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GREEN CITIES:
Cities and Climate Change in Brazil

Urban, Water and Disaster Risk Management Unit
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US$ 1 = BRL 1.76

ABBREVIATIONS AND ACRONYMS

CAIXA	Caxia Econômica Federal
CDM	Clean Development Mechanism
CETESB	São Paulo State Waste Management Agency
CFU	Carbon Finance Unit, Work Bank
CNM	National Confederation of Municipalities
CO2	Carbon Dioxide
COPPE	Post-graduate Engineering Programs Coordination
CPF	Carbon Finance Facility
CPTEC	Center for Weather Forecasts and Climate Studies
EASCS	China & Mongolia Sustainable Development Unit, World Bank
ETWTR	Transport Unit, World Bank
FEUUR	Urban Development Unit, World Bank
GHG	Greenhouse gases
IBGE	Brazilian Institute of Geography and Statistics
ICLEI	Local Governments for Sustainability
IEA	International Energy Agency
INPE	National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
LCSEG	Energy Unit, Latin America and the Caribbean Region, World Bank
LEED	Leadership in Energy and Environmental Design
LULUCF	Land Use, Land-Use Change, and Forestry
MCMV	*Minha Casa, Minha Vida* – National Housing Program
MW	Minimum wage
NMT	Non-motorized Transport
PAC	Government Accelerated Growth Plan
PNLT	National Logistics and Transport Plan
PNMC	National Plan on Climate Change
UFRJ	Federal University of Rio de Janeiro

UNITS OF MEASURE

CO2e	Carbon Dioxide Equivalent
Gt	Billions of Tons
Ha	Hectare
Kg	Kilogram
Km	Kilometer
km2	Square Kilometer
Kw	Kilowatt
Mt	Millions of Tons
MWh	Megawatt Hour
tCO2e	Tons of Carbon Dioxide Equivalent

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Executive Summary

Urban sources of GHG emissions in Brazilian cities are growing. At the national level, the dominance of greenhouse gas emissions from deforestation in Brazil masks the fact that emissions from other sectors, like Energy, Transport and Waste, are growing quite rapidly in cities. Compared to other cities around the world, Brazilian cities have low per capita greenhouse gas (GHG) emissions because of the high level of renewable energy production; but as Brazilian cities continue to grow, the pressure towards higher emissions will persist.

The majority of emissions from Energy in Brazil result from the use of fossil fuels and electric power by industry. Industrial processes using fossil fuels will continue to be the largest contributor to emissions growth over the long-term, but electricity generation will produce the highest emissions increase in the period up to 2030. For the past three decades, the trend has been for industries to move away from city centers to peripheral locations that are cheaper and have easier access to distribution networks. However, all the GHG emissions inventories completed to date by Brazilian cities are limited to municipal boundaries, making it difficult to assess the role of industrial emissions at the metropolitan level.

One clear trend within city boundaries is that residential consumption of electricity is increasing. As households become wealthier, the size of housing units tend to get larger and the number of domestic appliances increase and residential consumption of electricity is expected to grow drastically in the next two decades

Transport emissions are rapidly growing, especially in urban areas. Fossil fuel–based emissions in Brazil are low compared to other countries due to the prominence of renewable-energy sources for electricity and fuels. In fact, ethanol substitutes for two-fifths of gasoline fuel. However, transport-sector emissions are rapidly growing due to increased motorization and congestion. This is coupled with a tendency for smaller agglomerations to grow in a sprawling manner, which is directly impacting the growth of GHG emissions, since the amount of vehicle travel is linked to urban form, i.e. the location of housing, jobs, commerce and entertainment.

A distinguishing characteristic of Brazilian cities is the high percentage of emissions from waste. The waste sector constitutes about 4 percent of GHG emissions on average in cities.[1] A key driver of waste emissions is the amount of waste produced and collected. In Brazil the amount of waste collected has increased by about 4 percent per year since 1970. The amount of solid waste collected in urban areas is expected to continue increasing in the next two decades due to increased generation of waste and improvements in the collection system. This will likely result in an even higher share of GHG emissions for the overall sector.

Climate change impacts are widespread. Climate impacts from global warming in major Brazilian cities have been identified and include flooding from intense storms, increased temperatures, and droughts. Sea level rise is also identified as a concern for Brazil because 25 percent of Brazil's population lives in coastal cities.

[1] Based on a selection of cities listed later in this Policy Note.

Brazilian cities are taking action against climate change. In response to concerns about global climate change, Brazilian cities have been world leaders in defining GHG emissions reduction targets and adopted local climate change laws. Some cities have completed GHG inventories, established reduction targets, and taken measures to mitigate emissions.

There are multiple opportunities for mitigating urban GHG emissions. There are five key sectors where local governments could play a catalytic role in reducing emissions in Brazilian cities – Transport, Land Use and Urban Planning, Energy efficiency and Renewables, Waste Management, and Urban Forestry. Many demonstrated experiences from other cities around the world, as well as from the larger Brazilian metropolitan areas, could be replicated around the country.

Planning for adaptation to climate change at the city level is not as advanced. Adaptation to climate change is critical in Brazilian cities, due to the magnitude of the expected impacts. However, few cities have fully assessed their vulnerability to climate change. In the absence of these data, adaptation measures can only be discussed in general terms.

There are significant co-benefits to climate change investments in Brazilian cities. In the developing country context where resources are scarce, it is especially important for cities to focus on co-benefits. Climate change actions should also meet development targets and address local needs. In Brazil's case the approach would be to integrate climate change "knowledge" into the city's investment plan, rather than planning stand alone climate change investments.

Each ton of emissions mitigated does not have the same cost. In fact, it is estimated that the additional cost of mitigation measures in the Transport and Waste sectors will be R$262 billion and R$156 billion, respectively up to 2030. Mitigation of emissions from waste is an immediate and lower cost opportunity for cities to act upon right now. However, mitigation efforts related to transport and urban form can have a huge impact in the long-term and offer multiple co-benefits in terms of accessibility for the poor and quality of life for all city residents.

A. INTRODUCTION

A.1 Overall Context and Scope

Brazil is a highly urbanized country – 80 percent of its population lives in urban centers and 90 percent of GDP is created in cities. According to estimates by the UN Population Division for Brazil, the entire growth in population that is expected over the next three decades will be in cities where the national urbanization rate is expected to rise to over 90 percent. This will add about 63 million people to Brazil's cities, and total urban population will be over 200 million.

Not only is the rate of population growth significant, but the distribution of this population across the country has some distinct implications on the urban environment. Indeed, from 1940 and through the 1970s, the nine larger metropolitan regions, some of which ranked among the largest in the world, grew at an annual rate of 4.5 percent and accounted for 34 percent of national growth. Secondary cities in Brazil are also growing rapidly, with significant implications on urban planning, from the provision of basic public services such as drinking water, sanitation and waste management, to the financing of adequate public infrastructure (*e.g*. roads, housing), and the management of urban pollution.

In the past few years, investments from the Growth Acceleration Program (PAC) and the a housing stimulus program (*Minha Casa, Minha Vida* – MCMV) have become main drivers of urban growth and transformation in Brazil, leveraging significant private and local resources. However, concerns have been raised about the environmental and social sustainability of these investments, including the incorporation of urban planning and energy efficiency considerations, and the provision of complementary infrastructure and social services. Moreover, there is recognition that high concentration of population and economic activities in urban areas represent major contributions to climate change, and therefore that cities must consider mitigation and adaptation measures in a more strategic manner.

The national profile of GHG emissions tends to mask the relative importance of urban emissions. Indeed, with the presence of the Amazon rainforest, Brazil's contribution to global greenhouse gas (GHG) emissions is dominated by Land use, Land-use Change and Forestry (LULUCF). Furthermore, with its high share of hydro power used for electricity generation, together with the higher use of biomass energy (from bagasse cogeneration for electricity and heat production and sugarcane ethanol for automobile use), Brazilian cities have a relatively low share of GHG emissions compared to that of cities with similar income levels internationally. However, the *total* amount of GHG emissions from urban sources (energy end use, transportation, industry) is, in fact, significant. Total energy related GHG emissions (including electricity and heat production, manufacturing and construction, gas flaring, transportation, and other industries), amounted to 359 Mt CO_2 in 2005 (World Bank, 2010). In Brazil, most of these are energy emissions related to urban areas. Moreover, energy related emissions in Brazil grew by 71 percent from 1990 to 2005, almost doubling the world average growth of 38 percent and middle-income average growth of 39 percent during the same period. The magnitude of urban GHG emissions is thus significant, and the trend is one of high growth.

In response to requests from Brazilian municipalities, this Policy Note was prepared with the objective of providing initial policy inputs to federal, state and municipal governments in Brazil on strategies and policies for *green cities*, or environmentally sustainable and resilient cities, with a specific focus on cities and climate change. The intent of this Note is not to cover the entire urban sustainability agenda, but rather to provide an overview of the role of cities in climate change in Brazil as well as recommendations of local policy options that can be implemented - in metropolitan areas, to mitigate and adapt to impacts of climate change, and in secondary cities, to learn from and avoid replicating poor practices of metropolitan areas. The Note is based primarily on a desk review of the literature, in addition to a wealth of data and projections assembled for the Brazil Low-carbon country Case Study (LCCCS) that was publicly released in 2010.

While the analysis presented is centered on climate change, the benefits of these recommendations extend far beyond climate. Indeed, this Policy Note aims to prove that, in the context of Brazilian cities, climate change mitigation policies such as compact growth, faster and better public transport, mixtures of land use, greening, and energy efficient buildings also enhance the quality of population's life, making cities more livable and therefore more competitive. Many of these are "no-regret" mitigation policies that cities would be pursuing anyway (de la Torre, Fajnzylber, & Nash, 2009). Mitigation policies on climate change therefore lend another impetus for cities in Brazil to deploy resources for a simultaneously low carbon, livable and competitive city. Co-benefits are likely to be bigger at the city level, and this would be an important factor to sustain local political support for climate change actions.

It is important to remark that the content of this Policy Note is limited to the treatment of climate change considerations within city boundaries. Indeed, whereas a comprehensive analysis of climate change issues in an urban context should expand to include all emissions within metropolitan boundaries, this Note focuses exclusively on emissions within municipal boundaries. This presents a limitation when considering the full impact on climate change of metropolitan areas of the scale of Sao Paulo or Rio de Janeiro, for example, which comprise 31 and 16 individual municipalities, respectively, and where the trend in the past two to three decades has been for industry (the largest source of urban GHG emissions) to move away from city centers towards smaller, suburban cities.

As GHG emissions inventories become increasingly available it will be possible to aggregate emissions at the level of metropolitan areas, in order to carry out a more complete and representative analysis. However, at the present time, this information is not available, and therefore the data presented in this note are bound by city limits. It is clear that incorporating the full spectrum of emissions from metropolitan areas will only reinforce the conclusions and recommendations that will be drawn from this analysis, which highlight the importance of considering and planning for the overall contributions of urban areas to the country's climate change agenda.

A.2 Organization of Policy Note

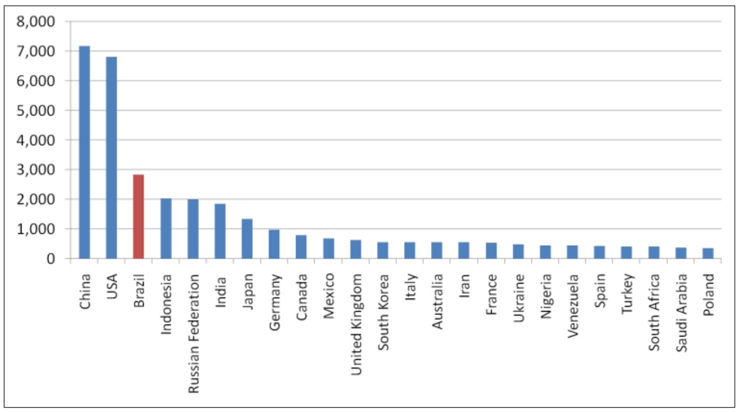
Section of this Note sets the context for the analysis conducted, by including an overview of urban GHG emissions in Brazil and their trends, compared to those of other countries of similar economic and industrial characteristics. This section also highlights the economic sectors responsible for the highest volumes of GHG emissions, in an urban setting, and finally presents results of climate change vulnerability analyses done in major Brazilian cities, which presents a clear justification for the importance of this topic. Section C summarizes major mitigation measures that can be put in place to address the main sources of urban emissions. Section D highlights the type of adaptation measures that could be developed in Brazilian cities. This is followed, in section E, by a summary of examples of what has been done by cities in Brazil in terms of climate change action plans. This section also includes a discussion of potential co-benefits of putting in place mitigation and adaptation measures, which may provide concrete motivation, at the local level, for the implementation of global climate change related measures. Finally, section F presents recommendations for implementation of mitigation and adaptation measures, including action at the institutional, technical, and financial levels.

URBAN CLIMATE CHANGE CONTEXT

B.1 Greenhouse Gas Emissions in Brazilian Cities

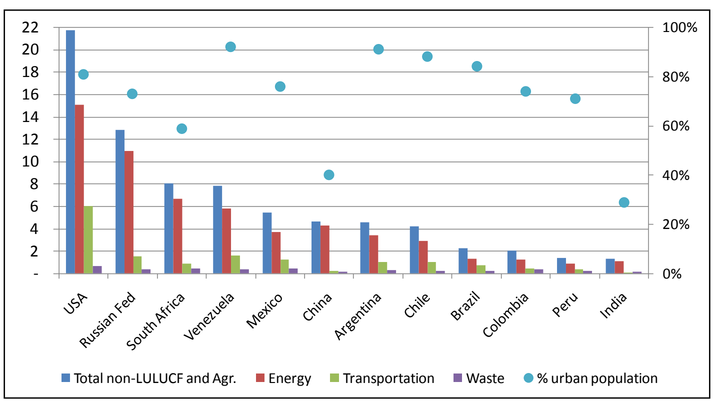
Greenhouse Gas Emissions in Brazilian cities are less than half of global urban emissions, but they are the fastest national growing source. Although Brazil was the third largest greenhouse gas (GHG) emitter in the World in 2005 (Figure 1), the urban contribution to total national GHG emissions is small, unlike that in other high emissions producing countries (Figure 2). Indeed, while cities consume over two-thirds of the world's energy and account for more than 70 percent of global CO2 emissions[2], Brazilian cities account for 29 percent of national GHG emissions, at most[3]. This is because an estimated 66 percent of national emissions come from Land use, Land-use Change and Forestry (LULUCF), as well as Agricultural sources. Energy (18 percent)[4], Transport (11 percent), and Waste (5 percent) constitute the remaining share of emissions, and represent those that could be characterized as coming from urban areas (Figure 3).

Figure 1: Comparison of GHG Emissions by Country, MtCO2e 2005 (including LULUCF)



Source: CAIT, World Resources Institute website, accessed February 11, 2010.

Figure 2: Cross-Country Comparison of GHG Emissions Per Capita and percent Urban Population



Source: CAIT, World Resources Institute website, accessed April 5, 2010 and DDP.

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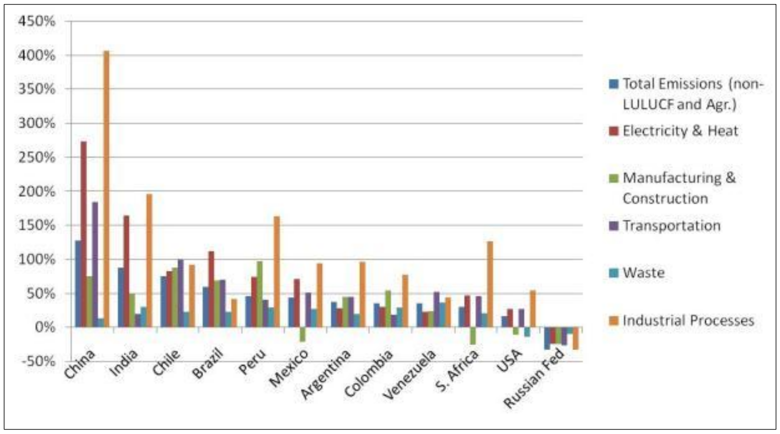
[2] International Energy Agency

[3] Author's calculation based on Total Emissions, less LULUCF, less Agriculture, less non-urban share of Transport.

[4] Energy is comprised of Power Generation (18 percent), Industrial Processes utilizing fossil fuels (57 percent) and Other Energy (25 percent).

