lack of action orientation is compounded by a general lack of public awareness of the risks associated with climate change (Assessment of Impacts and Adaptation to Climate Change, 2005).

Additionally, there is a mismatch in terms and scales. While the climate adaptation strategies like flood prevention and management need to take a long-term view and plan for the metropolitan region as a whole, most planning interventions address short-term needs and do not take a city-wide view (Murgida & Natenzon, 2007). "By analyzing who participated in the planning process and in which areas they did so, it becomes evident that the vast majority of interventions were partial, some were very specific, and a few encompass different areas and spheres" (Pírez, 2008). These issues become further complicated for the metropolitan region due to the overlap and aggregation of administrative units that lack a central governing authority.

The community of scientists and researchers has taken on an unusual task of coordinating climate-related programs and policies. A leading example of this effort was the launch of the Global Climate Change Research Program at Buenos Aires University (PIUBACC) in May 2007. The objective of this program is to map and link all research as well as city development projects within the metropolitan area so as to provide the government, civil society, and more-specifically interested groups directly involved in climate change programs a holistic and scientific assessment of climate change risks. Additionally, the scientists are drawing transferable lessons from community knowledge on flood management along the La Plata River coast with a dual focus on the vulnerability of the poor and on adaptation to storm-surge floods (Barros et al., 2005).

4.2 Delhi[13]

Delhi has a population of 16 million inhabitants, and is rapidly urbanizing with a 3.85 percent annual growth rate over the 1990s amounting to half a million migrants each year. In 1901 Delhi had 400,000 inhabitants. Furthermore, rising per capita incomes are increasing energy consumption, and over-stretching its infrastructure. Delhi is a city of contrasts—in 2000, 1.15 million people were living below the National Poverty line. On the other hand, Delhi's Gross State Domestic Product at current prices was about US $27 billion during 2007 (Department of Planning, 2008). At its widest dimensions, Delhi stretches 50 kilometers and occupies an area of 1,400 square kilometers. To compound

[13] This response is primarily based on feedback and documents provided by the Department of Environment, Government of National Capital Territory of Delhi, India. In particular, summarized here are some pivotal actions taken by the government of Delhi under the leadership of the Chief Minister of Delhi including issues raised during her participation at the C40 Large City Climate Summit in New York in 2007.

the challenges of rapid urban expansion and associated environmental risks, Delhi—like many Indian cities—faces several climate-related challenges and opportunities.[14]

Delhi has three distinct seasons—summer, winter, and monsoons with extreme temperatures and concentrated precipitation. Summers begin in mid-March lasting for three months and are dry and hot with temperatures peaking at about 40°C in the months of May and June. Monsoons are between mid-June and September during which period Delhi receives most of its 600 millimeters of annual rainfall with July and August getting as much as 225 millimeters each, see Figure 26 for seasonal variation in temperature and precipitation. Winters are dry and last from November to mid-March with December and January being the coldest months with temperatures as low as 7°C (Delhi, 2009).

Hazards

The National Action Plan for Climate Change and related analysis provides an overview of climate change issues confronting India as recognized by the federal government (see Government of India, 2002, 2008). Revi (2007) provides an overview of direct and derived climate-induced hazards in the context of urban India. Through a review of research on climate science, policy papers, and practitioner notes five hazards are identified. First, although there are uncertainties with scaling down global models such that they reflect regional climate conditions like the Indian monsoon, temperature, precipitation, and sea-level are likely to rise (see Table 14). Mean extreme temperature, as well as maxima and minima, are expected to increase by 2 to 4°C, likely to result in an average surface warming of 3.5 to 5°C within this century.

Second, average mean rainfall is projected to increase by 7 to 20 percent due to the increase in mean temperature and its impact on the Indian monsoon cycles within the latter half of this century. However, some drought-prone areas are expected to get dryer and flood-prone areas will very likely experience more intense periods of precipitation. Third, 0.8 meters is the projected centennial rise in mean sea level. Fourth, extreme events like the Mumbai flood of 2005 are expected to be more frequent in western and central India. A combination of these hazards expose the cities in this region to a range of other climate- induced extreme events like droughts, temporary and permanent flooding, both inland and in coastal areas, and cyclones.

