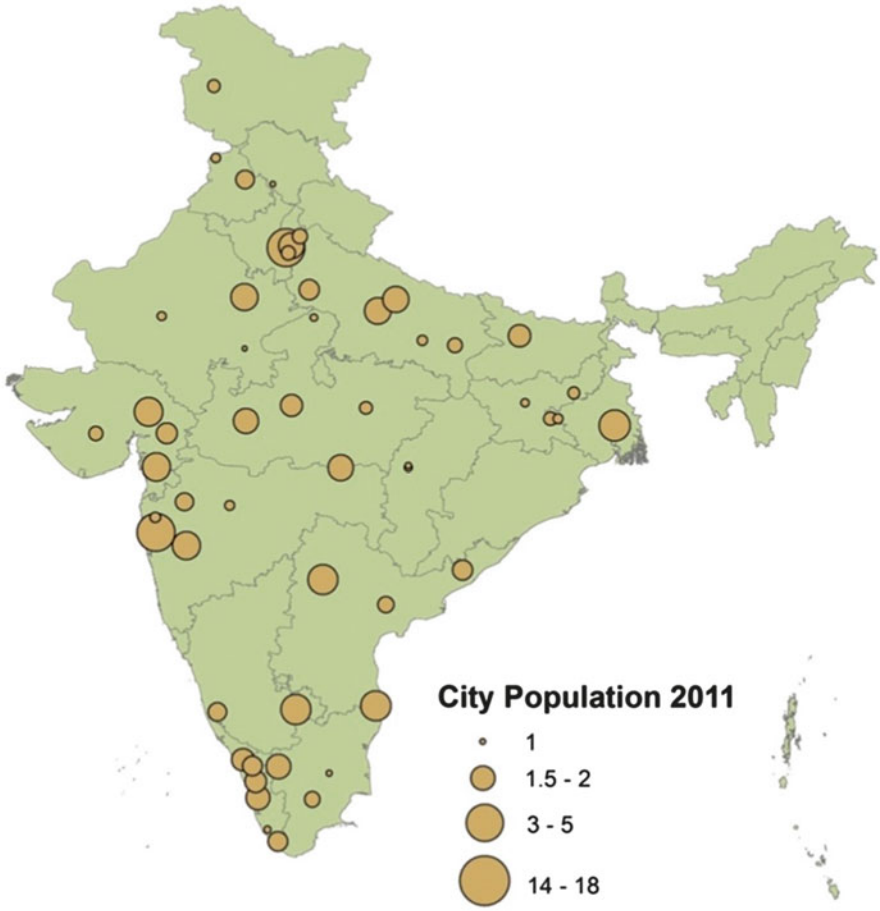

Fig. 8.1 Million plus cities in India in 2010 (by size) (Source: Data sourced from Census of India 2011)

It is projected that urbanization will continue in India till 2050, although the rate of urbanization will slow down after 2030. By 2050, India's urbanization level will cross the 50 % mark. Nearly 270 million people will be added to urban areas in India between 2030 and 2050 comprising one fifth of the total global urban population increase during the period (UN 2012). A large part of this growth will take place in cities with populations between 1 and 10 million.

Urbanization in India is accompanied by rapid economic growth. India's GDP (at constant prices) has nearly tripled from US $ 369 in 1996 to US $ 1,016 in 2008. In the financial year 2006–2007, India's real GDP grew at rate of over 7 % (WEO 2009). This growth is driven by cities which make a major contribution to the GDP of the country. Between now and 2030, India's GDP is projected to grow at an average annual rate of 7.4 % and cities are expected to account for 60 % of this growth

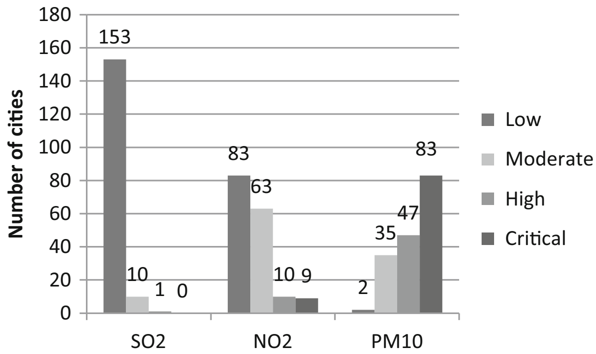

Fig. 8.2 Air quality in the cities (levels are classified into low, moderate, high, and critical based on exceedance factor which is observed mean concentration compared to annual standard. When exceedance factor is below 0.5, it is considered in low category while above 1.5 is classified as critical) (Source: CPCB 2012)

(MGI 2010). The trajectory of future growth in cities, especially with regard to local environmental problems like air quality, congestion, increasing risk from climate hazards, and poor quality of life, will have far-reaching implications on their global competitiveness, economic growth, livability, and overall well-being of citizens.

Environmental impacts in cities have resulted from increasing demand due to income effect, unguided growth, inadequate infrastructure, population density, and inefficient technologies. These are affecting the economic competitiveness and quality of life in the cities. According to a recent World Bank report, environmental degradation in India amounts to $80 billion annually or 5.7 % of annual GDP. This is mainly from health impacts of particulate matter from fossil fuels, inadequate access to clean water, sanitation, hygiene, and natural resource depletion (World Bank 2013a). Indian cities also face issues of poor water quality, threat to biodiversity, health impacts from inadequate solid waste disposal, and sanitation (Ramakrishna and Jayasheela 2010). Air quality is a serious issue in Indian cities. In recent years, rapid growth in vehicle populations coupled with industry and power plant emissions has resulted in very high levels of air pollution – especially particulate matter. At present, more than 50 % of the cities show critical levels of PM10 while nearly 30 % show high levels (Fig. 8.2). In case of sensitive areas, over 60 % of locations show critical levels of PM10. Levels of NOx are also a concern. 20 % of the cities showed high to critical levels of NOx (CPCB 2012).