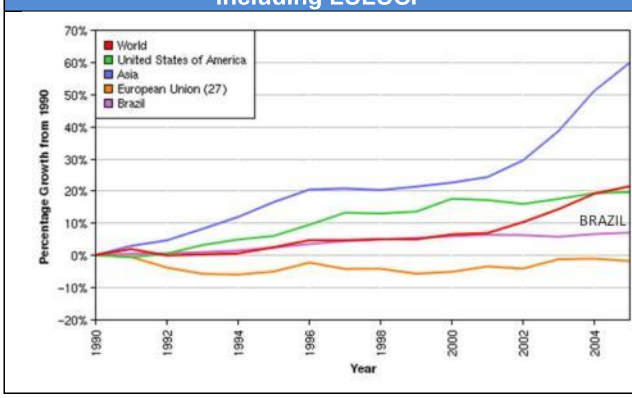
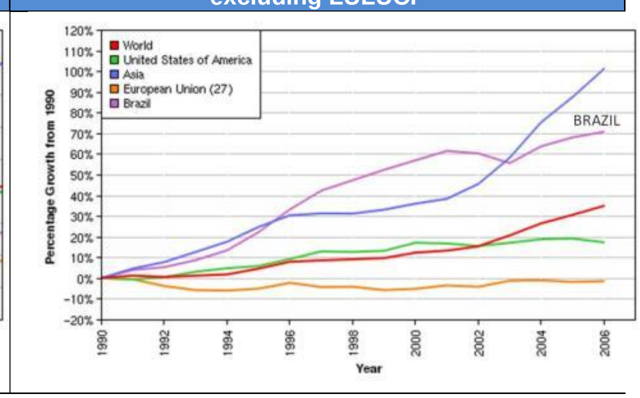
Figure 3: Cross-Country Comparison of Change in GHG Emissions by Sector, 1990-2005



Source: CAIT, World Resources Institute website, accessed April 5, 2010.

While cities are not currently the largest contributors to GHG emissions in Brazil, they are the fastest growing source. The total GHG emissions growth during the period 1990-2005 was relatively low in Brazil (approximately 8 percent). However, when LULUCF is excluded, the growth in emissions jumps to over 70 percent for the same period (Figure 4). The largest percentage growth was in the Energy sector, of which 43 percent was due to manufacturing and construction, and 33 percent from electricity and heat – all of which are arguably concentrated in urban areas. As the Brazilian economy continues to grow and the purchasing power of its citizens increases, emissions are likely to continue rising at a fast pace unless measures are taken to keep Brazilian cities on a low-carbon growth path.

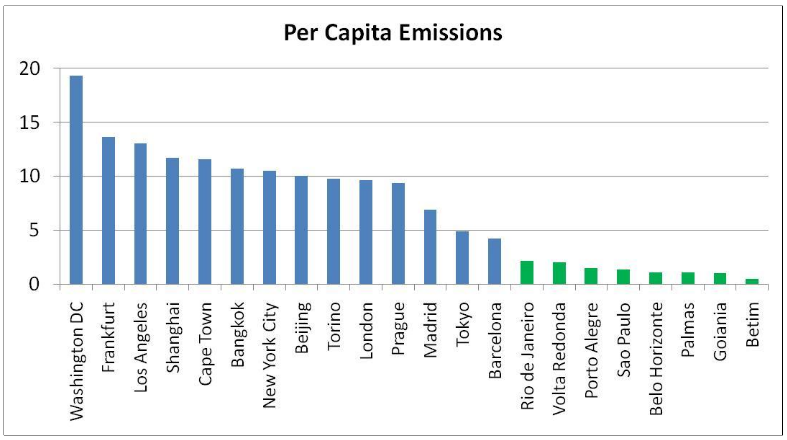
Figure 4: Comparison of Growth in GHG Emissions - Including and Excluding LULUCF

National CO2 Emissions, 1990-2005, including LULUCF	National CO2 Emissions, 1990-2005, excluding LULUCF
	

Source: CAIT, World Resources Institute website, accessed February 11, 2010.

Brazilian cities have relatively low per capita GHG emissions - Comparisons of global data clearly show that Brazilian cities have low per capita GHG emissions[5], relative to other cities around the world (Figure 5). It must be noted, however, that relative comparisons of GHG emissions among cities cannot be accurately made and should only be used qualitatively. Indeed, major variations exist among cities on (i) base years; (ii) sectoral categories; (iii) administrative boundaries (e.g. municipal versus metropolitan); and (iv) data sources, methodology, definitions, which make direct comparisons inaccurate. A major effort is in fact being led at the international level to try to standardize methodologies in order to facilitate comparisons of inventory data among cities. Figure 6 illustrates results from GHG inventories of a few representative Brazilian cities.

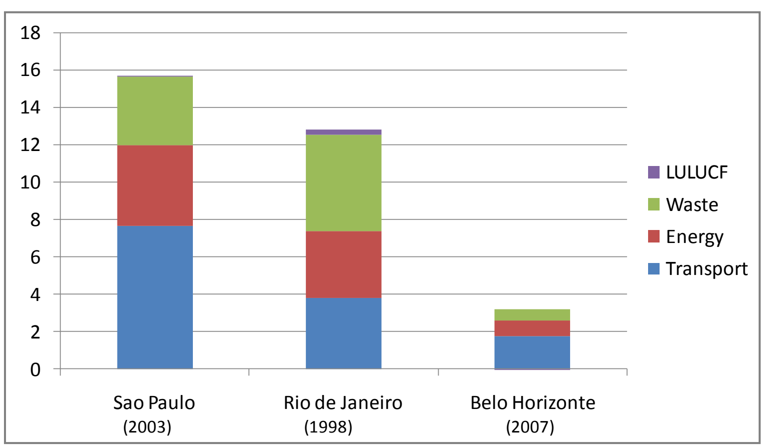
Figure 5: Cross-City Comparison of GHG Emissions per Capita (tons of CO2e)



Source: Kennedy, et al (2009). Note: Belo Horizonte was added using data from their 2009 inventory.
Volta Redonda, Porto Alegre, Palmas, and Betim were added using data from ICLEI.

Note: Emission data is not standardized and thus comparisons between cities are only shown for illustrative purposes

Figure 6: Comparison of GHG Emission from Large Municipalities in Brazil, Millions of Tons of CO2



Source: Municipal GHG inventories.

[5] São Paulo, Belo Horizonte, Betim, Porto Alegre, Goiânia, Volta Redonda, Palmas, and Curitiba developed GHG emissions inventories using methodology by ICLEI-Local Governments for Sustainability. Rio de Janeiro updated its 2000 inventory in 2010 using the the IPCC – 2006 methodology adapted to the municipal level.

A comprehensive set of city-level data to track the growth in GHG emissions over time in Brazil is not available. However, looking at cases where time-series data is available allows some insights. In Rio de Janeiro, between 1990 and 1998 emissions grew by 2 percent per year.[6] This overall growth rate, however, masks stronger growth in Electricity generation (22 percent), Road Transport (3 percent), and Waste generation (5 percent). During the same period, emissions from Air Transport and Industry decreased. GHG emissions in Belo Horizonte increased by an annual rate of 3 percent between 2000 and 2007, driven primarily by growth in emissions from the Waste (18 percent) and Air Transport (10 percent) sectors.

Table 1: Historical Emissions in the Municipality of Rio de Janeiro, Millions of Tons of CO2e

Source	1990	1996	1998	CAGR
Electricity	0.22	0.88	1.06	21.9 percent
Road Transport	2.97	3.45	3.81	3.1 percent
Industry	1.64	1.00	0.97	-6.4 percent
Air Transport	1.65	0.84	0.86	-7.9 percent
Waste	3.54	5.40	5.14	4.8 percent
Other	0.95	0.96	0.97	0.3 percent
Total	**10.97**	**12.54**	**12.80**	**1.9 percent**

Source: Rio de Janeiro GHG Emissions Inventory.

Table 2: Historical Emissions in the Municipality of Belo Horizonte, Millions of Tons of CO2e

Source	2000	2001	2002	2003	2004	2005	2006	2007	CAGR
Electricity	0.13	0.13	0.10	0.10	0.10	0.10	0.09	0.09	-5.3 percent
Road Transport	1.73	1.76	1.77	1.73	1.74	1.74	1.79	1.78	0.4 percent
Industry	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.0 percent
Air Transport	0.15	0.18	0.20	0.21	0.24	0.25	0.27	0.31	10.4 percent
Non-transport Fuels	0.28	0.29	0.30	0.29	0.29	0.29	0.29	0.30	1.1 percent
Waste	0.19	0.27	0.37	0.43	0.47	0.51	0.55	0.58	17.5 percent
Total	**2.59**	**2.74**	**2.87**	**2.88**	**2.96**	**3.01**	**3.12**	**3.17**	**2.9 percent**

Source: Belo Horizonte GHG Emissions Inventory.

B.2 Major Sources of Greenhouse Gas Emissions

Energy sector: industry is the greatest source but emissions from electricity generation will experience the fastest growth **-** The majority of emissions from Energy in Brazil are from the use of fossil fuels and electric power by industry. A breakdown of CO2 emissions by industry type is shown in Figure 7. Industrial processes using fossil fuels will continue to be the largest contributor to emissions growth over the long-term, but electricity generation will produce the highest emissions increase in the period up to 2030 (LCCCS).

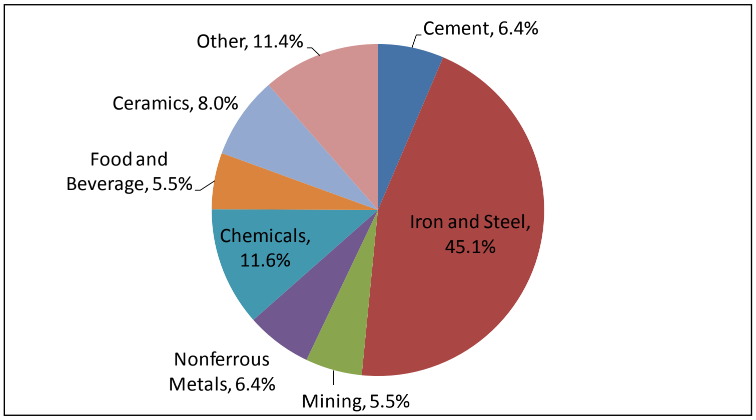
[6] Rio de Janeiro, the first Brazilian municipality to prepare an emissions inventory in 2000 updated it in 2010 using data from 2005. The revised GHG emissions CAGR for the period between 1996 and 2005 falls to 0.5 percent, with a slight decrease in emissions from Waste and a 1.4 percent CAGR in emissions from Road Transport during the period. The 1990 baseline was not updated.

Table 3: Projection of Emissions from Energy in Brazil

Emissions Source	CO2 Emissions in 2007 (Mt CO2)	Reference Scenario 2030	Low-Carbon Scenario 2030
Power Generation	36.7	95.0	79.4
Industrial Processes (fossil fuels)	124.7	280.6	164.8
Other (including refineries)	58.2	82.2	52.9
Total	256.3	457.8	297.1

Source: Brazil Low-Carbon Case Study, 2010

Figure 7: Estimate of Emission of Co2 (fossil fuel) by Industry in 2007



Source: Low Carbon Emissions Scenario in Brazil, Energy Area (COPPE 2010)

It is difficult to determine the percentage of industrial GHG emissions that are generated in Brazilian cities. For the past two decades, the trend has been for industries to move out from inner-city areas to peripheral locations that are cheaper and have easier access to distribution networks. For instance, in 1996, 37.1 percent of industries in the State of São Paulo were concentrated in the Municipality. By 2001, this share had decreased to 32.5 percent (SVMA 2005). In this context, the lack of metropolitan-level inventories makes it difficult to establish the share of industrial emissions within urban agglomerations in Brazil. The iron and steel sector, for example, representing the largest portion of Energy emissions from fossil fuels, is primarily based in the greater metropolitan regions of São Paulo, Rio de Janeiro and Porto Alegre, as well as in what is known as Steel Valley in the State of Minas Gerais. While the emissions from these steel mills are accounted for in state-level inventories, they are not reflected in municipal inventories completed to date.

With regards to electricity, around 95 percent of consumption in Brazil is from the industrial (51 percent), commercial and services (22 percent) and residential (22 percent) uses. Since hydropower represents more than three-fourths of installed generation capacity in Brazil, the contribution of these end-users to overall GHG emissions is relatively modest compared with other sectors.

Notwithstanding, as households become wealthier, the size of housing units tend to get larger and the number of domestic appliances increase. According to the 2000 census, 99 percent of urban households in Brazil had electricity connections. However, only 37 percent had washing machines, 9 percent had air conditioning, 22 percent had microwaves, and 12 percent had personal computers. This implies that there is ample room for growth in the purchase of what could be characterized as luxury domestic appliances. It is likely that the 2010 national census will show a dramatic increase in the consumption of domestic appliances over the last 10 years that parallels the increased economic growth in the country. Indeed, the production of domestic appliances in Brazil grew by over 31 percent since 2002 (IBGE). As a comparison, between 2000 and 2005, Mexico experienced an increase in ownership of washing machines from 52 percent to 63 percent, refrigerators from 69 percent to 79 percent, and personal computers 9 percent to 20 percent (INEGI, Population and Housing Count of 2005).

Table 4: Estimate of Electricity Consumption in the Residential Sector in Brazil

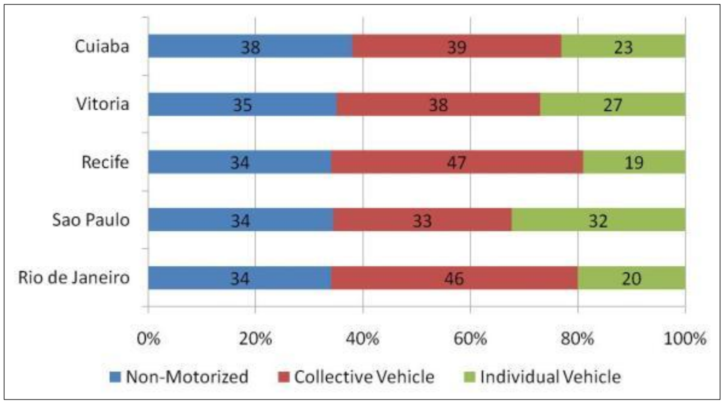
	2009		2030 Reference Scenario	
End Use Appliances	**Consumption (MWh)**	**percent**	**Consumption (MWh)**	**percent**
Electric Showers	248,170	6 percent	5,539,450	11 percent
Refrigerators	1,468,292	35 percent	34,639,079	66 percent
Air Conditioning	289,958	7 percent	10,115,689	19 percent
Lamps	2,187,610	52 percent	2,429,163	5 percent
Total	4,194,030	100 percent	52,723,381	

Source: Brazil Low-carbon Country Case Study, 2010

The LCCCS Reference Scenario estimates that emissions from residential end uses of electricity will be 11 times higher in 2030 that in 2009, and that electricity consumption will be 13 times higher. Domestic refrigerators alone are responsible for 60 percent of that increase.

Transport sector: share of emissions in Brazilian cities lower than in cities in other countries, but growing fast **-** Fossil fuel–based emissions in Brazil are low compared to other countries due to the prominence of renewable-energy sources for electricity and fuels. In fact, ethanol substitutes for two-fifths of gasoline fuel. However, transport-sector emissions are rapidly growing, especially in urban areas, due to increased motorization and congestion. Road transport is responsible for more than 90 percent of transport-sector emissions. Urban transport, which accounts for 58 percent of the transport sector emissions, is almost exclusively road-based (car or bus) (National Logistics and Transport Plan 2007). Figure 8 provides an overview of the transport modal shares for selected Brazilian cities.

Figure 8: Urban Transport Modal Split in Brazil by Metropolitan Region (2002)



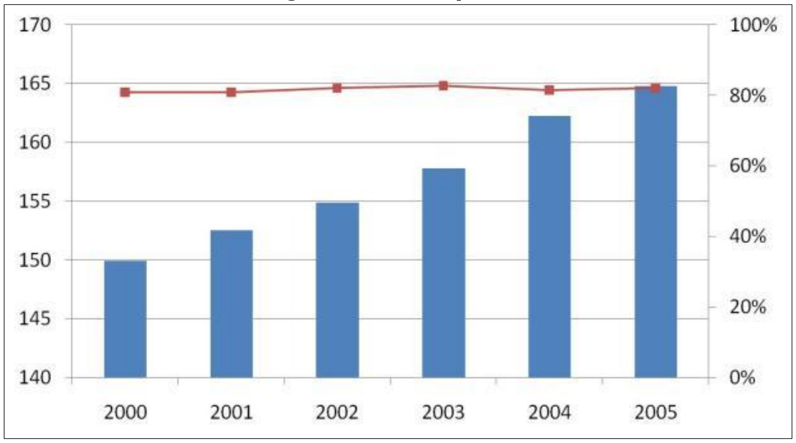
Source: Rio de Janeiro Transport Plan, 2003

Nationwide, projected vehicle ownership growth in Brazil is 4.1 percent for the period 2002-2030 (Dargay 2007). Based on historical data from the United States, it is likely that vehicle kilometer travel growth will be generally faster than vehicle ownership growth (U.S. Department of Transportation 2004). This implies that every year the number of vehicles in Brazilian cities is increasing, as is the distance they travel. Therefore, continued significant growth in transport-sector emissions is expected in the coming decades. In fact, kilometers traveled per year in urban areas are expected to double by 2030 and total urban transport related GHG emissions per year are expected to grow by 60 percent. In São Paulo, for example, the fleet is growing at an annual rate of 7.5 percent, with nearly 1,000 new cars bought each day. In 2008, that city‘s average rush-hour congestion exceeded 190 km (LCCCS 2010). Such intense congestion results in higher inefficiencies, greater fuel consumption, increased local pollution and GHG emissions.

