Melting Qori Kalis glacier, Peru. Qori Kalis is the largest outlet glacier of the world's largest tropical ice cap, the Quelccaya Ice Cap, which lies on a plateau 18,670 feet (5,691 meters) high in the Andes mountains of south central Peru. In 1978, the glacier was still advancing. By 2011, the glacier had retreated completely back on the land, leaving a lake some 86 acres in area and about 200 feet (60 meters) deep.

Source: Dr. Lonnie G. Thompson, Distinguished University Professor, Byrd Polar and Climate Research Center, The Ohio State University
This article explores climate change and action planning to increase resiliency in urban areas. It starts by describing climate change and its impacts on urban areas, and continues by discussing various levels of intervention actions on climate change ranging from intergovernmental processes to regional, national, and local level action plans. The article concludes by providing a case study from Philadelphia (USA) and summarizing what climate action plans means for resiliency and sustainability in urban areas.

CLIMATE CHANGE AND ITS IMPACT ON URBAN AREAS

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change is expected to affect the intensity and the frequency of extreme climatological and hydro-meteorological events. It also is expected to “amplify existing risks and create new risks for natural and human systems,” that result from “the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems, including their ability to adapt.”

Today more than half of the world’s population lives in urban areas and this share is expected to be 75 percent by 2050, making climate change adaptation and disaster risk reduction in urban areas more crucial than ever.

Furthermore, the 5th Report of the Intergovernmental Panel on Climate Change (IPCC) projects with very high confidence that “climate change is to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms, extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea-level rise, and storm surges” in urban areas, especially for those “lacking essential infrastructure and services or living in exposed areas.” In addition, according to Climate Change 2014 Report by the IPCC, there is very high confidence that “[d]ifferences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes.” Indeed, the embedded conditions of socio-economic, spatial and institutional vulnerabilities in cities, including inadequate capacity and unstable governance structures, sub-standard infrastructure, built-environment and urban services, as well as socio-economic inequalities leads to increased vulnerability and risk from natural hazards and the impacts of climate change in urban areas.

The IPCC also reports that “settlement patterns, urbanization, and changes in socio-economic conditions have all influenced observed trends in exposure and vulnerability to climate extremes,” and that “urban climate change risks, vulnerabilities, and impacts are in—
Drought in Arizona and Utah. Prolonged drought coupled with water withdrawals have caused a dramatic drop in Lake Powell’s water level. These images show the northern part of the lake, which is actually a deep, narrow, meandering reservoir that extends from Arizona upstream into southern Utah. The 1999 image shows water levels near full capacity. By April 2015, the lake had dropped to 42 percent of capacity. Images taken by the Landsat series of satellites. Source: NASA’s Earth Observatory.

Table 1: World Urbanizations Levels and Projections (Gencer 2013a)

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>CAC</th>
<th>Africa</th>
<th>Europe</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanization Levels (%) 2010 (Gencer 2013a)</td>
<td>57.27</td>
<td>61.87</td>
<td>43.52</td>
<td>70.71</td>
<td>56.07</td>
</tr>
<tr>
<td>Rate of Change (2010–2020)</td>
<td>0.98</td>
<td>0.65</td>
<td>2.20</td>
<td>0.35</td>
<td>0.80</td>
</tr>
<tr>
<td>Rate of Change (2020–2030)</td>
<td>1.10</td>
<td>0.77</td>
<td>1.40</td>
<td>0.46</td>
<td>0.90</td>
</tr>
</tbody>
</table>


Figure 1: Regional distribution of natural disasters, 1983–2012 (Gencer 2013b, 9).

creasing across the world in urban centres of all sizes, economic conditions and site characteristics. However, certain regions of the world experience higher urbanization levels than others. For instance, currently Central America, the Caribbean (CAC) and Europe are the most urbanized regions in the World; however, it is projected that within the next decades, African countries will face higher projected urbanization levels (see Table 1). Coupling with the existing vulnerabilities in the region, African nations are expected to have high risk from disasters, particularly from hydrological, climatological and biological events (see Figure 1 for current distribution rates for disasters per region).