For a summary of observed and projected temperature and precipitation for Delhi see Figures 3, 7, 13, and 17. Extreme minimum and maximum temperature events

[14] To address similar issues in a global context, in February 2008 Delhi hosted the Delhi Sustainable Development Summit, which was attended by several world leaders. The summit explored links between sustainable development and climate change. Similarly, in 2002 Delhi hosted the United Nations Conference on Climate Change. The Delhi Declaration of 2002 was signed by representatives of 185 countries.

appear to be increasing. In December of 2006, Delhi had the lowest temperature since 1935 (0.2°C), and the media reported the death toll from the cold wave in north India to be over a 100 people in and around the region. The following summer in June 2007, Delhi had a maximum temperature of 44.9°C, once again taking a toll on the people of the city. While these extreme temperatures cannot be directly linked to climate change, the challenge facing Delhi is variability in weather patterns and the potential for exacerbated extreme events due to climate change. Table 15 summarizes some of the months when temperature and precipitation were greater than 1.5 standard deviation from the mean, the hottest summer was in 1944, the coldest winter in 1935 and the wettest monsoon in 1958 (see Table 16), however recent years have seen similar extremes in temperature in 1978, 1988 and 1996 and precipitation in 1994, 1995, and 2003.

Vulnerabilities

Delhi's physical infrastructure, social services, and slum populations make the city highly vulnerable. Demand for basic infrastructure services like water, electricity, and public transport far exceeds supply (Delhi Development Authority, 2005). To add to the existing conditions, climate change- induced variability in rains could worsen the severe shortage of drinking water in summers and aggravate the floods in the monsoon season, thus making the existing energy shortage more challenging to address. With regard to transportation, Delhi has the highest per capita vehicular population in India—5.4 million automobiles for 15 million people. This poses a challenge for a city with mixed land use and varying urban densities within the metropolitan region to introduce effective modes of public transport. Carbon emissions from vehicles, traffic congestion, and increasing particulate matter all pose challenges. These and other challenges pose widespread public health risks to the inhabitants of Delhi. For example, lack of adequate sanitation facilities for the poor poses a problem for a rapidly growing city where a large proportion of population lives in slums.

The hyper-dense nature of the slums, despite Delhi's relatively low population density and the centrality of the poor in provision of services—from household help to a range of labor-intensive and low-wage tasks—poses an enormous challenge. The access to basic services is uneven across the city. While many parts of Delhi have high-quality infrastructure compared to other Indian cities, the slum dwellers lack access to many of these services. The extent of the vulnerability of the poor within the city is captured in the statistics offered by the Yamuna Action Plan, a river revitalization effort of the Government of India. They observe that about 45 percent of the city's population live in a combination of unregulated settlements, including unauthorized colonies, villages, slums, and the like. Further, three million people live along the Yamuna River, which is prone to flooding, where 600,000 dwellings are classified as slums. Further, they observe that:

> ". . . nearly 62,000 units are estimated to be located in the river bed of Yamuna on both sides of its stretch along Delhi and on the embankments of a few major storm water drains such as Najafgarh drain, Barapulla drain etc. During dry weather these slum dwellers use open areas around their units for defecation. In this way, the entire human waste generated from these 62,000 units along with the additional wastewater generated from their household is discharged untreated into the river Yamuna."

Moreover, increasing competition for scarce basic services caused by the rapidly growing population of Delhi poses public heath as well as quality-of-life challenges. For example, some poor settlements lack basic amenities resulting in open defecation. Although the extent of the impacts remains to be assessed, potential climate change impacts added to current local environmental stresses are likely to intensify this crisis. Moreover, the low quality of housing in slums and their proximity to environmentally degraded land and flood-prone areas further exacerbate the vulnerability of the poor. Within the slums, climate-induced stress is likely to affect certain social groups more than others, particularly the elderly, women, and children.