***Waste sector: more significant share of emissions in Brazilian cities than in cities is other countries* -** Waste treatment produces large quantities of greenhouse gases, principally methane, resulting from the anaerobic digestion of organic waste material. Waste emissions represent a larger share in Brazilian cities than what is experienced globally. For the global cities shown previously, Waste constitutes 6 percent of GHG emissions on average. In contrast, it represents 40 percent in Rio de Janeiro, 24 percent in São Paulo, and 18 percent in Belo Horizonte. (Note: São Paulo’s inventory preceded the installation of methane capture facilities at the Bandeirantes and São Joao landfills).

A key driver of waste emissions is the amount of waste produced and collected. In Brazil the amount of waste collected increased from approximately 14 million tons per year in 1970 to 55 million tons in 2005, about 4 percent per year (LCCCS 2010). Historical collection data for the municipality of São Paulo show an increase of 38 percent in the per capita waste generation for households and small businesses between 1978 and 2004, equivalent to a 1.2 percent compound annual growth rate over 26 years (Philippi et al 2005). Based on the predictions of the LCCCS, the amount of solid and liquid waste collected in urban areas is expected to continue growing due to increased generation of waste and improvements in the collection system and could increase by up to 50 percent by 2030.

Figure 9: Urban Solid Waste Collection in Brazil (1,000 tons/day) and Percentage Collected of Total Waste



Source: ABRELPE (2005)

How waste is disposed of also determines the amount of GHG emissions produced. In Brazil, it is estimated that only 39 percent of the country's 5,564 municipalities adequately dispose of their waste in sanitary landfills. Approximately 32 percent of municipalities deposit their waste in controlled landfills, and the remaining 30 percent in open dumps (ABRELPE 2007). It is common practice to allow biogas (a product of the anaerobic digestion of organic waste) to escape directly into the atmosphere (LCCCS 2010). There is an opportunity to use the biogas for energy generation, as is done in the Bandeirantes and São João landfills in São Paulo where thermoelectric power plants were installed to burn the GHG produced by the decaying waste (see Box 10).

B.3 Climate Change Impacts

Impacts from Increased Rainfall on Brazilian Cities

Urbanization exacerbates flooding by restricting the path of flood waters, quickening the flow of the water by covering the ground with impervious materials like asphalt and concrete, installing drains and channels that concentrate the flow of the water, removing vegetation that provides natural rainfall absorption, and obstructing natural channels.

Brazilian cities are vulnerable to multiple types of flooding due to climate change. First, localized flooding that occurs many times a year in specific areas of the city that lack adequate drainage or have ditches and culverts that often get blocked by waste and debris could increase. These are often concentrated in informal areas or *favelas* on the periphery of the urban area or in low-lying zones within the urban fabric. In Rio de Janeiro, for example, the flat topography of low-lying areas, combined with inadequate drainage, results in frequent flooding during the rainy season. In this case, low-lying areas exist across the socio-economic spectrum of the city. A second type of flooding could occur from streams in urban areas or constructed flood channels that rise quickly after heavy rain. Increased storm capacity or the accumulation of debris could cause them to exceed capacity. Finally, major water bodies flowing through urban areas could make them susceptible to flooding.

In addition to damaging buildings and endangering citizens, flooding could impact utilities such as water and sewer, electricity, and communications networks, and cause public health risks. As highlighted in the Rio de Janeiro vulnerability studies, flooding could have the potential to overburden the stormwater drainage and sewer systems, and cause untreated effluent to flow back into buildings or flow directly into recipient water bodies. In turn, this would raise public health concerns. In cities with mountainous topography, such as Rio de Janeiro, flooding also presents the risk of landslides. As rainwater saturates slopes, the soils may become weak and collapse.

Impacts from Sea Level Rise

Rising sea levels can inundate wetlands and other low-lying lands, erode beaches, and increase the salinity of rivers, bays, and groundwater tables. The changing form of the coastline and the impact of storm tides can have a catastrophic impact on coastal urban areas and port facilities. In many coastal Brazilian cities, rising sea level can compromise road networks, the sewage and stormwater drainage systems, causing untreated urban effluents to pollute rivers and other water bodies, in addition to raising public health concerns. The environmental degradation of coastal areas could translate into loss of touristic, residential and other assets, and increased insecurity for local residents. Such factors lead to economic losses and declining values for coastal properties (Zee 2009). This is a real and major concern for Brazilian cities, as one quarter of the country's population lives in coastal areas. In Recife, for example, sea level rise is believed to be one of the causes of shoreline recession – more than 6 feet per year from 1915 to 1950 and more than 8 feet per year from 1985 to 1995 (Neves and Muehe 1995).

Impacts from Increased Surface Temperature

Rising surface air temperatures may be exacerbated in urban areas due to the "heat island" effect, a concept that highlights that temperatures are often warmer in downtown districts in comparison to the periphery of the city. The built environment, including buildings and roads absorb sunlight and re-radiate heat. With less vegetative cover to provide shade and cooling, cities become warmer and susceptible to dangerous heat events (Corburn 2009). In the U.S., the difference in temperature between the city and its suburbs can reach up to 12°C in large urban areas at night and could amplify heat stress, especially during heat waves (U.S. Environment Protection Agency). In Brazil, there are also public health concerns associated with temperature rise, especially the expansion of mosquitoes transmitting dengue fever and malaria (La Rovere 2002).

In Brazil, urban areas with predicted temperature increase over 4°C (e.g. Manaus, Teresina, Palmas, and Porto Velho) and highly urbanized areas vulnerable to additional heat island effect (e.g. Rio de Janeiro, São Paulo, and Salvador) could be especially vulnerable. Low-income populations are generally more vulnerable to heat stress due to limited access to air conditioning and employment in occupations that require a high degree of physical labor. Elderly people are also more vulnerable than the general population because they have a reduced ability to thermoregulate.

Impacts from Increased Drought

The Brazilian Northeast has about 30 million inhabitants, 15 percent of the national population. Over half of the land area in the Northeast, referred to as the Drought Polygon, suffers from a chronic lack of water and has an annual rainfall of less than 800 mm (Marengo 2009). While storms and floods are easily recognized and their effects are immediately visible, droughts may be more complicated due to their spatial and temporal characteristics. In areas that have relatively consistent precipitation, temperature, and weather patterns, meteorological models can be developed to predict drought up to a year in advance. Usually, however, so many variables can affect the outcome of climatic interactions that it is not possible to predict a drought in advance. In fact, an area may already be in a drought before drought is even recognized (U.S. National Drought Mitigation Center).

There are multiple types of droughts, but the two types that could be of most impact on urban areas in Brazil are hydrological and socioeconomic. Hydrological drought occurs when there is a prolonged period of below-normal rainfall, causing deficiencies in the water supply, as measured by below-normal streamflow, lake and reservoir levels, groundwater levels, and depleted soil moisture content. Hydrological droughts usually lag the occurrence of below-average rainfall. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors (Ibid).

Socioeconomic drought refers to the moment when water shortages begin to effect people and their way of life. The supply of many economic goods (e.g. water, food grains, fish, and hydroelectric power) depends on weather. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply (Ibid). Scarcity of food and water caused by drought conditions would have an acute impact on the urban poor who already spend a higher proportion of their household budget on food than middle and high income families.

In Brazil, climate change could intensify existing difficulties in gaining access to water. The combination of less rainfall accompanied by high temperatures and high evaporation levels and competition for water resources, could force the poorer subsistence farmers in the semi-arid area of the Northeast to migrate to cities or areas where it is possible to develop irrigated agriculture. Over the last 41 years, the temperature in the Northeast has already increased by 1.5-2°C at its hottest (Marengo 2009).

B.4 Vulnerability of Brazilian Cities to Climate Change

Brazilian cities are vulnerable to the impacts of climate change. Some of these vulnerabilities have already become evident, like the multiple cases of landslides and floods resulting from intense rainfall events across the country in the last couple of years. Other vulnerabilities include increased intensity of heat waves, sea level rise, and an increased risk of drought and water shortage in already dry regions.

In the last few years, several severe rainfall events have impacted urban areas in Brazil. Most recently, in January 2011 the heaviest rainfall in 44 years caused mudslides and floods that swept away houses, killed about 500 people and left 4,600 homeless in Rio de Janeiro and Sao Paulo states. In April 2010, Rio de Janeiro, as well as Niterói and São Gonçalo, both in Rio’s metropolitan area, suffered heavy rain for almost a week, which combined with a tidal surge, resulted in landslides and the worst flood in the state in 46 years. Approximately 230 people perished and 5,000 were displaced. Over 150 areas are currently considered at risk. Just three months earlier, in January 2010, rain in Rio de Janeiro and the São Paulo coast left 75 dead and 4,000 displaced. Angra dos Reis and São Luiz do Paraitinga were the hardest hit. These events are not isolated to Rio and São Paulo. In April 2009, heavy rain led 207 towns, including São Luis, in the northern state of Maranhão to declare a state of emergency. There were over 40 deaths and an estimated R$1 billion in damages. In Santa Catarina, flooding in the Vale do Itajaí region in 2008 left 135 dead, over 5,600 displaced, and 150,000 without electricity. Many roads were cut off by landslides and the Itajaí Port was partially destroyed.

Changes in temperature, precipitation, sea level, and other climate-related factors can often exacerbate problems that are already of concern to local governments. In these cases, climate change preparation could serve as an impetus for addressing these concerns. For example, poor populations are expected to be the most vulnerable to climate change due to their lack of access to capital and capacity to respond in a timely manner (OECD 2009). The urban poor may also be more exposed to climate change, since they are likely to occupy risk-prone land like the hills in Rio de Janeiro and wetlands in São Luis. They are also more likely to use cheaper building materials and violate building or safety codes. In São Paulo, it is estimated that 30 percent of the population (approximately 3 million people) live in houses with some degree of informality (SEHAB). In Rio de Janeiro, there are an estimated 643 *favelas* in which about 20 percent of the population lives (IPP). These households are more likely to be located in at-risk areas such as steep slopes or flood plains.

Rainfall, sea level rise, and increased temperatures will impact the residents of Brazilian cities, but also the cities' infrastructure and economies. Changes in temperature and precipitation will likely shorten the maintenance and useful-life of infrastructure investments as well as impact their capacity if not addressed in the original design.

Climate Change Forecasts

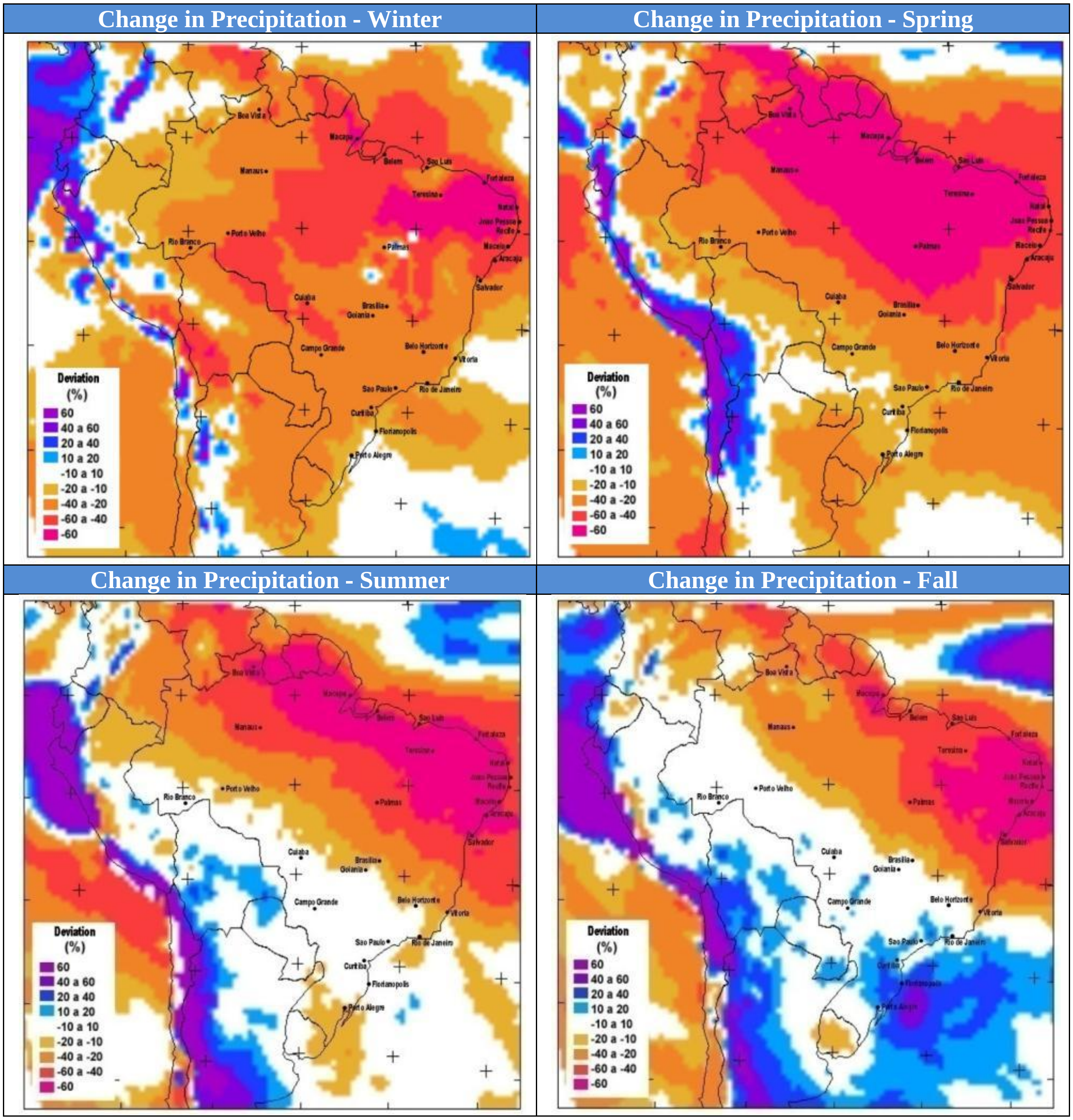
Rainfall - Results from modeling[7] done by the Center for Weather Forecasting and Climate Studies (CPTEC/INPE), under the Ministry of Science and Technology, show that the Northeast and Amazon regions of Brazil have not experienced a significant trend of increase or decrease in rainfall since 1960 (CPTEC 2007). However, there is a lack of data for these regions. Conversely, there has been a significant trend of increased rainfall in the Southeast region since 1960, along with increased intensity and frequency (Figure 10). It is projected that in the future there will be weaker rainfall in the North and Northeast regions, leading to a possible water shortage in the Northeast. According to ANA, more than 70 percent of cities (>5,000 pop) in the semi-arid Northeast will face water shortages by 2025.

Temperature - Projected changes to surface air temperature vary by region. An increase of 1.3 to 3.8°C in the national average temperature is expected by 2100. Regional predictions include: +3.0 to +5.3°C in the Amazon, +2.2 to +4.0°C in the Northeast, +3.4 to +4.6°C in the Pantanal, and +2.3 to +3.5°C in the South - Bacia do Prata (Figure 11).

[7] Projected through the use of an atmospheric model (Eta-CPTEC) for South America. The model features a special resolution of 40 km for the regionalized projections of future climate (period 2071-2100 with extreme IPCC scenarios of A2-high emissions and B2-low emissions of greenhouse gases).

