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Integrating and monitoring spatial planning, mitigation and adaptation issues

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Abstract

Cities and climate change: integrating and monitoring spatial planning, mitigation and adaptation issues.

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The urbanisation process poses a great pressure to the already delicate environment and development issues in low- and middle-income countries. In addition, climate changes consequences are already being felt and are likely to intensify, bringing further challenges to these nations. Spatial planning contributes to accommodate the expected unprecedented urban growth and the resulting pressure on land and other resources. In face of climate change, however, spatial planning can also play a key role in supporting mitigation and adaptation measures in cities.

Detailed facts in relation to urbanisation and climate change challenges, and the possible opportunities for achieving change are discussed. Moreover, the role and needs of cities in reacting to climate change is examined. As an essential investigation of this work, the contributions of spatial planning for reducing greenhouse gas emissions on the one hand, and risks and vulnerabilities, at the other, are analysed.

In order to integrate both issues at the local level, a strategic approach is necessary, strongly relying upon indicators to monitor the efficiency of actions being taken. For the suggestion of indicators, first an examination of existing frameworks is performed. In conclusion, the applicability of such a concept to developing countries is critically investigated, based on the relevant strengths and weaknesses, opportunities and threats influencing the overall conditions in their urban areas.

Keywords: urbanisation, climate change, spatial planning, mitigation, adaptation, cities, integrating, monitoring, indicator

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Abbreviations

ADB – Asian Development Bank

ARL – Academy for Spatial Research and Planning / *Akademie für Raumforschung und Landesplanung*

BMVBS – Federal Ministry of Transport, Building and Urban Affairs / *Bundesministerium für Verkehr, Bau und Stadtentwicklung*

BBSR – Federal Institute for Research on Building, Urban Affairs and Spatial Development/ *Bundesinsititut für Bau-, Stadt- und Raumforschung*

BBR – Federal Office for Building and Regional Planning / *Bundesamt für Bauwesen und Raumordnung*

CASE – Cities as Sustainable Ecosystems

CCP – Cities for Climate Protection

CDRI – Climate and Disaster Resilience Initiative

CDS – Cities Development Strategy

CER – Certified Emission Reductions

COP – Conference of Parties

DAEI – Directorate of International Economic Affairs (France)

DSS – Decision Support System

EEA – European Environmental Agency

EIA – Environmental Impact Assessment

GCIF – Global City Indicators Facility

GDP – Gross Domestic Product

GHG – Greenhouse Gas

GIS – Geographical Information System

GUO – Global Urban Observatory

ICLEI – Local Governments for Sustainability

IPCC – Intergovernmental Panel on Climate Change

IISD – International Institute for Sustainable Development

MDG – Millennium Development Goals

OECD – Organisation for Economic Cooperation and Development

OECC – Overseas Environmental Cooperation Centre (Japan)

SCP – Sustainable City Programme

PSS – Planning Support System

ppm – parts per million

ppb – parts per billion

R&D – Research and Development

RTPI – Royal Town Planning Institute (England)

SCP – Sustainable City Programme

t CO_2eq – tons of CO_2 equivalent

UBA – Federal Environment Agency / *Umweltbundesamt*

UN – United Nations

UNCED – United Nations Commission for Environment and Development

UNCSD – United Nations Committee of Sustainable Development

UNDESA – United Nations Department of Economics and Social Affairs

UNFCCC – United Nations Framework Convention on Climate Change

UN-HABITAT/UNCHS – United Nations Centre for Human Settlements

UNDP – United Nations Development Programme

UNEP – United Nations Environmental Programme

UNFPA – United Nations Population Fund

WCED – World Commission on Environment and Development

WB – World Bank

WHO – World Health Organisation

WRI – World Resource Institute

WWI – Worldwatch Institute

1 Introduction

1.1 Issue diagnosis

Urbanisation has been changing the face of the world. Urban population increased from 220 million in 1900 to currently 3.3 billion people. By 2030, urbanised areas will be home of 60 percent of the total world's population, around 5 billion dwellers. And 80 percent of this urban humanity will be living in towns and cities of the developing world. The scale and pace of urbanisation brings many challenges with it. A great part of urban dwellers in low and middle-income countries has no access to adequate infrastructure provision. Lack of housing, sanitation, water, energy and transportation, also leading to environmental degradation, together with other social and structural/governance problems is transforming cities in unsustainable machines.

The current suggested argument/perception is that, because society has not been able to reach sustainable paths of development the world is facing serious environmental and social problems. One of the main discussed topics nowadays, climate change, is reality, and its impacts are already being noticed worldwide. Activities related to use of fossil fuel energy (buildings, transportation) are concentrated in cities. The economic development and patterns of consumption and production in cities are main driving forces of greenhouse gas emissions. Also, negative consequences of climate change such as storms, floods, droughts, heat waves, water shortages and sea level rise, among others, will be felt in urban areas. Cities therefore concentrate great potential in tackling climate change by taking measures in relation to adaptation to its impacts and to mitigating its cause, the greenhouse gas emissions.

Emissions share of the low and middle-income countries is steadily increasing. As these nations rapidaly urbanise, also the built up area and the land and infrastructure demand increase. Investments made now are going to determine the carbon intensity of their economies in the future. In these countries and especially in their urban areas, many of the mistakes made by the developed world can be avoided; there is a great opportunity for green development and for planning more sustainable urban areas right from the beginning. Planning for sustainable cities is also strongly linked to adaptation. Cities generally concentrate great part of the gross domestic production of nations, and the likely impacts from climate change will have therefore strong economical negative consequences.

In this sense, spatial planning (land-use, urban form), which has been the focus of analytical and pragmatical approaches of how to achieve urban sustainability, can play an important role. Yet it is still necessary to better understand how to integrate climate change issues of mitigation and adaptation, especially for the developing countries. Up to now there are also few approaches of how to assess, measure or evaluate the influence of planning in helping cities to cope with climate change and urbanisation challenges.

1.2 Research questions

Based on an extensive literature review and theoretical analysis, the main objective of this work is to contribute for a better understanding of the role of cities and specifically of spatial planning in times of climate change. It focuses on the overall needs for adaptation and on the chances for mitigation in cities and on how spatial planning can influence these issues. Moreover, it aims recommending indicators for assessing and evaluating the contribution of spatial planning in achieving mitigation of and adaptation to climate change.

Specific research questions are:

- What are the facts and arguments that bring urbanisation and climate change issues as main threats for the future, and how these environmental and development challenges will hit the developing countries harder?

- What could be possible opportunities for change? What is the role of spatial planning, what approaches exist, what are the available options for mitigation and adaptation, and what is the possible link to sustainable development?

- Why should and how can cities and local governments take the lead in responding to climate change? What are the current initiatives going in this direction worldwide? How and what is needed for cities to integrate issues of mitigation and adaptation in their development?

- How do spatial planning (land use, urban form) can be a key in the processes of mitigation and adaptation? Where do they interact, where can synergies or trade-offs/conflicts be found?

- How can climate change be strategically integrated into spatial planning issues? What kinds of indicators exist? Which ones (and how do they) serve as a base for the development of specific indicators for spatial planning and mitigation and adaptation issues? What set of monitoring indicators can be recommended?

- To which extent is the integration and use of indicators to developing countries context applicable? What are possible strengths and weakness, opportunities and threats?

1.3 Structure of the work

After the introductory part in this **chapter 1**, dealing with the issue diagnoses and research questions, **chapter 2** focuses on the specific and detailed facts related to urbanisation and climate change issues. First, it concentrates on the figures and data about the urbanisation process in specific world regions, on the distribution of population by types and size of settlement, and additional on problems (social, environmental) related to urbanisation especially in the developing countries. In the second part the chapter deals with the climate change scientific facts (source of emissions, expected impacts) and with political matters briefly.

Chapter 3 explores the opportunities for change in face of the growing development and environmental challenges posed by urbanisation and climate change. It starts with an analysis of sustainable development, also having in the centre of attention pragmatical and analytical ways of achieving urban sustainable development, referring to different international approaches and to theoretical models. Furthermore it concentrates on spatial planning's instruments and tools and on theories such as new urbanism, smart growth and compact city, which take into consideration land use and urban form in the achievement of sustainable urban development.

In addition, **chapter 4** concentrates on the role of cities as actors of change. Initially it discourses about the necessity and the reasons for cities to take the lead in addressing global issues at the local level. Further, some of the international existing initiatives that help cities in these tasks are briefly mentioned, as well as the need and the tools available for the compilation and implementation of a Climate Action Plan. The connections between mitigation and adaptation in cities are analysed, as well as the need for a baseline evaluation of sources of emissions and of risks and vulnerabilities at the local level.

Chapter 5 concentrates on the role of spatial planning in tackling climate change. Options for mitigation take into consideration the fact that the urban metabolism and the associated amount of used energy is largely influenced by urban form and how its functions are distributed. Adaptation additionally needs to be undertaken through spatial planning by integrating measures that minimise flood and sea level raises risks, or increased heat island effects. Synergies and trade-offs are also succinctly analysed.

In order to find ways to integrate and monitor spatial planning and climate change issues, **chapter 6** deals shortly with a strategy development for participative decision making and reviews international and specific sets of indicators used for environmental, sustainable and urban development assessment. The review serve to identify adequate entry points for the analysed issues in already existing indicators frameworks, and as base for the suggestion of specific monitoring indicators.

Conclusively, **chapter 7** gives attention to the applicability of such a concept for developing countries, discussing possible strengths and weaknesses and opportunities and threats, and **chapter 8** clarifies overall conclusions and outlook.

2 Present and future challenges

The generations to come will have no choice but to live in a predominantly urbanised and constantly warming world. By 2030 it is expected that five billion people will live, most of them "survive" in cities [UN, 2006: 1]. And by 2050 the world could be experiencing, in average, 2 to 4 °C warmer temperatures than in pre-industrialisation times [IPCC, 2007b: 13].

The unprecedented demographic growth, essentially inefficient fossil fuel based energy/ production systems, vicious (and inequitable) patterns of consumption are among the drivers of current environmental change[1]. Earths carrying capacity is at the limit[2], and yet more than 1.2 billion people live with less than $1 a day. Almost 60 percent of the population in developing countries lack basic sanitation, nearly one third have no access to clean water, 25 percent lack adequate housing [UNFPA, 2001: 6]. These environmental and development problems will intensify, in face of the current unplanned urbanisation and associated pressures. Climate change challenges are going to bring further constraints, especially because expected impacts will also hit the developing countries harder [IPCC, 2007c].

The stewardship for the planet and for the wellbeing of its people is a shared duty and urgent changes are needed. In order to understand the problems, before trying to discuss about possible solutions, this chapter gives an overview about urbanisation and climate change issues and challenges.

2.1 Urbanisation

At the beginning of the twentieth century, around 1.6 billion people inhabited the planet. Mainly due to the improved health conditions, the industrial revolution, enhanced agricultural practices, earth population has steadily increased, reaching 6 billion in 1999. By 2050, United Nation's forecasts predict an increase up to 9 billion [UN, 2006: 1].

The development of urban population is even more drastic. In 1900 only 220 million people lived in urban areas (at the time 13 percent of total population), nowadays around 3.3 billion (over 50 percent of total) earth citizens inhabit cities. Different pressures are responsible for this explosive urban growth, for instance, poverty and the collapse of rural environment, lack of jobs and land, and an overall search for better services and opportunities in urban areas [UNFPA, 2001: 33].

[1] Global Environmental Change includes desertification, land degradation and stress of food producing systems, changes in hydrological systems and freshwater decline, biodiversity loss and ecosystems function, stratospheric ozone depletion and climate change.
[2] Carrying capacity is a term used to express the population size of a species that can be sustained by an environment in the long term (considering the food, habitat, water and other requirements the environment has to provide) [Wackernagel et al., 2006].

According to prognoses, by 2030, urbanisation will reach 60 percent, with nearly five billion people living in urban areas [UN, 2006: 1]. For a better visualisation, this figure means around 160 thousand people moving to urban areas every day, or approximately a new city of 1 million inhabitants every week. Human beings have become an urban species, and the twentieth first century will be the century of cities.

Over 80 percent of the current world population is located in the newly industrialised and developing countries. And this share will increase, since nearly all population growth will occur in the poor regions of the world. While America and Europe, and also Latin America have stable urban population fraction, Africa and Asia are facing enormous shifts. Even though less developed regions are less urbanised (28 to 44 percent share) compared to industrialised countries (75 percent share), they are home to more than twice the number of urban habitants, compared to more developed regions (2.3 billion vs. 0.9 billion) [UN, 2006: 3].

As of 2007, Africa had an average share of 39 percent of population living in urban areas (nearly 370 million dwellers). Variations are extreme, from Burundi with 11 and Ethiopia with 16 percent to Tunisia with 66 and Gabon with 85 percent. While northern and southern Africa already have over half of population living in cities (52 and 57 percent respectively), middle and western Africa's shares are 41 and 44 percent, and Eastern Africa only 23 percent [UNFPA, 2007: 89]. Urbanisation is critical in proportional terms, because of higher population growth rates, rural poverty, related to low agricultural productivity and conflicts that drive people into cities [WWI, 2007: 8]. By 2050 it is expected that total African population will grow from around 0.9 to 1.9 billion, and urban population will more than triple, reaching 1.23 billion, a 60 percent share.

The most populous region of the world, Asia, hold 41 percent of urban population, and variations among regions are also very strong. Western Asia (besides Yemen) is highly urban (65 percent), while south central (excluding Iran) is not (average 31 percent). Eastern and south-eastern Asia has shares of a bit less than 50 percent. Prognoses say total population in Asia will grow from current 4 billion to around 5.2 billion by 2050, while urban population will more than double, from 1.5 to 3.3 billion, also reaching a share of over 60 percent [UNFPA, 2007: 91]. Special attention has to be given to India and western China, where urbanisation is occurring very fast, but economic growth is not, and poverty puts pressure on a significant amount of the urban population [WWI, 2007: 9].

China and India together account for 37 percent of the world's population. Therefore their policies for coping with urban growth will be very decisive for the development of the region. While India urban areas have around 30 percent of the total population (expected to rise to over 40 percent by 2030), China is in its peak of urban transition. With currently over 660 cities (139 cities with 750 million inhabitants or more), it is predicted that in less than a decade, nearly 900 million people (over half of the population) will live in urban areas [UNFPA, 2007: 13].

Latin America and Caribbean region have already undergone urban transition similarly to Europe and North America. With a 78 percent share, urban population is currently estimated to be near 450 million, expected to grow to 680 million by 2050 (share of almost 90 percent). A large and increasing part of the population is living in slums [UNFPA, 2007: 92].

When it comes to the distribution of urban population by size class of settlement, it is worthy of note that only one tenth of world urban population (around 4 percent of total population) lived in the so-called megacities (cities with 10 million habitants or more) as of 2005. And this rate will not change much in the next 10 years. Seven percent is located in cities with 5 to 10 million inhabitants, and 11 percent in cities with half to one million dwellers. Around 22 percent live in settlements with 1 to 5 million inhabitants. Yet the smaller cities are the ones playing a very important role: over 50 percent of the urban population lives in cities with less than a half of a million habitants. Although their overall share is decreasing, they will continue to predominate in the years to come. There are positive and negative aspects associated with this: on the one hand, these cities can take actions in an easier and quicker way, and they are indeed more flexible in relation of territorial expansion, attracting investments and decision making. On the other hand, many problems remain unaddressed, also as a consequence of lacking technical, financial and human resources [UNFPA, 2007: 9; WWI, 2007: 9].

Worldwide there are 22 cities with a population of 5 to 10 million, 370 cities with a population of 1 to 5 million and 433 cities with a population of 0,5 to 1 million [UN-HABITAT, 2002]. In low and middle-income nations, within a generation, more than 200 agglomerations have grown past 1 million inhabitants. From the 23 megacities expected to be existent by 2015, only six will be located in the industrialised countries [UN, 2006: 1; WWI, 2007: 7].

2.1.1 Urbanisation challenges

Regarding to the facts listed above, it becomes clear that the greatest urbanisation problems will be felt in the developing world. Their urban regions will concentrate great parts of the world's population, not only in megacities, but also predominantly in smaller urban areas.

Moreover, it is expected that the total built-up urban area in developing countries will triple, from 200,000 to 600,000 square kilometres, within 30 years (base year 2000). As a matter of fact, this increase of 400,000 square kilometres is equivalent to the total built up urban area of the entire world, as of 2000 [Angel et al., 2005]. These unprecedented paces of population growth and of land take create or aggravate a series of environmental and development challenges.

It is important to highlight that the supply of food, water, and energy depend extensively on the availability of land. As urban areas quickly increase, demand conflicts for different land use might also appear, being necessary to guarantee that land for industry, transport, infrastructure, agriculture and for housing is available. Protection of

ecosystems and the necessity of open and green space in urban areas should also not be neglected [UN-HABITAT, 1996: 45].

As summarised by Keiner [2005], further challenges from urbanisation in developing countries are:

– Poor standards or even progressive decay in basic public infrastructure (energy supply, access to safe water, sewerage, schools, roads, preventive and curative health treatment, etc.);
– Malnutrition, food scarcity, and diseases (HIV/AIDS, malaria, etc.);
– Loss of fertile urban agricultural land for settlement purposes;
– Lack of sanitation, which leads to groundwater pollution by nitrates and bacteria and causes infections from cholera to tuberculosis;
– Poor drainage and poor waste management, entailing the contamination of rivers and streams by sewage outflows and waste disposal, which in turn leads to fresh water scarcity and consequently diseases;
– Deforestation of the city's surroundings because of the need for fuel (of mostly low-income households), leading to an entire depletion of the vegetation and the start of gully erosion;
– Air pollution and increased greenhouse gas emissions because of increasing traffic, industrial activity, and firewood and litter burning mixed with dust;
– Pressure on land use, poor land tenure security, and lack of affordable housing leading to unplanned settlements in the urban periphery and the mushrooming of nearby urban villages;
– Poor urban design, neglected public parks and greenways as well as pressure on urban agriculture;
– Inequality and urban poverty in general, combined with unemployment and low educational levels (listing taken from [Keiner, 2005: 5])

Parallel to the very rapid rates of urbanisation – which are also intrinsically accompanied by an increase in urban poorness and associated environmental degradation – a great burden for developing countries comes from the impossibilities of governments to react to these changes.

Although one could see urbanisation as a sign of progress, since cities can improve social development, drive economic growth, provide employment, offer leisure possibilities, cities also concentrate urban poverty, social disruption and environmental degradation. In the less and least developed regions, 43 to 78 percent of urban inhabitants live in squatter and slums.

The situation of urban poor varies from city to city and within cities, but in general the problems relate to shelter deprivation, non-durable housing, insecure tenure and lack of infrastructure. Moreover, urban inequity brings consequences to nutrition and health, gender equality and education [UN-HABITAT, 2008: 7]. And, even though wealth is associated to more energy/resources consumption and waste generation, the consequences of poverty also damage the environment [UNFPA, 2001: 28].

It is therefore important to have in mind that the pressure of urbanisation goes far beyond cities borders. On the one hand, there is the strong dependence on resources and ecological services from the hinterland. For instance the ecological footprint, as a resource accounting tool, provides figures about the unsustainability of current patterns of development[3]. On the other hand, the security of great part of the rural population further depends on activities within and decisions made by cities [UNFPA, 2007: 37].

A main limitation in developing countries will continue to be a proper improvement of infrastructure provision together with accommodation of the population growth. Local governments struggle to provide adequate housing, energy, transportation, sanitation and water. One constraint being faced by municipalities is also the lack of trained workers, of appropriate budget and tradition of civic governance [WWI, 2007: 7].

In fact, many authors [Keiner, 2005; Satterthwaite, 1996] argue that most of the problems in cities start and get worse because of the lack of good and participative governance. Accordingly, the challenges are not only related to the urban growth and its consequences, but are inherently connected to the difficulties (institutional, financial, technical) faced by local authorities.

Improving the living conditions of the urban poor, by e.g. providing access to infra-structure, taking measures for generating employment and for reducing overall cities' depletion of natural resources are immediate needs being now just partially addressed. But as urbanisation rates increases[4], land transformation accelerates and urban problems become worse, only longer-term visions for governing and administering the ever increasingly complex urban systems can bring the required changes. Decisions made now in preparation for this growth will determine the future of humanity, of the world's economy and of the planet [UNFPA, 2007: 2].

2.2 Climate change

According to the IPCC[5] Fourth Assessment Report, observed changes in climate, their causes and their effects are seen as robust findings and based on great consent within the international community [IPCC, 2007c].

[3] Ecological footprint is the area of productive biosphere required to maintain the material throughput of human economy. It estimates the consumption of energy, food and materials in terms of area of biologically productive land or sea required to provide these resources and to absorb the associated waste. If everybody on earth would have the same life standard than the average of the developed world, at least three earths would be necessary [Wackernagel and Rees, 1996].

[4] Brockerhoff [2000] argues that a better indicator for urban planning guidance is the number of people added to the urban regions than the urban growth rate [Brockerhoff, 2000].

[5] Intergovernmental Panel on Climate Change - a scientific intergovernmental body set up in 1988 by the World Meteorological Organisation (WMO) and United Nations Environment Programme (UNEP), established to provide decision makers and other groups interested in climate change with an objective source of information.

Human activities have changed the composition of the earth's atmosphere. Concentrations of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), the so-called greenhouse gases[6], are now far higher than their natural range over thousands of years before industrialisation. For example, since the industrial revolution, concentration of CO_2 increased from 280 ppm (parts per million) to 379 ppm and methane concentration doubled (from 715 to 1732 ppb – parts per billion) [IPCC, 2007e: 3].

The use of fossil fuel (coal, gas and oil) and in smaller scale the changes in land use patterns (deforestation) are mainly responsible for the increase in greenhouse gas emissions. The overall emissions can be further allocated to different sectors. A total of 66.5 percent of all emissions are energy related, including transportation (14.3 percent), electricity and heat (24.9 percent), industry (14.7 percent), other fuel combustion (8.6 percent) and fugitive emissions (4 percent). Industrial processes are responsible for 4.3 percent of emissions, land use change and agriculture for 12.2 and 13.8 percent respectively, and waste for 3.2 percent [Herzog, 2009].

For a better understanding of the emissions sources, these sectors can be further divided into activities or so-called end use sectors. For instance the emissions related to buildings (residential and commercial) account for the highest portion of the total 44.1 $Gt/CO_2eq.$, with 16.5 percent of total emissions. Road transport and deforestation have shares of 10 percent each, and the chemical, iron/steel and cement industries have together nearly 13 percent. In addition, significant shares of emissions are related to oil/gas extraction, refining and processing, other industries, agriculture soils and livestock/manure [IPCC, 2007e, 2007d].

The main source of carbon dioxide (77 percent of overall emissions) is therefore fossil fuel combustion for energy generation. Methane sources are associated with extraction and transport of fossil fuels, agriculture and waste management (15 percent). The emission of nitrous oxide is mainly related to agriculture and industry (7 percent). The remaining one percent is due to other gases such as CFCs, which have global warming potentials 2 to 5 orders of magnitude higher than that of CO_2, are mainly related to use of refrigerants, aluminium production and industrial processes [Herzog, 2009].

Regarding countries shares, the industrialised nations, representing around 20 percent of the world's population, are responsible for over half of the emissions. Emissions per capita in developing countries are in average over 3 times lower than in the developed countries. [IPCC, 2007d]

[6] The Kyoto Protocol lists 6 gases/group of gases, which should be reduced, the others ones being: sulphur hexafluoride (SF6); hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). A very important factor to be considered ist the different global warming potential, as an expression of the factor by which the gas in question is more (or less) damaging than the same mass of CO_2 over a given period of time.

The average per capita annual emission of non-Annex I[7] countries is 4.2 t CO_2eq, while that of Annex I countries is 16.1 t CO_2eq. Figures for single countries[8] illustrate the differences between developed and developing world. While Australia and Germany have 25.6 and 12.3 t CO_2eq/capita respectively, Brazil has 5.0 and India 1.9 t CO_2eq/capita.[9]

The IPCC report emphasises that human activity since 1750 have strongly influenced the concentration of the greenhouse gases in the atmosphere (in fact, 70 percent of the increase in emissions happened from 1970 to 2004), and therefore, is responsible for the global warming being experienced over the last 50 years[10].

The reported warming trend over the last century reaches 0.74 °C. Higher temperature increases are being felt particularly in the northern hemisphere. Observed effects are for example rising soil temperatures, permafrost area decrease and shorter freezing seasons of river and lake ice. But higher temperatures have also a great influence on many other parameters of the global climate system.

For instance, the sea level rose 17 centimetres in global average during the last hundred years. Ice extent is decreasing rapidly, in the Arctic in average of 2.7 percent each decade. Snow and mountain glaciers are also diminishing. Global and regional rain patterns are changing (dry regions will suffer even more from lack of water), and extreme weather events (heat waves, floods and droughts, heavy precipitation events, hurricanes and other storms) will continue to increase over most areas worldwide [IPCC, 2007e].

[7] Members of the international environmental treaty UNFCCC (United Nations Framework Convention on Climate Change) are divided into 3 groups, Annex I, the industrialised countries (includes economies in transition); Annex II, developed countries which pay for costs of developing countries, and the group of developing countries.

[8] Excluding CO_2 from international bunker fuels and land use change and forestry. Source: World Resource Institute – www.wri.org/

[9] The common unit used in the international community, refered as t CO_2eq is (metric) tonnes of CO_2 equivalent (takes into account each greenhouse gas as equivalent in carbon dioxide, by considering each specific global warming potential).

[10] It is due to the natural greenhouse effect that life is possible on earth. These gases allow the sun's short-wave radiation to enter the atmosphere, but do not allow from the earth reflected long-wave radiation to escape from the atmosphere, so the heat is trapped, and the mean surface temperature is in average 33 K higher that it would be if only the other physical factors were to influence. The higher the concentration of these molecules, the greater the heat amount that cannot escape from the atmosphere, so, the energy balance, which influence the climate system, is disrupted.

Table 2-1. Examples of major projected impacts on selected sectors.
Source: [UNEP, 2009a: 31]

Climate driven phenomena	Agriculture, forestry and ecosystems	Water resources	Human Health	Industry, settlements and society
Temperature change [11]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decresed cold temperature	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow/ice; effect on winter tourism
Heat waves/warm spells [12]	Reduced yields in warmer regions due to heat stress; increase danger of wildfire	Increase water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially of the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, young and poor
Heavy precipitation events [13]	Damage to crops; soil erosion; inability to cultivate land due to water logging of soils	Adverse effects on quality surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transportation and societies due to flooding; pressures on urban and rural infrastructure; loss of property
Droughts [14]	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risks of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry; reduced hydropower generation potentials; potential for population migration

[11] Over most land areas warmer and fewer cold days and nights, warmer and more frequent hot days and night (virually certain).
[12] Frequency increases over most land areas (very likely).
[13] Frequency increase over most land areas (very likely).
[14] Affected area increase (likely).

Climate driven phenomena	Agriculture, forestry and ecosystems	Water resources	Human Health	Industry, settlements and society
Tropical cyclones and storms[15]	Damage to crops; wind throw (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases, post-traumatic stress disorder	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for migrations; loss of property
Sea level rise[16]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased fresh water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of costal protection versus costs of land-use relocation; potential for movements of population and infrastructure; see also above

The consequences for physical and biological systems are already being felt and will become even more drastic in the future; prognoses until 2100 describe an increase in temperature from 1.8 to 4.0°C (in comparison to current levels) and sea level rise of 0.18 to 0.59 metre [IPCC, 2007e]. An increase of 2 °C can affect 1 to 3 billion people, due to for example water-related impacts. Food security, human health, and effects on ecosystems and infrastructure will pose additional pressure to human population. Table 2-1 shows the different kinds of climate driven impacts on selected sectors.

It is necessary to point out that the distribution of temperatures, precipitations and other changes also have a strong regional dependence and more accurate regional models are still being developed. The patterns of change calculated by diverse climate models are based on different scenarios[17], which also take into consideration the possible human behaviours, the resulting emissions and what effects this will have in the climate.

2.2.1 Climate change challenges

The preceding facts bring together, on the one hand, the main causes responsible for climate change, and on the other hand, the expected influences that the increase in atmospheric concentration of greenhouse gases might have.

[15] Frequency increases (likely).
[16] Increase incidence of extreme high see level, excludes tsunamis (likely).
[17] A scenario is a plausible and often simplified description of how the future may develop, based on a coherent set of assumptions: a set of working hypotheses about how society may develop, and what this will mean for the climate. The scenarios are based in two different sets of solutions, first, going into more regional or more global approaches, and, second, being based on more environmentally sound or more marked based development. For more information see [UNEP, 2009a].

Based on this causality, actions to be taken towards tackling climate change are related to reduction of greenhouse gas from the various sources, called mitigation, and to the adaptation to the impacts and vulnerabilities (see interlinkage in Figure 2-1).

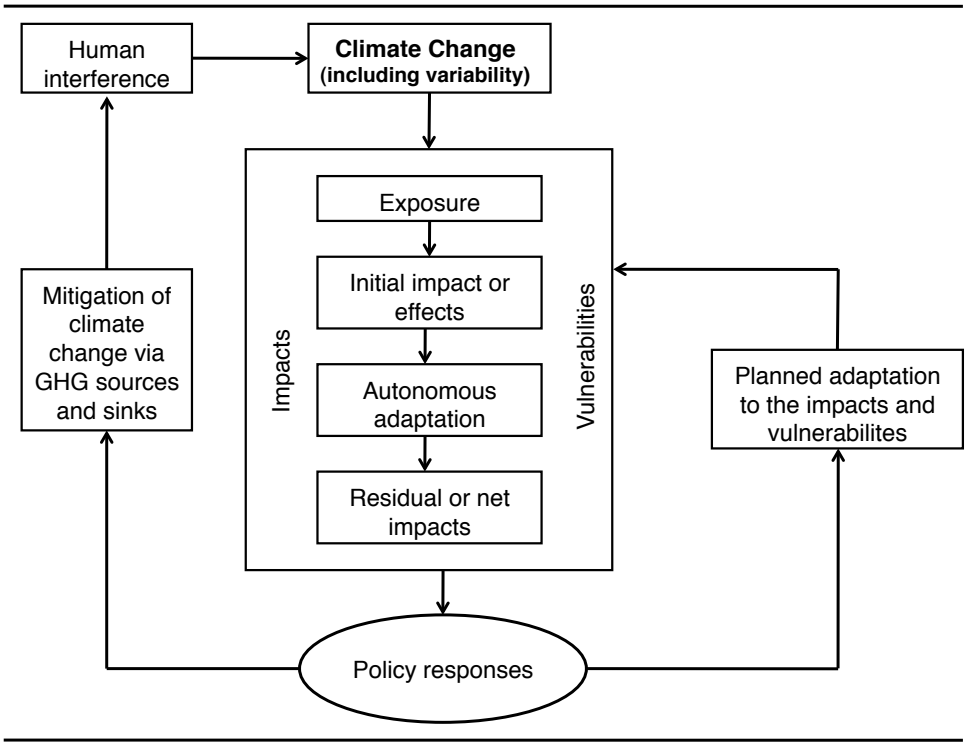

Figure 2-1. Climate change, impact/vulnerability, mitigation and adaptation linkages. Source: [Smit et al., 1999]

The international community agreed, in line with United Nations Framework Convention on Climate Change (UNFCCC), created in 1992, that it is necessary to reach a concentration level of greenhouse gas (GHG) in the atmosphere that does not irreversibly interfere in the overall climate system. The great majority of scientists agree with the fact that if a temperature increase greater than 2 °C occur, the consequences could become uncontrollable.

Thereupon, in 2005, the Kyoto Protocol entered in force, setting mandatory emission reductions. This international agreement did not set any target for developing countries or economies in transition, but it differentiated the commitments according to respective capabilities, economic structure and resource bases [UNFCCC, 2004]. For the period after 2012, a new international agreement still needs to be settled, and it will take place in December 2009 in Copenhagen at the 15th Conference of the Parts (COP).

The topics related to climate change have transcended the scientific and political communities. With the release/publication of the movie "*An inconvenient Truth"* and the so-called Stern Report, both in 2006, not only economists but also the broad public's interests in these issues have increased.

When considering the economic costs of climate protection, reference has to be made to Sir Nicholas Stern. The former chief economist of the World Bank states that the costs of inaction (figures are between 5 and 20 percent loss of the global economy by 2100) are much higher than taking immediate measures to reduce greenhouse gas concentrations, which is estimated to be 0.1 to 2.0 percent of the developed countries gross domestic product [Stern, 2006].

Moreover, as summarised in the McKinsey Report [McKinsey, 2007] there is a great range of measures for greenhouse gas reduction at negative or very low costs (such as building insulation, lighting systems, fuel efficient commercial vehicles). Economic savings directly accompanies these options, and in general, reducing emission is also linked to other co-benefits, such as reducing air pollution and the dependence on fossil fuels. Until now, however, no serious efforts for mitigation have been made, not even these low hanging fruits (negative cost options) have not been fully explored.

In fact, in order to achieve preventive climate protection through mitigation, and to go in conformity with the fact that avoiding is cheaper that adjusting, reduction of emissions would have to be happening at a much faster pace. While the Kyoto Protocol aimed at a reduction of around 5 percent of emissions until 2012 (with 1990 as baseline), the scientific community now say that a 80 percent reduction until 2050, in comparison to 1990 level, is necessary to avoid disastrous effects.

Even though some feedback effects are still not yet understood and/or fully considered in the models, the warming trends and related consequences cannot be stopped. For even if an immediate stabilisation or yet a reduction of GHG emission compared to current levels took place, the inertia of the climate system will further bring an increase in global temperature, with the various mentioned impacts.

Based on that, another concern would be that the expected climate scenarios can indeed become illusory, because the reactions of humanity to the real changes in climate and to the resulting economic consequences are barely indefinite [Graßl, 2008: 293]. It is also not clear how policies that are not related to climate change will affect emissions.

The global socio-economic pathway together with the ability of the international community to achieve emissions reductions is expected to determine the rate of temperature change in the future. Although scientific models analysing the interaction in the climate system become more accurate, the consequences to come remain open, since they depend on the political responses. Regardless the success in achieving emissions reductions, adaptation will be crucial.

Considering the regional distribution of emissions, it is a fact that overall contribution of countries such as China, India, Indonesia, Brazil and South Africa is steadily increasing, although per capita emissions still remain lower than global average. The Asian region concentrates a great part of the world population, and as economic and urban

development is happening at an unprecedented rate, emissions are expected to continue to increase.

In this sense, another challenge emerges. From the historical point of view, Europe, North America, Australia, Japan and others have greater responsibilities in reducing emissions. Not only these countries have been adding greenhouse gases to the atmosphere for a much longer period and their per capita emission is much higher, they indeed also have greater economic power to pay for emission reductions measures.[18]

On the other hand, only based in a consistent mitigation approach in Asia and for other emerging economies, the necessary reduction to tackle climate change can be achieved. Reductions of emissions in low and middle-income countries are certainly most cost/effective than many measures taken in the industrialised nations. About 57 percent of low cost emission reduction potentials are in the developing world [McKinsey, 2007].

The key point remains an equity and ethical question. Developing countries have contributed the least to current state of greenhouse gas concentrations and, according to expected prognoses, these countries will be hit hardest by climate change, while also having lower adaptive capacity due to lack of many resources.

Although there is a great chance for a “green” growth for the developing economies [UNEP, 2009b], the challenge remains to make use of this potential, meaning, to go towards a low carbon economy while developing at the same time. In the climate change discussions, further issues such as financing of mitigation options, financing of adaptation and technology transfer remains to be solved. A strong commitment is critical, not only ambitious emissions reductions targets need to be set and achieved but also a framework for strengthening adaptation has to be developed.

2.3 Summary and recommendations

Urbanisation is one of the most powerful and permanent processes modifying the face of the Earth. In a relatively short period of time, the amount of built-up area, the demand for infrastructure and resources, and the pressures on the environment will drastically increase. This current urban population growth and related consequences, as it has been happening in low and middle-income countries, will probably exacerbate the already delicate environmental, social and economic issues.

Climate change is another great challenge of our time. It is not only about scientific and technical issues; it is mostly a political problem. The main reason can be indeed

[18] Here the second and third principles proposed by the UNFCCC would apply, the polluter pays principle (stating that the polluters should pay for the damage theirs pollution cause) and the equity principle (stating that the rich and privileged should care about the generations to come, especially those in the poor countries who are even now experiencing the consequences of global climate change and brought almost no contribution to the problem) [Wright, 2005].

attributed to a certain paradox. The ones that contributed the least to its causes are the ones to be most affected by it.

At this point, to assure that the equity and the polluter pays principles are put into force has a two-fold meaning. High-income nations should be responsible for substantially increasing the pace and magnitude of emissions reduction. And moreover, they also need to make sufficient resources available for helping the poor countries to cope with the impacts of climate change.

Decisions made now, in order to tackle both challenges are crucial. Therefore long-term visions are needed. Basically two strategies are required. First, it is necessary to find appropriate ways to accommodate the drastic population growth. And parallel to that, to reduce the pressure on the environment and resources (in especial land) while improving the provision of infrastructure and overall quality of life for urban dwellers.

Second, because only a stabilisation of greenhouse gas concentrations in the atmosphere can mitigate the impacts of climate change, increased efforts for emissions reductions are necessary. Nevertheless, for the developing countries, adaptation remains a rather crititical issue. Increased concern and actions in this area are needed, both at national and at international levels.

The next chapter discusses possible ways to address these challenges.

3 Opportunities for change

Development and environmental challenges, as imposed by rapid urbanisation and climate change, can and should be tackled together. The sustainable development framework can set the principles for this path. This chapter first aims at a brief discussion of the vision of a sustainable development in general, and moreover of sustainable urban development.

Furthermore, it brings the topic of spatial development and urban design more in depth, analysing its tasks and different approaches to achieve sustainability. And last but not least, when thinking about the threads related to climate change, it is certain that concrete responses related to mitigation and adaptations are required. Therefore it is also important to review the current available options.

3.1 Sustainable development

There are many descriptions for the term sustainable development, but by far the most cited one is the definition coined by the United Nations World Commission on Environment and Development (known as Brundtland Commission). It states that sustainable development is the "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." [WCED, 1987: 8].

This widely used definition sound at first imprecise and with a focus on future generations. Yet, the further elaboration in the report managed to capture the two essential issues linked to environment and development: "*the environmental degradation that follows economics growth places limit for development (not absolute, but limited by technology and social organisation on environmental resources and the ability of the biosphere to absorb the effects of human activities*" [WCED, 1987: 8]. Yet economic growth (and equity of sharing resources) is needed to provide basic human needs and alleviate poverty [Adams, 2006; Kates et al., 2005].

The three pillars of sustainable development (*aka* triple bottom line) are economic growth, social equity and environmental protection, intrinsically correlated to each other. But it might also be argued that economies and societies do not exist without the environment, therefore being necessary to focus on the sustainability of the environment as a form of achieving social and economic development [Adams, 2006: 4].

In the last two decades, the concept of sustainable development has been contested and further elaborated [Kates et al., 2005]. In fact, the expression sustainable development has been *en vogue*. It has been used with quite great appeal not only in the political, but also in the public and academic scale. But maybe exactly because of this fact, it is also supposable easy to be misused. Furthermore it can be said that everyone can find another definition for the "magic" expression, and at the end, its meaning continue to be unclear. Yet the fully understanding of the concept is lacking and it is only

seen as a rhetorical goal for itself, while the concrete measures for putting it into practice still need to be truly understood and become more wide spread [Adams, 2006: 3ff].

