UN HABITAT
FOR A BETTER URBAN FUTURE

# Annexure B – Lecture Notes
# Module1: Theory and Concepts of Climate Change and Cities

## 1. Introduction

This lecture provides an overview to theories and concepts of climate change mitigation and adaptation and how these relate to cities. It will discuss the basics of climate science and the phenomenon of climate change, before elaborating on two key concepts relevant for climate change responses: mitigation and adaptation. This material will be used to better understand how these concepts are applied in an urban context.

Clarifying the concepts and theories underlying climate change is an important first step in getting to understand what climate change means in an urban context. Only if we can describe the problem of climate change, as well as any opportunities it may provide, are we able to then develop suitable solutions through the planning system.

Responding to climate change is a relatively recent phenomenon, and many organizations are still only coming to terms with its implications. It requires working together with professionals from other disciplines, with local residents and community representatives, with government officials from various levels of government, and with private businesses. It also involves dealing with different kinds of uncertainty, because most of the benefits of dealing with climate change, such as reduced greenhouse gas concentrations in the atmosphere and better adapted societies, lie in the future (IPCC, 2007a).

**The global climate system**

Although humans and other living beings experience climate locally, we need to look at the global Earth system to gain an understanding of what constitutes climate. This involves understanding how air, land, oceans, snow and ice, and all living things contribute to and interact with the global climate. This complex array of relationships is commonly referred to as the climate system (IPCC, 2007a). All the parameters of the Earth's climate (wind, rain, clouds, temperature, etc.) are the result of energy transfer and transformations within the atmosphere at the Earth's surface and in the oceans. Over time, the Earth's climate remains largely stable because the energy received is equal to that lost (the energy budget is balanced). The sunlight hitting earth (solar radiance) is on average, 1370 watts per square meter ($W/m^2$) (World Meteorological Organization 2012).

The glass walls in a greenhouse reduce airflow and increase the temperature of the air inside. Analogously, but through a different physical process, the Earth's greenhouse effect warms the surface of the planet. Without the natural greenhouse effect, the average temperature at Earth's surface would be below the freezing point of water. Thus, Earth's natural greenhouse effect makes life as we know it possible. The Sun powers Earth's climate, radiating energy at very short wavelengths, predominately in the visible or near-visible (e.g., ultraviolet) part of the spectrum. Roughly one-third of the solar energy that reaches the top of Earth's atmosphere is reflected directly back to space. The remaining two-thirds is absorbed by the surface and, to a lesser extent, by the atmosphere (IPCC, 2007a).

To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space. Because the Earth is much colder than the Sun, it radiates at much longer wavelengths, primarily in the infrared part of the spectrum. Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, and reradiated back to Earth. This is called the greenhouse effect. Part of the energy absorbed at the Earth's surface is radiated back (or re-admitted) to the atmosphere and space in the form of heat energy. The temperature we feel is a measure of this heat energy. In the atmosphere, not all radiation emitted by the Earth reaches outer space. Part of it is reflected back to the Earth's surface by the atmosphere (the greenhouse effect) leading to a global average of around 14°C, well above the -19°C which would be felt without the natural greenhouse effect.

Because the Earth is ovoid and because of its position in the solar system, more solar energy is absorbed in the tropics creating temperature differences from the equator to the poles. Atmospheric and oceanic circulation contributes to reducing these differences by transporting heat from the tropics to the mid-latitudes and the Polar Regions. These equator-to-pole exchanges are the main driving force of the climate system. The energy budget of the Earth can be changed, which in turn can affect the Earth's temperature. An increase in the greenhouse effect, feedbacks in the climate system, or other changes can modify the energy budget of the Earth.

It is important to note that many people commonly confuse weather and climate or consider them to be one and the same thing. In a scientific sense, and to understand climate change, it is important to differentiate between weather and climate. Weather is the status of the atmosphere. Weather typically changes on a daily basis. The weather can be observed by measuring meteorological parameters such as temperature, rainfall, atmospheric pressure, relative humidity, and wind speed. Climate is the average status of the atmosphere. It is typically defined over a standard period of 30 year. While it is possible to observe the day-to-day changes in weather, it is impossible to directly observe the climate without further scientific analysis (IPCC, 2007a).

**Observations of a changing climate**

Instrumental observations one and a half centuries show that temperatures at the surface have risen globally, with important regional variations. For the global average, warming in the last century has occurred in two phases, from the 1910s to the 1940s (0.35°C), and more strongly from the 1970s to the present (0.55°C). An increasing rate of warming has taken place over the last 25 years, and 11 of the 12 warmest years on record have occurred in the past 12 years. Above the surface, global observations since the late 1950s show that the troposphere (up to about 10 km) has warmed at a slightly greater rate than the surface, while the stratosphere (about 10–30 km) has cooled markedly since 1979 (IPCC, 2007a). The recent decade (2001-2010) has produced some of the warmest years globally on record. In 2011, the average temperature was warmer than the 30-year average in most regions around the world. Warming was particularly strong in the northern hemisphere, close to the Arctic Circle (Munich Re 2012).