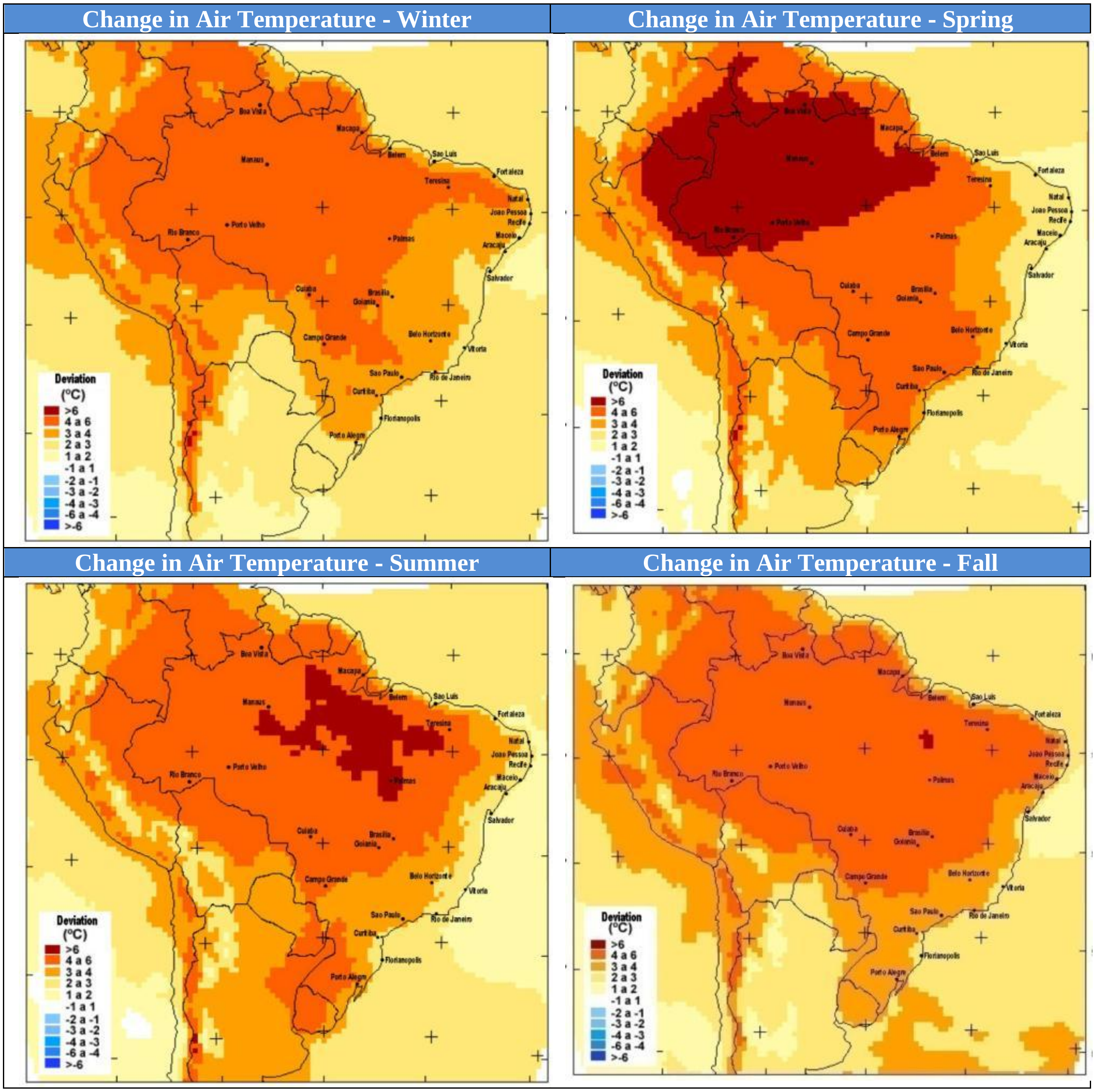
Sea level rise - Sea level rise is also identified as a concern for Brazil because 25 percent of Brazil's population lives in coastal cities. The IPCC estimates a 30-80cm sea level rise in the next 50-80 years. In Brazil, the Northeast coastline is the most susceptible to erosion -- a 50cm sea level rise could consume 100 meters along the coast. Finally, according to the study, Rio de Janeiro is considered the city most vulnerable to sea level rise.

Figure 10: Projected Change in Precipitation by 2071-2100 in Brazil



Source: CPTEC *Atlas of Future Climate Scenarios for Brazil (2007)* with overlay of major Brazilian cities. A2 emissions scenario.

Figure 11: Projected Change in Air Temperature by 2071-2100 in Brazil



Source: CPTEC *Atlas of Future Climate Scenarios for Brazil (2007)* with overlay of major Brazilian cities. A2 emissions scenario.

Assessing City-level Vulnerability

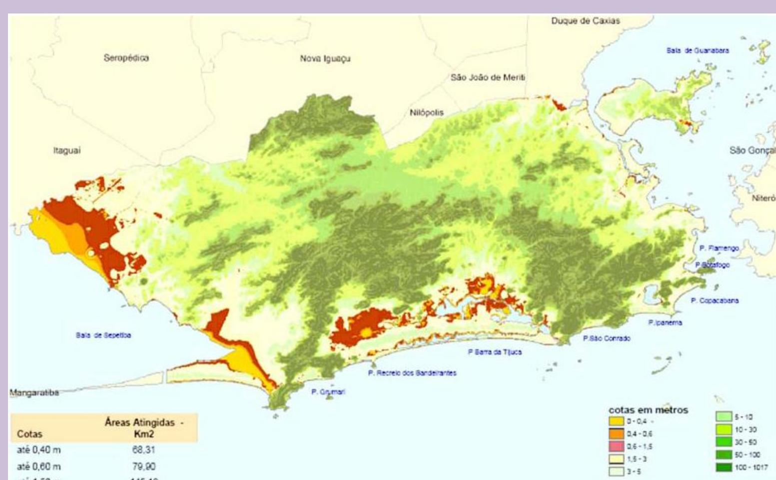
Few cities in Brazil have launched comprehensive assessments of climate change vulnerability. The National Climate Change Plan, released in 2008, calls for the mapping of urban vulnerabilities, and R$5.5 million was provided to the Ministry of Environment for this purpose (Amendment nº50230001). However, the result of this initiative has not yet been made public.

Rio de Janeiro completed a preliminary vulnerability assessment in 2007, and initiated a more detailed assessment in 2010. A vulnerability study of the São Paulo metropolitan area completed in June 2010 uses the Eta-CPTEC 40 km weather model, along with data on over 700 existing points of flooding and urban growth projections, to map the area that will be susceptible to flooding and landslides due to climate change (INPE 2010). The same study will be replicated for the Rio de Janeiro metropolitan area as well. The Municipality of Curitiba is also planning to launch a climate change vulnerability study in 2010.

Box 1: *Preliminary Vulnerability Assessment of Rio de Janeiro Municipality*

In 2007, the Pereira Passos Municipal Institute of Urbanism in Rio de Janeiro commissioned a set of climate change vulnerability studies. These studies focus primarily on the possible impacts to the city due to sea level rise of 0.2 to 1.4 meters as per the IPCC global estimates. Specifically, the studies assess the city's vulnerability related to topics including landslides, water and sanitation systems, micro and macro drainage, coastal eco-systems, wetlands, and public health.

Figure 12: GIS Map of Rio de Janeiro Identifying Low Altitude Areas



The studies highlighted the vulnerability of the water and sanitation system and the risk of landslides. The sewer system is vulnerable to increased flow rates due to invasion of stormwater into the separated system. If this occurs, it would compromise the pumping capacity of the system and cause blockages and overflows. The consequence would be a public health crisis due to sewage overflowing into residences and other buildings and escape of untreated effluent into local water bodies. Moreover, areas of the city not served by sewerage and stormwater drainage systems, and which rely on ditches for this purpose, would be in extreme public health risk.

Increased rain and storm events in Rio de Janeiro are expected to increase the risk of landslides. Rio's dramatic topography makes it more prone to landslide risks. The coastal mountains were once carpeted in thick Atlantic rainforest. As this protective covering has been progressively stripped away for urbanization, the thin soils have become prone to landslides, and the granite and gneiss bedrock has been left exposed to weathering, making it more prone to decomposition and erosion (Sherbinin et al 2007).

The urban poor in Rio de Janeiro are especially vulnerable to the impacts of climate change. There are an estimated 643 favelas in which about 20 percent of the population resides. These households are more likely to be located in at-risk areas such as steep slopes or flood plains. According to the proposed *Plano Diretor*, about 17 percent of the favelas are located near or inside of officially designated conservation areas. These are concentrated close to the urban core where households have sought out site proximate to employment centers.

Source: IPP (2007).

B. CLIMATE CHANGE MITIGATION

There are five key sectors where local governments could play a catalytic role in reducing emissions in Brazilian cities – Transport, Land Use and Urban Planning, Energy efficiency and Renewables, Waste Management, and Urban Forestry. The following sections provide a brief description of the issues and of potential mitigation measures.

C.1 Transport

The urban transport sector accounts for a large share of GHG emissions globally, and is expected to continue growing. In developing countries, energy consumption within the transport sector is usually growing much faster than in other sectors.

The Brazil Low-Carbon Country Case Study presents projections for direct CO_2 emissions from urban transport in 2030, assuming a Reference Scenario in which historic trends continue and current transport master plans are implemented, versus a Low-Carbon Scenario in which there is a significant modal shift to bus rapid transit (BRT) and metro use (see Table 5). The Study assumes that, for both the Reference and Low-Carbon scenarios, the use of ethanol to fuel private cars dramatically increases by at least 5 percent per year between 2007 and 2030.

Table 5: Projection of Emissions from Urban Transport in Brazil

		Reference Scenario				Low-Carbon Scenario	
		Load (Pax x km/year)		Direct CO2 Emissions (Mt CO2)		Load (Pax x km/year)	Direct CO2 Emissions (Mt CO2)
Vehicle type	Fuel type	2007	2030	2007	2030	2030	2030
Bus	Diesel	431,327	730,799	33.80	51.30	346,281	39.40
BRT	Diesel	0	102,332	0	3.36	470,621	13.35
Car	Ethanol	96,399	364,894	0	0	320,240	0
Car and motorbike	Gasoline	272,570	347,346	36.60	66.20	304,840	59.23
Metro	Electricity	28,412	55,385	0.02	0.04	212,844	0
Train	Electricity	35,370	50,699	0.02	0.03	26,577	0
Total		**864,078**	**1,651,455**	**70.44**	**120.93**	**1,681,403**	**111.97**

Source: Brazil Low-Carbon Country Case Study, 2010

The main challenge to realizing the Low-Carbon Scenario is not technological—mass-transport technologies, non-motorized transport options, and demand management measures are all available and road-tested. The primary challenge is that Brazilian municipalities (more than 5,000) administer their transit and transport systems independently, making the harmonization of plans and the mobilization of resources difficult.

Measures to mitigate transport emissions include: (i) improving the efficiency and coverage of public transportation; (ii) promoting non-motorized transport (NMT) options; (iii) curtailing demand for urban transport, especially the use of private vehicles (World Bank 2003); and (iv) raising the emissions performance of vehicles, through fuel switching and greater efficiency.

Improving the efficiency and coverage of public transportation is a necessary input for avoiding growth of private motorized transport. Cost-effective public transport programs, like bus rapid transit (BRT), can improve local air quality as well as help mitigate climate change. Non-motorized transport options are an important component to urban transport systems. NMT is propoor, low-cost, and relative easy to implement in the short-term. Specific investments could include the construction of dedicated bicycle lanes and pedestrian paths, and traffic calming measures to improve safety for pedestrians and cyclists.

Reducing the overall demand for motorized transport, especially private vehicles, is a key component of climate change mitigation. Emerging cities or suburbs at the edge of urban areas in Brazil are growing in a sprawling manner, making the establishment of cost-effective and efficient public transportation systems difficult. Although the location of jobs and housing is the biggest determinant of daily travel distances and mode of transport, helping to change the pattern of private car usage could be supported through transport demand management measures such as road pricing, restrictive parking policies, and fuel and vehicle charges, in addition to improved land planning measures.

Finally, given that, under the best case scenarios with respect to the above factors, the light-duty vehicle will remain in circulation, efforts to promote fuel switching and greater efficiency are needed. Municipalities can have an important direct impact, as well as a demonstration effect for the public more broadly, by adopting energy efficient fleets.

Box 2: Curitiba's Bus Rapid Transit System

Curitiba’s Bus Rapid Transit (BRT) system is an international best practice in public transport efficiency. It successfully integrates many features of a heavy-rail subway system like vehicle movements that are unimpeded by traffic signals and congestion, fare collection prior to boarding, and quick passenger loading and unloading into an above ground bus system. As a result, approximately 70 percent of Curitiba’s commuters use the BRT to travel to work.

The bus system in Curitiba has three tiers. First, a large fleet of minibuses serve residential neighborhoods. These minibuses link passengers to conventional buses that operate on circumferential routes around the central city and on inter-district routes. Finally, these conventional buses link to a BRT network that operates on the five main arteries leading into the center of the city.

Buses in the BRT have dedicated lanes and stop at cylindrical, clear-walled tube stations with turnstiles, steps, and wheelchair lifts. Passengers pay their fares as they enter the stations, and wait for buses on raised platforms. The BRT buses have extra wide doors and ramps that extend out to the station platform when the doors open. The tube stations serve the dual purpose of providing shelter and facilitating the simultaneous loading and unloading of passengers in an efficient manner. Passengers pay a single fare for travel throughout the system.

An important aspect of Curitiba’s public transport system is that it is integrated with land use in the city master plan. The master plan limits central area growth, while encouraging commercial growth along the transport arteries radiating out from the city center. The city center was partly closed to vehicular traffic, and pedestrian streets were created. Linear development along the arteries reduced the traditional importance of the downtown area as the primary focus of day-to-day transport activity, thereby minimizing congestion and the typical morning and afternoon flows of traffic. Instead, rush hour in Curitiba has heavy commuter movements in both directions along the public transportation arteries.

The adoption of a transit-oriented development policy has also contributed to the success of the transit system. Land within two blocks of the transit arteries is zoned for high density development. Beyond the two blocks, zoned residential densities taper in proportion to their distance from the main thoroughfares. Urban planners in Curitiba discourage auto-oriented commercial developments and channel new retail growth to the transit corridors. In addition, limited public parking is available in the downtown area, and most employers offer transportation subsidies to their employees.

Source: UN Habitat (2005), “Curitiba’s Bus System is Model for Rapid Transit”

C2. Land Use and Urban Planning

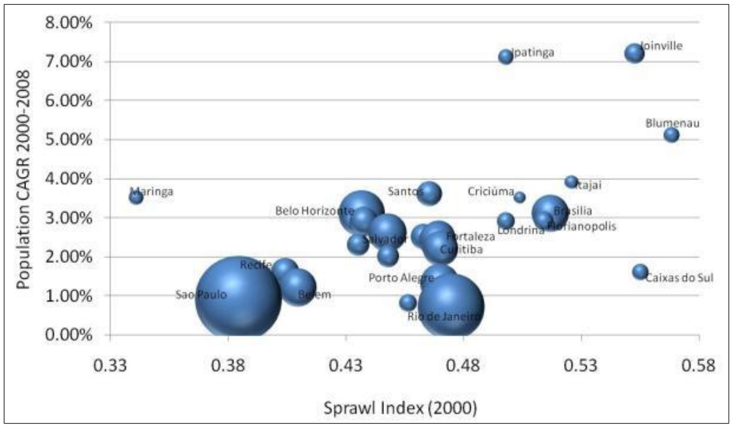
A critical determining factor for the level of vehicle travel is land use and urban form, as transport is a derived demand, and the location of housing, jobs, commerce and entertainment determines the need for travel (Giuliano 2004; Ewing & Cervero 2001). In fact, a study of the 27 state capitals in Brazil showed that the variables influencing average annual transportation energy use per capita was the urban density and the dimensions of the urban footprint (Rodrigues da Silva et al 2007).

Adequate planning and targeted urban design measures can thus reduce the demand for transport. Indeed, land use factors can be manipulated to influence how energy is distributed and used, thus resulting in direct impacts on emissions of GHG. Land use factors include (Ewing et al 2008):

i) *Density* - denser cities generate less GHG emissions because they require less and shorter vehicle travel and it is easier and more efficient to provide public transport services;
ii) *Land use diversity or mix* - the number of different uses in an area and how they are “balanced”;
iii) *Urban design* - street network design including block size, side walk, pedestrian crossings, street trees, and others; and
iv) *Destination accessibility* – the number of jobs or other attractions reachable within a given travel time; and distance to transit services.

The interactions between land use and transportation can be mutually reinforcing. For example, the lack of an effective public transport system would lead to higher private car dependency and thus more dispersed land development or sprawl. A Sprawl Index for Brazilian cities was developed in 2007 using IBGE 2000 census data (Ojima 2007). The index focused on 37 urban agglomerations and considered population density, fragmentation of the urban development, the orientation or linearity of the growth in the cities’ urban footprint, and the integration or amount of commuting within the agglomeration. Data showed that, independently of income, population size was not positively correlated with the degree of sprawl, and that the greater the sprawl, the larger the proportion of homes with at least one automobile.

Figure 13: Sprawl Index, Population Growth, and Size of Brazilian Urban Agglomerations



Source: Adapted from Ojima, R. and D. Hogan (2007)
Note: Higher score in the index implies greater degree of sprawl.

As shown in Figure 13, urban agglomerations that are experiencing the most population growth in Brazil had a higher degree of sprawl in 2000. It is clear that small- and medium-sized urban areas in Brazil have the opportunity to reconsider their current pattern of growth, and adopt measures to reduce sprawl as their population is growing. Once established, sprawling urban form makes it almost impossible to provide efficient public transport services for lack of necessary density. For rapidly growing cities in Brazil, therefore, mitigation investment is particularly important in the sense that once built, long-lived capital stock can lock-in emissions for decades or more.

Land use and urban planning measures can be conceived at four scales (Lincoln Institute for Land Policy 2009):

i) *At the building and parcel scale*, using building codes and zoning as planning tools For example, building codes could be revised to promote better energy efficiency (e.g. placement of windows to maximize daylight) and climate appropriate design to limit the need for energy-intensive air conditioning and heating;

ii) *At the neighborhood scale*, land use plans could reduce the need for vehicle trips by allowing a mix of uses within walking distance of residential developments. Moreover, permitting higher density residential developments strengthens the financial viability of retail uses and public transportation;

iii) *At the municipal level*, the city master plan, or *Plano Diretor* in Brazil, can promote more efficient use of land by promoting higher density development of land around existing or planned transit nodes, allowing mixed-use development, and supporting infill/brownfield development. Differentiated land-use taxes and development rights (CEPACs) could be used to incentivize higher density developments; and

iv) *At the metropolitan level*, planning and policy making for metropolitan areas needs strengthening in Brazil. Regional growth strategies and transportation plans are necessary to ensure the success and harmonization of actions taken by each municipality, especially considering that large urban areas are comprised of multiple municipal governments – São Paulo (39), Rio de Janeiro (16), Belo Horizonte (34), and Recife (14).

