Climate Change Impacts on Health: The Urban Poor in the World's Megacities

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Abstract

This research addresses the research question of whether climate change could disproportionately affect the health of the urban poor living in the world's megacities. It seeks to explain the health consequences of climate change and the impacts on urban populations, how major cities should respond with preparedness and adaptation strategies to lessen impacts and collective actions that can be taken to mitigate the health risks associated with climate change.

Climate change is a major concern that is closely related to our good health. A population's health is linked to the stability of the environment, and depends on the functioning of the world's climate system. The effects of climate change on health will impact most populations in the next decades, and major cities around the world will gradually face the consequences. The increase in risk factors will put the lives and safety of billions of people in jeopardy and will affect the population unequally. Climate change will compound existing vulnerabilities, increase poverty levels, and affect the urban poor, as they typically live in the most vulnerable lands within cities and are at high risk from the impacts of climate change and natural disasters. Overcrowded living conditions, inaccessibility to safe infrastructure and poor health conditions make the urban poor highly vulnerable to climate change impacts (Baker, 2011c).

Climate change can change the pattern of diseases, mortality, human settlements, food, water, and sanitation. Increased temperatures, rising seas, and frequent incidence of severe storms are known and growing effects of climate change. These effects produce dangerous sanitary consequences and are known health risks (Jensen, 2007).

This research outlines a methodology for developing and implementing the

Australian/New Zealand Risk Management Standard – AS/NZ ISO 31000 to climate change effects on populations. ISO 31000 supports a unique management approach to drive proactive steps to manage risk more effectively and to develop a united method to presenting adaptive strategies across cities around the world.

Adaptation and mitigation models that confront climate change impacts on health in urban populations, and particularly on the urban poor, who are the most vulnerable to climate variability, are crucial to minimize the disaster risks. As a result, disaster risk management becomes a fundamental component of climate change adaptation and mitigation program frameworks. This paper presents a strong business case that applies Risk Management ISO 31000, and recommends a systems view of risk assessment and proactive approach to risk management through a shared response at local and international levels.

This research uses the case study method to explore climate change health impacts on the urban poor in megacities and presents the examination of practical and theoretical cases, differentiated by geographic, demographic and socio-economic factors. It presents a case study of four megacities: New York, Beijing, Los Angeles and Rio de Janeiro. These cities have different economic and social driving forces and they are presently implementing strategies to combat climate change with different approaches and results. The evidence shows that a well-planned climate change risk-assessment and management plan modeled on the specific needs and conditions of each urban city will provide a viable advantage in order to combat climate change and its health impacts on the urban poor.

Author's Biographical Sketch

Cesar Marolla has received his Bachelor of Science in Business Administration and Marketing from Columbia College. For the last 20 years he has worked in the music industry performing and recording with some of the most popular and talented artists of contemporary music and has traveled to many different countries in Europe and North, Central and South America.

In 2004, he was invited by the Secretary of Defense to travel and entertain military personnel in support of "Operation Enduring Freedom." This initiative took him to the Middle East and northeast Africa performing for American and international troops. In one of his trips to Africa with the Department of Defense, he witnessed the catastrophic consequences of environmental degradation, the public health risks it poses, and its relation to poverty. The country he visited was Djibouti, located in northeast Africa on the Gulf of Aden and the Bab-el-Mandeb, at the southern entrance to the Red Sea. This experience impacted his life forever. Since then, Cesar has taken leading initiatives to develop and implement sustainability strategies at the corporate, public and government levels. He has received a Certificate of Appreciation from the Department of Defense, a Letter of Appreciation from the Office of the Assistant Secretary of Defense, and a Military Coin, which is given as a token of affiliation, support, patronage, respect, honor and gratitude, and presented by the Camp Victory Commander in Kuwait, Lieutenant Colonel Lawrence J. Smith. This thesis is the culmination of a rich and rewarding experience that amalgamates the knowledge acquired at Harvard University and the invaluable world experience he has accumulated throughout his life.

Dedication

To the pillars of my life: My wife Lisa, our three sons, Nicholas, Alexander and Michael, and my parents for their love, support, and continuous encouragement.

To the memory of the late Byung Y. Choi, Shaolin Kung Fu Master and a man who taught me not only hard work, but patience; not only patience, but dedication; and not only dedication, but perseverance.

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Thank you to all the men and women in uniform who serve and protect our rights and freedoms.

Think, learn, and spur change.

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Definition of Terms

AD-DICE model: The model is based on the DICE model. It is a Ramsey neoclassical growth model, where climate change is a stock variable which creates economic damages. The climate module describes how emissions translate into a global atmospheric temperature change. This module consists of geophysical equations. The model describes the whole cause and effect chain of climate change.

Albedo: The fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface.

Anthropogenic: Of, relating to, or resulting from the influence of human beings on nature.

Black Swan Theory: An event or occurrence that deviates beyond what is normally expected of a situation and that would be extremely difficult to predict. This term was popularized by Nassim Nicholas Taleb's book *The Black Swan: The Impact of the Highly Improbable.*

Climate Change: Change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.

Degraded Productivity: Reduced far below ordinary standards of labor efficiency. It can be measured by quantity of output per unit of time spent or numbers employed.

Epidemiological Studies: The study of the distribution and patterns of health-events and their characteristics as well as their causes or influences on well-defined populations.

Hadley CM2 Model: Hadley or HadCM2 stands for the Hadley Centre Coupled Model version 2. It was developed in 1995 for modeling the effects of climate change, and used in the Second Assessment Report of the Intergovernmental Panel on Climate Change.

Homelessness: Individuals who sleep in shelters. "Absolute homelessness" which describes individuals who sleep outdoors or in other places not intended for human habitation.

Headcount Index: A common measure of poverty, defined as the percentage of the population living below the poverty line.

Megacities: Spanish sociologist Manuel Castells' term for large cities in which some people are connected up to global information flows whilst others are disconnected and "information poor." It is also defined as a metropolitan area with a total population in excess of 10 million people.

Risk: Risk is the chance that something will happen that will have an impact on the planned outcomes of an organization.

Ramsey Rule: The consumption rate of discount assuming a transfer of money of a (representative) agent at one point in time to the same agent at another point in time. Climate policy (implicitly) transfers money not just over time but also between agents.

Risk Management: Attempts to reduce risks to an acceptable level, which is defined by an organization's legal responsibilities and sustainability policy. Risks can be viewed both as positive (the opportunities) and negative (the threats and losses). The process of managing risks considers both kinds of risks.

Urban Heat Island: The condition in which a city is relatively warmer than the surrounding areas due to the heat generated by conductors such as concrete, cars, and city buildings, and the lack of vegetation.

Zealotry: Excessive intolerance of opposing views.

"We shall require a substantially new manner of thinking if mankind is to survive."

Albert Einstein

Chapter 1 Introduction

In 2009, one of the world's leading general medical journals, *The Lancet,* and University College London (UCL) Institute for Global Health conducted a report of a year-long commission that opens up with the following statement: Climate Change is the biggest global health threat of the 21st century (Costello et al., 2009a). Climate has impacted our health for thousands of years, and the increased acknowledgment of climate change and its consequences creates a growing interest in how climate affects health. The range of health effect factors are varied, such as population growth, urbanization, land use reduction, and fresh water resources. All these elements have connotations for the population's health and magnify the impacts of climate change events (Haines, 2006a).

The importance of the consequences of climate change impacts on health is highlighted by the urgency and severity of this threat. First and most importantly, the poorest people in the world will suffer the worst consequences. Furthermore, the rural population's migration to major cities creates a steady growth in urban settlements with high density human-created structures that exacerbate the health-related problems of climate change. Climate change could aggravate the health issues faced by the urban poor to the extent that entire communities are devastated because the poor have the tendency to live in informal settlements that are more defenseless to drastic weather events. The increased vulnerability of the health of the urban poor due to reduced food security, drinking water, water-rodent borne diseases associated with floods, droughts, and the relation between high temperatures and heat stress will be worsened by climate change.

Therefore, climate change impacts on the urban poor will deepen the social and economic disparity among the population and will create a gradual problem that will affect future generations' health, and increase their risk factors (Costello et al., 2009b).

The C40 group is a worldwide network of cities working together to mitigate the impacts of climate change and reduce carbon emissions (About, 2012). The cities' network encompasses actions to reduce greenhouse gas (GHG) emissions and climate change impacts through a partnership with the Clinton Global Initiative to combat climate change. This is an important step toward a solution to diminish the urban poor's health risks due to climate change as megacities' populations are rapidly increasing, according to the latest United Nations report. Between 2007 and 2050, the urban areas of the developing world are expected to absorb an additional 3.1 billion people while the overall population will grow by just 2.5 billion people. The rapid and unplanned expansion of megacities exposes a greater number of urban residents to climate change health risks and increases their vulnerability to the threat of drastic climate events. Consequently, health impacts will depend on the region, susceptibility of populations and the capability of societies to adapt and mitigate the impacts (Dickson et al., 2011).

The challenge for megacities is to implement and develop an effective urban risk management framework to adapt and mitigate impacts and deliver essential services to deter climate change effects on health. Cities need to consider the issues of climate change and urban health by conducting evaluations of related risks to identify feasible measures in their planning and management processes (Dickson et al., 2011).

Additionally, susceptibility to climate change and subsequently its health effects are increased as the concentration of economic activity and population density exacerbates the health issues faced by the world's major cities. Therefore, climate change impacts on health intensify its effects on urban populations (Feiden, 2011). The capacity of the urban poor to adapt is weak in comparison with the rest of the population because the poor settle into inadequate facilities and are exposed to poor nutrition, overcrowded living conditions, and displacement. Resources and information are scarce and the urban poor cannot respond efficiently to take actions to mitigate climate change effects, and this situation creates a gradual exposure to health risks. The poor population's vulnerability will be exacerbated by exposure to severe weather effects and lack of ability to adapt to climate change (Haines, 2006a).

Rising sea levels makes cities vulnerable to drastic environmental changes and exacerbates the economic risks faced by poor residents. Furthermore, inland cities also have susceptibilities to climate change impacts, including urban settlements on steep slopes in hazard-prone areas, and the heat island effects (The impacts of, 2011).

Among the cities in the case study, the city of New York is vulnerable to mid-latitude cyclones and nor'easters, which reach a peak from November to April. Coastal erosion is increasing and makes the city defenseless to coastal flooding. Furthermore, cyclones and hurricanes have the potential to reach New York City and expose the urban population at a high risk of disaster (Fifth urban research, 2009).

Rio de Janeiro has a climate change factor that is a concern for cities near the coastline. The rise in sea level related to climate change will result in a variety of impacts (e.g., flooding, sanitation issues, quality and quantity of water resources) (Rosenzweig, 2010).

Furthermore, Los Angeles has developed a comprehensive adaptation and mitigation plan and conducted a pioneer study of the impacts of climate change in the county that can be exemplary to other megacities around the world. These initiatives help to conceive a solid strategy to address the cost of inaction to climate change impacts, and they focus on the health effects of severe climatic events and preventive actions to reduce the burden of disease. Lastly, the research focuses on the city of Beijing, assessing heat-related mortalities, the urban heat island effect on its residents, and air pollution issues that are becoming a major concern for climate change mitigation strategists in this megacity, all affecting the health of the urban poor in particular.

The local government involvement in developing a risk management plan is critical to improving the resilience of the urban poor (Rosenzweig, 2010). This research presents a risk management framework, the standard ISO 31000, which provides additional insights as to how major cities can prepare, develop, and implement a risk management structure to deal with climate change issues.

The next chapter presents the Background to this research and further addresses health risks associated with climate change for urban populations.

Chapter 2 Background

Climate Change Inequalities

Climate change impacts on human health are particularly inequitable. Climate change is rising as a threat to global public health and the poorest populations are exposed to greater risks. Poor populations living in major cities with rapid economic development will be most susceptible to climate change effects (Campbell-Lendrum et al., 2008). The health susceptibility factors of the urban poor, particularly in developing countries are: location, the effects of the urban heat island, air pollution, growing population and lack of proper sanitation (Campbell-Lendrum et al., 2008).

Climate Change and Public Health

According to the World Health Organization since the 1970s climate changes already are estimated to cause over 150,000 deaths annually. Higher temperatures and changing rainfall patterns resulting from global climate change also may influence transmission patterns for many diseases, including water-related diseases, such as diarrhea, and vector-borne infections, including malaria. Furthermore, climate change could have far-reaching effects on patterns of food production, which can have health impacts in terms of rates of malnutrition (Health and environment, 2013).

Following are some of the types of climate-related events that have occurred throughout the world:

Heat Waves in Europe

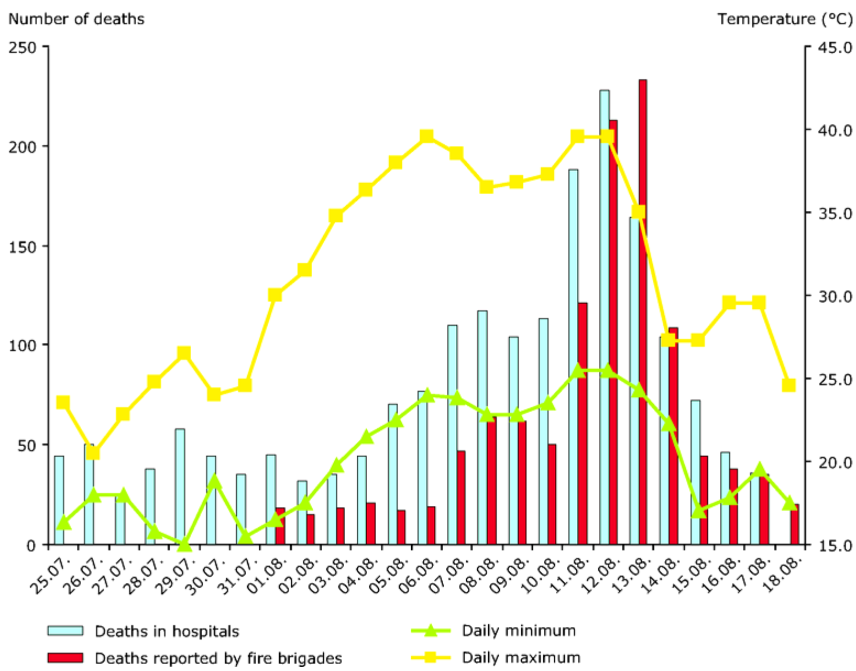
Some of these climate change impacts on human health have been experienced by many different countries and regions around world. France and Italy lost many lives due to a heat wave across Western Europe in the summer of 2003. More than 14,000 people perished in that event (Wang, 2005). Heat waves are just one source of the harms climate change causes to human health. The range of disease carrying insects will expand affecting populations that have never been exposed to those factors. Crop productivity will decrease, creating a parallel increase effect in malnutrition (Heinzerling, 2007).

Paris suffered a devastating heat wave from the 1^{th} to the 14^{th} of August, 2003, where the maximum and minimum temperatures reached unprecedented highs. The high temperatures were not accompanied with high relative humidity, as is usually reported, and on August 4, 300 excess deaths were reported. The reported deaths gradually increased until August 12, reaching 2,000 per day, and then quickly stopped within a few days. The death toll in the month of August reached to 14,800, which is equivalent to a 60% increase of expected mortality in France (Dhainaut et al, 2004).

The following chart shows the number of reported deaths and minimum and maximum temperature in Paris during the heat wave in summer 2003.

Chart 1: Reported Deaths and Minimum and Maximum Temperature in Paris

(European Environment Agency, 2005).



Climate Change and the Effects on the Environment

The effects of climate change on the environment have an impact on public health and include compromised water supplies, change in air quality, food security and direct effects on vectors (Portier et al, 2010a).

Change in Water Supply

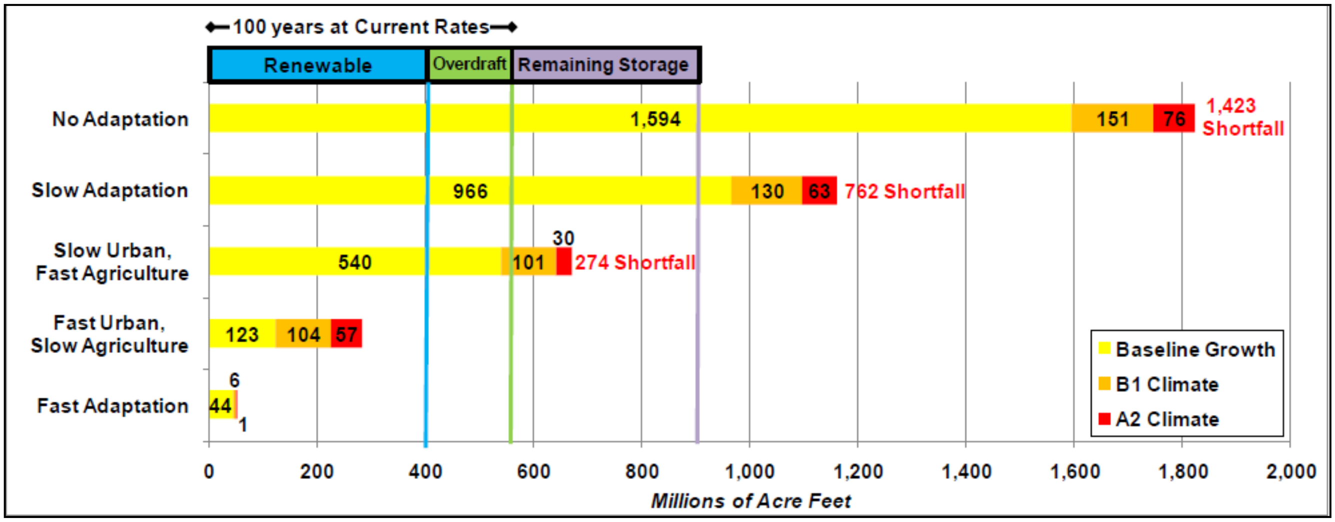
The change in rainfall will increase the severity and occurrence of droughts in some regions and floods in others. These events will impact the vector population, and water scarcity will affect crops and pasture yields. Change in precipitation patterns could change the population density of vector-borne diseases, infecting inhabitants in greater numbers and affecting the health of entire communities. Roads, schools, power supplies and houses are affected by flooding, destroying essential infrastructure to support communities and cities (Portier et al., 2010c).

Moreover, storm water discharges are damaged by heavy rains, putting waste into the water supply. Cities near the coast will be affected by rising sea levels, which consequently will result in salination of freshwater supplies, loss of land productivity and a change in coastal dwelling mosquitoes' breeding (Epstein, 2001).

In Africa alone, by 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change. Water security problems are also projected to intensify by the year 2030 in southern and eastern Australia. In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges (such as the Himalayas in Asia and the Andes in Latin America). In North America, the decreased snowpack in western mountains is projected to cause more winter flooding, and reduced summer flows, exacerbating competition for over-allocated water resources (Van Ypersele, 2007).

Freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins, is projected to decrease due to climate change, which could, in combination with other factors, adversely affect more than a billion people by the 2050s (Van Ypersele, 2007).

Chart 2: California's Projected Groundwater Extraction plus Shortfall, 2010 to 2110 (Ackerman & Stanton, 2011).



The above chart shows adaptation scenarios for California's urban and agricultural water use. There is a 15% reduction from conservation and efficiency on the <u>slow urban adaptation scenario</u> in addition to a 20 percent <u>price increase</u> by 2030.

A 5% reduction in water use plus a 10 percent price increase by 2030 is projected by a <u>slow agricultural adaptation</u>. A projection to highlight is that the savings from <u>slow urban and agricultural adaptation</u> <u>combined</u> are not enough to reduce California's water use to the sustainable level, even without the impacts of climate change (Ackerman & Stanton, 2011).

Change in Air Quality

Air pollutants are changed by higher temperatures. The higher temperatures also affect the range and concentration of pollen, affecting a larger range of the population (Portier et al., 2010a). For example, Los Angeles, remained the city with the worst ozone pollution problem, but reported its fewest unhealthy ozone days since the American Lung Association State of the Air reports began in 2000. The table below shows the seven most ozone-polluted cities in the United States, and it particularly illustrates cities in California leading the list in 2012. The statistics put emphasis on the correlation between poverty and health outcomes (Nolen et al, 2012).

Table 1: People at Risk in Seven Most Ozone-Polluted Cities in the US (Nolen et al, 2012).

2012 Rank	Metropolitan Statistical Areas	Total Pop.	Under 18	65 & over	Pediatric asthma	Adult asthma	Chronic bronchitis	Emphysema	Poverty
1	Los Angeles-Long Beach-Riverside-CA	17,877,006	4,565,478	1,951,619	302,853	1,017,973	557,067	228,858	2,869,935
2	Visalia-Porterville-CA	442,179	144,124	41,779	9,561	22,675	12,297	4,931	108,143
3	Bakersfield-Delano-CA	839,631	254,081	75,437	16,855	44,572	24,047	9,398	172,531
4	Fresno-Madera-CA	1,081,315	320,356	110,683	21,251	57,991	31,596	12,865	276,242
5	Hanford-Corcoran-CA	152,982	42,548	12,030	2,822	8,348	4,423	1,619	29,606
6	Sacramento--Arden-Arcade—Yuba City-CA-NV	2,461,780	610,637	306,306	40,690	143,119	79,611	34,539	361,014
7	San Diego-Carlsbad-San Marcos-CA	3,095,313	724,168	351,425	48,038	181,080	99,026	40,726	445,556

Public Health Burden of $PM_{2.5}$ and Ozone

In general, the percentage of all deaths due to $PM_{2.5}$ exposure is higher than it is for ozone. Southern California has the highest percentage of $PM_{2.5}$-related deaths among the United States population. If the air quality incrementally improves, the number of deaths related to $PM_{2.5}$ and ozone changes. For example, 23,000 $PM_{2.5}$-related mortalities would be avoided as a result of lowering 2005 annual mean $PM_{2.5}$ levels down to 10µg/m3 (micrograms per cubic meter of air) nationwide. The projected estimation concludes that approximately 80,000 premature mortalities would be preventable by lowering $PM_{2.5}$ levels to 5µg/m3 on a national scale (Fann et al, 2011).

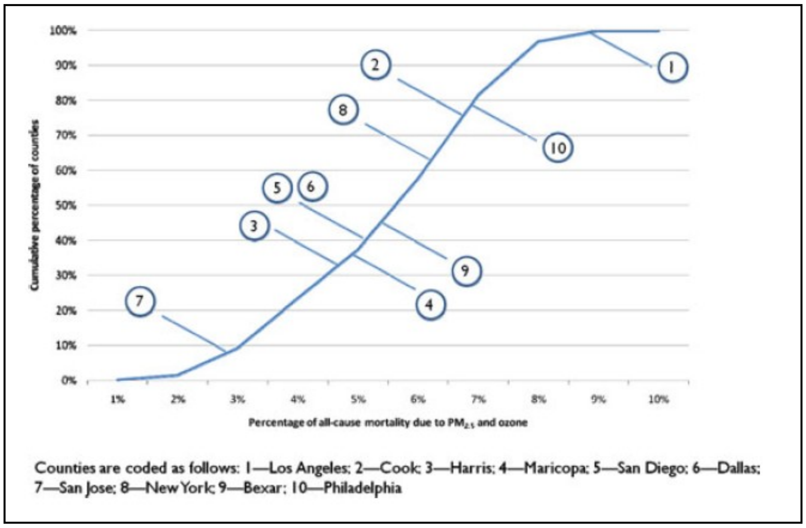


Chart 3: Cumulative Distribution-Percentage of All-Cause Mortality Attributable to $PM_{2.5}$ and Ozone among the 10 Most Populous U.S. Counties (Fann et al, 2011). As shown on the figure above, *y-axis* represents the cumulative percentage of counties and *x-axis* represents the percentage of all-cause mortality due to $PM_{2.5}$ and ozone (Fann et al, 2011).

The U.S. Environmental Protection Agency has taken important measures to protect the health of the U.S. residents and it has strengthened the annual health National Ambient Air Quality Standard for fine particles ($PM_{2.5}$) to 12.0 micrograms per cubic meter ($\mu g/m^3$). The agency also retained the existing standards for coarse particle pollution (PM_{10}) (The national ambient, 2012).

Change in Food Security

Food yields will be affected by climate change. It will affect populations around the world but, primarily, climate change will make a greater impact in regions where warmer temperatures and reduced rainfall will likely occur.

Coastal cities will be affected by a reduction in food supply caused by rising sea levels, heavy storms and floods, and a reduction of arable land. These negative factors are increased by acidification, warmer waters and reduced river flows (Killmann, 2008).

Climate Change and Infectious Diseases

There is a projected global increased in the distribution and incidence of infectious diseases because of climate change effects, and this implies a crises that will have economic and social implications. Malaria and other vector-transmitted diseases take most of the attention from climate change-scientists and health professionals. The latitudinal, altitudinal, seasonal and inter-annual connection between climate change and disease, along with historical and experimental evidence, concludes that climate, in addition to other causes, highly influences infectious diseases in a nonlinear fashion (Lafferty, 2009).

Malaria and Climate Change

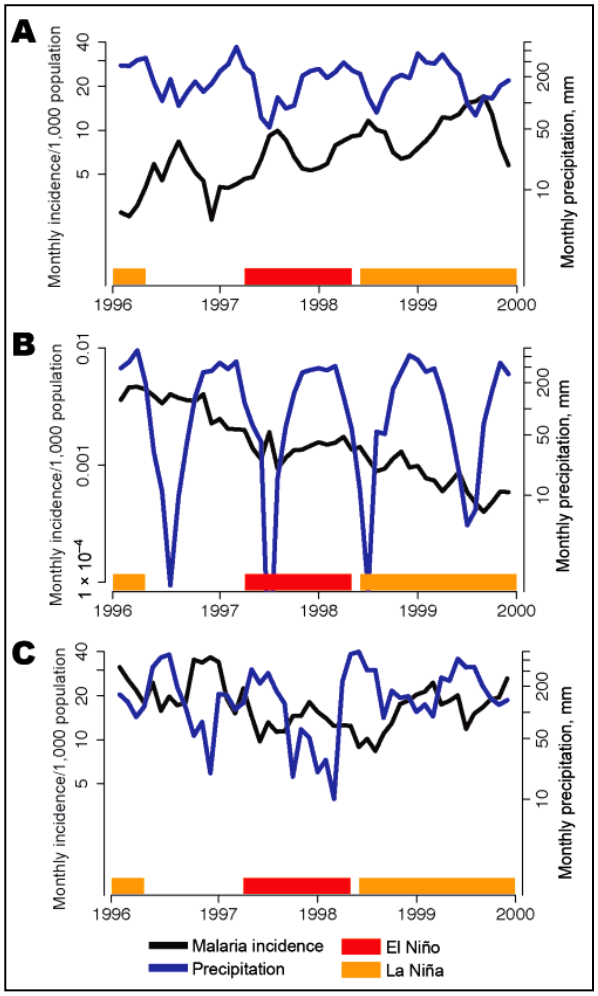
Climate change will alter the patterns and spread of malaria transmission. Rainfall affects malaria, acting not only on persistent of water bodies but also on physical and bio-chemical characteristics of aquatic environments. Heavy rains and flooding are known to cause major malaria outbreaks in semi-arid or arid lowlands; at the same time, spatial and temporal variations in rainfall determine the nature and scale of malaria transmission in highland areas (Gilioli & Mariani, 2011).

The Relation between Malaria and El Niño

After the El Niño events in South America and Asia, malaria transmission has been common, and it proved the strong association between higher temperatures and increased rainfall that creates the right environment for an increase in mosquito breeding sites because of surface water collections. Moreover, climate variability and drastic weather events have shown to have a direct impact on the increased risk of a St. Louis encephalitis outbreak (SLE). In general, SLE is restricted to specific areas, such as south of the 20°C June isotherm, but it has spread northerly where temperatures have been warmer in recent years. SLE also has the tendency to spread in periods of hot weather when temperatures are greater than 30°C for seven consecutive days (Hunter, 2003).

As an example, the relation between malaria and precipitation is shown in chart 4 in three different regions in Brazil.

Chart 4: The Relationship between Malaria and Climate (Olson et al, 2009).



The chart shows malaria incidence per 1,000 population (black lines) and mean monthly precipitation (blue lines) during La Niña (orange bars) and El Niño (red bars) events for the states of A) Amazonas, B) Mato Grosso, and C) Roraima, Brazil (Gilioli & Mariani, 2011). Furthermore, the chart shows precipitation drives malaria risk in the Amazon Basin, but the relationship varies in the uplands (more precipitation, more/less malaria), and is negative in areas dominated by wetlands and large rivers (more precipitation, less malaria) (Olson et al , 2009).