Air pollution in India is a result of increasing travel demand, inadequate infrastructure, emissions from industries and power plants within the cities, combustion of household fuels, resuspension of road dust, and open burning of waste. Air pollution has significant human health implications as a large proportion of urban population lives in slums and squatter settlements without access to basic infrastructure and healthcare facilities. Direct exposure to air pollution and poor health status make this population more vulnerable to the toxic effects of air pollutants. A recent analysis showed that reduction in PM_{10} concentration levels of 25 $\mu g/m^3$ can result

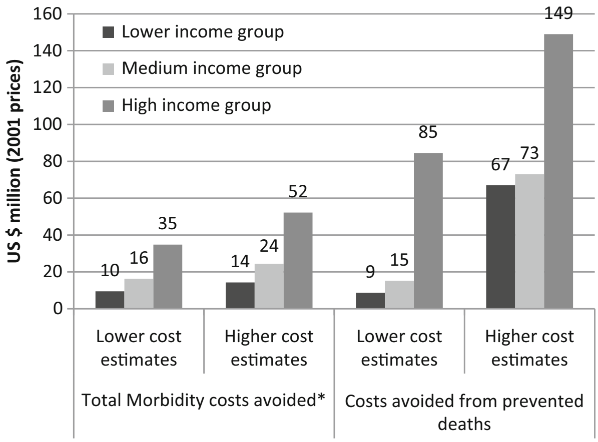

Fig. 8.3 Annual avoided health costs for different income groups from mortality and morbidity due to air pollution in Delhi (*when PM_{10} concentration levels in 2000 are reduced to 25 μg/m^3 throughout Delhi at higher mortality estimates) (Source: Garg 2011)

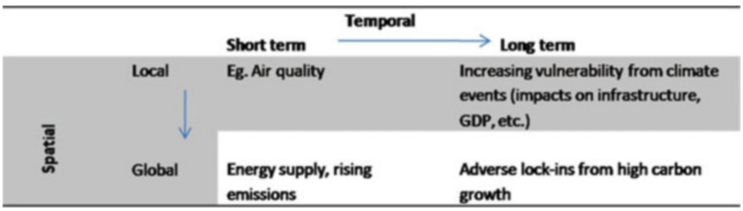

Fig. 8.4 Cities and environmental impacts (Source: Authors)

in cumulative savings ranging between US$ 23.5–101 million arising from improved health for all categories (Fig. 8.3). Cost savings from avoided deaths for the low-income group ranged from US $ 9 to 67 million while that for high-income group ranged from US$ 85 to 149 million at 2001 prices (Garg 2011).

Just as local activities in the cities contribute to environmental problems including air quality problems, water scarcity, and increasing emissions (Fig. 8.4), activities in the cities can also have regional and global impacts. There exists a complex relationship between the causal factors and impacts. Many of these problems arise from common sources and could have possible common solutions. At the same time, there could be tradeoffs between solutions for local short-term problems and long-term issues of climate change. Environmental impacts from cities can be temporally and spatially disaggregated.

8.3 Mitigation Challenges

There is a variation in per capita emissions among cities globally. Per capita GHG emissions for cities range from over 15 tons of carbon dioxide equivalent (tCO_2e) for several American cities to around less than half a ton for cities in developing

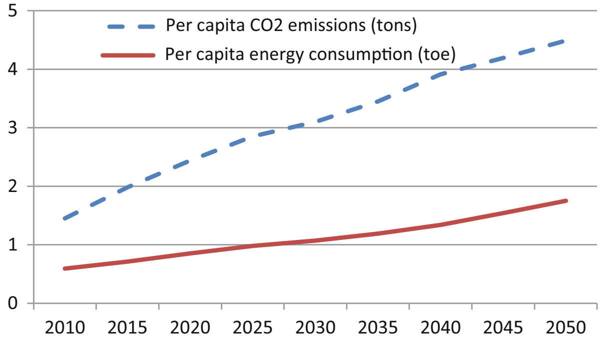

Fig. 8.5 Per capita energy consumption and CO_2 emissions for India in BAU scenario

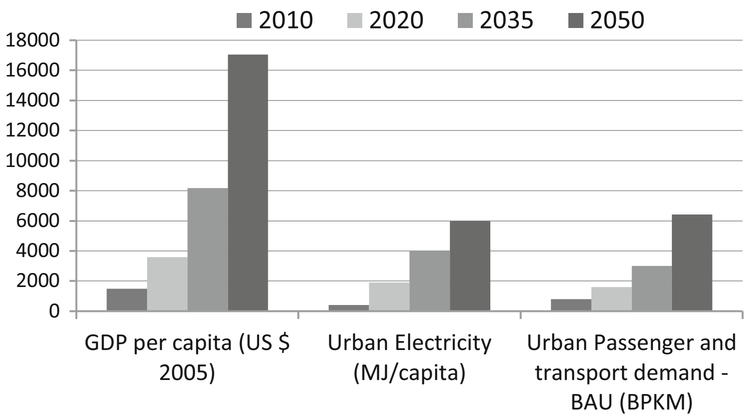

Fig. 8.6 Urban income and energy use projections for residential and transport

countries (Hoornweg et al. 2011; Dodman 2009). Although India's per capita emissions at 1.4 tons are low, India's total CO_2 emissions in 2012 reached about 2.0 billion tons, making it the fourth largest CO_2 emitting country globally (Oliver et al. 2012).

By 2060, the per capita income in India is projected to see a sevenfold increase (OECD 2012). This will drive the demand for energy for urban sectors – transport, building, industry, and urban services. In BAU scenario, energy use per capita will increase by three times between 2010 and 2050. During this period, per capita CO_2 emissions in India will increase by two and a half times and reach 4.5 tons by 2050 (Fig. 8.5). Urban population and income and consequent increase in urban floor space will result in a huge growth in energy demand for cooling, heating, appliances, and lighting, leading to significant electricity consumption in the buildings sector (Chaturvedi et al. 2012). Similarly, increase in income and population along with an increase in city size will lead to a significant increase in the total transport demand in the cities (Dhar et al. 2013) (Fig. 8.6). A study of three cities – Mumbai, Ahmedabad, and Surat – showed that total travel demand in the BAU scenario between 2005 and 2041 would increase five times in Mumbai, nearly six times in Ahmedabad, and ten times in Surat (Rayle and Pai 2009).

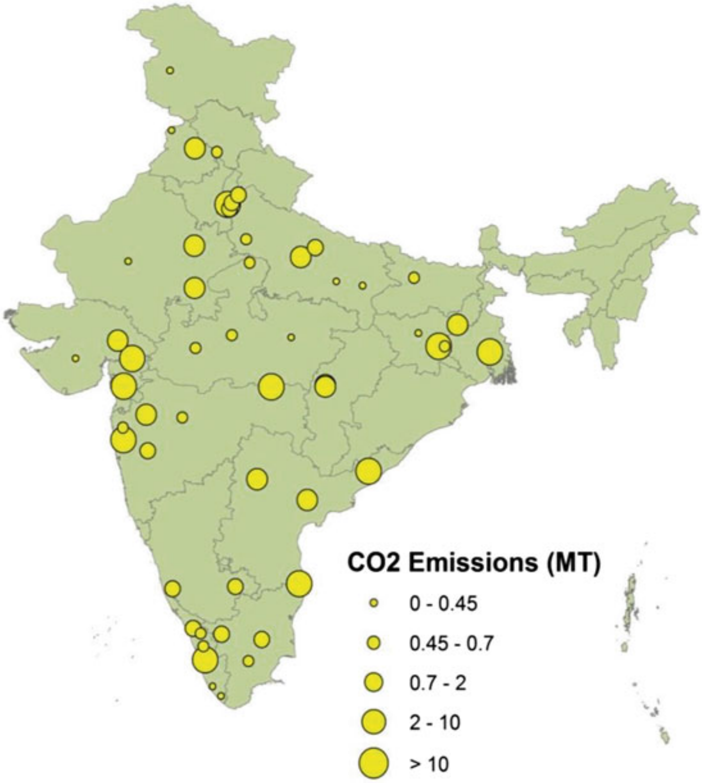

Fig. 8.7 CO_2 emissions for Indian cities (2010)