Adaptive Capacity

The government of Delhi has made many efforts towards climate change mitigation, but there is lesser emphasis on adaptation. In addition to the issues of energy, water, transportation, mitigation projects also encompass public health and other social and economic development efforts. Climate change mitigation efforts by the Government of Delhi were introduced first in the government departments and are being gradually expanded to include other stakeholders—schools, households, and firms. As seen below, most initiatives remain project-oriented (Department of Environment, 2008). Some projects, such as the Bhagidari program, seek participation from neighborhood groups, private-sector associations, schools, and non-governmental organizations to enhance civil society engagement in environmental management, creating an expanded policy space for addressing climate change. Such collaboration holds the potential to address broader issues of climate adaptation by building awareness as well as capacity of stakeholders to respond. However, the most striking of all climate mitigation initiatives in Delhi so far is the establishment of the world's largest fleet of compressed natural gas (CNG)-fueled public transport in response to a Supreme Court order.

This has resulted in 130,000 CNG-powered vehicles, 145 CNG fuel stations, as well as improved vehicular emission standards like those adopted in the European Union. The fuel quality has been improved with respect to benzene, sulphur, and lead content. Yet, the greatest lesson from this initiative is in recognizing the diverse set of triggers and actors that can initiative adaptation and mitigation programs (see Box 2).

Box 2: Change agents for CNG-operated public transport in Delhi

In 1995 a World Bank study found that poor air quality posed health hazards for households in Delhi. The study estimated that air pollution caused 1 death every 70 minutes in Delhi, and branded Delhi as one of the most polluted cities in the world (Brandon and Hommann, 1995). Subsequently, Cropper et al. also a World Bank study, argued that these death tolls may have been overestimated (1997), however the initial report generated public outrage in the city, and the Centre for Science and Environment (CSE, 2009) started a campaign demanding clean air. The health impacts of suspended particles matter (SPM) on lungs became apparent, and emissions from poorly managed polluting public transport were identified as one of the main causes of poor air quality.

The campaign mustered citizen support through involvement of professional associations, media, academies, and other stakeholders. The advocacy campaign involved bringing the message directly to the attention of the national political leadership. In response to the public outrage, the Supreme Court issued a judgment in 1998 requiring the government of Delhi to stem air pollution by introducing CNG-operated public transport, and to augment the supply of mass transit within a prescribed timeframe of 3 years, as well as required adoption of stringent emission standards within 5 years.

Automobile firms resisted the change and found some support within the government that raised safety and viability concerns. In response, the Supreme Court issued stringent directives including appointing a CNG czar to ensure compliance of new regulations, instituted large penalties for defaulters—including state and federal agencies—and increased funding of research and development. The Supreme Court, by now the principal driver of change, followed up with further directives. Both supply and demand for CNG and safety regulations were addressed through institutional mechanisms.

In about five years (1998-2002) all public transport in Delhi was converted to CNG-operated retrofitted buses. Further, this effort triggered several projects to increase supply of efficient and clean public transport systems like the Delhi metro and the Bus Rapid Transport all contributing to emission reductions as part of climate change mitigation efforts within the city. However, the key lesson illustrated here is that change agents are diverse—like in this case researchers, civil society, and the supreme court—and require creative and persistent efforts as well as the willingness to learn by doing.