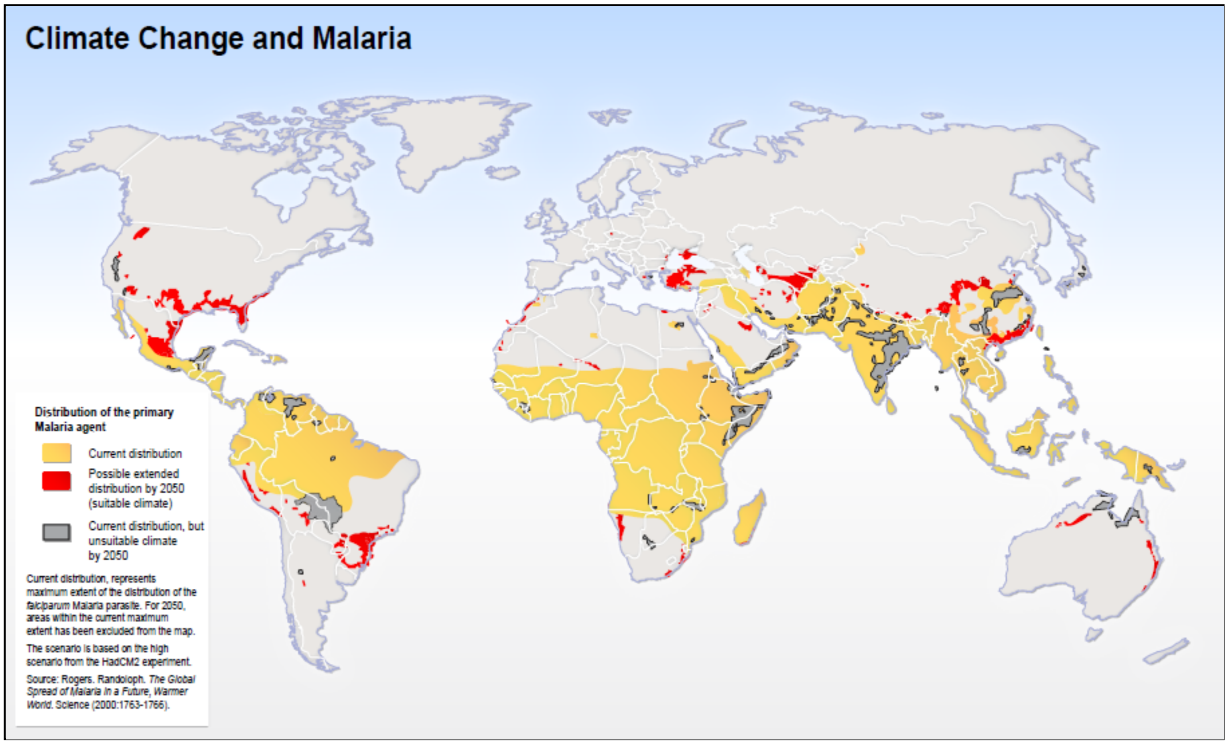


Figure 1: Climate Change and Malaria, Scenario for 2050 (Ahlenius, 2005).

The conditions and distribution of pests will change as climate conditions become more severe with climate change in the future. The primary malaria agent, the falciparum malaria parasite, will be able to spread into new areas, as displayed in this map, by 2050 using the Hadley CM2 high scenario. Yellow colored areas refer to the current distribution of the malaria agent. The red colored areas are possible extended distribution by 2050 (suitable climate). The dark grey areas represent the current distribution, but unsuitable climate by 2050 (Ahlenius, 2005).

Endemic Chagas Disease

Chagas disease *(American trypanosomiasis)* is a vector-borne disease. The disease is caused by a protozoon *(Trypanosoma cruzi)* and the transmission of the disease occurs through various species of "kissing bugs" *(Triatominae)* via bites, blood transfusion and other means. The disease affects more than 8 million people in Latin America. In the United States, there are 300,187 individuals infected by Chagas disease. Spain has the second highest number with an estimated 47,738 – 67,423 individuals (Rassi et al, 2010a).

The disease symptoms develop gradually, principally affecting the heart, where patients show progressive heart failure, cardiac arrhythmias or both, as well as intestinal problems (Aagaard-Hansen & Chaignat, 2010).

Foremost, it is the leading cause of the death and disability-adjusted life years (DALYs) lost that result from neglected tropical diseases (NTDs) in the Latin American and Caribbean (LAC) region. Chagas disease is one of the most prevalent NTDs in the Americas and it is among the primary causes of annual deaths and DALYs lost (Hotez et al, 2012).

Climate Change and Chagas Disease

Chagas disease is one of the most significant climate-sensitive vector-borne diseases in South America, and it is spreading throughout the continent. The "globalization" of the disease through climate change as well as other factors, such as migration (it can be increased by climate change impacts in certain regions), blood transfusion, etc., is a concern for developed countries, and these aspects are modifying and accelerating the transmission rate and distribution of the disease. The relation between Chagas disease and changes in temperature has been studied almost since the beginning of the disease's parasitological, clinical and epidemiological description. In 1916 Arthur Neiva, a Brazilian scientist and politician, reported the first cases of Chagas disease in Potosi, Bolivia. He conducted experimental work on the relation linking the influence of temperature variability on the evolution of *Triatoma infestans* embryos. The conclusion of the experiment demonstrated that warming accelerates the embryonic period (Carcavallo, 1999). Therefore, temperature can affect the distribution of the *triatomine* bug and the pathogen transmission efficacy through the vector. Changes in temperature and its relation to the transmission risk of vector-borne diseases can be listed as follow:

- ✓ Increase or decrease in survival of vector
- ✓ Changes in rate of vector population growth
- ✓ Changes in vector feeding behavior
- ✓ Changes in susceptibility of vector to pathogens
- ✓ Changes in incubation period of pathogen
- ✓ Changes in seasonality of vector activity
- ✓ Changes in seasonality of pathogen transmission

(Hunter, 2003).

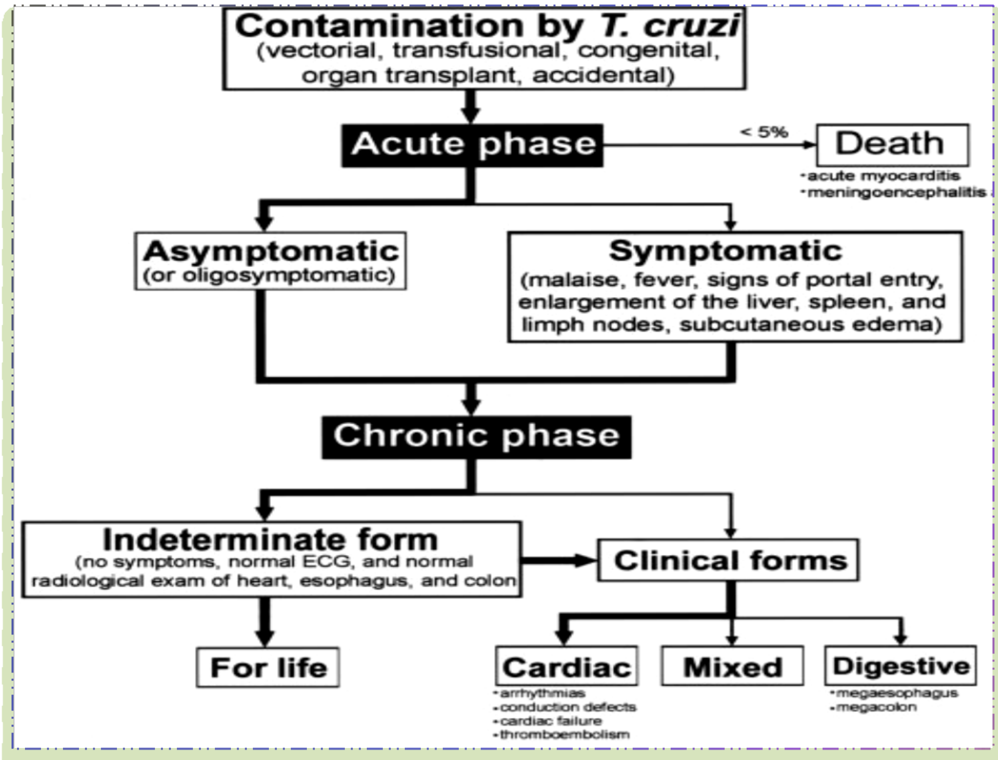


Figure 2: Diagram of the Natural History of Chagas Disease (Rassi et al, 2007b).

As the figure shows, there are two phases of the human disease: the acute, which will start about one week after the initial infection and is habitually asymptomatic; and the chronic, which is subdivided into indeterminate and clinical (cardiac, digestive or mixed) forms. The thickness of arrows generally point to the relative probability of a depicted pathway (Rassi et al, 2007b).

Theoretically, climate change could affect the transmission rate of Chagas disease but so far there is not enough evidence to support that. It is a climate-sensitive disease that responds to temperatures, but other important factors are involved for the spread of vector-borne diseases like Chagas (Haines, 2012d). Nonetheless, it is considered necessary to emphasis the susceptibility of Chagas disease to temperatures and the "globalization" of the disease to non-endemic countries. It estimated that up to 300,000 immigrants in the USA are chronically infected with *T. cruzi*, with estimated 30,000 – 45,000 cases of Chagasic cardiomyopathy, and as many of 300 congenital infections, yearly (Klein et al, 2012).

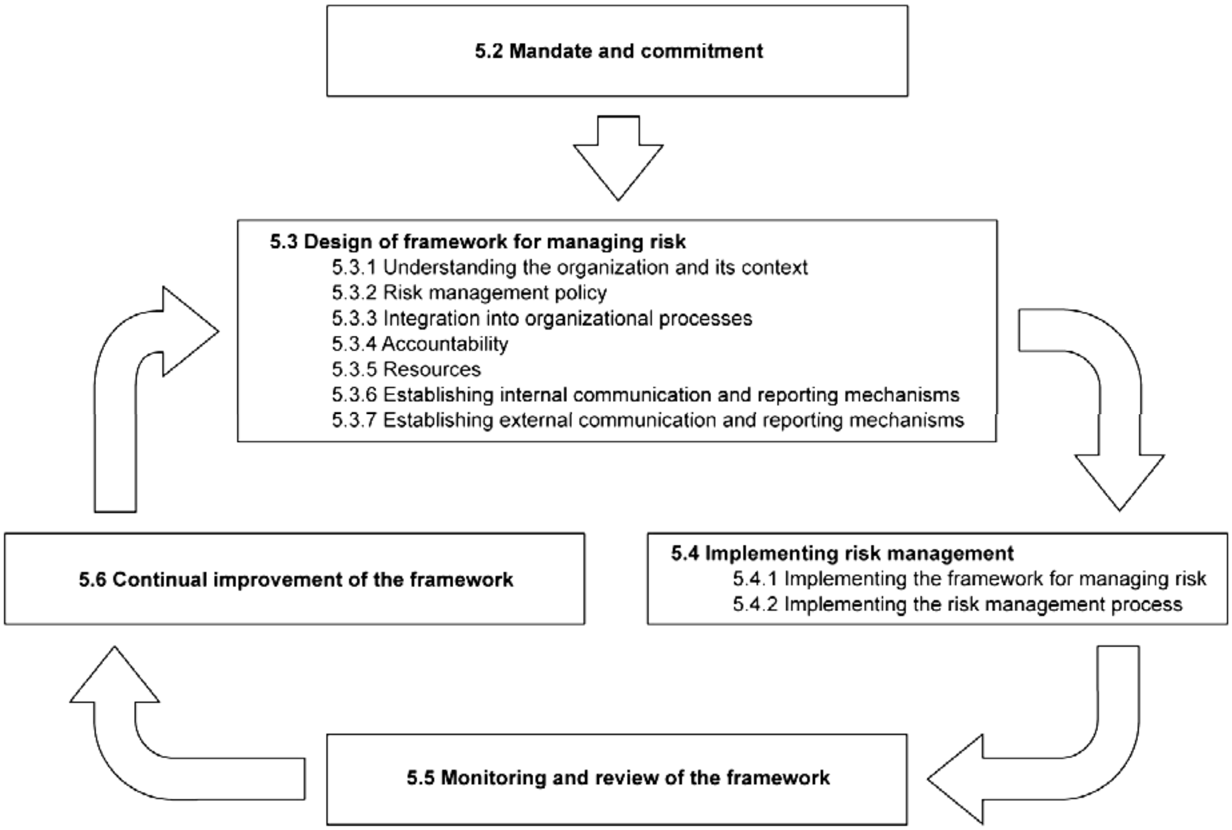
Risk Management

The cases examined will identify the effect of risk management and will explore the value of integrating a risk management framework such as ISO 31000. Climate events represent risks to people, organizations, and infrastructure and network systems. These risks arise from “normal” day-to-day, seasonal and year-to-year variability in climate, as well as regional climate differences (Climate change impacts, 2006). ISO 31000 provides a structure for managing the increased risk to cities and their residents due to climate change impacts. The risk management framework aims to help businesses and organizations to enumerate risks related to climate change impacts; prioritize risks that require further attention; and establish a process for ensuring that higher priority risks are managed effectively (Climate change impacts, 2006).

ISO 31000 is focused on the management of risk that impacts the achievement of objectives. Ensuring the objectives are addressed by top management, (city leaders, etc.), the management of risk is specifically included in the system. It requires the risk management process to be used in the development of business cases and strategic plans so that decision makers are presented with the risks that must be managed along with controls that will keep them at an acceptable level (Knight, 2013).

The ISO 31000 framework for managing risk follows a typical plan-do-check-act cycle. The elements of the framework are described in the following figure.

Figure 3: ISO 31000 Framework for Managing Risk (Risk management, 2009).



Governance of Risk Management

The organization's board of directors represents the center of its risk-management governance structure. It pursues shareholders interests and presents the mandate and commitment to risk management (Pojasek, 2011).

Design of the Risk Management Program

The process of designing or planning the company's risk management program includes the following components:

- Understanding the organization and its context
- Establishing risk management policy
- Creating accountability associated with the management of risk
- Integrating risk management into organizational processes
- Providing adequate resources for risk management
- Establishing internal and external communication
- Reporting mechanisms

(Pojasek, 2011).

Implementation of the Risk Management Program

Implementation means putting the theory into practice, making certain the risk owners understand the risk management process in carrying out the elements specified during the program's design phase. Through risk assessments, the risk management activities take place and decisions and business processes actually factor in risk thinking (Risk management update, 2009).

Monitoring and Review

The effectiveness of the various risk management elements and activities must be confirmed and meet the expectations of performing with excellence. Gaps and issues need to be identified for further documentation and applicable solutions (ISO 31000 overview, 2009).

Continual Improvement of the Framework

Decisions and actions should be made on how the risk management framework, policy and plan can be enhanced. The actions mentioned will generate necessary improvements in the risk management plan and the culture of the organization (Risk management, 2009).

Risk Management Process

ISO 31001 articulates a clear process for managing risk:

• Establishing context: It is important to view every risk in the context of the organization and the interests of the stakeholders.

• Risk identification, analysis and evaluation: The organization assesses key business risks using risk identification, analysis and evaluation methods.

• Risk treatment: The organization "treats" unacceptable risks in an effort to lower their risk threshold.

• Communication and consultation: The organization communicates all these activities to stakeholders in order to provide a proper level of engagement and consultation with organization management.

• Monitoring and review: The organization carries out extensive monitoring and review to determine how its risk profile is changing over time.

• Further risk assessment: The organization needs to carry out additional contextual analysis and further risk assessment and treatment when appropriate (Pojasek, 2011).

ISO 31000 can be used to establish a risk management policy, ensure that risk is managed properly and manage and control risk. Furthermore, it can explain how risk should be managed and controlled and provide a framework to develop risk management procedures and guides. Therefore, the risk management framework can reduce uncertainty in how to deal with climate change in the megacities by improving knowledge and understanding of risk.

Chapter 3 Research Methods

The case study method was used in this research to examine how climate change can disproportionally affect the health of the urban poor. The selected research method has been used to support the hypothesis that the urban poor's health risks are disproportionally affected in comparison with the rest of the population, and it follows an established multi-case study framework. The case study design emphasizes detailed contextual analysis of a limited number of events and conditions and their relationships (Yin, 2009).

The findings follow a trend or inclination that can be verified and consequently applied to other situations (Stewart & Cash, 2005).

Table 2: Case Study Design

Case Study Design Components	Application to the Research
Research Question	How can climate change disproportionally affect the urban poor?
Research Hypothesis	Because the urban poor don't have the infrastructure and resources to deal with the effects of climate change, they are more susceptible to health risk impacts from extreme weather events.
Unit of Analysis	Climate change health impacts of the urban poor in New York City; Los Angeles, Beijing, and Rio de Janeiro.

Data Interpretation Techniques	Explanation building in multiple case studies, cross-case synthesis and complex time series (Yin, 2009).
Criteria for Interpreting Data	Construct validity, internal validity, external validity and reliability (Yin, 2009).
Physical artifacts	Articles, online research documents.

The case study of unit of analysis is climate change health impacts of the urban poor in the cities of New York (NYC), Rio de Janeiro, Los Angeles and Beijing. The case study method requires the researcher to collect different types of evidence or data from multiple sources to support the research hypothesis to ensure construct validity.

The researcher applied for an exemption from the Committee on the Use of Human Subjects at Harvard University before any formal interviews have been conducted. The expected sources of evidence are presented in Table 3.

Table 3: Sources of Evidence

Source	**Evidence**
Documentation:	Scientific reports, data reports, articles and
	documentation regarding public health reports,
	urban populations and major cities.
Archival Records:	Records of different cases of health issues caused
	by climate change among the urban poor.
Interviews:	Interviews with key researchers and leaders in
	climate change and public urban health will
	supplement documentation and support archival

	documentation.
Direct Observations:	None.
Participant-Observation:	None.

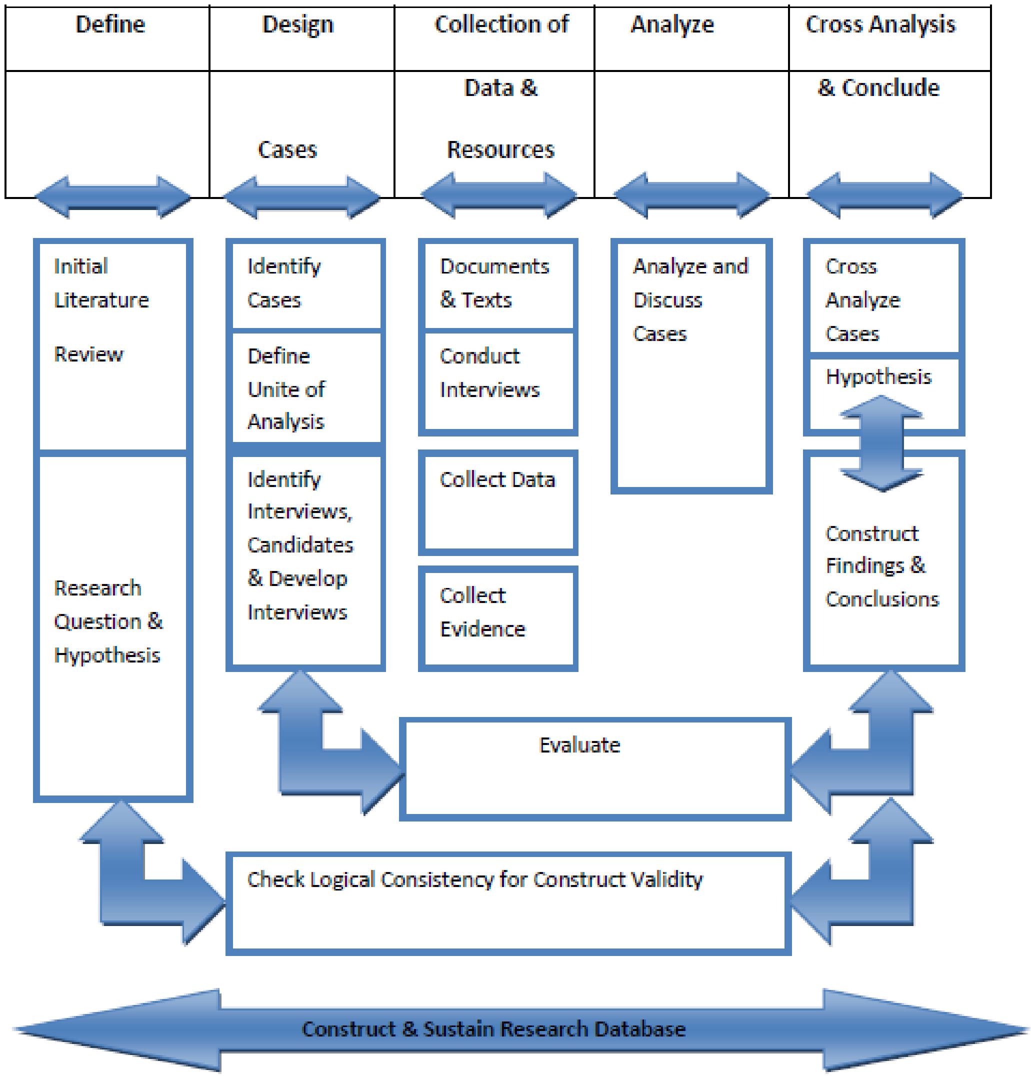
Data Analysis

After collection, careful analysis of the data follows the case study protocol. The analytical strategy supports the theoretical propositions inferred in the stated hypothesis (Yin, 2009).

As the data was collected it was analyzed according to the research protocols of pattern matching and explanation building (Yin, 2009). Pattern matching is a comparative analysis that looks for coinciding patterns from each case to identify evidence that will support the hypothesis. Explanation building is a special type of pattern matching and its goal is to analyze the data by building an explanation about the case, in that way that supports the hypothesis. It is mainly relevant to explanatory case studies. This form of analysis deals with creating causal links among the various forms of evidence, and by explaining what happened and why.

The cross-case synthesis only applies to multiple-case studies and pertains in this particular case as the research compares four major cities. Within this approach each case is examined as a separate study. The cases are then matched, applying methods that unify the collected data in such a way that they are comparable (Yin, 2009). The research protocol that will be followed to achieve these results is shown in the following figure.

Figure 4: Research Protocol Flowchart (Yin, 2009).



Risk Management ISO 31000

Another method that will be used to create a concise plan to major cities for preparing and mitigating climate change effects on the urban population is the Risk Management method ISO 31000. It establishes a framework for managing risk within an enterprise system. This framework follows a typical plan-do-check-act cycle. ISO 31000 provides a set of tools for risk management, including a wide range of root-cause analysis tools. It makes clear effective risk management, offering numerous opportunities for improvement (Pojasek, 2011). The benefit of reducing risks in the world's megacities must be greater than the cost of managing them.

Limitations of Method

There are several anticipated limitations to the proposed research project. Some limitations are bias, and time and resource constraints. Another limitation is the availability of data. While information on major cities is commonly available, it may be difficult to collect sufficient data on specific health issues impacting the urban poor. Climate change is a wide topic for research and the available information about health issues affecting the urban poor may not be sufficient to collect reliable data.

This research depended greatly on an environment of openness and trust. The research process can be undermined if either of these factors is not present. The research protocol helps to focus the researcher on the cases and limit diversions.

Chapter 4 State of Health in the World

Society's sustainable development is related to the well-being of populations. Their physical, social and psychological good health is important to maintain a balanced and productive society. Climate change directly harms human beings in extreme weather events and indirectly with changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure (Confalonieri et al., 2007a).

Population health has improved greatly over the last 50 years. For example, average life expectancy at birth has increased worldwide since the 1950s, first and foremost in the developed world (Life expectancy, 2012). However, in the 21^{st} century, some developed countries will experience a decline in life expectancy according to *The New England Journal of Medicine.*

S. Jay Olshansky, PhD, of the University of Illinois at Chicago, explains that obesity will have a negative effect on life expectancy. The United States population is projected to have a decline in life expectancy of 5 years in the next few decades unless obesity is combated aggressively to slow the rate of this chronic medical condition (Dollemore, 2005).

Inequalities in public health exist throughout different regions of the world. In many countries in Africa, life expectancy has dropped in the last 20 years mainly because of the HIV/AIDS epidemic, and some populations in the African continent are currently experiencing a 20% increase in infected inhabitants (e.g., Sub-Sahara Africa, which is disproportionally affected) (United Nations Programme, 2011).

The United Nations Millennium Development Goal (MDG) of reducing under-five mortality rates by two-thirds by 2015 is unlikely to be reached (Sachs & McArthur, 2005). As stated in the last paragraph populations living in poverty throughout the developing world are deeply burdened with untreated communicable diseases and are habitually marginalized by the health sector. These diseases are presently known to as Neglected Diseases of Neglected Populations **(**e.g**.,** Chagas disease, ectoparasitic skin infestations and parasitic zoonoses) (Ehrenberg & Ault., 2005). The aforementioned health issues are an indication of how people are disproportionally affected by diseases and, consequently, it provides an idea about how climate change can exacerbate the health risks to deprived populations that are exposed throughout the globe.

Population Health Sensitivity to Climate Change

Assessing climate change impacts on health and the vulnerability of the urban poor requires an understanding of the population's capacity to confront and mitigate the impacts of climate change, and the sensitivity of the population to health risks associated with climate variability (Ebi et al., 2005). There have been five main empirical studies on how climate change affects health that are amalgamated in the following table:

Table 4: Empirical Studies on Climate Change Health Effects (Parry et al., 2007).

1) Health impacts of individual extreme events (e.g., heat waves, floods, storms, droughts, extreme cold);
2) Spatial studies where climate is an explanatory variable in the distribution of the disease or the disease vector;
3) Temporal studies assessing the health effects of inter-annual climate variability, of short-term (daily, weekly) changes in temperature or rainfall, and of longer-term (decadal) changes in the context of detecting early effects of climate change;

4) Experimental laboratory and field studies of vector, pathogen, or plant (allergen) biology;

5) Intervention studies that investigate the effectiveness of public-health measures to protect people from climate hazards.

The studies conducted on climate change effects on health represented in the above figure are particularly challenging due to several factors, such as the environmental conditions of the living areas and the adaptive behavior of people (Portier et al., 2010a). Consequently, a variety of different factors are determined to establish the vulnerability of the population to climate change effects on health including biological susceptibility, the population's social and financial well-being, and their built environment (Portier et al., 2010a).

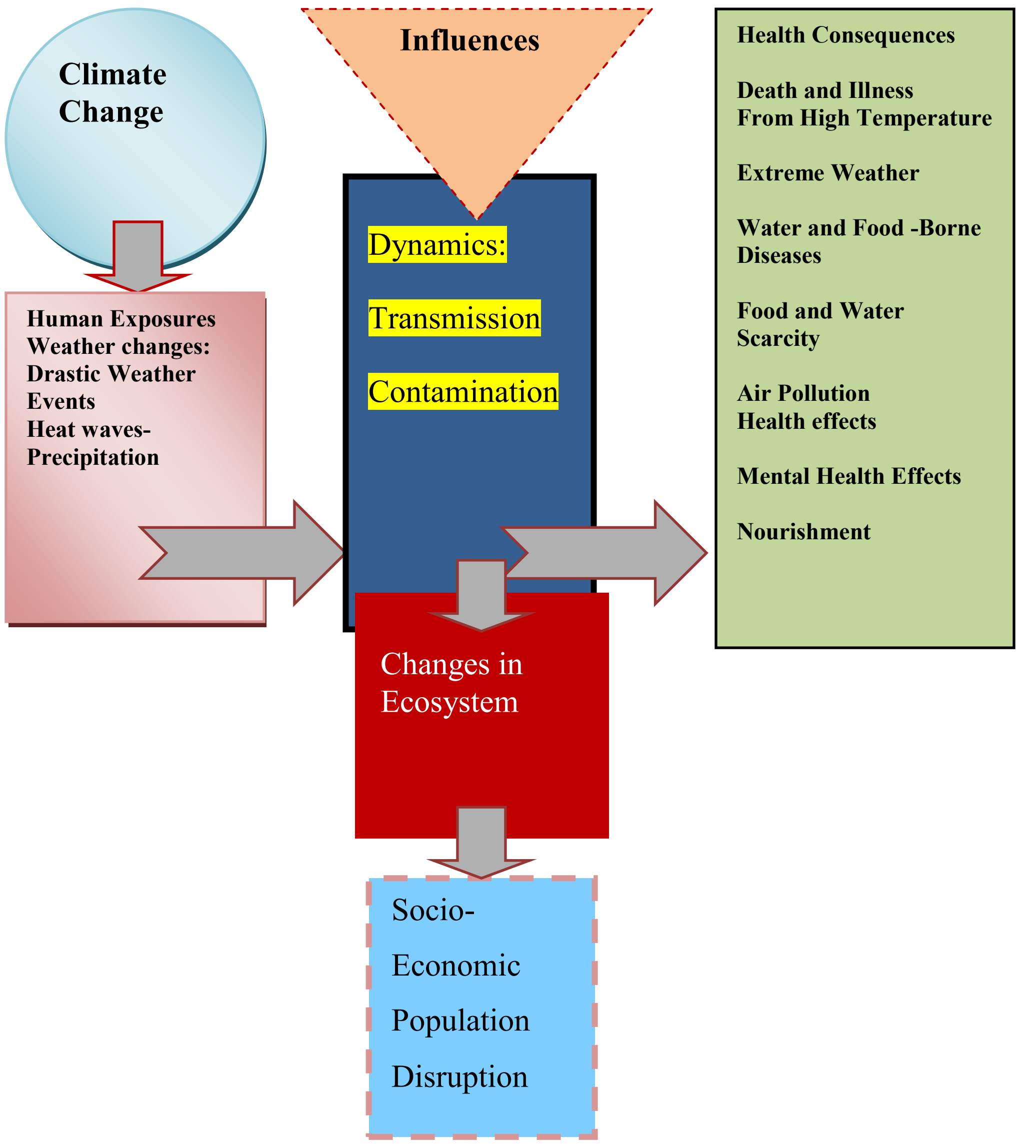
Preventive Measures and Health Risks Associated with Climate Change

The World Health Organization created the *Consultation on the Essential Public Health Package to Enhance Climate Change Resilience*, which to develop adequate preventive measures to mitigate climate change effects and determine the scale to which health risks are already incorporated into climate change adaptation planning (Neira et al., 2010).