The different frameworks developed rely on defining concrete goals, principles and values, and indicators to give the direction for and to measure development. For example the Commission on Sustainable Development (CSD)[19] defined a set of 58 indicators to help evaluate what is to be sustained (climate, clean air, land productivity, fresh water and biodiversity) and what is to be developed (equity, health, education, housing, security, stabilised population) [Kates et al., 2005; UN, 2007]. Putting the CSD framework into practice, the Agenda 21, as an environmental and development action programme, foresee, in its Chapter 28, the creation of Local Agendas 21. This is one of the approaches the international community has adopted to put sustainability issues into practice at the city level. This and other approaches are concisely discussed in the next section.

3.1.1 Urban sustainable development in the international agenda

Local Agendas 21 are of extreme importance, given that "*(..) many of the problems and solutions have their roots in local activities (..), local authorities construct, operate and maintain economic, social and environmental infrastructure, oversee planning processes, establish local environmental policies and regulations, and assist in implementing national and sub-national environmental policies. As the level of governance closest to the people, they play a vital role in educating, mobilising and responding to the public to promote sustainable development* " [UNCED, 1992: 291].

The Local Agenda 21 is structured in 40 chapters that indicate finality, objective, instruments and actions to be taken. In this sense, local authorities are encouraged to foster the participation of citizens, as well as organisations and the private sector in the decision making processes, through an open dialog that will help them formulate the necessary strategies for development.

In general, the strategy is based on a vision and on the integration of the triple bottom line issues. Moreover, for operationalisation, an action plan is developed, and after implementation of the concrete measures, a set of indicators help the assessment of success and offer the opportunity for review. Different topics can be contextualised, according to the needs and problems of each community, for example at the economic level, efforts to create a vibrant local economy or at the ecological level, actions to minimise the use of resources and the generation of waste. At the social level, action to provide access to basic needs or to strengthen local communities are also included. In reality, developed cities put a greater focus on issues related to resource consumption,

[19] The Commission is responsible for reviewing progress in the implementation of Agenda 21 and the Rio Declaration on Environment and Development. The Agenda 21 is an environmental and development action program that serves as a guidance document for local, national and global change in direction of sustainable development. For more information: www.un.org

whereas developing cities stresses poverty, education and health and general infra-structure provision (water provision, sanitation/waste water, waste management, transport) issues.

In addition, local authorities should use the following guiding principles: to use a 'bottom-up' approach involving local communities and NGOs in the policy process; to promote open governance and access to information; to recognise the need for 'cross-cutting' institutions that can act across all areas of policy; to implement complementarily between regulatory approaches and market mechanisms for addressing development and environmental needs [Grubb et al., 1993].

Although the amount of local governments that have adopted a Local Agenda 21 have dramatically increased worldwide, yet one of the critics often mentioned is that actions remain mostly untaken after the strategy is developed. The difficulties faced by the concept in general are serious, and also responsible for making it so questionable. There are first institutional/structural problems. To achieve change is difficult, as it probably requires challenging powerful interests and in general, political short term approaches rules over long-term solutions. Also economic/financial constraints exist. Inadequate government funding for long term change, the unwillingness to fix higher taxes and no financial incentives for "green" behaviour can be mentioned. Perceptual/ behavioural factors complete the list. Knowledge does not automatically translate into action, consumption is oft entrenched in cultural values and lifestyle aspirations are strongly in conflict with less use of resources, while there also exist an alienation from the decision-making processes [Moore, 1997: 16].

The Local Agenda 21, as a participatory, multi-stakeholder planning process, should help to achieve an integrated management at the urban level that offers opportunity to address environmental, social and economical issues together in order to create sustainable cities. Nevertheless, after over 15 years experience with this concept, many factors still remain to be improved: better engagement of participatory community planning, increased capacity development especially at community-based organisations, institutional and governance changes in order to make possible to implement changes. Moreover, it has also been pointed out that stronger national policy, especially in middle and lower income countries, for strengthening abilities of local governments are still lacking, and that a major issue remains the financial resources for taking actions. And finally, an effective and consistent monitoring mechanism is much needed for assessing progress/impacts and encouraging a focus on action and results [UNDESA/ICLEI, 2002: 3, 27].

The United Nations Conference on Human Settlements in 1996 in Istanbul (Habitat II) set the Habitat Agenda, also with a focus of encouraging interested parties at local level to formulate agreements and initiate local measures programmes. The Habitat Agenda similarly brings objectives, principles and set of recommendations and concrete actions. It offers a positive vision of sustainable human settlements - where all have adequate

shelter, a healthy and safe environment, basic services, and productive and freely chosen employment [UN-HABITAT, 1996: 5]. The Agenda has been adopted by 171 countries. It formulates concrete commitment in the areas of adequate shelter, sustainable human settlements, enablement and participation, gender equality, financing shelter and human settlements, international cooperation and on assessing progress. These strategies and approaches are formulated as a Global Plan of Action, including for instance a chapter on sustainable land use.[20] UN-Habitat has also carried out an ambitious monitoring method for the Agenda through the Global Urban Observatory, focusing on assessing conditions and trends of settlements, but yet a necessary improvement is to break down the monitoring in order to better address the local relevance of issues [UN-HABITAT, 2004].

As a global technical cooperation programme in the field of urban environmental planning and management (by UN-HABITAT and UNEP), the Sustainable City Programme (SCP) brings together approaches for operationalisation of sustainable urban development and therefore for the implementation of both Habitat Agenda and Agenda 21. It is a process-oriented framework, which permits the different stakeholders to negotiate strategies and seek solutions collectively. The systematic implementation of a set of activities and combination into existing institutions can bring profound changes in the ways development issues are perceived and addressed. It starts by involving key stakeholders in the preparation of the Environmental Profile, which will identify priorities areas. A City Consultation is then followed, where stakeholders (national government, local authorities, NGOs, CBOs, private sector, academics and scientists, other) come together to deliberate and agree on the priority environmental issues confronting their city. Further steps are: Establishing and Operationalising Working Groups; Negotiating (Formulating) Strategies and Action-Plans; as cross cutting and to be initiated parallel to the previous activities, there is the institutionalisation (political and administrative arrangements) of the Environmental Planning and Management (EPM) process. The Sustainable City Programme worked on two phases from 2000 to 2007 with 29 active partner cities plus replication in more 25 cities and 9 programmes at the national level. Another programme by UN-HABITAT, Localising Agenda 21 targeted on secondary cities, that often lacks expertise to tackle environmental problems. Activities consisted of preparing strategic action plans and implementing demonstration projects as well as building local capacity and fostering city-to-city cooperation initiatives.[21]

[20] For more information: http://ww2.unhabitat.org/declarations/habitat_agenda.asp
[21] For more information: http://www.unhabitat.org/

As a methodology developed by the Cities Alliance[22], the Cities Development Strategy (CDS), is both a process and a product that identifies ways of creating better conditions for urban sustainability along the dimensions of livelihood (creation of jobs, business development, sources of household incomes), environmental sustainability and energy efficiency of the city and the quality of its service delivery, spatial form and its infrastructure and financial resources and governance. It also builds on experience with participatory strategies in the context of Local Agenda 21 activities or by the Sustainable City Programme. Process methodology is based on various building blocks, from establishing the initial parameters, making initial assessment and setting a vision to identify strengths-weakness-opportunities-threats, to build awareness and start implementation [CitiesAlliance, 2006]. Even with CDS being disapproved and criticised because of inadequate knowledge and the failure in monitoring progress, two positive aspects can be emphasised: it has achieved a simplification of priorities for action and investment, and has managed to support valuable participation of local groups [DAEI, 2007: 36].

The Cities as Sustainable Ecosystems (CASE) is another approach created in order to help cities achieving sustainability. It is based on an ecosystem view, where humans are part of a social-ecological structure (local ecosystems through bioregions to the biosphere). The Melbourne Principles[23] aims at providing a strategic and integrated framework for action, by allowing cities to develop sustainable solutions that are relevant within their particular circumstances. These principles are listed as follow [Newman and Jennings, 2008: 4]:

(1) Vision: To provide a long-term vision for cities based on sustainability, intergenerational, social, economic and political equity and their individuality;
(2) Economy and Society: To achieve long-term economic and social security;
(3) Biodiversity: To recognise the intrinsic value of biodiversity and natural ecosystems, and protect and restore them;
(4) Ecological Footprints: To enable communities to minimise their ecological footprints;
(5) Model Cities on Ecosystems: To build on the characteristics of ecosystems in the development and nurturing of healthy and sustainable cities;
(6) Sense of Place: To recognise and build on the distinctive characteristics of cities, including their human and cultural values, history and natural systems;
(7) Empowerment: To empower people and foster participation;
(8) Partnerships: To expand and enable cooperative network to work towards a common, sustainable future:

[22] A multidonor (EU, ADB, World Bank, UNEP, UN-HABITAT), local authorities and national governments coaliton with overall objective of achieving urban poverty reduction. For more information: http://www.citiesalliance.org/
[23] They were developed at an International Workshop held in Melbourne in 2002, and for that the name Melbourne Principles.

(9) Sustainable Production and Consumption: To promote sustainable production and consumption, through appropriate use of environmentally sound technologies and effective demands management;
(10) Governance and Hope: To enable continual improvement, based on the accountability, transparency and good governance;

The CASE initiative, as developed by the UNEP Division of Technology, Industry and Economics, International Environmental Technology Centre, aimed at providing tools for analysing and comprehending the interactions of the environment and the urban activities (urban and economic system and their connections with natural systems). In addition, it also suggests ways of how to adapt the relationships to more sustainable ones. Despite the fact the programme has been put aside, the CASE ideas are available as one set of instruments that local governments can make use of, as the book by Newman and Jennings [2008] brings different motivating best practice.

This international agenda has been determinant in translating sustainability issues to the urban context. As discussed for the Local Agenda 21 process, some critical points can also be drawn for any other initiative.

In general, within the context of developing countries, the impacts achieved through these different pragmatical programmes and approaches remain in fact restricted to several successful cases. The scale at which changes are accomplished has not yet reached the desired levels.

An example of this moderate level of change can also be reflected in the achievements of the Millennium Development Goals[24] (MDG). Much more efforts are required to achieve for instance the goals for eradicating poverty (which is increasingly urban) and achieving environmental sustainability. One criticism is that not enough help from developed countries is made available for improving the development and environmental conditions of the low and middle-income countries.

Moreover, there are also many intrinsic problems that hinder the structural changes essential also to achieve urban sustainability. Lack of good governance and proper institutions as well as overall capacities are the main ones.

In the face of the expected urbanisation problems, there is thefore a strong requirement to further strength the extent of influence of the approaches provided by the international agenda. Some progress has been achieved, but yet a further massive scale-up is key. This task is surely not trivial, but at least different suitable tools and strategies are readily available.

[24] Internationally established goals, in 2001, to be achieved by 2015. The main objective is to encourage a development that brings social, ecological and economical improvements especial for the less and least developed countries. For more information: http://www.un.org/millenniumgoals/

3.1.2 Theoretical models for urban sustainable development

For more analytical purposes, also different models for achieving urban sustainable development exist, and will be discussed in this section. To start the analysis at a more theoretical level, a summary of the existing differences assigned to sustainable and conventional development strategies (at the urban, energy, environmental and technology level) are given in Table 3-1.

Table 3-1. Conventional and sustainable urban development models.
Source: [Byrne et al., 1994: 176]

	Conventional Model	Sustainable Model
Urban System	Urban concentrated industrial complexes	Regionally dispersed industry complexes
	Manufacturing oriented	Community oriented
	Short term economic growth emphasised	Long term development emphasised
	Commodity oriented	Conservation oriented
	Consumption driven	Balance sought between consumption and conservation
	Resource seen as inputs to production system	Resource seen as limited, vulnerable requiring stewardship
	Resource-intensive, governed by economic priorities	Resource conserving, governed by multiple priorities
	Economics costs are primary	Economic costs balanced by social/environmental costs
Energy System	Fossil fuel based	Alternative energy based
	Energy abundance and cheap supplies emphasised	Conservation and renewability emphasised
	Diversify source of supply	Reduce energy intensity
	Market based prices not reflecting social/environmental costs	Social/environmental costs based prices
	Technology focused	Conservation focused
	Efficiency in economic production emphasised	Efficiency in end-uses emphasised
	Scale economies and technological centralisation emphasised	Modularity and technological decentralisation sought
Environment System	Human dominate the environment	Humans and environment are seen as mutually dependent
	Environment as an abundant source of commodities	Exhaustibility of resources recognised
	Environmental impacts external to economic choices	Environmental impacts internal to economic choices
	Rehabilitation oriented	Prevention oriented
Technology System	Large scale economies sought	Moderate scales economies preferred
	Centralised systems emphasised	Decentralised systems emphasised
	Infrastructure driven technology choices	User-driven technology choices
	Technical decision governed by economic costs	Technical decisions governed by social/economic costs
	Environmental impacts ignored	Environment sensitive design promoted

Different options listed for the conventional model do not have to be automatically unsustainable. For instance, to diversify sources of energy supply or to seek for technological large scale economies can at times be beneficial. The main attention and positive aspects, nevertheless, are in regard to the recognition of the need for increasing environmental protection and resource conservation within the mentioned systems.

It becomes clear that at the long-term, not only environmental but also social development must be integrated into a new framework. Spatially, a model supposed to achieve sustainable development bases on well designed and dispersed industrial complexes, that also focus on reducing urban energy demand and environmental pollution.

Decentralisation of manufacturing together with strengthening community needs and promotion of urban centres that contributes to linking urban development to social goals and values are important options. Urban transport systems based on mass transportation and measures in the residential, commercial and industrial sectors are key elements. Energy efficiency, resource conservation and environmental protection are to be achieved by appropriate design in urban land use, landscape architecture and building construction. [Byrne et al., 1994: 178].

Moreover, further features of sustainable and unsustainable communities can be summarised according to different criteria (see Table 3-2). These are economic growth, citizenship, governance, community characteristics, urban design, environmental dimensions, quality of life and identity/belonging/safety.

It is important to discuss these views of sustainable and unsustainable communities. Regarding to the urban design and environment, urban sprawl, uniformed and zoned development, together with expansion into greenfields sites should be criticised as being unsustainable practices.

However, responses also go beyond a diversification of the architecture, increased urban densities, or reuse of brownfield sites and minimisation of transport. In reality, there are other factors that also contribute or are the base for urban sustainability; a suitable energy supply and overall resource efficient community for instance have not been mentioned.

Also governance and citizenship need to play a key role as elements contributing to sustainability of urban areas. While the focus yet has been on how a sustainable community looks like, starting points for implementation are critical as well.

In the previous description, for instance, social considerations have not been addressed. According to Racco [2006], important features of a sustainable community are related to the low level of crime and anti-social behaviour, as well as to the strong sense of community.

Table 3-2. Main features of unsustainable and sustainable communities.

Source: [Raco, 2007: 307]

Criteria	Unsustainable Community	Sustainable Community
Economic growth	Domination by dependent forms of development; lack of employment opportunities; vulnerable; insecure, short-term; and divisive	Flourishing economic base; built on long-term commitments; stable; and inclusive of broad range of workers
Citizenship	Passive and dependent citizens and communities; lack of community engagement or ownership, low levels of voluntary activity and/or social capital	Active citizens and communities, long-term community stewardship; effective political engagement; healthy voluntary sector and strong social capital
Governance	Closed, uncountable systems of governance, over-reliance on passive, representative forms of democracy, lack of visionary politics, parochialism	Representative, accountable governance systems; balance of strategic top-down visionary politics and bottom-up emphasis on inclusion
Community characteristics	Absence of skills within workforce; ill-balanced communities of place; high level of (physical) separation between groups; lack of diversity; formal and informal segregation of population	Broad range of skills within workforce; ethnically and socially diverse; mixture of socio-economic types of inhabitants; balanced community; well populated neighbourhoods
Urban design	Uniform, zoned, architecture; closed, gated and inaccessible public spaces, absence of communities facilities; urban sprawl; placeless suburban development	Diverse architecture; accessible public spaces; higher urban densities; provision of broad range of amenities; building which cater for a range of need; “self-contained” communities; creation of “place”
Environmt. Dimensions	Expansion into greenfields sites; maximisation of transport journeys; car dependence and the absence of public transport	Re-use of brownfield sites; minimisation of transport journeys, good-quality of public transport
Quality of life	Low quality of life, strong push for a range of social groups	Attractive environments; high quality of life, strong pull for a range of social groups
Identity, belonging and safety	Lack of local associational culture and ownership of public space; intolerant and divided local politics; high levels of crime, disorder and fear	Sense of community identity and belonging; tolerance, respect and engagement between people of diverse backgrounds; low levels of crime and anti-social behaviours

If one continues to search for sustainable urban development models, Haughton’s theory cannot be missed [Haughton, 1997, 1999a, 1999b]. In this case, the suggested models put emphasis on intra- and interregional balance, and, how the economic, social and ecological costs of resource management can be distributed within and between sub-areas, while the focus is also the relationship between the city and its hinterland.

Moreover, the theory is about how is it possible to adapt urban functions in order to better control ecological, as well as economical and social impacts. The models propose more concrete recommendations for action within the topics of economic growth,

regulation, externality costs, values systems, engagement, technology and nature. The features of Haughton's model are summarised in Table 3-3.

Table 3-3. Main feature of the four models of sustainable urban development.

Source: [Haughton, 1997]

	Externally dependent cities	**Redesigning cities**	**Self-reliant cities**	**Fair shares cities**
Main trade orientation	Global, market-driven; unrestricted hinterland	Market-led economic development; implicit to reduce negative external impacts	Bioregion; local capacity-driven; restricted hinterland ecological footprint	Global-local; restricted by carrying capacity and guided by equity concerns; attempts to manage hinterland trading
Economic growth	Go for it	Accommodate it	Selective growth, based on environmental desirability	Guide it
Regulation	Market regulation; create markets; deregulate; reduce inappropriate subsidies	State-regulation; land-use planning and design control; reduce inappropriate subsides	Self-regulation; alternative markets (e.g. LETS); decentralised control	Major market regulation for trade plus concern to establish and respect regional carrying capacities
Externality costs	Consumer/producer pays; no directed redistribution	Consumer/producer pays; infrastructure subsides removed	Alter production and consumer systems to internalise costs within bioregion	Consumer and producer pay or state redistribute; targeted redistribution to where costs borne
Value system	Market supremacy; neoliberalism; vary light green; price signals	Anthropocentric, light green, modify human behaviour by planning	Ecocentric; deep green; moral sanction	Nature.sensitive; market modification, "deep" green
Engage-ment	Information and individual choice; consumer sovereignty	Consultation, linked to democratic mandate of local, regional, national state	Participation; collective decision making	Mixture of roles; strong state role in redistributive policies
Tech-nology	Smart/high-technology	Environmental efficient technologies	Low/appropriate technology	Mixture of technologies
Nature	"Conquer" or price nature	Control, measure and manage nature	Work with/integrate nature	Attention to environmental tolerances and use of precautionary principle

For instance, the model of Redesigning Cities and their regions is based on the objective of "planning for compact and energy efficient regions". It is suggested to redesign urban form and structure (more compact cities, higher residential densities and more intensive mixed land use) and by that to reduce the total resource flow and generation of waste.

Redesign is also about improving building designs (use of recycle materials, better insulation, solar energy use, etc.)

A further model, Externally dependent city, is based on the “excessive externalisation of environmental costs, open systems, linear metabolism, and buying of additional “carrying capacity”. This model focus on the fact that by changing market mechanisms it should also be possible to achieve environmental goals. It is not about trying to reduce cities impact on their hinterland by having a more efficient resource and waste flow, but by using specific price mechanisms (for example gasoline tax) in order to be possible to manage the damage that economic activities caused to the environment.

The self-reliant cities model bears on “intensive internationalisation of economic and environmental activities, circular metabolism, bio-regionalism and urban autarky”. The objective here is first the reduction of external dependence by building strong local businesses. In the urban metabolism, therefore, the inputs and outputs (resources and waste) are in a circular flow. The approach is also based on the fact that it is easier to achieve such a metabolism by having less centralised and more community based regions.

As mentioned by Guy and Marvin [2000] it is difficult to create a scale to evaluate each of these models and it is not possible to say that one is more sustainable than another.

There are, therefore, depending on the model, different social, technological and economic contexts determining for example the land use, buildings planning and management in cities. Each model can point in the direction of improved policies for the sustainable city, but in fact no one can provide all the answers [Guy and Marvin, 2000; Haughton, 1997]. The fourth model, fair shares city, basically tries to combine and integrate the most interesting and beneficial aspects of the previous models, with an special feature thereby being the greater attention given to social justice and equity concerns.

Further theoretical/analytical approaches on sustainable urban models can be found in the literature, and this review exclusively intended to show where the main attention is given. While some models concentrate on energy, environmental and technological spheres of urban sustainability, others include issues such as economic growth, engagement and citizenship, regulation and governance.

None of them can be taken as fully applicable or valid in all cases, but they rather give an orientation of how sustainable communities would look like. The frameworks of how to achieve the goals also depend on various specific conditions within each community. In reality, there exist no fit-all receipts, but the basic principles that should be followed are linked to resources and environmental protection, to integrative social considerations, to stable and selective economic growth and to adequate regulations and governance, as well as enhanced participation.

It remains to point out that besides environmental justice, social equity and economic development, dimensions such as land use and urban design, transportation, energy and material use, green architecture and building, and urban ecology and restoration can offer more pragmatically views and concrete fields of activities for operationalisation of urban sustainability principles. The implementation of actions should then take place not only at the building and site and at the neighbourhood and district scale, but also at the city and regional scale. [Wheeler and Beatley, 2004]. In the next section the inter-related topics of land use, urban design and spatial planning are further explored.

3.2 Spatial planning, land use and urban form

Although the first cities originated thousands of years ago, the urban planning practices as known nowadays have a relatively recent history. These practices and processes have also constantly changed in the last century, resulting in a worldwide great variety of urban form, structure and designs. In many countries, urban development planning is done at the local scale, yet higher levels of government establish and can influence the planning framework, also providing incentives, mandates and funding [Wheeler, 2004: 152].

A recent study discussed about six typologies of planning. Some features of each one are listed as follow [Walters, 2007: 31ff]:

(1) Traditional or comprehensive planning: focused on producing clear statements about the form and content of new development.
(2) Systems planning: promoted a more scientific and analytical view of the city as a set of complex processes, not considering any form of final, physical plan.
(3) Democratic planning: included a participative approach giving people the opportunity of influencing decisions.
(4) Advocacy and equity planning: focused on addressing social inequalities and injustice on American and British cities and was a more activist form of democratic planning.
(5) Strategic and incremental planning: concentrated on small-scale objectives and considered pragmatic real-world constraints.
(6) Environmental planning: at last, emerged from the understanding of ecological and social implications of global development.

In the environmental planning approach, most practised nowadays, planners are encouraged to go back to an integrated thinking, analysing the types of growth and development's impacts on the natural environment in a regional context. In this sense, environmental planning is able to shape the community or region by taking measures to safeguard nature. In the United States of America this kind of regional planning is subjected to struggle since there is a fragmentation and competitiveness of local governments that makes it hard to find consensus on decisions that have regional impact [Walters, 2007: 31ff].

Moreover, Brugmann [2009] stresses that understanding how cities growth is crucial in order to take measures on shaping this development. He describes 4 different city-

building approaches: ad hoc city building, city system, city models and master-planed city.

Ad hoc city building involves additional development designed for the purpose of individuals only, not concerned with the relationship to other buildings, with mainly no share of interest or common understanding. This type of development occurs in many places, both within and without planning guidelines. City systems urbanism focus on an integration of interests from residents, community leaders, developers, and investors, which leads to common sense of place and enhances the city's efficiency and value, usually growing in an organic way, instead of based on technocratic planning and business investment. Both approaches have the similarity of being planned and designed by the users, yet nowadays different methods are used to form the urban landscape.

City models for example combine a city plan for the spatial arrangement of a large group of buildings and a business model for its delivery, trying to serve builders who request to make a predictable profit from their construction and the seek for rapid, regulated growth followed by government agencies. City models are built for future tenants and users and not with them. And the master plan city (prominent example is Brasilia), with detailed spatial organisation of activities, can comprise ad hoc and city model construction, and can create a development at large-scale that take better consideration to local needs and strategies when compared to city model development [Brugmann, 2009: 103ff].

Spatial planning, as applied by the public sector, has the power to control the allocation of activities in space. As a response to market forces, it can accomplish a more regular distribution of economic development, as it regulates the alteration of land. Its overall objective is a rational territorial organisation of land uses, with attention given to environmental protection and economic and social development (European Commission, cited in [UNECE, 2008: 1]).

Practices of planning differ among countries, but in general similarities exist and some common principles can be followed[25]. It can be said that spatial planning deals with land-use planning and also with policies that have an effect on function and nature of places. It has the ability, therefore, to indicate the conditions and locations of certain development, and guarantee that measures for enhancement of existing physical structures are taken. Spatial planning also influences the conditions for location and execution of further planned physical structures (controlling physical development brings the interface to determining urban form/morphology). Conclusively, it has an important responsibility also in relation to other sectoral policies, as these can be integrated in a long-term framework [UNECE, 2008]. Figure 3-1 shows the main activities and objectives of spatial planning, as well the components influenced by it.

[25] These are cited as the democratic principle, the subsidiarity principle, the participation principle, the integration principle, the proportionality principle and the precautionary principle – for more detailed information see [UNECE, 2008].

Urban planning, besides being a technical issue is also very political as well. Not only it is essential to understand how to construct a city, but also to consider who is responsible for doing that, and for what purposes and whose interests play a key role in the processes. Therefore urban planning must be supported by political processes that are embedded in a national framework context [UN-HABITAT, 2008: 185ff].

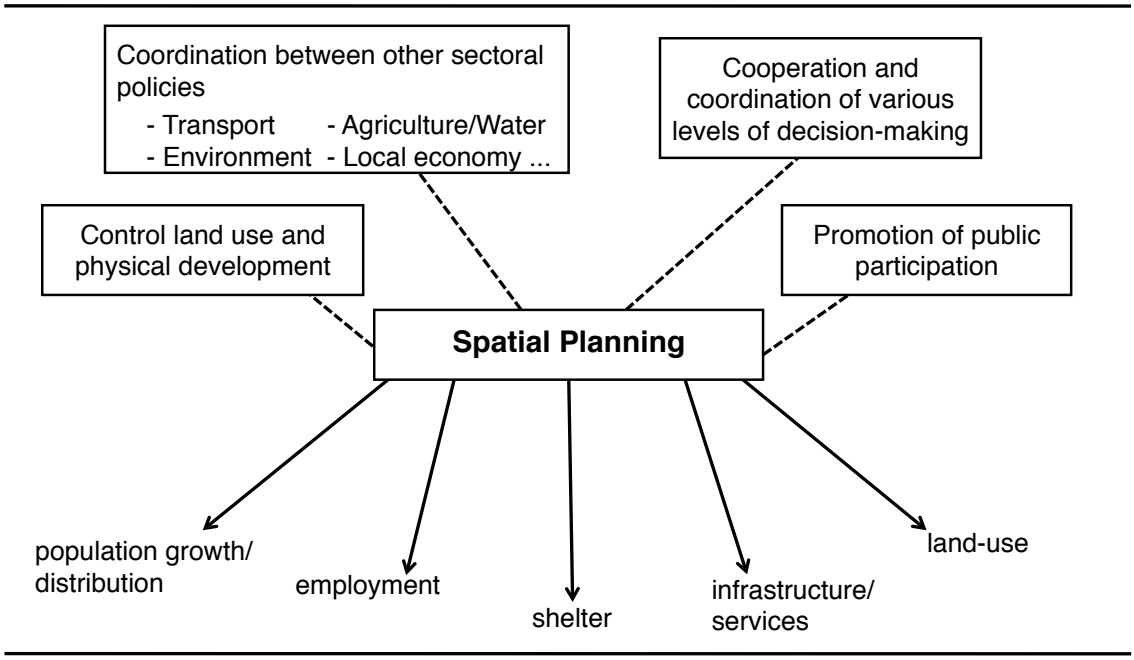

Figure 3-1. Simplified illustration of spatial planning activities and components. Source: Based on [UNECE, 2008]

Urban planning policies must use spatial planning in order to promote integration and control of land use, infrastructure and service, shelter, and overall population growth and employment. The national or regional frameworks need to offer the appropriate institutions and instruments for such policies to be put into action. (Habitat Agenda I cited in [UNECE, 2008: 4]).

Key activities comprise the integration of land use and physical planning (for an efficient and effective use of land and natural resources), together with the coordination of other sectoral policies, but also bringing together the different levels of decision making, and the encouragement of public participation [UNECE, 2008].

It is important to highlight that spatial planning is one of the most important policy options to be applied in face of the challenges of urbanisation. The unprecedented growth of urban areas associated with the need for population allocation/distribution, for employment generation, further demand for land and infrastructure are all issues that need to be embedded in a long-term vision. Spatial planning is the key in coordination and integration of these issues. It is not expected that it can solve all problems, but it gives the basis for start moving into the right direction.

In reality, the link between sustainable development and spatial planning can be reinforced, if planning takes into account practice such as suitable building technologies and ecologically sound designs, with ecological principles guiding land use and development, low energy consumption, promotion of renewable energy, efficient use of resources. And indispensable is also public participation in the decision-making process [UNECE, 2008].

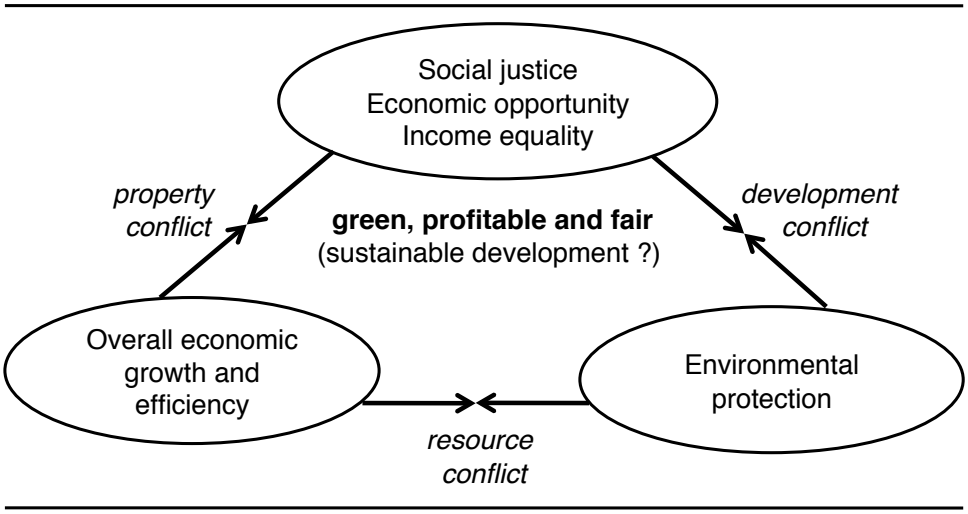

Figure 3-2. Campbell planner's triangle.
Source: [Campbell, 2003]

However, the contextualisation of the more general planning goals in the light of sustainable development is far more complex. According to Campbell's [2003], the three summarised objectives of planning (social justice/economic opportunity/income equality, overall economic growth and efficiency, and environmental protection) are constantly in conflict with each other, as it can be seen in Figure 3-2.

Given the property (economic vs. social), the development (social vs. environmental) and the resource (environmental vs. economic) conflicts, the task of achieving sustainable urban development is not an easy one. Nevertheless, it is still necessary to strive for it. In that sense, next section shows that most goals and functions assigned to spatial planned are related to the triple bottom line of sustainability.

3.2.1 Spatial planning objectives/functions and tools/instruments

A possible definition of spatial planning objectives is given as following [RTPI, 2008: 5]:
- Enable a vision for future regions and places that is based on evidence, local distinctiveness and community-derived objectives;
- Translate the vision into a set of policies, priorities, programmes and land allocations together with the public resources to deliver them;
- Create a framework for private investment and regeneration that promotes economic, environmental and social well being for the area; and

- Coordinate and deliver the public sector components of the vision with other agencies and processes.

Furthermore, other reaching goals of spatial planning, also in line with the support for sustainable quality of life in settlements can be mentioned. First, it should encourage democratic governance that reacts to the local communities requirements. It also has the responsibility for enhancing the urban environmental performance, to facilitating social cohesion and security. To promote market reform in the housing and urban sector and to improve land and real estate markets and securing private rights in land are also main tasks [UNECE, 2008: 9].

In relation to further specific functions and expected outcomes that are driven by spatial planning, a good outline is given in Table 3-4.

Table 3-4. Outcomes and functions of spatial planning.
Source: [RTPI, 2008]

<table>
<tr><td colspan="2">(1) making suitable land available and its efficient use for development in line with economic, social and environmental objectives to improve people's quality of life:
• ensuring the appropriate location of development
• encouraging an appropriate mix of development
• ensuring appropriate land supply and availability for various uses and activities
• increasing the supply of housing
• steering development towards brownfield land</td></tr>
<tr><td>(2) contributing to sustainable economic development:
• encouraging economic growth
• increasing competition, consumer choice and competitiveness
• contributing to urban renewal
• contributing to a rural renaissance
• reducing the need to travel
• improving our local and national infrastructure</td><td>(3) protecting and enhancing the natural and historic environment, the quality and character of the countryside, and existing communities:
• protecting greenfield land from unnecessary development
• preventing urban sprawl
• environmental protection (natural and built/historic)
• enhancing biodiversity
• improving landscape and environmental quality
• responding to climate change</td></tr>
<tr><td>(4) ensuring high quality development through good and inclusive design, and the efficient use of resources:
• enhancing the quality of places
• high quality design
• energy reduction
• promoting sustainable modes of travel
• contributing to other national strategies (e.g. waste, renewable energy)</td><td>(5) ensuring that development supports existing communities and contributes to the creation of safe, sustainable, liveable and mixed communities with good access to jobs and key services for all members of the community
• creation of sustainable communities
• enhancing the quality of life
• meeting the needs of the community
• provision of local services
• social inclusion
• accessibility</td></tr>
</table>

In order to achieve these goals and fulfil its function, spatial planning relies on different formal and informal tools/instruments. They are different from country to country, and need to be guided by and rooted in national, regional and local levels. Many important

determinations can and should be made at the local level, surely taking into consideration policies from the higher levels.

Formal instruments have a legal character and are also integrated in a strategic comprehensive planning. Preparatory land use plan, local development plan (or also zoning or master plans), redevelopment plan and building codes can be mentioned. More recently, planning tools also comprise Environmental Impact Assessment, as a formal tool to evaluate impacts on the environment.

In Germany, for instance, the legal basis for urban land-use planning is the Federal Building Code. Municipalities plan the development of their territories by performing the task of urban land-use planning, which takes place in two stages. First a single preparatory land-use plan is drawn up for the entire municipality. It gives a general outline of the types of land use prevailing or foreseen for the municipality (representation of land-use types). Additionally, a local development plan (legally binding) concentrate on a specific section of the municipal territory (designation of urban development).

The preparatory land use plan or zoning plans are in most case drawn up at a 1:10,000 scale and identify development zones and built-use zones, spaces for mitigation measures (assigned to those areas in which intrusion harmful to nature and to the landscape is anticipated), public amenities, green spaces, agricultural and woodland areas. Local development plans (scale 1:500 or 1:1,000) can contain designations of types and densities of built use, built surface areas and local thoroughfares/public highways, and must be in harmony with the aims of comprehensive spatial planning at federal and regional level [Turowski, 2002: 24].

Zoning is one of the main local planning tools in many countries. In each parcel's zoning, a set of approved uses that are allowed to operate legally is listed. These are published in governments ordinances or zoning regulations. This practice has fairly contributed to a suburban development, by, at times, favouring the separation of functions and allowing a decrease in densities, and thus encouraging the use of cars. It has also been responsible for raising housing costs and keeping "underprivileged" people out of certain prosperous areas (exclusionary zoning requires large lots and setbacks that guarantee that only exclusive housing is constructed). Initial forms of zoning laws, more than a century ago, simply divided cities into a few basic categories of permitted land use. Later, further prerequisites were introduced in relation to lot coverage ratios, parking requirement, dwelling units and allowable densities, floor area ration and various other aspects of site and building design. Zoning tools are criticised in the United States for not supporting a proactive planning such as the one that happened in Europe, where the public sector has been positively more involved in the whole process [Wheeler, 2004: 155].

As cities, especially in the developing world, faces difficulties in steering their development through financial and regulatory practices, tools to reserve land or to enforce the use assigned to a specific area are necessary. Similar to development plans, master plans and sector maps, which only work within a proper administrative and regulatory

framework, would set reference for public and private investment. Furthermore, as an essential tool for larger cities, the plan defines the location for key infrastructure and the main structure of the public domain network, together with preferred uses for urban spaces. It can also set planning regulations at district level, emergency actions (e.g. flood), preservation of large land areas and creation of a housing bank [DAEI, 2007: 35f].

In small and medium cities (up to two to three hundred thousand inhabitants), other tools to simplify management of spatial planning exist, for example urban reference maps. A medium-term planning structural document with no real zoning indicates the layout of principal roads and city services, jointly with expansion district areas and reserves for amenities for the next 5 to 10 years. It can also set limits for areas vacant for construction and suggest a particular kind of land use (industry, low cost housing, services, etc.) [DAEI, 2007: 35f].

A separate instrument for coordination of renewal and recovery of specific areas is redevelopment. Improvements are implemented in the area by a redevelopment agency mandated by the city government. These mechanisms can be mostly useful to coordinate transit-oriented development along new rail lines/roads, also in cleaning up and rebuilding older industrial or brownfield sites and in promoting investment in unfilled downtown districts. Additional measures to be integrated relate to provision of sufficient affordable housing, new urban parks and restoration sites [Wheeler, 2004: 160].

Moreover, at the development or redevelopment level, in order to regulate certain design elements, the building materials used, and the construction method, building codes are required. Building design regulations can also be partially addressed at the zoning level, but in general, specific building codes are responsible for guaranteeing that builders/developers integrate concrete measures promoting resource efficiency in the design and construction of buildings [Wheeler, 2004: 217].

To determine how and where development occurs, in other words, the subdivision of land and construction of buildings, are extremely important decisions, since it will settle for the future the form and qualities of a specific area. It will determine how communities are integrated to the environment, how resources and energy are used, and how distinct groups of people are distributed [Wheeler, 2004: 155].

More recently, within this approval process, environmental reviews started playing an increasing role. Environmental Impact Assessment (EIA) is required to decide whether a new planned development project is to be allowed or not. In summary, EIA can predict, depict and evaluate the environmental effect of development on human beings, soil water and air, fauna and flora, climate and landscape, including interaction among these and on cultural and any other material assets. It therefore helps to prevent, reduce or mitigate the unfavourable environmental effects related to a development project. It involves public participation cooperation between developers and public authorities [Turowski, 2002: 90; Wheeler, 2004: 157].

Informal instruments are linked to advising and making information available for decision-making and participative planning. It also involves the development and evaluation of scenarios and preparation of concepts and plans, for example, for energy, transport, risk management, among others.

Informal tools depend strongly on information-based systems such as Geographical Information System[26] (GIS) or Decision Support System (DSS) and Planning Support System (PSS). Support systems go beyond only storing information that has a spatial relevance; it contains models and indicators for the development of different scenarios and further support of decision-making and planning processes.[27]

Scenario modelling can decisively help to compare spatial outcomes of different possible development paths (certain land use and densities, specific spatial concentration of employment, different demand and provision of transport/infrastructure, to name a few) and thus to implement a planning that is based on appropriate information appraisal.

3.2.2 New urbanism, smart growth, compact city, eco-city

Urbanisation in the last decades, especially in North America and Australia, has followed patterns of low densification (urban sprawl) meaning a greater demand for land and corresponding infrastructure. Great part of the responsibility for this can be assigned to local planners.