Box 3: Noroeste Green Neighborhood Development in Brasilia

Brasilia is accommodating its population growth by expanding the city's Pilot Plan. The Noroeste Green Neighborhood is planned to house 40,000 residents and provide opportunities for commercial space as well as several retail shopping districts. Noroeste's design is consistent with the garden city approach of the Pilot Plan, and it will zone activities into specialized sectors. However, the project's mixture of office, retail, and residential uses within close proximity is somewhat of a departure from the original plan. This is an effort to allow people to live near their workplaces and to reduce the long driving commutes for which Brasilia is known.

Noroeste is located between two environmental preservation zones – the Brasilia National Park and the Burle Marx Ecologic Park. The desire to minimize the impact on these parks, as well as a concern for global climate change, influenced the design of the neighborhood. Motorized traffic is routed away from the parks, native plants and natural soil coverage will be retained, and built areas are limited to a maximum of 38 percent of the terrain.

Water-saving taps and toilets will help reduce water consumption, while rainwater harvesting systems and drainage ponds can provide water for non-potable uses, such as garden watering. Solar energy and central heating facilities will reduce energy consumption, and architectural design standards will maximize natural ventilation and lighting.

Noroeste will encourage the adoption of greener transportation choices with dedicated lanes for public transit, a pedestrian-oriented urban design, and bicycle paths that will support up to 2,000 bikers per hour.

To receive construction licenses, developers in the Noroeste neighborhood are required to meet the requirements outlined in the "Green Manual" produced by TERRACAP, the land development agency of the government of Brasilia. The sustainability requirements are based on the Leadership in Energy and Environmental Design for Neighborhoods (LEED-ND) pilot criteria.

Source: Capitals Alliance (2008); "Green Manual" for Noroeste, TERRACAP (2009)

Box 4: São Paulo's Urban Operation

An "Urban Operation" is defined by the Brazilian City Statute (ratified in 2001) as an urban policy instrument that allows municipalities, through partnerships with the private sector, to implement structural changes in specific urban areas where transformations are wanted, and which call for a use and occupation distinct from the general rules that govern the city. The City Statute requires each municipal law that permits such an Operation to include: the basic program and plan for the area, the program of economic and social service for the population that is directly affected by the operation, and a neighborhood impact study.

An Urban Operation consists of identifying a perimeter within the city endowed with infrastructure, undergoing rapid changes and having considerable underutilized capacity. In this perimeter, zoning can be altered and the increment in value of land is shared between the government and the private sector. The share that corresponds to the public sector should be converted into previously determined interventions within a prescribed "menu," which should be carried out within the perimeter of the Operation. Each Urban Operation should be proposed by the executive and approved by the legislative branch of the municipality.

The São Paulo Municipality in Brazil has been successful in using Urban Operations to generate resources for the development of activity poles in its territory and to create high density, mixed-use area. The most successful example is that of the Faria Lima Urban Operation (OUCFL) which was proposed and approved in 1995 with the objective of obtaining resources to compensate for the expenditures necessary to extend Faria Lima Avenue, one of the city's major arteries. The expected cost of the necessary works and expropriations was estimated at approximately US$150 million. Technical studies indicated that it would be possible to take advantage of an additional potential 2,250,000 square meters beyond what was already permitted by the city's zoning legislation. These additional building rights were granted using the existing "Solo-Criado" (Selling of Building Rights) instrument.

Source: Instituto POLIS; World Bank (2006); Lincoln Institute (2006)

C.3 Energy Efficiency and Renewable Energy Opportunities

Improving energy efficiency in Brazilian cities is an important goal that would address multiple issues currently faced by municipalities, including: (i) reducing energy demand and delay the need for construction of new and expensive electricity generation capacity; (ii) increasing the country's competitiveness by lowering energy costs; and (iii) reducing fossil-fuel consumption and GHG emissions. Brazil is planning to expand its electricity supply through the construction of new thermal (gas) and hydro plants. This will require time for planning, licensing and construction. Therefore, reducing demand through energy efficiency measures may be more cost-effective and can be implemented faster than developing new electricity supply capacity.

Investing in energy efficiency measures can result in large savings in energy, resources, and carbon emissions. Globally, it is estimated that more than 20 percent of energy can be saved through energy efficiency measures, with rates of return ranging from 20 to 30 percent. In a municipal context, where there are many pressing needs and limited resources, savings from energy efficiency can free resources that can be used for the provision of other services (Johnson and Meyer 2008).

There is an important role for municipal involvement in energy efficiency and market transformation, especially if all municipal agencies adopt common practices, energy efficiency targets, and purchase specifications. The municipal sector can assert market leadership and contribute to local market transformation by influencing manufacturers and other buyers in the endorsement of energy efficient products and services. Retrofitting municipal infrastructure allows aggregation into large purchases that may bring more competitive prices. Large purchases may also result in service standardization (installation through ISO or other international standard requirement) or the introduction of new energy efficiency products, which can help lead a shift in the market.

Municipal actions in Brazilian cities to improve energy efficiency are focused primarily on efficient lighting and public buildings. Lighting contributes significantly to energy use and peak demand, and has therefore been sought jointly by various municipalities and energy distribution utilities under the federal mandated Energy Efficiency Program (EEP). Promotion of energy efficiency in buildings has also been actively sought by municipalities, through incentives or regulations, regulating energy use in residential, commercial, and industrial sectors, and educating city dwellers on energy efficient practices (Johnson *et. al.* 2008).

Building sector

In residential, commercial, and public buildings, the design, construction, and selection of appliances and mechanical systems can have a large impact on energy consumption. Passive design decisions are relevant as they may reduce energy consumption of buildings by up to 60 percent. As buildings need about three times more energy for cooling than for heating, most passive design measures focus on keeping the building cool and avoid the use of cooling systems. These measures include: (i) building orientation so as to maximize access to natural light and minimize direct sunlight exposure; (ii) window size and placement; (iii) sun shielding devices (such as awnings or the use of vertical vegetation design elements); (iv) improved insulation for the building envelope, including windows, walls and roofs; and (v) natural ventilation methods.

Technology-driven measures can also help reduce building's energy consumption. Some of these measures include: (i) use of high efficiency appliances; (ii) replacement of incandescent bulbs with compact fluorescent lamps (CFL); (iii) installation of non-electrical water heaters (solar water heating systems); and (iv) installation of efficient plumbing fixtures. Technology-driven measures can be integrated into municipal building codes, piloted in the public building stock or required under municipal programs, such as social housing. In many cities in Brazil, they have been promoted through the EEP.

Significant structural barriers inhibit implementation of energy saving measures in buildings, including: (i) the complexity and fragmentation in the building value chain, which discourages a comprehensive approach to building design and use; (ii) split incentives between building owners and users, which often mean that return on investment do not go to those making them; (iii) insufficient awareness of energy efficiency benefits among building professionals; and (iv) lack of regulatory and financial incentives to make capital investments (see Box 5).

As part of the C-40, both Rio de Janeiro and Sao Paulo have recognized the need to take action in the creation of policies to accelerate the uptake of energy efficiency and eco-friendly technologies by addressing the following obstacles:

i) *Procurement rules* - Tendering criteria for public procurement almost always require that the least-cost proposal be adopted. However, most energy efficiency investments have higher initial costs and thus do not qualify for public procurement. Procurement rules must be changed to require that bids be assessed on a life-cycle cost bases, best value for money, or the overall economic benefits.

ii) *Technical expertise* – The incorporation of energy efficient and eco-friendly technologies often requires specific, technical expertise that is often not found in the public sector. The use of specialized Electricity Service Companies (ESCOs) and performance-based contracts allows cities to implement projects without the use of a large amount of their own resources, as these services are paid with the savings revenues.

iii) *Annual budgets cycles* - Budgeting rules may restrict multi-year contracts and instead only allow annual cycles. Successfully completing one-year energy efficiency projects, has allowed municipalities to move into multi-year energy efficiency contracts.

Box 5: Energy Efficiency Initiatives in Low-Income Housing in Mexico

Housing has a key role in increased energy demand and the potential generation of a large share of GHGs in Mexico. According to the National Housing Commission (*Comision Nacional de Vivienda*, CONAVI), Mexico currently has 24.8 million houses, which are expected to increase by about 7 million new housing construction in the next decade, and to 45 million houses by 2030. CONAVI estimates that a poorly designed house in a warm climate has an additional consumption of 1,000kWh per year, which represents about 600kg of C02 emissions. Given that a large share of the population lives in warm areas, in a business as usual scenario it is expected that 2.1 million tons of CO2 emissions are currently produced by the housing sector only. The impact of the housing sector in Mexico's emission inventory will therefore increase substantially over time.

The government aims to integrate housing policies, programs and instruments which are capable of abatrement of direct and indirect GHG emissions, and at the same time take advantage of the international carbon market opportunities for the housing sector. In this context, in December 2009, CONAVI issued a sustainable housing program within a climate change context (*Programa Especifico para el Desarrollo Habitacional Sustentable ante el*

Cambio Climatico, PEDHSSC) that sets the ground for incorporating energy efficiency technologies and CDM financial benefits into housing. In addition, in October 2009 CONAVI also developed the technical criteria for the development of sustainable subsidized housing (*Caracteristicas Paquete Basico para Programa de Subsidios*), which are consistent with criteria used for the existing "green mortgages" (*hipoteca verde*).[8] This allows the housing subsidy program "*Esta es Mi Casa*" to be eligible for the "green mortgage" and thus receive better financing to overcome upfront costs of energy efficient technology. Similarly, CONAVI has developed a CDM methodology (AMS-II.AE)[9] for efficiency and renewable energy measures in new residential buildings, which are expected to provide further financial incentives for green housing.

In the mid-term, the Mexican government aims to move to a low carbon development in cities through the establishment of concrete regulatory and financial frameworks that lead to the reduction of residential energy demand. In this context, it is expected that by the end of 2012, CONAVI will have developped a green housing policy that includes the adoption of a green building code, the adoption, monitoring and verification of sustainable housing CDM methodology, and the consolidation of the use of the housing subsidies coupled with green mortgages. These measures are expected to lead to GHG emissions mitigation of 1.2 MT/Co2e/year.

Source: Comisión Nacional de Vivienda (CONAVI). 2009. *Programa Específico para el Desarrollo Habitacional Sustentable ante el Cambio Climático*; *Características Paquete Básico para Programa de Subsidios*, CONAVI, October 2009.

Box 6: Energy Efficiency Initiatives in Belo Horizonte

The Municipal Committee on Climate Change and Eco-efficiency (CMMCE) in Belo Horizonte, led by the Deputy Mayor, is promoting energy efficiency measures. The municipality is working in partnership with the state energy company and the federal government to improve public lighting. The goal is to switch all mercury-vapor lamps to sodium vapor lamps, resulting in an energy savings of 12,500 MW per year. The benefits of this program are improved luminosity (and safety), and the reduction in energy consumption and costs. The partnership will also pilot a program in six public schools to reduce energy consumption through educational campaigns.

In 2007, the municipality passed a law (9.415) that, among other things, provides incentives to private owners and construction companies to use solar thermal energy, natural gas, and liquefied petroleum gas for water heating.

Finally, the municipality has required that all vehicles used by the public administration operate using biofuels (i.e., animal and vegetable oils, and/or waste food fats) mixed with diesel, at ratio of 2 percent. While this may appear to be a low-impact measure, it is indicative of a trend in policy towards greater sustainability in transport.

Source: Presentation by CMMCE

Utilities

Efficiency in water utilities is an area where important energy reductions can be achieved. In Brazil, where many water supply and sanitation utilities are still under municipal jurisdiction[10], energy expenses in water utilities can account for a large percentage of municipal energy

[8] The *hipoteca verde* is a mortgage product developed by INFONAVIT in 2007 for the financing of eco-technologies (that seek energy efficiency in energy and water use, and solid waste management) by providing an additional 20 percent of capital on the basis that the savings from the eco-technologies will provide a better cash-flow for mortgage repayment.

[9] Approved by UNFCCC July 17, 2009.

[10] Federal Law 11445 of January 2007 allowas water supply and sanitation to be provided by municipalities, private concessions, or PPPs. In Brazil there are around 1,600 water utilities at the municipal level and there are around 70 municipalities that have awarded 20 to 25 years concessions contracts to private operators.

consumption. In fact, energy consumption (mainly electricity for pumping) in water supply and sanitation is typically the largest variable cost for utility companies after personnel, accounting for up to 50 percent of operating costs in water and 60 percent in wastewater treatment[11]. Savings from energy efficiency measures in water supply and sanitation utilities could lower operations costs of water utilities significantly and enable them to connect more users without having to provide additional water. It is estimated that many efficiency projects have financial rates of return and payback periods ranging from a couple of months to about four years.

Reductions in energy consumption can be achieved by improving the efficiency of pumping systems, and/or improving water losses. In Brazil, substantial energy is used for pumping water from rivers, cleaning and filtering the water, and pumping water to reservoirs and throughout the network. The cleaning and filtering processes are more energy intensive during rainy seasons, when river water contains more sediment and is thus more difficult to clean. In the case of wastewater treatment, energy consumption is even greater than that used for water treatment and supply.

Implementation of water-related energy efficiency measures in the utility sector faces similar obstacles as in the building sector. There is an overall lack of awareness of potential energy efficiency savings and benefits, as well as of funding programs such as the PROCEEL SANEAR, which are targeted to the water supply and sanitation sector, or the Program for Modernization of the Sanitation Sector (PMSS). Procurement and budgeting issues similar to those in the building sector exist, such as bidding the lowest cost rather than lower life-cycle cost, or the limited duration of contracts, which may restrict multi-year performance-based contracts. An example of how municipal utilities have been able to overcome similar barriers, is the water and sanitation utility of the city of Campinas, is included in Box 7.

Box 7: Energy Management in the Provision of Water Services in Campinas, Brazil

Between 2000 and 2008, the City of Campinas, located in the state of Sao Paulo, developed a successful energy management program within its municipal water and sanitation utility, SANASA (*Sociedade de Abastecimento de Agua e Saneamento S.A.*). The utility was able to lower its operational costs and through the savings, increase tap water connections by 22 percent, in particular targeting the urban poor living in slums (favelas), without additional energy requirements.

SANASA undertook estimated R $1.8 million energy efficiency investments, achieving over 30 percent reduction in electricity consumption at its *Capivari* plant (1.4 GWh/year) and nearly 20 percent reduction in contracted demand. The energy efficiency activities included: (i) reduction of non-revenue water (NRW) through, among other, leakage control and management; (ii) optimization of network operation, such as changing the tariff schedule by switching to night shifts, using reservoirs, and modernization of management equipment (e.g. SCADA equipment); and (iii) energy efficiency measures sich as replacing energy inefficient equipment (e.g. replacement of standard motors with high efficiency ones or electricity meters for energy management)

According to SANASA's data, between 2003 and 2008, the company achieved electricity savings equivalent to about R$410,000/year (about US$230,000/year). The payback period for the investment was less than four years. Over 25percent of the savings were attributed to a reduction in electricity intensity, while the rest can be attributed to a reduction of NRW. Thus the utility was able to serve more people from the same amount of treated water.

[11] *Ibid*.

Source: Energy Efficiency Cities Initiative, ESMAP. 2011. "Campinas, Brazil – Energy Management in the Provision of Water Services", in Good Practice in Energy Efficiency.

Renewable Energy Opportunities

While renewable energy generation is widely used in Brazil (through primarily hydro and ethanol sources), it does not typically fall within the scope of the municipal administration. The two renewable energy opportunities that do fall within the purview of the municipality are waste energy (described in the next sub-section) and solar energy.

Widespread use of solar water heating has the potential to reduce electricity consumption and increase the quality of life for low-income residents. In Brazil, the use of electric showers for water heating is widespread. According to the National Program for Electricity Conservation (PROCEL), there are more than 30 million electric showers installed in Brazil. In addition to consuming about 6 percent of all electricity produced in the country, these showers account for approximately 18 percent of the peak demand of the national electric system. Solar water heating in social housing could have a large impact on low-income households because electric showers can account for as much as 50 percent of the total electricity bill. For families who earn between 1 to 2 minimum wages, the savings can reach 20 percent of the monthly budget (Brazilian Solar Cities Initiative).

Box 8: Solar Water Heating in the Minha Casa, Minha Vida Program

In early 2009, the Brazilian government launched an economic stimulus plan called *Minha Casa, Minha Vida* (MCMV) that aims to build one million new affordable homes by 2012. A unique feature of the program is that houses receiving public subsidy must fulfill a number of environmental requirements, such as installing solar water heating, having a collection system for the reuse of rain water, and building with certified wood. The program provides a subsidy for solar water heaters of R$2,500 for each dwelling unit in high-rise multifamily developments and R$1,800 for each housing unit in low-rise developments.