The foremost concerns related to climate change and the health impacts on populations are injuries, disability, drowning, and heat and cold stress. There are other health risks associated with climate change with an indirect impact, such as water-and food-borne diseases, malnutrition, psychological stress and vector-borne diseases (e.g., malaria, dengue, kala-azar, plague, Nipah virus, swine flu, bird flu, SARS, chikungunya).

The Climate Change and Health Promotion Unite of the World Health Organization has the mission of building the capacity of health systems networks to confront the health risks associated with climate change (Neira et al., 2010). The following figure shows the interrelations of climate change impacts on human health.

Figure 5: Climate Change Affecting Human Health (McMichael et al., 2003a).



Extreme weather events have been increasingly frequent in the last two decades and climate change effects on human health are presently evident as a growing number of studies led by many international organizations, such as the Intergovernmental Panel on Climate Change, demonstrate the effects of climate change on the spread of infectious diseases (Haines et al., 2006c).

Climate Change and Health: Vulnerability of Populations

The effects of climate change on health have been reported by the Intergovernmental Panel on Climate Change (Confalonieri et al., 2003b). Direct impacts such as thermal stress, floods and storms injury and indirect impacts such as borne-vector diseases, water-borne pathogens, water quality, air quality, and food availability and quality are concerns for urban populations. The socio-economic situations of the urban residents as well as the environmental conditions of the city are important factors that amplify the impacts of climate change on population's health (Climate change and, 2003).

Another factor to assess the vulnerability of populations is the existing city's adaptation and mitigation strategies and the viability of the institutions, technology in place, and risk management planning to be implemented when the city's leaders need to act upon the situation (Climate change and, 2003).

Table 5: Health Impacts of Climate Change: Classification (Markandya & Chiabai, 2009).

	Health impacts	
Climate impacts	**Direct**	**Indirect**
Temperature extremes (heat or cold waves).	Heat- and cold- related stresses	- Respiratory and cardio-vascular diseases due to the combined effect of exposure to high temperature and air pollutants
Extreme weather events		
Floods, landslides, storms, cyclones	Deaths and injuries	- Water-borne diseases caused by water contamination and poor sanitation conditions - Psychological morbidity
Droughts	–	- Malnutrition and under-nutrition, due to loss of agricultural production - Water-borne diseases caused by decreased water access and malnutrition - Vector-borne diseases due to changes in vector transmission and stagnation/contamination of small rivers and drainage canals - Respiratory diseases due to increased air-borne particulate matter and increased vulnerability caused by malnutrition and other diseases
Increased	–	- Vector-borne diseases due to higher risk of transmission and changes in geographical and

	Health impacts	
Climate impacts	**Direct**	**Indirect**
temperature		seasonal distribution - Food-borne diseases due to food contamination

The table above shows the different types of health risks impacting the urban population's health. The health impacts that are relatively direct are usually caused by weather extremes, in addition to the health consequences of various processes of environmental change and ecological disruption that occur in response to climate change. Furthermore, there are diverse health consequences that need to be accounted (e.g., traumatic, infectious, nutritional, psychological) that occur in demoralized and displaced populations in the wake of climate-induced economic dislocation, environmental decline and conflict situations (McMichael et al., 2003a).

Health and Poverty

Poverty is an important factor that exacerbates the health effects of climate change on populations. The insufficient access to health care for the poor is detrimental to the poor's susceptibility to drastic weather events. The risk of displacement is another factor of climate change for the poor, and the risk of disease is much higher. Therefore, preexisting conditions and situations increase the stress and vulnerability of the poor to extreme weather events and environmental degradation (Portier et al., 2010a).

People Living in Slums

Major cities in the developing world are experiencing an increased number of people living in slums. A particular characteristic of big cities in the developing world in comparison with cities in industrialized countries is that urban growth is generally uncontrolled. The map shows a small proportion of city dwellers with improved access to sanitation in many parts of the world (Bournay, 2006).

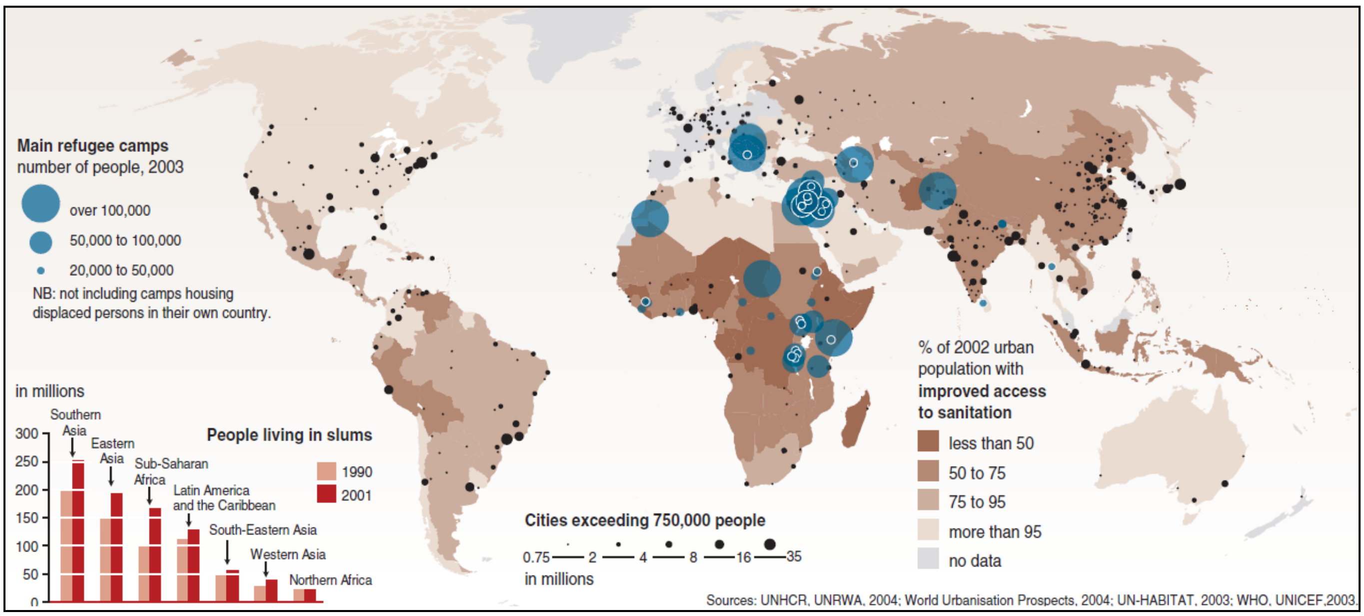


Figure 6: No shelter - Refugees, Sanitation and Slums (Bournay, 2006).

Vulnerable Urban Populations

Disease burdens can drastically increase as climate change increases temperatures in urban areas. Major cities are experiencing a higher rate of urban population growth than rural areas, and that factor, along with the increased percentage of low-income residents that are not capable of mitigating the effects of drastic weather events, magnifies the vulnerability of the urban poor to climate change (Parry et al., 2008).

The United Nations conducted a comprehensive study on urbanization and it concluded that the urban population increased from 220 million in 1900 to 732 million in 1950, and is estimated to have reached 3.2 billion in 2005 (World urbanization prospects, 2012). Major cities in developing countries are experiencing a sharp increased in urban populations in comparison to industrialized countries. The urban population comprised 74% of developed regions and 43% of developing regions. In 2030, approximately 60% of the global population will be living in urban areas (Parry et al., 2008).

Slums in developing countries contribute to an increased risk of climate change-related impacts, as population density plays a major factor in exacerbating the issues faced by the urban population. The frequency and intensity of heat waves will grow as higher temperatures and the heat-island effect work synergistically in megacities (Parry et al., 2008). Moreover, slums and precarious settlements are a tangible reality in urban cities that show deprivation and exclusion among the urban poor. Therefore, all of these inequalities and factors that shape this particular segment of society expose vulnerabilities to climate change, which can be among the world's most life-threatening environments (Bartlett et al., 2012).

Table 6: Population of Urban Agglomerations of the Four Megacities under Study and their Average Annual Rates of Change. Selected Periods: 1970-2025 (Revision of World, 2011).

	Population (millions)				**Average annual rate of change (percentage)**		
Urban agglomeration	***1970***	***1990***	***2011***	***2025***	***1970-1990***	***1990-2011***	***2011-2025***
Beijing	4.4	6.8	15.6	22.6	2.14	3.96	2.66
Los Angeles-Long Beach-Santa Ana	8.4	10.9	13.4	15.7	1.31	0.99	1.13
New York-Newark	16.2	16.1	20.4	23.6	-0.03	1.12	1.05
Rio de Janeiro	6.6	9.6	12.0	13.6	1.84	1.05	0.93

Climate Change and Urban Children: The Forgotten Population

Children with their physical, physiologic and cognitive immaturity are most often susceptible to health risks and subsequently climate change effects. Socio-economic factors also play an important role in adaptation and preparedness to climate variability and health impacts on children living in urban areas. As drastic weather events gradually increase, children will disproportionally suffer the consequences of climate variability and, as a result, they will be particularly exposed to certain infectious diseases, air pollution and stress from heat waves (Shea, 2007).

There are not enough data to compare mortality and illnesses rates among children in developed and developing countries. Nevertheless, one study compared heat wave related deaths in three major cities between 1991 and 1994: Delhi, Sao Paulo and London. The cities under the study are amalgamated into different demographic groups composed of diverse ages and socio-economic statuses. Children were associated with the majority of deaths. Most of the fatalities occurred under the age of 15 due to communicable diseases. In contrast, London and Sao Paulo presented a different scenario were the population over 65 experienced 80% and 48% of deaths respectively. Common data reflected that over 50% of all deaths were attributed to cardio-respiratory causes. According to the study, children need particular attention during heat waves because of their vulnerability to climate change and inability to adapt to climate hazards (Sverdlik, 2011).

More than one billion children are living in urban areas and the number is increasing rapidly, as half of all people already live in major urban settlements. Urban children are marginalized due to lack of access to health care and facilities to prevent and treat diseases and disaster risks (Bartlett et al., 2012).

Children's Health at Risk

New data and climate models continue to surface showing greenhouse gas (GHG) emissions modifying the atmosphere and resulting in higher mean temperatures. The climate variability created by GHG emissions creates severe storms and droughts leading to serious implications for children's health. The health impacts of climate change in children will be equally felt in developed and developing nations. Most of the mortality and morbidity rates related to climate change will come from the accessibility of drinkable water, shortage of food and the accelerated spread of vector-borne diseases where children are highly susceptible (Bernstein & Myers, 2011).

Climate variability (e.g., higher temperatures, heavy rains and droughts) leads to outbreaks of diarrheal disease, including cholera, cryptosporidiosis, and other water-borne diseases. More than one billion people are presently struggling to have access to drinkable water, food and the basic resources for subsistence. Diarrheal diseases are the cause of approximately 7% of childhood deaths worldwide as unsafe water, and poor sanitation and hygiene are the main factors for the illnesses (Bernstein & Myers, 2011).

Chart 5: Global Climate Change/Death Data by Age Categories (Sheffield & Landrigan, 2011).

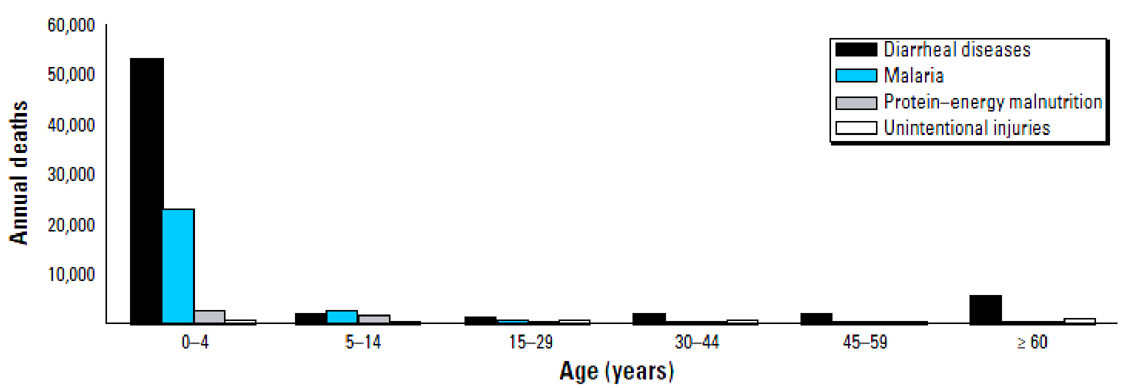


Chart 5 shows annual deaths attributable to global climate change: 2004 annual data in total numbers divided by age categories. The inequalities of children's death rates in comparison to other age groups are evident (Sheffield & Landrigan, 2011).

Climate Change and Undernourishment

Quantity and quality of nutritional food for children represent perhaps the greatest threat to their health. As stated before, more than one billion people suffer from malnutrition, and climate change will have a drastic impact on the accessibility of food and its nutritional value. Considering the statistics from undernourished children in developing countries, nearly one in three children are underdeveloped and this factor highlights the relation between undernourishment and childhood morbidity and mortality (Bernstein & Myers, 2011).

Air Pollution and Urban Children

Children living in urban areas are susceptible to air pollution. Asthma in children causes school absenteeism and, more importantly, is the primary cause of morbidity. Air pollution triggers asthma attacks, and climate change is increasing the effects of pollution and air particulates that directly affect children's health (Bernstein & Myers, 2011). The following chart reflects the vulnerability of children to the disease and shows the rise of asthma cases in the United States.

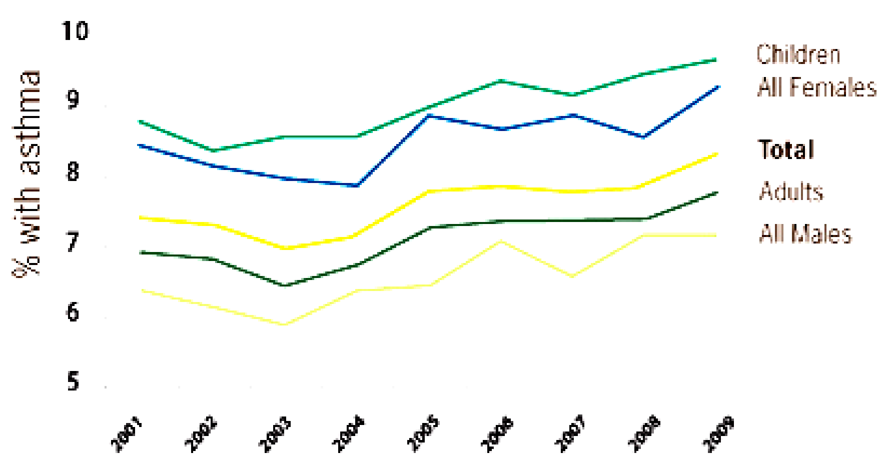


Chart 6: Asthma by Age and Sex US, 2001 - 2009. Percentages are age-adjusted SOURCE: National Center for Health Statistics; 2010 (Asthma in the, 2011).

Scarcity of Resources and Displacement

In certain regions of the world, climate change makes food and water supplies scarce. Cities near coast lines will become unlivable and will make population displacement a common path to chaos where children will suffer the most. Approximately one-third of the world population lives within 62 miles of the shore and less than 30 feet above sea level, and climate change impacts on urban populations will create a vast number of refugees, which will affect cities' social and economic activity. Mass population displacement increases risk and creates conflict over natural resources. The consequences of the aforementioned population displacement will affect the health status of people in general, and children in particular, being the population's sector that will suffer the most severe physical trauma, malnutrition, and infectious and psychiatric disease (Bernstein & Myers, 2011).

Health of the Homeless and Climate Change

Homeless populations have greater exposure and propensity to acquire diseases than the housed population. As climate change effects are more frequent, the homeless have poorer protection to climate events and therefore they have a higher vulnerability to climate-sensitive diseases. The poor tend to occupy high-risk urban areas and this result in greater rates of disease and death due to the health effects of heat waves, air pollution, droughts, floods and vector-borne diseases consequential to drastic climate variability (Ramin & Svoboda, 2009).

Urban cities are experiencing not only a steady growth in population but an increasing homeless population that is marginalized by social and economic factors, despite the positive outlook for capital growth and prosperity in the 21st century among megacities. As of today, there are not enough data representing the effects of climate change on the homeless population (Ramin & Svoboda, 2009).

However, knowing this segment of society is highly vulnerable to climate change because of their inability to adapt and their lack of access to health care centers and health care systems, the susceptibility of homeless to climate change impacts is likely to have a strong impact on their health. New York City has approximately 5 to 8 million homeless, and approximately 1% of homeless individuals who have experienced homelessness in the last 5 years have used an NYC shelter each year (Ramin & Svoboda, 2009).

Chronic diseases, heart disease, cardiovascular disease as well as other conditions, such as hypertension, high cholesterol and diabetes, are health risks common in the urban poor and, subsequently, the homeless population living in cities. Climate change and its impacts on health exacerbate those health conditions and accelerate the rate of morbidity and mortality among them. Homeless children in the United States are experiencing an increase in asthma attacks (six times the national rate) and a frequent occurrence of mental illness such as depression and schizophrenia.

Climate variability and the inaccessibility of health centers and adequate health care for the poor affects homeless children, especially since children who live on the streets are exposed to warmer temperatures that create a fertile ground for the spread of diseases. Therefore, low socioeconomic status and poor housing conditions are known risk factors for vulnerability to climate change impacts on health and consequently cause death among this particular and deprived urban population (Ramin & Svoboda, 2009).

Incidence, Prevalence and Morbidity

The prevalence of asthma has increased since the early 1960s and this trend affects children and adults with diverse backgrounds, lifestyles and locations. Furthermore, on a global context, the cases of other atopic disorders have also risen during the same time frame. These disorders are allergic rhinitis, atopic eczema and urticaria (Beggs & Bambrick, 2006).

The connection between allergic diseases such as asthma and aeroallergens is well established. Asthma incidents are increased as a result of faster plant growth, earlier plant maturity and longer growing seasons, plus earlier pollen seasons, increased season duration and increases in both pollen quantity and allergenicity with consequences leading to a rise in disease frequency. Climate change can be a potential factor for the increase of susceptibility of asthma and also its morbidity within the affected population's group. Infants are highly vulnerable and their exposure to allergens induces susceptibility to asthma and other atopic conditions such as eczema and allergic rhinitis (Beggs & Bambrick, 2006).

The substantial increase in pollen production as a result of elevated CO_2 concentrations is a cause of concern, and the trends of increased pollen amounts in the late 1990s are associated with local rises in temperatures. Consequently, the evidence suggests increased temperatures are connected to the strong allergenicity in pollen from trees (Beggs & Bambrick, 2006).

Pollen production from ragweed grown in chambers at the carbon dioxide concentration of a century ago (about 280 parts per million [ppm]) was about 5 grams per plant; at today's approximate carbon dioxide level, it is about 10 grams; and at a level projected to occur in about 2075 under the higher emissions scenario, it will be approximately 20 grams (Karl et al, 2009).

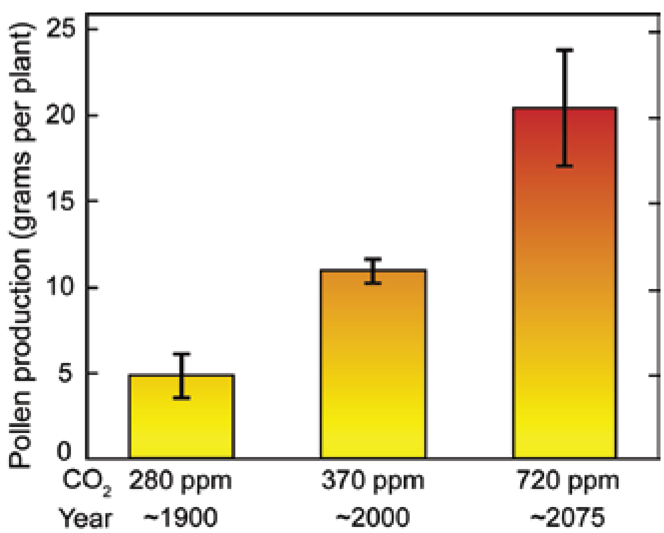


Chart 7: Climate Change Impacts on Pollen Aeroallergens (Karl et al, 2009).

The Developed World

Climate Change, Food Security and Health Impacts

Food security will be at risk in developed countries as anthropogenic GHG emissions and natural "climate forcings" (other mechanisms that lead to climate variability such as stratospheric volcanic aerosols) will lead to detrimental impacts on agriculture and food processing. Therefore, responding to these risks and adapting to climate change becomes crucial in the agricultural and food production industry and the response will be led by mitigation strategies with proposals to modify farming and food systems to reduce GHG emissions associated with the food chain. As another alternative to minimize GHG emissions, biofuels can play an important role in mitigating climate change impacts on agriculture and food production. Nonetheless, all the above initiatives will change the type of food availability to consumers in developed countries. Many nutritional components of the food consumed will change and consumer choice will be influenced by these modifications (Lake et al, 2012).

Food Sourcing, Consumption and Its Consequences

The modification of food belts is projected with climate change, and food consumed will be distributed from different regions around the globe. For example, according to the World Cancer Research Fund American Institute for Cancer Research of 2007, the United Kingdom obtains much of its selenium from grain (the element selenium may be protective against several types of cancer). From 1970 to 2000, there was a 50% reduction in dietary selenium consumption in the U.K. which was the result of a shift to the consumption of grain that was imported from Canada. Furthermore, food safety risks are another factor of importance. Climate change alters the locations where food is produced. In addition, as human behavior is affected by climate, and with the impacts of climate change, people may tend to consume different foods and subsequently this will impact food safety and nutrition (Lake et al, 2012).

Without a global commitment to reducing GHG emissions from all sectors, including agriculture, no amount of agricultural adaptation will be sufficient under the destabilized climate of the future (Beddington et al, 2012).

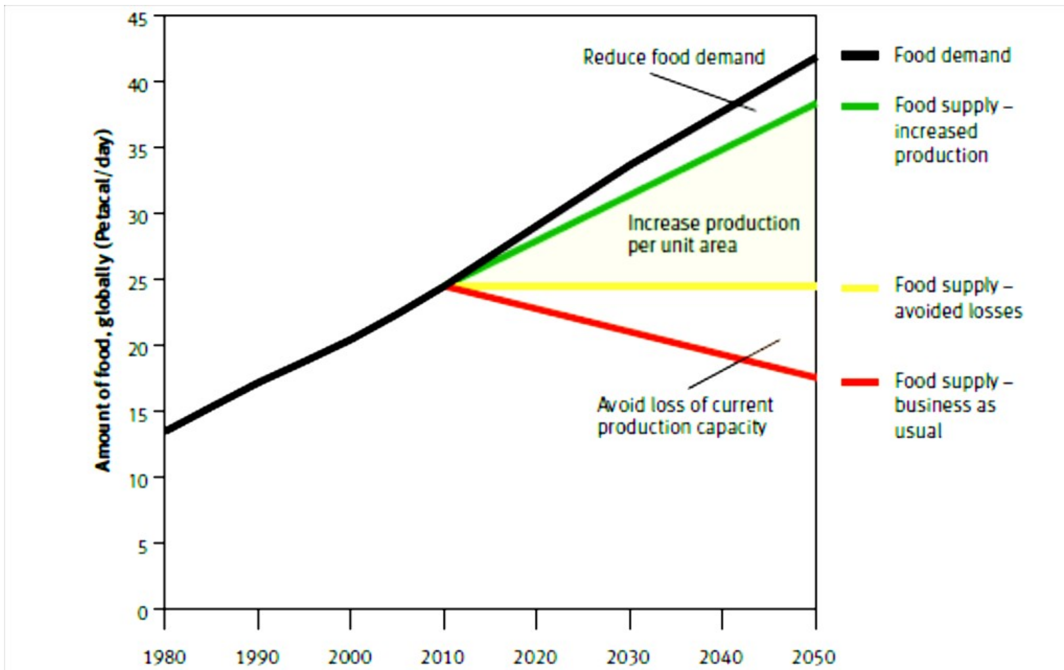


Chart 8: Balancing Food Supply and Demand.

Source: B Keating, CSIRO Sustainable Agriculture, based on Keating and Carberry (2010) (Beddington et al, 2012).

Globally, food demand will grow in the future due to population growth and changing diets (*upper line*) and food supply must somewhat exceed food demand if everyone's needs are to be met and food prices are to remain affordable. Under a "business as usual" approach, food production will decrease over time due to land degradation, climate change and the emergence of new pests (*lower line, post 2010*) (Beddington et al, 2012).

The large resulting gap between food supply and demand can be bridged by simultaneously applying three general approaches:

(1) Avoiding losses in current productive capacity can include actions to adapt to or mitigate climate change, to reduce land and water degradation and to protect against emerging pests and disease.

(2) Increasing agricultural production per unit land area can be achieved through use of improved technologies, practices and policies; more efficient use of existing agricultural land; and targeted expansion of agricultural land and water use (where negative environmental impacts are minimal).

(3) Reducing food demand can be accomplished through efforts to promote healthier and more sustainable food choices, and to reduce food waste across supply chains.

None of these three approaches alone are sufficient and all three require substantial innovation in the food system (Beddington et al, 2012).

Chapter 5 Assessment of the Potential Future Health Impacts of Climate Change

Developing an evaluation of potential future health impacts of climate change can be a valuable tool to prognosticate and address the health risks and consequences associated with climate variability. The framework for the assessment has to be performed highlighting the issues presented by climate change impacts on health according to the region, health outcomes and adaptation. The following table describes in detail the challenges and limitations faced by developing a comprehensive evaluation of health impacts.

Table 7: Health Impacts Evaluation (Confalonieri et al., 2007b).

- Limited region-specific projections of changes in exposure of importance to human health;
- The consideration of multiple, interacting and multi-causal health outcomes;
- The difficulty of attributing health outcomes to climate or climate change *per se*;
- The difficulty of generalizing health outcomes from one setting to another, when many diseases (such as malaria) have important local transmission dynamics that cannot easily be represented in simple relationships; limited inclusion of different developmental scenarios in health projections;
- The difficulty in identifying climate-related thresholds for population health;
- Limited understanding of the extent, rate, limiting forces and major drivers of adaptation of human populations to a changing climate.

Disease Outbreak and Climate Change

There is definite evidence of the relation between climate change, health risks, and the long term consequences to the global population. Moreover, disease outbreak in uncontrollable proportions disrupts the lives and displaces millions of people, forcing them to migrate. The ability to stop what is happening will continue to decrease day by day if world leaders do not take action. However, to roll back the clock, or even to slow down changes that are already in the system is nearly impossible. Therefore, the current state of the increase of diseases that we are witnessing in certain regions is evidence of how climatic change affects the outbreak of disease (McMichael et al., 2003b).

An argument can be presented as there is an urgent need to adapt and subsequently mitigate climate change impacts. Although many major cities around the world are already acting upon climate change effects, an immediate action plan is urgent and it needs to include a comprehensive health-risk assessment. Assessments cannot predict the future; therefore, caution needs to guide the process when developing and implementing risk management plans to mitigate climate change effects. Approximations and likely impact indicators of climate change effects are acceptable (McMichael et al., 2003b).