A variety of interests from landowners, developers and business also have been influencing decision on how to allocate land. A close link to the widespread of automobiles also exists, and as cause and consequence of suburbanisation, an ever-growing problem is the strong dependence on individual transport. And as housing prices in the suburbs increase, segregation of poor communities also emerges as a social problem.

On the other hand, in developing countries, the urbanisation and suburbanisation processes are far more complex, also due to lack of planning. Although, as for example in Latin America, the cities grew upwards, the space intensity of growth in middle and low-income countries is also increasing (for instance recall the figure of urban built up area triplicating in 30 years [Angel et al., 2005]).

As this growth takes place in non-adjacent transitional zones (between city and countryside), it is also called peri-urbanisation [UNFPA, 2007: 48ff]. These areas have often no clear administrative rights (lower capacity of governments to regulate them), suffering from typical problems such as environmental pollution and poverty. The difference from suburbs is yet the variety of economic activities taking place in these areas.

[26] A system that captures, stores, analyses, manages, and presents data/information that has a spatial relevance and is linked to a certain location.
[27] This work will not, for time constraint reasons, go in further detail about these systems.

As mentioned before, the form, structure and functions of a city determine the demand for infrastructure, influencing how people and goods move, the overall use of energy, the impacts posed on the environment and also the social arrangements.

Focusing on proper land use and urban design is therefore crucial to tackle harms arising from urbanisation. Although there are many differences between urbanisation in developed and in developing countries, the current alternatives on planning stresses, the needs for suitable urban density and mixed land use. The theories of new urbanism, smart growth, compact city and eco-city deal with these issues and are reviewed in this section.

New Urbanism[28], a movement originated almost 20 years ago in the USA, surged as an opposition to urban sprawl, criticising the incurring high levels of individual traffic (and associated high resource consumption), the high costs for large-scale infrastructure, and the fact that the neighbourhoods have become anonymous. More than changing form or design, the idea of new urbanism is also creating a community spirit. Principles of new urbanism are following: walkability, connectivity, mixed use and diversity, mixed housing, quality architecture and design, traditional neighbourhood structure, increased density, green transportation, sustainability and quality of life.

Function separation (work, housing, leisure, etc.) dominated for long time the planning patterns. Different environmental and social problems are directly or indirectly linked to this zoning culture. To reverse this situation requires changes in the roots of many planning models.

As summarised in Table 3-5, the new urbanism approach on land use zoning favours proximity of home to work and services by mixed-use zoning. With regard to the sub-divisions, it prefers clustering design with commons rather than subdividing entire parcels into individual lots and also advocates for diversity of housing types.

In principle, these changes, not only at subdivision and housing types levels, but also especially in relation to land use zoning are worth to be implemented. Although created to tackle urban sprawl, a problem rather typical from developed countries such as United States and Australia, it can also serve as foundation for guiding growth in developing countries. Still, recommendation cannot be generalised and applied for all situations, as it is not always possible to execute them, at times because of physical/spatial or institutional restrains.

[28] For more information: http://www.newurbanism.org/

Table 3-5. Reasons against current approach and how to foster new urbanism.
Source: [Roseland and Connelly, 2005: 139ff]

	Current approach I Why not?	**New Urbanism** I How to?
Land use zoning	Isolation of home from work and services by exclusive zoning	Proximity of home to work and services by mixed-use zoning
	- Excessive commuting required, increases automobile dependency - Empty residential areas in daytime and commercial areas at night; encourage crime - Decreases contact among people, does not build community or support services - High commuting costs and traffic congestions	- Design neighbourhood centres within walking distance - Flexible, mixed use zoning encourages participation in the community - Increased hours of occupancy support local services - Design for local and in-home employment
Subdivision	Subdivision of entire parcels into individual lots	Cluster design with commons
	- Lack of common space impairs community self-image - Residents isolated behind fences and in automobiles do not meet or watch out for their neighbours - Heavy emphasis on the private domain does not encourage participation - Utilities are widely extended and services dispersed	- Thoughtful public and semi-public space integrated with private lots - Design for meeting places and good visual supervision - Provide small neighbourhood parks, community gardens and playgrounds - Cluster design allow compact utility networks and concentrate services
Housing types	Limited housing types: single family detached	Many housing types
	- Poor range of affordability - Leads to limited social and economic mix among residents; ghettoisation - Inappropriate to aging residents and community-minded people - Has highest individual land requirements - Financially unstable due to dependence on only one market sector	- Provide apartments and townhouses as a more affordable option - Design mixed single-family and multi-family neighbourhoods for diversity and social enrichment; healthier communities - Provide support senior housing, co-housing and other options - Design for mini-lots and strata lots to conserve common land - Better financial stability by serving several market sectors

In fact, it can be said that another well-known theory, that of Smart Growth, and the new urbanism approach have many attributes in common. Both going against urban sprawl, smart growth addresses the need of giving attention to a stronger inner city development, with compact building design, and transit-oriented and walkable land use.[29] Specific guidelines for Smart Growth are:

[29] For more information: http://smartgrowthplanning.org/

(1) Mix land uses;
(2) Take advantage of compact building design;
(3) Create housing opportunities and choices for a range of household types, family size and incomes;
(4) Create walkable neighbourhoods;
(5) Foster distinctive, attractive communities with a strong sense of place;
(6) Preserve open space, farmland, natural beauty, and critical environmental areas;
(7) Reinvest in and strengthen existing communities & achieve more balanced regional development;
(8) Provide a variety of transportation choices;
(9) Make development decisions predictable, fair and cost-effective;
(10) Encourage citizen and stakeholder participation in development decisions.[30]

Wheeler [2004] reviewed, as for the current practice in North America, the aspects related to land use and urban design such as lot size, unit per lot and allowable densities, mixture of land use, amount others, as shortly depicted in Table 3-6.

Table 3-6. Current versus smart growth practices.
Source: [Wheeler, 2004: 158f]

	Typical current practice	**Smart growth alternative**
Dwelling units allowed per lot	Most urban land zoned for single family detached housing	Allow second units on existing lots; allow multiple units on vacant lots in single family districts if buildings design conforms to neighbourhood context
Allowable densities, downtown areas	Many suburban cities specify maximum residential densities of 20-40 dwellings units per acre even in high density zoning districts	Eliminate maximum densities; rely on height, bulk, and/or design restrictions instead. Institute minimum densities of 20-30 dwellings units/acre
Allowable densities, residential areas	Many suburban cities have maximum residential densities as little as 1-4 units per acre in low-density zoning districts	Establish minimum residential densities of 8-10 units per acre for a new family development and 20 units/acre for a multifamily development; allow residential infill at this level
Mixture of land uses	Only homes, stores, or workplaces allowed across large areas of cities	Allow a finer mix of land uses to reduce driving and enhance community vitality; allow housing and shops added to office parks, office and shops to housing districts
Mixed-use buildings	Not permitted in most places	Allow mixed-use of buildings within neighbourhood centres and along arterial strips; provide incentives for these

Moreover, the smart growth principle, in line with the new urbanism theory, strengthens the need for a greater mix of land uses, for increasing residential densities and housing

[30] For more information: US EPA website on smart growth: http://www.epa.gov/dced/index.htm

types diversity and establishing minimum density and building heights particularly in downtown and infill sites.

This theory also has a strong focus and is based on the suburban growth and planning as it occurs in the developed world. But again here, the practices do have partial significance in relation to planning in the developing countries. For instance mixture of land use and mixed-use buildings can bring economical, social and environmental benefits.

A particular variation in relation to New Urbanism is found on the proposed allowable densities, for inner city and residential areas. Smart Growth indeed recommends making use of compact building design, establishing minimum densities and encouraging higher densities by introducing design restrictions. Great part of these suggestions is also valuable for a better control and more sustainable growth of urban areas in many developing cities.

Finally, another famous model proposed for connecting urban form to sustainable planning is the well-known and discussed Compact City model [Jenks et al., 2000]. It also highlights the high densities, mixture of land use and high degree of connectivity and accessibility. As a result, compact cities will lead to shorter and less commuting, also encouraging economically viable public transport, all in one reducing energy consumption and associated pollution [Oberoi, 2004].

Table 3-7. Compact city and urban sprawl characteristics.
Source: [Neuman, 2005: 14f]

Urban Sprawl characteristics	Compact City characteristics
- Low residential density - Unlimited outward extension of new development - Spatial segregation of different types of land uses through zoning - Leapfrog development - No centralised ownership of land or planning of land development - All transportation dominated by privately owned motor vehicles - Fragmentation of governance authority of land uses among many local governments - Great variances in the fiscal capacity of local governments - Widespread commercial trip development along major roadways - Major reliance on a filtering process to provide housing for low-income households	- High residential and employment densities - Mixture of land uses - Fine grain of land uses (proximity of varied uses and small relative size of land parcels) - Increased social and economic interactions - Contiguous development (some parcels or structures may be vacant or abandoned or surface parking) - Contained urban development, demarcated by legible limits - Urban infrastructure, especially sewerage and water - Multimodal transportation - High degrees of accessibility: local/regional - High degrees of street connectivity (internal/external), including sidewalks and bicycle lanes - High degree of impervious surface coverage - Low open-space ratio - Unitary control of planning of land development, or closely coordinated control - Sufficient government fiscal capacity to finance urban facilities and infrastructure

In outline, Williams [2007] makes the case for the compact city model. First of all, high population density and proper public transport increases efficiency and feasible operation of cities. Mixed use and high density also result in less demand for travel since people can live near work places and leisure facilities. In addition, land use is used sustainably; land in the countryside can be preserved with the reduction of sprawl and the recycling in towns. An equitable accessibility, diversity, social cohesion and cultural development can also originate from compactness and mixed uses. And finally, a series of economically benefits results from cost-effective provision of infrastructure and supporting of local services and businesses [Williams, 2004: 1].

Having that in mind, Table 3-7 summarises the main compact cities characteristics. Once more, higher densities and mixed land uses are emphasised as main solutions. But compact city development also relies on centralised ownership of land or land development planning and an adequate fiscal capacity of local governments to provide infrastructure. These characteristics are in general not found in cities in developing countries.

Compact city development cannot offer all answers for an appropriate urban development because, regarding urban form, further alternative scenarios have been proposed. In the edge city model, increased population, housing densities and employment is placed at selected nodes within the city, and increased investment in orbital freeways is made to connect the edge cities. The corridor city focus on the growth along linear corridors emanating from the central business district (CBD) and supported by upgraded public transport infrastructure. The fringe city would focus on additional growth concentrated predominantly on the outskirts of the city and ultra city locates additional growth predominantly in provincial cities within 100 kilometres of a capital city and promote the link by high rail transport [Newton, 2000: 46].

Although an efficient and compact use of land is accompanied with an efficient provision of infrastructure and lower levels of energy consumption (compact is indeed more sustainable than sprawl), some criticism still can be underlined. The model does not take into consideration the negative effects of a high degree of impervious surface coverage and a small open space provision, nor is it based on any subjective evaluation of how much space is necessary to offer quality of life. In most urban centres and especially in squatter settlements in developing countries, the relatively high densities and in one way or another compact form does not necessarily mean a sustainable or equitable use of land.

As a last simple conceptual model linking responses on transport and urban form Kenworthy's [2006] Eco-City model can be referred. Also taking reference from the highly auto-dependent and resource consuming cities in Australia and USA, ten dimensions (that do not deal with poverty/inequalities or cover politics/urban decision-making processes) are proposed and discussed. These dimensions can be visualised in Figure 3-3.

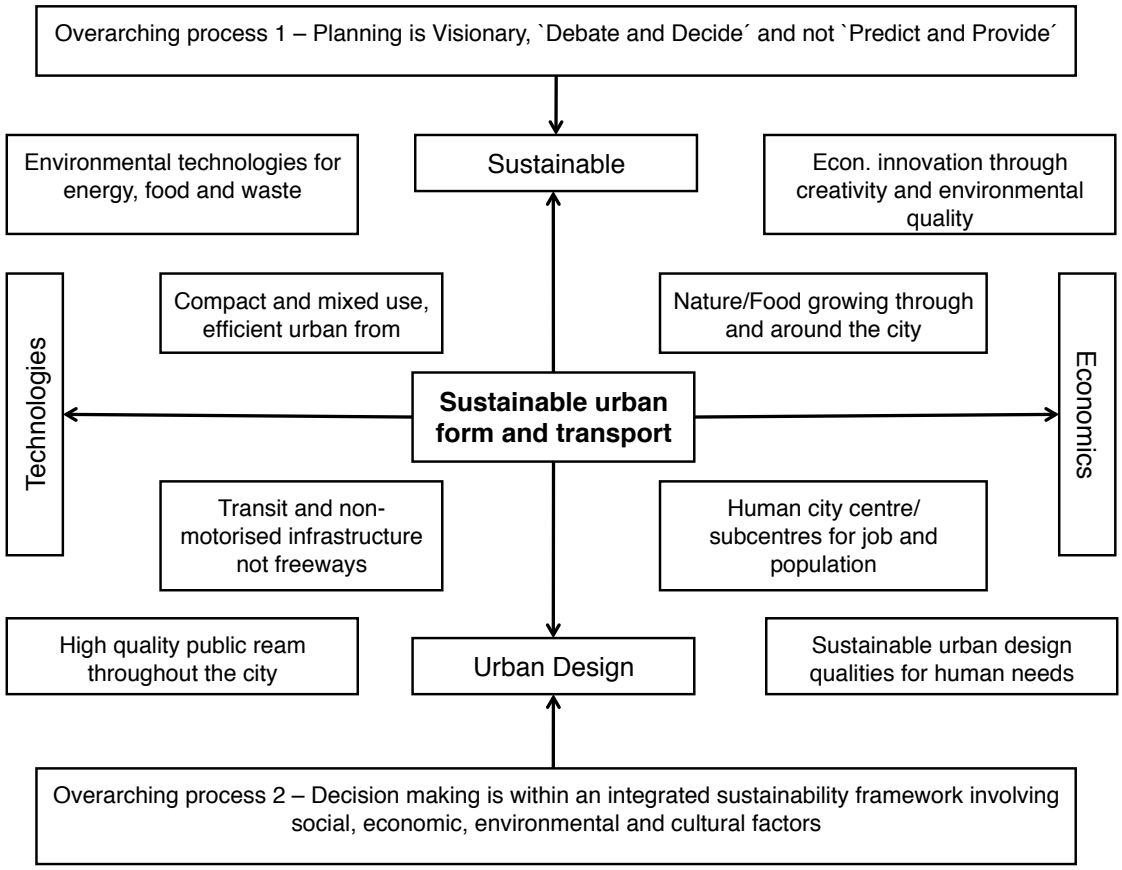

Figure 3-3. Ten transport and planning dimensions for sustainable city development. Source: [Kenworthy, 2006: 68]

Kenworthy [2008] eco-city planning framework aims at achieving a compact, mixed-use development and human-oriented city centres and subcentres with critical density levels. It also stresses the priority should be given to the provision of high quality public transport and non-motorised facilities, rather than more large roads, and also to increase the protection of natural areas and food production potential in cities.

For that, it is indispensable to create a vision-oriented and transformation principle, as it is also important to support the formation of strong democratic decision-making, that takes into consideration community needs. In the model, compact and mixed land uses are only the first of many entry points. Within the proposed dimensions, environmental technologies, economic performance and public realm also play an important role in achieving an eco-city.

In summary, it can be said that all these theories and models have tried to link transport planning to land use and urban planning, not only giving preference to higher density and mixed use, but also stressing the need for high quality transit systems [Newman and Kenworthy, 1996].

Density does not solve problems alone, if development is not integrated in a correct framework, even compact urban forms can disturb social and ecological systems [Song et al., 2005: 262]. Therefore an optimal city size does not exist, but rather an efficient size, dependent on the functional characteristics of the city and on the spatial organisation within the urban system [Capello and Camagni, 2000]. It is also necessary to give more emphasises to flow and process inside the city, and not only to its form.

As cities in low and middle-income countries also tend to adopt a suburban/periurban development, it becomes clear that models to contain sprawl such as those described previously could in principle be applied to these communities. But none of the models can offer all solutions, as many of them have also been developed in the light of the conditions in high-income cities.

Looking into social equity, improved public transport for instance might reduces social segregation and gives better access to facilities. Yet a point of critique to the models is related to reduced living space in poor settlements and a lack of affordable housing. These dimensions need to be further considered in order to achieve urban conditions that are socially sustainable [Burton, 2000].

The situation is at times more serious in developing cities, growth happens generally in rather unregulated way, with no administrative control from the government part and there is a great lack of understanding of how the urban areas are developing. Furthermore, another problem parallel to size and spatial organisation, continue to be not only the lack of adequate housing but also the low quality of public services and infrastructure [Lupala, 2002; UNFPA, 2007].

3.3 Tackling climate change

As mentioned previously, there are two main policy responses associated with climate change. First, in order to reduce the human interference affecting the climate, it is necessary to reduce the emissions of greenhouse gases at the source, or also to increase the sinks or avoid sink destruction (mitigation).

Second, adaptation has no direct influence on climate change; it responds to expected effects, aiming at minimising impacts and reducing risks and vulnerabilities to people, assets and ecosystems.

The next sections draw together the technologies, measures and policies related to mitigation, as well as available adaptation strategies and the necessary framework for applying these strategies.

3.3.1 Mitigation

Mitigation of greenhouse gas emissions has a strong relation to reduction of fossil fuel energy consumption. This section aims at summarising the key technologies and practices in each sector, as well as selected policies, measures and instruments that have shown to be environmentally effective at least in a number of national cases

(public research and development investment in low emission technologies have been proven to be effective in all sectors). Other measures such as behaviour change are not considered.

Table 3-8. Technologies, policies, opportunities and constraints for mitigation in the energy sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Energy	• Improved supply and distribution efficiency; • Fuel switching from coal to gas; • Renewable heat and power (hydropower, solar, wind, geothermal and bio energy); • Combined heat and power; • Nuclear power; • Early applications of Carbon Capture and Storage (CCS, e.g. storage of removed CO_2 from natural gas).	Reduction of fossil fuel subsidies; Taxes or carbon charges on fossil fuels	(-) Resistance by vested interests may make them difficult to implement
		Feed-in tariffs for renewable energy technologies; Renewable energy obligations; Producer subsidies	(+) May be appropriate to create markets for low emissions technologies
	Key technologies and practices projected to be commercialised before 2030		
	• CCS for gas, biomass and coal-fired electricity generating facilities; • advanced nuclear power; • advanced renewable energy, including tidal and waves energy, concentrating solar and solar PV (photovoltaic)		

Table 3-9. Technologies, policies, opportunities and constraints for mitigation in the transport sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Transport	• More fuel efficient vehicles; • Hybrid vehicles; • Cleaner diesel vehicles; • Biofuels; • Modal shifts from road transport to rail and public transport systems; • Non-motorised transport (cycling, walking); • Land-use and transport planning.	Mandatory fuel economy, bio fuel blending and CO_2 standards for road transport	(-) Partial coverage of vehicle fleet may limit effectiveness
		Taxes on vehicle purchase, registration, use and motor fuels, road and parking pricing	(-) Effectiveness may drop with higher incomes
		Influence mobility needs through land use regulations, and infrastructure planning; Investment in attractive public transport facilities and non- motorised forms of transport	(+) Particularly appropriate for countries that are building up their transportation systems
	Key technologies and practices projected to be commercialised before 2030		
	• Second-generation bio fuels; • Higher efficiency aircraft; • Advanced electric and hybrid vehicles with more powerful and reliable batteries		

Concentrating on the supply side, measures related to the energy sector are mainly fuel switching from coal to gas and use of renewable heat and power as well as energy efficiency. Some of the proposed mitigation options, such as for nuclear power, or carbon capture and storage, are options rather recommendable for industrialised countries. Also some of the transportation sector mentioned technologies (more fuel-efficient vehicles and modal shift from road to public and rail transport) are more suitable and able to be applied in higher income nations (Table 3-8 and Table 3-9).

Table 3-10. Technologies, policies, opportunities and constraints for mitigation in the building sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	**Policies, measures and instruments shown to be environmentally effective**	**Key constraints or opportunities**
Building	• 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, recovery and recycle of fluorinated gases.	Appliance standards and labelling	(+) Periodic revision of standards needed
		Building codes and certification	(-) Attractive for new buildings (-) Enforcement can be difficult
		Demand-side management programmes	(+) Need for regulations so that utilities may profit
		Public sector leadership programmes, including procurement	(+) Government purchasing can expand demand for energy- efficient products
		Incentives for energy service companies	(+) Success factor: Access to third party financing
	Key technologies and practices projected to be commercialised before 2030		
	• Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control; • Photovoltaic integrated in buildings.		

The building sector recommends a great variety of practices/technologies (Table 3-10) for example efficient lighting and electrical appliances, improved insulation and recycle of fluorinated gases (generally from air-conditioners). The sector is known for offering the greatest share of “low hanging fruits”, being possible to achieve emissions reduction at very low or even negative costs. One of the main associated difficulties in taking measures is the fragmentation of technologies and actors in this sector.

Also considering the end use of energy, the industry sector enforces the need for more energy efficiency of equipments, for heat and power recovery and for material recycling and substitution (Table 3-11). Especially the energy intensive sectors such as steel/iron, aluminium and cement production offer great leverage points for reducing emissions. The sector also offers a series of technology specific measures to reduce the so-called process emissions.

Table 3-11. Technologies, policies, opportunities and constraints for mitigation in the industry sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Industry	• More efficient end-use electrical equipment; • Heat and power recovery; • Material recycling and substitution; • Control of non-CO_2 gas emissions; • Wide array of process-specific technologies.	Provision of benchmark information; Performance standards; Subsidies, tax credits	(+) May be appropriate to stimulate technology uptake. (+) Stability of national policy important in view of international competitiveness
		Tradable permits	(-) Predictable allocation mechanisms and stable price signals important for investments
		Voluntary agreements	(+) Success factors include: clear targets, a baseline scenario, third party involvement in design and review and formal provisions of monitoring, (+) Close cooperation between government and industry
	Key technologies and practices projected to be commercialised before 2030		
	• Advanced energy efficiency; • CCS for cement, ammonia, and iron manufacture; • Inert electrodes for aluminium manufacture.		

Although the waste sector is responsible for a comparatively small share of emissions, it offers a great set of recognised technologies that can be applied in general at larger scales and at reasonable costs (compare Table 3-12).

Table 3-12. Technologies, policies, opportunities and constraints for mitigation in the waste sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Waste	• Landfill methane recovery; • Waste incineration with energy recovery; • Composting of organic waste; • Controlled waste water treatment; • Recycling and waste minimisation	Financial incentives for improved waste and wastewater management	(+) May stimulate technology diffusion
		Renewable energy incentives or obligations	(+) Local availability of low-cost fuel
		Waste management regulations	(+) Cost effectively applied at national level with enforcement strategies
	Key technologies and practices projected to be commercialised before 2030		
	• Bio covers and bio filters to optimise CH_4 oxidation.		

Table 3-13. Technologies, policies, opportunities and constraints for mitigation in the agriculture sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Agriculture	• Improved crop and grazing land management to increase soil carbon storage; • Restoration of cultivated peaty soils and degraded lands; • Improved rice cultivation techniques and livestock and manure management to reduce CH_4 emissions; • Improved nitrogen fertiliser application techniques to reduce N_2O emissions; • Dedicated energy crops to replace fossil fuel use; • Improved energy efficiency.	Financial incentives and regulations for improved land management, maintaining soil carbon content, efficient use of fertilisers and irrigation	(+) May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation
	Key technologies and practices projected to be commercialised before 2030		
	• Improvements of crops yields.		

As in the waste sector, emission reductions in the agriculture and forestry sectors are only partially related to reducing fossil fuel energy. In the agriculture sector, key mitigation options are connected to soil management and improved cultivation techniques as well as efficient use of fertilizers and irrigation (Table 3-13). The forestry sector focuses on practices of afforestation, reforestation and reducing deforestation but also on forest and wood product management options (Table 3-14).

Table 3-14. Technologies, policies, opportunities and constraints for mitigation in the forestry sector.

Source: [IPCC, 2007a: 10, 20]

	Key mitigation technologies and practices currently commercially available	Policies, measures and instruments shown to be environmentally effective	Key constraints or opportunities
Forestry/Forest	• Afforestation; • Reforestation; • Forest management; • Reduced deforestation; • Harvested wood product management; • Use of forestry products for bioenergy to replace fossil fuel use.	Financial incentives (national and international) to increase forest area, to reduce deforestation, and to maintain and manage forests Land use regulation and enforcement	(-) Constraints include lack of investment capital and land tenure issues. (+) Can help poverty alleviation
	Key technologies and practices projected to be commercialised before 2030		
	• Tree species improvement to increase biomass productivity and carbon sequestration; • Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential and mapping land use change.		

As seen by this sampling list for each IPCC sector, a great variety of key mitigation technologies are available. Policies, measures and instruments to achieve them vary from regulatory mechanisms, financial incentives (or reduction of those), voluntary agreements and taxation/pricing measures. Yet technologies can be seen as only part of the solution, it is also necessary to increase for instance awareness and achieve behaviour change.

Always important to mention in relation to action towards greenhouse gas mitigation are the resulting co-benefits. As for developing countries, economic and social development have higher priorities of action, co-benefits are a way of integrating efforts for addressing climate change issues [Metz and Kok, 2008].

In fact, one should take into account what are the development needs and goals governing action and explore the greenhouse gas emissions reductions potentials benefits that occur. As assumed by the OECC (Overseas Environmental Cooperation Centre of Japan), the following potential areas of action, development need-oriented efforts exist (examples, non extensive): energy demand, economic infrastructure, advanced industrial production, agriculture and rural development, poverty eradication. To each of these areas, examples of projects and the associated development benefits are listed in Table 3-15.

Table 3-15. Co-benefits based on selected development objectives.
Source: [OECC, 2007b]

Development objectives/ needs	Example of project	Concrete developm. benefits	Key action in achieving co-benefit	Climate-change related benefit: GHG emission reduction
Energy Demand	Construction of power plants	Increased energy supply	Energy efficiency, renewable energy	
Economic Infrastructure	Mass transit development	Increased mobility of passenger and products; economic competitiveness	Modal shift (transport mode change)	
Environmental Protection	Upgrading waste and production facilities	Increased waste processing capacity; reduction of air and water pollution	Avoiding landfill gas, cleaner production	
Advanced Industrial Production	Upgrading production facilities	Higher productivity and economic competitiveness	Demanded side energy efficiency	
Agriculture and Rural Development	Introducing farm machinery	Higher production capacity and income	Utilisation of biomass residue	
Poverty Eradication	Rural electrification	Higher living standards, enhanced economic activities	Renewable energy, fuel switch from non-renewable biomass	

Air quality management is one of the principal areas offering possibilities to attain co-benefit. Actions in the sectors energy supply (e.g. improvement of combustion efficiency), waste (waste recovery with heat/electricity use), transport (fuel switching) will lead to a reduction of air pollutants such as SO_x, NO_x and dust [OECC, 2007a, 2007b].

These reductions in air pollution further result in health and ecological improvements. In fact, the IPCC also state that the integration of air pollution abatement and climate change mitigation policies offers possibly large cost reductions, as if considering both policies in isolation.

Other perceived co-benefits, for instance, can be listed: reductions of traffic that save peoples time on congested roadways and reduce accidents related injuries; reduction in on-going maintenance and future operation costs derived from the use of energy efficient technologies; creation of new market opportunities and improvement of local economy [Kousky and Schneider, 2003]. Increased energy security, health improvements, reduced pressure on natural ecosystems, increased agricultural production are further co-benefits that would further also bring cost savings.

As one of the tools to achieve mitigation of emissions, the Clean Development Mechanism (CDM)[31] allows developed countries to invest in clean projects, that will lead to lower emissions (compared to a baseline business as usual scenario), in order to get Certified Emissions Reductions (CER) to help them to comply (in a cheaper way) to the national commitments [UNFCCC, 2004].

In principle, the design of the mechanism is integrated in a sustainable development strategy, where not only environmental but also economical and social benefits for host countries are aimed.

Total potential of the carbon market remained yet rather uncaptured and some critical arguments have been made about the inability of CDM to promote sustainable development, as the mechanism mainly focus on supplying cheap emissions credits to the industrialised countries [Michaelowa and Michaelowa, 2007].

Moreover, if comparing the sectors where CDM projects concentrate, it is visible that the transport and the building sector, which offer great potential for emission reduction, have not been explored. That is mainly due to the fragmentation and the difficult coordination of the various stakeholders involved in these sectors. Sectoral and programmatic approaches should help to improve the carbon market, although stronger and more integrated financing mechanisms are necessary to achieve the desired scaling-up of emissions reductions.

[31] One of the marked mechanisms created within the Kyoto Protocol. The Protocol was signed in 1997 and entered in force in 2005, and, along with the Marrakech Accords, requires industrialised nations to achieve specific emission reduction targets. Other flexible mechanisms are Joint Implementation and Emission Trading.

3.3.2 Adaptation

Adaptation measures have a much more heterogeneous sectoral effect, with great pressures being made especially in the water and agricultural sector. The following tables summarise selected examples of adaptation measures, also for the infrastructure/settlement, transport, energy, health and tourism sectors.

Table 3-16. Adaptation options/strategy, policy framework and opportunities/constraints in the water sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Water	• Expanded rainwater harvesting; • Water storage and conservation techniques; • Water re-use; • Desalination; • Water-use and irrigation efficiency	National water policies and integrated water resources management; Water-related hazards management	(-) Financial, human resources and physical barriers; (+) Integrated water resources management; synergies with other sectors

The water sector, already suffering from serious stress factors in many regions, will become even more vulnerable with the many water-related events linked to climate change. Adaptation efforts should therefore give strong attention to fighting scarcity, by reducing the amount and reusing water, but also investing in desalination and rainwater harvesting (Table 3-16). In relation to the infrastructure and settlement sector (including costal zones), one of the strategies will inevitable be the relocation of population. Yet a general integration of climate change issues into design, land use policies and building codes are also extremely necessary. For that, suitable standards and regulations are required, as well as land use and building codes designations (Table 3-17).

Table 3-17. Adaptation options/strategy, policy framework and opportunities/constraints in the infrastructure/settlement sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Infrastructure/settlement	• Relocation; • Seawalls and storm surge barriers; • Dune reinforcement; • Land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; • Protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; Land-use policies; Building codes; Insurance	(-) Financial and technological barriers; availability of relocation space; integrated policies and management; (+) Synergies with sustainable development goals

Similar to the infrastructure issues, option in the transport sector will also need stronger design standards and planning of roads and other infrastructure. Strategies for adaptation in the energy sector are in certain harmony with mitigation options, since it

also strengths the need for renewables and energy efficiency and achievement of energy security (see Table 3-18 and Table 3-19).

Table 3-18. Adaptation options/strategy, policy framework and opportunities/constraints in the transport sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Transport	• Realignment/relocation; • Design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; Investment in R&D for special situations, e.g. permafrost areas	(-) Financial and technological barriers; availability of less vulnerable routes; (+) Improved technologies and integration with key sectors (e.g. energy)

Table 3-19. Adaptation options/strategy, policy framework and opportunities/constraints in the energy sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Energy	• Strengthening of overhead transmission and distribution infrastructure; • Underground cabling for utilities; • Energy efficiency; • Use of renewable sources; • Reduced dependence on single sources of energy	National energy policies, regulations, and fiscal and financial incentives to encourage use of alternative sources; incorporating climate change in design standards	(-) Access to viable alternatives; financial and technological barriers; acceptance of new technologies; (+) Stimulation of new technologies; use of local resources

Also expected to be strongly affected by the impacts of climate change, the agricultural sector strategies are associated with an improved land and soil management, parallel to option related to crop relocation and variety adjustment (Table 3-20).

Table 3-20. Adaptation options/strategy, policy framework and opportunities/constraints in the agriculture sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Agriculture	• Adjustment of planting dates and crop variety; • Crop relocation; • Improved land management, e.g. erosion control and soil protection through tree planting	R&D policies; Institutional reform; Land tenure and land reform; Training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits	(-) Technological and financial constraints; access to new varieties; markets; (+) Longer growing season in higher latitudes; revenues from 'new' products

Finally, approaches related to human health would make use of heat-health action plans, improve disease surveillance and control and also in relation to water and sanitation measures. In the tourism sector, as well as with any other economic sector

expected to be affected by climate change impacts, the diversification of activities is going to play a key role as an adaptation option. For that, a set of financial incentives is necessary (see Table 3-21 and Table 3-22).

Table 3-21. Adaptation options, policy framework and opportunities/constraints in the human health sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Human Health	• Heat-health action plans; • Emergency medical services; • Improved climate-sensitive disease surveillance and control; • Safe water and improved sanitation	Public health policies that recognise climate risk; strengthened health services; Regional and international cooperation	(-) Limits to human tolerance (vulnerable groups); knowledge limitations; financial capacity; (+) Upgraded health services; improved quality of life

Table 3-22. Adaptation options, policy framework and opportunities/constraints in the tourism sector.

Source: [IPCC, 2007c: 15]

	Key adaptation option/strategy	Underlying policy framework	Key constraints and opportunities
Tourism	• Diversification of tourism attractions and revenues;	Integrated planning (e.g. carrying capacity; linkages with other sectors); financial incentives, e.g. subsidies and tax credits	(-) Appeal/marketing of new attractions; financial and logistical challenges; (+) Revenues from 'new' attractions; involvement of wider group of stakeholders

Presently the focal point in many countries has been mostly on mitigation actions, however adaptation has recently gained importance. The difference of pace is influenced by different factors. National adaptation studies carried under the UNFCCC help to develop the needed policies that are able to bring improvements in this area [Burton et al., 2002].

As seen from the presented options, all opportunities rely on a set of appropriate policies framework that should be chosen in an integrated approach, either to promote adaptation proactively but also actively. To plan for concrete measures, when the range of impacts is now well know, is for sure difficult, but taking action in an initial stage will mean increased resilience in the future. One of the very important adaptation strategies for many cities is related to early warning systems.

Cross-sectoral policies involving crucial areas are indispensable. Parallel, a large extent of measures in different fields and levels should be executed (technical, such as dyke building, design-engineering, such as new building materials, and administrative, such as disaster-protection management). New ways to design urban development and the

land use patterns are ultimate relevant areas that need to be more explored in the future [Birkmann et al., 2007: 3].

Adaptation needs and the urgency in helping the developing world must be translated in adequate financing funds and other monetary sources for adaptation measures. Measures to reduce risk and vulnerability should also have pro-poor character, and therefore complement development, since the poor will be hit hardest [Satterthwaite et al., 2009]. Furthermore, adequate knowledge of available operation options and the share of best practices also become fundamental, as well as raising awareness and improving research and availability of regional climate data.

Dang et al. [2003] reviewed what mitigation and adaptation strategies have in common or in difference. As it has been noted in regard to spatial planning, also mitigation and adaptation measures are inherently related to sustainability. The general reasons for implementing them are in line with the goal of achieving sustainable development.

Mitigation is based on proactive action, long-term reduction of impacts and therefore a benefit for later generations and at a more global level. In contrast, adaptation involves more reactive action (depending on the real impact, proactive if based on projected impacts), with benefits more or less visible for those bearing the costs and primarily at a local level. While adaptation requires a national/regional degree of cooperation, mitigation implies in a great global agreement [Dang et al., 2003].

3.4 Summary and recommendations

After reviewing the different initiatives developed by the international agenda and the theoretical models for sustainable development at urban scale, also the role of spatial planning and the approaches related to land use and urban form, and finally the strategies for mitigation and adaptation, some critical remarks need to be made.

Sustainable development, as the wide-ranging umbrella to help dealing with the challenges of our time, has not suffered from a lack of definitions or theoretical models. In fact, one can say that practice and action has simply not followed the rethoric.

Internationally, a comparatively long experience in dealing with sustainability issues exists. Approaches such as Local Agenda 21, Habitat Agenda, Sustainable City Programme or City Development Strategy have supported cities in understanding the need for an integrated consideration of social, economical and ecological issues, in order to achieve sustainable development at the urban level.

In addition, also many theoretical approaches are available to guide communities in their development. While some give more attention to technological or environmental issues, others concentrate on urban design, governance or economic growth. It can be said that no model is able to offer solution for all problems or be applicable in all cases. Even if

providing a good direction, their impact is directly related to particular situation in each community.

For the specific case of urban development in low and middle-income countries, there is consent that environmental justice, social equity and economic development urgently need to become more interlinked. In spite of the various theories and pragmatical ways of trying to interlink these issues, still much more needs to be accomplished.

It is decisive to understand what are the limitations and difficulties found in these countries. To seriously deal with the lack of participative processes and poor governance is the first step towards improving the outcomes of any model or approach. Moreover, a community can never be seen as an island. Measures to achieve economic growth and improve social conditions should not, to a certain extent, have uncontrolled negative influences elsewhere. The other way around, also strong external circumstances, which cannot be controlled by a given urban region, might determine the success of addressing the challenges.

Spatial planning, considering particularly urban form and land use, offers decisive tools for tackling the challenges of urbanisation (development planning, building codes, environmental assessments etc). In the last decades, theories such new urbanism, smart growth, compact and eco cities have highlighted the need for high-density and mixed form. It is clear, that densities, building sizes and forms, configuration and layout of cities definitely contribute to their sustainability, as they influence the overall energy uses, the impacts on the environment, or the social configurations.

But some criticism is also required, once considering the application of these concepts to developing countries. These models were created as responses to urban sprawl and automobile dependence in countries such as United States and Australia. The overall context, including demographic and spatial conditions are however fairly distinct in Asia or Africa. Great part of urban population growth happens unregulated and in informal settlements, affordable housing and proper infrastructure is generally missing, and in general the models do not directly address these concerns. Nevertheless, some of the values should be kept in mind, when formulating strategies for rapid growing cities in less developed countries.

There exist plausible ways for spatial planning to help tackling urbanisation problems, while improving the growth distribution and decreasing pressures on the environment, through considerations regarding urban form and land use issues. In the same way, also a great set of mitigation and adaptation options are available, that particularly focus on the need to reduce emissions related to energy use and central importance of adaptation in the water or agriculture, but also infrastructure/settlement sectors.

Different aspects influence the way countries have been making use of these strategies. First of all, in relation to mitigation, depending mainly on the economic structure of a region, different options can be prioritised, by first considering the total shares of emissions sources. Yet two other factors need also to be considered. Options linked to

the greatest leverage points (technological, political, behavioural) and options that present the lowest costs.

The underlying political frameworks need to be changed and concrete measures to encourage the elimination of constraints and the strengthening of opportunities need to find more expression. Potential conflicts resulting in non-action are related to short-term political thinking in contrast to the need for long-term strategies. But if this has been difficult to achieve in the industrialised nations, one can presume that much less can be done in the developing countries.

Even if considering the several co-benefits that are associated to the reduction of emissions, the reality is that tools such as the Clean Development Mechanism, have not yet managed to really integrate sustainable development principles in the overall process. The mechanism rather offers ways for developed countries to achieve their emissions reduction targets at relative low-cost.

Great part of mitigation options is indeed an important opportunity for green investment and for achieving a low carbon development. But so far, at the one hand, higher levels of investment are needed, and at the other hand, it is also still necessary to help the developing countries to make broader use of these options. As most regions are facing other development or environmental problems, it is necessary to focus on strategies that have emission reductions as co-benefits, while helping to achieve improvements on much needed economic, social and environmental structures.

Up to now, greater significance has been given to mitigation options in developing countries, as mentioned, especially due to the potential existing carbon market. Only recently, measures for adaptation started to gain influence. There are different complications regarding the proposed strategies, not really only at the technical level, but also at the political, financial and institutional level.