In the future, cities will house a large share of the country's population and will be the key drivers for economic growth and energy consumption. It is clear that meeting global targets will require cooperation of large developing economies like India and China (Satterthwaite 2010). Investments in infrastructure, urban planning and policies on building codes, and urban transportation will influence energy patterns of citizens in the future; therefore, decisions need to consider climate change to avoid getting into high carbon lock-ins.

Figure 8.7 shows the CO_2 emissions for major cities with the size of the bubble representing the amount of emissions. According to our analysis, total emissions from Indian cities range from 15 to 25 million tons. We analyzed the growth rates in emissions for these urban agglomerations for the period between 1990 and 2010. These ranged from 2 to 14 % with four cities showing a rate more than 8 % – Kochi, Vadodara, Surat and Kolkata. A large part of the emissions from these cities came from power plants and industries. Average per capita emissions from all million plus cities increased from 0.95 to 4.7 tons. A detailed modeling exercise for Ahmedabad City showed that a combination of low carbon interventions, if implemented can not only bring down CO_2 emissions but also deliver local environmental co-benefits. Box 8.1 gives a snapshot of the study.

Box 8.1: Future Energy and Emissions Projections for Ahmedabad

An exercise was carried out to understand the socioeconomic energy and emission parameters for Ahmedabad City. This data for the base year (2005) was methodically prepared using various approaches as enunciated in literature for various sectors. These parameters were used with the future energy service demands, energy technology assumptions, and socioeconomic assumptions for Ahmedabad to lead to assumptions for the target years (2035, 2050). This information was used to project future scenarios of energy and emissions in the future. This modeling was carried out using the Extended Snapshot Tool (ExSS) for two scenarios – business as usual and low carbon society (LCS) for 2035 and 2050.

Modeling results showed that the population of Ahmedabad would increase to 7.8 million in 2035 and would further rise to 12 million in 2050. Modeling results showed that the real GDP of Ahmedabad in 2050 is expected to be approximately INR 3,673 billion. Population and economic growth will result in increase in travel demand, increase in number of households, appliance ownership, and commercial floor area all, of which will result in increased energy consumption in all sectors. In the BAU scenario, primary energy consumption will increase nearly 10 times by 2035 and 15 times by 2050 compared to 2005 levels. Total CO_2 emissions increase from 10 million tons to 86 million tons by 2050. However, our analysis shows it is possible to bring down the BAU emissions with a combination of measures including lower energy intensity of economic activities, decarbonization of electricity-reduced energy demand in industrial and commercial sectors, fuel switch in power, transport and industrial sector, and measures promoting end-use device efficiency (Fig. 8.8).

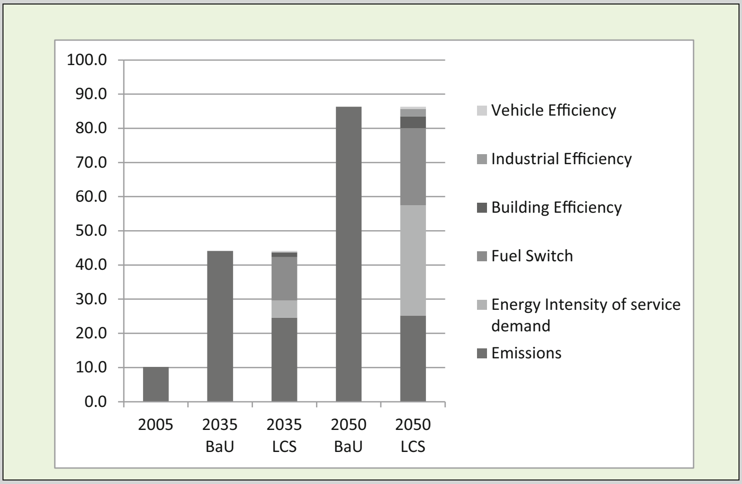

Fig. 8.8 Breakdown of emission reduction potential (million tons) (Source: IIMA 2010)

8.4 Adaptation Challenges

Vulnerability to climate events presents a special challenge for Indian cities. Climate change is projected to lead to temperature changes; higher variability in local conditions and changes in frequency, intensity, and location of precipitation and storms; sea level rise; river and inland flooding; and environmental health risks (Revi 2008). With a large part of the population still residing in informal settlements, the damage from extreme events in the future can be significant for these city residents, particularly in densely populated cities.

Climate change also impacts the physical assets used within cities for economic production, the costs of raw materials and inputs to economic production, the subsequent costs to businesses, and thus output and competitiveness (Sridhar 2010). Future urban growth will result in large populations in urban areas where many of these will live in informal settlements bringing forth the issues of managing equity, environment, urban development, and climate change. Going by the precautionary principle, in terms of preparedness, the city needs to remain prepared of a possibility of climate stabilization not achieving this target. Several of these cities, especially the small- and medium sized cities, do not have adequate resources to address the multiple challenges of environmental degradation, provision of basic services, urban poverty, and climate change.

PRECIS simulations show an all-round warming over the Indian subcontinent. A 3.5–4.3 °C rise in annual mean surface temperature is expected by the end of the century (MoEF 2012). Table 8.1 describes major impacts for climate change projected for India. For cities, this will exacerbate the heat island effects, water stress, impacts on infrastructure and major impacts from sea level rise coastal flooding and riverine flooding. This will be especially severe on densely populated cities.