Projections of Climate Change-Related Health Impacts

Adaptation strategies to include and implement a risk management plan addressing the health impacts of climate change are essential in order to protect and develop a realistic framework that is feasible to protect the megacities' urban poor populations (Nerlander et al., 2009).

The long term impacts of climate change need to be addressed in order to develop a comprehensive risk-management framework. Populations at risk are also considered in the projections of climate change-related health impacts. However, the economic situation of the population and the region or country analyzed cannot be directly related to disease burdens because climate change health risks and the gross domestic product are determined by different causes such as climate, and environmental and social factors. The well-being and good health of populations is determined by other factors than income per capita. Therefore, the increased per capita income does not improve the health of populations (Nerlander et al., 2009).

Projecting Heat-Related Mortality

Many studies have been conducted by the World Health Organization and the United Nations that provided convincing evidence to link climate change and premature death from many causes. Although these studies are valuable in understanding and mitigating the effects of drastic climate events on health, more efforts are needed to evaluate and eventually predict how climate change affects the health of populations. The average annual temperature in the United States has increased by 1°F during the 20th century. This national standard has been surpassed in the metropolitan area of New York. In the years between 1990 and 1997 New York temperature has increased an average of 2°F. The prior statement associates climate change on ambient temperatures and related mortality (Knowlton et al., 2007).

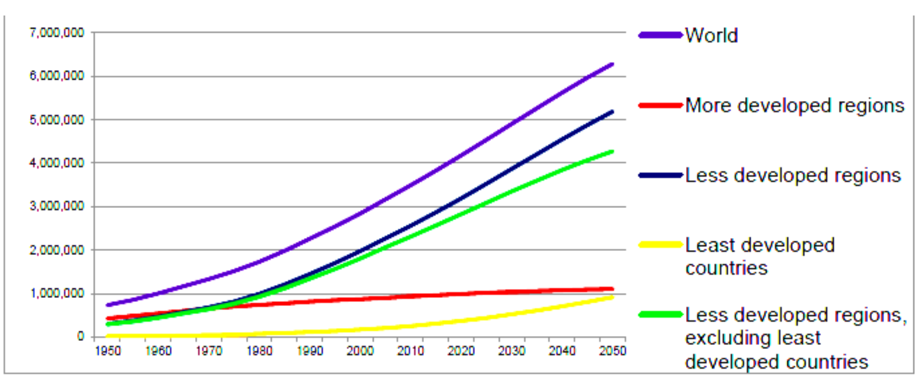
The increased temperature trend is still in place as warming temperatures and greenhouse gas emissions will continue to affect the climate well through the 21st century. The projections to a warmer climate are astonishing. The recent trends on the impact of anthropogenic emissions on global climate suggest the annual average temperatures will raise between 2.5°F to 6.5°F, with summer temperature increases of 2.7°F to 7.6°F, by the year 2050 and beyond (Knowlton et al., 2007).

Chapter 6 Megacities and Climate Change

The proportion of people living in urban areas has risen to 50 percent and will continue to grow to two-thirds, or 6 billion people, by 2050. Most of the global gross domestic product (GDP) will be devoted to providing energy and resources to the new city residents over the next decades. As the cities' structures are changing to accommodate the new wave of dwellers, these factors will have a deep impact on the environment and human health (Burdett & Sudjic, 2011).

Distorted landscapes are common features of urban areas. Megacities are far from natural ecosystems and processes and this leads to altered microclimates in addition to other effects, such as considerably elevated surface and air temperatures (Blake et al., 2011). The urban features of landscape obstruct long-wave radiative cooling processes. Because of the vertical geometry of the urban areas, the ventilation that circulates between buildings, houses and construction sites is generally reduced (Blake et al., 2011).

Chart 9: Urban Population Growth (thousands), 1950-2050 (Muggah, 2012).

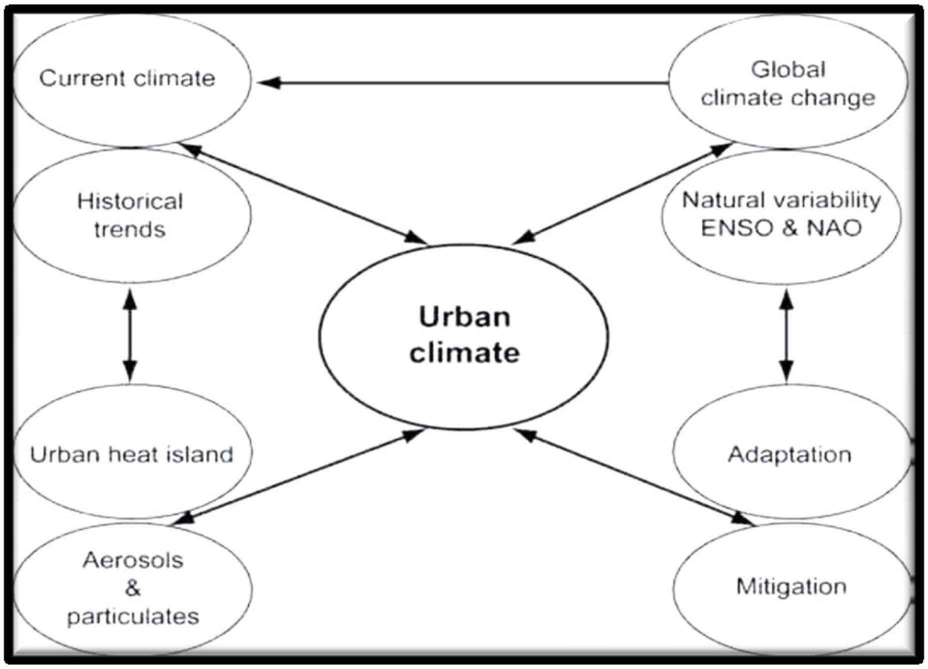


Statistics compiled from http://esa.un.org/unpd/wup/index.htm

Urbanization and Environmental Impacts

Urbanization has an effect on the environment to an extent that it changes the microclimate, creates loss of agricultural land, causes contamination of air, soil and water, increases water use and runoff (Rosenzweig et al., 2011). Albedo is “the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface” ("Global climate change,” 2009). Because cities have dark asphalt roadways, rooftops and urban-canyon light trapping, the city’s albedo is significantly lower than natural surfaces. Therefore, cities trap the heat and don’t release it back to the surface, creating the heat island effect. Furthermore, solid surfaces replace natural soil and vegetation, which creates the reduction of evapotranspiration and latent heat cooling. This net cooling effect and the increase of ambient urban carbon dioxide levels create a detrimental environment that is unhealthy for the urban population (Blake et al., 2011). The figure below shows the components of the effects of urban climate.

Figure 7: Major Elements Impacting Urban Climate (Blake et al., 2011).



The Impact of Climate Change on Cities

Cities are already affected by climate change and the projections indicate the impacts on cities will get worse (Global report on, 2011). Cities are motionless and this makes them vulnerable to the impacts and effects of climate variability (Cities and climate, 2010).

These characteristics create a liability as climate change poses a threat to infrastructure, population health, resources for subsistence and entire urban systems. As drastic weather events increase year after year, the acute vulnerability of urban populations, especially children, the elderly and the poor, will be exacerbated by climate change. The interruption of critical supplies to urban populations is a serious threat that is aggravated by the cities' dependency on food imports (Cities and climate, 2010).

Human health and safety will be affected by air quality. Health risks for heat-sensitive populations will increase. The vulnerabilities of the urban poor will be exacerbated by heat fatalities due to poor air circulation in congested slums and lack of access to air conditioning (Rodriguez, 2009).

Practically every C40 network of cities has determined it is exposed to physical risks that endanger its population. The C40 group has identified risks from climate change effects that are already happening or that are expected to take place in the near future. Most of the cities have identified several risks, such as more intense rainfall, increased severity of storms and floods and rising sea levels. Furthermore, there are many compounding factors that will aggravate the physical effects of climate change in the city (Global report on, 2011).

Table 8: Physical Effects of Climate Change Identified by Cities (Global report on, 2011).

Effect	% of respondents	Top 3 sectors affected
Temperature increase/heat waves	85%	Human Health, Energy, Water
More frequent/ intense rainfall	79%	Buildings, Water, Transport
Sea-level rise	67%	Buildings, Waste, Transport
Storms and floods	58%	Human Health, Buildings, Water
Drought	42%	Water, Human Health, Energy

Urbanization and Climate

Cities create drastic changes in biological and physical systems, as well as hazards affecting the health outcomes of the population. Climate change is a different type of global hazard because is spatial and temporarily diffuse. Climate change affects future generations and goes beyond any boundaries; the accountability factor is diffuse because it is difficult to hold one entity directly responsible (Rosenthal et al., 2007).

There are some serious issues that require an immediate response from our world’s leaders. The World Bank has conducted client-cities studies for many years and has concluded that poverty is a more pressing and troublesome problem than climate change. However, climate change is the most complex issue society faces today and it has global connotations. The required capability for cities and world leaders to deal with climate change presents a big challenge (Cities and climate, 2010).

Climate change impacts most city residents, particularly the urban poor, in both rich and poor countries. Urbanization and climate change are inextricably connected, as the consequences of the latter can detrimentally affect urban areas to the extent that entire urban systems are disrupted (Cities and climate, 2010).

Migration to major cities is increasing rapidly and problems and opportunities will grow in both importance and complexity. The effectiveness of the response of cities to climate change will provide critical awareness in how to adapt and deter other complex issues the world will face in the coming decades due to urbanization (Cities and climate, 2010).

The Urbanization of Poverty

Some observers believe that poverty is on an accelerated path to urban settlements, particularly in the developing world. As the distinguished scientific journalist and publisher Gerard Piel told an international conference in 1996: "The world's poor once huddled largely in rural areas. In the modern world they have gravitated to the cities". The rising numbers of the poor living in urban areas is known as "the urbanization of poverty." (Piel, 1997).

Megacities and the Poor

The rapid increase of the poor population in megacities is a particular characteristic of urban expansion. Also, in many developing countries the urban poor population is increasing in higher proportions than the actual population growth. This disparity results in more inequalities and economic and social injustice (Vlahov et al., 2011). The urban poor will be the most affected for the cost of staple foods increases as climate change creates droughts, heavy rains and affects agricultural production diminishing supplies. The socio-economic groups affected by climate change will likely see an increase in poverty rates that are parallel to extreme weather events (Gardner et al., 2009).

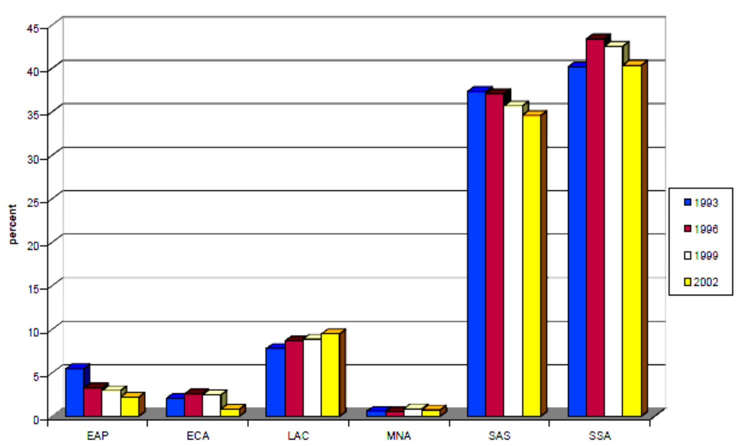
The effects of urbanization are more or less leading to the scarcity of health services, but primarily to "maldevelopment" (Vlahov et al., 2011). Maldevelopment is a qualitative notion that refers to a discrepancy between the needs of a specific population and the responses generated to meet those needs (Frenk et al., 2010).

The poor are particularly affected by climate change, and the repercussions of the climate change health impacts on the population are predominantly experienced in major cities around the world. Megacities are already besieged by the growing population and the services needed to provide to its residents. Taking into consideration that megacities need to accommodate more than three million new habitants every week, the resources, prevention, and adaptation measures are exhausted already without the added numbers of residents that overwhelm major cities' basic services every day (Abeygunawardena et al, 2003).

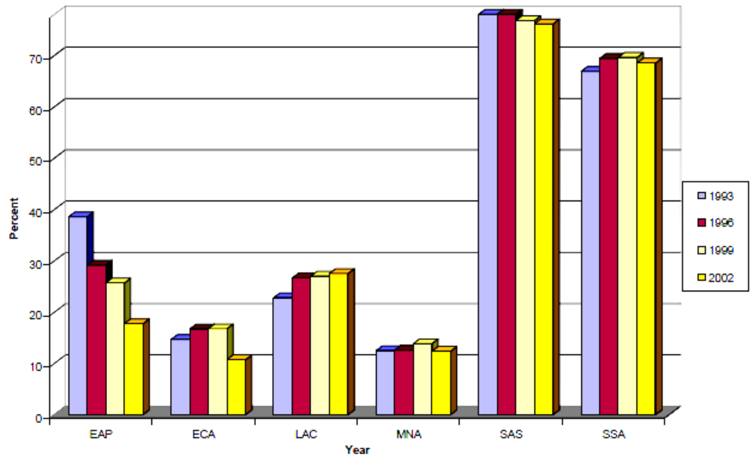
The number of poor people living in urban areas has been rising in all regions of the world with the exception of Europe and Central Asia (ECA).

Chart 10: Trends in Urban Poverty by Region, 1993-2002 (Baker, 2008d). Regions of the world- ECA: Europe and Central Asia. EAP: East Asia and Pacific Region. LAC: Latin America and the Caribbean. MNA: Middle East and North Africa. SAS: South Asian Seas Region**.** SSA: Sub-Saharan Africa.

a) Headcount Index Urban Areas: $1/Day Poverty Line.



b) Headcount Index Urban Areas: $2/Day Poverty Line.



Future projections indicate increases in urban poverty, but globally the majority of the poor will still be found in rural areas for some decades to come (shift to an urban majority estimated at approximately 2040 for the $1 per day line, and 2080 for the $2 per day line) (Baker, 2008d).

The Urban Heat Island in Relation to Public Health

Climate and the atmosphere are influenced by human activities through air pollution, GHG emissions, land alteration and airborne particles. Higher surfaces and near surface air temperatures are coupled in urban areas and this creates a hotter atmosphere, in addition to higher energy consumption and increased smog formation. Hence, urban heat islands (UHIs) are created by man-made exteriors, including dark roofs, asphalt lots and paths, which absorb sunlight and re-radiate energy as heat (Rosenzweig, 2011).

The heat island effect leads to increased temperatures affecting the public health and creates a high demand for cooling energy in commercial and residential buildings in summer, increasing GHG emissions. Urban populations are exposed to particulate matter, carbon monoxide, sulfur dioxide and nitrogen oxides that can exacerbate respiratory problems and damage lung tissue (Rosenzweig, 2011).

Greenhouse Gas Emissions

Climate change and urbanization are intrinsically linked and are two of the most important issues facing the world today. As a society, addressing challenges that our world leaders need to confront, poverty reduction and sustainable development remain as the center of global priorities. According to the International Energy Agency (IEA), urban areas presently account for more than 71 percent of energy-related global greenhouse gases. These percentages linked to the growing of urbanization and population density will increase to 76 percent by 2030. As a result, energy-related emissions are the largest single source of GHG emissions if allocated emissions are focused at the areas where the source has been generated (Hoornweg et al, 2011).

Urban residents and their associated affluence are likely to account for more than 80 percent of the world's total GHG emissions. Therefore, cities are blamed for the majority of the GHG emissions. However, recent studies have demonstrated that populations living in denser city centers can emit half the amount of the GHG emissions in comparison to the suburban residents. The disparities within major cities need to be acknowledged as well because emissions in cities in developing countries are lower than cities in developed countries, and especially low for the urban poor. As a comparative statistic within the cities analyzed in this research, Table 15 shows city-based GHG emissions per capita as reported by the Intergovernmental Panel on Climate Change

(IPCC). Variations in these values derive from production- and consumption-based values for cities (Hoornweg et al, 2011).

Table 9: GHG Baselines for Cities under Study (Hoornweg et al, 2011).
(i) Value includes emissions from aviation and marine sources.

City	**GHG emissions (tCO2e/capita)**	
Beijing	**0.1**	**2006 (3 i)**
Los Angeles	**3.0**	**2000 (5 i)**
New York City	**0.5**	**2005 (5 i)**
Rio de Janeiro	**2.1**	**1998 (3 i)**

There is substantial economic potential for the mitigation of global GHG emissions over the coming decades that could offset the projected growth of global emissions or reduce emissions below current levels. All sectors and regions have the potential to contribute to the reductions. The largest potential is in the buildings sector. Some of the commercially available options assessed by IPCC are: efficient lighting and day-lighting; more efficient electrical appliances and heating and cooling devices; improved cook stoves; improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids; and recovery and recycle of fluorinated gases. The IPCC estimates that by 2030, about 30 percent of the projected GHG emissions in the building sector can be avoided with net economic benefit. And there are also large co-benefits: e.g., improvements in indoor and outdoor air quality as well as improvement in social welfare (Van Ypersele, 2007).

Why Cities Can Be the Solution to Climate Change

Cities and city leaders can serve as a model for change. The promotion of innovative ideas, mitigation plans for climate change, environmental efficiency, risk management and frameworks that contribute to the well-being of the urban population will enhance the already established management plan as well as enabling prosperity through economic development (Cities and climate, 2010).

Cities have the opportunity to combat climate change from a local perspective and have a global impact. That translates into a tangible approach to act quickly to climate change events between the residents and cities' leaders.

The development of a set of common adaptive measures around climate, focusing on specific natural disasters that are climate related, creates the potential for big cities to consider a strategic plan that amalgamates the strategy under a universal framework. Big cities have perhaps the most to lose and therefore there is political momentum to develop an emergency plan as their assets are at a high risk (Pascual, 2012).

C40 Cities Climate Leadership Group

The C40 group network of cities is working to minimize their carbon footprint and implement programs to reduce GHG emissions. The transport sector is an important part of the carbon reduction program of the C40 group since these cities emit 300 million tons of CO2 per year. A small group of cities that encompass seventeen out of thirty-six responding cities have already implemented a comprehensive plan to reduce their CO2 emissions. The relation between population density and levels of per-capita carbon emissions from transport indicates harmful impact of urban areas on the environment.

Higher population density translates into lower transport emissions and the correlation between GDP and per-capita emissions from transport in C40 cities is also acknowledged (Climate action in, 2011).

Although the relation between density, major cities and transport emissions is clear, the statistics acquired in studies show many disparities among cities around the world. Some of the highest per capita GDPs made known are in the cities of London, Honk Kong and New York. However, they have relatively low per-capita carbon emissions. The reason behind this is that in some major cities the population is high density and uses an efficient and widespread public transportation system. But, in general, the highest transport-carbon emissions are related to the cities with the highest GDP, and conversely the cities with the lowest GDP tend to have lower emissions (Climate action in, 2011).

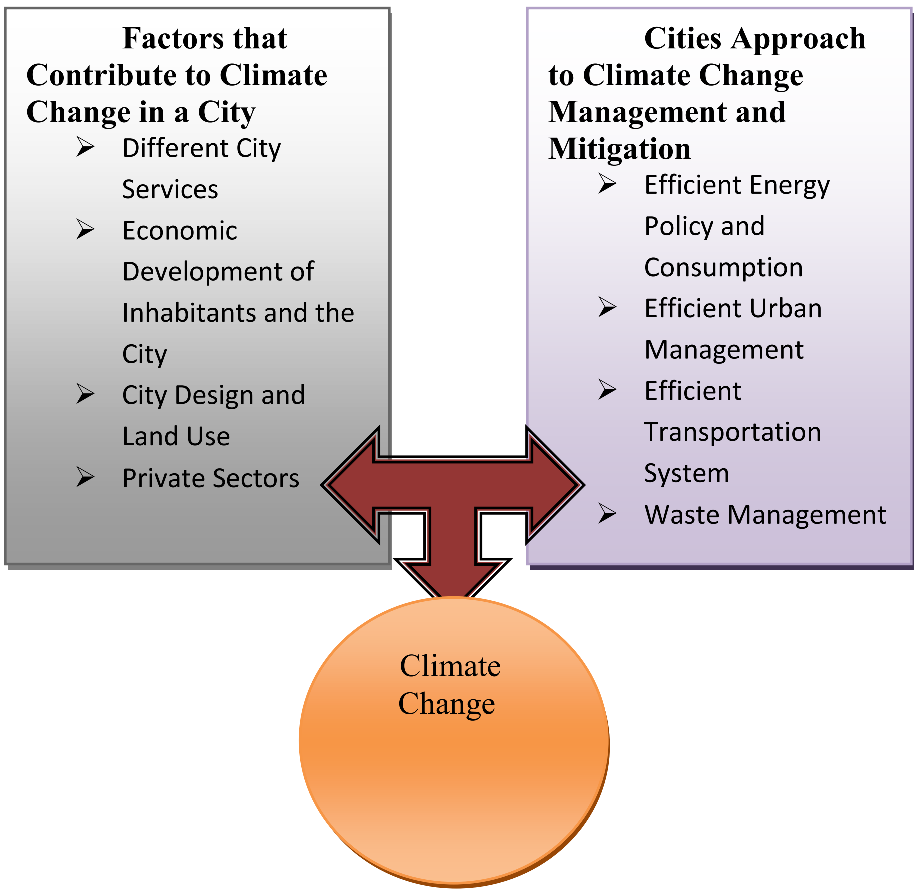
Conclusively, the C40 mayors working together for a common goal can make a big impact on reducing environmental damage, health effects and the deterioration of the urban system. They have the power and influence to mitigate the effects of GHG emissions from transportation and other sources (Climate action in, 2011).

Cities Contribution to Climate Change

The urgency for cities to mitigate climate change impacts is today more crucial than ever before. Some cities' contribution to GHG emissions is greater than many nations all together. New York City, for example, emits 63.1 Mt CO2e to climate change. This number is only 10% lower than the contribution of all of Ireland's GHG emissions (Karabag, 2011).

However, not all cities release the same amount of emissions, as transportation, waste management, urban systems, land use and technology differs among them (Karabag, 2011).

Figure 8: A Conceptual Figure of Factors Contributing to Climate Change in a City and Climate Change Management of a City (Karabag, 2011).



C40 Taking Action against Climate Change

City's mayors have control of budgets and resources to deliver actions that can have a relatively immediate impact on initiatives. Some cities have already taken initiatives and, depending on their success, other cities will follow. This statement is accurate particularly where mayors don’t have the power or resources to make changes and initiate projects. On the other hand, if mayors have control of important assets such as roads and pavements, they can implement “transformative” initiatives via direct projects and programs. Accordingly, these programs are often backed up by regulations and policies. Infrastructure initiatives led by mayors demonstrate they are capable of using their powers in an efficient and prompt way to collectively accelerate emissions reduction (Climate action in, 2011).

Coastal Megacities and Climate Change

Sea-level rise and other coastal implications, such as changing storm frequency, put populations at risk of climate change effects. The rapid urbanization experienced in the 20th century and the expansion observed today has already created 20 coastal megacities. In contrast, in the 1990s there were a total of seven coastal megacities in Asia (excluding Japan), and two in South America (Nicholls, 2004).

The fragility of the sedimentary strata where the megacities are located is a concern that exacerbates climate change impacts on urban populations. The repercussions of climate change on megacities are varied and require each city to have an independent assessment to mitigate and adapt to climate change (Nicholls, 2004).

Chapter 7 Megacities as Global Risk Areas

Since megacities are important centers of population concentration and growth, their basis of prosperity and importance are positioned in their long-standing commercial connections with the rest of the world. The majority of global cities are located on or near the coast for the main purpose of facilitating the flow of trade to create revenue for their prosperity. In addition, they are located near major rivers that serve as a channel for commerce (Sherbinin et al., 2007).

Megacities are confronting many issues related to climate change impacts and, as highlighted previously, the vulnerabilities are exacerbated in coastal cities. Sao Paulo and Rio de Janeiro present good examples, as they are located on a coastline of 8,000 km. Furthermore, these major cities are exposed to environmental risks augmented by climate change, for instance, sea level rise, drastic storms, floods, landslides, vector-borne diseases that are a consequence of high temperatures, variability in rainfall patterns, and severe weather events (Costa Ferreira et al., 2011).

New York, Rio de Janeiro, Beijing and Los Angeles

This research focused on the cities of New York (NYC), Rio de Janeiro, Beijing, and Los Angeles to strategize adaptation and mitigation plans. These four megacities can be considered highly vulnerable to climate change impacts and the outcomes will affect the urban population's health. NYC and Rio have some similarities as they are located on a coastal zone and they have dense urban populations with a dynamic economy and global trade resources. Therefore, New York and Rio, as well as other cities located in coastal regions, should be a priority for social and environmental policies that seek forms of mitigation and adaptation (Costa Ferreira et al., 2011).

Los Angeles has a vast territory with a dense population that is highly vulnerable to heat waves, wind storms and flooding. The county of Los Angeles encompasses a diverse ecosystem that makes adaptation and mitigation to climate change a priority to deter its impacts on such large and diverse population (Kersten et al, 2012).

Beijing is one of the 20 largest cities in the world and one of the most heavily polluted cities. This situation presents a challenge to its leaders as greenhouse gas emissions keep rising and millions of residents are exposed to health risks and subsequently a greater morbidity and mortality rate (Zhao, 2011).

The differences between these four major cities are accentuated by income distribution (New York and Los Angeles have a higher-income population), crime rates and radical social inequalities (particularly in cities of developing countries such as Rio). Climate change impacts and how it affects the urban population can also present inequities regarding preparedness, adaptation, mitigation strategies and resources to combat climate change.

Health is closely related to the population's socio-economic status. Brazil has a large number of slums and underprivileged urban residents and consequently these inequalities disproportionally affect the urban poor since the bottom of the social scale has poorer health than those at the top (Szwarcwald et al., 1999).

Consequently, the case study can be presented as a case model for other megacities to adopt, to develop and implement strategies to deal with climate change and the consequences of its impacts on the urban poor's health.

The City of New York

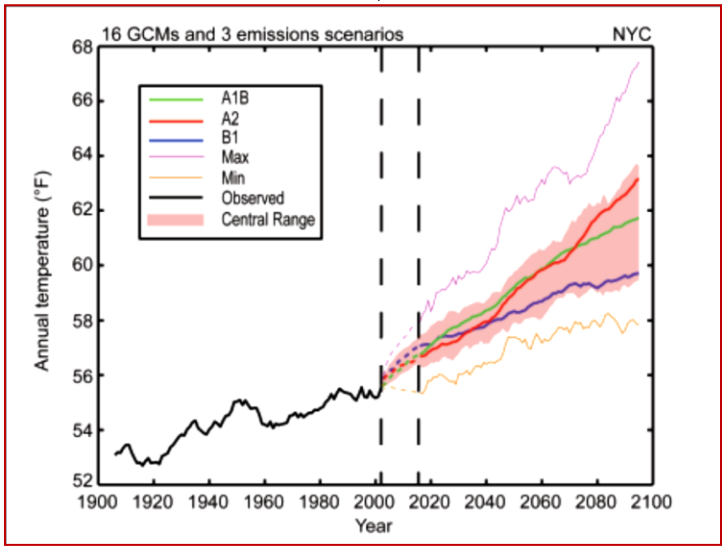
Over the past three decades the mean temperature of the globe increased due to natural and anthropogenic factors. Moreover, the average temperature across the United States has been risen by over 2°F since 1970. Precipitation has increased on an average of 5 percent, seal level has risen and drastic weather events (e.g., hurricanes) are more frequent (Karl et al., 2009). As climate change effects continue to impact cities, the projections for the city of New York are an increase in average temperature of 1.5 to 3°F by the 2020s; 3 to 5.5°F by the 2050s; and 4 to 9°F by 2080. These temperatures will vary accordingly to the GHG emissions level (Climate change facts, 2011). These climate change events will directly impact New Yorkers and their health.

Rising Sea Level

Rising sea level is caused by thermal expansion of the oceans. The melting and discharge of ice from mountain glaciers, ice caps and much larger ice sheets located in the Antarctic and Greenland significantly contribute to the rise of sea levels and are a result of anthropogenic climate effects (Schellnhuber et al, 2012).

Rising sea levels are extremely likely. Global Climate Model (GCM) based projections for mean annual sea level rise in New York City are 2–5 inches by the 2020s; 7–12 inches by the 2050s; and 12–23 inches by the 2080s. All the courses of action that contribute to sea level rise are not captured by GCMs. This “rapid ice-melt” approach implies sea levels may possibly rise, more or less, between 41 and 55 inches by the 2080s (Rosenzweig et al. , 2009).

Chart 11: Observed Climate & Future Projections for New York City (Rosenzweig et al., 2009).