Also a knowledge limitation, detailed models and expected impacts projection are still being developed for many regions. Surely, in order to know what to do adapt, it is important to first know to what exactly. A very critical challenge related to adaptation is also the financing question. Although building more resilient societies will at the long-term decrease the higher costs related to impacts. Over again, the majority of countries do not have monetary resources, but some also still lack of human and technical resources.

Further analysis, according to each specific case, regarding possible synergies, but also trade-offs between adaptation and mitigation is necessary. That is why it is very important to deal with both options in an integrated way, and not in a disconnected way as it has been the case up to now.

In a general way, there is a mutual link between appropriate spatial planning, mitigation and adaptation and the overall goal of sustainable development. For instance, achieving

paths of more sustainable development would help increase the mitigative capacity of economies (decouple growth from emissions), increase the adaptive capacity and reduce vulnerabilities, and also help tackling the urbanisation challenges. Only by taking measures to address the effects of urban population growth (through e.g. spatial planning) and climate change (mitigation and adaptation), is that sustainable development can be achieved. Nevertheless it seems that the inherent triple-bottom-line conflicts keeps hindering real changes to take place.

The best way to help developing countries to tackle the much-mentioned challenges are the recognised all-embracing capacity development and strengthening of good governance approaches. There is not a lack of strategies and options to achieve change, but rather a systemic difficulty in the implementation.

4 The role of cities

From the previous chapter it became clear, that it is in mainly in cities that challenges and opportunities surges and come together. Within the principles of sustainable development, and also through appropriate spatial/land-use planning measures and mitigation and adaptation actions, to be taken at urban scale, both environmental and development concerns arising from rapid urbanisation and from climate change need to be tackled.

There is a growing recognition that the city administrative level is a crucial one to address global issues. In cities, a variety of driving forces, impacts, responses and stakeholders are interconnected, and can be addressed. Yet many obstacles hinder cities from taking stronger commitments, and these are for instance related to contradictory perceptions, concerns, interests and priorities. In fact, as presented by Bai [2007], two arguments exist to explain why cities are not taking actions to address global environmental problems.

The first one, the scale argument, relates to the spatial, temporal and institutional dimensions, which are beyond the reach and concern of city government. Therefore the spatial scale brings the fact that global issues should be addressed at national/international level; the temporal scale is based on the remoteness of changes and the short time thinking related to typical juridical terms; and the institutional scale is related to different vertical and horizontal autonomy degrees. In the vertical case, the problem is that local government involvement is not always supported by higher levels of administration, Regarding the horizontal case, there is in general low influence level from local authorities in state-owned or private-owned organisations [Bai, 2007].

The second one, the readiness argument, takes into consideration cities in low and middle-income countries. Because these cities are confronted with much more pressing and urgent local environmental and development issues (such as poverty, sanitation, local air and water pollution and waste management), the argument states that they are not ready to handle global issues.

Yet the opportunities that remain hidden behind this analysis is that, in fact, local environmental benefits are the most important co-benefits of GHG reduction policy. Global and local issues can and should be tackled together, with a different range of resulting win-win solutions. The strategy is therefore to transform global concerns into local issues and address not only environmental issues but also employment, economic development and public health. Nevertheless, it is important to consider the level of autonomy of each different city in taking actions and applying policies for reducing emissions.

Localising mitigation issues should be done by using local hooks such as air pollution, transportation, solid waste management, and urban development among others, but also taking care about leakages, which will then only displace the problem to some other location [Bai, 2007]. Co-benefits (such as health, air quality, energy security) can and

should be used to localise climate issues for citizens, to justify climate policies to the public, and spending of public money and lastly to provide an opportunity to address multiple issues at the same time [Kousky and Schneider, 2003: 9].

Adaptation concerns, on the other hand, are by nature geographically placed in the local level. But because of the nature of the problem, adaptation tends to be reactive, focusing on waiting until more evidence on impacts are available, and proactive actions are difficult to justify once the baseline impacts are unknown [Dang et al., 2003]. Another evidence is that even though actions are to be taken more at the local level, suitable national, regional frameworks need to be existent. Due to lack of awareness and capacity, the local level is still struggling in understanding and taking actions on adaptation.

As argued by Bulkeley and Betsill [2005], main conflicts in relation to the resources and powers of local governments, as well as divergence between local goals for economic development and climate change mitigation, have limited the level of local action on climate change [Bulkeley and Betsill, 2005].

It is crucial to have in mind that whatever commitments national governments make within international agreements, almost all concrete climate protection actions will be implemented at the local level, in what relates to both mitigation (e.g. building, transport, waste management sectors, even agriculture and land use change are largely influenced by urban development) and adaptation (water, human health, infrastructure, transport, energy issues) to climate change.

Yet the subject bears a great deal of ***complexity***, different sectors, various stakeholders and interests, singular levels of leverage, diverse times scales for action, and further different physical/economic conditions and political frameworks influencing every particular city. Figure 4-1 illustrates, for instance, the three tiers of influence exerted by cities, namely corporate operations, municipal services and regional systems. The level of control is highest for the first tier, while the number of stakeholders, and the complexity and scope increase from inner to outer tiers [WorldBank, 2009].

Because of the diversity of conditions found in each city, there is no “king’s road solution”, every case is unique, and has always to consider the mentioned facts in an integrated way. With that in mind, it is highly recommended to foster the sharing of best practices, disseminate good experiences, and encourage a productive networking so that cities can profit from experiences of other cities. Many national and international local government networks and association are already taking solid actions in backstopping cities in matters of climate protection actions.

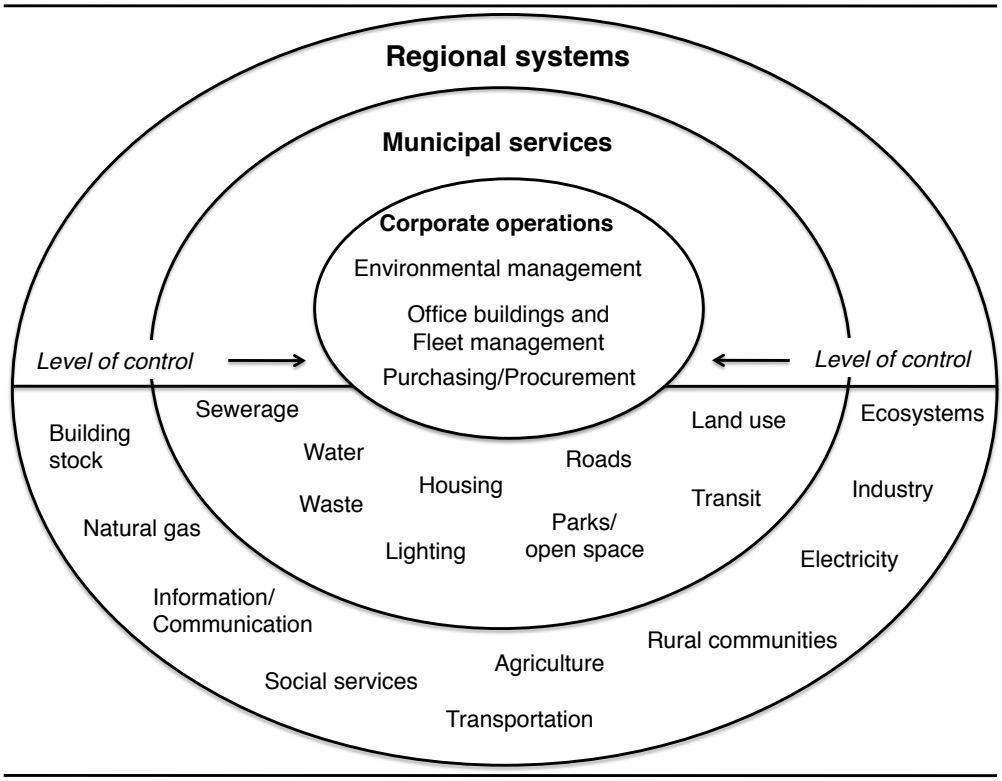

Figure 4-1. Three tiers of city influence.
Source: [WorldBank, 2009: 51]

Within cities, it is important to promote initiatives where the government leaders and municipal staff, private sector (small, medium and large businesses; CO_2 intensive and non-intensive businesses; businesses with old and new technology that addresses climate, service organisations, etc.), academia and all civil society (non profit organisation, local activists, community leaders) get together to find creative solutions [Dawson et al., 2009; Natcap, 2007]. Cities can and should make use of a set of tools and approaches available for stakeholder involvement, for learning how to encourage and engage the numerous involved groups.[32]

4.1 International initiatives

The post-Kyoto agreement will have to strongly recognise the needs of cities and local governments and their importance for a global process of change. That is why the Local Governments for Sustainability (ICLEI)[33], one of the leading international associations of local governments as well as national and regional local government organisations committed to sustainable development, have started an initiative called Local

[32] As cited in the Climate Protection Manual for Cities [Natcap, 2007], three strategies, each having a different audience and purpose (yet following similar processes) are recommended: LASER, Tools of Change and Business for Social Responsibility. For more information: Climate Protection Manual.
[33] Formally International Council for Local Environmental Initiative.

Government Climate Roadmap[34]. This initiative, an accompanying 2-year process to the international negotiations, has the objective of strengthening the role of cities and local governments, and working towards having their key position recognised in the post-2012 climate regime. It starts by encouraging and supporting local and regional governments to intensify their own activities for local climate mitigation and adaptation. In addition, it helps local governments to advocate for joint developed messages/positions through their members and partners on national scale. Further organisation involved in the process are: United Cities and Local Governments (UCLG), World Mayors Council on Climate Change (WMCCC), C40 Climate Leadership Group (C40), Metropolis (more on each one shortly).

As cited in the draft text prepared by ICLEI [ICLEI, 2009b]: "*Action of nations in view of limiting global warming must ensure a strong recognition, empowerment and partnership with their local governments, as well as include the necessary enabling structures and resources to ensure that local climate action is a consistent part of national climate strategies. Any future multilateral agreement, decisions or agreed efforts on limiting global warming and combating climate change must therefore highlight the need for partnership between national and local governments so as to ensure consistent planning and implementation at appropriate authority level.*"

Further three topics are also dealt with in this framework for advocacy, adaptation, carbon trading, and CDMs and access to financing. Key messages are:

Adaptation – national and international risk prevention and resilience planning as well as mechanisms and funding have to include local governments; it is a task of national government to create structures, provide capacities and resources to enable local governments to plan and implement required adaptation measures.
Carbon trading – role of local governments promoting GHG mitigation have to be strengthened with more local, national or regional schemes for carbon trading, allowing for example local offsetting, or also it should be possible for organisations to connect to the global challenge through carbon permits which can be exchanged through national and international schemes.
CDMs and access to finances – understanding of and access to financing mechanisms for mitigation and adaptation is the key; in regard to CDM, carbon finance will play an increasing role in financially supporting cities in their mitigation efforts. Long term and integrated programmes solutions should be pushed harder by local authorities[ICLEI, 2009b].

In conclusion, as cities can effectively control legislation, planning, policies and measures, they will have to strategically cooperate to national levels of government, which by their turn, have to provide empowerment, capacities, resources and access to funding as well as facilitate regulations and framework conditions for the local level.

[34] Climate Roadmap: www.iclei.org/climate-roadmap/

Worldwide, an ever-growing amount of developed and developing cities are starting to take action and designing/implementing ambitious climate strategies.

ICLEI[35], as a network created in 1990 and composed by more than thousand cities, towns, countries and theirs associations, is working on supporting them through different campaigns and programmes. For instance, the Cities for Climate Protection Campaign (CCP), has reached around 700 local governments worldwide on integrating climate change mitigation into their decision-making processes.

United Cities and Local Governments (UCLG)[36], founded in 2004 as a combination of the former International Union of Local Authorities (IULA) and World Federation of United Towns and Cities (UTO), has over 1000 direct members in 95 countries and 112 local government associations. Current relevant campaigns are the Millennium City Campaign (support to the implementation of the Millennium Development Goals) and the Climate Campaign (World Mayors and Local Governments Climate Protection Agreement).

C40 Climate Leadership Group (C40)[37], as a group of the world's largest cities, initiated activities in 2005 with a strong commitment to tackling climate change. Cities consented in creating policies and promoting alliances that will result in stronger assimilation of climate friendly technologies and impact the market place. Many participating and affiliated cities have created climate change action plans setting concrete emission reductions targets. In 2006 the partnering with the Clinton Climate Initiative took place.

The World Association of Major Metropolises (Metropolis)[38] is also the metropolitan section of the UCLG, focusing on the promotion of ideas exchanges for concrete responding to problems being faced by cities such as city planning, economic development, the environment, etc. The Asia-Pacific region counts with 29 members, Europe 20, Latin America and Caribbean 12 and North America 6 metropolises.

The purpose of the World Mayors Council on Climate Change (WMCCC), an alliance of 20 committed local government leaders is also to foster international cooperation and to advocate for effective climate protection policies.

The Climate Alliance (*Klimabündnis*)[39] is the largest European city network for climate protection. It promotes the exchange of experience and also offers different recommendation/tools services. Another central activity is the lobbying for improved framework conditions for local climate change policies on international, European and national level.

These and many other existing networks and associations at the international or regional level concentrate efforts on helping the exchange of knowledge and experience

[35] For more information: http://www.iclei.org/
[36] For more information: http://www.cities-localgovernments.org/
[37] For more information: http://www.c40cities.org/
[38] For more information: http://www.metropolis-server.com/metropolis/
[39] For more information: http://www.klimabuendnis.org/

among capacity building and supporting implementation of actions at the local level, and are also responsible for the growing commitments that cities worldwide are undertaking.[40]

4.2 Climate action plan

There exist no standard definition of an urban climate action plan. Yet a common understanding is that it is a personalised plan developed for and by a particular city. That includes a time frame, costs and financing instruments, and concrete assignments and tasks to city departments and actions, the city must implement for achieving a certain target, and it is based on participative processes [Natcap, 2007].

Such a plan should build up on the relevance of climate change to the four city functions: city as consumer (public buildings/procurement), city as planner and regulator (urban development / land use planning; traffic planning); city as service provider (energy supply; public transport services) and city as advisor and promoter (funding schemes for renewable energies; campaigning and public outreach).

Table 4-1. Climate Alliance's modules of the Climate Compass methodology. Source: Climate Alliance

Module 1: Initiation	Module 2: Inventory	Module 3: Institutionalisation
• Informing relevant departments of the administration • Clarifying needs and expectations • Raising awareness of local climate change policies	• Analysing the setting • Surveying previous priorities and activities • Characterising the initial conditions	• Building organisational structures • Assigning responsibilities and nominating persons in charge
Module 4: Climate action programmes		**Module 5: Monitoring and Reporting**
• Defining targets • Selecting priority measures • Formulating strategic resolutions (on criteria, standards…) • Agreeing the mid- and long-term climate strategy		• Developing indicators • Collecting data for CO_2 monitoring • Preparatory work for future reporting

One example, a tool developed by Climate Alliance[41], is the Climate-Compass. As a roadmap for local climate protection, the methodology aims at supporting local authorities at designing and start implementing such plans. The process/tool is divided in five modules (see Table 4-1).

[40] Other organisations/associations worth mentioning are: CEMR – Council of European Municipalities and Regions (http://www.ccre.org/); ASPAC – UCLG Asia Pacific Regional Section (http://www.uclg-aspac.org/); FLACMA – Federación Latinoamericana de Ciudades, Municipios y Asociaciones. (www.flacma.org/); Eurocities (www.eurocities.eu/); Energie-Cités (http://www.energie-cites.eu/);
[41] For more information see: http://www.climate-compass.net/

The Climate Compass methodology found use especially in Europe. It starts integrating climate change policy into already in place new development strategies of cities by concentrating first on activities and experiences in the respective local authority.

As one of the most important programmes carried out by ICLEI, the Cities for Climate Protection (CCP) also has been supporting cities to adopt policies and implement quantifiable measures to reduce local greenhouse gas emissions, improve air quality, and enhance urban liveability and sustainability. It is based on a proved five steps methodology, and ICLEI also makes different tools available to implement these milestones[42]:

Table 4-2. ICLEI's Cities for Climate Protection Milestones.
Source: ICLEI

Milestone 1. Conduct a baseline emissions inventory and forecast: for base and forecast year. Provides a benchmark for measuring progress.
Milestone 2. Adopt an emissions reduction target for the forecast year: target both fosters political will and creates a framework to guide the planning and implementation of measures.
Milestone 3. Develop a Local Action Plan: through multi-stakeholder process. The action plan describes the policies and measures that will be taken to reduce emissions and achieve targets. Most plans include a timeline, a description of financing mechanisms, and an assignment of responsibility to departments and staff. Public awareness and education efforts are also included
Milestone 4. Implement policies and measures: measures are implemented (typically include energy efficiency improvements to municipal buildings and water treatment facilities, streetlight retrofits, public transit improvements, installation of renewable power applications, and methane recovery from waste management).
Milestone 5. Monitor and verify results: starts once measures are implemented and continues for the life of the measures, providing important feedback that can be used to improve the measures over time.

It can be noticed, from the relatively similar presented concepts, and also based on the examination of most of the initiatives, that currently efforts concentrate on measures for greenhouse gas emissions reductions [Bulkeley and Betsill, 2005]. A great number of cities in the US as well as in Europe have prepared Climate Action Plans[43], and are taking strong commitment for greenhouse gas emissions reduction. However, a growing concern that needs to be integrated into local action plan or programmes still refers to adaptation measures.

[42] For more information see www.iclei.org/co2

[43] Some examples: Munique (commited to a emission reduction by 2030 of 50 percent, compared to 1990) London (commited to a emission reduction by 2025 of 60 percent, compared to 1990), Copenhagen (commited to a reduction of 20 percent between 2005 and 2015).

4.3 Cities and mitigation

As discussed by Satterthwaite [2008] and Dodman [2009], even though cities have been frequently given responsibility of 75 to 80 percent of anthropogenic GHG emissions, a detailed analysis shows that the figure is rather less than 50 percent.

In fact, if considering the figures given by the IPCC, deforestation and agriculture together already account for 30 percent, and also part of the emissions related to transport, building, industry energy generation are not generated within city boundaries.

The authors further analysed the emissions per capita in different cities, and compared to the respective national per capita emissions. In nearly all cases – with exception of the studied Chinese cities - the per capita emissions of the cities are lower than the per capita emissions of the country. For example, London and Toronto emit 6.2 and 8.2 t CO_2eq annually per capita while the average for England and Canada are 11.2 and 23.7 t CO_2eq per capita respectively [Dodman, 2009].

As one of the difficulties stated, the comparison between cities is rather not appropriate, since methodologies used for assessment are different (there is no international framework to guide the realisation of urban emission inventories). Also the year of analysis is not the same. It could be assumed, that for instance in low and middle-income countries, many large cities indeed will present higher averages per capita emissions level than the national one, since they concentrate wealth and increasing patterns of high consumption when compared to rural areas. Yet only a few inventories for such cities are available.

Moreover, the authors question if it is correct to allocate emissions to the producers or to the consumers. Based on this, there are problems for instance in the allocation of emission from commuters and from air transport, from emissions related to goods and services related emissions, and so on. The importance of definition of boundary is brought up (different boundaries have been identified: core city, the contiguous built-up area, the metropolitan area and an extended planning region), as well as the necessity to address higher portion of emissions to cities in considering that these can be assigned to the location of final products and services consumers [Satterthwaite, 2008b]. Also Ramaswami et al. [2008] distinguishes about direct versus indirect emissions in urban areas, and proposes a demand-centred, hybrid life-cycle approach, that considers surface and airline transportation allocation and embodied energy of key urban materials [Ramaswami et al., 2008].

In a study by Lebel et al. [2007], the considered driving forces resulting in emissions are related to the function of the city, namely to provide convenient mobility, comfortable shelter, adequate and safe food and enjoyable lifestyle. These also depend on the form of a city (density, extent and topography; modularity and connectivity; land surface covers and edges and transitions) and are influenced by the role of the city (manufacturing – from light to heavy; governing – planning and administering; servicing – finance, tourism and commerce; and educating – R&D, innovation, training). The study

further points out that the focus for emissions reductions has concentrated on sector-specific strategies, while it is also necessary to decouple an emission's increase from improvements in well-being, changing the focus to how urban functions are provided and also policies that shape the cities' form and role [Lebel et al., 2007].

To understand where and why greenhouse gas emissions in cities are produced is crucial in order to take action to mitigate those. Two points are of significance; first, cities are very different in regard to the breakdown of their emission, and, second, on the causes for this difference (e.g. economic structure, climatic region - influence need for cooling/heating, etc. – see next paragraph). For instance for all of them, London, Milan and New York, buildings use consumption is responsible for a great majority of emissions (around 2/3). Transportation comes at second place (with around 25 percent), whereas in Bangkok transportation accounts to half of emissions, in Mexico City to 42 percent. In both buildings use consumption are much lower, and for instance in Mexico City, 22 percent of emissions is due to industrial sector [Croci et al., 2009: 13].

A different set of factors is listed as causes/drivers of emissions, energy use, in specific, which is dependent on urban characteristics such as spatial structure, the infrastructures and further characteristics related to urban population and its activities. These factors are further broken down in: compactness of the urban settlement; urban zoning and functions; nature of the transportation system; income level and lifestyle; energy efficiency of key technologies; nature of economic activities; building technologies and building floor space use; waste management; climate factors [Dhakal, 2004, 2008].

In summary, at the local level, studies of greenhouse gas emissions are still restricted. It is important to highlight that also different cities have different levels of leverage on how to influence their emissions and it is difficult to benchmark/compare cities with each other, also because the drivers of emissions are fairly different.

Nevertheless, if cities are going to commit to any mitigation targets, they first need to inventory their emissions, in order to understand where they come from and based on that, define priorities on action, and also as well to measure progress in achieving the stipulated goals. Following subsection deals with urban greenhouse gas inventories.

4.3.1 Urban greenhouse gas inventory

ICLEI is one of the pioneers in the process of offering methods for assessing local greenhouse gas and air pollution emission reductions. HEAT [44] (Harmonised Emissions Analysis Tool) software has been used by local authorities as a planning instrument in order to achieve emission reductions.

The tool can therefore setup an emissions inventory based on local energy use, transportation demand, and waste practices; with that, the city is able to build a simple emission forecast, and based on that to set a target/goal for reducing emissions. The

[44] For more information see: http://heat.iclei.org/

tool also enables the quantification of emission reduction activities and their co-benefits, and is connected to report, and track progress made in meeting the set target.

Although the HEAT tool has been widely used (India, Indonesia, South Africa, Brazil, etc.), many cities adopt their own methodology[45] for creating a baseline of emissions, and until now no global protocol for attributing GHG emissions to urban areas exists [Dodman, 2009].

And in fact, as discussed previously, there exists a methodological problem in accessing emissions from cities. It is not trivial to decide about how to allocate emissions in urban areas.

There is thus a distinction between a city inventory, and city footprint. Many of the emissions generated within a city's boundary are produced elsewhere. For instance the World Resource Institute Protocol[46] for mapping city scale emissions uses a hybrid methodology: in-boundary emissions and out-boundary ones (considering airline and other out of boundary travel and embodied emissions from key urban materials: cement, water, food, steel, fuel). Adding out of boundary activities is necessary to avoid perverse incentives, to create win-win policies and to communicate consistently with public as it includes human activities/behaviour. Caution is necessary in taking measures to reduce inventory but that do not increase footprint in another place [Ramaswami et al., 2008].

ICLEI is also proposing the adoption of a general common protocol for cities [ICLEI, 2009a]. The protocol is based on following scopes: local government operation emissions (emissions that are a consequence of the local government's operations must be included, regardless of where those emissions occur – this considers the organisational boundary) and community emissions (all greenhouse gas emissions associated with activity occurring within the local government's geopolitical boundary), or in more detail:

Organisational Boundary/Government Operations Analysis - includes following scopes of emissions (see Table 4-3):
Scope 1 emissions – Direct emission sources owned or operated by the local government; Scope 2 emissions – Indirect emission sources limited to electricity, district heating, steam and cooling consumption; Scope 3 emissions – All other indirect and embodied emissions over which the local government exerts significant control or influence.

Geopolitical Boundary/Community Analysis - with following scopes (see Table 4-4):
Scope 1 emissions – All direct emissions sources located within the geopolitical

[45] IPCC Methodology for GHG inventories is a produced based GHG emission assessment, i.e. what is emitted inside the territory.
[46] WRI protocol for corporations for example has 3 scopes for allocating emissions: scope 1: emissions owned (within corporate boundaries); scope 2: electricity consumed by the company; and scope 3: consequence of company's activities, e.g. product use); For more information see: http://www.ghgprotocol.org/

boundary of the local government; Scope 2 emissions – Indirect emissions that result of activity within the jurisdiction's geopolitical boundary limited to electricity, district heating, steam and cooling consumption; Scope 3 emissions – All other indirect and embodied emissions that occur as a result of activity within the geopolitical boundary.

Table 4-3. Government emissions within 3 different scopes.
Source: [ICLEI, 2009a]

Macro Sector IPCC		Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
Energy	Stationary combustion	Utility delivered fuel consumption; Decentralised fuel consumption; Utility consumed fuel for electricity/heat generation;	n/a	Stationary combustion-based emissions from facilities operated by contracted businesses performing essential government services; Upstream/downstream emissions (e.g. mining/transport of coal);
	Electricity/ heat consump.	n/a	Electricity/Heat/Steam consumption	Electricity/heat/steam consumption-based emissions from facilities operated by contracted businesses performing essential government services; Upstream/downstream emissions (e.g. mining/transport of coal);
	Mobile combustion	Tailpipe emissions from government owned and operated vehicles	n/a	Tailpipe emissions from vehicles operated by contracted businesses performing essential services; Upstream/downstream emissions;
		n/a	n/a	Tailpipe emissions from vehicles operated by government employees travelling to and from work; Upstream/downstream emissions;
	Fugitive emissions	Fugitive emissions not already accounted for	n/a	Upstream/downstream emissions
Industrial Processes and Product Use		Fugitive emissions from industrial processes	n/a	Upstream/downstream emissions
Agriculture, forestry and other land use		Methane from government owned livestock	n/a	n/a
		Net biogenic carbon flux of government	n/a	n/a

Macro Sector IPCC	Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
	owned/operated sources		
Waste	Government owned/operated landfill, incineration, compost and wastewater facilities	n/a	Analysis-year emissions from government waste disposed to date; Embodied future emissions associated with analysis-year waste generation; Upstream/downstream emissions (e.g., transport to the landfill)

Table 4-4. Community emissions within 3 different scopes.

Source: [ICLEI, 2009a]

Macro Sector IPCC		Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
Energy	Stationary combustion	Utility-delivered fuel consumption Decentralised fuel consumption Utility-consumed fuel for electricity / heat generation	n/a	Upstream/downstream emissions (e.g., mining/transport of coal)
	Electricity/ heat consump.	n/a	Utility-delivered electricity / heat /steam consumption; Decentralised electricity / heat /steam consumption;	Upstream/downstream emissions (e.g., mining/transport of coal)
	Mobile combustion	Tailpipe emissions from on-road vehicles; Tailpipe emissions from rail, sea, airborne and non-road vehicles operating within the community:	Electricity consumption associated with vehicle movement within the community (e.g., light, rail)	Tailpipe emissions from vehicles used by community residents; Upstream/downstream emissions (e.g., mining/transport of oil) Tailpipe emissions from rail, sea, and airborne vehicles departing from or arriving into the community
	Other energy	Fugitive emissions not already accounted for	n/a	Upstream/downstream emissions
Industrial Processes and Product Use		Decentralised process emissions	n/a	Upstream/downstream emissions
Agriculture, forestry and other land use		Livestock methane, managed soils	n/a	Upstream/downstream emissions
		Net biogenic carbon flux	n/a	Upstream/downstream emissions from fertiliser, pesticide manufacturing

Macro Sector IPCC		Scope 1 Emissions	Scope 2 Emissions	Scope 3 Emissions
Waste	Solid Waste Disposal	Direct emissions from landfill, incineration and compost facilities located inside the community	n/a	Landfill, incineration and compost emissions in present-year from waste produced to date inside the community; Future emissions from waste disposed; Upstream/downstream emissions (e.g., transport to the landfill)
	Wastewater Treatment and Discharge	Direct emissions from wastewater facilities located inside the community	n/a	Present-year emissions from wastewater produced to date inside the community; Future emissions from treated wastewater; Upstream/downstream emissions (e.g., transport to landfill)

By means of such a standardised methodology that also takes into account out-boundary emissions, the inventory tool would provide a much more realistic emission baseline. Imperative to have in mind is that actions taken at city level might leakage and influence the emissions in another place (scope 3). The differentiated analysis shows the real points of control, which can easily by exerted by the local government.

4.4 Cities and adaptation

The main responsibilities for planning, implementing and managing great part of actions that can contribute to adaptation lie within city and municipal governments tasks [Satterthwaite, 2008a: 10].

Table 4-5. Climate change impacts on urban areas.
Source: [IPCC, 2007c; WorldBank, 2008] cited in [McCarney, 2009]

Change in Climate	City Impacts
Temperature change	- Heat island effect - Increased demand for cooling and energy shortages - Declining air quality in cities - Reduced disruption to transport due to snow, ice - Increased water demand - Water quality problems - Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated - Reduction in quality of life for people in warm areas without appropriate housing
Alterations in precipitation - Frequency of increase	- Adverse effects on quality of surface and groundwater - Contamination of water supply - Waterborne diseases - Poor solid waste disposal - Increased risk of deaths, injuries, and infectious, respiratory, and skin diseases

Change in Climate	City Impacts
- Drought	- Disruption of settlements, commerce, transport, and societies due to flooding - Large displacement of people - Pressures on urban and rural infrastructures - Destruction of urban infrastructure - Loss of property - In-migration from climate change affected areas - Food and water shortage - Increased price of food - Increased migration to cities
Storm activity increase (high winds, cyclones, hurricanes, etc.)	- Power outages - Distress migration to urban areas - Disruption of public water supply - Increased risk of deaths, injuries, water and food-borne diseases; post-traumatic stress disorders - Disruption by flood and high winds - Withdrawal of risk coverage in vulnerable areas by private insurers - Potential for population migrations - Loss of property
Sea level change	- Decreased freshwater availability due to saltwater intrusion - Increased risk of deaths and injuries by drowning in floods and migration-related health effects - Loss of property and livelihood - Permanent erosion and submersion of land - Costs of coastal protection versus costs of land-use relocation - Potential for movement of populations and infrastructure - Increased salinity in estuaries and coastal aquifers - Rising coastal water tables and impeded drainage. - Degraded dykes that are unable to sustain future tides - Encroachment of settlement onto low lying areas - Destruction of urban infrastructure - Effect on long-term economic growth

To start, an appropriate understanding of what kind of impacts will fall over urban settlements is indispensable [Bigio, 2003; Satterthwaite et al., 2009]. Table 4-5 summarises the impacts to be felt in urban settlements.

Flooding and landslides, as a result of sea-level rise, from heavier rainfall and from changes that increase river flows, such as glacial melt, will have great impact on roads, buildings and overall infrastructure. As paved areas prevent rainfall from infiltrating into soil, surface water can overwhelm drainage systems. Water supply/treatment plants and sanitation (damage to pit latrines, septic tanks) are also at risk, the same with sewage and waste treatment plants. In developing countries, the lack of sanitation will also lead to contamination of urban floodwater.

Sea level rise also pose great impact for costal urban population and their infrastructure. Affected are coastal areas subject to erosion, river floors in estuarine zones subject to sedimentation and wetlands and tidal flats subject to flooding. Groundwater is at risk of increasing salinisation and costal aquifers at risk of decreasing, affecting fresh water supply and peri-urban agriculture. Where overall rainfall decreases, water supply will be influenced, since droughts will likely compromise the replenishment of the water tables.

Higher temperatures and heat waves will also influence the frequency of extreme events and generate increased problems with air pollution (formation of some air pollutants is dependent on temperature and humidity e.g. ground ozone). Increased heat stress due to heat island effect will have impacts on health, labour productivity, leisure activities, higher costs for cooling in buildings (and increase emissions if used energy comes from fossil fuels), formation of smog and degradation of green spaces.

Further health impacts will result from altered spatial distribution of infectious disease vectors and also from lack of disaster preparedness and poor responses after disaster events (malaria, dengue fever, cholera, leptospirosis), or allergic and respiratory disorders.

Again it is necessary to stress that, in especial for the developing world, the higher vulnerabilities of urban areas are related to already existing risks faced by urban poor. Therefore, adaptation and pro-poor development present strong synergies [Satterthwaite et al., 2009].

Differently from the discussion in relation to greenhouse gas emissions originated in cities, the logic underlying the adaptation strategies is fairly distinct. While the mitigation measures are based and depend concretely on the factual emissions and on the leverage points available, adaptation is much more imprecise. A city needs, in order to prepare for the impacts, first to understand what kind of impacts (as cited previously) is likely to happen. There is a great difference of risks across cities and inside of one city, depending on a variety of factors that need to be assessed, in order to serve as baseline for adaptation action. In the following subsection, a proposed urban climate risk assessment will be discussed.

4.4.1 Urban climate risk assessment

When it comes to adaptation, to understand climate risks are prerequisite for action. As recently reviewed, [Rosenzweig et al., 2009] a framework that help deconstruct risk would increasingly assist policy makers in taking more proactive adaptation measures. The proposed framework builds up on a combination of physical science, geographical, and socioeconomic elements that can be used by municipal governments to create and carry out climate change action plans.

Some of these elements include climate indicators, global climate change scenarios, downscaled regional scenarios, change anticipated in extreme events, qualitative assessment of high-impact and low-probability events. The study also focuses on a different analysis of impacts on population (poor and non-poor urban residents) and on sectors (disaggregating implications for infrastructure and health).

The framework recommends to evaluate risk based on: (i) hazards, for instance, observed and projected data on key climate parameters; (ii) vulnerability, according to physical, social and economic conditions (iii) adaptive capacity, considering the ability and willingness of key stakeholders to address problems.

Measuring hazards through climate change scenarios, to any particular city, should be based on observed and projected data on key parameters – temperature, precipitation, sea-level rise, frequency of extreme events, among others. Basically more than one model simulation should be used, taking into account different development possibilities in regard to concentrations of greenhouse gases and the resulting associated impacts.

Vulnerability can be understood as the extent of predisposition to adverse climate change effects, being a function of certain conditions and characteristics of the city. So for example the location (proximity to sea), topography or other landscape and physical geography attributes determine how susceptible a city might be. Moreover, population size, composition, city size and density, quality of infrastructure, type and quality of built environment also has a great influence on the overall vulnerability. Also the total percentage of poor, and the share of the city in the production of national GDP (city's economic relevance) are factors to be considered.

Measuring adaptive capacity in relation to willingness and ability of key stakeholders to cope with adverse impacts, it is based on awareness and availability of information/ resources, capacity of institutions within different levels of governments /departments, but also of private sector, community groups and non-governmental organisations. Willingness to take action can be analysed by identifying existing initiatives of all stakeholders.[47]

Some authors have listed different characteristics determining the adaptive capacity of a society or an organisation [Frommer, 2009; Smit and Pilifosova, 2001]:

(1) Economical resources/wealth – the higher the economical power, the easier can the costs for adaptation measures be put into practice;
(2) Technology – availability and access to technologies such as early warning systems (for storms, sea level rise or heat events), technical flood control measures;
(3) Knowledge: existing information about impacts of climate change, understanding about proper adaptation measures;
(4) Infrastructure: technical as well as social infrastructure can make simpler the access to resources, however, active infrastructure can also have a negative influence, since technical plants are normally planned for a long lifetime and there is not enough short time flexibility to adapt those;
(5) Institutions: a suitable institutional capacity is essential for dealing with adaptation;
(6) Equity: inconsistency in the access to knowledge, infrastructure, technology and economical resources lead to a decreased adaptive capacity, the close link of these factor among each other becomes thereby visible.

[47] For more information: Urban Climate Change Research Network: http://www.uccrn.org/

Developed at the Kyoto University[48] and based on different dimensions of resilience, a methodological approach has been proposed to define a Climate Disaster Resilience Index (CDRI). The dimensions and field of analysis are following [Shaw, 2009]:

Natural: topography, disaster, natural environmental degradation, hydro-meteorological situation;
Physical: history, location, accessibility, infrastructure and utilities (electricity, water supply, solid waste, road), housing conditions, land tenure, environmental degradation, warning systems;
Social: population, health, education, knowledge and awareness, social capital, conflict, crime;
Economic: income, employment, expenditures, household assets, access to financial services, financing coping mechanism;
Institutional: development plan, internal and external institutions, institution collaboration, coordination and cohesion;

According to the evaluation of these dimensions for a city, policies and concrete measures can thus be developed. Another suggestion to improve the responses to impacts relates to understanding how these will affect first natural systems, but also the built environment and human populations, in any specific city [Carmin et al., 2009]. Besides, the author also suggests that local adaptation needs to be linked to local priorities and ongoing initiatives and general strategic plan need to be agreed along with sector-specific goals and targets.

4.5 Summary and recommendations

There is a growing recognition that to tackle climate change at city level is feasible and imperative. Yet, different factors influence the readiness and the scale to which actions are taken. In many cases, the local governments still need to better consider and understand about the various co-benefits associated to mitigation and adaptation, in order to implement broader measures (or, as mentioned before, the other way around).

Because there are many differences among cities, it can be said that there is no fit-all solution. As the interaction between the different stakeholders varies, and also the leverage points within the 3 tiers of influence (cities' corporate activities, in relation to municipal services and to regional systems) are also different, each city needs to develop its own strategy. Understanding the complexity of stakeholders/actors is a very important step in bringing them all together to work towards a common direction.

In one way or another, cities worldwide need a great support in the completion of tasks related to climate change, as they face, in fact, a fair share of many other problems. A

[48] Also in initiative with other organisations, among others, Citynet, a regional network of local authorities for the management of human settlements. For more information: Citynet: http://www.citynet-ap.org/

growing number of local governments initiatives have been created for this purpose and are showing successful results.

The sharing of experiences and best practices among cities and the overall improvement of government's capacities become more and more important, and these international networking organisations are key in achieving this. At this point it is recommended, that not only north-south cooperation should be fostered. Also an increased south-south interchange is necessary, as similarities in conditions and requirements increase the effectivity of the experiences' exchange and mutual learning process.

A remark has also to be made in regard to the aspiration for benchmarking tools for the comparison of cities. It is understandable that such an instrument can help for instance the allocation of investments and the facilitation in achieving benefits from national governments. Nevertheless, it is difficult to measure and compare cities performance in relation to another city, for the same reason each city has to develop an own mitigation/ adaptation strategy. The conditions to which they are exposed are in general very distinct.

Therefore, it is in fact recommended that cities measure their efficiency in relation to the achievement of reasonable and realistic goals they decide to commit to. Climate action plans (again, rather concentrating on mitigation up to now) are gaining increased power as a road map for action in many cities worldwide.

As baseline for action, two different appraisals are needed. First a greenhouse gas inventory (related to the factors driving emissions in cities). And, in order to improve actions towards adaptation, an urban climate risk assessment (based on concrete impacts to be felt by cities and their given vulnerability and adaptive capacity) is necessary.

The development of such tools is advancing fast. Reasonable simplicity, applicability and cost-benefit are essential. More than ever, also increased support for cities in the compilation of these baselines is necessary, as they are important for definition of targets and elaboration of concrete measures catalogue.

5 Spatial planning, mitigation and adaptation

As formerly discussed, both mitigation and adaptation measures in cities are essential to tackle climate change. Yet, in general, actions have been dichotomised between these two areas, which have been continuously treated differently and disconnectedly by policy and research communities [Dang et al., 2003; McEvoy et al., 2006].

This dichotomy appears not only because of the difference in the way knowledge is produced (mono vs. trans-disciplinary), but also due to a distinction in the temporal, spatial and stakeholder involvement, and in relation to the institutional complexity and to the analytical approach underlying the issues. Thus, the designed strategies for mitigation and adaptation are also fairly distinct [Biesbroek et al., 2009].