Confirmation of global warming comes from warming of the oceans, rising sea levels, glaciers melting, sea ice retreating in the Arctic and diminished snow cover in the Northern Hemisphere. Consistent with observed increases in surface temperature, there have been decreases in the length of river and lake ice seasons. Further, there has been an almost worldwide reduction in glacial mass and extent in the 20th century; melting of the Greenland Ice Sheet has recently become apparent; snow cover has decreased in many Northern Hemisphere regions; sea ice thickness and extent have decreased in the Arctic in all seasons, most dramatically in spring and summer; the oceans are warming; and sea level is rising due to thermal expansion of the oceans and melting of land ice (IPCC, 2007a).

**Natural climatic variability**

Natural fluctuations of the global climate have always occurred and will continue to influence the Earth's climate. These fluctuations, also called natural radiative forcings, arise due to solar changes and explosive volcanic eruptions. Solar output has increased gradually in the industrial era, causing a small positive radiative forcing (i.e. relative warming). This is in addition to the cyclic changes in solar radiation that follow an 11-year cycle. Solar energy directly heats the climate system and can also affect the atmospheric abundance of some greenhouse gases, such as stratospheric ozone.

Explosive volcanic eruptions can create a short-lived (2 to 3 years) negative forcing (i.e. relative cooling) through the temporary increases that occur in sulphate aerosol in the stratosphere. The stratosphere is currently free of volcanic aerosol, since the last major eruption was in 1991 (Mt. Pinatubo).

The differences in natural radiative forcing estimates between the present day and the start of the industrial era for solar irradiance changes and volcanoes are both very small compared to the differences in radiative forcing estimated to have resulted from human activities. As a result, in today's atmosphere, the radiative forcing from human activities is much more important for current and future climate change than the estimated radiative forcing from changes in natural processes

Climate change is also influenced by various regional patterns of climate variability, some of which may become exacerbated by climate change. For example, El Niño Southern Oscillation (ENSO) is a climatic phenomenon that occurs in the southern Pacific Ocean episodically. ENSO can be linked to global anomalies in climate. These temperature anomalies are an overlay to the general warming trend observed globally.

The World Meteorological Organization summarizes ENSO as follows:

*"Research conducted over recent decades has shed considerable light on the important role played by interactions between the atmosphere and ocean in the tropical belt of the Pacific Ocean in altering global weather and climate patterns. During El Niño events, for example, sea temperatures at the surface in the central and eastern tropical Pacific Ocean become substantially higher than normal. In contrast, during La Niña events, the sea surface temperatures in these regions become lower than normal. These temperature changes are strongly linked to major climate fluctuations around the globe and, once initiated, such events can last for 12 months or more. The strong El Niño event of 1997-1998 was followed by a prolonged La Niña phase that extended from mid-1998 to early 2001. El Niño/La Niña events change the likelihood of particular climate patterns around the globe, but the outcomes of each event are never exactly the same. Furthermore, while there is generally a relationship between the global impacts of an El Niño/La Niña event and its intensity, there is always potential for an event to generate serious impacts in some regions irrespective of its intensity."*

(Source: World Meteorological Organization 2012: n.p.)

**Anthropogenic greenhouse gas emissions**

Human activities are responsible for post-industrial age climate change by causing changes in Earth's atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and outgoing infrared (thermal) radiation that are part of Earth's energy balance. The most significant greenhouse gases and their origins are (IPCC, 2007b).

- Carbon dioxide has increased from fossil fuel use in transportation, building heating and cooling and the manufacture of cement and other goods. Deforestation releases CO2 and reduces its uptake by plants. Carbon dioxide is also released in natural processes such as the decay of plant matter.
- Methane has increased as a result of human activities related to agriculture, natural gas distribution and landfills. Methane is also released from natural processes that occur, for example, in wetlands. Methane concentrations are not currently increasing in the atmosphere because growth rates decreased over the last two decades.
- Nitrous oxide is also emitted by human activities such as fertilizer use and fossil fuel burning. Natural processes in soils and the oceans also release nitrous oxide.
- Halocarbon gas concentrations have increased primarily due to human activities. Natural processes are also a small source. Principal halocarbons include the chlorofluorocarbons (e.g., CFC-11 and CFC-12), which were used extensively as refrigeration agents and in other industrial processes before their presence in the atmosphere was found to cause stratospheric ozone depletion. The abundance of chlorofluorocarbon gases is decreasing as a result of international regulations designed to protect the ozone layer.