The goal for the first phase of MCMV is to provide solar water heaters to 40,000 units in the low-income segment. This corresponds to a newly installed collector area of 80,000 square meters. Once the implementation of the program is completed, the government-owned bank, Caixa Economica Federal (CAIXA) will evaluate whether to make solar water heating a compulsory item in housing developments that use its financing sources. In June 2009, CAIXA created the *Selo Casa Azul* (Blue House Label), through which housing projects can be classified and labeled according to 53 criteria in six categories, including: Urban Quality, Project Design and Comfort, Energy Efficiency, Material Resource Conservation, Water Management, and Social Practices.

The states of Minas Gerais and São Paulo are regarded as the pioneers in the installation of solar water heaters in social housing, having adopted similar policies since 2008, before the government announced MCMV. As a result, by the end of 2008 over 40,000 low-income families had taken advantage of the benefits provided by solar water heaters.

Source: Global Solar Thermal Energy Council (2009); Brazilian Solar Cities Initiative

Box 9: Solar Energy Bill in the City of São Paulo

In 2007, the City of São Paulo passed a solar energy bill, now used as model by more than 50 other Brazilian cities. The bill mandates, among other things, buildings with more than 3 bathrooms (homes, apartments, service or industrial buildings) to use passive solar heating systems. Expected impacts are 3,400 tons CO2 reduction and 8.7

million kWh of energy saved per year.

Source: Brazilian Solar Cities Initiative; OECD 2009

C.4 Waste Management

In Brazil, landfills, wastewater management, and recycling are the responsibility of municipalities. Many cities are currently looking for opportunities to recycle and to safely process and dispose of waste with a minimum impact on the environment. There are opportunities to reduce GHG emissions in the solid waste sector throughout the entire supply stream (International Solid Waste Association 2009):

i) *Prevention* - Solid waste prevention programs can have a significant impact on GHG emissions reductions and municipal systems. The prime example of waste prevention is reducing unnecessary packaging from manufactured products. Actions that can be taken at the municipal level could include, for example, integrating waste prevention measures into public procurement (e.g. require vendors to eliminate, reduce, or reuse packaging), instituting resource efficient office practices (e.g. double-sided printing), instituting a tax on plastic bags to promote the use of reusable shopping bags, and creating regulations on construction waste in public projects;

ii) *Recycling* - Recycling reduces GHG emissions in two ways – it reduces the amount of waste that must be disposed, and it provides substitutes for raw materials in product manufacturing. Recycling programs in Brazilian cities have also presented employment opportunities for the poor, especially waste pickers who are economically displaced by the development of sanitary landfills;

iii) *Collection* - The waste collection process also presents an opportunity to reduce emissions because it involves the use of vehicles and fuel consumption. Specific actions that municipalities could take to reduce collection-related GHG emissions include improving the efficiency of collections operations, requiring the use of biofuels in waste collection trucks, and minimizing transport distances between collections sites and the final disposal destination.

iv) *Disposal* - The final disposal of solid waste in Brazil is usually a landfill. Several cities in Brazil are taking advantage of the fact that waste is a significant renewable energy source that can be exploited through the use of landfill gas. The Clean Development Mechanism (CDM) was established under the Kyoto Protocol to attract presents a major opportunity for municipalities in Brazil to receive financing support for constructing new landfills and safely closing older ones.

Box 10: Landfill Gas to Energy Projects in São Paulo

The Bandeirantes and São Joao landfills were disabled in 2007 and 2009, respectively, and thermoelectric power plants were installed to burn GHG produced by the decaying waste. It is estimated that 11 million tons of CO2 eq will be prevented from being thrown in the atmosphere by 2012, generating tradable Certificates of Emissions Reduction (CERs).

Through a public bidding process, the City of São Paulo gave a concession to the holding company Biogas Co. to install thermoelectric power plants to burn biogases emitted by decaying waste from the Bandeirantes and São Joao landfills in order to produce clean energy and prevent GHG to be vented into the atmosphere. By capturing and burning the methane gas, the landfills generate the equivalent to 7 percent of the electricity consumed in the city. Each facility now generates more than 175,000 MW/h, enough to supply power to 600,000 residents for 10 years.

Both landfills with approved as Clean Development Mechanism (CDM) projects and issued tradable CERs. According to the concession agreement, 100 percent of the energy and 50 percent of the carbon credits produced by the landfills belong to Biogas Co. to be traded in the market, while the City of São Paulo has the right to sell the other half of carbon credits at public auctions.

In September 2007, the City of São Paulo held the first CERs Auction, raising about US$18 million (US$ 22 per credit) from the Bandeirantes Landfill between December 2003 and December 2006. A second Auction, held in September 2008, offered CERs from both landfills and collected more than US$19 million (US$ 28 per credit).

In addition to the mitigation of greenhouse gases, the landfill gas to energy projects in São Paulo also aim to revitalize the surrounding communities. In 2009, two public plazas, Cuitegi and Mogeiro, near Bandeirantes landfill were inaugurated. Cuitegi Plaza has 2,300m² of leisure area, playgrounds, and seating. Minor road works were also done to facilitate mobility within the local community. The Mogeiro Plaza has 6,897m² of leisure area and offers a walking path, exercise equipment, playground, seating and community space.

Source: C40 Case Study

C.5 Urban Forestry

Urban forestry and green spaces can contribute to mitigating impacts of climate change in two ways: (i) urban trees act as a carbon sinks by removing carbon from the atmosphere and storing it as cellulose in their trunks, branches, leaves and roots, while releasing oxygen back into the air; and (ii) trees help to reduce the need for air conditioning by shading homes and offices (U.S. Forest Service). Urban forestry has additional co-benefits that improve the quality of life in urban centers. For example, street trees can reduce air pollution by trapping and holding particulate pollutants (e.g. dust, ash, pollen and smoke) that can damage human lungs. They can also absorb and block noise from the urban environment.

In 2010, the Secretary of Environment in Rio de Janeiro launched one of the largest reforestation projects in the history of the city in the catchment area of the Jacarepaguá – *Rio Capital Verde*. Approximately 158 hectares of native species from the Mata Atlântica will be planted, an area about 200 times the size of the Maracanã stadium. This is the first step in the implementation of Rio Capital Verde, which aims to reforest and rehabilitate 2,800 hectares of land as a means of reducing the municipality's GHG emissions by about 8 percent by 2012.

Table 6: Summary of Potential Local Government Mitigation Actions by Sector

Sector	Potential Mitigation	Possible Co-benefits	Public Cost	Key Issues
Transport	Improve the efficiency and coverage of public transportation	- Reduced traffic congestion - Improved accessibility	High	Long-term planning
	Implement traffic calming measures and dedicated bicycle	- Improved air quality - Improved safety - Improved access for the poor	Medium	Insertion into transportation master plans
	Implement workplace fees, road-user charging, and restrictive parking regulations	- Reduced traffic congestion	Low	Public resistance
	Raise the emission	- Improved air quality	Medium/	Could require

Sector	Potential Mitigation	Possible Co-benefits	Public Cost	Key Issues
	performance of vehicles through fuel switching and greater efficiency (focus on municipal fleet)		High	negotiation with private service providers; technical feasibility
Land use and urban planning	Develop municipal and metropolitan growth and transport plans that focus on transit-oriented development	- Improved access to jobs for low-income households	Medium	Requires strong leadership from state government and institutional coordination
	Promote the use of differentiated land-use taxes to catalyze infill development of underutilized land in the urban core	- Promotes efficient use of land	Low	Implementation challenges; public resistance
	Allow and promote mixed-use neighborhoods	- Less reliance on transport to access services	Low	Coordination with transport investments
	Increase residential density	- Lowers overall cost of housing	Low	Some Brazilian cities are already quite dense
	Promote infill/ brownfield developments	- Reusing existing infrastructure	Low	Land acquisition and assembly constraints
	Building codes to promote better energy efficiency and climate appropriate design	- Lowers energy costs - Reduces need to air conditioning and heating	Low	Enforceability in irregular settlement
Energy	Promote high energy efficiency standards in new public buildings	- Lower energy bills for government	Medium	Scarce resources
	Provide guidance for architects and developers on energy efficiency	- Possible innovation in geographically specific construction methods/materials	Low	Partnership with utilities, academia and trade associations
	Promote campaigns for energy efficiency	- Greater awareness of environmental issues	Medium	Partnership with utilities
	Provide grants for energy efficiency measures	- Lower energy bill for poor if targeted at low-income housing	Medium	Difficult to monitor; scarcity of resources
	Solar powered public lighting	- Lower energy bill for government	Medium	May require more maintenance
	Solar water heating in social housing programs	- Lower energy bills for low income households	Low	May require more maintenance
Waste management	Waste prevention programs to reduce product packaging and the use of plastic bags	- Reduce need for landfills - Conservation of natural resources	Low	Requires collaboration of private sector
	Campaigns and programs for reducing, reusing, recycling	- Greater awareness of environmental issues	Medium	Scarce public resources

Sector	Potential Mitigation	Possible Co-benefits	Public Cost	Key Issues
	waste			
	Require recycling and reuse within the municipal government	- Public sector savings	Low	Require strong political will
	Public procurement of recycled goods	- Build demand for recycled products	Low/ medium	May require flexibility in procurement regulations
	Provision of sites for recycling, composting and 'waste to energy' facilities	- Conservation of natural resources - Possible source of revenue for the municipality	Depends on ownership/ management structure	Land scarcity; Public-private partnerships
	Promote landfill gas capture	- Possible source of revenue for the municipality	Depends on ownership/ management structure	Public-private partnerships
Urban forestry	Street tree planting programs	- Increase comfort for pedestrians - Improved air quality	Medium	Require public right-of-way
	Tree/bush planting programs for high incline terrain	- Reduced risk of landslides	Medium	Require public right-of-way

Source: Authors with inputs from PLANYC, Corfee-Morlot, et al. (2009), Kamal-Chaoui and Roberts (2009).

C. ADAPTATION TO CLIMATE CHANGE

The IPCC defines adaptation as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects". The lack of city climate change vulnerability assessments in Brazil, limits the depth of recommendations for adaptation that can be offered. However, based on the CPTEC Atlas of Future Climate Scenarios for Brazil, with an overlay of major cities, a set of broad city impact typologies was developed (summarized in Table 7).

D.1 Flooding due to Increased Rainfall

Adaptation to flooding can be divided into the following four general actions:

i) *Controlling rainwater on site* - The more rainwater that can be controlled onsite, the less demand on the public stormwater drainage system and risk of flooding due to exceeded capacity. There are several interventions that can be incorporated into site and building design. For example, a roof rainwater harvesting system can prevent rainwater from reaching the ground by collecting it in containers and either allowing the water to evaporate or using it for non-potable household uses. Alternatively, green roofs can absorb all or part of the rainwater load reaching the roof of a house or building. Rainwater that is channeled off of structures or outside their perimeter could be captured in small stormwater retention ponds. Another on-site measure could be the installation of pervious pavement. This type of pavement allows rainwater to seep back into the ground rather than cascading into the public stormwater drainage system or perimeter roadways;

ii) *Improving the public stormwater drainage system* - Significantly increase rainfall could cause public stormwater drainage systems to exceed capacity. As discussed in the case of Rio de Janeiro, increased flow rates could compromise the pumping capacity of the system and cause blockages and overflows. Not only could this paralyze the system, but infiltration of stormwater into a segregated or non-segregated sewage system could become a public health crisis due to sewage overflowing into residences and other buildings and escape of untreated effluent into local water bodies. Adaptation measures to avoid this situation would include increasing the pumping capacity of the system, installing or expanding flood channels, removing obstructions for waterways and riverbeds, and ensuring that discharge channels are of adequate height from water bodies that could also rise due to increased rainfall;

iii) *Land use changes* - Increased rainfall could cause flooding in low-lying areas and landslide risk on steep slopes. Therefore, changes to permitted land uses (or enforcement of existing zoning) to prevent the development of buildings in at-risk areas are key adaptation measures to avoid loss of lives and assets. In addition, increasing park and other vegetation land uses, like reforesting hillsides and preserving natural retention ponds, can facilitate the reduction of rainwater run-off. Several municipalities have implemented an Ecological Property Tax (*IPTU Ecológico*). For example, in the city of Ubá in Minas Gerais homeowners can receive a discount of up to 50 percent on their property tax in exchange for planting native species on their land; and

iv) *Installation of early warning systems* – These systems are designed to inform residents of flood and landslide risks such that they can reduce loss of lives and assets. For example, the City of Rio de Janeiro Alert System for Intense Rains and Landslide was create in 1996 with the objective of providing alert bulletins to the population through television and radio during storms that could cause flooding or geotechnical risks. The system uses real time information collected from 32 measuring stations in the municipality, meteorological radar images, lightning detectors, climate data from two meteorological stations, satellite imaging, and internet information. Data are analyzed in a centralized computer center by geotechnical and meteorological experts 24 hours a day (Municipality of Rio de Janeiro).

Box 11: Rio de Janeiro's Community Reforestation Project

The City of Rio de Janeiro’s Municipal Secretariat of Social Development created the Community Reforestation Project in 1986. The project, also referred to as the Paid Self-Help Reforestation Project or the Mutirão Project, aims to control erosion and reduce the associated landslide and flood risks through the reforestation of erosion-prone areas of the city, particularly where *favelas* (squatter settlements) are located. Furthermore, the project aims to employ local residents and reintroduce native tree species to the hillsides. The individual reforestation projects are carried out on relatively small areas of land, ranging from plots of one hectare to larger parcels of 18 to 30 hectares. In each area to be reforested, the project is implemented over a three to four year period.

Source: ICLEI Case Study

Box 52: Linear Parks in São Paulo and Curitiba

The City of São Paulo currently has more than 20 linear parks under construction, aiming at combating floods recovering areas under environmental protection, and promoting leisure activities for the population who live in the surrounding areas. The *Varzea do Tiete* Linear Park is the most important climate change adaptation action in São Paulo. It aims at expanding green areas, increasing the soil absorbing capacity to prevent floods, installing proper sanitation, promoting residential programs to move the population living in high risk areas to safer neighborhoods and creating leisure, sports and cultural areas. The park is being built with the support of the state government, as an environmental offset to the reconstruction of Marginal Tiete, an important highway along the Tiete River that crosses the urban area.

Curitiba has about 50 square meters of parkland per person, most of which were created in the last 30 years. This is more parkland per person than Amsterdam (45), Rome (45), New York (29), and London (27). Roughly 21 million square meters are linear parks along rivers and streams that act as buffers between flood-prone rivers and the city. Legislation set aside certain low-lying areas and river basins as special protection and management areas. The city also purchased land at a number of critical sites around the city. Engineers built small damns and created new lakes that act as holding basins when flooding occurs. In effect, these green spaces are giant stormwater facilities, with the lakes as central features. If rains are heavy, the lake rises over the surrounding parks.

Source: PMSP website; The Trust for Public Land

D.2 Sea Level Rise

Measures for adapting to sea level rise that can be implemented at the municipal level can be broadly divided into the following three categories - engineering measures, strengthening of natural barriers and revisions or enforcement of development regulations.

i) *Engineering measures* – These measures would include, for example, installation or strengthening of levee system, the construction of dikes to protect road infrastructure, and upgrading or moving public infrastructure (e.g. sewage, stormwater drainage, etc.). Levees and dikes are constructed to block rising waters from entering urban areas, and the risk of harming people or assets, by utilizing man-made barriers. The goal is to allow existing land use activities to continue despite rising water levels. If it is determined that it is not possible to block the entry of water into public infrastructure, like the sewage or stormwater drainage system, then an engineering solution to move or re-route the system would be necessary;

ii) *Strengthening of natural barriers* - Reinforcement of natural barriers could also protect people and assets from rising sea levels. This could include the reinforcement of natural breakwaters, beach nourishment to maintain the shoreline, or wetlands rehabilitation. A positive aspect of these measures is that they can be implemented incrementally over time as the sea level rises, thereby providing more flexibility to the local government. However, this type of protection mechanism requires knowledge and understanding of physical coastal processes in the region (McLean 2001).

iii) *Revisions or enforcement of development regulations* - Local land use and building codes may be revised to include anticipated sea level rise; enforcement could be strengthened if the existing regulations already provide for this type of vulnerability of coastal or low-lying zones. A top priority is the relocation of at-risk dwellings and facilities that have been built in vulnerable areas. An example would be the informal settlements built along the edge of the Beberibe River in Recife. A regulatory measure would be to implement a sea level rise review prior to making public investments in infrastructure as a means of avoiding future vulnerabilities.

D.3 Surface Temperature

There are two general approaches to reducing the heat island effect:

i) *Planting and greening programs* - Planting programs can help reduce urban temperatures as trees, shrubs, and other plants shade buildings and sidewalks, capture solar radiation, and cool the air through evapotranspiration. Indeed, trees and vegetation provide multiple co-benefits – they cool the air, clean air and water, provide flood protection, hold soil in place, and remove pollutants.

ii) *Materials selection* - Much of the developed areas in Brazilian cities are paved with surfaces, like asphalt and concrete, which tend to absorb solar radiation, adding to problems associated with the urban heat island effect. Paved surfaces include roads, parking lots, driveways, and sidewalks. These surfaces are often darker in color and impervious to rainfall. *Cool paving* refers to asphalts and concrete that is produced to have higher reflectance, to reflect solar radiation, and/or higher porosity to retain moisture from rainfall, thus cooling through evaporation.