A simplified casual relationship between climate change and spatial planning can be taken from Figure 5-1. Spatial planning can influence mitigation and adaptation, as measures required to cope with climate change. The figure also indicates the functions and outcomes of spatial planning, which have been detailed listed in Section 3.2.1. These, as well as the different mitigation and adaptation options are, in addition, influenced by other sectoral policies.

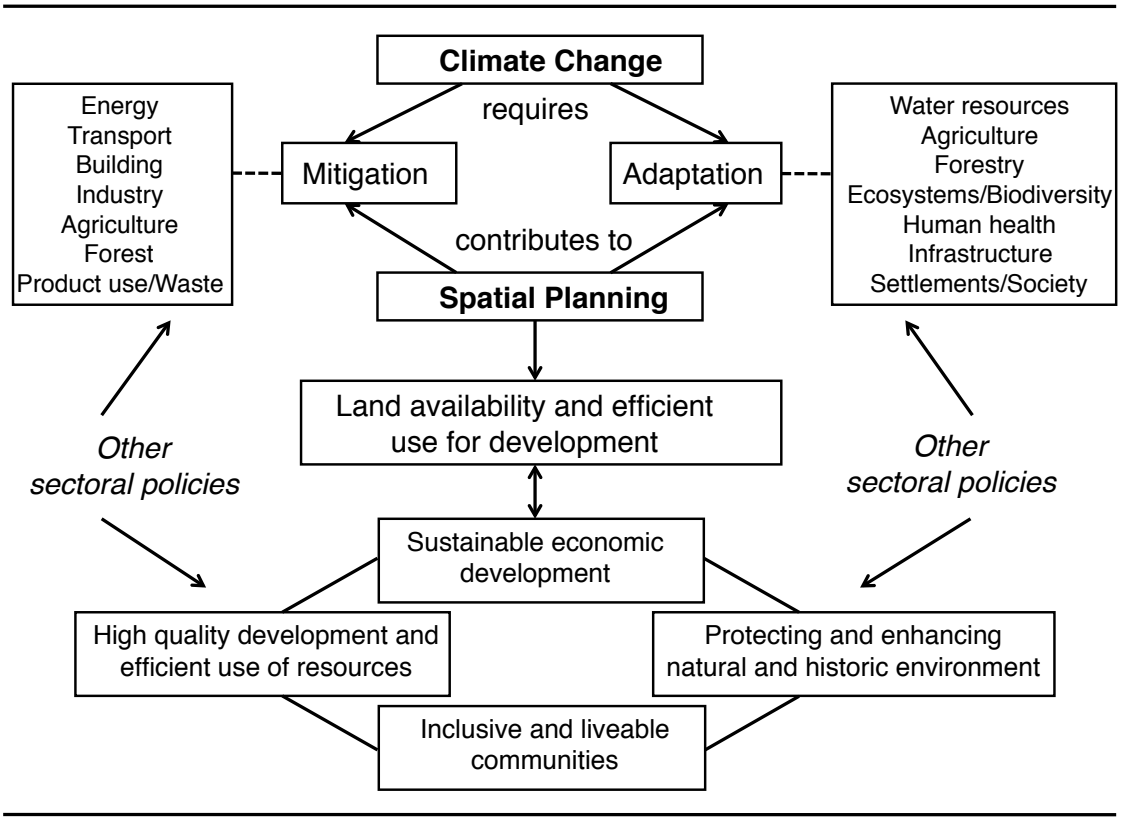

Figure 5-1. Spatial planning outcomes and casual relationship spatial planning and climate change.

Source: Based on [RTPI, 2008: 9]

Another possible simplified depiction of correlations between environmental and sectoral issues to climate change, spatial planning and also driving forces such as population growth and economic development can be seen in Figure 5-2. Also very important to be considered is the issue of urban poverty. Spatial planning in developing countries, more than ever, can play a key role in also integrating pro-poor actions, in order to improve social and economical conditions of great part of the urban population. These measures can strongly influence vulnerability and adaptive capacity to cope with impacts [Satterthwaite et al., 2009].

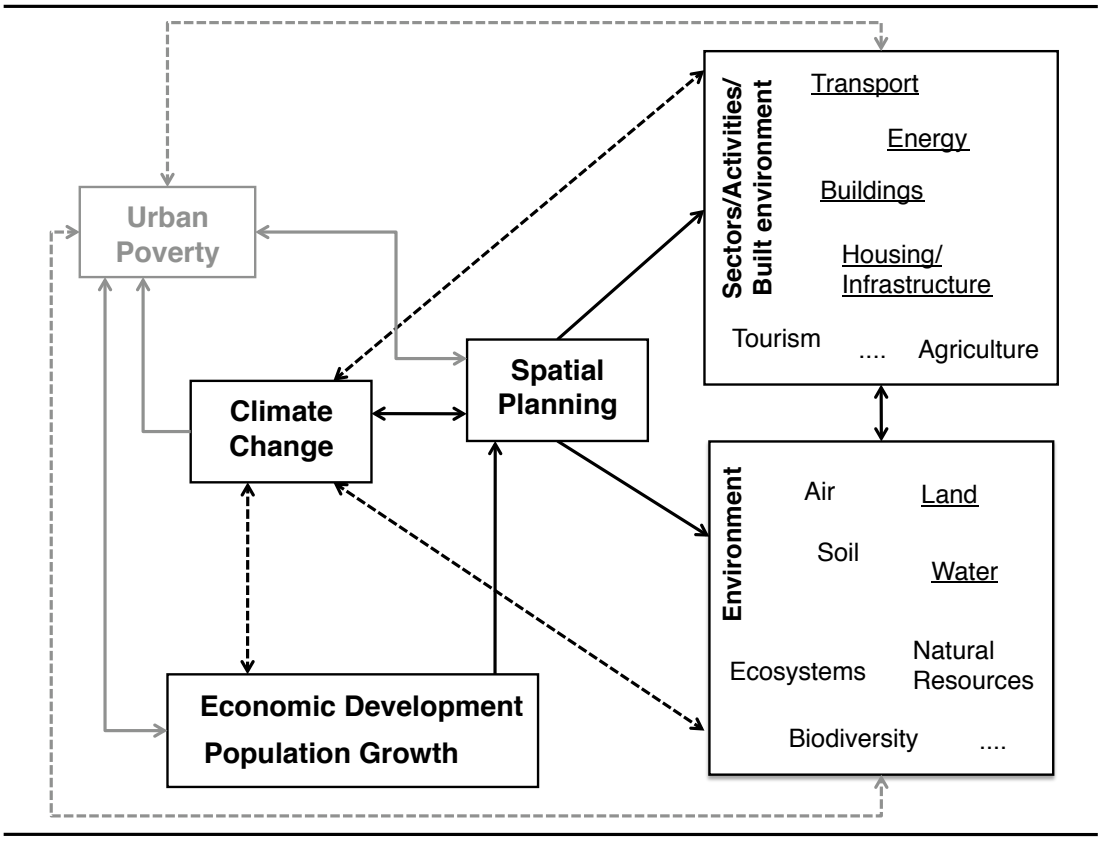

Figure 5-2. Simplified correlations climate change, spatial planning, and sectors.

As argued by different authors [Biesbroek et al., 2009; Bulkeley, 2006; Campbell, 2006] urban planning is capable of becoming the strategic integration framework where actions towards mitigation and adaptation are placed in a wider context of sustainable development. Spatial planning is stated to have a crosscutting function also for the coordination of sector specific decisions [Birkmann et al., 2007; RTPI, 2008; UNECE, 2008]. But so far the role of spatial planning has not been entirely quantified, and it also has not taken any prominent position in the international climate debate [Alber, 2007; Bulkeley, 2006].

Although spatial planning will not offer all solutions [Biesbroek et al., 2009; Birkmann et al., 2007] it is necessary to better understand how it influences mitigation and adaptation, and what interactions, synergies and trade-offs exist. In the middle and long term, having in mind the unprecedented rapid growth of urban areas in the developing world,

appropriate measures in spatial planning can set the foundations for tackling climate change, while accommodating the population growth, reducing the pressure on land and other resources, and guaranteeing a continuous improvement of shelter/housing provision for the urban poor.

The next section focuses on the role of spatial planning in contributing for mitigation and adaptation at local level, through a broad review of current literature. The main attention is given to the influence of land use and physical development measures.

5.1 Spatial planning and mitigation

Urban form, land use and spatial planning have a great influence on the metabolism of the city, especially in relation to energy requirements. Considerable contributions to reducing energy demand can be achieved by shaping the build environment including design that promotes energy efficiency and maximising location and density to reduce dependence on private transport [Roy, 2009]. Different empirical studies have quantified the influence of transport, urban form and housing density on the resulting energy consumption and greenhouse gas emissions [Bertaud, 2009; Newman and Kenworthy, 1996; Newton, 2000; Norman et al., 2006].

Nevertheless, the overall understanding of the impacts of urban form and function on the biophysical process needs to be improved, with regards for example to implication of land use zoning, transport infrastructure, commodities and people flows in the total energy use and emissions [Sanchéz-Rodrígues et al., 2005]. To understand the linkages between urban form, models of urban development and the carbon cycle is essential, in order to simulate future paths of concentration of greenhouse gases in the atmosphere [Churkina, 2008: 107].

The influence of planning can be said to be related, for example, to both individual dwelling parameters (lot size, dwelling size, dwelling type) and to local area characteristics generally assumed to relate to travel behaviour (population density, physical proximity to activities, jobs/housing balance, land use mix, etc.). By considering for instance the energy demand and resulting greenhouse gas emissions, there is a strong relationship between dwelling characteristics and energy use and urban structure and transport-related energy use [Rickwood et al., 2008].

Measures at local/city scale through urban planning should consequently give attention to limit urban sprawl and control and limit the use of cars in city centres, as well as decentralising and multiplying service hubs, which will reduce the need for travel. Ways to achieve this are listed as follows [UNEP, 2009a: 47]:

- Limit urban sprawl: make this goal a priority in official urban planning documents; subsidise collective housing in city centres; subsidise the rehabilitation of unused or insalubrious buildings in city centres; discourage real state speculation in city centres (high housing tax for non-occupied building, office space in particular; use city and or state pre-emption rights to acquire land or building in town centres, for allocation to

affordable collective housing);
- Control and limit use of cars in city centres: develop pedestrian zones; develop bicycle lanes and parks; build car parks on city outskirts close to public transportation nodes; widen pavements, making them easy for everyone to use (handicapped, strollers, etc.);

The two main responses approaches should consider first the need for reduction of energy amount required by end use (focus transportation and buildings) and by reducing the carbon intensity of the energy supply, for example, increasing shares of renewable energy [McEvoy et al., 2006]. Therefore, as mentioned in section 3.2.2, policies concentrating in new urbanism and in achieving smart growth and compact cities would essentially contribute to greenhouse gas mitigations through urban planning.

Relationship between transportation emissions (related to amount of kilometres travelled) and urban design are summarised as follows [Ewing et al., 2008: 70f]:
- Density – higher persons, jobs and/or dwelling units per unit area;
- Diversity – greater mix of land uses to include residential, employment, and retail/services in close proximity to each other;
- Design – smaller block size or larger number of intersections per square mile, more sidewalk coverage, smaller building setbacks, smaller street width, more pedestrian crossings, more street trees;
- Destination accessibility – more jobs or other attractions reachable within a reasonable travel time; tends to be highest in urban cores;
- Distance to transit – shorter distance from home or work to nearest rail station or bus stop.

Bulkeley and Betsill [2005] also resume the planning policies related to energy use and hence to greenhouse gas emission. As the first way of addressing these parameters through planning, the reduction of need to travel is emphasised. This can be achieved by promoting development of inner-city locations and on previously developed land; by also promoting mixed land-use developments and by increasing housing densities [Bulkeley and Betsill, 2005: 76].

In order to reduce the number and length of motorised journeys, policies that locate major development where they are accessible to public transport hubs are necessary, in addition, it is important to include public transport, cycle and walking access for new development and restrict land-take for roads and parking.

Designing for energy conservation can be achieved by taking advantage of passive solar energy in the design of developments as well as include energy conservation standards for buildings in design guidance. Finally, include renewable energy is fundamental, as for example by promoting the use of combined heat and power (CHP) in development proposals.

Regional planning bodies should as well support the adoption of climate change policies that concentrate on increase resource efficiency in buildings and urban systems and promote land use that acts as carbon sink (forestry) [Crawford and French, 2008: 4576].

Indeed, spatial planning has a key role in the control of renewables and low carbon energy technologies for ensuring the availability of appropriate locations in new developments (and inclusion of on-site renewables in residential, commercial and industrial developments) [Bulkeley, 2006; Jackson, 2006].

Moreover, Wicken and Janssen [2006] discuss about further measures. These are related to an ecologically reasonable selection of specific land use area with regard to the use of solar energy and to the avoidance of energy losses. Also the impacts of heating needs for new development areas can be achieved through building codes/construction plan requirements (energy-efficient buildings, promotion of the use of solar collectors by favourable roof slope, minimisation of heat loss through acceptable building size and compact design, active and passive use of solar energy by choice of low shading location of the buildings to each other and plantings and green coverings). To give proper attention to local and district heating in new settlement (favourable decentralisation of supply), and in relation to transport issues, for example promote traffic control through area-wide parking concepts [Wilcken and Janssen, 2006].

The German Association of Cities and Towns (*Deutscher Städtetag*) in its position paper from 2008 lists the essential fields of activities for climate protection in cities, from the point of view of urban development planning [Welge, 2008]:

- Concentration of settlement activity in central locations;
- Preserving and strengthening the use of existing mixed uses, development of municipal structures of the short distances;
- Reduction of land use through the creation of compact settlement structures and controlled new development (inward and not outward development);
- Creation of an optimised supply network (e.g. heat);
- Consideration of energy-optimised architecture and design;
- Increased re-use of urban brownfield sites and empty buildings; renewal of spatially segregated areas and creation of housing near to public and private services;
- Preservation of open spaces near residential and recreational areas;
- Coordination of urban development with the needs of a favourable accessibility by public transport;
- Increase the share of public transport modal split by optimal networking, and make attractive paths for non-motorised transport;

Designation instruments for achieving some of these urbanite characteristics would be: determination of buildings' position, in particular by defining main or longitudinal orientation; designation of plot area to be built on, in the form of building lines and boundaries; determination of the degree of structural use; designations that avoid shading and that promote greening of part of settlements/facilities; designation for passive use of solar energy (south orientation); determination of CO_2 saving energy supply concepts (supply areas for CHP, supply lines), requirements for thermal insulation, among others [Welge, 2008: 8f].

As concisely listed in a recent study by the German Ministry of Transport, Building and Urban affairs [BMVBS/BBSR, 2009: 35], strategic priority areas for integration of mitigation and spatial planning are:

- Energy-saving, integrated urban and traffic development: quantitative and spatial control of settlement development; resource efficient transport.
- Spatial preparedness for climate-energy: spatial provision for the expansion of renewable energies (space compatible); spatial preparedness for the efficient utilisation of native energy sources; creation/support of regional energy concepts; spatial requirements for energy lines.
- Climate protective land use: permanent secure the strengthening of the CO_2 storage capacity (forestry).

5.2 Spatial planning and adaptation

Adaptation strategies in urban areas are beginning to gain momentum recently, and in fact also in relation to the role of spatial planning in achieving risk reduction and decreasing vulnerability. A vast literature on planning for natural disaster can be useful the planning for adaptation (see [Hamnett, 2006]).

Climate change impacts (sudden or gradual) have distinct spatial relevance. Considered of high relevance are river flood, landside/avalanche and storm surge, as well as the gradual sea level rise. Medium significance is given to gradual vegetation change and also to flash flood, drought, forest fire, extreme precipitation events and extreme heat waves. Spatial planning can only react to events that take place and bring change gradually [Fleischhauer, 2004].

One task of planning, regarding adaptation measures, would be to undertake assessment of vulnerabilities and risks to be felt by areas in danger and to link this appraisal to the existing capacities for adaptation. Additional measures are in the direction of decreasing vulnerabilities and risks by means of an spatial planning itself [Birkmann et al., 2007; Frommer, 2009]. A land-use planning that stays away from high-risks areas, transfer activities to other locations and, as a very important factor, that take into consideration low-income groups and the provision of safe sites for affordable land for housing should be encouraged and supported [Satterthwaite, 2008a].

Actions related to adaptation to climate change will require for example significant land for the provision of open space, used for instance for storm water management. Another option is to plan for larger river flood plains and to protect wetland in areas where severe storms are likely to increase. Additionally, changing building codes to reflect the need for more natural cooling and less contribution to the heat island effect. Communities also focus on adapting infrastructure and disaster plans to include forecasts for climate change [Hamin and Gurran, 2009].

Additional adaptation measures, as suggested by McEvoy et al [2006] are: reduce exposure of vulnerable places by hard and soft engineering, as well as reduce vulnerability of building materials and avoid ‘at risk’ locations; provide enhanced cooling without

loss of efficiency of winter heating systems; reduce exposure and provide cooling through green and blue infrastructure and plan for greater resilience of buildings and infrastructure and for storage and recycling of water [McEvoy et al., 2006: 187].

Frommer [2009] reviewed the influence possibilities of spatial planning to contribute to adaptation through formal and informal instrument. The instruments that have direct effect on the safeguarding of land would be:

- Designation of land for protection or to capture the consequences of natural events (at all levels of planning), which includes measures such as: free avalanche endangered areas, designation of priority and reserve areas for preventive flood control, etc.;
- Designation of areas to avoid or reduce the risks (all levels of planning), comprising for instance the relocation of dikes, water retention basins (protective), expansion of woodlands (development function) or ensuring the effectiveness of response mechanisms (keep free rescue lanes and collection points);
- Keep land free for fresh air supply (at all levels of planning).

Furthermore, indirect effects on land use management, that would usually make use of technical solutions and implemented through sector departments (initiative and coordination by regional planning) e.g., technical flood protection, securing of roads and transport infrastructure management, cultivation methods, crop variety and "good practices" in agriculture and forestry or forest management plans.

Another approach is based on the establishment of rules for municipal services and construction in vulnerable areas. In relation to design of settlements and to building/construction/development (local level planning), tools would include reduction of density (at land utilisation plan and buildings development plan levels[49]) and plants requirements, greening of facades and roofs, and rainwater reuse concepts (at buildings development plans levels). In relation to specific statements regarding building provision, there should be stipulation of certain building configuration (e.g. roof slope, prohibition of basement – also at buildings development plan levels) [Frommer, 2009: 133].

The study by the German Ministry of Transport, Building and Urban affairs [BMVBS/BBSR, 2009: 34], also lists the strategic priority areas for integration of adaptation and spatial planning:

- Preventive flood protection in river basins: securing existing and reclaiming new areas as flood retention areas; risk management in potential flood areas;
- Municipal climate change / bioclimatic impact zones: protection of critical infrastructure; protection of climate effective free space/compensation areas; spatial control of development of urban areas and infrastructure; green corridors/ fresh air lanes/green breaks; blue, i.e. water-bound areas in the settlement area;
- Regional water shortages: enhanced protection of water resources; support the preservation and improvement of ground water;

[49] In German: *Flächennutzungsplan und Bebauungsplan*

- Coastal protection: protection against erosion, flood protection; designation of flood-prone coastal areas behind levees;
- Change of tourism behaviour: location of new spatial planning, climate change-adapted tourism institutions and infrastructure;
- Shift in the habitats of animals and plants: regional and cross-functional security of a network of ecologically significant shared spaces; minimise further fragmentation.

5.3 Interactions, synergies, tradeoffs

As mentioned previously, one of the challenges faced by the international community and local governments is to combine both action towards mitigation and adaptation. In order to address both within the framework of spatial planning, it is therefore necessary to understand relations, conflicts, and synergies of the measures to be carried out.

Hamin and Gurran [2009] reviewed the current planning practices, at local level, that are related to climate change mitigation and adaptation in different cities (focus in coastal areas) in the United States, Australia and United Kingdom. These are summarised (based on sectors affected) in a matrix, including measures in the area of housing/infrastructure/economy, environment and community wellbeing.

Table 5-1. Practices related to housing, infrastructure and economy.
Source: [Hamin and Gurran, 2009: 242f]

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
Housing/Infrastructure/Economy	Housing/infrastructure	Increase home density and mixing of uses		■	■
		Assess location of and design of standards for existing and planned infrastructure and assess vulnerability to sudden or cumulative climate impact	■		
		Revise infrastructure capacity plan to take future climate scenarios into account, rather than historical weather events and adjust settlement thresholds accordingly	■		
		Identify and reserve location for relocation of major infrastructure and for new decentralised energy, water or waste management plants	■	■	■
		Prioritise new infrastructure that delivers multiple environmental services while serving basic settlement needs	■	■	
		Major developments should self provide basic infrastructure services (energy, water, waste) through strategies such as micro-energy generation, water retention, demand reduction technologies, reuse recycling, waste minimisation	■	■	■
	Water	Emphasise the protection of natural hydrological systems to improve their resilience to possible impacts	■		■
		Prioritise water supply options that are associated with minimal contributions to	■	■	

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
		climate change impacts, including water demand management strategies			
		Maintain space for flood and water retention in regions where rainfall patterns are likely to become more volatile	■		■
	Transportation	Design and reconfigure settlements to reduce need for trips generation and to maximise viability of public transport; assess the transportation impacts of major new developments	■	■	■
		Ensure that new settlements are accessible by all weather roads or alternative routes	■		
	Energy	Draft renewable friendly energy planning codes, so broader environmental benefits can be assessed with local impacts		■	
		Create planning requirements for major new development to preserve and utilise local resources and RE as much as possible, or provide offset payments to stimulate investment in local energy generation		■	
		Protect solar access to ensure that development retain capacity for onsite solar energy generation		■	■
		Enforce building and urban design requirements that minimise energy requirement and maximise thermal comfort	■	■	■
	Waste	Reserve local site to accommodate waste sorting, recycling and reuse, and requiring that major development include a sustainable waste strategy as condition of planning approval		■	■
		Establish provision for composting at site or neighbourhood level, reducing landfill and water needs		■	■
	Economy	Ensure that new tourism developments are not exposed to future climate change impacts	■		
		Improve climatic comfort of key destinations through climate sensitive urban design	■	■	
		Feature climate friendly design requirements for tourist development, appealing to eco tourism markets	■	■	
		Enable multifunction use of agricultural lands, provided that additional uses do not threaten the long term agricultural quality of land	■		
		Support planning policies that prioritises and foster local food production and consumption	■	■	■
		Protect wetland and require natural buffer areas between agricultural and waterways, to reduce impacts of flooding on marine life and fisheries	■		■

In Table 5-1, the authors put together the current practices being undertaken in regard to housing and infrastructure, water, transport, energy and waste and also economic measures, with their respective adaptation and mitigation effects, and their judgment whether potential conflicts exist.

Considering energy supply, for example, shifting to low carbon and decentralised sources is also considered an important adaptation measure, since it reduces risks related to power losses to occur in cases of severe storms or from peak power loads under temperature extremes.

Yet one of the mains points of conflict is related to urban densities. In order to minimise emissions from transport through densification, there occurs a loss of permeable surfaces and tree covers, and therefore flood and storm water risks increase. Another effect is the intensification of the heat island effect through more compact structures.

To deal with this conflict is not that trivial, and situations are also different from city to city. While it has been argued that densification is a key to reduce emissions from transport, other principles can be applied. These take into account urban design and form, for reduction of non-transport related energy use, and also mixed land use, destination accessibility and distance to transit.

Some of the principles of smart growth should be applied to reduce urban sprawl along with maintenance and enlargement of green surfaces and storm water retention areas. The preservation of urban forestry as a sink of carbon also has a positive mitigation effect.

Table 5-2. Practices related to the environment.
Source: [Hamin and Gurran, 2009: 242f]

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
Environment	Biodiversity	Use costal setback areas to reintroduce and restore local biodiversity, protect important vegetation and coastal habitat within an environmental protection zone or equivalent	■		■
		Connect habitat through dedicated habitat protection corridors	■		■
		Create planning systems incentives and requirements for new development to retain and restore local biodiversity	■		■
	Coastal processes and beaches	Protect low lying and exposed areas and reintroduce natural “soft” defence measures	■		■
		Prohibit development that threatens coastal processes or requires filling of wetland or mangroves. Requires referral to expert agencies for development in particularly vulnerable areas or of a certain scale	■		■
		Introduce environmental assessment requirements for areas where existing information is insufficient to determine the impact of potential development scenarios	■		

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
		without additional costly research			
	Natural hazards	Specify sea level/natural hazards threshold or indicators (by climate projects) as a basis for setting coastline building rules for setback/elevation/removal of building	■		
		Revise land-use designations and permitted building forms in the light of natural hazards assessment, informed by climate projections	■		
		Establish policy framework for re-situating land uses that may become unsafe or unsuitable in the future due to climate change	■		

Practices related to the environmental area, with strong attention to biodiversity, coastal processes and beaches and natural hazards, are shown in Table 5-2. In theory, amenity communities located in coastal areas do have rather an adaptation focus, and concentrate on biodiversity protection, with some effect of achieving reduction of density. This could bring some conflict between adaptation and mitigation. It is nevertheless important to keep in mind that processes are in general much more complex and need to be analysed in more detail in any specific situation [Hamin and Gurran, 2009]. Each community has also indeed to set priorities, and increasingly, adaptation measures will become more indispensable and inevitable than mitigation.

Health, quality of life and amenity, emergency management and governance have also been analysed in the frame of community wellbeing (see Table 5-3). Health practices are directly related for instance with the climatic conditions within the urban area. Measures aiming at reducing the urban heat island effect can at times conflict with actions for mitigation. Also here potential conflicts are related to measures that lead to a decrease in density, for example, open space, shadding and vegetation.

Table 5-3. Practices related to the community wellbeing.
Source: [Hamin and Gurran, 2009: 242f]

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
Community wellbeing	Health	Tailor urban and building design guidelines to local climatic conditions	■	■	
		Consider impact of planning requirements on potential for spread of water borne and vector borne disease	■		
		Require shading, shelter and appropriate vegetation to cool areas of open space and walkways or cycle paths	■	■	■
		Review design standards for manufactured home estates and caravan parks for safety and energy efficiency	■	■	

Area		Practices	Adaptation effect	Mitigation effect	Potential conflict?
	Quality of life and amenity	Increase costal setbacks and natural or soft defence measures through land use overlays and planned retreat zones	■		■
		Use natural restoration works to increase visitor and recreational opportunities associated with the area	■		
		Link walkways and areas of natural habitat and vegetation	■		■
		Use urban shade strategies to improve visitor facilities and outdoor amenity	■	■	
	Emergency management	Maintain space for emergency access, shelter and evacuation; reserve location for intermediate post emergency recovery (multifunction)	■		
		Weatherisation programme to reduce home energy use and improve resilience to storms for low-income families	■	■	
		Actively plan ahead for settlements reorientation or design following a major natural disaster, and ensure supportive land-use decisions	■		
	Governance	Mainstream climate change across planning and management decision. Adopt strong objectives for climate change mitigation and adaptation within statutory land-use plans	■	■	
		Collaborate with other local governments at regional level on future climate scenarios and potential responses	■		
		Establish effective and ongoing public involvement processes for identifying and prioritising mitigation and adaptation measures	■	■	

For instance, to cope with higher temperatures, increased cooling, if through air conditioning, will also lead to higher energy consumption. Building codes for optimised passive solar energy use and for consideration of renewable energy use (photovoltaic) requires right orientation, sunny locations and lower building. For achieving cooling through shading, rather higher buildings are appropriate. In this case, as buildings are also moderately high, and placed to achieve cooling through ventilation, a decrease in overall density occurs.

The analysis made by Hamin and Gurran [2009] can be seen as the begin of a systematic evaluation of conflicts and synergies between mitigation and adaptation, however, more detailed work is still necessary, considering the particular situations of every different urban areas. Their analysis concentrates in defining conflict between mitigation and adaptation whenever a measure achieves a decrease in urban density. It is not trivial to deal with this situation.

Increasing density *per se*, meaning also a proper use of resource land, sounds appropriate, but cannot be always recommendable. It should also not be taken as the only possible way to achieve emissions reduction at the spatial planning level. Great caution is necessary when balacing the decision between mitigation and adaptation, whenever such conflicts exist.

5.4 Proposed mitigation and adaptation measures

Building upon the existing reviewed literature, it is now necessary to compile, in a simple way, the mitigation and adaptation areas of action and goals. It is also proposed to divide the levels of influence by using a layered approach (based on [Storch, 2009]).

In this logic, the upper layer is related to the land use level; the middle layer to district/subdivision level, and the lowest layer comprise the housing/building level. Local plans or building codes, for examples, serves as tools able to provided the necessary designations.

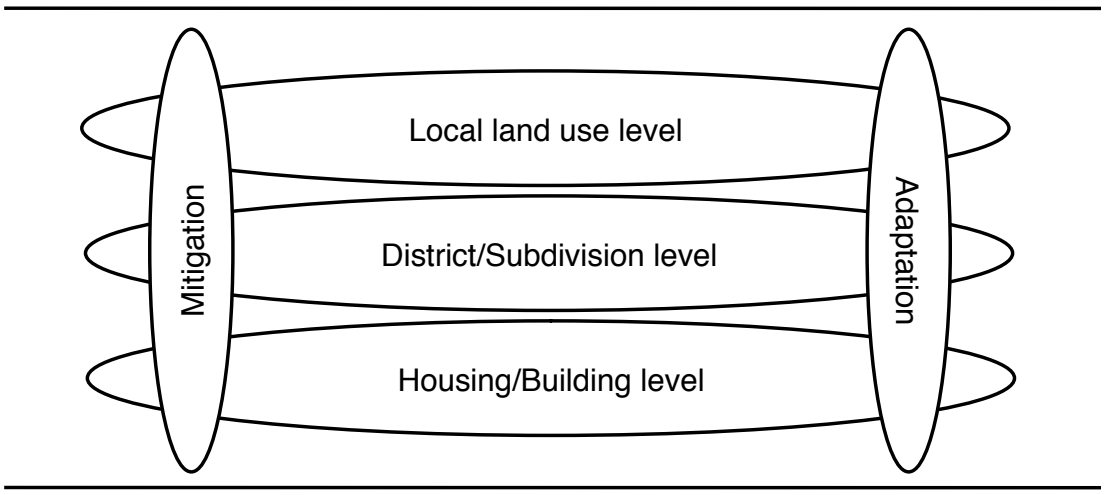

Figure 5-3. Layered levels of influence for mitigation and adaptation actions.

In summary, the role of spatial planning for the contribution to mitigation of greenhouse gases is based on the mentioned aggregated goals (see Figure 5-4). Further specific sets of measures and actions can be assigned to each category (see Table 5-4).

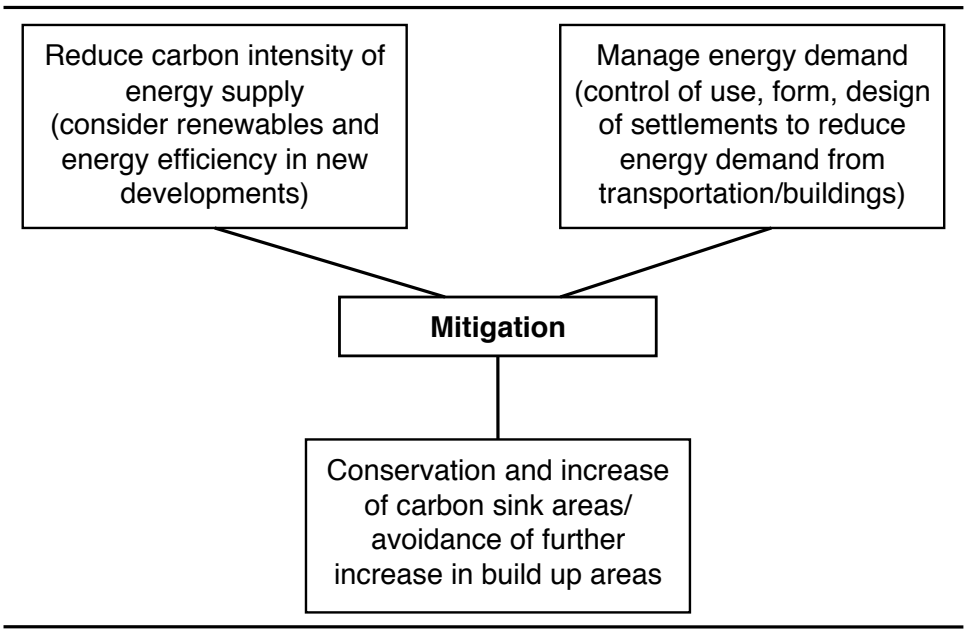

Figure 5-4. Simplified visualisation of spatial planning goals in relation to mitigation.

Table 5-4. Specific spatial planning fields of action/measures for mitigation. Summarised from diverse sources.

	Reduction of energy demand (transport, building)	**Consideration of renewables/energy efficiency**	**Conservation and increase of sinks**
Local land use level	- *Limit urban sprawl/avoid greenfield development)/reduce travel need* - Inward development/ brownfield recycle/ redevelopment, densification - Mixed land use	- Designations for spatial provision for renewables	- *Limit urban sprawl/avoid greenfield development)* - Preservation of green areas - Designation of new areas for urban forestry
Subdivision/ District level	- Mixed land use - Mixed building use - Densification - Accessibility/distance to transit considerations - *Design/architecture considerations*	- Consider provision of space for renewables in new developments - Combined heat and power (CHP) use; decentralisation of heat supply	- Assurance of preservation/creation of green areas
Building/ Housing level	- *Design/Architecture designations* (plot area/lot size, dwelling size/type, orientation, materials, insulation, solar passive use, etc.)	- *Design/Architecture designations* - For on-site renewables use in residential/commercial buildings	- n/a
In *italics* – higher aggregation level of action – further details not always included			

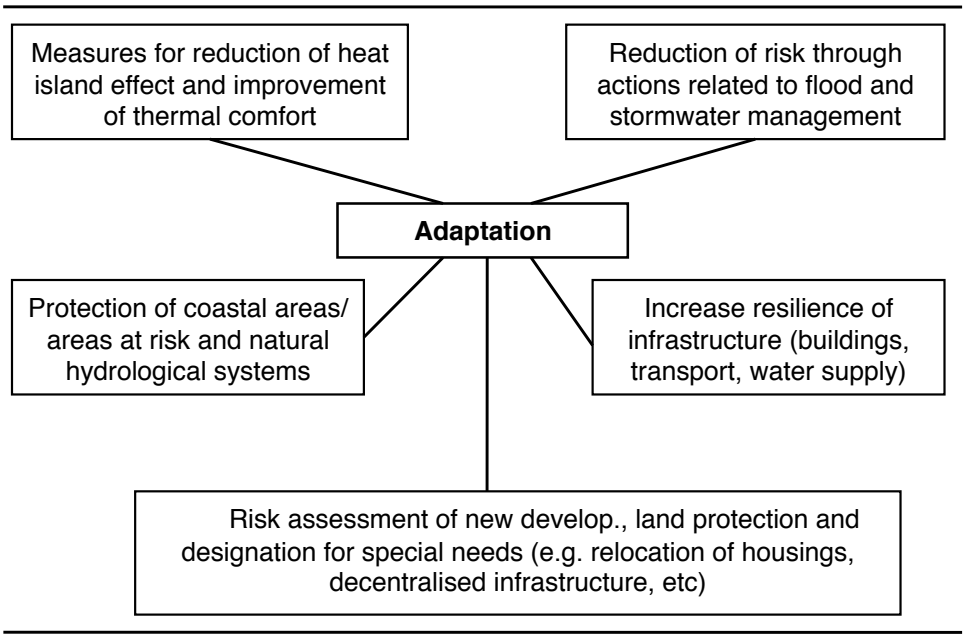

Figure 5-5. Simplified visualisation of spatial planning measures and adaptation.

Regarding adaptation to climate change, the categories/goals can be visualised in Figure 5-5. Also here, additional specific sets of measures and actions can be assigned to local land use level, subdivision/district/street block and building/housing/urban structure levels (as seen in Table 5-5).

Table 5-5. Specific spatial planning fields of action/measures for adaptation. Summarised from diverse sources

	Reduction heat island effect/therm. comfort	**Risk reduction/ flood managt.**	**Protection of coastal areas/hydr. systems**	**Land designation for special needs**	**Increase infra-structure resilience**
Local land use level	- Expansion/ preservation of green and open areas - Provide cooling through green and blue infrastructure	- Green and open areas - Wetland and river basin protection - Floodprone protection	- Avoid areas at risk - Protection against coastal erosion and flood	- Spatial provision for decentralisation of infra-structure and for relocation of housing	- Consider impacts (at planning level) to infra-structure (transport, energy supply)
Sub-division/ district level	- Same as above; - Reduce densification	- Same as above	- n/a	- Same as above; - Reserve areas for rescue lanes	- Same as above
Building/ housing level	- *Design/ Architecture* (building codes for natural cooling, etc.	- *Design/ Architecture* (roof slope, avoid basements, etc.)	- n/a	- n/a	- *Design/ Architecture* (building stability, rainwater reuse, etc.)
In *italics* – higher aggregation level of action – further details not always included					

The distinct interactions, conflicts and synergies, as mentioned previously, might vary according to specific local conditions. Yet some major rules can be applied, as seen from Table 5-6.

Table 5-6. Possible synergies and trade-offs of mitigation and adaptation measures. Summarised from diverse sources

	Synergies	Trade-offs
Local land use level	- Urban forestry (carbon sink, important for improving flood management and heat island effect) - Decentralisation of renewable energy use	- Compact form (for reducing energy demand) versus demand for large open and green areas (for e.g. flood management and control of heat island effect)
Subdivision/ district level	- Same as above	- Same as above
Building/ Housing level	- Appropriate design/architecture for improving thermal comfort can also achieve a reducing for cooling and heating need	- Conflict at some level: high/dense vs. low/loose form; (in regard to heat island effect, shadding for cooling/passive energy use, considerations for renewable energy provision)

This last analysis aimed at achieving a simplified compilation of the main areas of action where spatial planning (land use, urban form) can achieve mitigation and adaptation. It did not intend to be extensive, many other factors, as cited already in the first section of this chapter, can be further considered.

5.5 Summary and recommendations

Mitigation and adaptation at local level need to find a more integrated framework for action, and spatial planning, even if not fully understood and quantified, or considered at the international level, could serve as a good base for this integration.

Spatial planning goals for mitigation, as summarised from the current practices listed in the literature, have to concentrate on decreasing the carbon intensity of energy supply (including renewable energy in new developments) and also on managing energy demand through density, form and design of urban areas (decrease emissions from transport and buildings).

Adaptation measures require, in general, actions for managing the urban heat island effect, for adequate water management (flood and storm water) and for increasing resilience of infrastructure and buildings. Moreover, the suitable protection of coastal areas/areas at risk, and also for land designation for special needs hast to be considered (relocations, decentralised infrastructure).

Potential synergies and trade-offs have to be analysed and handled according to each specific circumstance. But in general, one of the areas of conflict between mitigation and adaptation is related to density and form.

Putting it in a simple way, while higher densities support the decrease in energy consumption from transport and buildings, more open, green and infiltration areas (leading to lower density) have a greater adaptation impact, for improving floodwater management and reducing urban heat island effect. In any particular case, also existing synergies should be explored, for example in relation to resilient building and urban forestry.

Hamin and Gurran [2009] tried to describe a harmonious combination of these in fact conflicting issues. It is thus recommended to promote the creation of urban form that is resilient and makes use of available resources in multiple ways. Especially in regard to buildings, good synergy points can be obtained, while promoting natural cooling and renewable energy. Concentration on high density should be avoided, moderate densities together with a carefully planned open space are a rather the preferable option.