The above chart shows a black line representing a combined observed and projected temperature, precipitation and sea level rise. The green, red, and blue lines represent the average for each emissions scenario across the 16 GCMs (7 in the case of sea level). The central range is represented by the shaded area, and each year's minimum and maximum projections throughout the set of simulations are shown by the bottom and top lines on the graph. A ten-year filter has been applied to the observed data and model output. The spotted area for the years between 2003 and 2015 stands for the phase that is not covered due to the smoothing procedure (2002 - 2015 for sea level rise) (Rosenzweig et al., 2009.

Ozone-Related Health Impacts

Climate change alters public health by increasing the concentrations of outdoor air pollutants. A study in 31 counties in New York about ozone-related health impacts projected a median 4.5% increase in ozone-related acute summer mortality by the 2050s as compared to the 1990s (Bell, 2007).

The Urban Heat Effect

The urban heat island (UHI) increases effect in major cities, exacerbating the impacts of warmer temperatures and affecting the population's health. New York City is particularly vulnerable to climate change because of the urban heat island effect. Urban heat islands are formed when human-made surfaces in cities made of concrete, asphalt, metal and stone take up incident sunlight during day time, which is re-radiated as heat with the strongest effect at night (Knowlton et al., 2007). The result generates an overall effect in urban areas of higher surface and near-surface air temperatures compared with suburban and rural areas (Knowlton et al. (2007). There are many risk factors intensifying the vulnerability of specific demographic groups to heat weaves and drastic weather events. New York City is a diverse metropolitan area that has a large adult population of millions of residents as well as residents with cardiovascular or respiratory illness, increasing their susceptibility to summer heat stress (Knowlton et al. (2007).

The urban heat island effect is a complex meteorological phenomenon that is influenced by several different conditions. Urban land use may affect cloud cover and the speed of wind. Precipitation patterns are also influenced by the city's land use and local climate, and those conditions model the UHI-effect impact on the city (Rosenthal et al., 2009). New York City has experienced the UHI-effect since at least the end of the 19th century. In the 20th century the city experienced climate variability that impacted the health of its habitants. Climate variability was caused by the UHI effect and the drift caused by global warming of the earth's lower atmosphere. Over the past century the temperature has risen approximately 2ºF (1.1ºC) according to the Columbia Earth Institute's Metropolitan East Coast Study (Rosenthal et al., 2009).

Sudden and Disruptive Climate Change

When Svante Arrhenius, winner of the Nobel Prize in Chemistry 1903, made the first comprehensive quantitative estimate of how human-caused emissions of carbon dioxide (CO_2) would modify and influence the climate, many scientists at the time interpreted the change would be a slow process. Therefore, society as a whole would have plenty of time to respond to climate changes and consequently apply policies to deter climate change (MacCracken et al., 2008). He published his results in 1896 (between 10,000 and 100,000 calculations), and the Nobel Prize winner concluded that reduced CO_2 levels will decrease earth's temperature by 4-5C and divergently doubling CO_2 levels would trigger a rise of about 5-6C (Arrhenius & Waltz, 1990). He was a pioneer in the study of climate change and how it affects our environment. Accordingly, the UN-sponsored Intergovernmental Panel on Climate Change (IPCC) summarized and evaluated a comprehensive and credible assessment 110 years later; projecting that ongoing dependence on fossil fuels to provide most of the world's energy will generate an increase in the global average surface temperature of approximately 1.4 - 5.5°C (about 2.5 - 10°F) by the year 2100, adding to the observed increase of about 0.6°C (about 1.1°F) over the course of the 20th century (MacCracken et al., 2008).

The Destructive Path of Hurricanes

Millions of residents living in megacities have already experienced the catastrophic effects of climate change and the aforesaid statements lead researchers to the following question: *Are there trends in extreme weather-event destruction?* There has been a noticeable increase in the destructive potential of hurricanes and their frequency according to an identified trend in an accumulated annual index of power dissipation in the North Atlantic and western North Pacific since the 1970s (Emanuel, 2005).

A recollection of past events shows the intensity and destructive force of hurricanes. Hurricanes are unique as they are not the largest storm systems neither the most violent, but they combine these properties to become a very powerful storms. These spiral masses need a complex combination of atmospheric processes to grow, mature and then die. They are amid the most lethal and costly natural disasters, with vast implications for humanity. The deadly Galveston, Texas, hurricane of 1900 was among one of the most destructive hurricanes the United States has experienced, as well as hurricane Mitch, which killed more than 11,000 people in Central America in 1998. Developing countries have been impacted by these hurricanes with a much larger deadly outcome due to the lack of preparedness, adaptability, infrastructure and regulations. Although hurricane land-falling frequency is much less common in developed countries, they are experiencing property loss to new levels, and those losses are rapidly escalating because of the accelerated developments in construction and urbanization in hurricane-prone areas (Emanuel et al., 2006).

1, 833 people died because of hurricane Katrina and the death toll carries other consequences related to social and economic factors that will prevail for decades (King & Anderson-Berry, 2010).

The financial losses were astonishing and they were estimated as follows: $21 billion on structural damages; $36 billion on commercial equipment; $75 billon on residential structures and content damages; $231 million on electric utility damages; $3 billion on highway damages; $1.2 billion on sewer system damages; and $4.6 billion on commercial revenue losses. The water system, the consequences of the loss of life, and damage to the environment were not estimated, but they account for a large economic loss as well. The total economic loss estimated by risk management was at $125 billion and the estimations from Washington politicians reached a total cost of approximately $200 billion (McGee, 2008).

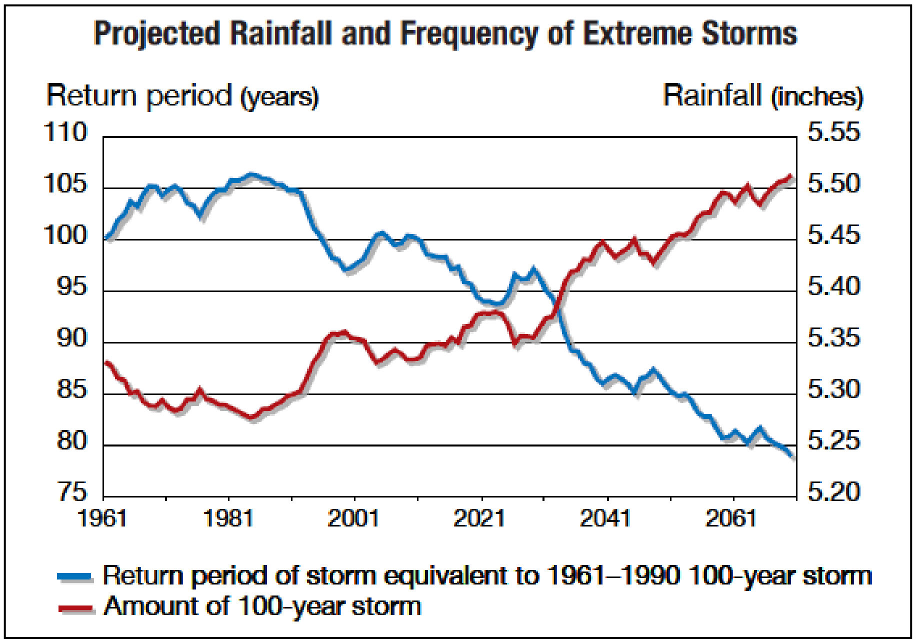


Chart 12: The Projection for the "100-Year Storm" (1961-2061) shows an increase of the amount of rain fall (*red line*). The number of years between such storms, which is called the return period, shows a projected decline (*blue line*). Consequently, the severity of the storms will be more intense and more frequent. These conclusions, from the UK Met Office Hadley Centre Climate Model Version 3 (HadCM3), are in accordance with previous observations of 15 other GCMs used by the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State (ClimAID) (Rosenzweig et al, 2011).

Megacities and Mega-Catastrophes

New York City and the adjacent region of northern New Jersey and Long Island, New York, are located at the pinnacle of a vulnerable angle exposed to hurricane storm surge. This region is particularly influenced by tides and weather because of its geographic composition of narrow rivers, estuaries, islands and waterways. The metropolitan region is less than 5-meters above mean sea level (MSL). The risk from storm surge flooding has a range of 260-square kilometer, and the sea walls that surround lower Manhattan are only ~1.5-meter above MSL, making the area highly susceptible to severe weather events. For example, if a category-3 hurricane hit NYC, it is projected that nearly 30% of the south side of Manhattan would be flooded with catastrophic consequences for the infrastructure of the city and the well-being of the population (Colle et al., 2008).

Accounts show the region has been struck by extreme storms such as the New York City 1921 hurricane, which produced a 4-meter (13-foot) wall of water flooding lower Manhattan as far north as Canal Street. In 1938, Long Island experienced the impacts of the "Long Island Express" storm, with flood heights of 3 – 3.5 meter (10 – 12-foot) and up to 5.2-meter (17-foot) in southern New England. The death toll has reached roughly 700 people. Furthermore, Hurricane Donna, with a 2.55-meter (8.36-foot) water elevation, flooded lower Manhattan to West and Cortland Streets in 1960. These historical events and the statistics presented, put New York City in a highly vulnerable situation, particularly because much of the seawall that protects lower Manhattan is only about 1.5-meter above mean sea level. Therefore, a comprehensive risk management strategy addressing each of these hazards and their combination needs to be urgently developed.

Risk mitigation frameworks and related decision making will provide a path to minimize hurricane impacts on communications, transportation, roads, rail networks and people. However, in places like New York, which is often threatened by high-intensity, low-frequency hurricanes, risk assessments based on traditional data may not be relevant to accurately make projections because historical records of hurricane storm surge at a particular location are not sufficient to make meaningful estimates of surge risks (Lin et al, 2010).

The New Normal

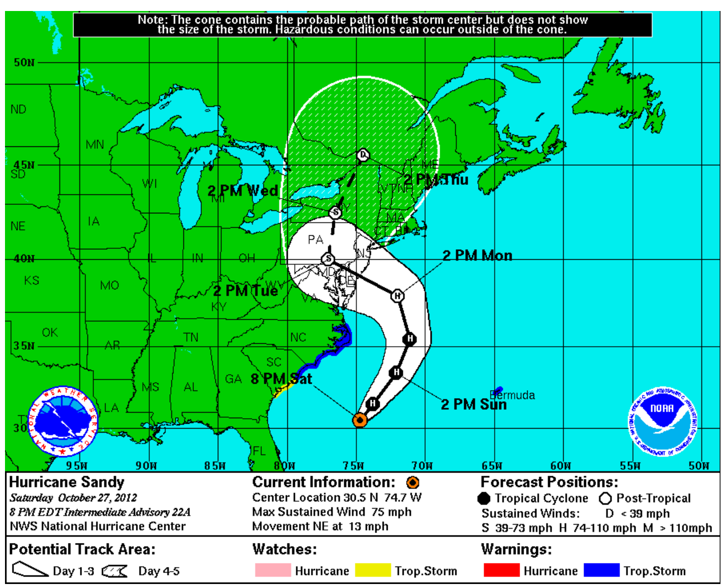
Hurricane Sandy Battered New York City

The increased frequency of drastic climate events in the United States, such as the recent hurricane Sandy, which battered New York and New Jersey, raises questions about how climate change is linked to the trend of these monster storms. Kevin Trenberth, senior scientist at the National Center for Atmospheric Research in Boulder, Colorado, stated: “The answer to the oft-asked question of whether an (extreme) event is caused by climate change is that it is the wrong question. All weather events are affected by climate change, because the environment in which they occur is warmer and moister than it used to be” (“Betts,” 2012).

Hurricane Sandy landed near Atlantic City, New Jersey, on October 29, 2012. This destructive storm caused 113 deaths, left up to 40,000 people homeless, and the economic losses are estimated at $50 billion dollars, with approximately 200,000 homes damaged (Neria & Shultz, 2012).

The storm changed course from a tropical to a post-tropical cyclone. The storm had wind speeds that reached 80 miles per hour and a central minimum pressure that reached 946 millibars at landfall. In addition, hurricane Sandy generated tropical storm force winds extending nearly 500 miles from its center, intense flooding, destructive wind power and power outages that immobilize and affected millions of residents, which made it a catastrophic weather event without precedent in the New York area (Post-tropical cyclone sandy, 2012). According to the Intergovernmental Panel on Climate Change report on coastal systems and low-lying areas, throughout the 20th century the global rise in sea level and warmer temperatures have contributed to more frequent coastal inundations, erosion and ecosystem sea ice loss, melting of permafrost (soil or rock that ordinarily remains permanently frozen), associated coastal retreat, and continuing coral bleaching and mortality (IPCC, 2007). Globally, 120 million people are exposed to tropical cyclone hazards every year, which killed 250,000 people from 1980 to 2000 (Nicholls et al, 2007).

The following graphic of hurricane Sandy from the National Oceanic and Atmospheric Administration weather service shows the storm's path toward the U.S. north-east coast (National hurricane center, 2012).



Graph 1: Sandy graphics archive (National Oceanic and Atmospheric Administration, 2012).

The Tragic Similarities between Katrina and Sandy

The similarities among the two devastating hurricanes are noteworthy and of an urgent concern for climatologists, scientists, city mayors and public health officials alike. The flooding of major cities and its harmful effect on the dense coastal population, financial loss in the billions of dollars, deaths, injuries and health issues, as well as the loss of electric power paralyzing businesses and infrastructures are all common hazards that have detrimentally impacted millions of lives (Voiland, 2012). The changing composition of the atmosphere, including its greenhouse gas and aerosol content, is a major internal forcing mechanism of climate change. Because of natural disasters of the magnitude of hurricane Sandy and Katrina, it is progressively becoming clear that it is more difficult to defend the idea that these severe climate events are not caused by climate change (Van Ypersele, 2013).

Mental Health Effects

The intensity of exposure to a natural disaster will determine the mental health effect on people. Psychological harm is closely correlated to personal injuries. Moreover, a person going through the experience of the death of a family member, friend or neighbor because of the disaster can be a strong forecast of a mental health condition influx. Researchers have pointed out displacement, migration, and the loss of personal assets and financial stability are factors that contribute to mental health issues, such as posttraumatic stress disorder (PTSD) and depression (Neria & Shultz, 2012).

There are some other serious mental health effects that are a consequence of climate variability and extreme events, such as general distress, anxiety and other psychiatric disorders. Risk assessments must highlight these subgroups that carry a greater exposure to the consequences of drastic weather events. Hurricane Sandy has demonstrated a new form of natural disaster that impacts millions of residents in the areas affected and creates a new pattern of future extreme incidents exacerbated by climate change. Preparedness and proactive efforts to lessen mental health effects are important steps to take, in addition to identifying the population at risk and applying appropriate psychological intervention. Furthermore, an evidence-based strategy in mental health response for prevention and chronic disability become essential to address the outcomes of climate change (Neria & Shultz, 2012).

Adaptation is an Urgent Agenda in Today's Climate

Hurricane Sandy's destructive power taught the local and global coastal community the urgent need to implement an adaptation strategy for coastal zones. The incorporation of climate change and sea-level information into land-use planning is crucial to develop a practical plan for megacities such as New York City. A good example of land-use planning for New York would be to establish setback zones a minimum distance from the shore for new coastal developments. Furthermore, optimal timing for adaptation depends on monitoring coastal hazard zones and coordinating efforts across the State of New York (Buonaiuto, 2011).

New York Adaptation and Mitigation Programs

As the effects of climate change on human health become clearer to understand through accurate data and scientific reports, the need for adaptation and mitigation and a way to operate in the evolving environment is vital for survival. Mayor Michael Bloomberg, with funding from the Rockefeller Foundation, convened the New York City Panel on Climate Change (NPCC) in August 2008. The NPCC advises the Mayor and the New York City Climate Change Adaptation Task Force on matters related to the risk to infrastructure posed by climate change (Horton et al., 2009).

New York City Government: Leading Example

New York City's ambitious plan to reduce municipal GHG emissions 30% by the year 2017 is the result of a long-term visualization of a framework that affects several sectors of the government. The implementation of the framework has different priorities highlighted as follows:

- Building Efficiency – The city is implementing a comprehensive strategy to reduce GHG emissions for existing buildings with a goal of at least 57%. The initiative includes energy audits, operation and maintenance improvements, retrofits and ongoing data analysis (Maron, 2012).

- Energy Audits and Retrofits –The average age of New York City buildings is 60 years old, and this plan presents an opportunity to replace inefficient lighting, and cooling, heating and ventilation systems (Maron, 2012). Identifying and implementing energy conservation measures for the city's buildings over 50,000 square feet is a priority that can effectively improve the existing energy systems and minimize GHG emissions. "An energy audit is an inspection, survey and analysis of energy flows for energy conservation in a building, a process or system to reduce the amount of energy input into the system without negatively affecting the output" ("Goal of energy," 2012). The city's audits follow ASHRAE Level II energy audit guidelines, and it covers electrical, ventilation and building envelope systems to determine energy retrofits and clean energy installations (Maron, 2012).

- <u>Operations & Maintenance</u> – Monitoring energy use, maintaining equipment, and operating the building's ventilation, lighting, heating and air conditioning is an efficient way to decrease GHG emissions and reach the city's goal of 12% reduction by 2017 (Maron, 2012). The city of New York is implementing an energy efficiency operations and maintenance plan to reduce its GHG emissions impact that is amalgamated into three main objectives:

1) Efficiently repair, maintain, and operate existing equipment.
2) Improve skills and raise awareness through training and outreach programs.
3) Accountability and transparency.
(Maron, 2012).

- <u>Clean Distributed Generation</u> – Clean distributed generation (Clean DG) technologies is on-site energy generation that uses clean or renewable fuel sources to produce electricity and, in some cases, steam or hot water. Clean DG uses a variety of renewable energy sources such as solar thermal, wind, biomass technologies and solar photovoltaic (Maron, 2012).

- Cogeneration or Combined Heat and Power (CHP) – Thermal and electric energy is combined to improve a building's energy efficiency and reduce GHG emissions. This technology improves grid constraints, creates a cost-saving energy program and provides operational independence. Nevertheless, the city is implementing a string of programs that include cost-effective renewable energy applications and new technologies to exploit solar, wind and biomass sources (Maron, 2012).

- Wastewater Treatment Plants – The potential to reduce GHG emissions for the city using wastewater-treatment-plant projects is promising. The negative aspect of this plan is that it releases a significant amount of methane gas (one of the strongest GHG emissions sources), but the city is making general efficiency improvements and fixing methane gas leaks by recapturing methane to power electricity-generating equipment (Maron, 2012).

- Vehicle Fleet – The City is greening its fleet by accelerating the purchase of more fuel-efficient vehicles, mandating the use of biodiesel, adopting best practices to economize vehicle miles traveled, improving vehicular deployment and fleet reduction programs (Maron, 2012).

- Street Lighting – Efficiency in energy reductions through the installation of 250,000 lower-watt streetlights fixtures. The decrease of energy consumption has reached 25% since FY 2006. The investment was $65 million, and with reductions that have led to the total elimination of more than 40,000 MgCO2e since 2007, a full return on investment (ROI) is expected in approximately 5 years (Maron, 2012).

- CO2 reduction – 30% annual reduction from 2006 base year by 2017 (Maron, 2012).

Rio de Janeiro

The population of Rio de Janeiro is just over ten million, and it is the second most populous city in Brazil after Sao Paulo. Furthermore, Rio de Janeiro has the highest urbanization rate (97%) (Confalonieri et al., 2009). The challenges Rio faces are unregulated settlements in hazardous areas where the urban poor live, industrial waste and sewage removal. (De Sherbinin et al., 2007).

Hazard Risks

Rio de Janeiro is facing high environmental risk levels. As shown in Figure 9, hazard risk represents a cumulative score based on risk of cyclones, flooding, landslides and drought. The vulnerability of Rio is represented by the city located near the coast, making Rio's dramatic topography more prone to certain types of hazard and its population density (De Sherbinin et al., 2007).

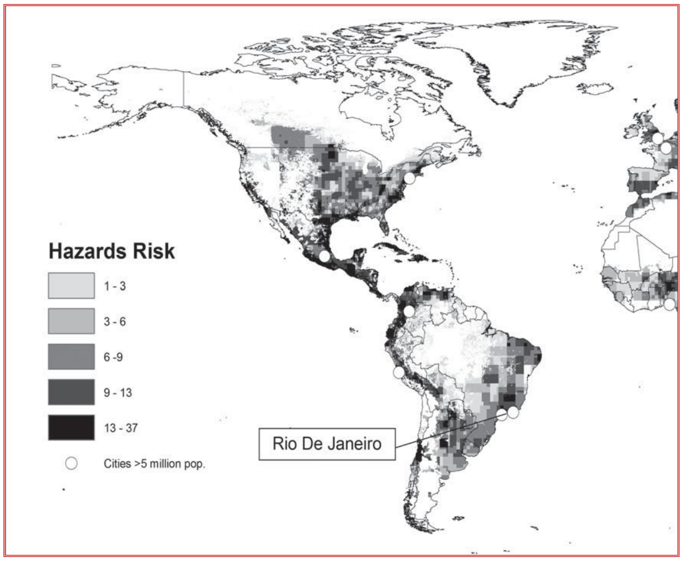


Figure 9: Large Cities in Relation to Current Climate-Related Hazards (De Sherbinin et al., 2007).

Urban Poverty and Vulnerability to Climate Change in Rio

The urban poor inhabit land sites in large concentrations in Latin America, making the populations highly vulnerable to extreme weather events. The most vulnerable people are low income people living in *favelas* (slums) in Rio, which are often located on hills within the city. *Favelas* are usually built with lower standards of security and located in riskier areas. Landslides and floods have often taken people's lives. Sea elevation in the next decades might affect people living in some susceptible areas, which will demand adaptation of infrastructure (Paes & Rosa, 2013).

Favelas are unregulated shanty towns. These slums are populated by more than 1.1 million people in the city of Rio and they sprawl over the hills and slopes of the Tijuca mountain range (De Sherbinin et al., 2007).

Although the *favelas* have improved their living conditions through the years, the paving of sidewalks deteriorates over time and increases runoff in the rainy season, and water runs down from the mountains to flood the lowlands, creating a sanitary problem and spreading certain diseases related to water contamination. Wastes accumulate when they are not collected and constitute a special concern for environmental health in Rio. Furthermore, disposal and treatment of waste can produce emissions of several greenhouse gases, which contribute to climate change, creating a rebound effect (De Sherbinin et al., 2007).

Epidemics after Natural Disasters

The incidence of disease is affected by climate. Nevertheless, migration, socio-demographic influences, nutrition and drug resistance, as well as environmental influences, are other factors that contribute to the incidence of health issues. Contaminated water and sewage as a result of climate change are causing illnesses. After a flood-related outbreak of leptospirosis in Brazil in 1996, spatial analysis indicated that incidence rates of leptospirosis, which is an epidemic-prone zoonotic bacterial disease, had drastically increased inside the flood-prone areas of Rio de Janeiro, which are mostly located in the slums. This disease is transmitted by contact with contaminated water (Watson, 2007).

Reducing Rio's Population Vulnerabilities

The World Cup in 2014 and the 2016 Summer Olympics will be hosted by Rio de Janeiro, and this presents an intrinsically new challenge for the city (Laffiteau, 2012).

Mitigating the adverse impacts of air pollution, urban transportation, and GHG emissions that contributes to climate change will require the government of Rio de Janeiro to take the lead in deterring the detrimental effects of harmful pollutants, flooding and some other drastic environmental risks that could jeopardize the sporting event.

Tourism can be affected by drastic weather events before and/or during this major sport event. The city's slum dwellers can also be affected due to the consequences of flooding, high temperatures and contaminated air (Laffiteau, 2012).

Climate-Proofing Rio

Many floods and landslides have demonstrated the vulnerabilities of Rio de Janeiro and its high level of risk to climate change. In April of 2010, a catastrophic event impacted the city where approximately 200 people died because of floods and landslides. The drastic weather event also caused several thousands to become homeless, and in early 2011, 450 residents died in mudslides in the State of Rio de Janeiro (De Sherbinin et al., 2007).

The city of Rio de Janeiro holds 5 million people, and the metropolitan region approximately 11 million. The topography of the city makes it susceptible to landslides and flooding in low-lying areas. The diminishing areas of Atlantic rainforest expose the vulnerabilities of the thin soil, which has been stripped away from many hillsides. This effect, along with granite and gneiss bedrock that has been left exposed to weathering, creates landslides, decomposition and erosion. Flooding is frequent during the rainy season, between January and March, because of the shape of the topography, with low-lying areas and a lack of drainage that makes the situation more susceptible to those weather events (De Sherbinin et al., 2007).

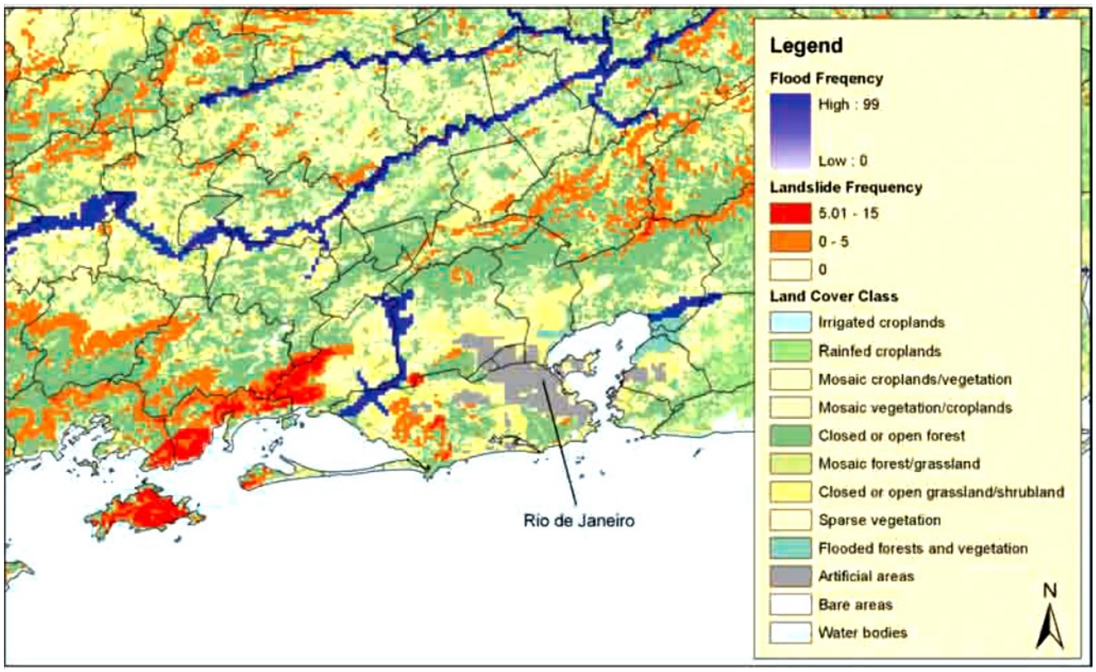


Figure 10: Rio de Janeiro: Flood and Landside Risk (Global Risk Data Platform Preview). Flood frequency is the expected average number of events per 100 years. Landslide frequency is the expected annual probability and percentage of pixel of occurrence of a potentially destructive landslide event ×1,000,000 (De Sherbinin et al., 2007).

Population Density

More than one million people live in *favelas* (approximately 20 percent of the municipalities' population). The population density of Rio de Janeiro is 4,640 persons per sq km, but densities in the smaller administrative units of the metro area are between 8,000 and 12,000 persons per sq km (De Sherbinin et al., 2007).

As the large and poor migrant population coming from Brazil's arid northeast region settles in Rio, government efforts to deter these new migrants trying to move up hillsides to search for new land are in place. The government regulations to control the *favelas* and to restrict building in hazard-prone areas are initiatives that help to improve access to basic infrastructure and avoid risks (De Sherbinin et al., 2007).

Extreme Precipitations

Climate change is expected to increase precipitation and exacerbate the population health risks (De Sherbinin et al., 2007). The increased frequency of precipitation has severe repercussions for the rates of mortality and morbidity. Moreover, floods and storms also increase the frequency of deaths and non-fatal injuries, and diarrheal and vector-borne diseases (Nerlander, 2009).

Climatic profile, the continental size of its territory, geographical features, and social and economic issues affecting large population groups are characteristics of the country of Brazil (Confalonieri et al., 2009c).

Rio de Janeiro is subject to unique health risks. The most dangerous natural event is heavy rainfall that provokes landslides and flooding, which are more frequent during summertime. The city is acting to adapt and better respond to that risk with a crisis management system. The Center of Operations of the City of Rio de Janeiro is a forecasting system that is based on a unified mathematical model of Rio that pulls data from the river basin, topographic surveys, the municipality's historical rainfall logs and radar feeds. The system predicts rain and possible flash floods, and has also begun to evaluate the effects of weather incidents on other city situations, such as city traffic or power outages. That allows city leaders to develop reaction protocols that can be effective in reducing damage, and especially in protecting lives. The Center also helps to organize information to support decision making (Paes & Rosa, 2013).