- Ozone is a greenhouse gas that is continually produced and destroyed in the atmosphere by chemical reactions. In the troposphere, human activities have increased ozone through the release of gases such as carbon monoxide, hydrocarbons and nitrogen oxide, which chemically react to produce ozone. As mentioned above, halocarbons released by human activities destroy ozone in the stratosphere and have caused the ozone hole over Antarctica.
- Water vapour is the most abundant and important greenhouse gas in the atmosphere. However, human activities have only a small direct influence on the amount of atmospheric water vapour. Indirectly, humans have the potential to affect water vapour substantially by changing climate. For example, a warmer atmosphere contains more water vapour. Human activities also influence water vapour through CH4 emissions, because CH4 undergoes chemical destruction in the stratosphere, producing a small amount of water vapour.
- Aerosols are small particles present in the atmosphere with widely varying size, concentration and chemical composition. Some aerosols are emitted directly into the atmosphere while others are formed from emitted compounds. Aerosols contain both naturally occurring compounds and those emitted as a result of human activities. Fossil fuel and biomass burning have increased aerosols containing sulphur compounds, organic compounds and black carbon (soot). Human activities such as surface mining and industrial processes have increased dust in the atmosphere. Natural aerosols include mineral dust released from the surface, sea salt aerosols, biogenic emissions from the land and oceans and sulphate and dust aerosols produced by volcanic eruptions.

Often, global greenhouse gas emissions are expressed as $CO_2$e, which refers to ‘carbon dioxide equivalent’. This is a measure for describing how much global warming a given type and amount of greenhouse gas may cause, expressed as the equivalent amount or concentration of carbon dioxide ($CO_2$). As the IPCC confirmed in 2007, greenhouse gas concentrations in the atmosphere have increased significantly over the past 250 years when compared with the long-time average over the past 2,000 years (IPCC, 2007a). But where do these greenhouse gas emissions come from? The production of greenhouse gases is distributed quite unevenly in geographic terms and across sectors. While power generation is the origin of over one quarter of all greenhouse gas emissions, industry, land-use change and forestry, agriculture and transportation are other sectors that significantly contribute to global emissions. Urban planning can have an effect on a number of these sectors, and it is often directly responsible for land use changes, as well as a critical force in making changes to transportation systems and efficient power use (The World Bank, 2010).

## 2. Climate change mitigation

**Definition**

Climate change mitigation has been defined in the following ways:

*'Implementing policies to reduce greenhouse gas emissions and enhance sinks' (IPCC 2007)*

'A human intervention to reduce the sources or enhance the sinks of greenhouse gases' (UNFCCC 1997).

While the first one refers primarily to policies to reduce greenhouse gas emissions, the second definition goes beyond just policies and defines mitigation as any human intervention to reduce greenhouse gas emissions.

There are many examples of climate change mitigation actions, such as:

- Increasing energy efficiency in industrial processes, including electricity generation itself
- Switching from fossil fuels to renewable energy such as solar or wind power
- Increase the insulation performance of buildings
- Expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.

The second definition by the United Nations Framework Convention on Climate Change refers to both carbon sources and sinks. Carbon sinks are natural organisms such as forests or oceans that are able to absorb carbon and thereby remove it from the atmosphere. One of the largest, yet shrinking terrestrial carbon sinks world-wide is the Amazon rainforest in South America.

**Greenhouse gas emission sources and carbon sinks**

To be able to act on mitigation, it is critical to gain a robust understanding on the origins of greenhouse gases. Emissions from the burning of gas have steadily increased in absolute and relative terms since the 1970s. Oil-based emissions have been relatively stable over the past 40 years, while the most significant increases in CO2 emissions from fuel combustion are based on an increase in the burning of coal and peat. Emissions from this source increased in particular during the early 2000s, peaking in about 2008.

Geographically, significant differences exist. Historically, industrialized countries are responsible for a lion's share of accumulated greenhouse gas emissions, which rapidly increased with the beginning of the industrial age in Europe and North America. In recent times, the BRICS countries (Brazil, Russia, India, China and South Africa), and China and India in particular, are responsible for a rapidly growing share of global CO2 emissions, which is associated with the rapid economic growth these countries are undergoing. Similarly, the total emissions from industrialized countries (Annex 1 countries) have decreased slightly (International Energy Agency, 2012).

Another way of looking at global CO2 emissions is to look at the intensity of emissions per capita or per economic unit produced, differentiated by country. North America has the highest regional per capita emissions in the world, followed by Asia and Oceania combined (Australia has the highest individual country per capita emissions in the world; International Energy Agency, 2012).

The graph also shows that there are significant questions regarding the equity of carbon emissions and their consequences: The per capita emissions of African countries are minuscule when compared with those of North America. However, as will be discussed later on, many of the climate change impacts are experienced disproportionately in poorer African, Latin American and Asian countries, which have not been responsible for a large share of emissions to date (International Energy Agency, 2012).

Carbon sinks are artificial or natural reservoirs that absorb and store carbon from the atmosphere for a period of time. This process of absorbing carbon is called carbon sequestration. Without the carbon sink capacity of the oceans and the land mass, our current $CO_2$ concentrations in the atmosphere would be significantly higher than what they actually are. $CO_2$. The carbon concentration we are left with today is significantly less than what we could expect to measure if the oceans and land mass wouldn't act as significant carbon sinks.