Important for adaptation, the promotion of green spaces (e.g. along transit routes) penetrating the entire urban structure has also a modest mitigation (sink) potential. An overall protection of floodplains can also be linked to achievement of green/open spaces along these areas. This is certainly a very essential measure in reducing risks from flooding.

Based on these potential conflicts and synergies, it is not recommendable to analyse both issues in a disconnected way. It has been observed, however, that many strategies being developed currently emphasise one or the other view. In this light, it is also important to highlight that parallel to contributing to mitigation and adaptation, spatial planning is also assigned with other tasks. A proper integration of climate change issues, need also in fact to consider other synergies and conflicts with these main tasks of planning.

Further remarks, regarding the applicability to developing countries context can be taken from chapter 7.

6 Integrating and monitoring spatial planning and climate change issues

The previous chapter dealt with the influence spatial planning has on climate change mitigation and adaptation at the local level. It is again important to emphasise that there is no silver bullet receipt, and the development of strategies has a tailor made character, depending on the conditions of each city. The development of a specific strategy for integrating spatial planning and climate change issues, nonetheless, can be based on some key rules, which can be followed by most of the cities. First objective of this chapter is to briefly overview and discuss how such a strategy can be developed.

Moreover, once a spatial planning strategy that integrates climate change issues is in place, it is necessary to have indicators to help monitor the efficiency of measures being taken and assess the achievement of formulated goals. The second part of this chapter attempts to define which indicators or parameters could be helpful in making visible the impact of spatial planning decisions in reducing greenhouse gas emissions and also in helping to cope with impacts and reducing risks and vulnerabilities (therefore supporting adaptation measures).

6.1 Strategy development

As mentioned previously, spatial/urban planning has the potential of setting the base for an integration framework, which consider measures to achieve both mitigation and adaptation to climate change at local level, embedded also in the context of sustainable urban development.

But this is confronted with a set of difficulties, starting with the dichotomy that indeed exists between adaptation and mitigation in a broader level itself, going through the fact that the role of spatial planning has not yet been fully understood or quantified in relation to climate change issues, and also because of some intrinsic conflicts between mitigation and adaptation issues at the spatial planning level and of conflicts of those climate change issues in relation to broader goals of economic and social development [Alber, 2007].

Another challenge is that spatial planning concepts are different from region to region, and depend very much on specific local urban background. Furthermore, the planning tools and methods used are different, and the understanding of sustainability at the city scale also varies [Keiner, 2005; McGranahan and Satterthwaite, 2003; Storch, 2007].

Yet, to assure that a community/city is able to integrate spatial planning and climate change issues a strategic framework is needed. Based on recognised decision-making and strategic approaches, some planning guidance can be formulated, to support cities in this integration. Many cities already use such processes for example within the Local Agenda 21 framework.

First, the well-known strategic cycle for management/planning processes can be applied. It foresees, in general, the establishment of a vision followed by the implementation of action and monitoring of measures efficiency. Based on this evaluation, it also involves a feedback into the established vision, for the sake of continuous improvement and eventual reformulation of goals. The concrete process can be simplified as illustrated in Figure 6-1:

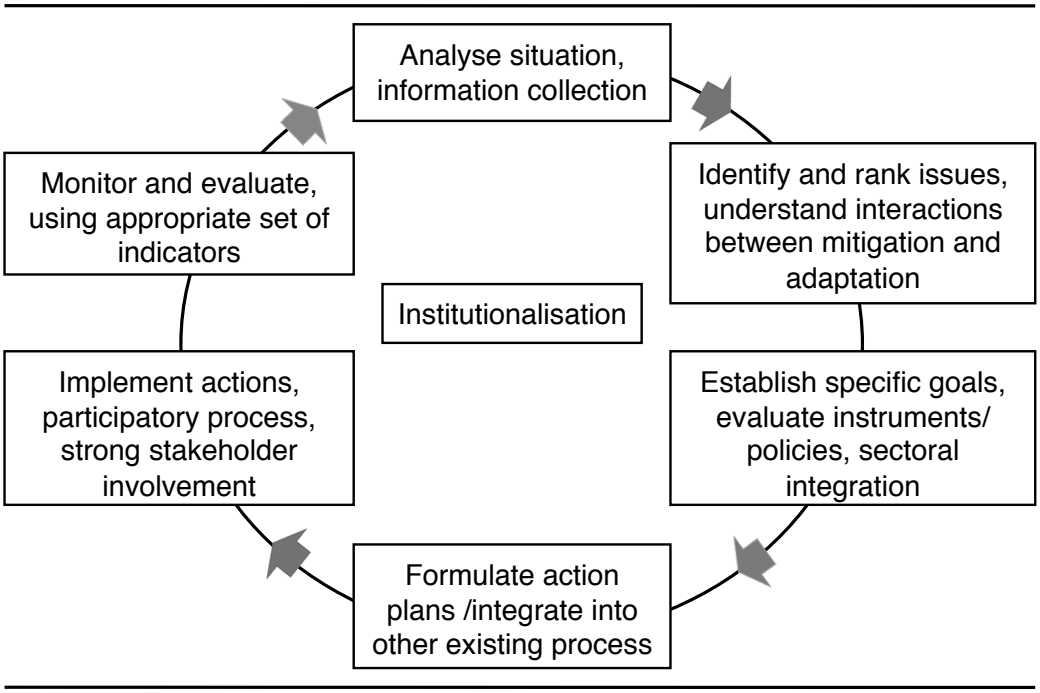

Figure 6-1. Strategic and participatory decision making-process cycle.
Source: Adapted from [Frommer, 2009; Meyrick and Meyrick, 2002; UN-HABITAT/UNEP, 2003]

In all steps of such a process it is necessary to guarantee a general and continuous awareness raising, capacity building, and stakeholders participation in all levels. The institutionalisation of the decision-making procedure is also crucial for the future viability of the method.

Coming back to the development of a Local Agenda 21, an example of a related process is visualised in the so-called Agenda-house in Figure 6-2. The pillars define the different steps required to assure the accomplishment of the agenda. Always based on determined principles and goals, it involves the performance control through the comparison of actual situation in relation to a certain defined target. The protective roof is responsible for supporting and securing the entire process.

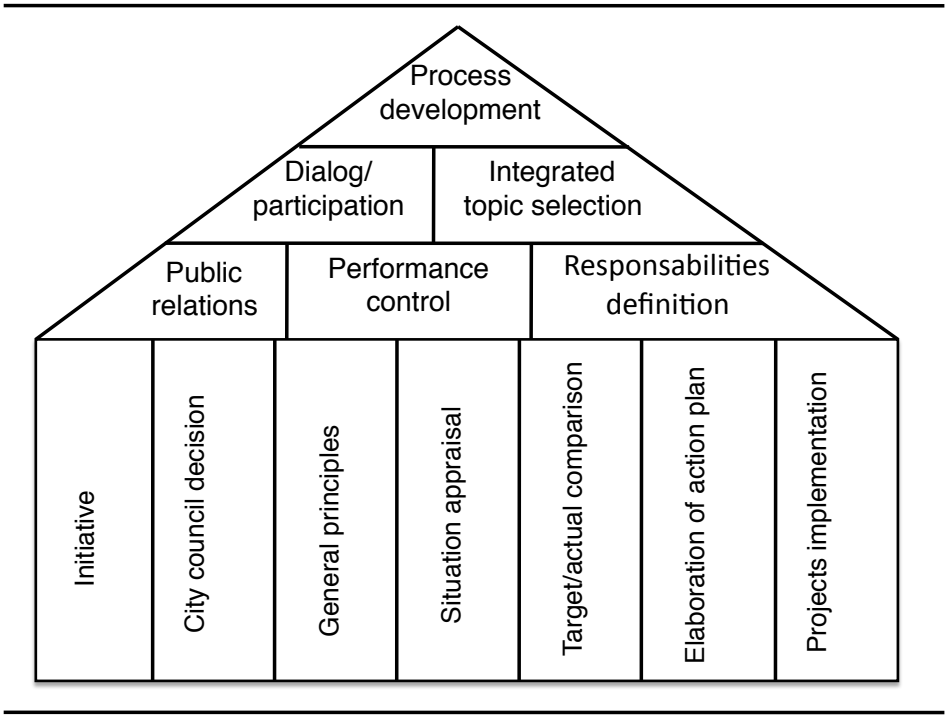

Figure 6-2. Local Agenda 21 house.
Source: [Gather and Habenicht, 2001]

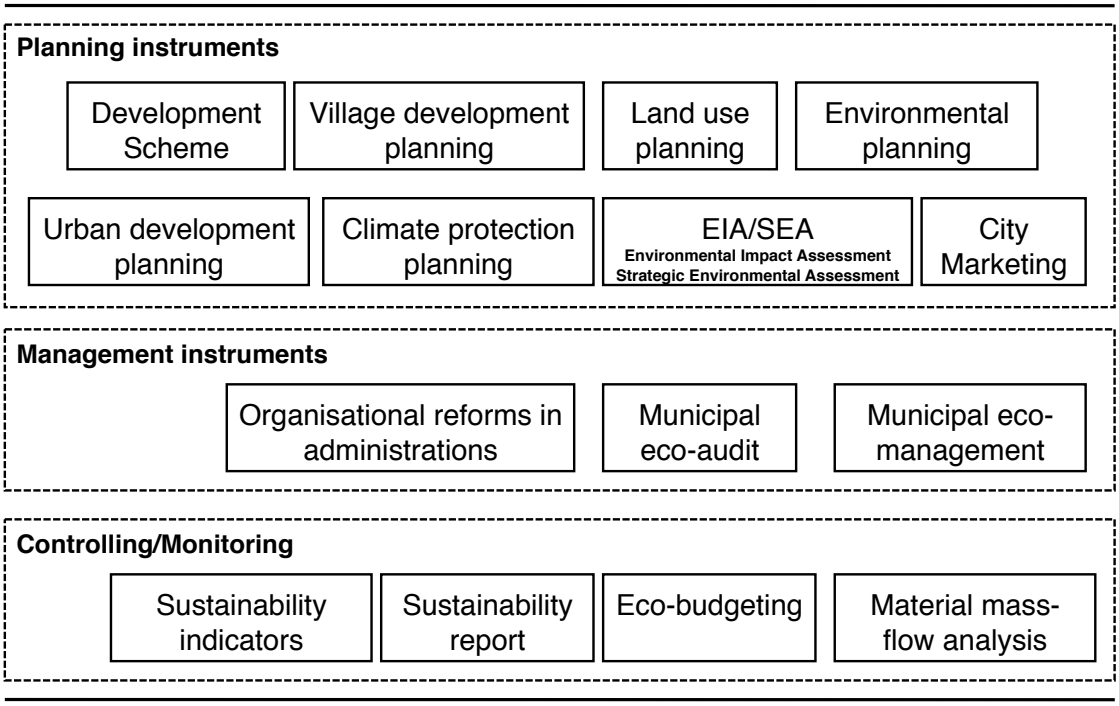

Figure 6-3. Local level planning, management, controlling/monitoring instruments.
Source: Based on [UBA, 2002]

The development of a Local Agenda 21 process also occurs with interactions with many different planning, management and controlling/monitoring instruments (See Figure 6-3).

It is necessary to point out that, in fact, land use, environmental, urban development and climate protection planning are intrinsically correlated to each other, and yet none of them alone can substitute the Local Agenda 21 process. As most of the instruments offer potential for supporting sustainable development on the municipal level, they also have to be taken into account when considering the integration of spatial planning and climate change concerns. To achieve a better framework for the overall planning and management process of local governments is required, together with an adequate and integrated use of all instruments [UBA, 2002].

If a city is preparing to take decisions that can influence spatial planning and climate change issues at the local level, it is surely decisive to take into consideration a broader external context. Regional or national polices and instruments might at times incapacitate them to implement higher leverages options, or be source of incentives. To such external conditions also belong further legal, economical and political factors, as well as social, physical/ecological and cultural concerns.

With regard to the internal context of strategic planning, there is also a need to consider the planning culture within the community, the role of initiators and promoters, further micro-political influences and available resources and capacities [Frommer, 2009].

It is also important to not initiate or execute such a process isolated from correlated and interfaced sectoral issues or from other process that might already have been implemented (such as the mentioned Local Agenda 21 process, or, if applicable, the Sustainable City Programme, the City Development Strategy, or Climate Action Plans).

The strategic integration of spatial planning and climate change issues requires, as already explained, a constant monitoring of the achievements. Indicators, as a controlling/monitoring instrument, are an integral part of the process structure.

6.2 Indicators set development

This section is dedicated to an overview on indicators basic knowledge. Moreover, it also accomplishes a simplified assessment about required data to measure progress achievement, once a strategy/process has been initiated. This assessment is first based on the analysis of existing indicators sets.

Indicators are indeed a quite broad and far-reaching subject, and the following analysis does not intend to reach completeness. Rather, it aims, to a certain extent, in gathering information and setting an initial discussion on spatial planning and climate change indicators.

6.2.1 Basics on indicators

The use of monitoring has different purposes, mainly the observation, controlling and also development assessment of issues and processes. The goal of a monitoring system is to capture initial conditions and the trends of progress, to describe and illustrate those, and to make facts available for interpretation, as well as to provide basis for planning and political decision-making processes [Birkmann, 2005]. All the required data is collected in form of indicators.

As there are numerous initiatives working with development and use of indicators, there are various and heterogeneous definitions for it. For instance, indicators are defined as "*a parameter, or a value derived from parameters, which provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value*." [OECD, 2003: 5]. Or another definition is given as: "*An indicator quantifies and simplifies phenomena and helps us understand complex realities. Indicators are aggregates of raw and processed data but they can be further aggregated to form complex indices*." [IISD, 2002]

In economic and social sciences, the use of indicators has a rather long history. Yet indicators of environment and sustainable development recently started to gain importance, since the Conference on Environment and Development in 1992 in Rio de Janeiro and with the establishment of the Agenda 21. This process foresees, as stated in Chapter 40, the development and promotion of global use of indicators for sustainable development. One of the tasks is to support decision-makers at all levels in the formulation of appropriate policies [UNCED, 1992].

In fact, indicators are also used to directly connect different set of data/measurements to policy issues. Indicators are therefore a valuable tool in the prospective sense, for policy making and also in the retrospective sense for assessing policy implementation effects [McCarney, 2009: 25].

But they also have further functions and purposes, depending on the target audience:

Table 6-1. Indicators characteristics according to target audience.
Source: [Maclaren, 1996] cited in [Ditor et al., 2001]

Target audience	Indicators/Data format
Professional analysts, scientists	Raw Data; highly detailed and complex indicators; emphasis on scientific validity and system complexity
Policy-makers	Indicators directly relate to: policy objectives, evaluation criteria, target values
Media, general public	Reduced set of indicators; easy to understand, represent issues of direct concern

Indicators are also important in the involvement of stakeholders, to support participation, communication, for initiation of discussions and for awareness raising [Fraser et al., 2006].

In summary, indicators are useful for understanding problems (helps to identify relevant aspects, current position and progress), in order to make decisions (define goals, recognise demand for action, benchmarking), for controlling (monitor, interpret, steer), for motivation (participation, communication, initiate discussions) and for solving conflicts (coordination, mediation). There are also different levels of application, strategic level, concept/programme level and project level [Carabias-Hütter and Renner, 2004].

As indicators can be used within distinct analytical levels, depending on the structure and goal of a monitoring system, different frameworks can provide the support for the development of an indicator set.

First, from the way sets of indicators can be developed, there are top-down and bottom-up approaches. In the first case, general scientific models or social goals influence the deduction of indicators. In the second one, the indicators are based on a situation description at small scale, or constructed upon available data sets. In practice, it is not possible to completely separate both processes, and, at different phases of an indicator set development, either one or the other approaches can be used [Gehrlein, 2003].

Another framework is related to the systematic of differentiating or aggregating issues and themes [Gehrlein, 2003; Stegnestam, 2002]. As a result, for example sustainability indicators have generally been analysed in social, economic, ecological, institutional dimensions separately. Thematic indicators have greater ability to be linked to the policy process and targets [UN-HABITAT, 2004].

Indicators can be developed and selected as reference/target ones. Therefore they are used for a direct assessment or evaluation. Analytical/descriptive indicators (reference indicators) give neutral information about a situation or a process, while the normative indicators (target indicator) describe the actual condition in relation to a desired goal. For instance performance or distance-to-target indicators are a variation of such normative approach, which assume a defined target is existent [Gehrlein, 2003].

An additional distinction is related to project or system based indicators. A project-based framework, also found in the literature as input-output-outcome-impact framework[50], is used to monitor the success and effectivity of projects or programmes, while a system-based approach focus on a much more broader and less detailed level, such as global, national or local systems as a whole [Stegnestam, 2002].

Further, indicators also have causality and effects correlations, and can be analysed within this causal-based lens. A first version of such a framework is based on pressure-state-response (PSR) indicators.[51] It has evoluted to the driver-state-response (DSR)

[50] Input indicators: monitor the project-specific resources provided; Output indicators: measure goods and services provided by the project; Outcome indicators: measure the immediate, or short-term results of the project; Impact indicators: monitor the longer-term or more pervasive results of the project [Stegnestam, 2002].

[51] As developed by the Organisation for Economic Development and Cooperation (OECD).

framework,[52] with the replacement of pressure by driving force and then, with the addition of impacts, to a driver-pressure-state-impact-response (DPSIR) indicator.[53]

The correlation between these aspects can be seen in Figure 6-4:

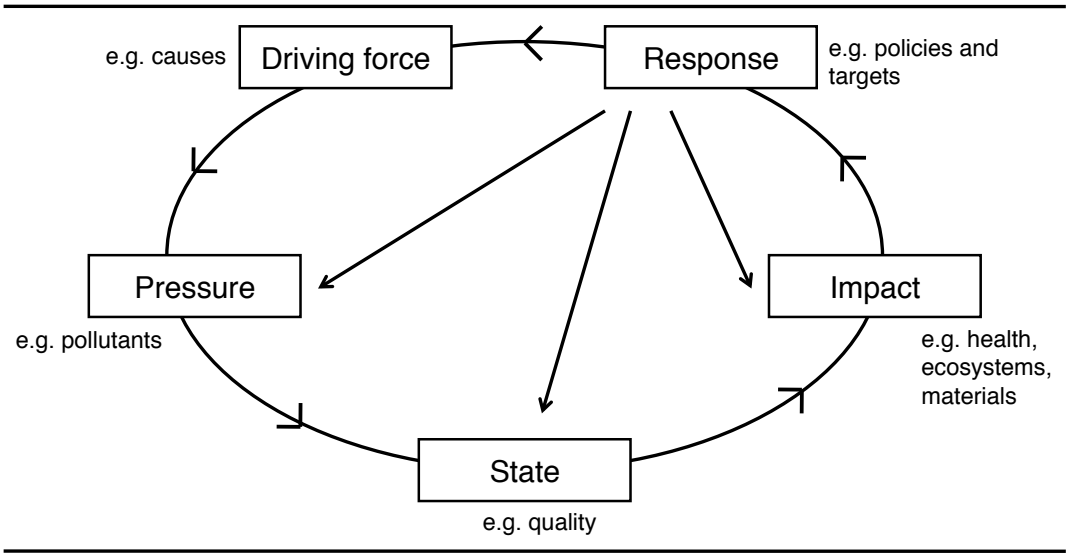

Figure 6-4. The driver-pressure-state-impact-response model.
Source: [Gabrielsen and Bosch, 2003: 8]

In principle, pressures are related to human activities that, exerting load on the system, are the reason for occurrence of problems. Examples are income growth, trade pattern, energy, industrial, and transportation activities. State indicators involve observable changes as results of the pressure, being qualitivative or quantitative and measured at a specific time. For instance, air and water pollution, soil erosion are state indicators. And responses measure to which extent action (policies, investments, information, etc) is being taken to address the changes. Drivers or driving forces indicators have a broader use than pressure ones, since it involves not only environmental but also social, economical and institutional issues and are related not only to negative impacts but also to relieving forces. Impact indicators are used then to capture influences of change in environmental quality [Gehrlein, 2003; Stegnestam, 2002].

The European Environment Agency also uses a classification of indicators into following types: descriptive, focusing on what is happening; performance, to measure if targets are being reached; efficiency, to determine if improvement is being achieved; policy effectiveness, to determine if taken measures are effective, and total welfare indicators, that concentrates in measuring total sustainability as a balance of economical, social and environmental development [Gabrielsen and Bosch, 2003; Stanners et al., 2008].

[52] As developed by the United Nation Commission on Sustainable Development (UNCSD).
[53] As developed by the European Environmental Agency (EEA).

Additionally, it is also important to discuss about the criteria and requirements that indicators set need to have. Based on different compilations [Ditor et al., 2001; GCIF, 2009; Natcap, 2007; WorldBank, 2007] following criteria can be cited:

(1) Objective, relevant: well defined, precise, simple to understand, concentrating on clear problems and directly related to the objectives;
(2) Measurable, replicable, verifiable: quantifiable, statistically accurate and scientifically consistent, data availability over time should be given, and third-party verification should be possible;
(3) Flexible: accommodate continuous improvement and modification on what is measured and how;
(4) Effective and result oriented: tool in decision making and in planning and management and that can focus on measurement of the effect of the actions taken
(5) Cost-effective: relatively inexpensive to monitor without diminishing the effectiveness or quality of data;
(6) Interrelated: indicators should be constructed in an interconnected fashion (social, environmental and economics).

6.2.2 Methodology for indicators investigation

After the introduction about definitions, purposes, frameworks and criteria for indicators, it is now necessary to set the frame of how the analysis of existing indicators will be performed. The choice of sets is not trivial, since there is a vast amount of approaches available.

It is advisible to include and start the analysis with the indicators mentioned previously (OECD, UNCSD, EEA) as they are recognised and used internationally. Additional indicators, also used at the international level, but designed for specific urban issues have been selected as well. And to support a more complete overview of the investigated issues, further relevant indicators should also been included. Table 6-2 lists the set of indicators analysed (for each set, summarised information as well as the indicators in extenso are found in the Annex).

Table 6-2. List of analysed indicators sets.

Indicator	Reference
Core Environmental Indicators (CEI) – OECD	[OECD, 1993, 2003]
Key Environmental Indicators (KEI) - OECD	[OECD, 2003]
Sectoral Environmental Indicators (SEI) – OECD (energy, transport, household consumption)	[OECD, 2003]
Indicators of Sustainable Development (UNCSD)	[UN, 2001, 2007]
Core set of indicators (EEA) (climate change, urban environment, household consumption)	*(internet sources, see annex)*
Global Urban Indicators Database (UN-HABITAT)	[UN-HABITAT, 2004]
Healthy City Indicators (WHO)	*(internet sources, see annex)*
Global City Indicator (WB)	[GCIF, 2009]
Environmental Sustainability Indicators (MDG7/UNEP)	[CitiesAlliance, 2006: 131]

Indicator	Reference
Outcomes Sustainability Indicators (King County)	[Miller, 2004: 119f]
Sustainable city indicators (Santa Monica)	[SantaMonica, 2006]
"Cities of the future" Indicators *(Städte der Zukunft - BBR)*	[Fuhrich, 2004]
Development/master plan elements and sustainability indicators	[Alshuwaikhat, 2003]
Spatial Planning Output Indicators (RTPI)	[RTPI, 2008]
Sustainability indicators - multi-layered urban typologies	[Storch, 2007]
INDEX Indicators	[Allen, 2008]

For the decision on how to screen the indicators, it is important to understand the given relationships. Figures in chapter 5, as well as Figure 6-5 attempts to provide a better visualisation of the relationships between the different elements (last one puts a special attention to the effect chain related to climate change).

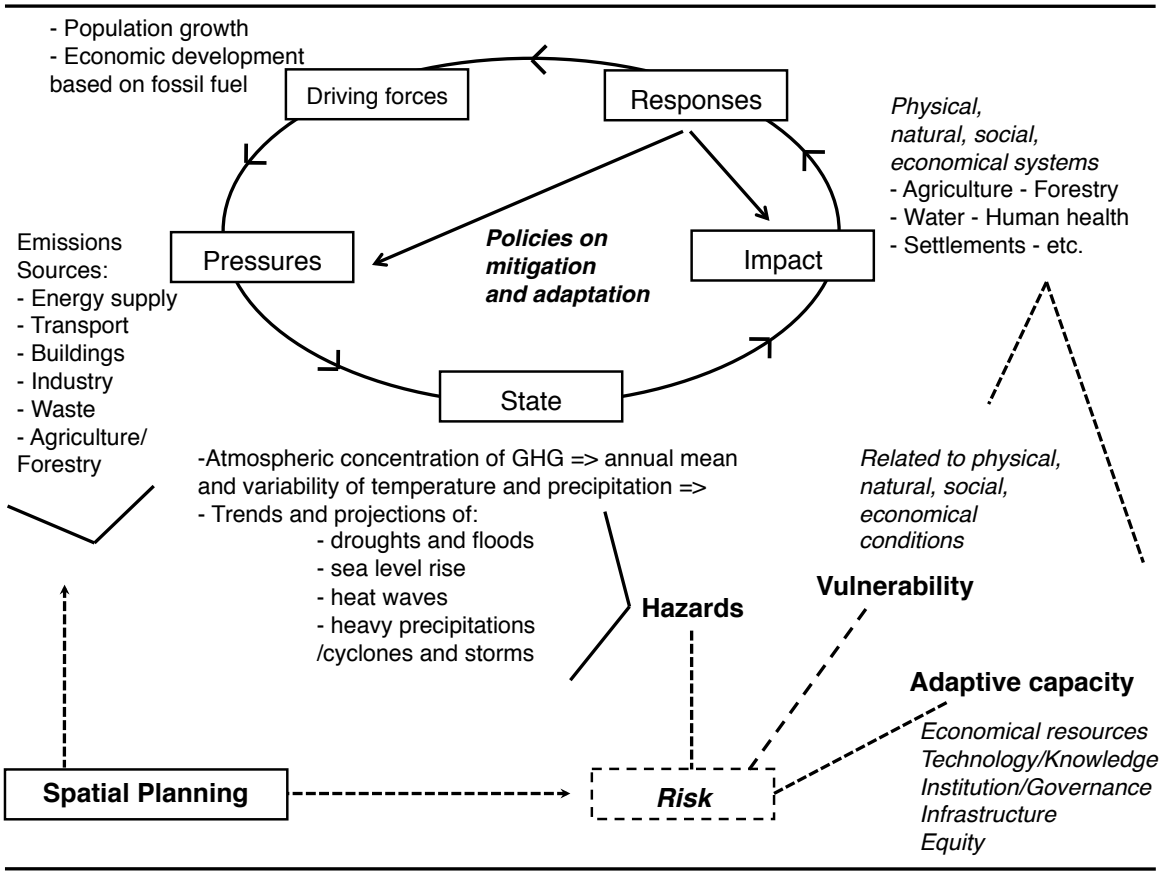

Figure 6-5. Simplified DPSIR model for climate change.

All in one, the different sectors, and the environment as such, are in this relationship also represented in interrelated. Concurrently, as discussed before, spatial planning has the chance to influence mitigation in the energy, transport and building sector, but also has a great potential in relation to adaptation as it can help reduce the risks (related to vulnerability and/or to adaptive capacity) for example in relation to land and water issues. There exist also an interface to natural resources and ecosystems and to in particular to social/economical issues, for instance related to the urban poor.

Therefore, considering each of the selected indicators set, those parameters related specifically to climate change and to spatial planning, land-use or urban form, have been screened. As spatial planning also is influenced by and influences other sectoral planning, which in their turn, have influence on the environment, further purposely sectoral and environmental indicators can also be relevant. And as already mentioned, information in relation to urban poverty (economic or social conditions, related to adaptation – vulnerability, adaptive capacity) have also been collected.

6.2.3 International indicators

As previously mentioned, the starting point of this section is an analysis of the existing systems at the international level. Different environment and sustainability indicators [OECD, 1993, 2003; UN, 2007] are directly or indirectly linked to the diverse set of urban/city indicators currently available.

This section aims at reviewing, first these indicators set, and further, some different city/urban indicators used at international level, in order to identify, from the available indicators, possible relevant ones related to spatial planning and climate change (as explained previously).

Core environmental indicators (pressure-state-response) developed by the OECD are further grouped into different issues. Goal is to track environmental progress and performance and the core set of about 50 indicators reflecting the main environmental concerns in OECD countries. Climate change and urban environmental quality are the issues of greater interest for this work. Also sets of key environmental indicators (for public information), and sectoral environmental indicators (promoting integration of sectoral policies, transport, energy, households consumption), all being intrinsically linked, have been developed [OECD, 2003].

Furthermore, the United Nations Comission on Sustainable Development (UNCSD) framework, recently reviewed, focuses on social and economical issues, based on the process of the Agenda 21 on encouraging international, governmental and non-governmental organisations to develop indicators also to provide a solid base for decision making at all levels [UN, 2007].

The European Environmental Agency (EEA) has also developed extensive indicators methodologies in all relevant environmental areas, or sectors and activities. Issues of climate change, household consumptions, and urban environment, among others, are therefore of interest for this work.[54]

After reviewing these frameworks focusing on the spatial planning/climate change background, it becomes clear that some (yet limited) direct entry points serve as indicators that could be downscaled and interrelate national to local issues.

For instance, the OECD framework (core environmental indicators) consider the issues

[54] For more information: http://www.eea.org

of climate change and of urban environmental quality, and the UNCSD indicators also bring atmosphere and land themes with sub-themes such as climate change and land use and status, and in relation to patterns of consumption, it refers to the sub-themes energy use and transportation.

The OECD sectoral environmental indicators on energy and transport refer directly to land use and air pollution. Household consumption's set considers the residential energy consumption intensity and structure and also the direct use of land resources/space and protected areas (land covered by urban development, land use patterns, land used for recreation, access to green areas). Also the EEA indicators deal directly with climate change, urban environment and household consumptions issues, with similar parameters.

As a matter of fact, the indicators found are able to provide a picture, at least on the global level, about overall emissions of greenhouse gases, about energy use for transport or households, and at times for driving forces such as population growth and economic development. They also can give some information about the total land used for energy or transport systems, and the land covered by urban development and green areas. Nevertheless, to find real correlations (especially responses) from mitigation of climate change and adaptation to its impact cannot be expected from these frameworks.

Moreover, many other different sets of indicators have been developed at the international level, which put attention on monitoring issues related to cities. The analysis continues with these indicators set specifically developed for the local/urban level.

The United Nations Centre for Human Settlements (UNCHS/UN-HABITAT) has been a front-runner in the development of urban indicators. As it started the Housing Indicators Programme monitored shelter performances. Later it became the Urban Indicators Programme (1996) and focussed on broader urban issues. The Global Urban Observatory (GUO) has been then created to help in the development of a global monitoring of progress for the implementation of the Habitat Agenda. Overall data should be collected and analysed by national statistics offices, ministries responsible for urban issues, city and metropolitan authorities and the research community. Indicators are divided into following topics: shelter, social development and eradication of poverty, environmental management, economic development and governance (20 key indicators, 13 extensive indicators and 9 check-lists) [UN-HABITAT, 2004].

Also the World Health Organisation (WHO), as they started the Healthy City Programme[55] in 1992, established, after revisions, a set of 32 urban indicators, which have already been used by many cities worldwide to describe health. The programme put emphasis on participatory governance, urban poverty and health inequalities, the

[55] For more information: http://www.euro.who.int/healthy-cities

needs of vulnerable groups and the social, economic and environmental determinants of health. It also attempts to incorporate health considerations in economic, regeneration and urban development efforts. Indicators are divided into issues related to health and health services, but also compile environmental and socio-economic indicators.

Moreover, building on the work by UN-HABITAT, the Global City Indicators Programme (GCI) also aims at supporting cities in monitoring their performance. The initiative has started as a way to tackle the lack of standardisation related to the many indicators available to assess city performance. Led by the World Bank, and based on a bottom-up approach, it has structured its 53 indicators around 22 themes divided into two broader categories, city service and quality of life (27 core and 33 additional indicators) and a detailed methodology to collect the indicators ensure the comparability of reported results. [56]

Proposed by Cities Alliance, ICLEI and UNEP, a set of 19 simplified indicators on sustainability has been developed based on the Millennium Development Goal number seven, on environmental sustainability, and on current work by UNEP on city environment assessment methodology. Each of 19 indicator can be used either as benchmark, baseline or target [CitiesAlliance, 2006: 131].

Additional international initiatives working in defining and developing urban/local level indicators do exist, yet it has been decided to restrict the analysis to these selected ones.

In this analysis, it is interesting to observe that in all sets, the specific mention of land used for energy, transport or household (built up land) does not occur, yet the amount of green area (per habitant or relative to total surface of the city) is referred, as well as the land use change from non urban to urban. Shelter, housing and poor households are in all frameworks strongly represented, this being one of the most relevant issues indirectly related to adaptation, since it address the most vulnerable, the urban poor.

It can be said, however, that also these international indicators only offer some entry points for addressing the issues of spatial planning and climate change. The links and relationships, if based only on the suggested parameters, cannot be fully understood, and therefore, analysing further specific sets of indicators might bring further support.

As a recapitulation, Table 6-3 shows the relevant (direct and indirect) indicators related to spatial planning and climate change, from the different categories of indicators analysed up to now.

[56] For more information: http://www.cityindicators.org

Table 6-3. Identified relevant indicators within international sets of indicators. Based on different listed indicators sources

Issue	Indicators
Climate change	- CO_2 emissions intensities - Index of greenhouse gas emissions - Atmospheric concentration of GHG - Global mean temperature - Transport emissions and emissions intensities - Energy emissions and related intensities - Residential energy use emissions
Land/Land use	- Green space (area protected from urban development) - Public access to green space - Use of land resource and space (urbanisation: land covered by urban development; land use patterns and conversion in sensitive areas; land used for recreation; access to green areas in cities - Land use change/land degradation - Land use change from non-urban to urban - Change in land use by transport infrastructure - Public transport network cover; pedestrian streets - Land taken up by energy production, transport, transformation - Green area per 100,000 habitants - Housing in hazardous locations - Reduction of land covered by forest and woodland; loss of natural vegetation cover and green areas - Area of informal settlements as a percent of city area - Planned settlements - Latest approval date of master plan
Transport	*- Final energy consumption by the transport sector, trends and intensities by mode* *- Transport emissions and emissions intensities* *- Change in land use by transport infrastructure* *- Public transport network cover; pedestrian streets* - Road network length and density - Urban traffic density - Transport modes - Kilometres of transportation systems per 100,00 habitants
Buildings	*- Total housing energy consumption* *- Residential energy use emissions* - Living space
Energy	*- Land taken up by energy production, transport, transformation* *- Energy emissions and related intensities* *- Sectoral end uses; total primary energy supply by fuel type; energy produced nationally*
Other (driving forces)	- Population growth and density - Urban population growth - Degree of urbanisation - Household size, population structure
Other (vulnerability, adaptive capacity)	- Durable structures, secure tenure - Proportion of city residents without access to secure tenure - Percentage of population living in substandard accommodation - Percentage of population living in slums - Percentage of population with access to sanitation, drinking water, energy - Vulnerability to natural hazards
In *Italics* also related to other issues.	

6.2.4 Other relevant indicators

A myriad of regional and local governments have developed specific indicators sets that not only focus on the environmental issues but also, for a more complete view of sustainable development, include social and economical matters as well. Many of them indeed compile indicators from the international frameworks already discussed. But still some of them bring specific issues not analysed in depth in those previous indicators sets.

In the United States, for instance, the metropolitan Seattle/King County in Washington, developed indicators focusing on following outcomes: economic development, environment, affordable housing, land use and transportation [Miller, 2004].

Also in Santa Monica, a community in California that has a longer tradition with the use of sustainability indicators, the themes addressed are: resource conservation, environmental and public health, transportation, economic development, open space and land use, housing, community education and civic participation, human dignity (in line with an overall strategy and specific targets in each category).

In both cases, land use analysis appears, as expected as a key parameter within the indicators set. Furthermore, transportation and housing are also considered. In this sense, indicators such as land cover changes in urban and rural areas over time, new housing units in urban areas, new housing units through redevelopment, ratio of land consumption to population growth are used.

Moreover, open space area (and open space area that is permeable), percent of canopy coverage by neighbourhood, percent of residential, mixed use projects that are within certain distances of transit nodes, among others, are also important indicators that concretely bring the issues of land use/spatial characteristics that are important for mitigation and adaptation to climate change. Indirectly, relation to urban form and function is also given by energy consumption in the different sectors (transport, households).

Developed by the German Federal Office for Building and Regional Planning, the “Cities of the Future” also has the goal of providing guidance for local practices. It formulates specific strategies on 5 topics (land management, mobility management, environment protection, housing supply and economic development), also providing an indicator-based framework for measuring success towards sustainable urban development. The specific standard indicators related to land management are: settlement and traffic area, intensity of land use, protected areas and re-use of brownfield sites.

Alshuwaikhat [2003] compiled the most important indicators related to urban development/master plans, divided into elements of land use, transportation, environment, infrastructure, urban design, housing, energy, economic development and population. They can be seen as a very suitable baseline, since include themes such as urban footprinting, use mix, infill, land redeveloped, open space and natural area protection, housing density.

Specifically designed to evaluate planning outcomes, developed by British Royal Transport and Planning Institute, the indicators listed are directly related to the five objectives attributed to planning, and bring together issues such as loss of protected area, change in area of parks as green spaces, change in urban carbon footprint, change in commuting mode.

The trend of land-use change and the resulting land consumption can be monitored in terms of spatial structural distribution, a system of activity centres and use densities and the patterns of interaction (commuting). The set of indicators developed by Storch [2007] is structured into four different layers: physical structure; urban land use patterns; public infrastructure patterns; and social sciences and human geography. Especially related to compactness, useful indicators are cited, such as floor area/height; build up ratio, block size and shape, structure of the street network and multi-functionality and mixture usage.

As a software tool, INDEX works with indicators for assessing current land use and transportation conditions and evaluating alternative courses of action in a neighbourhood, community, or region (based on alternative scenarios). The set is divided into following categories: demographics, land use, housing, employment, recreation, transportation and environment. A good part of the indicators exhibit sufficient linkages to the spatial planning (land use, housing, transport) issues.

A last different category has been analysed, with indicators proposed specifically to measure progress towards sustainable development and climate change [UNDSD, 2008] . Taking as a starting point the UNCSD indicators set, the framework includes mitigation and adaptation, but also financing and technology. If no UNCSD indicator is available for a given class, a related or new indicator is recommended. This set of indicators has a rather lower relevance in relation to spatial planning issues. But as it concentrates on the causes of and impacts caused by climate change, at the local level, their assessment, whenever possible, is recommendable.

In summary, Table 6-4 shows the most relevant indicators identified in this second analysis of more specific urban/spatial planning indicators.

Table 6-4. Identified relevant indicators among other analysed sets of indicators.