Tropical Cyclones: A New Reality

Tropical cyclones have never occurred in the vicinity of Rio de Janeiro and the city has not been affected by an extreme tropical storm in the past decades. However, that situation changed as the state of Santa Catarina was impacted by a hurricane in March of 2004. In addition, the city receives a strong El Niño-Southern Oscillation (ENSO) signal as well as higher precipitations during El Niño years. In 1988, Rio de Janeiro experienced extreme floods as the result of two intense periods of rainfall that caused 480 millimetres of rain, which equals one-third of the total rainfall in a year (De Sherbinin et al., 2007).

Vulnerabilities

The vulnerabilities can be highlighted by different categories that emphasize the factors that determine a poor response to climate change for the city of Rio de Janeiro and the country as well. These vulnerabilities are differentiated as follows:

- Health impacts such as climate-sensitive infectious diseases of public concern.

- Social impacts, which are factors that determine an ineffective reaction to climate change risks.

The next figure (11) represents the vulnerabilities of climate change impacts on health. Policy-making processes could include this vulnerability description aiming at the implementation of climate change adaptation. Proper policies for adaptation may reduce current vulnerabilities and improve the execution of climate change adaptation strategies (Confalonieri et al, 2009c). The methodological-theoretical framework below was based on a general "exposure-response" model. Identification of proximate drivers of vulnerabilities, ranging from individual characteristics such as age, sexual category and physical aptitude to social-environmental characteristics such as geographical features, was included. Furthermore, the magnitude and timing of human exposures to climatic hazards, and the capacity and effectiveness of the responses to the impacts resulting from exposures, were modulated to incorporate all aspects of vulnerability to health impacts of climate. Structural characteristics such as education, income, governance and political power, which were called "primary" or "ultimate" drivers of vulnerability, are shown on the bottom right of Figure 11, as well as the ultimate consequences of climate change impacts, which are morbidity and mortality as a result of social incapability and response to climate change impacts (Confalonieri et al., 2009c).

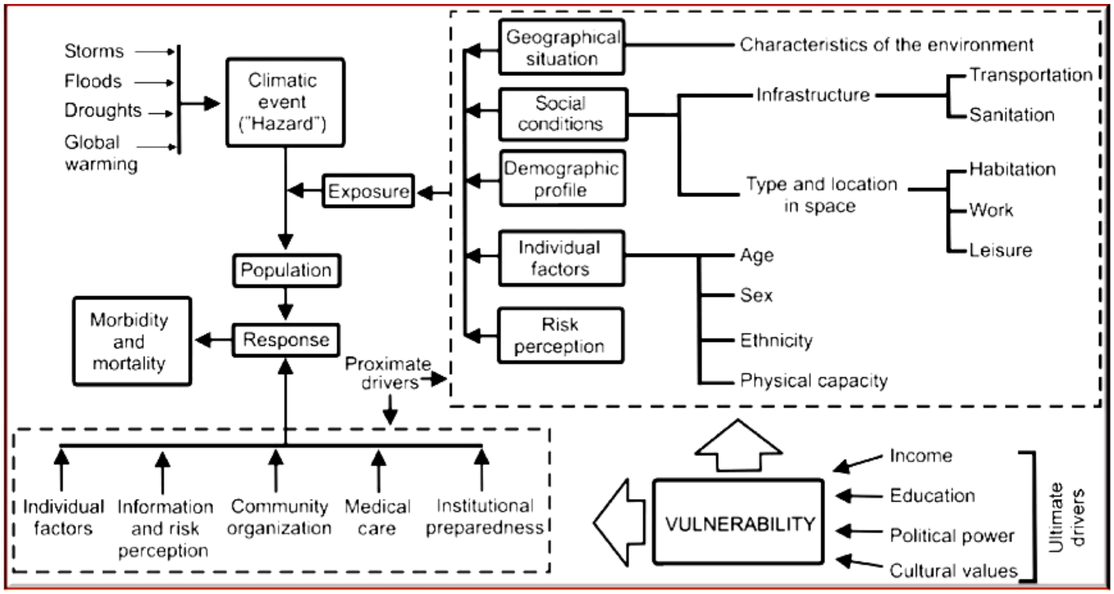


Figure 11: Conceptual Model for Vulnerability to Health Impacts of Climate

(Confalonieri et al, 2009c).

Urban Areas and Poverty: A Closer Look

Urban areas in Rio de Janeiro have been expanding for decades mainly in vacant lands that are not suited for occupation. These urban areas are composed of wetlands, steep hillsides, outcrops and rocky shores, and estuarine channels, rivers and forest remnants. The urban poor are placing themselves to hazardous environments that affect their quality of living and, subsequently, their health. Considering many of Rio de Janeiro's urban residents live under precarious conditions that are particularly concentrated in popular areas and slums, they posses closely related characteristics such as scarcity of water supply, lack of sewerage and street paving, illegal occupations and unhealthy housing conditions, among others. These conditions frame the social, political and economic inequality of the urban poor and highlight their vulnerable situation.

Moreover, the equitable distribution of resources poses a significant challenge in addressing climate change-effects on the urban poor (Pelling, 2011a).

Rise in Sea Level

The increase in the mean level of the ocean is a primary concern for coastal cities as climate change exacerbates the risks associated with its effects and consequences. Average sea levels have been increasing in the last few decades with a considerable regional variation. By the year 2080 sea level rise will affect five times as many coastal residents as it did in 1990 (The impacts of, 2011).

The vulnerabilities of Rio's coastal zone to climate change are shown in Figure 12. The effective response to new meteorological and oceanographic conditions is crucial for coastal residents to counter the effects climate change. The urban poor may not respond adequately to those conditions because of Rio de Janeiro's diversified and extremely modified coastal geomorphology. These coastal characteristics will damagingly affect the response of Rio's population to sea level rise (Pelling, 2011a).

The Special Characteristics of Coastal Cities

The characteristics of coastal cities and their vulnerabilities to climate change impacts are highlighted as follows, and particularly affect Rio's population:

a) Low Elevation: The majority of coastal cities are located at or near sea level. Coastal flooding represents a threat due to changes in sea level. Tidal-wave effects, cyclones or frontal systems are also climate events exacerbated by climate change (Pelling, 2011b).

b) <u>Topography</u>: Some coastal cities are surrounded by mountains/topographic barriers. These geographic obstacles serve to increase precipitation (Pelling, 2011b).

c) <u>Land Use</u>: Megacities serve as port and point of trade, locally and internationally. Industrial activities are also part of their economic activity and result in GHG emissions with significant health consequences for local and regional populations, deteriorating air quality (Pelling, 2011b).

d) <u>Sea/Land Breezes</u>: Water and land nearness creates day-time sea breezes and land breezes (on-shore and off-shore flows of air respectively). This effect concentrates pollutants and re-circulates them across the coast, with significant consequences for the health of coastal residents. The heath implication is worse at night, as the urban boundary layer decreases and magnifies the harmful health effects (Pelling, 2011b).

e) <u>Population Density</u>: The combination of scarcity of land availability and large populations creates an elevated division of impervious spaces/low fraction of greenspace as seen in Rio's slums urban areas. The urban effects, particularly urban warming are magnified due to energy flux partitioning-latent heat fluxes (which is the evapotranspiration rate; links between the properties of the urban environment and the exchange to the atmosphere). The evapotranspiration rates are suppressed, while sensible and storage heat fluxes are enhanced, creating greater heating of the air and substrate, intensifying urban effects (Pelling, 2011b).

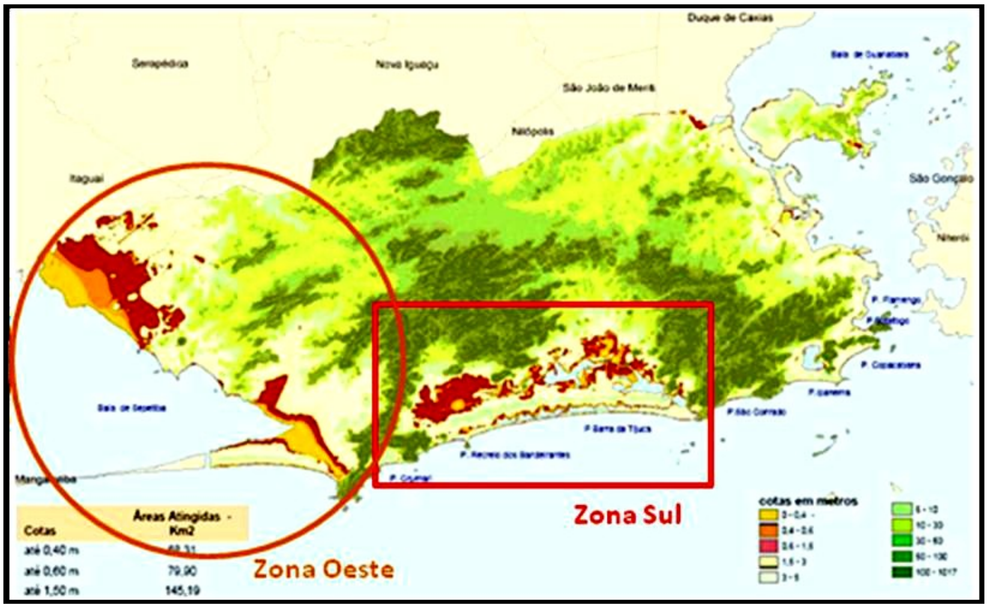


Figure 12: Vulnerable Areas to Sea Level Rise until 2100, Rio de Janeiro city – Source: IPP, 2008 (Pelling, 2011).

Rising sea levels will magnify the highlighted areas under risk, and the increase in frequency and intensity of storms associated with the elevation in the ocean temperature will exacerbate the problem in urban areas and particularly in large coastal cities such as Rio de Janeiro (Muehe, 2010).

Management Plans to Address Climate Change

The new Master Plan for the City of Rio de Janeiro[1] incorporates climate change mitigation and adaptation among the environmental guidelines already established. Furthermore, there are recent enactments such as the State Law on Climate Change (State Law No. 5690, of April 14, 2010) and the Municipal Law on Climate Change and

[1] Complementary Law No. 111/11 establishing the Master Plan of the City of Rio de Janeiro enacted on February 2, 2011.

Sustainable Development for reducing greenhouse gas emissions (Law No. 5248, enacted on January 28, 2011) (Barata, 2013).

The municipal strategic plan developed for the period 2009-2012 addresses the following initiatives considering climate change. The main objective is to implement a greenhouse-gas-emissions mitigation strategy:

➔ Implement new solutions for waste disposal in the city, closing the landfill of Gramacho. (Rio's Jardim Gramacho landfill, Latin America's largest, covering a land mass of 1.3 million square meters. This landfill is considered responsible for delivering tons of contaminants into Guanabara Bay.) It would enable an 8% reduction in emissions of greenhouse gases by the end of 2012, considering as reference the inventory of 2005 emissions.

➔ Expand the network of cycling city of Rio de Janeiro.

➔ Expand the public transportation system (BRT and subway) to reduce traffic congestion (Barata, 2013).

Furthermore, city leaders are working on a broad and deep adaptation plan for Rio de Janeiro. There is an established risk analysis strategy on the most vulnerable settlements (*favelas)* that has helped implement interventions when needed. Gradually, the city is improving that analysis with more information about the exposure to hazards of its population and their precarious housing infrastructure. The protocol of interventions and crisis management plans are all based on that information (Paes & Rosa, 2013).

The city has established tackling climate change as one of the strategic projects for the administration. The mayor of Rio has set targets for emissions reductions by 8%

in 2012, 16% in 2016 and 20% in 2020, reinforced by a law approved by City Council. The city leaders also manage the Rio low carbon city development program, in partnership with the World Bank, which develops a system to manage projects and their impacts on carbon emissions (Paes & Rosa, 2013).

Municipal Services and Climate Change

Transportation is the main source of carbon emissions in Rio de Janeiro, according to the most recent greenhouse gas inventory of its 2005 emissions. It accounts for 48% of emissions within the city. All policies and public concessions of transportation services such as bus, bus rapid transit (BRT) services and urban bike paths are highly essential for the implementation of plans that promote a sustainable living and tackle climate change. The mayor of Rio de Janeiro, Mr. Eduardo Paes, is working on greener solutions for the transportation sector. The city is currently testing several technologies such as hybrid, electric and biofuel to address its greenhouse gas emissions impact, emphasizing many innovative alternatives for mobility with a greener approach (Paes & Rosa, 2013).

Beijing

China's economic growth has been remarkable in the last few decades, and the increased in production from many sectors of society, such as trade and manufacturing, are associated with rapid increases in the use of fossil fuels, the primary source of carbon dioxide. Economic activity and energy demand keeps expanding at an accelerated rate, and that carries environmental consequences and presents serious challenges. As an example, if China continues to consume energy from coal as it is presently doing, by the year 2020 China's average per capita energy consumption will match the current global average and will account for almost one-third of the world's total GHG emissions (Hongyuan, 2008). Climate change combined with the current conditions presents a complicated situation for major cities in the country, and local governments need to address these issues as the environmental degradation caused by the aforementioned factors will ultimately impact China's economic development.

City of Ember

As one of the 20 largest in the world, Beijing also holds the justified reputation of being one of the most heavily polluted cities. Before the 2008 Olympic Games, Beijing was engaged in a series of actions to achieve a "Green Olympics," which translated into investments in alternative-fuel buses and taxis, as well as raising auto emission standards. These actions have helped to create initiatives to adapt a climate change mitigation strategy and, being as an important political and economic centre, Beijing serves as an interesting comparison city for the case studies of other global cities that are developing a concrete adaptation and mitigation strategy to combat climate change impacts on the health of their populations (Zhao, 2011).

Climate Change and Beijing's Urban Population

Beijing is located near the Bohai Sea and it covers an area of 16,807.8 km2. The population of this megacity is 15.4 million, with 12.9 million living in urban areas and 2.5 million living in rural areas. The immigrant population is estimated at 3.57 million people. Climate change impacts on the large city's population is of serious concern for scientists and heath officials, as the interactions of rapid urbanization and climate change effects are already felt among its residents with an increased frequency of heat waves in the center of the city and with less cooling at night (Qi et al , 2007).

The Urban Heat Island Effect in Beijing

The accelerated urbanization in developing countries makes the study and development of strategies to mitigate the urban effect on local and global climate a highly significant issue for megacities. Considering climate change conditions in the Beijing area, the knowledge of urban climate changes can add important information for adjusting urban human-settlement environments (Liu et al, 2009). Beijing's rapid urban development carries a series of consequences impacting its urban residents, and there have been a series of studies observing this phenomenon. The temperature from urban areas has been increasing in comparison to rural areas from 1961 to 2008 (Biao, 2011).

The detrimental effect of the urban heat island present in Beijing affects human health, increases the number of heat-related illnesses and deteriorates the quality of the air in the urban area. An observational evaluation conducted by Chengshan Wang and Xiumian Hu from July to August (1993 - 2003) concluded that the intensity of the urban heat island effect has increased every year. A heat wave affected the Beijing urban population from July 7 to July 15, 2003. The temperature during that period reached 35°C and emergency hospital admission visits increased 30% as a result of heat stroke and heat exhaustion. Additionally, 4,500 admissions to children's hospitals were reported as a consequence of fever and intestinal diseases (Qi et al, 2007).

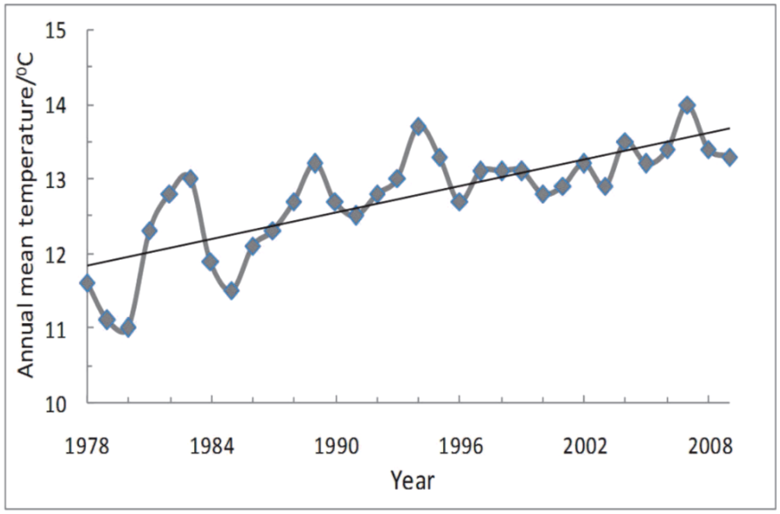
Air Quality in the Megacity

Approximately 70% of the air quality in the urban areas in China does not meet national ambient air quality standards. 75 percent of urban residents are exposed to air pollution as a consequence of a drastic increase of vehicle ownership in Beijing that has grown from 0.5 million in 1990 to 2 million in 2002. Air pollution from coal smoke and automotive exhaust fumes, including 80% CO and 40% NO_X, are the main sources of industrial and domestic air pollution. Furthermore, pathogenic microbes, heavy metals and toxic organics, which are a consequence of the rapid urban expansion experienced in Beijing, are deteriorating the quality of the air (Qi et al, 2007). The effects of air pollution, especially aerosols (particulate matter, PM), have been established to indicate that is leading to global warming and consequently detrimentally impacting the health of Beijing's urban population (Raes & Seinfeld, 2009).

Temperatures in Beijing

Based on the major observed evidence of climate change, China's annual average air temperatures have increased by 0.5-0.8C during the past 100 years and Beijing is presently experiencing fluctuating increases in temperature as temperatures has risen by 1.7C, from 11.6C in 1978 to 13.3C in 2009. The projections for 2020 are an increase of 1.3-2.1 C and 2.3- 3.3 C in 2050 in comparison with 2000 temperatures (Biao, 2011).

Chart 13: Annual Average Temperature in Beijing from 1978 to 2009 (Biao, 2011).



High Temperatures and Mortality in Vulnerable Populations

Research conducted on the greater urban area of Beijing has established the exposure-response relationship between temperatures and residents' death rate. Assessing the health risks of premature death related to higher temperatures is an effective way to contribute to the development of new policies addressing climate change impacts on health. For this particular study, the county of Beijing was divided into three regions that amalgamate the following sectors: Urban, inner suburban and outer suburban areas, according to the classification of Beijing Statistical Yearbook (National Bureau of Statistics of China 2008). The main reason for the separation of Beijing into three regions for the study is that health risks vary accordingly to the areas chosen and many differences exist in the population of each region (Tian Tian et al, 2012).

The urban area under the study included the Dongcheng, Xicheng, Chongwen and Xuanwu districts. The inner suburban area was encompassed by the Chaoyang, Fengtai, Shijingshan and Haidian districts. Finally, Fangshan, Tongzhou, Shunyi, Changping, Daxing, Mentougou, Pinggu and Huairou districts, along with Miyun and Yanqing county, compiled the outer suburban area for the analysis of the assessment. The method used for the study was developed using a Poisson generalized linear regression model with Beijing mortality and temperature data from October 1, 2006 to September 30, 2008. This statistical model calculates the exposure-response relationship for temperature and mortality in the central city, and the inner suburban and outer suburban regions. A health risk model was also used to evaluate heat-related premature death risks in the summer of 2009 in the months of June to August. The findings have shown that the highest mortality rate was recorded in the outer suburbs. Residents from the central city had a mid-range risk and, lastly, the inner suburbs presented the lowest risk among its inhabitants (Tian Tian et al, 2012).

The number of deaths according to the risk assessment performed was 1581. The highest number of premature deaths was recorded in the areas of Chaoyang and Haidian districts. Fangshan, Fengtai, Daxing and Tongzhou districts showed a mid-range rate in mortality. Considering the above facts from the statistical model carried out, premature death and higher temperatures are closely related in the city of Beijing. The vulnerability of the population to temperatures was highlighted in the city and outer suburban area. The following table shows the daily average mortality and temperature in Beijing from October 1, 2006 to September 30, 2008 (Tian Tian et al, 2012).

Table 10: Daily Average Mortality and Temperature (Tian Tian et al, 2012).

	N	$x \pm s$	**Min.**	**Max.**
Daily average Mortality (No./d)	**731**	**168.3±34.5**	**53.0**	**273.0**

Temperature (°C)	**731**	**13.8±10.8**	**-6.8**	**30.7**

The numbers of deaths in the summer of 2009 in Beijing are shown below on Figure 13, in view of each region. Central City (CC) including Dongcheng (DC), Xicheng (XC), Chongwen (CW), and Xuanwu (XW). Chaoyang (CY), Fengtai (FT), Shijingshan (SJS), Haidian (HD), Fangshan (FS), Tongzhou (TZ), Shunyi (SY), Changping (CP), Daxing (DX), Mentougou (MTG), Pinggu (PG), Huairou (HR), Miyun (MY), and Yanqing (YQ) (Tian Tian et al, 2012).

Central urban and outer suburban areas have experienced a greater effect of temperature on mortality. The different vulnerabilities of the population to the temperatures' effect in relation to the areas of study are highlighted (Tian Tian et al, 2012).

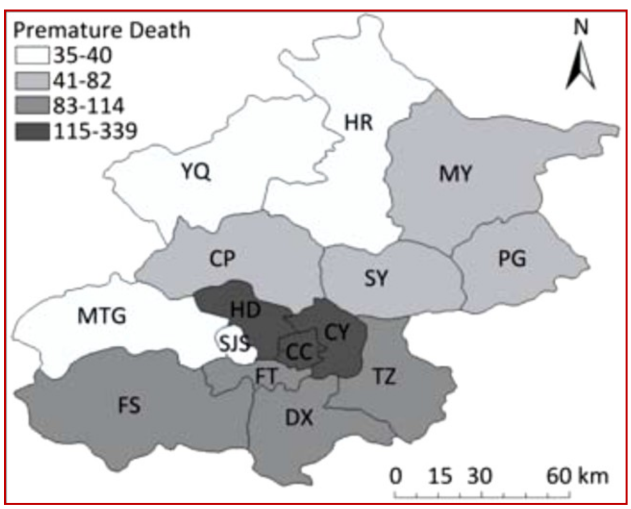


Figure 13: Temperature-Related Premature Deaths (Tian Tian et al, 2012).

Economic status also influences the vulnerability of the residents. Low-income populations are more susceptible to the impacts of climate change and drastic weather events such as heat waves. Socio-economic levels dictate the degree of risk exposure. As high population density is concentrated in the central area of Beijing, that part of the region has more residents with greater vulnerabilities to heat. Consequently, Beijing residents from the outer suburban area are relatively low-income as well, and may be exposed to more vulnerability to climate change impacts on health (Tian Tian et al, 2012).

Water Scarcity and Climate Change in Beijing

Beijing has a warm temperature that is described as a continental monsoon climate. There are observed changes in Beijing's climate that are characterized by an increase in annual average temperatures and a probability of a decrease in rainfall and runoff average, as well as more heat weaves. Therefore, climate change actions should not be taken in isolation but rather in conjunction with climate changes and pertinent issues that affect the city growth and its development (Biao, 2011).

Beijing is located in a semi-arid area and, as the current available water resources keeps decreasing at alarming rates, water scarcity is of urgent concern for the residents and government officials (Cui et al, 2009).

Transportation Sector in Beijing

The global average temperature may be much more sensitive to greenhouse gases in the atmosphere than is commonly believed; according to NASA scientist Dr. James E.

Hansen, to avoid severe climate change effects, we may need to reduce the concentration of CO2 in the atmosphere from today's 385 ppm to 350 ppm CO2 by 2100, if not sooner (Ackerman et al, 2009). 74 percent of the GHG emissions are induced by road vehicle usage, and transport is responsible for 23 percent of world energy-related greenhouse gas (GHG) emissions. These emissions have been increasing more rapidly in the transportation sector than in any other sector over the past decade. Furthermore, an accelerated increase of 80 percent is projected by the year 2030 if cities keep operating as they do today.

The concern comes from the rapid growth in urbanization and, consequently, the increased rate of vehicle ownership that grew 570 percent from 1990 to 2006. The interesting data comes from knowing that 1% of China's population drives 10% of China's vehicles (Creutzig & He, 2008).

As Beijing experiences rapid motorization, the city is also experiencing environmental and economic issues that must be confronted with urgency. The drastic increase in vehicles in Beijing poses an environmental hazard, and leaders need to implement a mitigation plan to confront this problem that affects the health of millions of residents. Means of transportation increased from 1.2 million in 2000 to 2.5 million in 2005 and to 3.5 million in 2008 in the city. The health of Beijing's inhabitants has been deteriorating as air pollution is critically affecting them and has become one of the leading causes of illness and death. The municipalities surrounding Beijing city are also affected. For example, in Tianjin, a municipality neighboring Beijing, air pollution is associated with $1.1 billion, i.e. 3.7% of Tianjin's GDP, in terms of health costs in 2003 (Creutzig & He, 2008).

Climate change mitigation strategies must highlight the transportation sector and its repercussions on environmental degradation and GHG emissions. There are external costs associated with motor vehicle use in Beijing and, with the sum of global climate change externalities, they equal approximately 7.5 - 15% of Beijing's GDP. These GDP percentages are contingent to suppositions of social costs that are converted into economic costs.

Evaluating and measuring social costs of climate change is challenging and can lead to uncertainty. However, if long-term costs and risks are internalized, the impact and consequences of climate change externalities can be parallel to congestion costs and air pollution (Creutzig & He, 2008).

GHG Mitigation Initiatives

Energy efficiency has become an important factor to address for the Beijing Municipal Government, as changing energy structure, promoting renewable energy, and advancing education and awareness of energy conservation and environmental protection are primordial initiatives for the city to put into practice. Energy shortage in Beijing is an issue the city leaders are trying to battle, in addition to the deterioration of air quality that sickens thousands of residents and even causes death. Furthermore, some of the above-mentioned initiatives have also developed GHG reduction measures that are benefiting the health of inhabitants and encouraging lower-carbon economic development in Beijing (Zhao, 2011).

Some Progress Along the Way

Beijing shows an increase in the total amount of energy consumption and CO_2 emissions, which is related to its rapid economic growth. However, energy consumption and CO_2 emissions per unit of GDP production have decreased as a consequence of great efforts by the city to increase energy efficiency and reduce energy intensity. These important efforts put the city of Beijing in the lead of mitigation strategies among other major Chinese cities. CO_2 reduction was also achieved by an increase in forest coverage and wetlands and, between 2001 and 2006, all the aforementioned activities accounted for 80 million tons of CO_2 reduction (Zhao, 2011).

Los Angeles

The greater Los Angeles area has a population of nearly 18 million residents. This megacity generates nearly $750 billion in economic activity every year (Hall et al, 2012a). The city of Los Angeles has a population of approximately 4 million people in a setting that possesses a diverse community structure within 469 square-mile area. Part of the Southern California economy, and the 14th largest in the world, Los Angeles is also a main center of global trade and has a well-established entertainment industry (Green Los Angeles, 2007).

Los Angeles County is a good representation of how major municipalities work within the United States structural government. These cities are not a formal political designation structure as some other major cities are around the world. Instead, Los Angeles is a reflection of urban sprawl or the "suburbanization" of America. The division or fragmentation of government is evident, and presents a challenge in dealing with local and global issues where the population is affected. The disparity between political and urban delimitation leads to several issues Los Angeles (as other megacities) currently faces, such as traffic congestion and air and water pollution. Inner-cities have financial challenges in addressing climate change impacts on the poor, as well other urgent issues such as crime, population density and health risks (Schroeder & Bulkeley, 2009).

The Effect of Climate Change on Air Quality

Air quality is interrelated and influenced by climate events and it is highly sensitive to climate change. Moreover, surface ozone and temperature in polluted regions leads to harmful environmental effects, as high temperatures exacerbate this condition.

The detrimental effects of climate change will be relentlessly felt in polluted areas by 1 – 10 ppb (parts-per-billion) over the coming decades. As stated throughout this research, urban areas and populations will be severely affected, as well as cities with pollution episodes such as Los Angeles. The aforesaid information came from GCM–CTM studies of the detrimental effects of climate change on air quality. Particulate matter (PM) concentrations such as soot into the air are going to be affected by climate change in accordance to the GCM–CTM studies by _0.1–1 mgm_3 over the coming decades and, as the County of Los Angeles and, accordingly, the State of California is regularly affected by wildfires, these uncontrolled fires in combustible vegetation could become an important source of PM (Jacob & Winner, 2009).