**Greenhouse gas emissions and cities**

Now that we have a better understanding of the amount, causes and distribution of carbon emissions across countries and regions, it is useful to consider the role that cities play in $CO_2$ emissions production, carbon management and climate change mitigation.

In 2012, over half the global population lives in cities. This figure is set to increase to about 70% in 2050. This means that the majority of carbon emissions will be produced in cities, where most of the population and related global economic activity are concentrated. This makes cities and urban areas particularly important players in the fight against global warming. It also means that many of the climatic changes will be experienced by urban dwellers (The World Bank, 2010). While the urban population is expected to double by 2030, the global built-up area is expected to triple during the same period (Angel et al. 2005). This will dramatically increase energy requirements and costs of new infrastructure. Poorly managed cities exacerbate enormous new demands for energy and infrastructure investment.

With regard to greenhouse gas emissions, cities matter because they are large economies in themselves. The greenhouse gas emissions impact of cities is proportional to the level of economic output and the combination of energy sources they use. For example, richer cities, less dense cities, and cities that depend predominantly on coal to produce energy all emit more greenhouse gases than the average. The world's 50 largest cities by population and the C40 alone have combined economies second only to the United States, and larger than all of China or Japan. The world's 50 largest cities, with more than 500 million people, generate about 2.6 billion $tCO_2e$.

However, it is generally difficult to determine what percentage of global greenhouse gas emissions are generated by cities. This is due to factors such as varying definitions of what constitutes a city or an urban areas, and due to boundary issues with the emissions, i.e. decisions about if emissions should be allocated to a city or not. One of the key debates about city emissions calculations is whether to calculate emissions based on the location of production or on the basis of consumption. For example, a factory located in an urban area produces greenhouse gases. Using a production approach, its emissions would definitely appear in the city's emissions balance sheets. If a consumption approach is used, however, emissions are only included if a product's location of consumption is within the city limits. UN Habitat, in its 2011 Report on Human Settlements, estimated that, using a production approach, large cities emit between 30 and 40% of global total greenhouse gas emissions.

There is however a risk that production-based approaches divert attention for emission reductions away from high-income countries (where many goods and services are consumed) to middle-income countries that are growing rapidly and are engaged in energy-intensive production of industrial goods. A consumption-based approach seems more appropriate, because it ensures that „there is a reduction in the transfer of environmental costs to other people, distant places or future times"(UN Habitat 2011). The International Energy Agency (IEA) estimates that urban areas currently account for over 67% of energy-related global greenhouse gases, which is expected to rise to 74% by 2030. It is estimated that 89% of the increase in $CO_2$ from energy use will be from developing countries (IEA 2012).

Energy use and carbon emissions are mostly driven by how electricity is produced and how energy is used in buildings and transportation. Currently cities meet approximately 72% of their total energy demand from coal, oil, and natural gas, which are the main contributors to greenhouse gas emissions. Cities and urban centres require concentrated energy supplies. Most cities are supplied with electricity from large-scale power plants, transmitted over a distance as short as possible to reduce transmission losses. Similarly, trucks, automobiles, and aircraft require fuel with high energy content. Renewable energy sources, such as wind and solar, will be an important and growing source of energy for cities, but as currently envisaged, they will likely not be able to replace the more concentrated carbon-based, and nuclear energy sources in the near future. Major changes in energy supply for the purpose of reducing greenhouse gas emissions will also require changes to the energy use habits—for example, less automobile use and more energy efficient buildings.

**Measuring city emissions**

A first step towards reducing greenhouse gas emissions is to measure them. However, measurement can be tricky because baseline data often is not easy to obtain, and because it can be difficult to decide where the boundaries of responsibility for greenhouse gas emissions are. For example, is a municipality responsible for the emissions produced by its residents or by its businesses, or are they themselves responsible for them? Can municipalities be held to account for emissions related to making the products the municipality uses, even if these products were produced elsewhere, outside the city limits?

Internationally, a standard for dealing with these differences has emerged that specifies three different ‘emissions scopes’. Emissions under Scope 1 are greenhouse gases emitted from any sources under the direct control of an organization, e.g. emissions from vehicles and city-owned buildings. Scope 2 emissions are those from electricity consumed by the municipality, although the actual emissions may be produced in a power station outside the city. Scope 3 emissions are those that are those that can be associated with the extraction, production or transportation of goods and services used by the municipality. For example, while the emissions produced from vehicles owned by the municipality count as scope 1 emissions, the emissions produced to make the vehicles in the first place count as scope 3 emissions.

Most early climate action plans for cities inventoried and then made recommendations only for the emissions that were the direct responsibility of municipal authorities – the municipal car fleet, heating municipal buildings, etc. (see ICLEI greenhouse gas emissions measurement system). This was an excellent first step, but did not capture most emissions from urban areas, which result from private property and resident and business activity.