Issue	Indicators
Climate change	- Total city wide emissions (per capita, source and sector) - *(Total city wide energy use, per capita, sector)* - Urban CO_2 emission - Change in carbon footprint
Land/Land use	- New housing units in urban areas, urban centres - New housing units through redevelopment - Ratio of land consumption to population growth - Ration of achieved density to allowed density of residential development - Area of urban parks and open spaces - Percent of open space that is permeable - Percent of total land dedicated to open space - Percent of residential, mixed-use projects within certain distance to

Issue	Indicators
	transit nodes - Settlement and traffic area - Intensity of land use - Re-use of brownfield sites - Growth of settlements inward/outwards - Loss of protected area; - Change in area of parks and green spaces per 1,000 habitants; percent change in derelict land stock - Multi-functionality, mixture of usage - Land use structure, green area - Change in wetland area and function - Area of canopy coverage per neighbourhood - Total community land area per resident - Percent of designated area redeveloped per year
Transport	- Percentage of residents per modal split - Car density, use of car in the city, public transport developed - Travel density (distance travel per capita by mode of transportation) - Density, ratio, efficiency of public transportation - Transit proximity to housing
Form/Design/ Building/housing	- Dwellings units per area of land designated for residential use - Floor area, height - Build up ratio - Block size and shape - Average parcel size - Structure of street network - Residential footprint (net area/1,000 habitants) - Single family, multifamily dwelling share
Other	- Imperviousness (% of total net land area) - Floodplain encroachment - Land suitability (% net vacant land developable) - Supply and demand of affordable housing - Total city wide energy use, intensity of energy use - Ratio of jobs to housing in sub-regions - Jobs/housing balance - Availability of affordable housing/Distribution of affordable housing - Additional new homes completed

This review of existing indicators sets and screening of pertinent indicators related to spatial planning and mitigation and adaptation is relevant for two reasons. First of all, it makes visible that for the frameworks used at the international level, some relevant indicators are available to describe the correlation between the issues. Second, the suggestion of further concrete indicators to measure the integration of spatial planning and climate change can be based on a significant amount of the ones already available.

6.2.5 Suggested indicators

Having all the previous analysis in mind, a set of indicators (non-extensive) can be suggested at this point. The framework is based on the already mentioned layered structure considering local land use, subdivision/district and building/housing, urban structure levels. Indicators are divided into pressure, state and response.

It is important to briefly mention the 2 strategies once more. In the mitigation strategy, the overall aim is to decrease emissions related from energy, transport and residential/households sources. Elements of action are related to reducing carbon intensity of energy supply (consideration of renewable energy), to decrease demand from energy through control of use, form and design of settlements (reduction of sprawl) and also to conserve/increase carbon sink areas.

In the adaptation case, the goal is to achieve reduction of flood risks, reduction in the heat island effect, protection of coastal areas, other areas at risk, land designation for special needs and increase infrastructure resilience.

Table 6-5. Mitigation/adaptation indicators at the local land use level.

	Pressure	State	Response
Mitigation	- Energy emissions - Transport emissions - Residential emis. *(+ related intensities)*	- Dwellings unit per area - Inhabitants unit per area - Land taken up by energy sector - Land taken up by transport sector - Land covered by urban development - Land covered by green space and open space - Land use structure - Green area/100,000 habitants - Km of transportation systems/100,000 habitants	- Change in population density - Change in overall land use take/ change in brownfield use, change in redevelopment - Change in land taken by residential area - Change in land taken by transport infrastructure - Change in green space - Change in designated land used for renewable energy - Change in green area - Change in dwelling density - Regulations for mixed use
Adaptation	*- Projects of impacts and areas expected to be affected*	Same as above - Land covered by urban development - Land covered by green space and open space - Land use structure - Percent of hazard prone areas *- Percentage of population living in hazard prone areas* *- Percent of population living in coastal areas* *- Area of informal settlement*	- Assessment of areas at risk - Change in designation of protected areas - Change in green areas, open areas - Change in flood prone protected areas - Change in wetland areas - Change in coastal/river area protected - Change in area designated for decentralized infrastructure - Change in supply of affordable housing - Change in informal settlement area - Change in dwelling density - Regulations for mixed use

Indicators related to the first layer, local land use level, are seen in Table 6-5. Indicators for the second layer, district/subdivision level can be taken from Table 6-6. Not all of them are required. The selection depends on which specific strategy is being applied, and also on what data is available.

Table 6-6. Mitigation/adaptation indicators at the district/subdivision level.

	Pressure	State	Response
Mitigation	- Energy emissions - Transport emissions - Residential emis. *(+ related intensities) at district level*	At some extent, same as for local land use level - Block size, shape, street network, intersections - Plot area, lot size - Built up ratio - Floor area/height - Average parcel size - Street network density - Transit proximity to housing	- Change in population density - Change in dwelling density - Change in designated land used for renewable energy - Change in green area - Change in dwelling density - Regulation for block size and shape and street network - Regulation for built up ratio, floor area/height - Regulation for average parcel size - Regulations for multifunctional, mixed building uses - Regulation for transit accessibility/distances/street networks
Adaptation	*- Projects of impacts and areas expected to be affected*	At some extent, same as for local land use level	- Assessment of areas at risk - Change in designation of protected areas - Change in green areas, open areas - Change in flood prone protected areas/ Impervious area - Change in area designated for decentralized infrastructure - Change in dwelling density (-> Other regulation indicators as above related to densification)

The proposed indicators for the third layer, housing and building level, are listed in Table 6-7. At this level, building codes are the main tool needed to regulate design, form and function of buildings. For the first and second layer, land use plan, development plans, or similar are responsible for integrating the needed measures.

Table 6-7. Mitigation/adaptation indicators at the housing/building level.

	Pressure	State	Response
Mitigation	- Household energy consumption	- Plot area, lot size - Built up ratio - Floor area/height	- Regulation for built up ratio, floor area/height - Regulation for passive solar energy use/orientation of building - Regulation for renewable energy use (e.g. photovoltaic) - Regulations for design with better energy efficiency, insulation, etc.
Adaptation	-	-	- Regulation for passive solar energy use/Building codes for natural cooling - Regulations for facade and roof greening - Regulations to increase resilience and improve use of decentralised infrastructure (e.g. water, sanitation)

The previous analysis aimed at listing possible recommendable indicators, to be used to measure the efforts in achieving mitigation and adaptation (at the three different levels influenced by spatial planning). The indicators list should rather be seen as non-extensive, and further responses options can be added. Also in relation to the pressure and state components, especially for the district and building levels, further parameters need to be investigated and suggested. However, the proposed indicators give a good base for monitoring progress.

Many of the indicators chosen from the different analysed sets offer a good starting point for analysis, but also other data might be needed. In fact, different indicators exist, which give significant information in relation to urban poor. As it has been mentioned previously, addressing measures to improve the conditions of urban poor are very important regarding reducing vulnerability and improving adaptive capacity. This information, although not fully considered in the recommended indicators, offer great potential to examine the commitment for adaptation. For example, availability of affordable housing, area of informal settlement upgrading, amount of dwellers being removed from areas at risk, among others.

6.3 Summary and recommendations

Cities can better integrate the considerations of climate change into spatial planning through a strategic framework. Whenever applicable, it needs to consider any other approach already in place (such as Local Agenda 21) and take into account the interactions with the various instruments for planning and the different sectors also involved.

In such a process, the use of indicators is a basic requirement for the monitoring of actions. Hence, they are also important to support decision-making and development of policies. The selection of good indicators is not always a trivial process, but currently, a great amount of established sets are available.

The analysis of existing different set of indicators showed that, at some extent, the frameworks used at international levels offer some entry points for evaluating mitigation and adaptation issues at the spatial planning level, although other data might also be required. Each city needs to set their specific parameters, also considering the data availability. Many cities lack resources for collecting data and the use of difficult to collect or complicated indicators is not advisable.

Further efforts need to be taken, especially in developing countries, to strengthen and intensify the utilisation of indicators for improvement of governance at the local level.

7 Overview of issues in developing countries

This chapter has the objective to summarise, based on the analysis made until now, the specific issues for the developing countries.

The figures for population growth in urban areas, particularly for Asia and Africa, are worrying. By 2050 urban population will triple in Africa reaching over 1.2 billion, and, more than double in Asia, reaching around 3.3 billion people [WWI, 2007]. Globally, projections from the World Bank mention an increase in urban built up area from 200,000 square kilometres (compared to 2000) to 600,000 square kilometres by 2030 [Angel et al., 2005]. Urban areas with population around one million or smaller will absorb great part of this development, growing very rapidly and irregularly.

Such a disproportionate growth will rather aggravate many of the environment and development constraints already being faced by the low- and middle-income countries. These problems are related for example to very low levels of environmental protection, deprivation of housing and lack of basic infrastructure, and an overall inequality and high share of urban poverty. Considerable part of the population growth in urban areas will occur in squatter settlements.

Parallel to this, the impacts of global environmental changes, including climate change, also bring a series of constraints. Even though it is not always possible to advise with exact certainty about the impacts (or their regional distribution). It is very likely, as predicted by the IPCC models, that the effects to physical and biological systems will likely be disastrous. Consequences to agriculture, forestry/ecosystems, water resources, human health and settlements are already being felt now [IPCC, 2007a].

Taking the evidences of currently experienced hazards and of future prognoses, consensus within the scientific and political communities states that the negative effects of climate change will inevitably continue to hit the developing countries in a much acute way. Risks are associated to a concentrated increase in intensity and number of extreme weather events (cyclones, hurricanes, heavy rainstorms), leading to flooding, but also to an overall increase in heat waves frequencies and in the area affected by droughts. All these changes will pose further pressures for the already delicate situation in urban areas.

It is not easy to predict the number of urban habitants at risk. But in order to have an idea the given example brings up that almost two-thirds of cities with more than five million inhabitants are located in coastal zones at less than 10 metres above the sea level (and a high percentage of these cities are in lower-middle income nations). A fact to be acknowledged is that coastal flooding through sea level rise and tropical cyclones/storms, but also serious water supply constraints, increased heat-stress and heath effects are notably going to have a serious effect on the urban poor in the low and middle-income countries [Satterthwaite, 2008a].

Reasons for this higher vulnerability of the urban poor are distinct. As documented by Satterthwaite et al. [2001], this group normally lives (illegally settled) in areas that are more exposed to hazards and therefore at greater risk from climate change, such as floodplains, unstable slopes, or other areas at high risk of flooding.

The population most at risk is not able to avoid impacts, directly or indirectly. Because they lack infrastructure, secure tenure and assets, and due to occupation in the informal economy, it is not possible for them to easily find new employment or places to live, neither they have any legal or insurance protection. In fact, the areas most at risk are the single ones where they settle. Also women, infants and the elderly, more vulnerable and less able to cope, are likely to be most affected, in relation to illness, heat waves, etc. [Satterthwaite, 2008a].

Another argument, pointed out by different authors ([Dodman, 2009; Satterthwaite, 2008b]), is that the urban poor have contributed the least to the causes of climate change, and there is indeed very little what they can do for reducing greenhouse gases. It is true that, if intended development and improved life conditions are going to be extended to the unprivileged social groups, an increase in emission would be expected. Although it is possible and desirable to advocate for a low carbon development in urban areas in the developing countries, due to the greater challenges posed by the mentioned high vulnerability, it might be rather essential to focus on adaptation.

As discussed previously, local authorities have a crucial role in taking action to cope with the problems arising from urbanisation and climate change. At the local level, spatial planning is the key in reducing pressures on land use and preparing to accommodate and distribute the expected population growth. The intrinsic link to infrastructure provision and to the influence on the metabolism of urban areas, together with the strong interfaces to other relevant sectoral policies allow that spatial planning, as a main conclusion of this work, can make valuable contributions for mitigation and adaptation in cities.

The different options for achieving mitigation and adaptation through spatial planning, and possible indicators to help monitor these issues have been proposed. Yet, it is still necessary to further analyse the underlying social, institutional, economic, environmental barriers and chances for the particular situation of low- and middle-income countries.

For that, a so-called SWOT matrix can be compiled. The Strength – Weakness – Opportunity - Threat analysis is a useful tool for the comparison of different internal/external positive and negative aspects of a certain approach (more information from Meyrick and Meyrick [2002]).

Internal strengths and weakness are, to certain extent, within the control of the local governments, or, can be solved at their specific level, while external opportunities and threats are outside the control of city governments, or to be solved by other levels (see Table 7-1 - non-extensive).

Table 7-1. SWOT analysis of integration and monitoring of spatial planning and climate change issues at local level for developing countries.

Strengths	- Spatial planning offer many possibilities for the integration of mitigation and adaptation at city level - Many benefits for early action, related to social and economical issues exist (avoided costs, improvement of life quality of urban poor) - To address issues at the spatial planning level offers a chance for participative planning, that also address broader problems of communities, and promote community-based actions - Use of indicators can be of great help in monitoring effectivity of measures	**Weakness**	- Spatial planning is at times already overburdened with tasks of accommodating population growth and alleviating constraints related to urbanisation; it can not solve all the problems - The compact city (focus on mitigation) as model is partially conflicting with adaptation measures, and rather difficult to be applied - Lack of spatially related data makes the use of indicators difficult - Still exist difficulties in assessing impacts and vulnerability at local level - Lack of capacity and knowledge, lack of financial resources, lack of good governance, proper institution and structures are also constraints for the process
Opportunities	- The role of cities, also in developing countries, in tackling climate change is becoming more and more recognised and international support steadily increase - Mitigation of emissions also offer important synergies to sustainable development - In a general level, especially adaptation (with focus on pro-poor measures) is in synergy with development policies - Use of indicators can be of great help in decision making processes and to improve governance issues - Regional spatial planning concepts giving attention to adaptation issues are required	**Threats**	- Although interrelated, cities are confronted with other urgent development and environmental issues, there is still need to improve the integration of climate change - International focus has been on mitigation, while the scale up of co-benefits has not been achieved; moreover adaptation issues have not been enough considered - National and regional policies still need to improve conditions for cities to take action - Low economic development, income inequalities, lack of infrastructure/ shelter, and high demographic growth worsen the overall problems of climate change - Regional climate change models providing important information still need to be developed

The overall recommendation starts from the point that cities in developing countries should be advised towards an integration and evaluation of spatial planning, and mitigation and adaptation issues. Some further critical remarks, also from the SWOT analysis are important.

Some remarks need to be formulated in relation to the proposed options for mitigation and adaptation (in chapter 5). It is argued (see also e.g. Williams [2004]), in the general

case, that measures considering the physical form of urban areas as the best way to achieve sustainability (and intrinsically emission reductions) do not precisely accomplish the best outcomes. One point of criticism is that densities are already comparatively high and other problems such as lack of infrastructure need to be addressed rather than the urban form (with the perception that measures related for example to environmental resource management, or technological improvements are expected to bring more impacts than achieving densification). Another recommendation would also be to focus on the flows inside the city. Controlling these can also influence reduction of emissions.

In fact, the focus given by the current approaches to integrate mitigation to spatial planning are rather applicable to industrialised countries (as with the new urbanism and smart growth approach itself). It is true, that emission from transport and buildings will increase in the developing nations, but yet, it is also a fact that the rapid, unplanned and mostly irregular growth only give room for some restrictions at the planning level.

In relation to adaptation, on the other side, greater impacts can be achieved through planning. Also in this case, the irregular growth of settlements poses a great challenge, since a great part of the urban poor generally inhabit the areas most at risk in cities. Conflicts might appear related to improvements for flood management measures, for example. People living at floodplains or instable slope location might need to be relocated. A great challenge for governments will be to make enough land available for relocation of population most at risk.

Overall adaptation strategies for the urban poor are indeed related to the provision of infrastructure and secure tenure at safe sites, to improve their ability to cope with impacts. An important opportunity arises from the fact that infrastructure is lacking. What is build from now on can be built in a more resilient way. Spatial planning can play a key role in this case.

The contribution from spatial planning to low- and middle-income countries can be especially significant for adaptation. But whenever possible (absence of conflict or existence of synergy) also mitigation through the proposed measures should be aimed.

Proper and forward-looking spatial planning is also still compulsory to deal with the mentioned climate change problems in industrialised countries as well. Cities in the developing world thus need to have improved access and support, in relation to dissemination of best practices, and to policy, technology and behaviour requirements for encouraging change.

On the other hand, the challenges they are facing are fairly different from the situation in high-income cities. It can be proposed, that the planning approaches as required in the developing world might need to be reinvented. More flexibility, more decentralisation are key. In this sense, it is important to understand what basic conditions need to be created, in order to achieve more efficient actions. Furthermore

questions like what other concrete issues are pressing and why the current tools failed, how can approaches be better integrated and tools be improved, are worth being asked. Many questions remain open; as such a reinvention is not at all a trivial procedure.

As spatial planning also has the important tasks to deal with economic and social developments, and it can have a coordinating function among other sectors, it will remain critical that climate change issues are addresses, at any point, at the spatial planning level. Keywords are pro-poor adaptation. Disaster risk management also needs to be better considered in any developed strategy.

And in conclusion, it is imperative to underline, that spatial planning can only help to integrate climate change issues in low- and middle-income countries when embedded in an overall regional and national policy framework. In addition, without further efforts to build capacity and improve governance at the local level, it is not possible to expect or demand that issues are tackled with success.

8 Conclusions and outlook

First part of this work briefly analysed hard facts related to urbanisation and climate change and how higher pressures are forced on already delicate social, environmental and economical constraints in low- and middle-income countries. Both issues are intrinsically related to environmental and development challenges and can and should be tackled together. Therefore long-term visions are needed. At the one hand, it is important to find appropriate ways to accommodate the drastic population growth in urban areas, while reducing pressure on the environment and resources and improving the provision of infrastructure and life quality of urban dwellers. On the other hand, it is necessary to find ways to cope to climate change, not only by mitigation of emissions, but also increasingly by taking actions towards adaptation.

Furthermore, different opportunities for changes were discussed. Starting from the concept of sustainable development, it can be said that there is not a lack in theoretical models, but rather that practice and action have not followed the rhetoric. With the help of different models (more applicable to the developed countries) and internationally fostered pragmatical approaches (giving more attention to the developing world), sustainable urban development has been promoted worldwide. Many different approaches at the spatial planning level have also been tested with focus on mixed land use, densification and other actions to reduce urban sprawl. Yet the valid effectivitiy of measures could be questioned. It can also be said, that strategies (technologies and policies) for mitigation and adaptation, also in a mutual relationship with sustainability, have not achieved up to now the required breakthrough to really make the difference and accomplish change. For both cases, spatial planning and climate change, it seems that inherent conflicts between social, environmental and economical goals might continue to hinder true sustainable development.

All challenges and opportunities indeed mainly come together in cities. Reasons for action or inaction were investigated. It is necessary to localise actions by using local hooks or co-benefit approaches, especially in the case of cities in developing countries, where more urgent issues have greater priority in the agenda. However, there is a growing recognition that tackle climate change at city level become feasible and imperative. Because there are many differences among cities, there is no all-embracing solution. Understanding the complexity of stakeholders/actors, and bringing them all to work together towards a common direction is key. A growing number of local governments initiatives is being created to support cities in the completion of responsibilities related to climate change. As baseline for action, two different appraisals are needed. First a greenhouse gas inventory (related to the factors driving emissions in cities). And, in order to improve actions towards adaptation, an urban climate risk assessment (based on concrete impacts to be felt by cities and their given vulnerability and adaptive capacity) is necessary.

Up to now mitigation and adaptation strategies are rather handled in a disconnected way. A main reason for this is the temporal and spatial divergence of how actions are

taken and differences in stakeholder involvement, institutional complexity and analytical approach. It is therefore suggested that these issues are approached in an integrated way at the spatial planning level. Different measures to achieve mitigation and adaptation (through regulations for land use and urban form) were proposed.

Summarised spatial planning goals for mitigation have to concentrate on decreasing the carbon intensity of energy supply (including renewable energy in new developments) and also on managing energy demand through density, form and design of urban areas (decrease emissions from transport and buildings). Adaptation measures require, in general, actions for managing the urban heat island effect, actions for adequate water management (flood and storm water) and for increasing resilience of infrastructure and buildings. Moreover, the suitable protection of coastal areas/areas at risk, and also for land designation for special needs has to be considered (relocations, decentralised infrastructure).

Potential synergies and trade-offs have to be analysed and handled according to each specific circumstance. But in general, one of the areas of conflict between mitigation and adaptation is density and form. Therefore, one suggestion is to promote moderate densities together with the provision of enough green/open space (flood management and decrease of the urban heat island effect). It is also important to emphasise the need for avoiding development at high-risk areas and considering in advance the designation of areas for potential relocations.

Also it was proposed to integrate spatial planning and climate change issues in a strategic development, within an improved participatory decision-making framework. Indicators are important tools necessary to monitor progress. Basic knowledge on indicators was presented. Moreover, different sets of indicators were briefly analysed, and relevant indicators for the issues of climate change and spatial planning were selected. Some indicators in the three levels of influence (land use, district/subdivision, housing building) were recommended. Further efforts need to be taken, especially in developing countries, to strengthen and intensify the utilisation of indicators for improvement of governance, improving decision-making and policy development at local level.

The last part of the work opens a view on the issues in the light of existing conditions in developing countries, analysing problems and chances. Most cities are already struggling with the main tasks of accommodating population growth, reducing the pressure on land and other resources, and guaranteeing a continuous improvement of shelter/housing provision for the urban poor. The consideration of climate change issues at the planning level is necessary and recommendable. But for an adequate support better framework conditions (e.g. more flexibility, more decentralisation) for spatial planning to function in these countries at all are necessarily. Informal and unplanned growth remains a challenge, and indeed, low levels of adaptation will strongly increase the risk exposure of urban poor.

The overall goal of this work is to give directions for the integration and monitoring of climate change and spatial development issues and to contribute for a better understanding of the role of cities. Yet many other issues still need to be analysed. As it is not only important to know what concrete measure to take, but also to understand the necessary framework conditions to achieve desirable outcomes. Also it is important to analyse in more detail social and economical aspects, and not only the technical aspects of how to build resilient cities. For further promotion of a change the role of the private sector, of economic instruments, of different available tools need to be better understood, and so on. The list could go forth infinitely, as it is in cities, as discussed, that the many challenges join together. But as cities concentrate cultural, technological and socio-economic innovation potentials, they are inherently part of the solution. Achieving patterns of sustainable development will strongly depend on the contribution of cities.

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Selbständigkeitserklärung

Hiermit versichere ich, dass ich die vorliegende Diplomarbeit selbständig und nur unter Verwendung der angegebenen Quellen und Hilfsmittel angefertigt habe.

Weimar, im September 2009

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Annex A – Basic information about different indicators sets I

Core Environmental Indicators (CEI) - OECD

Developed by: Organisation for Economic Cooperation and Development (OECD)

Level/Objective/Target Group: Global/ Tracking environmental progress and performance/Use at national or international level to describe the state, and based on that to measure environmental performance and report progress towards sustainable development

Characteristic: Indicators of environmental pressure (direct and indirect), indicators of environmental conditions and of society's response. (PSR model)

Detailed Information: Around 50 indicators in following issues: climate change, ozone layer depletion, eutrophication, acidification, toxic contamination, urban environmental quality, biodiversity water, forest, fish resources, biodiversity, cultural landscapes, waste and materials resources

Sources: [OECD, 1993, 2003]

Key Environmental Indicators (KEI) - OECD

Developed by: Organisation for Economic Cooperation and Development (OECD)

Level/Objective/Target Group: Global/Reduced set of core indicators with the objective of informing public and provide key signals to policy makers

Characteristic: Based on the CEI but focusing on key trends, it is divided into pollution issues and natural resources and assets issues, with 5 available indicators for each issue, and further medium term indicators

Detailed Information: Pollution issues: climate change, ozone layer, air quality, waste generation, fresh water quality; Natural resources and assets: fresh water resources, forest resources, fish resources, energy resources, biodiversity

Sources: [OECD, 2003]

Sectoral Environmental Indicators (SEI) - OECD

Developed by: Organisation for Economic Cooperation and Development (OECD)

Level/Objective/Target Group: Global/Sectoral/Different sets designed to help integrate environmental concerns into sectoral policies

Characteristic: Indicators are classified in: sectoral trends of environmental significance; their interactions with the environment (including positive and negative effects); and related economic and policy considerations.

Detailed Information: Transport environmental indicators: Sectoral trends and patterns of environmental significance includes: overall traffic tends and modal split, infrastructure, vehicles and mobile equipment, energy use; Interaction with environment includes: land use, air pollution, water pollution, noise, waste, risk and safety; Economic and policy aspects are: environmental damage, environmental expenditure, taxation and subsidies, prices structures and trade and environment; Energy environmental indicators: Sectoral trends and patterns of environmental significance includes: overall energy use and related intensities, energy efficiencies, energy mix, indigenous production; Interaction with environment includes: energy resources, air pollution, water pollution, waste, land use, risk and safety; Economic and policy aspects are: environmental damage, environmental expenditure, taxation and subsides, prices structures; Household consumption indicators: Environmentally significant trends and patterns: economical, socio-demographic trends, transport and communications, consumption of durable and non-durable goods, recreation and tourism, housing related energy and water use; Interactions with the environment in relation to: air, waste, water, noise, land and biodiversity; Economic and policy aspects: regulatory instruments, economic instruments, information/social instruments, trade aspects

Sources: [OECD, 2003]

Indicators of Sustainable Development (UNCSD)

Developed by: United Nation Commission on Sustainable Development (UNCSD)

Objective/Target Group: Global/Serve as reference for countries to develop or revise national indicators of sustainable development.

Characteristics: Themes covered by this set are: poverty; governance; health; education; demographics; natural hazards; atmosphere; land, oceans, seas and coasts; freshwater; biodiversity; economic development; global economic partnership; consumption and production patterns (total 134 indicators); Also serve as base for the Agenda 21 Indicators

Detailed Information: Each theme is further divided is subthemes: Poverty: income poverty, income inequality, sanitation, drinking water, access to energy, living conditions; Governance: corruption, crime; Health: mortality, health care delivery, nutrional status, health status and risks; Education: educational level, literacy; Demographics: population, tourism; Natural Hazards: vulnerability to natural hazards, disaster preparedness and response; Atmosphere: climate change, ozone layer depletion, air quality; Land: land use status, desertification, agriculture, forests; Oceans, seas and coasts: costal zone, fisheries, marine environment; Freshwater: water quantity, water quality; Biodiversity: ecosystem, species; Economic Development: macroeconomic performance, sustainable public finance, employment, information and communication technologies, research and development, tourism; Global Economic Partnership: trade, external financing; Consumption and Production Patterns: material consumption, energy use, waste generation and management, transportation

Sources: [UN, 2001, 2007]

Core set of indicators (EEA)

Developed by: European Environmental Agency (EEA)

Level/Objectives/Target Group: European/Information collection, results communication and improved environmental issued assessment and monitoring

Characteristics: Different set of indicators divided by themes: Environmental Issues: Air, Biodiversity change, Chemicals, Climate change, Environment and Human health, Land use, Natural Resources, Noise, Soil, Waste and materials resources, Water, various other issues; Sector and Activities: Agriculture, Energy, Fisheries, Households Consumption, Industry, Population and economy, Tourism, Transport; Environment in specific areas: Coasts and seas; urban environment; Cross-cutting: policy instruments, environmental scenarios,

Detailed Information: Some examples:
Climate change: atmospheric GHG concentrations; global and European temperatures; GHG emissions trends and projections, transport emissions of greenhouse gases and by mode;
Urban environment: municipal waste generation; land take; drinking water quality; emissions to water of hazardous substances from urban sources; water use by sectors; urban spatial characteristics and transport;
Households consumption: municipal waste generation, drinking water quality, urban waste water treatment, emissions to water of hazardous substances from urban sources, household expenditure categories, penetration of environmentally friendly products, household energy consumption, household number and size

Source: http://themes.eea.europa.eu/indicators/

Global Urban Indicators Database (UN-HABITAT)

Developed by: United Nations Human Settlements Programme (UN-HABITAT)

Level/Objective/Target Group: Local/helping to monitor the implementation of Habitat Agenda in cities, and provide a quantitative, comparative base for the condition of cities

Characteristics: The indicators are divided into 5 chapters: shelter, social development and eradication of poverty, environmental management, economic development and governance. There are 20 key indicators, relatively easy to collect and relevant for policy, other 13 extensive indicators for a more detailed assessment and 9 checklists for areas which cannot be easily measured quantitatively.

Detailed Information: The specific goals are listed below: Chapter 1 – Shelter: promote the right to adequate housing; provide security of tenure; provide equal access to credit; provide equal access to land; promote access to basic service. Chapter 2 – Social development and eradication of poverty: provide equal opportunities for a save and healthy life; promote social integration and support disadvantaged groups; promote gender equality in human settlements development. Chapter 3 – Environmental Management: promote geographically balanced settlement structures; manage supply and demand for water in an effective manner; reduce urban pollution; prevent disasters and rebuild settlements; promote effective and environmentally sound transportation systems; support mechanisms to prepare and implement environmental plans and local Agenda 21 initiatives. Chapter 4 – Economic Development: Strengthen small and micro-enterprises, particularly those developed by women; encourage public-private sector partnership and stimulate productive employment opportunities. Chapter 5 – Governance: Promote decentralisation and strengthen local authorities; encourage and support participation and civic engagement; ensure transparent, accountable and efficient governance towns, cities and metropolitan areas

Source: [UN-HABITAT, 2004] and http://ww2.unhabitat.org/programmes/guo/

Healthy City Indicators (WHO)

Developed by: World Health organisation (WHO)

Level/Objectives/Target Group: Local/Assess information that is able to provide a comprehensive picture of health in a city, also by collection of qualitative data to describe further health issues in cities

Characteristics: Indicators cover areas of heath, and health services, environmental and socio-economic conditions

Detailed Information: Health indicators: Mortality: all causes; Cause of death; Low Birth weight; Health service indicators: Existence of a city health education programme; Percentage of children fully immunised Number of inhabitants per practising primary health care practitioner; Number of inhabitants per nurse; Percentage of population covered by health insurance; Availability of primary health care services in foreign languages; Number of health related questions examined by the city council every year; Environmental indicators: Atmospheric pollution; Water quality; Percentage of water pollutants removed from total sewage produced; Household waste collection quality index; Household waste treatment quality index; Relative surface area of green spaces in the city; Public access to green space; Derelict industrial sites; Sport and leisure; Pedestrian streets; Cycling in city; Public transport; Public transport network cover; Living space; Socio economic indicators: Percentage of population living in substandard accommodation; Estimated number of homeless people; Unemployment rate; Percentage of people earning less than the mean per capita income; Percentage of child care places for pre-school children; Percentage of all live births to mothers > 20; 20-34; 35+; Abortion rate in relation to total number of live births; Percentage of disabled persons employed

Source: http://www.euro.who.int/Healthy-cities and http://www.euro.who.int/document/hcp/ehcpquest.pdf

Global City Indicator (WB)

Developed by: Global City Indicator Facility - World Bank and University of Toronto

Level/Objective/Target Group: Local/Support cities with the performance monitoring by providing a framework to facilitate consistent and comparative collection of city indicators

Characteristics: The 53 indicators are divided into two categories, city services (which include services typically provides by city government and other entities) and quality of life (which includes critical contributors to overall quality of live, though the city government may have little direct control).

Detailed Information: Category city service is subdivided into: education, energy, finance, fire & emergency response, governance, health, recreation, safety, social services, solid waste, transportation, urban planning, wastewater, water; Category quality of life is subdivided into: civic engagement, culture, economy, environment, shelter, social equity, subjective well-being, technology and innovation

Source: [GCIF, 2009] and www.cityindicators.org

Environmental Sustainability Indicators (MDG7/UNEP)

Developed by: based on the Millennium Development Goal # 7 (environmental sustainability) and on the city environmental assessment methodology by UNEP

Level/Objective/Target Group: Local/Make information available for stakeholders to evaluate results of actions; **Characteristics**: 19 indicators – see list in Annex C

Source: [CitiesAlliance, 2006: 131]

Annex B - Basic information about different indicators sets II

Outcomes Sustainability Indicators (King County)

Developed by: King County/Washington

Level/Objective/Target Group: Regional/Local level of King County/Washington; To help municipality measure progress towards sustainability

Characteristics: Indicators set is divided into following outcomes: economic development, environment, affordable housing, land use and transportation

Detailed Information: Outcomes for:
Economic development: promote family wage jobs; increase income and reduce poverty; increase business formation, expansion, retention; create jobs that add to economic base; increase education skill levels;
Environment: protect and enhance natural ecosystems; improve air quality; protect water quality and quantity; protect wetlands; protect diversity of plants and wide life; increase salmon stock; decrease noise levels; decrease waste disposal and increase recycling;
Affordable housing: provide sufficient affordable housing; promote affordable housing ownership; opportunities; promote equitable distribution of affordable low-income housing
Land use: encourage a greater share of growth in urban areas and urban centre, limit growth in urban area; make efficient use of urban land; accommodate residential and job growth in urban areas; encourage liveable, diverse communities – balance jobs and household growth; maintain quality and quantity of natural resource lands;
Transportation: transportation and land use linkage; availability of modes other than drive alone modal split; reduce commercial traffic congestion; protect and improve transportation infrastructure

Source: [Miller, 2004: 119f]

Sustainable city indicators (Santa Monica)

Developed by: Santa Monica/ Municipality

Level/Objective/Target Group: Local/ Indicators for monitoring achievement of goals/targets

Characteristics: For each specific goal: system level and programme level indicators

Detailed Information: Focus on eight goal areas: resource conservation, environmental and public health, transportation, economic development, open space and land use, housing, community education and civic participation, human dignity;
Indicators areas at system level: resource conservation: solid waste generation, water use, energy use, renewable energy use, greenhouse gas emissions, ecological footprint, indicator for sustainable procurement; environmental and public health: Santa Monica Bay, wastewater (sewage) generation, vehicle miles travelled, air quality; transportation: modal split, residential use of sustainable transportation options, sufficiency of transportation options, bicycle lanes and paths, vehicle ownership; economic development: business diversity, business reinvestment in the community, jobs/housing balance, cost of living, quality of job creation, income disparity, resource efficiency of local businesses; open space and land use: open space, trees, parks-accessibility, land use and development, regionally appropriate vegetation; housing: availability of affordable housing; distribution of affordable housing; community education and civic participation: voter participation, participation in civic affairs, empowerment, community involvement, volunteering; participation in neighbourhood organisations, sustainable community involvement; human dignity: basic needs – shelter, basic need – health care, basic needs - economic opportunity, basic needs – public safety; residents perception of safety, incidents of abuse, incidents of discrimination, education/youth, empowerment, ability to meet basic needs

Source: [SantaMonica, 2006]

"Cities of the future" Indicators (Städte der Zukunft - BBR)

Developed by: Bundesamt für Bauwesen und Raumordnung (BBR) – German Federal Office for Building and Regional Planning

Level/Objective/Target Group: Local/For measuring success of urban development with the support of indicators

Characteristics: The indicator set is based on 5 fields of action: (Provident) Land Management, (Precautionary) Environmental Protection; (City-compatible) Mobility Management; **(**Socially Responsible) Housing Supply and (Local-securing) Economic Development

Detailed Information: The field of action: Provident Land Management has following goals: Reduction of the increase in built-up settlement area; Reuse of urban wasteland and vacant buildings; Optimum use of urban density; Conservation and integration of climate-effective open spaces; Reduction of soil sealing; Precautionary Environmental Protection has following goals: Energy conservation and increased share of renewable energies; Reduction of air pollutants and greenhouse gases; Protection and maintenance of groundwater and local water resources; Strengthening of material cycles and reduction of waste generation; City-compatible Mobility Management has following goals: Connecting neighbourhoods and workplaces to the public; Reduction in the space for motorised transport; Expansion of bicycle paths; Increase the quality of stay for pedestrians; Socially-responsible Housing Supply has following goals: Resource saving and cost reduced housing; Supply of housing seekers with special housing needs; Promote neighbourhood self-help; Securing housing-near basic provisions; Local-securing Economic Development has following goals: Securing of central business locations; Creating of neighbourhood-compatible jobs; Strengthening and development of urban centres; Promotion of environmentally friendly businesses;

Source: [Fuhrich, 2004] (translation by author)

Development/master plan elements and sustainability indicators

Developed by: Compiled by Alshuwaikhat, H.

Level/Objective/Target Group: Operationalisation of the development/master plan elements and sustainability indicators

Characteristics: Divided into planning elements: land use, transportation, environment, infrastructure, urban design, housing, energy, economic development, and population

Detailed Information: Themes for each element: land use: urban area footprint, infill, use mix, land redeveloped, jobs/housing balance; transportation: travel density, transit service density, auto use, pedestrianisation; environment: natural areas protection, species biodiversity, agricultural land conversion, imperviousness, water quantity, water quality, air quality climate change, ozone depletion; infrastructure: water consumption, park space availability, waste generation and management; urban design: preservation of historic and archaeological sites and buildings, open space protection; housing; density, affordability, transit proximity; energy: energy use; economic development: economic performance, level of investment, employment; population: human health, poverty, education, security, social inclusiveness

Source: [Alshuwaikhat, 2003]

Spatial planning Output Indicators (RTPI)

Developed by: RTPI – Royal Town Planning Institute

Level/Objective/Target Group: Indicators for evaluation of spatial planning outcomes

Characteristics: Outcome indicators need to be 'plan-derived' and 'objectives-derived' in a plan led system; They must reflect spatial planning's contribution to the achievement of integrating specified key sectoral policies in different parts of the UK; and Outcomes have to be interpreted in light of the wider context.

Detailed Information: Indicators bundled into following categories (main outcomes of spatial planning): making suitable land available and it is efficient use for development; sustainable economic development, protection and enhancing the natural and historic environment, high quality development and efficient use of resource, inclusive and liveable communities

Source: [RTPI, 2008]

Sustainability indicators - multi-layered urban typologies

Developed by: Harry Storch

Level/Objective/Target Group: Spatial Planning/ Trend of land-use change and the resulting land consumption can be monitored in terms of spatial structural distribution, a system of activity centres and use densities and the patterns of interaction (commuting)

Characteristics: Four different layers: physical structure; urban land use patterns; public infrastructure patterns; and social sciences and human geography;

Detailed Information: physical structure: compactness, informality, accessibility; urban/ environment land use: land resource, green area, community space, underground and surface water; public infrastructure service: sanitation, water pollution, disposal/collection, treatment, transport modes, energy; social sciences and human geography: density, population change, economic structure, poverty, unemployment

Source: [Storch, 2007]

INDEX Indicators

Developed by: Criterion Planners

Level/Objective/Target Group: Indicators for assessing current land use and transportation conditions and evaluating alternative courses of action in a neighbourhood, community, or region

Characteristics: INDEX is a static, rule-based geographic information system (GIS) tool with a menu of indicators that can be applied to user-created scenarios to gauge achievement of user-defined goals.