Table 8.1 Impacts from climate change in India

Dimension	Projected impacts
Extreme heat	Increase in frequency of extreme heat events including more frequent warm days and nights
Changing rainfall patters	Change in rainfall pattern in terms of seasonal variations, frequency, and intensity
Water	Erratic monsoon patterns will lead to water shortages. These will also be exacerbated due to higher demand from increase in population, services, and industry
Food production	Increase in seasonal variability of rainfall, water shortages, and heat are all likely to impact agricultural production in the region
Energy security	Climate changed-induced water availability can affect power generation from thermal and hydro power
Health	Climate change impacts on human health could trigger or increase the incidence of vector-borne diseases and mortality and morbidity from heat stress

Source: Adapted from World Bank (2013b)

Climate risks differ for cities depending on their geographical features. For coastal cities, challenges of sea level rise will necessitate investments in particular infrastructure. Cities along rivers where higher precipitation is expected may face risks from floods. On the other hand, landlocked cities which have high built-up area and where climate change is expected to result in reduced precipitation will face risks from drought, reduced water tables, and food scarcity (UN Habitat 2009). An assessment of 59 Indian cities showed that Indian cities face a wide range of environmental risks including risks from climate change and lock-ins from high carbon infrastructure. The study estimated nearly 70 million people living in poverty and exposed to multiple stressors (CDKN 2013).

In another assessment, 14 cities in India on the basis of climate factors, altitude, and demographic, social and economic parameters highlighted different concerns for each of the cities. Mumbai ranked the highest on account of a very high population density exposed to cumulative risks from rise of temperature sea level and flooding. Temperature rise was a significant factor for Ahmedabad, while for Surat, it was flooding due to sea level rise (Parikh et al. 2011).

Kelkar et al. (2011) define vulnerability in terms of the loss of security provided by critical capitals that exist in the cities. These include natural capital, financial capital, human capital, infrastructure capital, built capital, social capital, governance capital, and technological capital. They concluded that economic status of the cities does not make them less vulnerable; however, cities with diversified economic profile had better adaptive capacity and those with poor local environment had a much higher risk of adapting to climate change.

The following are the specific climate change related risks for Indian cities.

8.4.1 Water Security

Population in cities and high demand for water have already put cities under water stress. Figure 8.9 shows the average per capita water supply and consumption in Indian cities. Assessments show that gross per capita water availability (including utilizable surface water and replenishable groundwater) is projected to decline from around 1,820 m^3 per year in 2001 to about 1,140 m^3 per year in 2050 due to population growth alone (World Bank 2013a). Climate change impacts on water sector could result in deterioration of water quality due to higher temperatures, from increase in sediment loads in rivers, land subsidence, and salt water intrusion from sea level rise (Major et al. 2011).

Indian cities face inadequate water supply, despite a significant effort and investments by urban local bodies. A number of cities do not meet national standards for water supply. Water stress in cities is likely to aggravate further due to increase in demand and deteriorating status of surface and groundwater resources. Impacts from climate change will affect the existing resources and therefore the availability of water in the cities. Box 8.2 shows climate change impacts on water availability for Delhi City.

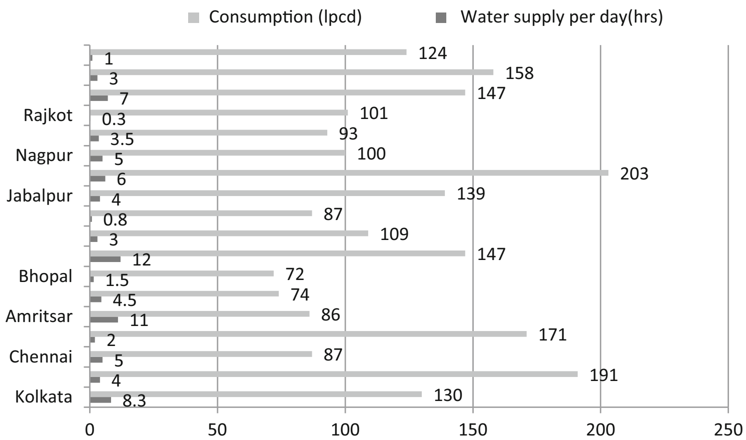

Fig. 8.9 Water supply in select Indian cities (2006) (Source: ADB 2007)

Box 8.2: Water Availability – Case of Delhi

Delhi depends largely on three river systems for its raw water supply, namely, Yamuna, Ganga, and the Beas. Other than the raw water from the rivers, a small proportion of supply is contributed by ground water. The current water supply stands at 225 liters per capita per day, however, its distribution is not uniform – some areas receive the supply 24-h supply, whereas some receive it for only 1–2 h (MPD – 2021). The major source of raw water is Yamuna River. Delhi gets 750 cusecs of water from the Western Yamuna Canal amounting to 310 MGD which is 48 % of Delhi's total water supply. Other sources include raw water from Upper Ganga Canal and Bhakra Beas Management Board (BBMB). At present, the contribution of raw water from the three sources is 84 % of the total. Currently about 100 MGD of the demand is met through groundwater extraction. Figure 8.10 shows the water supply from various sources till 2101. The assumption that there would be no further source of supply is based on the fact that the sources identified take into account the total groundwater potential of the national capital region and future dam projects envisaged.

Under climate change, it is assumed that the water availability from the Yamuna River would vary with the change in discharges. The availability from Beas and Ganga would vary according to 0.03 °C temperature rise scenario developed in the DFID study for Ganga discharge at Haridwar. Beas River carries more glacial content compared to Ganga River, and therefore, it is expected that the discharges would change more rapidly in case of Beas. The water supply from various sources was revised based on the assumptions made regarding existing sources, availability of water from Beas and Ganga, as well as rainfall changes, and the surplus deficit sensitivity analysis was carried

(continued)

Box 8.2 (continued)
out. It was found that under climate change, there is an increase in water availability till 2041 and then a sharp decline in the latter part of the century. The highest impact is experienced by the water availability under additional plan which is to be procured from the three dam projects. Owing to their location in the Himalayas, these sources would be able to add only 692 MGD in 2041 against the envisaged 865 MGD. This would further decline to 501 MGD by the end of the century. Existing riverine sources will also be impacted and would decline from approximately 828 MGD in 2011 to approximately 550 MGD in 2101. Figure 8.11 shows the water supply from various sources under climate change.

There would be a surplus of water for the next few decades, and Delhi would be in a position to meet its water demand as a result of additional discharges in the existing and additionally planned water from riverine sources. This would be followed by a steep decline in the post-2041 period as a result of depletion of glacier systems. By 2101 there will be a deficit of 631 MGD for a population stabilization of 40 million as against 130 MGD in the case without taking into account the climate change impacts. This would create even more severe water shortages than experienced now. The current analysis is conducted considering the Delhi Jal Board recommended norm of 60 gallons per capita per day. But as the population increases, this norm would increase further and the shortages could be much higher than what is being displayed by the current analysis.