In 2010 the United Nations Environment Programme, together with UN-Habitat and the World Bank, introduced draft standards that all cities can use to measure their greenhouse gas emissions. Following the IPCC, that guidance identified three scopes of measurement (UNEP 2010 p. 4):

Scope 1: GHG emissions that occur within the territorial boundary of the city or local region

Scope 2: Indirect emissions that occur outside of the city boundary as a result of activities that occur within the city, limited to only:

- electricity consumption
- district heating, steam and cooling

Scope 3: Other indirect emissions and embodied emissions that occur outside of the city boundary, as a result of activities of the city, including (but not limited to):

- electrical transmission and distribution losses
- solid waste disposal
- waste incineration
- wastewater handling
- aviation
- marine
- embodied emissions upstream of power plants
- embodied emissions in fuels
- embodied emissions in imported construction materials
- embodied emissions in imported water
- embodied emissions in imported food

In 2012, C40 and ICLEI-Local Governments for Sustainability, in collaboration with the World Resources Institute and others, published a pilot version of their Global Protocol for Community-

Scale Greenhouse Gas Emissions. This protocol builds on the work by UNEP et al. (2010) mentioned above.

**Why mitigation makes sense**

Reducing greenhouse gas emissions to reduce overall long-term climate change is a primary responsibility for high-emissions countries. It is also important for rapidly developing countries, to avoid high-carbon emissions development that may contribute significantly to climate change in the future.

But for all countries, mitigation can have rapid and local benefits as well. The United Nations Environment Programme reports:

*'It is estimated that more than 1 billion people are exposed to outdoor air pollution annually. Urban air pollution is linked to up to 1 million premature deaths … each year. Urban air pollution is estimated to cost approximately 2% of GDP in developed countries and 5% in developing countries. Rapid urbanisation has resulted in increasing urban air pollution in major cities, especially in developing countries. Over 90% of air pollution in cities in these countries is attributed to vehicle emissions brought about by high number of older vehicles coupled with poor vehicle maintenance, inadequate infrastructure and low fuel quality.'*

(Source: UNEP 2012).

Many of the actions taken to reduce overall emissions will also reduce the particulates and other pollutants that go with carbon emissions. As a result, local air will be cleaner even while global benefits accrue. In economic terms, many mitigation actions have negative costs, i.e. net benefits, where the long term savings outweigh the initial costs. Such measures include promoting energy efficiency in buildings, increasing efficiency of electricity generation, and the use of hybrid engines. Although developed and developing countries have similar potential for negative cost (net benefit) measures and high-cost measures, the middle range of low-cost mitigation options is predominantly situated in developing countries (with many in agriculture and forestry). Some of the most effective and most costly mitigation activities are advanced technologies, such as carbon capture and storage. However, many other, less costly measures exist that will result in significant emissions reductions.

**Taking action on mitigation**

Some sectors offer a fast return on investment for mitigation. These include buildings, transport, and waste, which are estimated to on average yield positive returns on energy savings alone (ICLEI 2007). Typical sectoral mitigation actions are:

- Transportation – improve public transport and assure homes and businesses develop near transport
- Homes and Office Buildings – encourage dense development, eco-friendly buildings
- Industrial Production – seek efficiency and reduction of pollution

- Poverty Reduction – necessary for people to make better choices

A UN-Habitat slide show describes each of the abovementioned four elements this way:

Transport:

1. Encourage the use of an optimal combination of modes of transport, including walking, cycling, public and private means of transportation (ex: bus and bicycle lanes)

2. Create government and private sectors incentives for public or alternative transportation including fuel efficient vehicles and carpooling (ex: access to free parking close to office)

3. Create disincentives for those who fail to adopt sustainable measures (ex: polluter pays mechanisms)

4. Promote, regulate and enforce, quiet, use-efficient and low-polluting technologies including fuel efficient engines, emissions controls and fuel with a low level of polluting emissions

Buildings:

1. Stimulate through fiscal incentives or other measures the adoption of energy efficient and environmentally sounds technologies (ex: insulation, appliances, ventilation and lighting)

2. Create disincentives for the purchase/use of harmful technologies/products.

3. Encourage increased density in the CBD, efficient use of space, multi-residential buildings, etc.

4. Use legislation to create sustainable construction (ex: all new buildings must meet a certain environmental standard)

5. Create of incentive to encourage the renovations of existing structures (ex: free home/office energy audits, BASF's 3 liter house)

Industrial production:

1. Reduce waste through disincentives (ex: higher costs of waste disposal) and through incentives (ex: markets for waste product)

2. Introduce or amend user charges and/or other measures to promote the efficient use of energy

3. Reduce fuel consumption through the adoption of efficient and economically viable technologies

4. Encourage energy efficient systems such as combining heating and cooling systems that utilize waste heat recovery

5. Increase efficiency through free energy/waste audits and education programs for all employees

Poverty reduction:

1. Reduce the need for poor to use unsustainable energy sources such as charcoal and kerosene (explain charcoal)

2. Incentives/disincentives will not work on those who cannot afford other energy sources therefore the reduction of poverty is key in the implementation of climate change mitigation

3. Create incentives for private sector involvement in poverty reduction

4. Create educational and training initiatives to teach low income citizens and slum dwellers the importance of the environment and sustainable urban development

(Source: UN Habitat (2007): Climate change mitigation through urban planning and development – an overview. Presentation, 11 May 2007. http://unfccc.int/files/methods_and_science/**mitigation**/application/1_karl_unhabitat.pdf).