In addition to urbanization levels, the size, functions and geographical location of cities also impact their risk from hazards and the impacts of climate change. In their World Risk Report 2014, the United Nations University Institute for Environment and Human Security (UNU-EHS) has classified nations in 10 different groups categorized by level of urbanization, level of income, average urban population growth per year, and per capita GDP growth per year. Similarly, in the chapter discussing urban areas, the authors of the IPCC 5th Assessment report have stated that there are “diverse physical and societal challenges and large differences in levels of adaptive capacity” between case studies and regional reviews assessing urban vulnerabilities to climate change. While, “[t]he global distribution of urban risks” is stated to be “highly context specific, dynamic, and uneven among and within regions” (ibid.), “[a]bsolute exposure to extreme events over the next few decades” is projected to be concentrating in “large cities and countries with populations in low-lying coastal areas, as in many Asian nations.” Furthermore, according to the IPCC (2001), “the developing countries, particularly the least developed countries... have lesser capacity to adapt and are more vulnerable to climate change damages, just as they are more vulnerable to other stresses,” and that, “[t]his condition is most extreme among the poorest people.” Indeed, currently, there are over 400 cities with populations of one million or more, and a large proportion of them are located in low- and middle-income nations and in hazard-prone areas particularly in Africa, Asia and Latin America, a trend which is expected to continue within the next decade (see Table 2).

Among the biggest risks of climate change are the impacts of sea level rise and accompanying hazards, such as storm surge, on cities on Small Island Developing States (SIDS) and coastal cities, which are typically situated in low-lying areas. Sixty-five percent of the world’s urban population currently lives in coastal areas, and this percentage is expected to increase to 74 percent by 2025. Most mega-cities are either located on seacoasts or directly linked with riverbeds, increasing the exposure in their hazard-prone areas. Coastal flooding, beach erosion and salt water intrusion, river sedimentation flooding and landslides are some of the potential hazards that can affect coastal areas and cities built near rivers, such as in New York City (see Figure 2). According to Swiss Re (2013), currently, over 379 million people living in metropolitan areas globally are potentially affected by extreme riverine floods.

Cities are also expected to be affected by severe heat and cold events which may result from climate change. Extreme cold events could lead to increased use of energy and worsening air pollution conditions. Expected heat waves could worsen in cities “pronounced as heat islands” due to the heating up of the concrete buildings and paved areas. Both heat waves and cold events will affect food security. Indeed, many cities in Europe were highly affected by heat waves in the last two decades leading to deaths as well as high monetary damage due to the impact on agricultural crops. According to the projections of IPCC,
Beijing Growth 2000 to 2009. A new study shows that Beijing’s physical infrastructure quadrupled between 2000 and 2009 and that the new buildings and roads themselves - not including pollution created by new inhabitants and their vehicles - increased winter temperatures by about 5 to 7 °F (3 to 4 °C) and reduced wind speed by about 2 to 7 miles per hour (1 to 3 meters per second), making the air more stagnant. 

Gray and black indicate buildings, with the tallest and largest buildings in the city’s commercial core appearing lighter gray. Other colors show changes in areas not yet urbanized (for example, cutting down trees). Blue-green indicates the least change, yellow-orange more change and red the greatest change. Images taken by NASA’s QuikScat satellite. Source: NASA/JPL-Caltech.

Table 2: Distribution of Urban Population by Size of Agglomerations (%) 2010 (Gencer 2013a)

<table>
<thead>
<tr>
<th></th>
<th>≥ 10 MILLION</th>
<th>5-10 MILLION</th>
<th>1-5 MILLION</th>
<th>500K-1 MILLION</th>
<th>&lt; 500K</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARIBBEAN</td>
<td>-</td>
<td>-</td>
<td>32.50</td>
<td>6.30</td>
<td>61.20</td>
</tr>
<tr>
<td>CENTRAL AMERICA</td>
<td>17.70</td>
<td>-</td>
<td>25.10</td>
<td>15.40</td>
<td>41.80</td>
</tr>
<tr>
<td>WORLD AVERAGE</td>
<td>9.30</td>
<td>6.70</td>
<td>22.10</td>
<td>10.20</td>
<td>51.60</td>
</tr>
<tr>
<td>AFRICA</td>
<td>3.56</td>
<td>4.08</td>
<td>27.64</td>
<td>8.94</td>
<td>55.74</td>
</tr>
<tr>
<td>ASIA</td>
<td>9.07</td>
<td>7.50</td>
<td>21.70</td>
<td>9.77</td>
<td>51.97</td>
</tr>
<tr>
<td>EUROPE</td>
<td>3.07</td>
<td>5.37</td>
<td>15.27</td>
<td>9.85</td>
<td>53.18</td>
</tr>
</tbody>
</table>

Data Source: Calculated and drawn from raw data in UN-DESA 2010.  
heat waves and drought are expected to continue to impact Europe, particularly the cities of Southern Europe creating not only negative consequences for agriculture and water supply, but also affect multiple sectors such as tourism and health and trigger massive forest fires endangering the rural continuum of urban areas and food security.18

INTERNATIONAL, MULTI-NATIONAL AND LOCAL CLIMATE ACTION PLANNING

The following case studies illustrate Climate planning approaches at various levels of governance. The examples include the intergovernmental process undertaken by the United Nations, a regional approach by the European Union, National action planning by United States of America (USA) and a local planning example from the State of Oregon in the USA.