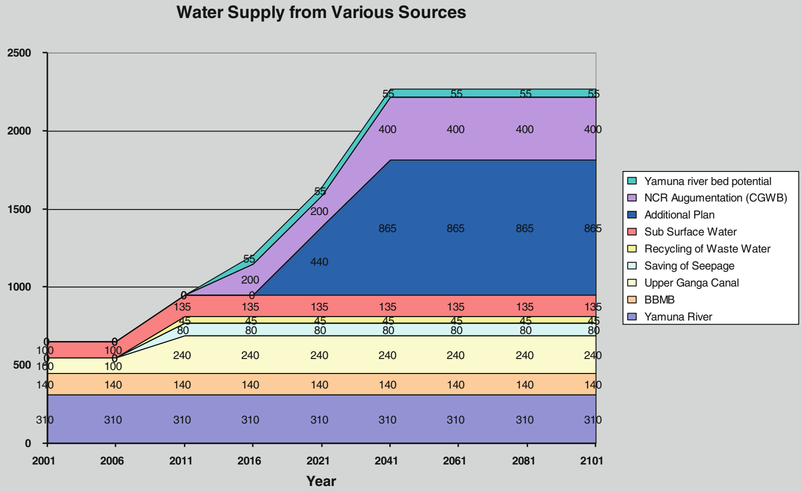

Fig. 8.10 Existing and envisaged water sources for Delhi

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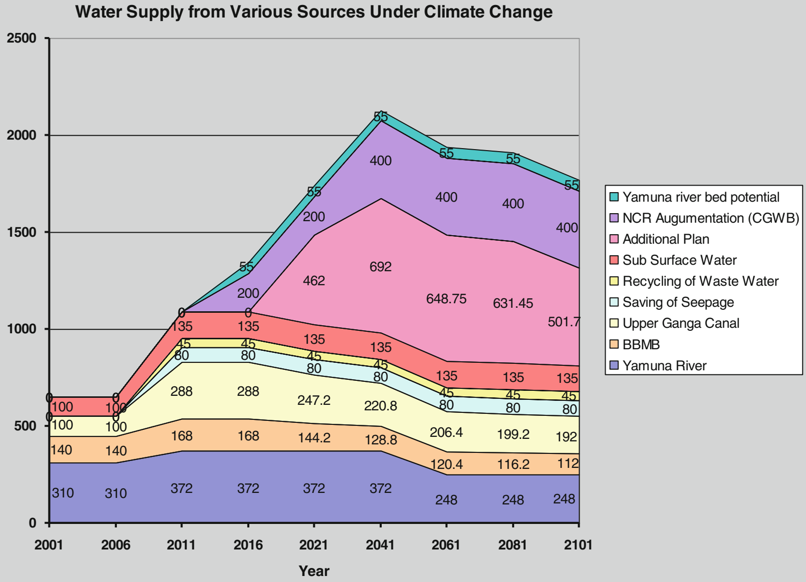

Fig. 8.11 Existing and envisaged sources of water for Delhi under climate change (Source: IIMA 2009)

8.4.2 Flood Risk

For city planners, floods pose a major problem as the most expensive and damaging climate disasters. Evidences show an increase in the frequency and severity of floods in recent years. A recent World Bank study highlights the case study of two large cities – Mumbai and Kolkata – where large populations are vulnerable to sea level rise, tropical cyclones, and riverine flooding.

With a high population density and a large part of the city in low-lying areas, Mumbai is extremely vulnerable to coastal flooding (World Bank 2013b). Another OECD study found that by 2080 in a SRES A2 scenario, the likelihood of a 2005-like flood event for Mumbai could double in the upper-bound climate scenario. This will result in tripling of the total losses for a 1-in-100-year event compared to current costs. The analysis also showed that the losses would amount to $250 million for the poor marginalized population, which could be a significant figure for these households (Hallegatte et al. 2010).

The current annual rainfall in Mumbai is 2,809 mm. An assessment carried out at IIMA (2009) showed that under B2 scenario, the average would increase to 3,200 mm with a standard deviation of 627 mm and under A2 scenario, the average is likely to increase even further to 3,476 mm with a standard deviation of 687 mm. The study revealed that the probability of 100–200 mm rainfall in a day would increase by 18 times and 13 times approximately for the A2 and B2 scenarios. Flood-prone low-lying areas of Mumbai would expect a price decline of more than 15 % with no prospects of price recovery owing to recurring characteristic of flash floods in the climate change scenario (IIMA 2009).

8.4.3 Heat Stress

Mean temperatures are increasing around the world, and it is expected that rising temperatures will lead to an increase in frequency and severity of extreme heat and heat wave events (Tebaldi et al. 2006). According to IPCC, climate change can affect human health directly from extreme events and cause indirect impacts by disrupting social and economic systems (IPCC 2007). Urban heat island impacts caused to reduced green cover, higher concrete, and asphalt and urban heat sources further aggravate heat waves (Barata et al. 2011). Direct threat to health from heat stress is more likely to affect the vulnerable groups including the elderly, young children, and those with preexisting health problems.

We studied the impacts of temperature on mortality for the cities of Ahmedabad and Mumbai (Figs. 8.12 and 8.13). These are among the largest cities in India and are representative of a hot and dry (Ahmedabad) and warm and humid (Mumbai) climate. For the summer (March to July) season, the relationship between daily deaths and daily maximum temperature (from 2005 to 2012) was modeled using standard time-series approaches described in public health literature. The outcome of interest was the percentage change in mortality between the 99th and 95th percentile of temperature distribution (called heat effect). A similar analysis was carried

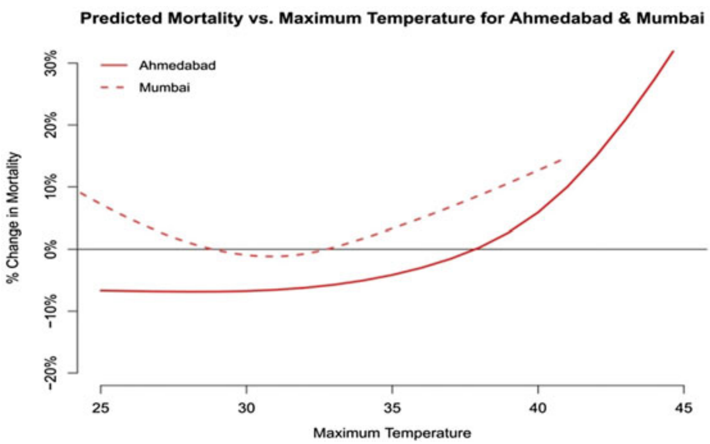

Fig. 8.12 Temperature and mortality relationship in summer season (Source: Dholakia 2014)