But each city will find its situation to be unique. As part of the C40-Megacities initiative from the Clinton Foundation, cities have reported their mitigation activities (Carbon Disclosure Project 2012). Whiles only a small number of developing country cities have completed mitigation plans, there are a few examples. Bangkok is one such example. Their Action Plan on Global Warming Mitigation 2007 – 2012 aims at greenhouse gas emission reduction by at least 15% of the total emission anticipated in the year 2012 under business as usual projection (Bangkok Metropolitan Administration 2007).

The Action Plan includes five initiatives:

1. Expand the Mass Transit Rail System within Bangkok Metropolitan Area;
2. Promote the Use of Renewable Energy;
3. Improve Building Electricity Consumption Efficiency;
4. Improve Solid Waste Management and Wastewater Treatment Efficiency; and
5. Expand Park Area.

Potential mitigation actions are discussed in more detail in modules 2 and 3 of this course.

## 3. Climate change adaptation

### Definitions

Climate change adaptation is another form of response to climate change that is primarily concerned with the impacts of climate change on the natural and human world. Here are two commonly used definitions of climate change adaptation:

*'Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (UNFCCC 1997)*

*'Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC 2007)*

The first definition, issued by the United Nations Framework Convention on Climate Change in 1997, is probably the most commonly used definition. It takes a systemic point of view, highlighting that adaptation is both about human and natural systems, about currently observable as well as future changes, and both about negative and positive consequences.

The second definition from the Intergovernmental Panel on Climate Change introduces the concept of vulnerability, which will be discussed later in this lecture. Again, a systemic perspective is key to this definition, but the focus lies on the notion of vulnerability reduction as the ultimate goal of adaptation. Adaptation measures can take a myriad of forms, from technological measures, to measures related to planning and design, to social measures such as raising awareness and education.

### Understanding climate change impacts

Climate change has led to observable effects on our natural and human systems. Biophysical systems, such as ecosystems, are coupled with human systems, such as cities or agricultural systems. This means that many impacts on natural systems result in immediate or indirect flow-on effects on human systems, such as food and agricultural, human health and well-being, and the built environment.

The most significant projected climate change impacts on natural systems are (IPCC, 2007c):

- Changes to average river run-off and water availability
- A global increase in drought-affected areas
- A decline in snow cover and glacier extent in mountain areas
- Accelerated extinction of plant and animal species
- Progressive acidification of oceans and coral bleaching
- Rising sea levels and coastal erosion

As a consequence of physical climate change impacts, human systems will be affected by climate change in many different ways. These impacts include (IPCC, 2007c):

- Changes to crop productivity due to changing temperatures and rainfall patterns
- Inundation of coastal settlements due to sea level rise
- Increased vulnerability of people most dependent on climate-sensitive resources, such as water and food
- Increased deaths, disease and injury due to heatwaves, floods, storms, fires and droughts
- Increased burden of diarrhoeal disease
- Changes in the spatial distribution of infectious diseases.

Climate change impacts will not be experienced equally across the different continents and regions of the world. Impacts differ between climatic zones, across different types of landscapes, and between ecosystems of similar nature located in different parts of the world.

Within any one region, some systems, species and people will be more able to absorb similar climate change impacts than others due to differences in their adaptive capacity. For example, it is generally assumed that people living in developed countries are more able to adapt to heatwaves and other extreme weather events than people living in developing countries or least developed countries, due to the former having access to safe shelter, cool spaces, and supportive infrastructure and systems such as emergency services and communication systems.

Africa is considered one of the most vulnerable continents due to multiple stresses and low adaptive capacity. Coastal areas in all parts of the world are considered vulnerable to climate change impacts, in particular in highly populated areas. For example, highly populated delta regions in Southeast Asia are at great risk due to flooding from the sea and from large rivers. Small islands are especially vulnerable to sea level rise and extreme weather events such as storms (IPCC, 2007c).