   The materials used on roofs in urban areas also affect the temperature within the building. There are two basic roofing technologies that are available to achieve a *cool roof* – covering the surface with a reflective roofing product or installing a green roof. The color of a roofing surface has a profound effect on the temperature it will reach while exposed to the sun. A *cool* roofing material should reflect solar radiation, absorbing very little energy, while it readily emits any heat energy that is absorbed. The result is a cooler roof surface that transmits less energy to the structure beneath it. Green roofs incorporate vegetation into the construction of the surface of the roof structure, and promote cooler temperatures through shading and evapotranspiration (Cool Houston! 2004).

D.4 Drought

The primary adaptation measures for cities experiencing droughts include:

i) *Reduction of water usage* - Efforts to reduce the use of water include, for example, promoting the installation of low-flow water fixtures in bathrooms and kitchens, limiting the use of drinking water for gardening and cleaning, increasing water tariffs, and launching public awareness campaigns.

ii) *Protecting existing water resources* - In many Brazilian cities, there is a need to protect water resources from encroachment by informal settlements. This includes resettling households that have constructed their homes in proximity to tributaries.

iii) *"Creating" new supply* - This includes, for example, re-using grey water for irrigation and within buildings for toilet water, the installation of rainwater collection tanks, and the development of desalination plants in coastal cities. While desalination would have the benefit of converting salt water into drinking water, the process is energy intensive.

Table 7: Summary of Types of Climate Impacts in Brazil and Adaptation Actions

Climate Impact	Impacted Urban Areas	Adaptation Measures	Social Impacts on Vulnerable Populations	Policy Considerations
Flooding – increased rainfall	Southeastern Brazil, possibly including: - São Paulo - Curitiba - Florianopolis - Porto Alegre - Rio de Janeiro	Controlling rainwater onsite: - Increase pervious paving - Installation of green roofs - Rainwater harvesting - Stormwater retention ponds Improving the public stormwater drainage system: - Installation or expansion of flood channels - Strengthen pumping station capacity - Widening of existing waterways and river beds - Maintaining and freeing river beds of obstructions - Ensuring that discharge channels are of adequate height from recipient water bodies Change to land use: - Relocation of at risk dwellings - Installation of additional water retention ponds - Building construction modifications to reduce waste water and stormwater runoff - Reforestation of hillsides Warning system: - Installation of early warning systems	- Informal settlements at great risk to landslides and water filtration	- Disaster risk management capacity - Building code modifications
Sea level rise	All low-laying coastal cities, especially those with a concentrated urban population, possibly including: - Rio de Janeiro - Recife - Porto Alegre - Santos - São Luis - Fortaleza	Engineering Measures: - Construction of dikes to protect road infrastructure - Install or strengthen levy systems Natural Barriers: - Reinforcement of natural and artificial breakwaters - Beach nourishment - Wetlands rehabilitation Regulations: - Relocation of at risk dwellings and facilities - Integration of flood areas into infrastructure planning - Building code modifications – elevated foundations	- Low income populations who inhabit stilt housing or riverbeds are at heightened risk	- Disaster risk management capacity - Early warning systems - Modification of land use plans
Surface temperature	Urban areas with predicted temperature increase over 4 degrees Celsius, such as:	Materials/construction: - Improved building design (ventilation, window placement, materials, etc.) for hotter temperatures	- Low-income population more vulnerable due to limited access to air	- Heatwave early warning and response plans - Education: messages

Climate Impact	Impacted Urban Areas	Adaptation Measures	Social Impacts on Vulnerable Populations	Policy Considerations
	- Manaus - Teresina - Palmas - Porto Velho Highly urbanized areas vulnerable to additional heat island effect, such as: - Rio de Janeiro - São Paulo - Salvador	- Installation of "cool" roofs - Installation of "cool" pavement - Reduction in asphalted areas <u>Vegetation</u>: - Street tree planting - Increased native vegetation areas	conditioning and physical labor - Elderly have reduced ability to thermoregulate	detailing ways to lower body temperature to prevent the onset of heat stress
Drought	Cities in the Northeast Drought Polygon, such as: - Teresina - Fortaleza - Natal	<u>Reduce consumption</u>: - Installation of low-flow fixtures - Grey water re-use <u>Protect water supply</u>: - Relocation of households from at risk water resources <u>Create "new" supply</u>: - Installation of desalination plants (coastal cities) - Rain water collection tanks		- Differentiated water pricing - Water conservation educational campaigns

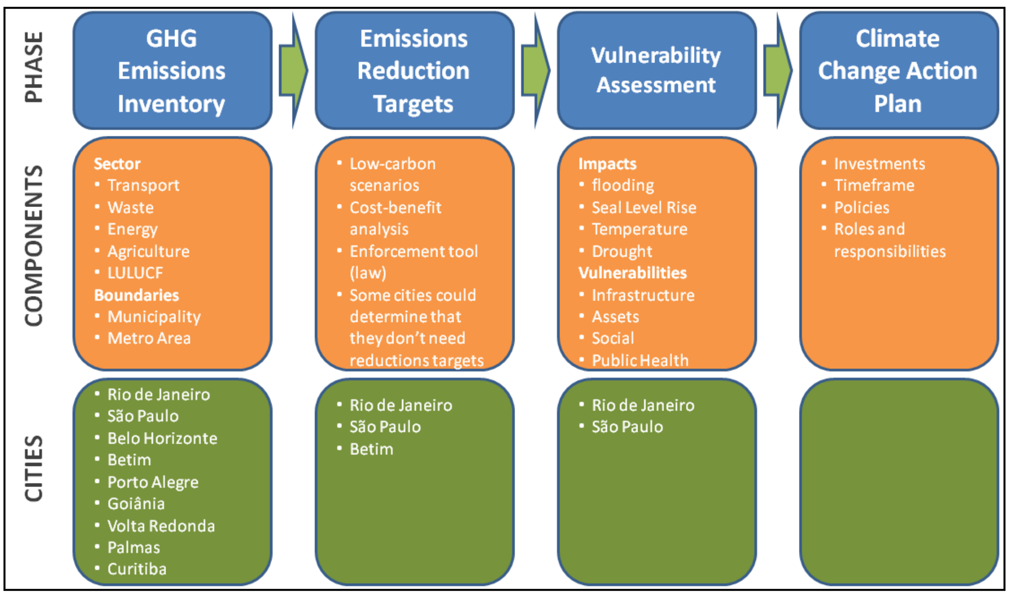
D. CITYWIDE RESPONSES TO CLIMATE CHANGE IN BRAZIL

E.1 Framework for Climate Change Action

According to a survey of over 5,000 municipalities in Brazil conducted by the National Confederation of Municipalities (CNM) in 2009, 197 (3.9 percent) said they have a bill or an act creating municipal policies for climate change. However, only 112 (2 percent) municipalities have created laws or regulations that could be put into practice. Municipalities with climate change laws or regulations were also asked if they had any specific goal for the reduction of greenhouse gases. Of the 112 cities, 60 claimed to have a specific GHG mitigation goal.

The general framework to respond to climate change that is emerging for Brazilian cities includes four phases: (1) Preparing a GHG emissions inventory; (2) Establishing an emissions reduction target; (3) Preparing a vulnerability assessment; and (4) Developing a climate change action plan (see Figure 14).

Figure 14: Emerging Framework for Climate Change Action in Brazilian Cities



While multiple cities in Brazil have completed GHG inventories, only a few have set actual emissions reduction targets. Rio de Janeiro was the first Brazilian city to complete a GHG inventory, which was updated in 2010. Rio has set (by Law ambitious emissions reduction targets, including reductions of 8 percent, 16 percent and 20 percent of GHG emissions relative to 2005 levels, by 2012, 2016 and 2020, respectively. In 2002, the municipality of São Paulo published its Agenda 21, which was greatly focused on climate change. In 2003, the municipality joined ICLEI's Cities for Climate Protection (CCP), a campaign to promote local climate change policymaking. Through this program, São Paulo completed an inventory of its emissions. In 2009, the municipality ratified a law that establishes a target of 30 percent reduction in emissions over the subsequent four years. However, comprehensive climate change action plans or strategies have not yet been developed in either city.

The current challenge is to help Brazilian cities to enter the framework or to move to the next respective stage. It is important to note, however, that climate change related actions are not limited to the cities listed in the framework above. Many cities and states have developed plans and taken measures in sectors and activities that fall within the broad definition of climate change. These include, for example, targeted disaster risk management plans and investments, energy efficiency policies, water use management initiatives, etc. The distinction between these actions and the planning outlined above is one of scale (citywide or metropolitan) and integration (mitigation and adaptation). Curitiba is an example of a Brazilian city that has taken a citywide approach to sustainability. While it does not have a climate change strategy per se, many aspects of its current sustainable city agenda overlap with the climate change agenda.

A review of climate change action plans from across the globe suggests a number of commonalities. First, an inter-disciplinary committee of stakeholders is formed to guide the preparation process. Second, the plan is usually the culmination of a series of studies, sectoral plans, or actions by the government. Third, the plans serve as both a guide for the local government and a means of engaging broad support from stakeholder and constituents. In some cases, the climate action plan is a stand-alone document; in others is part of a comprehensive city strategy or growth plan.

With regards to the contents of climate change action plans, there are also some best practices from international experience. The main components of action plans include: (i) a description of the current level of emissions and areas of climate vulnerability; (ii) measurable targets and actions with a set timeframe and assignment of responsibilities; (iii) an estimated cost for each action; and (iv) identification of co-benefits (Box 13).

Box 13: Mexico City Climate Action Program

The Mexico City Climate Action Program 2008-2012 (PACCM) was launched in 2007 with the support of the Word Bank. It uses as a starting point and foundation the General Program for Development of Mexico City 2007-2012 and the Environmental Agenda of Mexico City 2007-2012.

In September 2007, the first PACCM executive meeting was held, during which government officials, civic associations, academics, businesses, and consultants had a free exchange of views on necessary actions to reduce GHG emissions in the areas of energy, water, transport, and waste. This meeting also identified adaptation actions, as well as education and communication needs. The activities took place over three days in six working groups attended.

Between September and December of 2007, analysis was done on potential for GHG emissions reductions and climate change adaptation actions. The purpose of the analysis was to assess the costs, technical feasibility, environmental benefits, social and economic impacts, and to identify potential barriers to implementation. These findings were presented at the second PACCM executive meeting in December 2007.

In March 2008, two consultation processes were conducted. The first was an internal review by local government agencies to obtain their views on the proposed actions. The second process was a public consultation open to the general public.

The resulting PACCM has two main objectives: (i) to reduce carbon dioxide (CO2) equivalent emissions by seven million tons during the 2008-2012 period; and (ii) to initiate an integrated program for adaptation to climate change and have it fully functional by 2012.

To accomplish these objectives, the PACCM contemplates actions in five key areas: energy, transportation, water, waste, and adaptation. At the same time, communications and environmental education will occur along two lines of action: mitigation and adaptation. A total of 26 greenhouse gas mitigation actions are proposed. If implemented, they will reduce emissions by 4.4 million tons a year, which represents 12 percent of the annual GHG emissions in Mexico City. The budget for the implementation of these actions is $56,152 million pesos (US$ 4.4 billion).

Examples of the mitigation actions included in the Program are described in the table below:

Action	CO_2 equiv. Emission Reductions (tons /year)	Investment or Budget (millions of Pesos)
Energy: Energy efficiency program in Mexico City government	107,391	415
Water: Infrastructure improvement through leak suppression and pipe rehabilitation and sectioning at water distribution facilities	45,500	2,970
Transportation: Replacement of medium capacity vehicle service concession with new high capacity vehicles	200,000	2,000
Waste: Capture and exploitation of biogas from the Bordo Poniente Stage 4 landfill	1,400,000	3,880

A program of climate change adaptation measures has been integrated into the PACCM and consists of a set of both short and long range actions to reduce potential climate change risks to the Mexico City population and economy. The primary lines of adaptation actions are: the identification of primary threats and a vulnerability analysis; the integration of an adaptation perspective in order to build on existing Mexico City government plans; and, lastly, the implementation of adaptation actions. These three lines of action include twelve climate change adaptation actions requiring an investment of $2,999 million pesos during the 2008-2012 period.

The adaptation actions are organized into two groups – the first integrates components associated with an early alert system and the second includes components related to a medium term response.

Examples of the adaptation actions included in the Program are described in the table below:

Action	Investment or Budget (millions of Pesos)
Early Warning Systems:	
Metropolitan Hydro-meteorological Monitoring and Forecasting System for the Valley of Mexico: Early Warning System	111
Micro-basin management 1: Urban Ravines	694
Remote detection and monitoring of forest fires with cameras	279
Medium Term Response:	
Alternative reforestation with species resilient to climate change	103
Soil and water conservation projects	450
Rooftop naturation	202

Issues of education and communications were incorporated into the PACCM in an effort to reinforce climate change adaptation actions and GHG emission mitigation measures. In order to influence behavior patterns, habits, and attitudes of the Mexico City population regarding the issue of climate change, it was determined that this kind of program is necessary. The proposed communications actions require a total budget of $404 million pesos for the 2008-2012 period.

Source: Mexico City Climate Action Program 2008-2012

E.2 Co-benefits of Climate Change Actions and Investments

An essential component of the green, sustainable city discussion is one of motivation. What motivates cities to undertake a sustainable growth path, and within the specific scope of this Policy Note, how can cities be motivated to adopt policies against climate change? In the current context of limited resources and numerous competing priorities, in order for cities to take action against climate change, the evidence must be compelling that, in fact, addressing climate change brings direct benefits to their residents. This Policy Note has presented data showing that climate change impacts on Brazilian cities will likely be significant. Therefore, putting in place adaptation measures to protect local residents from future impacts presents obvious long-term benefits for cities. Beyond that, a series of opportunities has been discussed in earlier sections, introduced as mitigation approaches aimed at reducing global GHG emissions. However, it has been shown that these actions have distinct benefits to local residents, from improving transit systems and reducing congestion to reducing energy costs, improving urban waste management and reducing pollution. Therefore, in broad terms, adaptation and mitigation policies translate into actions that improve the quality of life and that reduce future environmental-based risk of city residents.

The discussion on motivation can then be reversed and framed in a context of improving quality of life of urban residents, of resource management and thus competitiveness of cities, as they increase coverage and enhance the quality of service provision within municipal budgets (See Table 8). Climate change actions represent concrete measures to address local urban needs, with the added co-benefit of reducing GHG emissions. By addressing these local needs strategically, the global co-benefits can be maximized (*e.g.* landfill gas capture rather than flaring, bio-fuels rather than fossil-fuels).

Table 8: Examples of Local Benefits from Climate Change Measures

Category	Measure	Climate Change Issue	Local benefit
Accessibility	Improved public transport	Mitigation	• Reduction in travel time and cost of transport for low-income people
	Installation of walking and biking paths	Mitigation	• Reduced crime and violence by providing "safe" pedestrian access • Low-cost transport option
	Compact cities/ mixed-use zoning	Mitigation	• Reduction in travel time • Proximity of services and social networks
	Reduced private vehicle use	Mitigation	• Improved air quality • Reduction in bus travel time due to reduced congestion
Housing	Construction improvements in social housing programs	Mitigation and Adaptation	• Better quality of housing materials • Design that is sensitive to local climate (breeze and daylight) • Reduced energy expense • Increase personal safety

Category	Measure	Climate Change Issue	Local benefit
			from flood risk
	Avoiding development in hazardous or sensitive areas	Adaptation	• Reduction in construction of housing in high-risk areas • Personal safety
	Use of energy efficient appliances	Mitigation	• Reduced energy expense
	Installation of solar water heating	Mitigation	• Improve the quality of life for low-income residents by providing warm showers
Public Space/ Urban Environment	Solid waste collection and recycling programs	Mitigation	• Employment opportunities in recycling/sorting • Improved urban environment
	Tree and vegetation planting programs	Mitigation	• Improved access to green space • Improved air quality and temperature • Reduced heat island effect benefits the elderly and outdoor workers
	Expansion or installation of storrnwater drainage	Adaptation	• Less frequent flooding of pedestrian areas • Reduced health risk from stagnant water

While many pro-climate measures can provide local co-benefits, there are also potential trade-offs that need to be considered. For example, improvements to a municipal waste water system may not have a significant impact on mitigating GHG emissions at the global scale, but could have a significant impact on quality of life for residents. On the other hand, a fuel tax could help reduce emissions from private vehicle use, but could negatively impact lower-income constituents who rely on that mode of transport to get to work.

E.3 Financing Climate Change Actions in Cities

A recent analysis of the economic impact of climate change in Brazil, modeled after the Stern Report, found that climate change could affect national GDP by 0.5 percent to 2.3 percent by 2050. Adjusted to present values, discounted at a rate of 1 percent per year, these losses would range between R$719 billion and R$3.6 trillion (approximately US$410 billion and US$2 trillion), which would be equivalent to losing at least an entire year of growth over the next 40 years (Economia do Clima 2009).