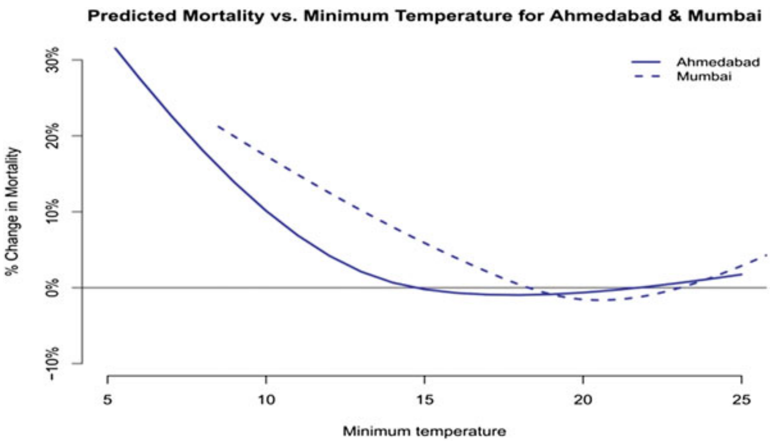

Fig. 8.13 Temperature and mortality relationship in winter season (Source: Dholakia 2014)

Table 8.2 City characteristics and heat and cold effects for Ahmedabad and Mumbai

City	Temperature (°C)		Daily deaths	PM_{10} (μg/m³)	Population (millions)	Heat effect (%)	Cold effect (%)
	Max.	Min.					
Ahmedabad	34 ± 4.6	21.5 ± 5.6	100 ± 18	93.9 ± 58.7	6.3	6.56	7.09
Mumbai	32 ± 2.4	22.7 ± 4	225 ± 30.7	174 ± 86.6	18.4	3.53	5.33

Sources: Central Pollution Control Board; Indian Meteorological Department; Ahmedabad & Mumbai Municipal Corporations; Census of India 2011

out for the winter season (November to February) to understand the cold effect, i.e., percentage change in mortality between the 1st and 5th percentile of minimum temperature distribution.

For each city, we find a "U-" or "J"-shaped relationship between temperature and mortality which have been described previously for other cities in Europe and United States. In the summer season, mortality increases significantly above 32.2 °C for Ahmedabad and 30.9 °C for Mumbai. The corresponding values for winter season are 20.6 °C for Mumbai and 17.8 °C for Ahmedabad. However, mortality is determined by the rate of increase as well as the temperature range that a city experiences.

The heat effect was found to be 3.53 % (95 % CI: 1.69, 5.4) for Mumbai and 6.56 % (95 % CI: 4.84, 8.31) for Ahmedabad. The respective cold effects for Mumbai and Ahmedabad were found to be 5.33 % (95 % CI: 2.6, 8.12) and 7.1 (95 % CI: 4.3, 9.96). These effects were robust to a range of alternate model specifications and were independent of effects of air pollution (Table 8.2).

The differences in heat and cold effects can be explained by the fact that being a coastal city, Mumbai has less extreme weather (moderation due to land and sea breeze). Ahmedabad on the other hand is located in the interior of the Indian landmass and is subject to a more extreme form of weather. Thus, Ahmedabad has higher heat and cold effects in comparison to Mumbai. In addition, higher cold effects for Ahmedabad could be explained by population acclimatization to the hot and dry climate.

Projections of mortality show that heat-related mortality is set to increase in the future while cold-related mortality will reduce. However, decreases in cold-related mortality will not offset the increases in heat-related mortality – thus, there will be a net increase in future temperature-related mortality. Under the RCP 4.5 scenario, in the 2050s, we estimate 38 % excess deaths (~5,700 deaths) due to heat for Ahmedabad and 40 % excess (~4,200 deaths) for Mumbai compared to the baseline period of 2000–2009. The corresponding reductions for cold related mortality are 63 % (~900 deaths) for Ahmedabad and 37 % (~3,800 deaths) for Mumbai. The magnitude of death is much higher under an extreme climate change scenario such as RCP 8.5. Acclimatization will likely have only modest impacts in reducing future mortality, thereby underscoring the need for planned adaptation.

Planned adaptation measures could potentially include but are not limited to public awareness through information, education, and communication programs; city-level heat-health warning systems; efficient functioning of emergency medical services; shelters to reduce exposure for the poor, children, and elderly; greening of urban landscapes; and district level heating or cooling measures. Implementing these involves a comprehensive, coordinated approach at multiple levels that include various stakeholders as well as a dedicated pool of financial and other resources. Ahmedabad City has recently initiated a Heat Action Plan which is the first comprehensive early warning system and preparedness plan for extreme heat events in India. The plan creates immediate and longer-term actions to increase preparedness, information sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations (AMC 2013).

8.4.4 Urban Infrastructure

Urban infrastructure includes energy infrastructure including power plants, gas supply, transport infrastructure, water supply, housing, and waste water systems. Increased growth and development of cities has led to increasing demand for urban infrastructure. Currently, India spends $17 per capita per year in urban infrastructure, whereas the most benchmarks suggest a requirement of $100. The investment required for building urban infrastructure in India, over the next 20 years, is estimated at approximately US$1 trillion (Planning Commission 2013).

Infrastructure in the cities is influenced by the changing dynamics in the future – population, economic growth, availability of financial resources, and capacity of local governments. Infrastructure are long-life assets that are exposed to nature and therefore face uncertainties of weather parameters such as rainfall, temperature and other extreme weather events Garg et al. 2013. This exposure uncertainty creates risks for their economic performance, for instance, rainfall pattern in the catchment areas of a hydroelectric dam could drastically reduce in the future, making the dam a stranded economic asset. Different sectors and assets exhibit different levels of sensitivity to climate change because of varying vulnerability and adaptive capabilities (Garg et al. 2007).

There are complex dimensions to infrastructure and climate change in the cities. One is that inadequate infrastructure in the cities including sewerage, storm water drains, and water supply can exacerbate climate risk, and therefore, investments in infrastructure can reduce vulnerability to climate change. Hallegatte et al. (2010) found that investment in drainage systems in Mumbai could result in reduced vulnerability of the population from flood risk. Climate change impacts can cause significant damage to urban infrastructure including transport, water supply, and sewage and energy infrastructure leading to huge losses for the cities. Finally, urban infrastructure choices will determine the consumption patterns and contribute to GHG emissions. The city form and infrastructure influences the way energy is consumed and therefore has bearing on the future emission patterns. For instance, the choice of building mass transit infrastructure or choice of energy infrastructure would facilitate low carbon choices for citizens in the future and support transition to a low carbon society. In addition to high carbon technology lock-ins, infrastructure also influences choices of the citizens. This could also lead to preference lock-ins, which could influence people's behavior in a certain pattern (Mukhopadhyay 2010).