Source: Adapted from Centre for Science and Environment (www.cseindia.org), and C40 Cities (www.c40cities.org)

Some mitigation measures have co-benefits for adaptation as well. For instance, adoption of green building technology that is mandatory for the Public Works Department and the Airport Authority was introduced to address mitigation, but has adaptation benefits as well. Building guidelines include: (a) optimum energy efficiency in lighting, air-conditioning, and water systems; (b) eco-friendly heating, ventilation, and air-conditioning systems; (c) green screens for east and west building walls as well as for the roof; (d) maximizing natural lighting in buildings and using energy-graded glass; (e) use of certified eco-friendly building materials; (f) efficient water-dispensing technologies for kitchenware, toilets, and irrigation systems; (g) construction material

from recycled products like fly ash bricks, recycled material in false ceilings, and recycled asphalt for roads; (h) landscape design to minimize soil erosion, reduce water usage, and ensure natural drainage systems. Expected greenhouse gas emissions reductions are 35 to 50 percent in general energy consumption and 100 percent in energy for water heating. Moreover, the New Delhi Municipal Council aims to reduce demand for energy by 15,000 kilowatts by 2009 and the Municipal Corporation of Delhi is making efforts to install compact fluorescent lamps, and capacitor banks to increase energy efficiency. Further, the government has a program that subsidizes electric vehicles and is encouraging the introduction of the Reva car, as well as battery-operated two and three-wheelers.

Delhi has expanded its forest cover over the past ten years. The cities greening program is considered to be one of the largest in the world. The forest cover has grown from 3 percent in 1998 to 19 percent in 2005. The city planted 1.7 million trees in 2007 and the forest cover grew to 300 square kilometers. To maintain the momentum, the city plans to plant 1.8 million samplings in the fiscal year 2009, increasing the greenery cover to a total of 326 square kilometers. The city also has a policy to plant ten trees for every tree chopped down. This project is done in collaboration with several stakeholders including school children, housewives, and neighborhood associations. The samplings are distributed gratis through a host of vendors. This afforestation effort is part of a CDM project proposal. To scale-up mitigation efforts, the Delhi government has established a program with the aim to raise awareness about carbon credits and clean development mechanisms among various departments. The objective is to develop a holistic approach towards reducing green house gas emission and developing projects that can redeem carbon credits. In essence, these mitigation projects can prove vital for adaptive capacity as well. For example, green roofs and walls, and tree-planting help to cool the urban environment and reduce heat island effects, as do many of the energy-efficiency projects related to buildings.

While the neglect of adaptation remains a concern, another co-benefit to mitigation efforts in Delhi is the climate change awareness and administrative capacity being built as a result of mitigation projects that may help as adaptation projects and policy measures are introduced. Not only is the government developing financial incentives to introduce programs and adopting a multi-sectoral approach that involves various departments within the city jusrisdiction, they are also learning to utilize mechanisms like UNFCC's Clean Development Mechanism (CDM) funds that are likely be equally relevant for adaptation. Illustrations of such efforts are the CDM projects and certified emission reductions (CERs) in the water, energy, and transport sectors.

Delhi Jal Board—the department in charge of Delhi's Water and Sanitation service—has energy-efficiency improvement programs in water supply, wastewater treatment, and methane recovery. Delhi Jal Board has proposed a project under the Clean Development Mechanism (CDM) with the objective to reduce greenhouse gas

emissions. The Municipal Corporation of Delhi also has an ongoing project, sanctioned by the World Bank, for methane recovery and reuse from three landfill sites. The project involves landfill gas extraction, gas testing, a feasibility study, and technical design of the project. Expected emission reduction from this project is three million tons of carbon dioxide equivalents. Further, electricity-generating companies are taking initiatives to enhance efficiency of power plants through improvement in heat rates. Renovation of 210 megawatt units under a proposed CDM project is expected to improve heat rates by 25 percent—from 200 to 250 kilocalories per kilowatt hour. The expected emissions reductions are 128,000 tonnes of carbon dioxide per unit.