Cost of Mitigation

Based on the Brazil Low-carbon Case Study, the cumulative additional investment costs of low-carbon growth is estimated at US$389 billion in nominal terms over the 2010-2030 period. Mitigation measures related to transportation and waste nationwide are estimated to cost US$141 billion and US$84 billion over the 2010-2030 period, respectively (World Bank 2009).

As illustrated in Table 9, there is a wide range in the cost per ton of CO2 abatement by type of mitigation measure. Among the potential mitigation measures included in the analysis that are broadly within the scope of municipal government – Energy Conservation, Urban Transport, and Waste Management – Waste Management could have the most impact with the lowest average cost. It is important to note that the potential impact of urban growth policies was not included in the analysis, and may represent a powerful (albeit indirect) tool that municipalities have in reducing GHG emissions.

Table 9: Comparison of Sectoral Investment Requirements by Mitigation Option, 2010-2030

Sector/Abatement Measure	Abatement Potential (Mt CO2e)	Additional Investment (US$ billion)	Cost per Ton of CO2e Abatement (US$)
LULUCF	**7,481**	**114.7**	**15.33**
ENERGY	**2,444**	**147.4**	**60.29**
Energy Generation	205	42.9	209.26
Energy Conservation	95	9.6	101.29
Residential solar heater	3	1.2	388.67
Residential lighting	3	0.3	98.00
Refrigerators	10	6.1	605.10
Commercial lighting	1	0.5	483.00
Electric motors	2	1.2	601.00
Industrial lighting	1	0.2	178.00
Recycling	75	0.2	3.32
Fossil-fuel Production	246	14.4	58.34
Fossil-fuel Conservation	594	50.3	84.60
Fossil-fuel Substitution	1,304	30.2	23.18
TRANSPORT	**524**	**92.5**	**176.58**
Regional	278	48.6	174.66
Urban	246	44.0	178.75
Metro and BRT	187	42.6	227.91
Traffic optimization	45	1.1	23.33
Bicycle lanes	14	0.3	21.64
WASTE MANAGEMENT	**1,317**	**34.6**	**26.24**
Landfill Methane Destruction	963	3.7	3.85
Wastewater Treatment + Methane Destruction	116	1.6	13.82
Wastewater Treatment + Methane Destruction (ind)	238	29.3	122.92
TOTAL	**11,766**	**389.1**	**33.07**

Source: Adapted from the Brazil Low-Carbon Country Case Study, 2010.

Cost of Adaptation

Several estimates of the cost of global adaptation have been prepared, and the most commonly cited include: World Bank (2006), Stern (2006), Oxfam (2007), and UNDP (2007), Project Catalyst (2009), and World Bank (2010). The latter of which provides methodologies for the calculation of adaption costs by sector. However, adaptation strategies, and their related investment plans, are extremely local and unique. This makes it difficult to extrapolate global estimates to the municipal level. Brazilian cities must implement vulnerability assessments in order to understand their unique risk situation and priority investments.

E.4 Institutional Considerations

Brazil has created a range of institutional mechanisms to implement climate-related policies at all levels of government. At the federal level, the main actors are the Ministry of Environment (MOE) and the Ministry of Science and Technology (MCT). Under the MCT, the CPTEC (Center for Weather and Climate Studies) has a special study group dedicated to climate change – the GPMC. The *Rede Clima* was recently established at MCT to generate and disseminate information on climate change. The "Brazilian Forum for Climate Change" (FBMC) was established in 2000 by presidential decree as a platform for federal ministries, state-run companies like Petrobrás, research institutions, private sector and civil society. The objective of the forum is to mobilize these groups regarding climate change issues. In 1999, an inter-ministerial committee on climate change was created, jointly chaired by the MCT and the MOE (La Rovere 2002). This committee released the National Climate Change Plan (PNMC) in 2008.

At the state level, climate change issues are generally under the purview of the Secretary of Environment. In some case, the Secretary has established specific climate change departments or units. In the state of São Paulo, for example, PROCLIMA (*Programa Estadual de Mudanças Climáticas*), established in 1995, is responsible for overseeing the development of GHG inventories, monitoring vulnerabilities, and implementing adaptation measures. In 2009, the Governor established PEMC (*Politica Estadual de Mudanças Climáticas*) that will develop a GHG inventory (with assistance from the UK government). In the state of Rio de Janeiro, the Superintendency of Climate and Carbon Markets was established. Most studies for the Superintendency are conducted by Coppe-UFRJ. In 2005, the state government of Minas Gerais established the inter-secretarial Forum on Global Climate Change to lead discussion regarding climate change. The Forum also has three representatives from local universities and two representatives from the private sector.

A similar structure is seen in some major cities in Brazil. Generally, the municipal Secretary of Environment is the lead actor, sometimes with a special stakeholder committee to broaden discussions like the Municipal Committee on Climate Change and Eco-efficiency (CMMCE) in Belo Horizonte which is led by the Deputy Mayor. Local authorities in Brazil also participate in international climate networks like the Cities for Climate Protection (CPP) campaign. As representatives of Brazil, São Paulo and Rio de Janeiro participate in the Large Cities Climate Leadership Group (C40). In addition, several Brazilian cities are members of ICLEI.

Brazilian civil society is also engaged in the public debate on climate change. For example, the NGO Vitae Civilis participates in the international NGO network Climate Action Network (CAN). In addition, the *Instituto Socioambiental* (ISA) and networks like *Amigos da Terra* and the Brazilian Forum of NGOs and Social Movements for Sustainable Development and Environment have been actively engaged.

The private sector is also involved in climate change discussions. For example, during the Ibero-American Congress for Sustainable Development in São Paulo, the Brazilian Council of Entrepreneurs for Sustainable Development (CEBDS), Petrobrás, Alcoa and Votorantim signed an environmental agreement with Greenpeace and the WWF to enforce climate protection. Among other agreements, Petrobrás committed itself to eliminate 18.5 million tons of carbon dioxide emissions by 2011 (Hermanns 2007). At 15th Conference of the Parties (COP-15) of the United Nations Framework Convention on Climate Change in 2009, twenty-two organizations, including some of Brazil's most important publicly listed companies presented an open letter presenting their voluntary commitments to cut greenhouse gas emissions. The initiative, led by Vale, the Ethos Institute and the Sustainable Amazon Forum, also provided suggestions regarding the Brazilian government's position at Conference. Signatories also support the creation of an incentive mechanism aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD), which will promote conservation and sustainable forest management.

There are clearly a broad range of actors involved in the climate change agenda. The key challenge at the municipal level, currently, is that climate change is a multi-sectoral issue that requires more integration among municipal secretariats. Implementing a climate change plan that includes mitigation and adaptation measures requires full cooperation of all sectors. Indeed, planning for climate change requires an approach to urban development that needs to be mainstreamed in all aspects of urban management.

Moreover, climate change measures are not, by nature, limited to administrative boundaries. A lack of collaboration among municipalities within metropolitan regions can present an obstacle to actions to mitigate and adapt to climate change, which often most efficiently and successfully addressed at the metropolitan level. In most cases in Brazil, carbon-emitting sources, economic activities, flows of materials and energy, and transport between economic hubs and households overlap across multiple jurisdictions. This requires city officials to engage in discussions and cooperation with other municipalities. While climate change initiatives are strongly moving forward in Rio de Janeiro and São Paulo, for example, they do not include the broader metropolitan areas. The lack of a metropolitan mechanism for urban growth management, for example, has led to sprawling and uncontrolled development in peripheral municipalities that often have lower capacity to manage urban development.

Local Climate Change Governance

According to a recent OECD study, at least four modes of urban governance can apply to climate change actions in cities (Alber and Kern 2009):

i) The municipality could act as a consumer and limit their consumption and ecological footprint through measures such as promoting the energy efficiency of municipal buildings, green procurement, and the greening of public transport vehicles. This is the most widespread form of local action globally, and it is driven in many cases by the direct financial benefits of energy savings. In Belo Horizonte, for instance, the municipality has required that all vehicles used by the public administration operate using biofuels, and plans to be the first state capital to convert all of its public lighting to more energy efficient bulbs;

ii) The city may serve as an enabler of pro-climate actions. For example, the municipality could establish public-private partnerships (PPP) for the provision of services and infrastructure. In Brazil, cities have taken the initiative to promote PPPs for the capture of methane from landfills;

iii) The municipality may serve as the provider of services like water, electricity, or public housing, it can play a strong role in modifying public consumption and waste disposal patterns. The City of São Paulo's Secretariat of Housing (SEHAB), for example, is currently preparing guidelines for the development of social housing that will obligate developers to meet minimum "green" or sustainable design requirements; and

iv) The local government may serve as regulator. In this case, the municipality would enact regulations to reduce CO2 emissions in policy areas such as energy, transport, land use and waste (see Table 10).

Table 10: Summary of Governance of Climate Change Actions at the Municipal Level

Governance Type	Description	Examples in Brazil
Consumer	Municipality limits its own ecological footprint through the measures such as promoting the energy efficiency of municipal buildings, green procurement, and the greening of public transport vehicles	Belo Horizonte: • Requires all vehicles used by the public administration to operate using biofuels • Energy efficient public lighting National: • The RELUZ program aims to substitute 9.5 million (about 2/3) of existing public lighting between 2000 and 2010, and to add 3 million new efficient public lighting units
Enabler	Municipality enables pro-climate actions and activities, including PPPs for the provision of services and infrastructure	São Paulo: • São Joao and Bandeirantes landfill gas to energy projects were implemented jointly with a private company.
Provider	Municipality integrates "green" actions when it serves as the provider of services like water, electricity, or social housing	São Paulo: • The municipality is currently drafting green/environmental guidelines for all social housing
Regulator	Municipality enacts regulations to reduce CO2 emissions in the policy areas such as energy, transport, land use and waste	São Paulo: • Solar energy bill that mandates that buildings with more than 3 bathrooms use passive solar heating systems

Source: Adapted from OECD 2009

E. SUMMARY AND RECOMMENDATIONS

The relevance of urban GHG emissions in Brazil – GHG emission in Brazilian cities are less than half of emissions from comparable cities around the world. While cities account for less than 30 percent of national GHG emissions in Brazil, they are the fastest growing source. Indeed, the total GHG emissions growth during the period 1990-2005 was relatively low (approximately 8 percent). However, when LULUCF is excluded, emissions growth jumped to over 70 percent for the same period, of which the large majority was concentrated in urban areas. As cities continue to grow, the pressure towards higher emissions will increase. Specifically:

(i) At current rates of increasing motorization and congestion, and in spite of relatively low level of emissions (due in large part to the use of renewable fuels), total urban transport-related GHG emissions per year are expected to grow by 60 percent by 2030;

(ii) Secondary cities and smaller agglomerations are growing rapidly, and in a sprawling manner, the exact opposite of the urban form necessary to efficiently provide massive public transportation. In fact urban areas experiencing the most population growth are also showing the highest degree of sprawl;

(iii) Waste emissions represent a larger share in Brazilian cities than what is experienced globally. Per capita waste generation in large cities continues to increase annually. With rates of collection and disposal increasing by 4-5 percent per year, it is expected that emissions from the waste sector may grow by up to 50 percent by 2030 with increasing coverage of solid and liquid waste collection services;

(iv) Industry contributes to the largest share of GHG emissions from the energy sector in Brazil and the expected trend is for increasing emissions. However, the share of those emissions that are attributed to urban areas is difficult to estimate given the manner in which metropolitan emissions are accounted across municipal boundaries. Within the energy sector, the largest expected growth of GHG emissions will come from the residential sector, where electricity consumption is growing rapidly. In fact, it is estimated that residential consumption of electricity will increase thirteen-fold by 2030.

The metropolitan dimension must be considered – Climate change measures are not, by nature, limited to administrative boundaries. A lack of collaboration among municipalities within metropolitan regions can present an obstacle to actions to mitigate and adapt to climate change. In most cases in Brazil, carbon-emitting sources, economic activities, flows of materials and energy, and transport between economic hubs and households overlap across multiple jurisdictions. Peripheral municipalities often have lower capacity than larger cities, and therefore a coordinated approach at the level of the metropolitan area is the most effective and efficient way to design and implement climate change adaptation and mitigation measures.

The importance of supporting mitigation actions – Brazil's per capita GHG emissions are comparatively low, by international standards, owing primarily to the widespread use of renewable energy sources and fuels. However, in spite of the prevalence of low-carbon alternatives, national GHG emissions have increased over the past decades and are expected to continue on a growing trend. Under the current scenarios, and without taking actions to reduce emissions in the largest emitting sectors, the emissions profile for the country will change quite drastically. Specifically within the urban context, the implementation of mitigation measures in five key sectors has the potential to significantly reduce GHG emissions: (i) transport sector, primarily by increasing coverage and effectiveness of public transport systems, and reducing demand for motorized transport, especially private vehicles ; (ii) land use and urban planning, where small and medium-sized urban areas have the opportunity to reconsider their current growth patterns and adopt measures to reduce sprawl; (iii) energy efficiency and renewables, where municipalities have tremendous opportunities to reduce emissions and save costs through the implementation of energy efficiency programs, primarily in public lighting, public buildings and utility companies; (iv) waste management, through programs aimed at reducing and recycling waste, and through the adequate management of gases generated at landfills; and (v) urban forestry, through greening programs aimed at increasing capture of CO2 by trees and shrubbery, which also provide shade and relief to heat island effects. The cost of implementing mitigation actions varies (*i.e.* cost per ton of CO2 abated) by type. Within the scope of municipal governments, waste management measures could have the most impact with the lowest average costs.

A need to consider risk management and adaptation – Few Brazilian cities have completed assessments of vulnerabilities to climate change, although it is well known that significant impacts are expected across the country due extreme rainfall, drought, temperature variations and sea level rise. In the absence of detailed vulnerability analyses it is difficult to design consistent adaptation plans. In the recent years, however, extreme climate events (rainfall, flooding) have demonstrated the importance of putting in place strategies to evaluate and to manage the risks posed by climate change. The vulnerability of those most affected by these climate events (i.e. the urban poor) is such, and their ability to adapt and respond to them is so limited, that cities must act soon to reduce their risks and to limit their impacts.

Importance of climate change action plans – City-wide action plans against climate change are essential tools for cities to design comprehensive strategies that effectively consider opportunities across sectors, with the overall objective of emission reduction targets. Interlinkages between sector initiatives are numerous (*e.g.* as transport and urban land use, energy and waste), and it is therefore in the best interest of cities to have an overall perspective of ongoing initiatives and how they can be improved to optimize potential reductions in GHG emissions. New and complementary measures can later be built in to bridge gaps and to achieve even more significant reductions. City-wide action plans can also help in the identification of sources of financing for the various actions.

A key aspect to address is a city's motivation for action - What motivates cities to adopt policies against climate change? In the current global context of limited resources and numerous competing priorities, in order for cities to take action against climate change, the evidence must be compelling that, in fact, addressing climate change brings direct benefits to their residents. The case must be made to the policy-makers, and to the public, that taking action on adaptation and mitigation translates, locally, into improved quality of life for city residents, a reduced use of resources and thus an increase in the city's competitiveness. The case must be made that climate change actions represent concrete measures to address local urban needs, with the added co-benefit of reducing GHG emissions.

The critical role of secondary cities - Secondary cities in Brazil are growing rapidly, with significant implications on urban planning, from the provision of basic public services such as drinking water, sanitation and waste management, to the financing of adequate public infrastructure, and the management of urban pollution. With the wealth of data currently available and with the hindsight provided by the growth paths of Brazilian metropolitan areas, the present time offers an important opportunity to transform the way in which secondary cities are developing. Understanding the future needs of these smaller cities and building into their development plans sustainability considerations including land use and planning, infrastructure needs, energy sources, water use, integrated waste management, and pollution control could completely re-shape the way in which these cities will grow, the impact they will have on the environment and thus the quality of life of their future residents. At the same time, and with little to no incremental costs, these development plans will have built-in GHG emission mitigation measures and adaptation strategies.

Opportunities for collaboration – The World Bank is well positioned to work alongside Brazilian cities in the design and implementation of climate change mitigation and adaptation measures. The Bank has an extensive portfolio of operations in Brazil aimed at promoting sustainable development in the energy, housing, transportation, environment, urban and agriculture sectors, which are ideal vehicles to mainstream climate change adaptation and mitigation measures across sectors. Indeed, one of the outcomes of this Policy Note is to present arguments to demonstrate that taking action against climate change (by reducing GHG emissions) is not an objective in itself, but rather that strategic investments focusing on local development have the potential to deliver major global co-benefits in terms of GHG emissions, if the alternatives are carefully considered. The Bank's expertise in the area of Carbon Finance, in particular, could be further tapped in Brazil in order to provide cities with additional sources of financing for the implementation of mitigation measures. The Bank is already working with Rio de Janeiro, for instance, in the development of a City-Wide Approach to Carbon Financing, which will allow the city to develop an overall carbon asset that includes contributions from its main GHG generation sectors, and to sell it in the international carbon market.

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