**Climate change impacts on cities**

Cities around the world have always experienced the impacts of climatic extremes, such as wind storms, hail storms, flooding and heatwaves. Flooding can cause significant disruptions to urban systems, such as transportation, which can bring local economies to a standstill and affect the lives and incomes of millions of urban residents. Severe and prolonged floods, such as the ones experienced in Pakistan in 2010, can threaten the viability of cities and lead to massive problems for human health and well-being, as well as to highly costly damages to physical infrastructure. Other climate change impacts such as heatwaves may lead to less disruption of day-to-day activities in cities, while still having significant impacts on human health, including surges in hospital admissions and deaths due to heat stress. In cities, heatwaves are often combined with poor air quality due to either smog generated from fossil fuel combustion or wildfires. Short-term extreme weather events, such as intensive rain and hailstorms, can have immediate negative effects on residents and local economies. To avoid such consequences, it is important to ensure, for example, that drainage systems can cope with increased intensity rainfall events. Wildfires can threaten houses, residents and infrastructure on the fringes of cities. This is particularly the case in Mediterranean climates, where hot summers combined with dry spells and strong winds can quickly lead to catastrophic situations of wildfires spreading out of control. Wildfires are naturally occurring in many ecosystems and are indeed vital for their survival, but as many expanding cities are encroaching into treed areas on their perimeters, wildfires become a threat to human lives. Cities are also at risk of gradual, slow-onset climate change impacts, such as sea-level rise and coastal erosion. Large urban populations live in low elevation coastal zones (LECZs), including those residing in some of the world's largest megacities. Urban populations in the Caribbean, Southeast Asia and the Pacific are particularly vulnerable to the impacts of sea level rise.

Many of these events have caused disasters in cities, resulting in the loss of human lives, the destruction of infrastructure, and the loss of valuable assets. However, we need to distinguish between climatic impacts in general and climate change impacts. Under climate change, these extreme events are likely to increase in frequency and in intensity. For example, a one in one hundred year flood event may occur much more frequently (e.g. once every ten years).

**Urban poverty and climate change**

Climate change is only one of many drivers that can lead to severe consequences for urban populations. In developing countries and in some developed countries, urban poverty is probably the key underlying that influences if and to what extent individuals are able to prepare themselves for and respond to climate change impacts. Informal urban development, the lack of good urban planning, and poor quality of housing stock are important factors that will affect people's ability to cope with climate change impacts in urban areas. It is not only sudden, extreme events that are likely to have significant impacts but also changes in means, and changes in exposure. These factors and many other important drivers can be subsumed under the concept of vulnerability.

Climate change puts urban populations at increased risk to suffer harm from extreme climate-related events. This will mean that vulnerable populations will be exposed to climate change events more frequently, and they may find it more difficult to recover from an event and prepare themselves to be better equipped for when the next disaster occurs.

City administrations and those in charge of urban planning and development have a responsibility to avoid harm to people and property (in legal terms, this is called 'duty of care'). Sound urban planning is one of the key strategic approaches that can be employed for adapting the changing climate and prepare an urban area for the impacts of climate change.

**Adaptation planning**

The IPCC introduce adaptation in their AR4 Summary for Policymakers this way:

*'Societies have a long record of managing the impacts of weather- and climate-related events. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. Moreover, vulnerability to climate change can be exacerbated by other stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS. {4.2}*

*Some planned adaptation to climate change is already occurring on a limited basis. Adaptation can reduce vulnerability especially when it is embedded within broader sectoral initiatives (Table SPM.4). There is high confidence that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios.'*

(IPCC 2007 p. 14).

While adaptation can't address the overall global increases in greenhouse gas emissions and subsequent global warming, what it can do is reduce the impact locally of those changes. A key example is heat waves. Urban heat island effects (see module 3) mean that neighborhoods with lots of impermeable surfaces can be 4 – 8 degrees F warmer than the surrounding countryside.

As Hamin and Abunnasr report, the impact of climate events and thus the experience of climate change can be magnified (or reduced) by the form and/or design of on-going urbanization processes (Hardoy and Pandiella, 2009; IPCC, 2012; Schipper and Burton, 2009), which create micro-climates that influence human climate-experience and ecological functions. One key variable is the amount of impervious surface. Higher imperviousness tends to lead to more flooding, more intense urban heat island effects, and increased desertification. These affect an environmental feedback loop that results in higher levels of particulates in the air; increased levels of pollutants, particularly ozone; decreases in floral and faunal diversity and numbers; and increasing destabilization of soils and floodplain systems. These in turn result in a higher incidence of human health problems (Few, 2007; Shea et al., 2008), property damage and loss, and ecological degradation and species extinction. The poor tend to be disproportionately affected by these changes as economic forces push them into areas that are highly impervious and flood prone with high heat indexes and unstable soils (United Nations Human Settlements Programme (UN-Habitat), 2011). Thus, if cities are built with little green space and urban forest and the poor continue to be pushed into high risk areas, vulnerability to climate variability increases regardless of climate change, and is magnified with it (United Nations Human Settlements Programme (UN-Habitat), 2011). A city designed with green infrastructure to reduce urban heat island effects, with on-site stormwater harvesting accompanied by effective watershed management systems, and with climate-adapted buildings built on stable soils, is better positioned to manage current climate variability.

## 4. Case studies

**Lagos, Nigeria**

The following is a case study summary for the city of Lagos' resilience building activities, taken from the Resilient Cities 2011 Congress Report, p.13f. (http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2011/RC2011_Congress_report_20120228.pdf). This case study can be introduced as part of the lecture to illustrate key points, and then be examined further through internet-based research by students, as part of student led learning activities (e.g. as part of the *seminar* or the *group project* - see Module 1 Syllabus).