United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) is guiding adaptation and mitigation strategies with a variety of approaches. The UNFCCC is an international environmental treaty with the objective to “stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” Adaptation activities span five general components: observation; assessment of climate impacts and vulnerability; planning; implementation; and monitoring and evaluation of adaptation actions. Societies can respond to climate change by reducing greenhouse gas (GHG) emissions and enhancing sinks and reservoirs. The capacity to do so depends on socio-economic and environmental circumstances and the availability of information and technology. To this end, a wide variety of policies and instruments are
available to governments to create the incentives for mitigation action. Mitigation is essential to meet the UNFCCC’s objective of stabilizing GHG concentrations in the atmosphere (UNFCCC, 2015).

**Urban Adaptation to Climate Change in Europe**

The European Environmental Agency (EEA) provides climate change information and coordinates global climate change response for its European Union members and several other cooperating nations. It publicizes member adaptation and mitigation strategies.

Of particular significance, the EEA publication “Urban adaptation to climate change in Europe” consolidates response options, planning strategies and multi-level governance approaches. The report identifies key direct challenges to be: heat; flooding; water scarcity and drought. It also discusses three types of options: “grey measures” infrastructure physical interventions, “green measures” infrastructure ecosystem resilience and “soft measures”. Soft measures consist of the design and the application of policies and procedures such as land-use controls and the dissemination of information and economic incentives to reduce vulnerability, encourage adaptive behavior or avoid mal-adaptations.

The report outlines urban planning from the perspectives of adaptive capacity, planning steps and success factors. Adaptive capacity is composed of the community’s: 1) awareness, knowledge and equity, 2) ability, which is defined as access to technology and infrastructure; and, 3) actions which affect the nation’s economy, resources and institutions. The planning steps are consistent with the rational planning model: 1) getting started, which consists of the initiate adaptation to ensure commitment and management; 2) the assessment of potential climate change risks and vulnerabilities; 3) the identification of a wide range of adapta-
CLIMATE CHANGE AND ACTION · PLANNING TO INCREASE RESILIENCY

...SCIENCE, ACUMULATED AND REVISED OVER DECADES, TELLS US THAT OUR PLANET IS CHANGING IN WAYS THAT WILL HAVE PAINFUL IMPACTS ON ALL OF HUMANITY... THOSE WHO ARE ALREADY FEELING THE EFFECTS OF CLIMATE CHANGE DON’T HAVE TIME TO DENY IT—THEY’RE JUST DEALING WITH IT...

PREMIER OBAMA, 2013

Moving forward, the Obama Administration will help states, cities, and towns build stronger communities and infrastructure, protect critical sectors of our economy as well as our natural resources, and use sound science to better understand and manage climate impacts.

ASSESS THE IMPACTS OF CLIMATE CHANGE

GOALS

- Provide an assessment of climate change impacts on the state, region, city, or town, and develop adaptation plans to address specific impacts.

SUPPORT CLIMATE-RESILIENT INVESTMENTS

GOALS

- Reduce expenditure on climate-vulnerable infrastructure and assets.
- Improve efficiency in climate-vulnerable infrastructure and assets.

REBUILD AND LEARN FROM SUPERSTORM SANDY

GOALS

- Restore and protect coastal systems and communities.
- Implement the recommendations from the Post-Sandy Federal/State Commission.

LAUNCH AN EffORT TO CREATE SUSTAINABLE AND RESILIENT HOSPITALS

GOALS

- Establish a public-private partnership to develop a framework for the healthcare sector.
- Adapt to climate impacts and ensure resilience.

MAINTAIN AGRICULTURE PRODUCTIVITY

GOALS

- Assess the impact of climate change on agricultural productivity.
- Develop and implement adaptation strategies.

PROVIDE TOOLS FOR CLIMATE RESILIENCE

GOALS

- Develop and implement tools for climate resilience.
- Enhance the ability of communities to adapt to climate change.

REDUCE RISK OF DROUGHTS AND WILDFIRES

GOALS

- Increase resilience to droughts and wildfires.
- Enhance the ability of communities to adapt to climate change.

...through multi-level climate-proofing, territorial governance, developing institutional capacities across levels, securing access to funding for adaptation measures, and multi-level knowledge base (EEA, 2012).

United States Presidential Climate Action Plan

The U.S. Presidential Climate Action Plan focuses on carbon reduction mitigation measures for power plants with the “Clean Power Plan.”