Efforts by the electricity distribution companies include: (a) installation of electronic chokes and compact fluorescent lamps (CFL)—installing CFL in homes can earn 1.22 million tons of CERs annually; (b) mandatory installation of solar water heating systems in buildings that are 500 meter square and more; (c) installation of energy-efficient water pumps, power capacitors, as well as foot and reflex valves for farmers; (d) promotion of low energy light-emitting diodes (LEDs) at traffic lights; (e) performance ranking among power distribution companies. Likewise, the Municipal Corporation of Delhi's integrated waste-management project—waste to energy—proposes to convert 2050 million tons of municipal solid waste into 16 megawatts of power. The anticipated greenhouse gas emissions reductions from this project are substantial. The project is registered with UNFCCC to earn 2.6 million CERs over ten years.

In the transport sector, the Delhi Metro Rail Corporation has provided the city with a subway system. Its efforts to mitigate emissions include: (a) reduction in net energy consumption through introduction of regressive brakes that convert kinetic energy released during deceleration of the train and generate electricity that is supplied to the overhead electric supply lines. The expected emission reduction as registered with UNFCC is 400,000 CERs over ten years and is the world's first railroad project that includes carbon credits.

Finally, the government has several schemes through which it gives subsidies, low-interest loans, matching grants—like, buy one-get one free—to promote the use of less energy-intensive technologies. Although these instruments work well for capital investment like installing a solar heater or roof-top water harvesting system, these incentives often fail to sustain the projects overtime because operation and maintenance are ignored. Thus, the net impact of such program is often low.

Emerging Issues

While Delhi is making major efforts towards mitigation of climate change through carbon emission reductions and other environmental improvements, there is a significant lack of awareness about the need for adaptation to climate change. Therefore, the city has not yet planned for adaptation.

Further, Delhi's response to climate change is often less-than-effective as well as piecemeal because its efforts are primarily project-oriented. In the experience of the Delhi government, incentives—subsidies and grants—have been effective for initiating projects, but operation and management frequently remain neglected. For instance, subsidies to install rainwater-harvesting systems have created demand but subsequent maintenance is too-often ignored and many systems fall into disrepair. Such experiences hold the potential to inform adaptation efforts as well.

Gradually the city is developing a programmatic approach, but there is a need to coordinate between departments and among levels of government. For example, while the Prime Minister of India has recently released the National Action Plan for Climate Change, Delhi's local efforts will need to be reconciled with regional and national priorities.

4.3 Lagos

Lagos is Africa's second most populous city, which grew explosively, from 300,000 in 1950 to an expected 18 million by 2010, when it will be ranked as one of the world's ten largest cities. The metropolitan area, an estimated 1,000 square kilometers, is a group of islands surrounded by creeks and lagoons and bordered by the Atlantic Ocean. With a GDP triple that of any other West African country, Lagos is the commercial and industrial hub of Nigeria. Lagos is home to many industries and much large commercial infrastructure, and has greatly benefited from Nigeria's natural resources of oil, natural gas, coal, fuel wood and water. For an overview of the state of Nigerian cities see UN-Habitat (2004).

The climate of Lagos is affected by ocean and atmospheric interactions both within and outside its environment, in which the Inter-Tropical Convergence Zone (ITCZ) plays a controlling factor. The movement of the ITCZ is associated with the warm humid maritime Tropical air mass with its southwestern winds and the hot and dry continental air mass with its dry northeasterly winds. Maximum temperatures recorded during the dry season are high and range from 28–33^{0}C when the region is dominated by the dry northeast trade winds. Minimum temperature of about 24–26^{0}C is experienced during the wet season of May to September.

The city of Lagos experiences relatively high to very high temperatures throughout the year. The mean annual temperature is about 28^{0}C and the maximum and minimum temperature is 33^{0}C and 26^{0}C respectively. High to very high monthly rainfall is also experienced between May and November, although significant variations in monthly rainfall peak values are experienced. For example, between 1950 and 2006, more than 10 instances were recorded with a maximum rainfall of over 700 millimeters. Minimum monthly rainfall of less than 50 millimeters is experienced between December and March. Occasionally, extreme precipitation events are experienced in June. On June 17, 2004, for example, 243 millimeters of rain was experienced in Victoria Island