*Setting the scene*

Lagos is the economic center of Nigeria. The city contributes roughly 25 per cent to the country's GDP. Lagos' urban population grows at an annual growth rate of 6 to 8 per cent ballooning to 18 million people in 2010. Lagos is the country's gate to the sea accounting for 80 per cent of national seaport activity. These developments are placing huge pressure on the provision of urban services including water, energy, sewage, waste, transport and housing. The city also suffers from corruption and poverty, an unfortunate common occurrence in the region.

Situated on a lagoon and estuary, Lagos is prone to coastal erosion, tidal and river flooding, as well as storm surges. All of which are very likely to worsen according to local climate change projections. Higher temperatures and more intense heat wave episodes might also put vulnerable populations at higher risk.

*Towards an adaptation strategy and coping with immediate risks*

Addressing climate change has been identified among Lagos State's leaders as a political priority. Faced with incredible development challenges, climate change uncertainties are adding to the complexity of the development challenge in Lagos. The full picture on the influence of climate change has still to be fully analyzed to better understand local impacts and vulnerabilities. This is the first step towards a proper, step-by-step adaptation strategy. Such a strategy will have to ensure that basic services are provided to the local population particularly to the urban poor.

To date, action has predominantly concentrated on individual projects but the need for integration is becoming more obvious. The drainage infrastructure suffered from blockages due to a general lack of maintenance aggravated by dumping of waste and informal settlements. Several drains have been cleaned up and structurally improved. A vast program to improve waste management from collection to disposal had positive impacts on water and air quality, drainage, and general urban cleanliness. At Bar Beach, coastal erosion is being addressed with a sea wall to protect the valuable investments of Eko City estate development. Furthermore, awareness and education campaigns on climate change have been run in Lagos' schools.

*Resilience. A key to Lagos development?*

The State Governor has shown political will to address climate change. A strong climate leadership could be a considerable opportunity for the State of Lagos to build resilience and develop sustainably. Some participants in the workshop suggested that switching to resilience as an overall policy could result in greater local value for the city and its population. It presents an opportunity to better integrate the various dimensions into urban development. Assessments can help to identify areas for improvement that have catalytic and multiplying effects. For example a proper waste management system allows for cleaner streets and drains, creates jobs, improves air quality improvements, and reduces epidemic risks, etc. In addition to this, promoting local resilience and identifying projects could help leverage funds. Participants acknowledged the great challenge ahead.

**Ho Chi Minh City, Vietnam**

The following is a case study summary for Ho Chi Minh City's adaptation and mitigation activities, taken from the Resilient Cities 2011 Congress Report, p.12f. (http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2011/RC2011_Congress_report_20120228.pdf). This case study can be introduced as part of the lecture to illustrate key points, and then be examined further through internet-based research by students, as part of student led learning activities (e.g. as part of the *seminar* or the *group project* - see Module 1 Syllabus).

*Setting the scene*

Ho Chi Minh City (HCMC) is an emerging mega-city. The urban agglomeration has experienced continued population growth reaching 7 million inhabitants in 2010. It is also a hub of economic activity. The mega-city contributes around 22 per cent to the country's GDP and 40 per cent to its exports. Growth has resulted in an intense but relatively controlled urban development.

However, HCMC is a city at risk, the most serious of which is coastal flooding due to its location on the Thi Vai River. With climate change sea levels will rise and the intensity of rainfalls and storm surges will increase. Thus risk of flooding and erosion will rapidly increase. Further problems include vector borne diseases and higher temperatures.

*Adapting to the climate challenge*

The adaptation strategy is at a preliminary stage and is part of the "Action Plan for climate change of HCMC". This Action Plan is addressing both mitigation and adaptation. One important component is the assessment of the local pattern of climate change. This helps in identifying vulnerabilities and informing the development of a methodology for the adaptation planning.

*Challenging status quo, exploring new solutions*

Research has suggested that planned urban development in HCMC is currently aggravating flood vulnerabilities and potentially causing more harm than the impacts of local climate change. While in most developing countries informal settlement patterns are a major factor for vulnerability, this is less an issue in HCMC. The circumstances have complex roots that make the city both unique and particularly vulnerable. In part it is explained by the history and dynamics of its development. The workshop's discussion suggested that the municipal boundaries tend to direct infrastructure development towards the sea, away from the jurisdiction of neighboring municipalities. Also large infrastructure investments, supported by international funders and decided at the national level, have concentrated development in the southern part of the city – an especially risk-prone area.

Solutions are not straightforward. Drainage works are already underway to limit the impact of regular flooding. The recent creation of a steering committee was commended by participants as it allows the city to coordinate climate action across departments. Going further, participants suggested greater integration of flood prevention and other natural hazard risk assessments in the masterplan. However redefining the 10-year master plan is a complex process that involves numerous actors and requires a final approval by the central government. Awareness of the challenge, based on sound climate data downscaled to the local level and vulnerability assessments, is an important step towards change.

**Semarang, Indonesia**

See detailed summary of City of Semarang case study as a separate document.