Figure 8.14 shows the infrastructure investments in public transport for large Indian cities. Mass transit infrastructure including BRTS and Metro is already operational or planned for 21 cities in India. However, this planning has not integrated the environment and climate change considerations. Out of the 21 cities where Metro is operational or planned (Figure), nearly half of these cities have already been identified as being highly vulnerable to flooding risk due to a combination of climate-induced risk coupled with inadequate infrastructure (Parikh et al. 2013). Six of these cities face threats from cyclones in the future.

For climate proofing infrastructure assets, it is important to identify system dynamics, climate change parameters, and developmental parameters affecting the

Fig. 8.14 Mass transit infrastructure investments (existing and planned)

system under consideration and capture various impact parameters. This is normally done based on the past data, and a damage function is created that captures the adverse impacts of all the variables on the system. While creating this damage function, future climatological projections must be incorporated to adjust for increased frequency and variability of relevant critical climate parameters.

8.5 Strategies for Synergizing Climate and Development Goals in the Cities

Cities have environment and social priorities – increasing the percentage of green cover, improving local air quality, and reducing congestion. This necessitates the search for delineating win-win options that deliver multiple benefits – of better local environment like cleaner air, more green spaces, and water bodies, improved energy access, reduced congestion in the transport system, and reduced risks from residual climate change. The business-as-usual approach does not integrate climate objectives into development priorities. Therefore, alternate frameworks are necessary.

The framework (Fig. 8.15) suggested here uses an integrated assessment framework which aligns global climate change concerns and issues within the urban development agenda. The three stages include identifying climate risks, constructing future scenarios, and assessing synergies to prioritize actions.

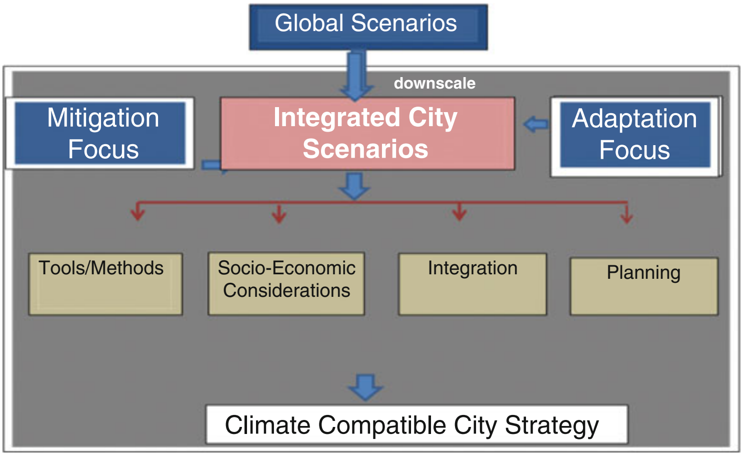

Fig. 8.15 Integrated framework for climate compatible development for the cities

8.5.1 Identification of Climate Risks

Action on climate change starts with reliable comprehensive information on climate change. For example, for a city, the impacts from meteorological events such as rainfall, extremes of water such as heat stress enhanced by the urban heat island effect, as well as long-term impacts of building design, role of transportation design on air quality and health (WMO 2010). Climate modeling over Asia is complex due to its unique topography. As a result, global climate models (GCMs) fail to properly represent physical processes. Also climate change impacts may vary significantly among regions within the country as well as locally due to the unique features of the cities. There is a need to improve the resolution by downscaling using models and tools (Salinger et al. 2014).

Urban meteorological networks can be set up within and around the cities to study vertical profiles of temperature, rainfall, wind humidity, turbulence, air quality, particles, reflectivity, and refractivity. There is a need to improve the understanding of the impacts of atmospheric data over complex urban surfaces through observations and to delineate the impact of urban areas on climate from natural processes (WMO 2010). Cities do not operate in isolation. Therefore, it is important to consider global scenarios. At the same time, global scenarios are insufficient to understand impacts at the local level. Global and regional conditions must be downscaled using statistical relationships or physical methods that take into account specificities of the urban context.

Local socioeconomic scenarios and environment information are used to understand a city's vulnerability. It is necessary to take a broad view and understand all components of socioeconomic activity and their interactions to comprehend direct and indirect impacts from climate change on a city (Hallegate et al. 2008).

Similarly, planning for climate change mitigation requires comparable, consistent and robust information on energy use and emissions. Greenhouse gas inventory is a necessary first step for planning for mitigation actions. Cities need a robust inventory that tells them what the emissions are and which sectors they come from (Hoornweg et al. 2011). There is currently little information on urban energy use and emissions in Indian cities in recent years. Since emissions are greatly influenced by the activities at a spatial scale, it is important to link emission inventories with information on land use and activities.

8.5.2 Constructing City Scenarios

A city scenario will require alignment of both top-down and bottom up information. Top-down information includes information on the risks and uncertainties at the global level, national policies and targets, climate change information, and assessment of future technologies. Integration of global storylines is essential for the cities as it will influence many key choices like infrastructures, technologies and behavior.

For example, key elements for climate resilient developments like technology sharing may differ between a fragmented future global world versus a cooperative society. Similarly, cities need to look at global climate projections, emission pathways, and mitigation goals. Global scenarios have to be downscaled to regional or local level and fitted within the policy time frame.

This has to be integrated with bottom-up information including an understanding of the city's form, activities that influence energy use and emissions, and vulnerability within the city. Since urban form influences future emissions and vulnerabilities, it is important to include this information while constructing city scenarios. Other challenges with respect to implementation of plans include old city lock-ins, density and land use lock-ins, inertia of public behavior, and life of the city infrastructure. Prioritizing climate change will require an understanding of these spatial impacts. A city's capacity to act (mitigation and adaptation) and the socioeconomic status of its population are also important to consider in developing city scenarios.

8.5.3 Integrated Assessment

Climate change is influenced by a several complex interactions among several factors; therefore, understanding complexities would require a more comprehensive approach. Integrated assessment is a process that combines knowledge from various disciplines including natural and social sciences to examine and comprehend the interactions between these complex systems (IPCC 1996).

The integrated assessment methodology for GHG emissions and climate impacts developed by the Tyndall Center for Climate Change Research provides an approach for analysis at the local level. These parameters influence regional economy and land use. The approach ensures that though the land use modeling is spatially explicit at the local level, it integrates regional and global parameters (Dawson et al. 2009).

It is now increasingly becoming clear that urban development in India will have to be compatible with the changing climate. However, cities have environment and social priorities – increasing the percentage of green cover, improving local air quality, and reducing congestion. Literature in the past decade converges on the fact that cities now need to look for solutions that address both mitigation and adaptation challenges simultaneously. Recognizing that urban centers will play a key role in implementing national and development goals, cities need to be energy and resource efficient, reduce environmental externalities, and at the same time achieve social and economic goals. Looking at these challenges, cities will have to delineate win-win options that deliver multiple co-benefits, besides climate change benefits, of better local environment like cleaner air, more green spaces and water bodies, improved energy access, reduced congestion in the transport system, and improved resilience.