The association of particulate air pollution with mortality was studied by the American Cancer Society (ACS), using a cohort to assess the connection between the two. Several studies have concluded air pollution effects on all-cause and cause-specific mortality are confirmed. The Harvard Six-Cities study (one of the most influential, innovative, and longest-running experiments concerning the health effects of air pollution in America) and the ACS studies have been used in regulatory interventions by the government, such as the U.S. Environmental Protection Agency's National Air Quality Standard for Fine Particles, and by the World Health Organization to estimate the cause of deaths by air pollution (Jerrett et al, 2005).

Exposure of PM 2.5 (tiny particles or droplets in the air that are two and one-half microns or less in width) may be even larger than earlier studies suggested within city gradients, as the relation between PM exposure and hazardous health effects have been established. The study also found that the effects of PM on health are nearly three times greater within city gradients in comparison to communities (Jerrett et al, 2005).

Utilizing the dynamical downscaling method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs), a study examined the climate and air quality response to local CO_2 over Los Angeles for six months. The results presented an increase of ozone and PM as a result of CO_2 emissions. In general, GCMs have a resolution of 150-300 km by 150-300 km and the Los Angeles domain resolution is the highest resolution that has been detected in this particular region using the dynamical downscaling system (Zhao et al, 2011).

The Poor in the Urban Communities

Heat waves can have resonant consequences among poor residents of Los Angeles as they do not have the necessary resources to pay for air conditioning and eventually will leave hot spots and migrate from central city areas affected by these conditions (O'Brien & Leichenko, 2000). Migration will be one of the consequences of anthropogenic climate change. Many of the urban poor will not be able to migrate far and, consequently, Los Angeles will experience a migratory shift between neighboring counties (Friel et al, 2011).

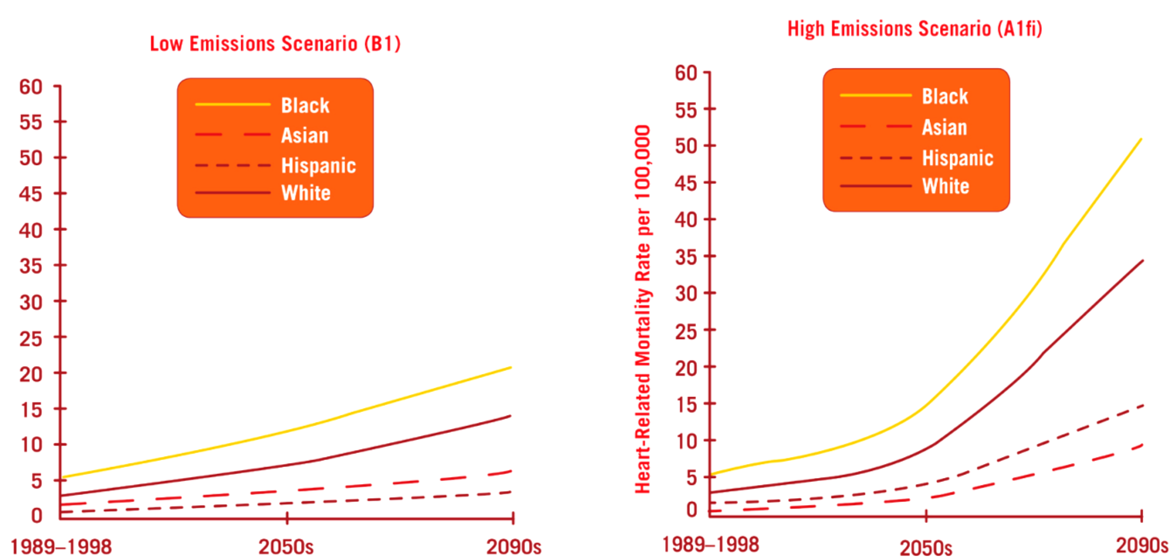
The Poor and Their Vulnerabilities

The wealth of Los Angeles and its diverse economy is well-known, as it is supported by leading entertainment, business and finance, health care, sports, transportation, and high technology companies. However, 15 percent of the county population is living at or below the federal poverty level, including more than 1 in 5 children. Los Angeles also has one of the largest populations of homeless, which amounts to approximately 80,000 people (Cousineau, 2009).

Moreover, the urban poor and, more specifically, minority groups are also highly vulnerable to climate change, heat waves and drastic weather events in Los Angeles. In regards to external factors, low-income urban neighborhoods and communities of color are particularly vulnerable to heat waves because they are segregated in the inner city, which is more likely to experience the heat island effect. These subgroups lack access to health care centers and immediate aid to confront climate changes affecting their health. Recent research conducted in four California urban areas presents a positive relationship between the concrete infrastructures, heat-trapping surfaces and community poverty, and a negative relationship between the quantity of tree cover and the poverty level of the community involved in the study (Morello-Frosch et al, 2012). This representation shows the inequality of heat island exposure to low-income populations compared with higher-income populations. Furthermore, African Americans show a higher heat wave mortality rate than other demographic groups in Los Angeles, which is nearly twice than average, as shown on the chart below (Morello-Frosch et al, 2012).

Chart 14: Relative Heat-Wave Mortality Rates by Race/Ethnicity for Los Angeles*

* Actual historical values (1989–1998) and projected future values (2050s – 2090s) for high-emissions (A1fi) and low-emissions (B1) scenarios. (HadCM3 projections only) (Morello-Frosch et al, 2012).



Water: A Vital and Valuable Natural Resource

Climate change will influence and put at risk water management operations and the existing infrastructures that provide the effective operation of water supply reliability. As the risk of climate change consequences increases, existing practices for designing water-related infrastructure must be adjusted to adapt to the current threat of severe climate changes. Also, drinkable water standards need to be met, and increased turbidity may increase considerably the costs and challenges of treating water to those abovementioned standards. Structural measures are necessary for climate change adaptation strategies as well as for forecasting/warning systems, insurance instruments, innovative ways to improve efficiency of water use (e.g. via demand management) and economic and fiscal frameworks that attack the issue, such as the making of laws, institutional change and new policies (Kundzewicz et al, 2008).

The majority of Los Angeles' 4 million residents depend on Eastern-Sierra Nevada water sources. The large natural reservoir of snowpack and melt-water is stored and, subsequently, delivered to the city by the Los Angeles Aqueduct (LAA), which is 340 miles long. The storage capacity of the seven reservoirs surrounding the aqueduct is approximately 300 thousand acre-feet, and the availability of this water supply source is crucial to the well-being of Los Angeles residents, and the future of its economy. Several problems with water supply and the quality of drinkable water have created new pressures for city leaders to address this issue. In 2007, "water-limited" Los Angeles faced the lowest snowpack on record in the Eastern Sierra, where Los Angeles historically receives the greatest share of its water supply, and the driest year on record.

Over 70% of annual runoff originates from snowmelt in urban centers throughout the western United States. One-sixth of the world's population relies on these layers of snow, which accumulate in geographic regions and high altitudes where the climate includes cold weather for extended periods during the year. All of the above concerns are of a high priority for the city's mayor, and illustrate the severity of this urgent problem

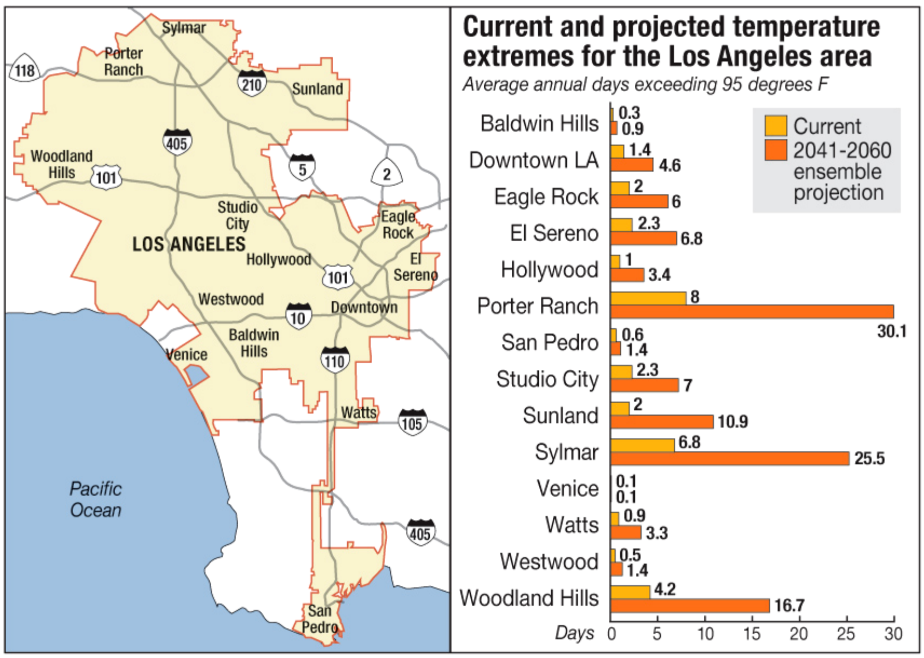
(Mills et al, 2012). Public health is in danger as water quality will deteriorate; water quantity will be reduced and sanitation systems will cause environmental contamination if a climate change strategy for water supply is not achieved (Summary and policy, 2009).

Los Angeles Pioneer Initiatives

The city of Los Angeles leads the way in conducting analysis of climate change and its impacts. The first in a series of groundbreaking climate change studies was produced by UCLA researchers (University of California, Los Angeles), with financial support from the city in collaboration with the Los Angeles Regional Collaborative for Climate Action and Sustainability (LARC) (Pascual, 2012).

The study conducted by UCLA modeled temperature change at high resolution (2km as opposed to 200km) and within a period of time that can be relevant to policy makers so they can develop and implement the appropriate measures. A suitable time frame for implementation follows a 30 - 50 year prospect (mid-century; the years 2041 - 2060). The study considered two different greenhouse gas emissions situations: business-as-usual (RCP 8.5) and an aggressive mitigation strategy (RCP 2.6). The Intergovernmental Panel on Climate Change 5th Assessment Report has established these new terms, and they symbolize the range of policy options (high and low) that are generally presented in concessions under an international context. The concentrations of greenhouse gasses are 1200 ppm or 460 ppm of CO_2 equivalent concentration by 2100, in that order (Hall et al, 2012b).

Los Angeles will experience a drastic increase in temperatures between the years 2041 - 2060. The results also show the benefit of future-climate modeling on a regional scale, as Los Angeles has a complex climatic environment given its proximity to the ocean, mountainous surroundings and dissimilarity in seasonality (Hall et al, 2012b).



Source: UCLA LARC study, 2012; chart based on the mean/average projected by the 19 climate models

Figure 14: Los Angeles Temperatures Extremes Study (Hall et al, 2012c).

As shown above, the UCLA study used 19 global climate models downscaled for Los Angeles, and it is composed of a state of the art regional modeling technique. The technique is called dynamical downscaling and it utilizes intense computation at a high resolution to model the climate's physical processes. Port Ranch and Sylmar will experience the highest level of temperature. Hollywood will also be exposed to a higher temperature, which will triple. A highlighted note to the study is that coastal areas will likely experience a warmer climate but the temperatures will be lower than the inland areas, where some, as noted on the map, will reach extremely higher temperatures (Hall et al, 2012c).

The positive argument for the study is that it was focused on a regional level, and specifically conducted to fit the diverse ecosystem that represents Los Angeles County. Santa Monica, for example, is quite different from Lancaster, as it is near the beach and has a different topography than the latter, which is a charter city in northern Los Angeles County, with a high desert environment (Pascual, 2012).

Mitigation Strategies

Los Angeles emits one-fifth of 1 percent of the world's carbon dioxide. Although it seems a minuscule number, it is equivalent to the carbon dioxide emissions of the entire country of Sweden. The plan, under Mayor Antonio Villaraigosa, combines different environmental initiatives with a goal of reducing greenhouse gas emissions 35% below 1990 levels by 2030 (Pascual, 2012). This ambitious plan includes strategies such as urban planning, which are crucial to achieve this goal and amalgamating a series of initiatives to improve energy conservation, transition to renewable power sources and change the ways residents commute to work and school. The plan encompasses actions to revamp the city to build more parks and open space, in addition to reducing municipal waste, improving water efficiency and setting smart new standards for "green building" and land-use planning (Villaraigosa, 2007).

Asking the Climate Question

The Center for Clean Air Policy (CCAP) has been working on issues associated with climate and air quality since 1985. As a non-profit organization, it works exclusively on the issues mentioned, on a local, national and international level. In 2006, CCAP started a relationship with county and city leaders to start the Urban Leaders Adaptation Initiative ("Urban Leaders"). Adaptation strategies have become an urgent agenda for Los Angeles and, as a result of participating in Urban Leaders, the city developed adaptation programs, and established a Climate Adaptation Division within their Environmental Affairs Department (Lowe et al, 2009).

Micro-scale projects for adaptation plans are also part of the strategy as a smaller scale approach doesn't conflict with mitigation strategies, and creates efficiency while implementing those projects. The health of Los Angeles residents became a priority for the mayor as the city initiated the Million Trees LA program (MTLA), a partnership between city agencies and not-for-profit community-based organizations to plant trees along streets and in parks (Lowe et al, 2009).

Furthermore, the Los Angeles Green Building program aims at minimizing the use of natural resources. The acknowledgment of the detrimental consequences of development on a local, regional and global ecosystem is emphasized. The main areas the program addresses are:

1. Site: location, site planning, landscaping, storm water management, construction and demolition recycling.

2. Water Efficiency: efficient fixtures, wastewater reuse and efficient irrigation.

3. Energy & Atmosphere: energy efficiency and clean/renewable energy.

4. Materials & Resources: materials reuse, efficient building systems and use of recycled and rapidly renewable materials.

5. Indoor Environmental Quality: improved indoor air quality, increased natural lighting and improved thermal comfort/control.

(Delgadillo, 2008).

Moving Forward

Greenhouse gas (GHG) mitigation strategies must be a priority for the city of Los Angeles, considering the high volume of motor vehicles within its territory. The Los Angeles County Metropolitan Transportation Authority (Metro) is developing sustainability strategies to make best use of transportation efficiency, access, and safety and operation excellence, while minimizing energy use, consumption, pollution and waste. As transportation is a highlighted issue for the city and its counties, the proposed plan includes those focused on Metro's vehicle fleet, buildings and prospects to efficiently reduce vehicle miles traveled (VMT) (Greenhouse gas emissions, 2010).

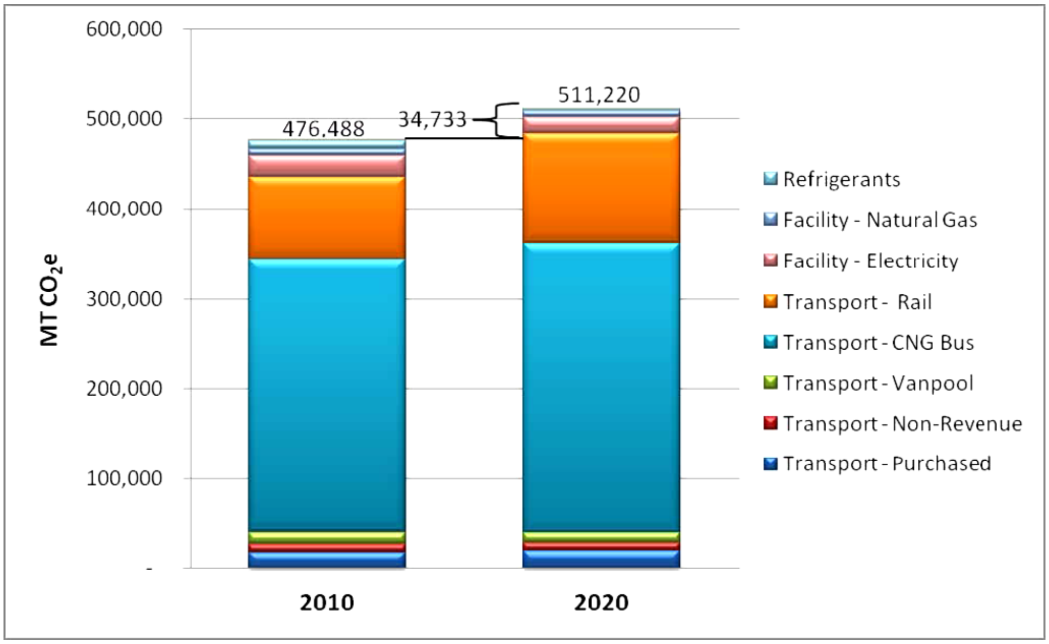
Los Angeles is on track to implement a sustainability plan that will transform the city, as it is developing a strategy to add 60 new transit-oriented development areas alongside subway lines. These developments include dense housing, walkable streets and mixed-used developments near transit options. The main focus is to diminish the residents' dependence on motor vehicles to help reduce greenhouse gas emissions. Regarding how the city operates in a sustainable way, more than half of the vehicles are currently hybrid or run on alternative fuels such as natural gas, which counts for all the city's buses. What is more, air pollution from the Port of Los Angeles has been a problem for decades but now it has been reduced by 45 percent (Greenhouse gas emissions, 2010).

The sustainability program under the Los Angeles County Metropolitan Transportation Authority (Metro) follows the "Plan-Do-Check-Act" model that was established through Metro's Environmental Management System (EMS). EMS is an effective framework that can ensure compliance with environmental regulations and facilitate environmental stewardship. The Climate Action and Adaptation Plan conducted by the city of Los Angeles is a positive strategy to develop initiatives that will ensure a proactive approach toward adaptation and mitigation to lessen climate change impacts on the city and its population (Climate action and, 2012a).

Metro's GHG Emissions Projections: 2020

The increase of Metro's internal emissions is substantial if compared with the 2010 report. By 2020 emissions will increase by 34,733 metric tons (MT), or 7%, to 511,220 MT (See Chart 15). Most of the emissions increase will be from an expanded rail system, as rail emissions will be accountable for the majority of the total emissions in 2020 in comparison to 2010 emissions. Los Angeles' population is expected to keep increasing, and the CNG bus emissions are also expected to increase. Improvements in building energy efficiency and electricity supply that are less carbon intensive will provide a lesser impact on emissions emitted by the sector. Taking into consideration buses, rail and vanpools, GHG will account for 95% of the Metro's transit service in 2020. On a positive note, GHG emissions per boarding will fall 4.4%, from 1.04 MTCO2e per thousand boardings to 0.99 MTCO2e per thousand boardings, even though annual boardings are projected to rise in 2020 to 516 million, up 12% from 2010 (Climate action and, 2012b).

Chart 15: Metro Internal Emissions by Source in 2020 (%) (Climate action and, 2012b).



The next chapter discusses the methods and benefits of conducting an adaptation and mitigation strategy as a response to climate change and its implications.

Chapter 8 Adaptation and Mitigation as an Effective Response to Climate Change

Pragmatic Arguments for Adaptation

Uncertain difficulties and future events pose a risk for society and expose the challenges in addressing a common concern. Consequently, the diversion of land, water and other resources can have catastrophic effects for the poor and this emphasis the need for a concise adaptation and risk management plan.

As city's leaders face the threat of no action toward the implementation of a comprehensive risk management plan to adapt and mitigate climate change impacts, it is possible to reframe these challenges and aim them at the people who are directly impacted by drastic weather events (Lynch, 2008).

The main course of action is motivated by the outcomes of damaging drought, heat waves, flood or other disaster identified with climate change. The opportunities to field-test policies and a risk management plan to combat climate change are available when risk is present (Lynch, 2008). For example, The World Bank works directly with clients preparing projects to provide recommendations and then works with them to implement the plans to finance them. Working collaboratively with the city or country is vital for effective development and implementation of the strategic plan (Baker, 2012a). Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions. Adaptation is essential, particularly in addressing near-term impacts, because even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades. However, adaptation alone is not expected to cope with all the projected effects of climate change, and especially not over the long run, as most impacts will increase in magnitude over time (Van Ypersele, 2007).

Reducing Climate Change Impacts Implementing an Adaptation Framework

Restrictions on adapting to climate change can be costly, and the effects of climate change and the consequences of inaction will be irreversible. Figure 15 corresponds to the Net Present Value (NVP) (a way of comparing the value of money now with the value of money in the future) of total climate change costs, which is the discounted sum of adaptation and mitigation costs, and residual damages over all periods, given as a percentage of NVP output (GDP). It shows different situations where optimal adaptation is applied and where no adaptation at all has been implemented.

The potential for reducing climate change impacts implementing an adaptation framework is shown when optimal adaptation is implemented as the NVP of total climate change costs equals 0.9% of the NVP of GDP. In the contrary, it increases to 1.5% of the NVP of GDP when adaptation is not present. The major component of climate costs is the residual damages, even in the case of optimal adaptation. A highlighted note on the analysis is that when adaptation programs are not put into practice, mitigation costs are much higher. As adaptation decreases, the marginal value of mitigation increases, increasing mitigation levels and decreasing the damages (De Bruin & Dellink, 2011).

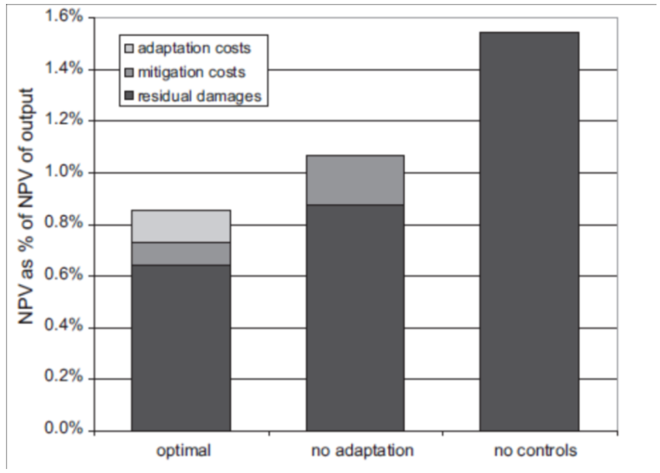


Figure 15: Optimal Adaptation, No Adaptation and No Controls (De Bruin & Dellink, 2011).

The figure above calculates the NPV of output in the AD-DICE model and expresses all climate change costs as a percentage of that. The NPV is the sum of the output over the whole time horizon (60 periods), discounted using the Ramsey discount rate in the DICE model. The Ramsey rate includes time preference and the elasticity of marginal utility with respect to consumption (De Bruin & Dellink, 2011).

Adaptation as an Effective Way to Minimize Climate Change Impacts on Health

Climate change and the impacts on the environment are presently affecting our health, and these effects will be highly significant in the long term. The effects on the socio-economic systems will also be relevant to developing an adaptation plan to combat climate change. Megacities need to evaluate their policies and adaptation capabilities to react and deter climate change impacts on their populations. Therefore, an integrated analysis of optimal mitigation and adaptation needs to be addressed in every major city (Lomborg, 2010).

Adaptation can be an efficient way to minimize the impacts of climate change on human health. Adaptation expenditures are a challenge for many countries in the present economic conditions. However, the benefit-cost ratio to implement an adaptation framework has a larger benefit than many of the different scenarios without a risk management plan. Moreover, the adaptation and mitigation plans have an even larger benefit when implemented in cooperation. Adaptation measures present a challenge when implementing them, particularly in major cities. There is an emphasis on synergetic interventions but it can be difficult to coordinate adaptation measures under this model, and this can affect the mitigation and implementation initiatives. Cities can evaluate their risk management framework efficiently if they examine their mitigation and adaptation needs independently (Bosello et al., 2009a).

Public Health, Climate Change and Adaptation Stratagem

The certainty of climate change impacts on public health has led to justified concerns in addressing public health actions to foresee, manage and minimize the health risks these climate events will inflict on inhabitants (Frumkin et al, 2008).

The United States Health Department has developed an adaptation plan by following a process called BRACE (Building Resilience Against Climate Effects), which is an adaptation planning framework for public health agencies (Luber, 2012). There are five sequential steps in the BRACE Framework:

1. Forecast climate impacts and assess hazard vulnerabilities where a health department identifies the scope of the most likely climate impacts, the potential health prospect associated with those climatic changes, as well as the health impacts within jurisdictions, and the vulnerability profile of the county through a population's assessment attributes.

2. Project the disease burden. This step is important in order to prioritize actions and decision making.

3. Assess public health interventions where a health department seeks to identify the most suitable health interventions for the health impacts of greatest concern.

4. Developing and implementing a climate and health adaptation plan. The health department develops and implements a health adaptation plan for climate change, addressing health impacts and a plan to improve adaptive capacity in the jurisdiction.

5. Evaluate impact and improve quality of activities whereby a health department can evaluate the processes utilized, and determine the value of the framework and climate and health activities undertaken (Luber, 2012).

ISO 31000 fits very well into the healthcare sector as it and its predecessor AS/NZS 4360 have a long history of use in the healthcare industry in Australia, New Zealand and the UK. Many of the processes in healthcare readily feed into the ISO 31000 process, and where ISO 31000 has been adopted it has strengthened the existing processes (Knight, 2013).

Furthermore, implementing adaptation strategies for climate change impacts will alleviate poverty, improving people's health and resilience. It is necessary to focus on the agricultural systems because one of the main concerns for the poor is the effect of climate change on food prices. Therefore, a public health adaptation strategy could consist of increasing agriculture outputs as well as avoiding competition between food and biofuel production, as this threats the availability of adequate food supplies for people (Haines, 2012d).

Framework for Public Health Action

The following framework can be utilized as the base for public health action and for initiatives pertinent to climate change. Table 11 specifically describes the actions necessary to address climate change events (Frumkin et al, 2008).

Table 11 —The 10 Essential Services of Public Health, With Climate Change Examples (Frumkin et al, 2008).

Service	Climate Change Example
1. Monitor health status to identify and solve community health problems.	Tracking of diseases and trends related to climate change.
2. Diagnose and investigate health problems and health hazards in the community.	Investigation of infectious water-, food-, and vector-borne disease outbreaks.
3. Inform, educate, and empower people about health impacts of climate change.	Informing the public and policymakers about health issues.
4. Mobilize community partnerships and action to	Public health partnerships with industry

identify and solve health problems .	and faith community groups to craft and implement solutions.
.	
5. Develop policies and plans that support individual and community health efforts.	Municipal heat wave preparedness plans.
6. Enforce laws and regulations that protect health and ensure safety.	(Little role for public health.)
7. Link people to needed personal health services and ensure the provision of health care when otherwise unavailable.	Health care service provision following disasters.
8. Ensure a competent public and personal health care workforce.	Training of health care providers for health aspects of climate change.
9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services. .	Program assessment of preparedness efforts, such as heat wave plans.
10. Research new insights and innovative solutions to innovative health problems.	Research health effects of climate change, including techniques, such as modeling, and research on optimal adaptation strategies.

Practical and ethical issues related to climate change have been called into consideration by scientists, clinicians and public health professionals alike. A proactive public health strategy is needed to address the challenges climate change impacts on health will have on people, and there are several well-established principles that aim at a dynamic, practical approach.

⇒ Primary Prevention: Preventing the onset of injury or illness.

⇒ Secondary Prevention: Early diagnosis to control its advance and minimize the health burden.

⇒ Tertiary Prevention: After disease is diagnosed, this prevention stage focuses on reducing morbidity, avoids complications and restores function.

There are clear similarities between a proactive public health approach and climate change adaptation and mitigation strategies. Adaptation strategies belong to secondary and tertiary preventions, and they are the efforts to prepare and predict climate change risks and subsequently reduce the effects of the climate change burden on public health. Mitigation strategies can be implemented not only in the health sector but in the energy, transportation, and building sectors as well. However, the health sector can efficiently contribute to implement an adaptation strategy that minimizes detrimental health impacts of climate change in a cost-effective manner (Frumkin et al, 2008).

Viable Strategies to Combat Climate Change

Megacities are at an early stage regarding adaptation reporting on both national and international levels. Among the C40 group of cities a very few of them have reported adaptation actions toward climate change. The C40 survey shows only four countries are required by their governments to report on adaptation strategies (Global report on, 2011).

Adaptation and mitigation to minimize and deter the impacts of climate change are viable strategies to implement in major cities, and can help to lessen the health risks caused by drastic weather events and climate change. However, these strategies confront the issue from different angles. Mitigation has a global context in application and it is considered a long-term strategy. Adaptation is a strategy that has a short-term implementation and a local application. As observed, both approaches work on different spatial and time scales (Bosello et al., 2009b).

City's mayors seek permanent solutions to prevent the impacts of climate change, and mitigation strategies can be the right answer for anthropogenic climate change. It offers a continuing approach as well as a framework that can be developed accordingly to the region impacted by climate change and reduces the risk of effects (Lomborg, 2010).

Diseases, injuries and food scarcity are consequences of climate change and therefore will affect entire populations, particularly the poor, children and elderly. Implementing adaptation strategies provides a temporary solution to address current or expected hazards (Bosello et al., 2009b). Adaptation strategies need to be flexible in adjusting to changing circumstances and situations should the damage and disaster risk differ from what was initially anticipated (Bosello et al., 2009b).