The June 2014, Environmental Protection Agency (EPA) Clean Power Plan proposed carbon pollution standards for existing power plants. Power plants are the largest single source of carbon pollution, accounting for about one-third of all domestic greenhouse gas emissions. The Clean Power Plan proposed a 30 percent reduction in carbon pollution from the power sector by 2030.

Additional U.S. initiatives towards climate change mitigation include:

- Lead public sector financing towards cleaner energy
- Bilateral cooperation with major economies
- Expand clean energy use and cut energy waste
- Combat short-lived climate pollutants
- Reduce emissions from deforestation and forest degradation
- Negotiate global free trade in environmental goods and services
- Enhance multi-lateral engagement with major economies
- Mobilize climate finance
In addition to the Clean Power Plan, in November 2014, The President of the United States announced a historic joint agreement with China. The United States pledged to reduce 2025 greenhouse gas emissions in the by approximately 26 to 28 percent below 2005 levels. China announced its intent to peak carbon emissions around 2030 and to double its share of zero-carbon energy to 20 percent.

Oregon Cool Planning Handbook
At the local level, communities are designing programs for adaptation and mitigation specific to their environmental, economic and social context. The Oregon Transportation and Growth Management Program (TGM) prepared a handbook to assist climate action planning for local governments. Cool Planning: A Handbook on Local Planning Strategies to Slow Climate Change introduces climate change, impacts, specific implementation actions, and climate action plans. The central message of this transportation-centric publication was that if communities reduce their vehicle miles traveled, then CO2 emissions will lessen, and these changes will help mitigate climate change. The “ways to grow cooler” are described in the following topics:

- Grow more compact
- Get centered
- Mix up your land uses
- Recycle urban land and buildings
- Make streets complete
- Make way for pedestrians
- Make your city bike-friendly for everyone
- Get well-connected
- Put parking in its place
- Make way for transit and transit-oriented development
- Change travel habits
- Find better models for big trip generators
- Green your buildings
- Plant trees in your town

The Handbook concludes with taking action, steps to develop a climate action plan, elements of a climate action plan, and tools for measuring a plan’s effectiveness. Cities may tailor these guidelines to fit their individual Comprehensive [Master] Plans and zoning codes and/or modify their municipal planning regulations to include these implementation actions.

Figure 5: Cover of Cool Planning: A Handbook of Local Strategies To Slow Climate Change. Source: Oregon Department of Transportation and the Oregon Department of Land Conservation and Development
Introduction
The Southeastern Pennsylvania Transportation Authority (SEPTA), created in 1964, is the metropolitan and regional transportation agency serving the Pennsylvania portion of the Philadelphia Metropolitan Region. Its service area contains 4 million people and consisting of the City of Philadelphia and the suburban counties of Delaware, Chester, Montgomery and Bucks, with connecting service to New Jersey and Delaware. It is the 6th-largest U.S. transit system by ridership, and the 5th largest overall transit system, with 330 million annual unlinked trips. It controls 280 active stations, over 450 miles (720 km) of track, 2,295 revenue vehicles and 196 routes. SEPTA is one of only two U.S. transit authorities that operates all of the five major types of transit vehicles: regional (commuter) rail trains, “heavy” rapid transit (subway/elevated) trains, light rail vehicles (trolleys), electric trolleybuses and motor buses. Unlike some US systems which supply commuter rail, SEPTA acquired the system previously owned and operated by two railroad companies – therefore, the SEPTA rail system is “legacy network” constructed around the turn of the 20th century.

Overview of The Study Area
Within the SEPTA system, the Manayunk/ Norristown (M/N) line was selected for study based on an agency screening for vulnerability to extreme weather. The M/N line has a weekly ridership of about 10,000 weekday passenger trips. Annually it provides approximately 1,650,000 inbound trips and 1,555,848 outbound riders. However, its proximity to the nearby Schuylkill River makes the line extremely flood prone.

Likely Climate Change Conditions
Examination of climate models projections found that four changes were likely to occur in the SEPTA region over the next 50 years: 1. higher temperatures; 2. heavier rain events; 3. more snow; and 4. more frequent tropical storms. The temperature by mid-century is expected to increase by 3 to 6 degrees F and the number of very hot summer days was expected to be more frequent. Precipitation is expected to increase by 7%, an increase of almost 2 inches a year, much of the increase to occur during the winter months. The occurrence of heavy precipitation events (daily rainfall in excess of 1.5 inches) is also expected to increase by one or two days a year.

Climate Change Induced Vulnerabilities
Heat – the M/N line would be vulnerable to sagging wires, equipment stress, and track buckling. The regional power grid may also be stressed and subject to brownouts during periods of high heat. SEPTA’s power system is thus further vulnerable to the extent that it is reliant on utility-provided electricity.