On the mitigation side, effective sectoral mitigation opportunities exist in the cities. Local governments control policies on land use, transport, water, and energy efficiency which are keys to mitigation responses. These include public transport, land use planning, water supply, zoning, building codes, energy conservation, taxation, waste management, etc.

At the same time, cities will have to stay prepared to mitigate impacts from residual climate change. Unmitigated climate risks impose huge costs, for instance, insurance payments from not addressing adaptation (Sathaye et al. 2006). Different cities have different priorities. There is a mismatch between needs and responses are occurring in regard to who should mitigate, how much to adapt, and why. Cities need to look at climate risks and mitigation options simultaneously in order to balance adaptation and mitigation. (Mehrotra et al. 2011). For instance, rapidly growing cities will need to prioritize investments in low carbon infrastructure. On the other hand, small and medium coastal towns which have very low emissions will need to prioritize adaptation.

Synergies between mitigation and adaptation actions have been reported for cities. For example, urban design to include climate safe citing, building codes, and transportation requirements could reduce energy use and emissions while at the same time reduce the negative impacts of climate change such as for low-lying coastal areas or areas prone to flooding (Swart and Raes 2007). Decision makers can integrate climate change into plans if clear information is available on quantified climate benefits and other benefits that include cost savings in the long run from damage due to extreme events, avoided deaths from air quality improvements, mobility benefits, etc.

The integrated assessment framework suggested below suggests several important areas of integration for effectively addressing the issue of mainstreaming climate change concerns in urban planning. These include a vertical integration from global to local, spatial and temporal integration, integration of scientific information with policies, and finally integration of mitigation and adaptation into city plans.

8.5.4 Mainstreaming Climate Change Concerns in Development Plans

The period of 2007–2012 witnessed high growth rate, however, it also witnessed impoverishment and exclusion of large sections of population from the benefits of development (Hussain 2012). The Government of India recognizes that development should be equitable and environmentally sustainable. The central theme of India's 12th Five-Year Plan (2012–2017) is Inclusive Green Growth (GoI 2012). The stated vision is that "of India moving forward in a way that would ensure a broad-based improvement in living standards of all sections of the people through a growth process which is faster than in the past, more inclusive and also more environmentally sustainable." Similarly, the eight submissions under India's National Action Plan on Climate Change, (2008) emphasize development and environment objectives including protecting ecosystems, agricultural sustainability, biodiversity, and quality of life in addition to climate change mitigation and adaptation measures (GoI 2008).

There are several existing programs focusing on urban areas including the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), the National Mission on Sustainable Habitat, and the latest National Urban Livelihood Mission. The National Environment Policy (2006) of the Government of India emphasizes the simultaneous goals of mainstreaming environment protection and livelihoods while promoting economic growth (MoEF 2006). The local Agenda for Environment Management by the Government of India underlines that urban environment management tasks should be appreciated in terms of the linkages between the city economy, infrastructure, productivity, poverty, and environmental health (GoI 2013). Similarly, several policies have been introduced at the state and central level to promote renewable energy with the objective of achieving energy security, improving air quality, reducing GHG emissions, and providing local jobs (MNRE 2013).

In other words, cities need to grow, attract skill and knowledge, and increase competitiveness. This will require robust infrastructure systems – housing, transport, and services which are efficient and accessible to all sections of the society. Within this urban growth and development strategy, cities will need to embed low carbon and climate resilience. A way to start would be to integrate climate strategies into existing urban redevelopment programs such as the JnNURM and bottom-up mobilization with the help of NGOs, CBOs, and stakeholder participation (Revi 2008).

In this context, the concepts of co-benefits and ancillary benefits play an important role in aligning climate change concerns into sector-specific developmental goals. Also, co-benefits provide the necessary bridge for the alignment of climate change concerns with national development objectives (Yedla and Park 2009). Urban planning decisions could offer synergies of development, infrastructure supply, low carbon development, and climate resilience. A more sustainable-oriented urban planning approach offers significant opportunities for cost savings and environmental benefits. For instance, efficient, fast, and reliable public transport systems can reduce local pollution and promote low carbon transport (Sathaye et al. 2006).

A structured approach for low carbon growth requires integration of an urban Environmental Management Plan to be integrated with sectoral policies including energy, transport, and infrastructure. This usually begins with establishing the baseline environmental conditions in urban areas by assessment of major environmental components including air quality, water, land, energy, biota, socioeconomic, and built environment (Nallathiga 2010).

Instead of a climate centric approach, Indian cities can work on incorporating climate goals into the planning exercise. Some potential areas could include integrating climate risks in urban infrastructure projects, local development control regulations, energy and mobility plans.

The importance of states and cities in achieving national objectives is being recognized. Increasingly, more and more subnational governments are making a significant contribution in energy efficiency, climate governance, and environmental actions. Actions initiated at the city level have a good chance of succeeding because city governments are in a better position to comprehend local issues, can address these through locally specific solutions, and engage local businesses and citizens more effectively. The formulation and implementation of climate action in cities poses governance challenges for the cities. In developing countries, local governments lack the capacity and power to implement these (McCarney et al. 2011). Some technology and infrastructure choices still remain out of control for city governments. For instance, the electricity mix is dependent on the energy mix of the regional grid and state policies.

Local low carbon actions including solid waste management systems and efficient public transport which can be implemented in the short term 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 government institutions and between local-state governments.

8.6 Conclusion

Results from several studies clearly show the need for an integrated approach to urban planning. Indian cities continue to battle local problems – of air pollution, water scarcity, and inadequate infrastructure. Climate change challenges – of curbing the rising energy use and emissions and reducing vulnerability from extreme events – have added to these. While it is recognized that future development will need to be low carbon and climate resilient, climate change does not figure prominently on the policy agenda for local governments. This entails the need for a framework that aligns climate change – both the issue of reducing emissions and coping with these. Integrating climate change into city plans at the developmental stage can help avoid costs in the long run and prevent adverse impacts arising due to lock-ins. The framework presented in this chapter is a starting point. There are several gaps regarding information on climate systems at the urban level and their interactions with the urban profiles both current and in the future. In the overall, the chapter argues for (1) robust information for cities on short-term and long-term risks for cities (2) a quantitative assessment of co-benefits and risks to delineate the roadmap, and, finally, (3) an integrated strategy that aligns mitigation, adaptation, and urban sustainability goals.

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