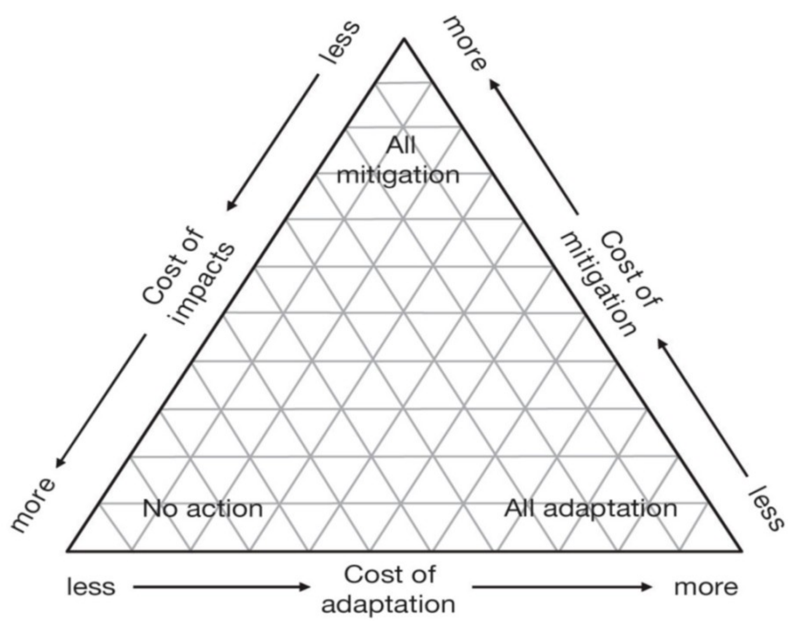


Figure 16: Mitigation, Adaptation and Impacts: a Schematic "Decision Space"

(Bosello et al., 2009c).

Practical and effective strategies would be a combination of mitigation and adaptation measures, where the city's leaders place themselves somewhere inside the decision space represented by the triangle of Figure 16. There is a possibility of vertex or highest point in the figure, but it is unlikely in this situation (Bosello et al., 2009c).

Mitigation Actions

A fundamental change in energy policy and international cooperation is required for a concrete mitigation strategy. The management of scarcity is required for concise carbon budgeting, in this case, the scarcity of the earth's capacity to take up GHG emissions (Watkins, 2007). It is also fundamental to establish an economy-wide carbon-pricing system and balance it with significant policies for effectiveness. The near-term reduction of emissions with the application of efficient methods of energy consumption and low-emission energy sources in transportation and electric sectors is a way to confront climate change risks (McCarl, 2004).

Furthermore, carbon capture viability through an established technical and economic framework, as well as promotion of the retrofitting, retirement or replacement of GHG emission-intense infrastructure is imperative for a climate change mitigation plan. Special attention to disadvantage populations (e.g., urban poor, children, elderly) needs to be emphasized to propose and implement policies to promote equitable outcomes (McCarl, 2004).

Reducing climate change adverse impacts and enhancing the benefits of climate variability is adaptation's main priority, but it cannot be implemented without a high cost

(Smit & Pilifosova, 2001). It also carries residual damage and become less effective as the magnitude of climate change impacts increase. For that reason, the burden of adaptation measures diminishes as the level of mitigation strategies increase at affordable cost. Global carbon trading will dramatically increase under the current trends, and an effective reform of carbon trading and carbon offsets can encourage environmentally sustainable practices, improve adaptive capacity and highly benefit mitigation strategies (Yohe et al., 2007).

Investing in advance measurements and monitoring techniques (use of statistics and computer modeling, remote sensing, global positioning systems and geographic information systems) to improve the accuracy and development of strategies can reduce transaction expenditures as changes in stock of carbon are precisely estimated at a lower cost (Yohe et al., 2007).

A New Development Strategy

It is necessary to develop policies and frameworks for climate change adaptation and mitigation. ISO 31000 Risk Management can efficiently increase the likelihood of achieving objectives; improve the identification of opportunities and threats; improve governance; establish a reliable basis for decision making and planning; effectively allocate resources for risk treatment; improve operational effectiveness and efficiency; enhance health and safety performance, as well as environmental protection; and improve loss prevention and incident management (ISO 31000, 2009).

Additionally, pro-poor investments can increase profitability of environmentally sustainable practices and deter the consequences of climate change impacts. Streamlining the measurement and enforcement of offsets, financial flows and carbon credits for investors are essential to accomplishing the strategy's objective (Yohe et al., 2007).

Chapter 9 Risk Management and Its Relation to Climate Change

Risk management serves to effectively identify potential opportunities, manage and take action toward adverse effects. The probability of events and their consequences is emphasized, and this can be measured qualitatively or quantitatively. In addition, these characterizations can be applied to climate change risks and planning evaluations (Jones & Preston, 2010).

Risk management frameworks, and specifically ISO 31000, can be highly useful to world leaders about minimizing risks of climate change effects on populations. However, one of the great problems with climate change is separating the zealotry from the reality of what we can actually achieve. So the first step is to critically examine the objectives that are being set. Are they in fact achievable or are they a desirable pie in the sky hope? Will they actually provide meaningful outcomes or are they essentially feel good images? This is where ISO 31000 apply the process for testing the objectives and developing an effective understanding of what uncertainty exists and how or if it can be controlled within the resources and knowledge available to the program.

ISO 31000 provides the information needed to establish the principals, and to develop the right changes to the management system to be employed and a process for understanding and managing the risks that will imperil the achievement of our objectives with respect to protecting the population from aspects of climate change. It also enables us to identify which aspects we can change and which we cannot, as well as to know the difference between the two (Knight, 2013).

Different Stages of Risk

Risk management can identify the different stages of risk and the development of measurement processes for climate change. The framework to identify risk is a recursive process that can be evaluated periodically. The Intergovernmental Panel on Climate Change has identified and approved four generations of risk management. First and second generations investigate the nature of climate change concerns, as well as focusing on identifying and analyzing risks and impacts. The third generation examines the nature of adaptation, and the fourth generation implements the methods of evaluation and risk management. Additionally, there is an emphasis on a fifth generation for researchers and stakeholders to highlight the adaptation's advantages and to develop frameworks to assess such benefits for improvement (Jones & Preston, 2010). The following steps are important to determining risk management processes to evaluate climate vulnerability, climate change impacts and adaptation strategies:

- A scoping exercise where the context of the assessment is established. This identifies the overall method to be used and establishes relationships between stakeholders and researchers.
- Risk identification. This step also identifies scenario-development needs.
- Risk analysis, where the consequences and their likelihood are analyzed. This is a highly developed area with a wide range of available methods to undertake impact analysis.
- Risk evaluation, where adaptation and mitigation methods are prioritized.

- Risk management or treatment, where selected adaptation-mitigation measures are applied.

- Monitoring and review, where measures are assessed and the decision made to reinforce, re-evaluate or repeat the risk assessment process (Jones & Preston, 2010).

Analyzing Risk

The assessment framework is developed to methodically analyze the risks. Then, risk is evaluated by identifying the consequences and probabilities in the context of existing controls. Taking into consideration the source of risk is important and it has to be emphasized to understand the positive and negative effects and probabilities. An individual analysis of the consequences and likelihoods is needed to perform a qualitative climate change risk assessment based on particular outcomes. Analyzing past events, practice and relevant information, as well as applicable published literature, is underlined for an effective analysis of risk (Guide to climate, 2011).

The Risk Analysis Stages

Analyze existing controls – Identifying existing controls to minimize the consequences and likelihood of each risk. Only existing controls which are funded and require no further work to be implemented should be measured in this stage. Assuming the climate change scenario is occurring, reducing the consequences and likelihoods of risk should be evaluated (Guide to climate, 2011).

Analyze the event's magnitude of consequence and likelihood – Determine the phase of the magnitude of an event's consequence and its likelihood of occurring.

Particular consideration should be paid to climate change scenarios and the existing controls to manage the risk (Guide to climate, 2011).

Assign the risk priority rating – Using the risk priority table developed below, the risk rating can be obtained. The process of analyzing different climate change scenarios has to be put into practice for each risk (Guide to climate, 2011).

	CONSEQUENCE					
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic	
Almost certain	Medium	Medium	High	Extreme	Extreme	
Likely	Low	Medium	High	High	Extreme	
Possible	Low	Medium	Medium	High	High	
Unlikely	Low	Low	Medium	Medium	Medium	
Rare	Low	Low	Low	Low	Medium	

Table 12: Risk Priority Ratings Example (given that a scenario arises) (Guide to climate, 2011).

Level of Risk: Likelihood X Consequence

ISO 31000:2009 provides the level of risk, which is expressed in terms of the product of the likelihood and consequence. Therefore, a description of the likelihoods and consequences to define the level of risk is fundamental to developing a risk management strategy for climate change (Rollason, 2010).

Evaluating Risks

ISO 31000:2009 classifies risk evaluation as a framework to compare the results of the risk analysis with risk criteria, and to determine if the level of risk is acceptable, allowable or intolerable. The priority of action is given to intolerable risks. It is not possible to treat every risk, and there is a possibility of having a high cost of implementation that offsets the benefits or risk reduction achieved. The methods of risk level reduction are evaluated, and then the actions to investigate new management measures are put in place. The amalgamation of the likelihood and consequence in the previous step presents the "unmitigated risk," which are the risks that are not diminished or moderated in intensity or severity. After implementing existing management measures in the assessment, identifying risk priorities that need immediate attention take place (Rollason, 2010).

Treating the Risks

Risk treatments can be regarded as one type of climate change adaptation. Climate change risk treatments can follow a series of principals that will positively and efficiently impact the implementation of the framework.

1) Keep a balance between climate and non-climate risks.
2) Focus on high priority risks to ensure adaptation effort.
3) Implement small, flexible and incremental changes based on regular monitoring and revision of plans.
4) Keep options for new adaptations open where possible.
5) Focus on cost-effective actions.

6) Review treatment strategies.
7) Review existing risk controls to determine if existing controls are not sufficient.
8) Identify changes in thinking or new measures to overcome gaps (Guide to climate, 2011).

Ongoing Monitoring and Review

Information about climate change is continuously updated. Therefore, the risk assessment process includes monitoring and review as an important part of the framework. This process should include the following steps:

1) Obtain new climate change information as it becomes available.
2) Check that controls are effective.
3) Assess new information obtained from events.
4) Account for any changes in the process.
5) Identify new risks and take action.

(Guide to climate, 2011).

Risk Assessment Framework Concerns

Implementation of adaptation and mitigation risk-management frameworks for climate change has many benefits as described in this paper. However, there are many concerns and questions regarding the challenges for many cities in executing risk management plans. The main key to addressing those issues is further research and policy development to prevent potential risks due to climate change (Fifth urban research, 2009).

These actions raise ethical questions about the level of government involvement and what combination of stakeholders should prioritize the initiatives and, consequently, the implementation of climate change strategies. Considering that awareness of climate change impacts is low among vulnerable sectors of society and the uncertainty of issues related to climate change at the local level is still high, cities face challenges in addressing the specific needs of the most vulnerable sections of its inhabitants—the urban poor (Fifth urban research, 2009).

In developing an assessment considering all factors of climate change impacts and potential risk, in addition to adaptive resilience and mitigation strategies that are not mere recommendations in reports but instead direct tangible actions toward the problem, is vital for the success of any risk assessments framework. Clearly, the absence of a city's climate change strategy will exacerbate climate change impacts, accentuating the risks to the urban poor (Fifth urban research, 2009).

Crafting a flexible and calibrated approach for building resilience and prepare social institutions for public health or disaster management to be retrofitted to adapt to climate change are also important elements for city leaders to employ. Strategies that work for vertical coordination among national and local policy efforts must be emphasized. Furthermore, promoting horizontal collaboration among different city's departments and between global cities in a joint action has to be encouraged to get results (Fifth urban research, 2009).

Financial Risks of Climate Change: The Importance of Risk Management

The choices many cities make today will reflect the outcome and degree of climate change impacts on populations and infrastructure with severe consequences if city's government officials, leaders and stakeholders do not take urgent action. The quantification of costs is important to assessing and developing a risk management plan, and insurance can help in that regard (Mistry et al., 2005).

Climate change could increase both the average annual losses and risk-capital requirements of insurers and, consequently, will increase the risk premium. For the U.S. under a higher emission scenario, risk premium could increase by nearly 80% by the year 2080. The potential costs of climate change impacts on cities can be avoided if a comprehensive risk management plan is put into action. Therefore, financial costs of climate change must be integrated in risk management to determine the proper actions for the future (Mistry et al., 2005).

Turning Theory into Reality

The Benefits of a Risk Management Approach

Environmental risk management frameworks are much attuned with adaptation and mitigation strategies for climate change. Global and local organizations are increasing utilizing risk assessment approaches to better manage risk and improve operations, as risk is an important driver in climate change adaptation strategies. Risk is the center concept in vulnerability theory. Therefore, risk management becomes the leading and highly standardized organizational practice effective in confronting uncertainty and threats (Fuenfgeld & McEvoy, 2011).

GHG Emissions and Climate Change Risks

Greenhouse gas emissions create considerable climate change risks and reducing those emissions can significantly impact the health of urban populations. The majority of experts on climate change have advocated minimizing individual carbon footprints, and the investment of billions of dollars to reduce the risks of drastic changes in the earth's environment (Glaeser & Kahn, 2009). Combined evidence of anthropogenic climate change effects has determined that the leading net annual flow of carbon released to the environment comes from carbon dioxide (CO_2) emissions from fossil fuel combustion (Braconnot et al., 2007).

The dataset below is derived from the following sources: IEA (International Energy Agency), CDIAC (Carbon Dioxide Information Analysis Center), EPA (Environmental Protection Agency), EIA (Energy Information Administration), and EC-JRC/PBL (European Commission, Joint Research Centre/Netherlands Environmental Assessment Agency). For comparative purposes the latest version of the dataset includes greenhouse gas data through 2008 for three major countries with densely populated cities (World Resources Institute, 2012).

Table 13: GHG Emissions for USA, China, and Brazil. All totals exclude GHG emissions associated with land use, land-use change, the forestry sector and bunker fuels (World Resources Institute, 2012).

- Emissions: million metric tons CO2 equivalent (MtCO2e)
- Per Capita Emissions: metric tons of CO2 equivalent (mtCO2e) per person

- Emissions Intensity: metric tons of CO_2 equivalent per million international dollars (mtCO2e/million $intl)

Region	Year	GHG_Emissions_Total	GHG_Emissions_Intensity	GHG_Emissions_Per_Capita	CO2_Emissions_Total
World	1990	30017.6101	851.26	5.69	21091.13
USA	1990	5978.9	750.22	23.95	4912.68
China	1990	3593.9	2876.39	3.17	2315.93
Brazil	1990	691.5	643.99	4.62	209.85
World	2000	33187.76504	694.63	5.46	23673.80
USA	2000	6824.6	611.10	24.19	5747.85
China	2000	4818.5	1430.65	3.82	3335.43
Brazil	2000	938.2	680.05	5.38	324.90
World	2008	No data	No data	No data	29986.04
USA	2008	No data	No data	No data	5648.96
China	2008	No data	No data	No data	7200.08

Brazil	2008	No data	No data	No data	394.40

Agents of Change

Analyzing carbon inventory for cities is a crucial step in leveraging the capacity to reduce GHG emissions. However, cities do not have identical emissions profiles when addressing climate change impacts on urban areas. Targeting the main sources of emission after determining their origins is primordial for effective implementation. The strategy can target four different categories: buildings, transportation, energy supply and municipal services (Glenn, 2010).

Strategic Approach for Cities

Reducing a city's GHG emissions requires a set of strategic plans that, amalgamated toward a common goal, can be very effective in minimizing carbon emissions. Strategic steps to reduce GHG emissions such as energy efficiency in buildings and reducing traffic and car use on the roads are effective in lessening a city's carbon footprint (Glenn, 2010).

Strategies for cities to develop and implement their infrastructure in a sustainable way will be crucial to combating climate change and will determine the future path of its success (Pennell, 2010).

GHG Reduction Strategies

A city's commitment to reduce GHG emissions needs to be reinforced by an aggressive and informed strategy. The following grouping represents the strategy targeting the primary sources:

Table 14: GHG Reduction Strategies (Glenn, 2010).

Sector	Description of Approach	Technological and Policy Options
Buildings	**Buildings are major consumers of heating fuels and electricity.** **Buildings account for up to 40% of GHG emissions and this can be reduced to nearly zero.** **Sustainable building design can produce carbon-neutral buildings (e.g., modern technologies, photovoltaic, solar water and air heaters, and ground source heat pumps).**	**1) Retrofitting residential, commercial and industrial buildings to increase the level of insulation; minimizing air leakage; and using energy efficient appliances can reduce the GHG emissions impact.** **2) Solar energy through photovoltaics, solar water and space heating as well as passive solar design.** **3) Using ground source heat pumps to generate waste heat.**
Transportation	**Reduce vehicle use and implement ways to maximize public transportation with natural gas and electric vehicles; promote walking and cycling; and provide the necessary infrastructure and offer financial incentives for drivers to change their behavior.**	**4) Balance land use and population densities to reduce the average miles a passenger travels.** **5) Improve public transportation (e.g., bus rapid transit, light rail transit, subways and commuter rail).** **6) Promote dynamic transportation forms with health benefits such as biking and**

		walking. 7) Implement financial policies to lessen car use, including tolls, taxes, and increased parking fees during pick hours. 8) Alternative vehicles power-driven by biomass, fuel cells and electricity.
Energy Supply	**Investment in renewable energy technology. Promote and facilitate the expansion of more efficient district heating and cooling and underground thermal storage, and develop a combined method of heat and power systems.**	**9) Generate electricity from renewable sources (e.g., wind, solar radiation, tides, waves and geothermal). 10) Encourage underground thermal energy storage utilizing aquifers or boreholes. 11) Efficient and low energy heating and cooling systems benefitting buildings through a network of piping. 12) Combine heat and power systems to maximize system efficiencies. 13) Support integrated community energy systems. Promote and encourage an economy of scale for investment and resource recovery.**
Municipal Services	**Manage waste, deliver water and maintain the urban tree canopy. Cost effective climate-friendly waste management. Better use of the "3Rs" (Reduce, Reuse & Recycle). Encourage waste-to-energy projects supporting diversion targets. Capture methane from landfills to minimize air pollution and deter GHG emissions. Develop urban**	**14) Increase support for the 3Rs. Focus on recycling to redirect wastes from landfill and minimize virgin materials depletion. 15) Produce biomass and compost to use as energy source. 16) Incentives for waste incineration and gasification. 17) Focus on landfills to capture**

	vegetation to sequester CO_2.	**methane gasses.**
		18) Reduce water demand and increase the effectiveness of treatment and delivery.
		19) Develop more urban greenery and the tree canopy.
		20) Support and encourage urban agriculture and CO_2-enriched greenhouses.
		21) Explore geological sequestration to minimize the impact of GHG emissions.
		22) Buy carbon offsets to reduce environmental impact and develop new technologies that will mitigate climate change.

The above strategies can be applied in any megacity. Consequently, any framework for adaptation from the different sectors described on the figure does not operate independently, but needs to be integrated throughout national and local planning processes (Climate change adaptation, 2012).

The Hestia Project

The scientific understanding of carbon exchange with the land surface is crucial to creating an effective carbon monitoring system (Gurney et al., 2012a).

Utilizing top-down or bottom-up methods are an efficient way to create results of mitigation studies. Bottom-up studies are based on assessment of mitigation options and they target the usage of energy and greenhouse gases emitting equipment (e.g., powergenerating stations or vehicle engines). Finally, policy measures are included to create results (Al-Moneef et al., 2001).

The “Hestia Project” is the first research effort that uses bottom-up methods to quantify all fossil fuel CO_2 emissions, amalgamating individual buildings, road segments, industrial infrastructures and industrial facilities for the generation of electric power on an hourly basis for an entire urban landscape (Gurney et al., 2012a).

Combining a series of data sets and simulation tools, such as a building energy simulation model, traffic data, power production reporting and local air pollution reporting, this method can be utilized in any major city in the United States. It can be applied as a principal factor in monitoring carbon emissions and implementing valuable greenhouse gas mitigation and planning. When measuring levels by zip code, the Hestia team attains a bias-adjusted Pearson r correlation value of 0.92 ($p < 0.001$) (Gurney et al., 2012a). The Pearson r measures the linear relationship linking two interval/ratio level variables. “The stronger the association of the two variables the closer the Pearson correlation coefficient, *r*, will be to either +1 or -1 depending on whether the relationship is positive or negative, respectively” (Pearson product moment correlation, 2012). It is crucial to interpret the global carbon cycle effectively through quantitative measures. This is a principal factor in advancing our understanding of climate change and its projections, and in expanding our understanding of ecosystem level biogeochemical principles to resourcefully manage climate change detrimental effects (Gurney et al., 2009b).

Establishing the Context and Setting Objectives of Risk Management Assessments

The location and extent of the study and the processes operating in the area that may generate risk have to be established to set the objectives of a risk management assessment for climate change. There are several areas where an assessment seeks to identify and investigate risks to efficiently describe the actions that are required to attain the objectives. The aforesaid areas are: (1) The potential impact on (i.e., damage to) (2) a particular value (e.g. house) from (3) a threatening process (e.g. waves, sea level rise) (Rollason et al., 2011).

As a consequence, the economic, social and environmental values of the land where the strategic framework applies must also be included in the assessment. Furthermore, a risk criterion is an important factor to be considered in order to establish the framework of the risk assessment. Likelihoods and consequences scales and their combination in the prevailing conditions of risk must be included in establishing and defining the acceptable risk level. City leaders and stakeholders should determine the risk level that is believed acceptable and identify tolerable and intolerable risks (requiring priority treatment to the latter) that need to be modified accordingly to local conditions (Rollason et al., 2011).

Adaptation and Risk Reduction Costs

The cost benefits of reducing climate change impacts need to be emphasized when incorporating a methodological plan to reduce risk. Urban infrastructure investments, adequate services in slum areas, information systems and capacity building, as well as any other physical investment, have to be included in the adaptation and risk reduction cost. In order to building resilience for the poor a combination of public and private resources must be in position to finance investments that contribute to building resilience for the poor (Baker, 2012a).

When considering investments for climate change adaptation and disaster risk reduction in cities, it is important to understand they can have a different impact on the poor. Large-scale cities with a wide infrastructure investment may be necessary but they are expensive and the situation will not get better for the residents experiencing the current impacts of the more frequent climate events that are not severe but can have appalling impacts on the urban poor. Smaller-scale investments in basic infrastructure don’t have to be costly. In addition to local improvements in infrastructure, social programs in slums aimed at community development can be of great benefit, particularly when focused on land issues (Baker, 2012b).

Summary of the Current Situation

Epidemiologists had not paid much attention to the study and importance of climate change and its health risks before the acknowledgment of anthropogenic climate change surfaced in the scientific community as an impending threat to society. Until recently, modern epidemiology has concentrated principally on non-communicable diseases and their risk factors affecting individuals. Therefore, populations were not integrated in a case study to analyze the significance of the issue. Largely, climate-related thermal stress and its associated health risks have been the most integrated studies in conventional epidemiology (McMichael et al, 2006).

Climate change health impacts are likely to affect many regions of the world beyond national borders. The incidence and severity of diseases are increasing as a consequence of famine, drought, extreme weather events and regional conflicts. All the aforementioned related factors of climate change, as well as other health impacts, make it crucial to emphasize the importance of acting upon the issue at local, regional, national and global levels. The interaction and relation between these and other climate change risks must be considered to determine the capacity and extent of climate change and health research required (Portier et al, 2010b).

The fundamental concept that has been analyzed and described is the growing awareness that adaptation and mitigation strategies are not fundamentally different approaches to dealing with climate change, as they address the same problem and could share possible trade-offs and synergies. Currently, there are a wide range of available options to mitigate and adapt to climate change. These options include strategies at the institutional level, through technological developments, financing, innovations or spatial measures. The combination of both strategic approaches presents a unique and enormous opportunity to capably combat climate change impacts (Biesbroek et al, 2009).

Furthermore, the inclusion of policies to promote a better quality of life, such as pollution reduction in cities like Los Angeles and Beijing, and developing clean energy sources, must be put into action (Van Ypersele, 2013).

Presently, there is no consensus for a solid framework that deals with risks associated with climate change impacts. The motivation to implement an adaptation and mitigation program can be led by private or public interest. Private decision makers include individuals, households, businesses and corporations; public interests are served by governments at all levels. All the aforementioned sectors can work together to develop a comprehensive plan to address the risks of climate change. Although the function of private and public sectors are differentiated by several factors according to their purposes and resources, they are interrelated and are important players for addressing climate change effects on populations in a local and global context (Burton, 2004).

Recommendations

Climate change impacts on health are an important and urgent concern. The climate change impacts on urban populations are increasingly more powerful and it has become clear that a proactive and effective approach to deter climate change effects is crucial in order to minimize the detrimental impacts on people. Moreover, ensuring food security, reducing poverty and public health risks and advocating for long-term socio-economic development become part of an urgent agenda in today's society.

We live in a world that is becoming increasingly unstable, and the potential for a severe climate event that could cause sudden change, affecting millions of people from different scales of society, is greater than ever. Climate change impacts cannot be treated as "black swan" events anymore. The development and implementation of a concise adaptation and mitigation approach to coordinate and align strategies, actions and financial resources must be implemented locally and globally across all different sectors of society, including the public health sector.

Risk management ISO 31000 should not be a burden, but a discipline in dealing with uncertainty. This standard efficiently encompasses actions to remediate, mitigate risk and reconstitute capability in the event of loss or degradation. The effective management of risk is not just a desirable business activity, it is also vital at the national, regional and local levels of government if society is to utilize its resources efficiently and for the general good of the population.

The management of risk is seen as a business activity, but it should also be considered to develop infrastructure that will withstand natural disasters and provide programs to minimize human suffering. This is not to suggest that it is a panacea for all the ills of society, but if used properly, it empowers people to become more responsible for their actions.

The greatest risk of all is to take no risk at all. Without risk, there is no advancement. The challenge for us all is to manage risk so as to ensure a successful outcome. Risk must be taken if we are to learn, feel, change, grow and live. ISO Standard 31000 and ISO 31010 (supporting standard for ISO 31000 that provides guidance on selection and application of systematic techniques for risk assessment) are designed to help us manage risk. “Only the person who risks is free” (Knight, 2013).

Chapter 10 Conclusion

Individual actions cannot resolve collective problems. Therefore, a cooperative approach to respond to climate change is needed. Actions toward adaptation to and mitigation of climate change impacts on health are generally warranted by the risks this issue presents to cities. Climate change is on the forefront of public attention and the risks affecting entire populations are clearer now than ever before. Although climate change has received a fair amount of consideration, particularly after several droughts, flooding and hurricanes that affected the United States, as well as other countries around the globe in recent years, a comprehensive strategy to address climate change and public health is not in place and it is primordial to implement it, as health professionals have the responsibility to prevent health risks and provide proper treatment. Furthermore, climate change provides opportunities to world leaders to develop and implement policies and pragmatic initiatives that particularly target the poor (and as a consequence benefit the whole population), as their vulnerabilities are exacerbated by climate change. Climate change impacts can create a global chain reaction of effects that would be devastating for the world community.

The identification of climate change risks and their repercussions on public health is an important step for developing suitable actions. Therefore, policies made to address this issue can be adopted more speedily and efficiently as the evidence of climate change impacts on health become more palpable. The awareness of the health risks to humanity will lead to a comprehensive strategic plan for cities and will build the case for policies and procedures that directly aim at the problem.

We are confronting a challenge that has never been faced before by human beings, and the world community cannot avoid the threats, as the consequences of inaction will be costly. We have an obligation to present and future generations to act accordingly to prevent the far-reaching effects of climate change, as we have the resources, determination, and leadership to address the severity of the imperilment. Deterring of climate change and its impact on the health of the urban poor will depend on how rapidly and efficiently global adaptation and mitigation strategies are implemented. World leaders need to find a common ground of understanding this critical issue, as our survival depends upon the immediate actions of all the parties involved.

The fundamental solution to the problem climate change poses to the world's welfare is ***management***. This research presents a series of highly important strategies and innovative approaches to the common concern, as well as a thoughtful description of health risks and subsequent consequences of their impacts on people. As presented in this research, the recommended method is the International Risk Management Standard AS/NZS ISO 31000.

A paradigm shift in the way of thinking and acting toward climate change is needed to radically shift the course of climate change impacts on health and the urban poor. Now is the time to implement proactive rather than reactive management of climate change risks, and for world leaders to identify the valid significance of sustainability in order to advocate for the well-being of the global community.

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