Heavy Rain Events – The M/N line is highly vulnerable to flooding from heavy rain events. When rain falls, it combines with runoff from upstream and can overwhelm culverts and cause severe flooding on the line. In these places, runoff and direct precipitation combine to flood the rail line, deposit debris along the track, and often wash out the track and the embankment. Heavy rains are often accompanied by high winds, which can lead to downed trees, damage to catenaries, power outages, and damage to signals.

Snow and Winter Storms – Snow is the most disruptive recurring weather-related event on the M/N line. Snow removal is both time-intensive and expensive, and third-party workers are often required to clear the snow. SEPTA is also vulnerable to snowstorms because of downed power lines and power...
Figure 6: Flooding along the Manayunk/Norristown Transit line. Source SEPTA

Figure 7: Flooded Spring Mill Station. Source SEPTA
outages that affect the community at large. In addition, snow and ice can cause interlocking and signal failures. Extreme cold temperatures, regardless of snowfall, can also cause significant damage to SEPTA infrastructure. Extreme cold causes equipment failures, switch failures, broken track, wire fatigue, and broken wires.

Tropical Storms – The M/N line is highly vulnerable to damage from the tropical storms that affect the Philadelphia area. Tropical storms combine high winds and high precipitation volumes and, therefore, can cause not only flooding but extensive infrastructure damage. Even more so than heavy precipitation events, tropical storms are likely to cause downed trees, damage to catenaries, power outages, and damage to signals. Some tropical storms can also cause severe flooding. Tropical storms also cause unsafe travel conditions, making it difficult or dangerous for staff and passengers alike to get to SEPTA facilities. Tropical storms often cause significant service disruptions, with service cancelled and residual delays potentially lasting for multiple days (the FTA report includes a case study on Hurricane Sandy in 2012, which shuttered SEPTA service for a period of 1.5 days).

Recommendations
Having identified the vulnerabilities, adaptation strategies were developed and discussed which had the potential to reduce SEPTA’s vulnerability to climate risks. The result of this dynamic process led to the identification of capital and operational strategies designed to mitigate climate induced impacts. In addition, SEPTA will be investing $6 million, supported by a $4.5 million federal grant, to stabilize 2.45 miles along the M/N railroad right of way adjacent to the Schuylkill River.
SUMMARY

Climate change is expected not only to alter the intensity and the frequency of hazards, but also to increase the vulnerability of societies. As recent observations and projections of climate change have shown, climate-induced hazards and its impacts will increasingly impact urban areas, due to heightened exposure from increasing urbanization levels and inherent characteristics of vulnerability especially in cities located near coast areas.

Urbanization and economic growth coupled with the impacts of climate change will greatly increase the impacts of disasters in urban areas, which inherently have diverse complexities, requiring new strategies for disaster risk reduction, climate change adaptation and resilience building.

To mitigate the impacts of climate change—induced damage requires an integrated approach taking into consideration: a) leadership commitment and multi-stakeholder engagement; b) capacity development (institutional, financial, technical and social); c) multi-category risk assessment; d) selection of appropriate measures (disaster risk reduction, climate change adaptation and/or mitigation); e) implementation; f) monitoring and evaluation.

Climate Action planning should not only aim to reduce disaster risks and mitigate CO2 levels, but to adapt societies and increase their resiliency as well creating equitable, healthy, innovative, mixed-use, regenerative, safe, sustainable, transit-oriented, walkable and vibrant communities. Climate action planning is more than ‘disaster preparedness and response;” it is necessary for making cities resilient. 

ENDNOTES


2. (IPCC 2014a, 10)
3. (IPCC 2014b, 13)
4. (UN DESA 2012)
5. (UN DESA 2012, 15–16)
6. (IPCC 2014c, 7)
7. (IPCC 2012, 7)
8. (Revi et al., 2014, 3)
9. India and China also have plans to build or have begun construction for many new cities.
10. (UN–Habitat 2011).
11. (Gencer 2013b, 12)
12. (ibid., McGranahan et al., 2007)
14. (Gencer 2013b, 13)
16. (Gencer 2014, 11).
18. (Gencer 2014, 11).
19. Currently the only international climate policy venue with broad legitimacy, due in part to its virtually universal membership with 196 parties
20. This section is based on the report “A Vulnerability and Risk Assessment of SEPTA’s Regional Rail: A Transit Climate Change Adaptation Assessment Pilot” published by the (USA) Federal Transit Administration and prepared by ICF International, August 2013.
21. Transit in New Jersey is provided by others.
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