Detailed Information: Partial list of available indicators is divided into following categories: demographics, land use, housing, employment, recreation, transportation and environment

Source: [Allen, 2008]

Annex C – Different indicators sets in extenso I

Core Environmental Indicators (CEI-OECD)

Issue		Indicators		
Climate Change	Pressure	Index of greenhouse gas emissions* *- CO_2 emissions* *- $CH_4/N_2O/CFC$*	M S S/M	●
	State	^ Atmospheric concentration of greenhouse gases, global mean temperature	S	●
	Response	Energy efficiency *- Energy intensity* (total primary energy supply per unit of GDP or capita)* *- Economic and fiscal instruments*	M/L S S/M	●
Ozone layer depletion	Pressure	^ Index of apparent consumption of ozone depleting substances (ODP)* *- Apparent consumption of CFCs/and halons*	M	
	State	Atmospheric concentration of ODP Ground level UB-B radiation *- Stratospheric ozone levels*	S/M S/M	
	Response	CFC recovery rate	M	
Eutrophication	Pressure	Nutrient balance *Emission of N and P in water and soil* *- N and P from fertilizer use* and from livestock*	L S	
	State	BOD/DO in inland waters, in marine waters* Concentration of N/P in inland waters, in marine waters	S/M	
	Response	Population connected to biological and/or chemical sewage treatment plants *- Population connected to sewage treatment plant* *- User charges for waste water treatment* *- Market share of phosphate-free detergents*	M/L S M S/M	
Acidification	Pressure	Index of acidifying substances *- Emissions of NO_X, SO_X*	M/L S	
	State	Exceedance of critical loads of pH in water and soil *- Concentration in acid precipitation*	M/L S	
	Response	% of car fleet equipped with catalytic converters Capacity of SO_x abatement equipment of stationary sources	S/M M/L	
Toxic contamination	Pressure	Emissions of heavy metals Emissions of organic compounds *- Consumption of pesticides*	M/L L S/M	
	State	Concentration of heavy metal and organic compounds in environmental media and in living species *- Concentration of heavy metal in rivers*	L S/M	
	Response	Changes in toxic contents in products and production processes *- Market share of unleaded petrol*	L S	
Urban Environmental Quality	Pressure	Urban air emission *- Urban traffic density* *- Urban car ownership* *- Degree of urbanisation (urban population growth rate, urban land)* *	M/L M/S S S/M	●
	State	Population exposure to air pollution, to noise *- Concentration of air pollutants** Ambient water conditions in urban areas	L/M S M/L	●
	Response	Green space (area protected from urban development) Economic, fiscal and regulatory instruments *- Water treatment and noise abetment expenditure*	M/L M S/M	●
Biodiversity	Pressure	Habitat alteration and land conversion from natural state *To be further developed (e.g.…road network density, change in land cover, etc.)*	L	
	State	Threatened or extinct species as a share of total species known* Area of ecosystems*	S M	
	Response	Protected area as % of national territory* and by ecosystem *- Protected species*	S/L S	●

Issue		Core indicator		
Cultural landscapes		*Indicators to be further developed* *e.g. presence of artificial elements, sites protected for historical, cultural or aesthetic reasons*		
Waste	Pressure	Generation of waste (municipal, industrial, hazardous, nuclear) *- Movements of hazardous waste*	S S	
	Response	Waste minimisation *(to be further developed)* *- Recycling rates** *- Economic and fiscal instruments, expenditure*	L S/M M	
Water resources	Pressure	Intensity of use of water resources (abstraction/available resources)	S	
	State	Frequency, duration and extent of water shortages	M/L	
	Response	Water prices and user charges for sewage treatment	S/M	
Forest resources	Pressure	Intensity of forest resource use* (actual harvest/productive capacity)	M	
	State	Area*, volume and structure of forests	S/M	
	Response	Forest area management and protection (e.g. % of protected area in total forest area; % of harvest area successfully regenerated of afforested	M/L	
Fish resources	Pressure	Fish catches*	S	
	State	Size of spawning stocks	M	
	Response	Fishing quotas	S/M	
Soil degradation (desertification/erosion)	Pressure	Erosion risks: potential and actual use of land for agriculture *- Change in land use*	L S	
	State	Degree of top soil losses	M/L	
	Response	Rehabilitated areas	M/L	
Materials resources		Intensity of use of material resources* (Indicators to be developed, link to material flow accounting)		
Socio-economic, sectoral and general indicators (not attributable to specific environment issue)	Pressure	Population growth and density* Growth and structure of GDP* Private and government final consumption expenditure Industrial production Structure of energy supply* Road traffic volumes Stock of road vehicles Agricultural production	S S S S S S S S	● ●
	Response	Environment expenditure *- Pollution abatement and control expenditure* *- Official development assistance** *(Indicator added on the bases of experience with environment performance reviews)* Public option	M/L S/M S S	●

- In Italics, complementary indicators and proxy indicators
- Indicators that are identical or similar to those proposed in the UNCSD set are marked with *.
- Each character specifies the indicator's measurability: S = short term, basic data currently available for a majority of OECD countries; M =medium term, basic data partially available, but calling for further efforts to improve their quality (consistency, comparability, timeliness) and their geographical coverage (number of countries covered); L = long term, basic data not available for a majority OECD of countries, calling for a sustained data collection and conceptual efforts.

In general - ● for indicator directly correlated to issues of climate change and spatial planning and ■ for indirect linkages

Key Environmental Indicators (KEI-OECD)

Theme		Available indicators*	Medium term indicators**	
Pollution issue	Climate Change	CO_2 emissions intensities	Index of GHG emissions	●
	Ozone layer	Indices of apparent consumption of ozone depleting substances	Same, plus generation into one index of apparent consumption of ODS	
	Air quality	SO_x NO_x emissions intensities	Population exposure to air pollution	
	Waste generation	Municipal waste generation intensities	Total waste generation intensities; indicators derived from material flow accounting	
	Fresh water quality	Waste water treatment connection rate	Pollution loads to water bodies	
Natural resources and assets	Fresh water resources	Intensity of use of water resources	Same plus sub-national breakdown	
	Forest resources	Intensity of use of forest resources	Same	
	Fish resources	Intensity of use of fish resource	Same plus sub-national breakdown	
	Energy resources	Intensity of energy use	Energy efficiency index	●
	Biodiversity	Threatened species	Species and habitat or ecosystems diversity; Area of key ecosystems	

* indicators which data are available for a majority of OECD countries
** Indicators that require further specification and development (availability of basic data set, underlying concepts and definition)

Sectoral Environmental Indicators (OECD-SEI) – Energy

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
Sectoral trends and patterns of environmental significance						
Overall energy use and related intensities	Total primary energy supply (TPES) and related intensities (TPES per unit of GDP and per capita)	1	1	1	1	
	Total final consumption (TFC) and related intensities (TFC per unit of GDP and per capita)	1	1	1	1	
Energy efficiencies	Total final consumption by sector	1	1	1	1	●
	Sectoral end uses - industry (Toe per unit of value added) - residential (Toe per capita) - commercial and public sector (Toe per sq. metre) - transport (Toe per 1000 vehicle kms)	 1 1 1	 1 1 2	 1 1 1	 1/2 2 1	●
	Fossil fuel efficiency for electricity generation	1	1	1	1	
Energy mix	Total primary energy supply by fuel type	1	1	1	1	
	Total final consumption by fuel type	1	1	1	1	
	Electricity generation by fuel type	1	1	1	1	
Indigenous production	Primary energy produced nationally as per cent of total primary energy supply	1	1	1	1	
Interactions with the environment						
Energy resources	Proven coal/oil/gas reserves in Toe	1	2	2	2	
Air pollution	Energy emissions - CO_2, NO_x, SO_x, etc. (share in total by end uses) and related intensities (per capita, per GDP)	1	1	2	2	●
Water pollution	Tons of oil released through accidents on a continuous basis	2	1	2	2	
Waste	Volume of solid waste from energy production and related intensities (per GDP)	2	1	1	2	
	Volume of radioactive waste (spent fuel) and related intensities (per capita, per GDP)	1	1	1	1	
Land use	Land taken up by energy production, transport and transformation	2	1	2	2	●
Risk and safety	Numbers killed and injured	1	2	2	2	
Economic and policy aspects						
Environmental damage	Environmental damage relating to energy production and consumption	1	2	2	-	
Environmental expenditure	Total expenditure on pollution prevention and clean-up	1	2	2	2	

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
	"Environmentally related" R&D expenditures in the energy sector	1	2	2	2	
	R&D expenditure on energy	2	2	2	2	
Taxation and subsidies	Total economic subsidies to energy	1	1	2	1	
	Relative taxation in per cent by different fuel types	1	1	2	1	
Price structures	Real energy end-use prices by fuel type	1	1	1	1	

* Classifications used for evaluating the indicators: policy relevance (1=high; 2=medium; 3=low) ; analytical soundness (1=good; 2=average; 3=poor); measurability in terms of data availability (1=short term; 2=medium term; 3=long term) and of data quality including international comparability (1=good; 2=average; 3=poor)

Sectoral Environmental Indicators (OECD-SEI) –Transport

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
Sectoral trends and patterns of environmental significance						
Overall traffic trend and modal split	Passenger transport trends by mode	1	1	2	2/3	●
	Freight transport trends by mode	1	1	2	2/3	
	Road traffic trends and densities	1	1	1/2	2	
	Trends of airport traffic	2	1	1/2	1	
Infrastructure	Capital expenditure by mode	1	2	1	1	
	Road network length and density	1	1	1	1	
	Rail network length and density	1	1	1	1	
Vehicles and mobile equipment	Road vehicle stocks	1	1	1	1	
	Structure of road vehicle fleet	1	1	2	2	
	Private car ownership	1	1	1	1	
Energy use	Final energy consumption by the transport sector	1	1	1	1	●
	Consumption of road fuels	1	1	1	1	
Interactions with the environment						
Land use	Change in land use by transport infrastructure	1	1	2	2/3	●
	Access to basic services	1	2	3	3	●
Air pollution	Transport emissions and emission intensities	1	1	2	2	●
	Population exposed to air pollution from transport	1	1	2	2/3	
Water pollution	Oil released from marine transport	1	1	2	2	
Noise	Population exposed to transport noise 65db(A)	1	1	2	2/3	
Waste	Transport-related waste and related recovery rates	1	1	2	-	
	Hazardous waste imported or exported	1	1	2	2	
Risk and safety	Road traffic fatalities	1	1	1	2	
	Hazardous material transported by mode	1	1	2	-	
Economic and policy aspects						
Environmental damage	Environmental damage relating to transport	1	1	3	3	
	Social cost of transport	1	1	3	3	
Environmental expenditure	Total expenditure on pollution prevention and clean-up	1	2	2	-	
	R&D expenditure on “eco-vehicles”	1	2	3	-	
	R&D expenditure on clean transport fuels	1	2	3	-	
Taxation and subsidies	Direct subsidies to transport	1	2	3	-	
	Total economic subsidies to transport	1	2	3	-	
	Relative taxation of vehicles and vehicle use	1	2	2	-	
Price structures	Structure of road fuel prices	1	1	1	1	
	Trends in public transport prices	1	2	3	3	

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
Trade and environment	Indicators to be developed (e.g. trends in international transport of goods, relative importance of cross-border vs. domestic transport)...	2	2	2	-	

* Classifications used for evaluating the indicators: policy relevance (1=high; 2=medium; 3=low) ; analytical soundness (1=good; 2=average; 3=poor); measurability in terms of data availability (1=short term; 2=medium term; 3=long term) and of data quality including international comparability (1=good; 2=average; 3=poor)

Sectoral Environmental Indicators (OECD-SEI) – Household Consumption

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
Environmentally significant trends and patterns						
General trends						
Economic trends	Expenditure shares of GDP	1	1	1	1	
	Saving rates (genuine savings)	2	1	1	1	
	Government consumption: public final consumption expenditure	1	1	1	1	
	Household consumption: private final consumption expenditure	1	1	1	1	
Socio-demographic trends	Household size	1	1	3	3	
	Population structure	1	1	1	1	
Key household consumption activities						
Transport and communication **(For transport, more details in transport sectoral environ. indicators)**	Passenger transport - trends and intensities by mode - road traffic by passenger cars - share of public transport - Passenger car stocks, structure and ownership	 1 1 1 1	 1 1 1/2 1	 2/3 1/2 2/3 1	 2 2 2/3 2	●
	Energy consumption by transport - trends and intensities by mode - consumption of road fuels	 1 1	 1 1	 1 1	 1 1	●
	Communication tools - Newspaper circulation - Telephone lines, computers and/or Internet connections	 1 1	 1 1	 1 1	 2 2	
Consumption of durable and non-durable goods	Household consumption expenditure by type of good	1	1	2	1	
	Ownership of selected household commodities	1	2	2	2	
	Average length of product life	1	3	3	3	
	Paper consumption	1	1	1	1	
	Food consumption - by type of food - by growing method and/or level of process	 1/2 1/2	 1/2 3	 1 3	 2 3	
Recreation and Tourism	Trends in international tourism: international tourist receipts	2	1	1	1	
	Household consumption expenditure on recreation	1	1	1/2	1	
	Leisure travel	1	2	3	3	
Housing related energy and water use **(For energy, more details in energy sectoral environ.**	Total final energy consumption: intensity and structure by type of use	1	1	1	1	●
	Residential energy consumption: intensity & structure	1	2	2/3	3	●
	Household water	1	2	2/3	3	

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
indicators)	consumption: intensity & structure					
Interaction with environment						
Air pollution	Air emissions from residential energy use	1	1	1	2/3	●
	Air emissions from passenger transport	1	2	3	3	●
	Air emissions from road transport	2	2	1/2	2	●
Waste	Generation of household waste	1	1	1/2	2	
	Waste recycling rates (paper, glass, etc.)	1	2	1/2	2	
Water pollution	Water abstractions for public supply	1	2	2	2	
	Waste water discharges by households	1	2	3	2	
	Population connected to waste water treatment plants	1	2	1/2	1/2	
Noise	Population exposed to noise from various sources	2	1	2/3	2/3	
Land and biodiversity	Use of land resources and of space: - Urbanisation: land covered by urban development - Land use patterns and conversions in sensitive areas - Land used for recreation - Access to green areas in cities	 2 2 2 2	 1 2 2 2	 2 3 3 3	 2 3 3 3	●
	Protected areas	2/3	1	1	1	
Economic and policy aspects						
Regulatory instruments	No indicators proposed					
Economic instruments	Consumer price index	1/2	1	1	1	
	Pollution abatement and control expenditure (public sector, households)	1	2	2	2	
	Energy prices and taxes - Energy prices and taxes for households - Road fuel prices and taxes	 1 1	 1 1	 1 1	 1 1	
	Prices for public water supply	1	2	1/2	2	
	Charges for waste water treatment	1	2	3	3	
	Subsidies for transport, efficient building technologies and practices, and water/energy saving devices	1	3	3	3	
	Tax rates on natural resource use compared to tax on services	1	2	3	3	
Information/social instruments	Consumer attitudes towards environment	1	2	2	2	
	Eco-labelled products	2	2	3	3	
	Public expenditure on environmental information	1	2	3	3	

Area	Indicators	Policy relevance	Analytical soundness	Measurability		
				Data availability	Data quality	
	and education					
	Public support to green NGOs	2	2	3	3	
Trade and environment	Composition of internationally traded goods	2	1	2	2	
	Ratio between imported and domestically produced goods in domestic consumption	2	2	2	2	

* Classifications used for evaluating the indicators: policy relevance (1=high; 2=medium; 3=low) ; analytical soundness (1=good; 2=average; 3=poor); measurability in terms of data availability (1=short term; 2=medium term; 3=long term) and of data quality including international comparability (1=good; 2=average; 3=poor).
Legend: : Indicators identical or similar to indicators proposed in the UNCSD set.

Indicators of Sustainable Development (UN-CSD)

Theme	Sub-Theme	Core indicator	Other indicator	
Poverty	Income poverty	Proportion of population living below national poverty line	Proportion of population living below 1 $ a day	■
	Income inequality	Ratio of share in national income of highest to lowest quintile		■
	Sanitation	Proportion of population using an improved sanitation facility		■
	Drinking water	Proportion of population using an improved water source		■
	Access to energy	Share of household without electricity or other modern energy service	Percentage of population using solid fuel for cooking	■
	Living conditions	Proportion of populations living in slums		■
Governance	Corruption	Percentage of population having paid bribes		
	Crime	Number of intentional homicides per 100,000 population		
Health	Mortality	Under-five mortality rate Life expectancy at birth	Health life expectancy at birth	
	Health care delivery	Percent of population with access to primary health care facilities Immunisation against infectious childhood diseases	Contraceptive prevalence rate	
	Nutrional status	Nutritional status of children		
	Health status and risks	Morbidity of major diseases such as HIV/AIDS, malaria, tuberculosis	Prevalence of tobacco use	
Education	Education level	Gross intake ratio to last grade of primary education Net enrolment rate in primary education Adult secondary (tertiary) schooling attainment level	Life long learning	
	Literacy	Adult literacy rate		
Demographics	Population	Population growth rate Dependecy ratio	Total fertility rate	
	Tourism		Ratio of local residents to tourists in major tourist regions and destinations	
Natural hazards	Vulnerability to natural hazards	Percentage of population living in hazard prone areas		■
	Disaster preparedness and response		Human and economic loss due to natural disasters	■
Atmo-sphere	Climate change	Carbon dioxide emissions	Emissions of greenhouse gases	●
	Ozone depletion	Consumption of ozone depleting substances		
Land	Land use and status		Land use change Land degradation	●
	Desertification		Land effected by desertification	
	Agriculture	Arable and permanent crop are	Fertilizer use efficiency Use of agricultural pesticides Area under organic farming	
	Forests	Proportion of land area covered by forests	Percent of forest trees damaged by defoliation Area of forest under sustainable management	

Theme	Sub-Theme	Core indicator	Other indicator	
Oceans, seas and coasts	Costal zone	Percentage of total population living in coastal areas	Bathing water quality	
	Fisheries	Proportion of fish stock within safe biological limits		
	Marine environment	Proportion of marine area protected	Marine tropic index Area of coral reef ecosystems and percentage live cover	
Freshwater	Water quantity	Proportion of total water resources used Water use intensity by economic activity		
	Water quality	Presence of faecal coli forms in freshwater	Biochemical oxygen demand in water bodies Wastewater treatment	
Biodiversity	Ecosystem	Proportion of terrestrial area protected, total and by ecological region	Management effectiveness of protected areas Area of selected key ecosystems Fragmentation of habitats	
	Species	Change in threat status of species	Abundance of selected key species Abundance of invasive alien species	
Economic development	Macroeconomic performance	Gross domestic product (GDP) per capita Investment share in GDP	Gross saving Adjusted net savings as percentage of gross national income (GNI) Inflation rate	
	Sustainable public finance	Debt of GNI ratio		
	Employment	Employment-population ratio Labour productivity and unit labour costs Share of women in wage employment in the non agricultural sector	Vulnerable employment	
	Information and communication technologies	Internet user per 100 population	Fixed telephones lines per 100 population Mobile cellular telephones per 100 population	
	Research and Development		Gross domestic expenditure on R&D as a percent of GDP	
	Tourism	Tourism contribution to GDP		
Global economic partnership	Trade	Current account deficit as percentage of GDP	Share of imports from developing countries and from LDCs Average tariff barriers imposed on exports from developing countries and LDCs	
	External financing	Net Official Development Aid (ODA) given or received as a percentage of GDI	Foreign direct investment (FDI) net inflows and net outflows as percentage of GDP	
Consumption and production patterns	Material consumption	Material intensity of the economy	Domestic material consumption	
	Energy use	Annual energy consumption total and by main user category	Share of renewables in total energy use	•
	Waste generation and management	Generation of hazardous waste Waste treatment and disposal	Generation of waste Management of radioactive waste	
	Transportation	Modal split of passenger transportation	Modal split of freight transport Energy intensity of transport	•

Urban indicators (UN-HABITAT)

Chapter	Habitat Agenda Goal	Indicator	Cluster	
Shelter	1. Promote the right to adequate housing.	Key indicator 1: durable structures Key indicator 2: overcrowding check-list 1: right to adequate housing extensive indicator 1: housing price and rent-to-income	A A B B	■
	2. Provide security of tenure	Key indicator 3: secure tenure extensive indicator 2: authorised housing extensive indicator 3: evictions	B B B	
	3. Promote equal access to credit	check-list 2: housing finance	B	
	3. Provide equal access to land	extensive indicator 4: land price-to-income	B	
	5. Promote access to basic services	Key indicator 4: access to safe water Key indicator 5: access to improved sanitation Key indicator 6: connection to services	A A A	■
Social Development and eradication of poverty	6. Provide equal opportunities for a safe and healthy life	Key indicator 7: under-five mortality Key indicator 8: homicides check-list 3: urban violence extensive indicator 5: HIV prevalence	A B B A-B	
	7. Promote social integration and support disadvantaged groups	Key indicator 9: poor households	A	
	8. Promote gender equality in human settlements development	Key indicator 10: literacy rates check-list 4: gender inclusion extensive indicator 6: school enrolment extensive indicator 7: women councillors	A B A B	
Environmental Management	9. Promote geographically-balanced settlement structures	Key indicator 11: urban population growth Key indicator 12: planned settlements	A B	●
	10. Manage supply and demand for water in an effective manner	Key indicator 13: price of water extensive indicator 8: water consumption	B B	
	11. Reduce urban pollution	Key indicator 14: wastewater treated Key indicator 15: solid waste disposal extensive indicator 9: regular solid waste collection	B B	
	12. Prevent disasters and rebuild settlements	check-list 5: disaster prevention and mitigation instruments extensive indicator 10: houses in hazardous locations B	B B	■
	13. Promote effective and environmentally sound transportation system	Key indicator 16: travel time extensive indicators 11: transport modes	B	●
	14. Support mechanisms to prepare and implement local environmental plans and local Agenda 21 initiatives	check-list 6: local environmental plans	B	●
Economic Development	15. Strengthen small and micro-enterprises, particularly those developed by women	Key indicator 17: informal employment	A-B	
	16. Encourage public-private sector partnership and stimulate productive employment opportunities	Key indicator 18: city product Key indicator 19: unemployment	B A-B	
Governance	17. Promote decentralisation and strengthen local authorities	Key indicator 20: local government revenue Check-list 7: decentralisation	B B	■
	18. Encourage and support participation and civic engagement	Check-list 8: citizens participation extensive indicator 12: voters participation extensive indicator 13: civic associations	B	
	19. Ensure transparent, accountable and efficient governance of towns, cities and	Check-list 9: transparency and accountability	B	

Chapter	Habitat Agenda Goal	Indicator	Cluster	
	metropolitan areas qualitative data 8: transparency and accountability			

CLUSTER A - Indicators to be obtained from Censuses and national households surveys, including Demographic and Health Surveys and Multiple Indicators Cluster Surveys.
CLUSTER B - Indicators to be obtained from other sources such as official record and published studies of Government institutions, housing boards and agencies, service parastatals, finance institutions, police, NGOs as well as using informed estimates made by small groups of experts on specific issues.

Healthy City Indicators (WHO)

Theme	Indicators	Definition	
Health	Mortality: all causes	Annual mortality rate: all causes, according to age group	
	Cause of death	Annual mortality rate per cause of death studied	
	Low Birth weight	Percentage of children weighing 2.5 kg or less than 2.5 kg at birth	
Health service	Existence of a city health education programme	Health education programmes are made up of one or several projects, which aim to improve knowledge, assistance and services to individuals for developing and maintaining a healthy way of life. Indicate programmes, which have been fully or partly financed or assisted by the city in the following areas: 1. Tobacco/2. Alcohol/3. Nutrition/4. Drugs/5. Accidents /6.other	
	Percentage of children fully immunised	1. Indicate the type of vaccine cover given by the age of six for each compulsory vaccination. The list of compulsory vaccinations may be different in each country. Each city should give information on the rules in force in the country; e.g. infections and illnesses for which the public health authorities usually demand a compulsory vaccination: measles, polio, tetanus, rubella, diphtheria. 2. Percentage of infants who by their first birthday have been immunised against diphtheria/pertussis/tetanus (3 doses), poliomyelitis (3 doses), measles (1 dose) and where required by law, tuberculosis (BCG, 1 dose). 3. Proportion of children immunised against measles before their second birthday, where the country schedule prescribes such immunisation. 4. If children are immunised against rubella and haemophilus influenzae (in your city) please provide appropriate percentages.	
	Number of inhabitants per practising primary health care practitioner	1. Doctors who carry out their activity in the field of primary care. Several countries keep a register/list of doctors working in a given area. 2. Nurses who carry out their activity in the field of primary health care. 3. Other primary health care practitioners (specify)	
	Number of inhabitants per nurse	1. Nurses to be included are those working in the areas(s) concerned, wherever they work (primary health or first aid services either in general or specialist fields e.g. midwifery and paediatrics/mental health/elderly people, etc.; either general or specialised hospitals, clinics, homes for the elderly, reception centres, etc. 2. Midwives working in hospitals 3. Mental health nurses in hospitals	
	Percentage of population covered by health insurance	Indicate people who have health insurance, if possible, by type (public or private), etc. i.e. 1. % of the population covered by public insurance funds 2. % of population covered by private insurance funds	
	Availability of primary health care services in foreign languages	Indicate the availability of primary health care services where ethnic minority languages, which are significantly representative in the city, are spoken, or interpreters in the languages are available. If interpreters are available indicate: 1. if they are employed by the service specifically for interpreting 2. the availability of the interpreters all health carers i.e. available any times or only at specific times and services	
	Number of health related questions examined by the city council every year	"Health related questions" are those asked directly by the elected representatives of health, social and environmental services/departments. Those questions asked by the elected representatives of other services/departments which gave rise to discussions by the city council on health, social and environmental aspects should also be listed. 1. Number of meetings organised by the city's elected representatives dealing with matters related to health 2. Health related questions raised by the city's elected representatives (a) directly with departments of health/social services and environment. (b) at the assembly of elected members which have resulted in a discussion or debate	
Environmental	Atmospheric pollution	This indicator should allow the air quality in cities to be assessed. Each of the following atmospheric pollutants should be evaluated independently: NO2, CO, O3, SO2, Dust, Black smoke, Lead. Indicate: 1. Number of monitoring stations 2. Annual mean for each pollutant	
	Water quality	Percentage of measurements exceeding the recommended WHO guidelines	
	Percentage of water pollutants removed from total sewage produced	This indicator aims to show the quality of water purification before disposal Please also provide information on: (1) details of waste water treatment (2) testing requirements	
	Household waste collection quality index	This indicator should show the quality of the collection in relation to the types of collecting systems used. If possible also include details on: 1. quantity and composition of waste collected 2. proportion of waste materials recycled 3. proportion of waste not collected or illegally dumped	

Theme	Indicators	Definition	
	Household waste treatment quality index	This index should give the type and percentage of treatment used for household waste by cities.	
	Relative surface area of green spaces in the city	This indicator gives an idea of vegetation in the city and is based on the percentage of the surface area of green spaces relative to the surface area of the city. Please categorise under following headings 1. public park 2. private domestic gardens used for food rowing 3. unmanaged areas that may be wild vegetation or wild life havens	●
	Public access to green space	This indicator allows the surface area of green spaces per inhabitant to be open to the public Has a land use survey been carried out in the city? If so, please give details of survey with regards to public access to green spaces.	●
	Derelict industrial sites	Percentage of derelict industrial sites compared to the total surface area of the city. Derelict industrial sites include sites, which were formerly used as factories, etc., but now have been shut down and the area remains unused and undeveloped for any other purpose.	
	Sport and leisure	Number of sports facilities per 1000 inhabitants If possible, include details of the age structure and gender of the people who use these facilities	
	Pedestrian streets	This indicator shows the importance accorded to pedestrian streets. Pedestrian streets are defined as streets entirely used for pedestrians from which all vehicular traffic is banned.	
	Cycling in city	This indicator shows the importance accorded to cycle paths Cycle paths are defined as paths in streets marked out to be used exclusively by cycles	
	Public transport	Number of seats on public transport per 1000 inhabitants (also include standing room) If possible also give details on (1) frequency and reliability of the public transport (2) approximate cost per 10 km travelled on public transport against the cost to travel a similar distance in a private car	●
	Public transport network cover	Number of kilometres served by public transport compared to the total number of kilometres of streets in the city. Include information on the proportion of people who use public and those who use private transport.	●
	Living space	Average number of rooms per inhabitant The rooms are counted if they have a distinct purpose or if they are >4m^2 (e.g. kitchen, dining room, bedrooms, etc.) bathrooms, laundry rooms, hallways, etc., are not counted as rooms	●
Socio-economic	Percentage of population living in substandard accommodation	The percentage of population living in substandard housing conditions, that is to say accommodation which does not fulfil the following requirements: exclusive use of toilet and bath or shower; tap water inside the dwelling	■
	Estimated number of homeless people	Number of people having no housing (not including people who live in mobile homes) Include both people who are homeless and living in hostels and shelters provided for homeless people and also those homeless and not in any such accommodation but living on the streets. If possible also provide separate figures for each category.	■
	Unemployment rate	Percentage of working population, which is unemployed. The unemployed comprise all persons (aged 15-64 years) who during the reference period were (1) “without work” i.e. not in paid employment or self employment (2) “currently available for work” i.e. were available for paid employment or self employment during the reference period and “seeking work” i.e. had taken specific steps in a specified recent period to seek paid employment or self employment	
	Percentage of people earning less than the mean per capita income	This threshold varies from country to country (1) % of people earning less than the mean per capita income of the country (2) Proportion of people receiving state and welfare benefits	
	Percentage of child care places for pre-school children	Number of child care places available for pre-school children	
	Percentage of all live births to mothers > 20; 20-34; 35+	% of all live births to mothers in the specific age bands	
	Abortion rate in relation to total number of live births	Percentage of total number of abortions and miscarriages in relation to total number of live births	
	Percentage of disabled persons employed	Percentage of disabled persons of working age engaged in regular occupational activities	

Global City Indicator

	Theme	Core Indicator	Supporting indicators	
City Service	Education	Percentage of children completing primary and secondary education Percentage of school aged children enrolled in schools (by gender)	Student/teacher ratio	
	Energy	Percentage of city population with authorised electrical service	Total electrical use per capita Number and duration of electrical interruptions per year per customer	●
	Finance	Debt service ratio	Tax collected as percentage of tax billed Own-source revenue as a percent of total expenditures	
	Fire and emergency response	Number of fire fighters per 100,000 population Number of fire related deaths per 100,000 population	Response time for fire department from initial call	
	Governance	Accountability and transparency	Percentage of government workforce that are women and minorities	
	Health	Under age five mortality per 1,000 live births Immunisation against infectious childhood diseases	Number of in-patient hospital beds per 100,000 population Number of physicians per 100,000 of population	
	Recreation	Square metres of public recreation facility spaces per capita	City expenditure on public recreation as a percentage of overall city budget	
	Safety	Number of homicides per 100,000 population Number of sworn police officers per 100,000 population	Violent crime rate per 100,000 population	
	Social services	Under development		
	Solid waste	Percentage of population with regular solid waste collection Percentage of solid waste disposed to sanitary landfill/incinerated and burned openly/disposed to open dump/recycled/other	Total solid waste generation per capita	
	Transportation	Km of transportation systems per 100,000 population Annual number of public transit trips per capita	Commercial air connectivity (number of nonstops commercial air destinations) Average travel speed on primary thoroughfares during peak hours Transport fatalities per 100,000 population	●
	Urban Planning	Latest approval date of Master Plan	Green area per 100,000 population Housing in hazardous locations	●
	Wastewater	Percentage of city population served by wastewater collection Percentage of wastewater receiving primary, secondary, tertiary treatment		
	Water	Percentage of city population with potable water supply services	Domestic water consumption per capita Number of interruption of water services	
Quality of life	Civic engagement	Voter participation (as a percent of eligible voters)	Number of local officials elected to office per 100,000 population Number of civic organisations per 100,000 population	
	Culture	Number of cultural establishments per 100,000 population	City expenditure on culture as a percentage of overall city budget	
	Economy	City product per capita	Employment rate by age and sex	
	Environment	Greenhouse gas emissions in tons per		●

	Theme	Core Indicator	Supporting indicators	
		capita		
	Shelter	Percentage of city population living in slums	Areal size of informal settlements as a percent of city area and population	■
	Social equity	Percentage of city population living in poverty		■
	Subjective well-being	Under development		
	Technology and Innovation	Number of internet connections per 100,000 population	Number of telephones (land lines and cell phones) per 100,00 population	

Environmental Sustainability Indicators (MDG7/UNEP)

Population growth—total number of inhabitants over a ten year period	
Dwellings in low-income settlements to be upgraded—number of dwellings	■
Land use changes from non-urban to urban use (km^2 of urban area)	●
Proportion of city residents without access to secure tenure	■
Gini index (social inequality)	
Incidence of following diseases: diarrhoea, poliomyelitis and Hepatitis A, tuberculosis, worm infections, skin and eye infections, insect transmitted diseases for example, malaria, yellow fever, dengue (number per 1000 population per annum)	
Death rate per 100,000 residents per annum from cardiovascular and respiratory diseases, strokes, cancer, and HIV/AIDS	
Population with access to piped, safe drinking water—number and percent of total	■
Population in dwellings without access to septic tank or an urban sewerage system linked to a wastewater treatment plant— number of inhabitants and volume of untreated sewage	■
Generation of household solid waste—kg/per capita/per day or per annum	
Collection of household solid waste (percent of households) Emissions of CO_2 equivalent per capita/annum (tons)	
Atmospheric emissions: volume (tons/capita/annum) and number of days/annum when WHO standards for PM_{10}, CO, NO_x, C_6H_6, Pb & SO_2 at specific monitoring points are exceeded	
Consumption of gas & electrical energy (KWh/per capita/ annum)	●
Water consumption litres per capita per day or annum	
Reduction of land covered by forest and woodland (ha)	●
Loss of natural vegetation cover and green areas (ha)	●
Area of environmentally-sensitive land protected to maintain biodiversity (ha)	●

Annex D – Different indicators sets in extenso II

Outcomes Sustainability Indicators (King County Benchmarks)

Level	Outcome	Indicator	
Economic Development	Promote family wage jobs	- Real wage per worker - Personal/median household income	
	Increase income and reduce poverty	- Percentage of population below poverty level - New business created	
	Increase business formation, expansion and retention	- New jobs created by employment sector	
	Create jobs that add to economic base	- Employment in industries that export	
	Increased educational skill levels	- Educational level of adult population - High school graduation rate	
Environment	Protect and enhance natural ecosystems	- Land cover changes in urban and rural areas over time	■
	Improve air quality	- Air quality - Energy consumption - Vehicle miles travelled per year	●
	Protect water quality and quantity	- Surface water and groundwater quality - Water consumption - Change in groundwater levels	
	Protect wetlands	- Change in wetland acreage and functions	■
	Protect the diversity of plants and wildlife	- Continuity of terrestrial and aquatic networks	
	Increase salmon stock	- Change in number of salmon	
	Decrease noise levels	- Rate of increase in noise from vehicles, planes and yard equipment	
	Decrease waste disposal and increase recycling	- Pounds of waste disposed and recycled per capita	
Affordable housing	Provide sufficient affordable housing for all residents	- Supply and demand for affordable housing - Percentage of income paid for housing - Homelessness - Apartment vacancy rate	■
	Promote affordable home ownership	- Home purchase affordability gap for buyers with median household income	
	Opportunities	- Home ownership rate - Trend in housing costs vs. income	
	Promote equitable distribution of affordable low income housing throughout households	- Public dollars spent for low income housing - Housing units affordable to low-income	
Land use	Encourage a greater share of growth in urban areas and urban centres: limit growth in rural areas	- New housing units in urban areas and rural/resource areas, urban centres - Employment in urban areas, rural/resource areas, urban centres, Mfg. centres	●
	Make efficient use of urban land	- New housing units through redevelopment - Ratio of land consumption to pop. Growth - Ratio of achieved density to allowed density of residential development	●
	Accommodate residential and job growth in urban areas	- Ratio of land capacity to 20 year target - Land with 6 years of infrastructure capacity	
	Encourage liveable, diverse communities – balance job and households growth	- Acres of urban parks and open spaces - Ratio of jobs to housing in sub-regions	●
	Maintain Quality and quantity of natural resource lands	- Acres in forest land and farm land - Number and average size of farms	
Transportation	Transportation and land use linkage	- Percentage of residents who commute one-way within 30 min	■
	Availability of modes other than drive alone	- Metro transit ridership	
	Modal split	- Percentage of residents who walk or use transit, bicycles, carpools	■
	Reduce commercial traffic congestion	- Ability of goods and services to move efficiently through region	
	Protect and improve transportation infrastructure	- Number of lane miles of city, county, state roads, bridges needing repair	

Sustainable city indicators (Santa Monica Sustainable City)

Theme	Indicator	Subindicator	
Resource conservation	Solid waste generation	- Total citywide generation (also per capita, sector) - Amount land filled - Amount diverted (recycled, composted, etc) from landfill	
	Water use	- Total citywide use (also per capita, sector) - Percent local vs. imported - Potable vs. non-potable	
	Energy use	- Total citywide use (also per capita, sector)	■
	Renewable energy use	Percent of citywide energy use from renewables and more efficient sources: - Total renewable energy use (also by sector) - Total energy use from clean distributed generation sources (also by sector)	■
	Greenhouse gas emissions	- Total citywide emissions (also reported per capita, by source and by sector)	●
	Ecological footprint		■
	Indicator of sustainable procurement		
	Green construction	*Total number of LEED® certified building as a percent of new construction*	
Environmental and Public health	Wastewater (sewage generation)	- Total city wide generation (also per capita, sector)	
	Vehicle miles travelled	- Total; local vs. drive through	■
	Air quality	Percent and demographic profile of residents who live within a certain distance radius of significant emissions sources	
	Residential households hazardous waste		
	City purchase of hazardous materials		
	Toxic air contaminant (TAC) releases		
	Urban runoff reduction		
	Fresh, local, organic produce		
	Organic produce – farmers markets		
	Restaurant produce purchases		
	Food choices		
Transportation	Modal split	- Number of trips per type, citywide - Average vehicle trip (AVR) of business with more than 50 employees	■
	Residential use of sustainable transportation options	Percent of residents who have intentionally not used their car (instead used a sustainable mode of transportation) in the last past month	
	Sufficiency of transportation options	Percent of residents who perceive that the available sustainable modes of transportation meet their needs	
	Bicycle lanes and paths	- Percent of total miles of city arterial streets with bike lanes - Total miles of bike paths	
	Vehicle ownership	Average number of vehicles per person of driving age - Total number of vehicles per person - percent of total that are qualified low emissions/ alternative fuel vehicle	
	Bus ridership		
	Alternative fuelled vehicles		
	Traffic congestion		
	Pedestrian and bicycle safety		
	Traffic impact to emergency response		
Economic Development	Economic Diversity	Percent of total economic activity/output by business sector (as percent of total ages)	
	Business reinvestment in the community		
	Jobs/housing balance	- Ratio of number of jobs to the amount of housing - Percent of residents employed in the city	
	Cost of living	Households income in relation a certain index	
	Quality of job creation	Number of net new job created in the city that pay greater than or equal to the index as a percent of total new jobs created	
	Income disparity	- Percent of households earning less than a certain amount/year; Percent of households earning more than a certain amount/year	

Theme	Indicator	Subindicator	
	Resource efficiency of local businesses	- Ratio of energy use to total economic activity by business sector - Ratio of total water use to total economic activity by business sector	
	Local employment of city staff		
Open space and land use	Open space	- Area of public open space by type (including beaches, parks, gardens, etc.) - Percent of open space that is permeable	●
	Trees	- Percent of canopy coverage by neighbourhood - Percent of newly planted and total trees that meet defined sustainability criteria	●
	Parks - Accessibility	Percent of households and population within a certain distance of a park by neighbourhood	●
	Land use and development	Percent of residential, mixed-use projects that are within certain distance of transit nodes and are otherwise consistent with Sustainable City Programme goals	●
	Regionally appropriate vegetation	Percent of new or replaced, non-turf, public landscape area and non-recreational turf areas planted with regionally appropriate plants	
Housing	Availability of affordable housing	Percent of all existing and new housing affordable to very low, low, moderate and upper income households	■
	Distribution of affordable housing	Distribution of low income housing by neighbourhood	■
	Affordable housing for special needs groups		
	Production of liveable housing		
	Production of "green" housing		
Community education and civic participation	Voter participation	Percent of registered voters who vote in scheduled elections	
	Participation in civic affairs	Percent of residents who have attended a city-sponsored meeting of any kind in the past year, including city council meetings, cit commission meetings, special workshops	
	Empowerment	Percent of residents who feel they have the opportunity to voice their interests	
	Community involvement	Percent of residents who attend community events	
	Volunteering	Percent of residents volunteering and total hours volunteered in selected programmes	
	Participation in neighbourhood organisations	Percent of residents that are active members in recognised neighbourhood organisations	
	Sustainable community involvement	- Percent of residents who are aware of Ecological footprint and understand their contribution to it	
Human dignity	Basic needs - shelter	- Number of homeless - Percent of homeless population served by city shelter that transition to permanent housing	
	Basic needs – heath care	- Percent of residents with health insurance - Capacity of local health service providers to meet the basic health care needs of residents	
	Basic needs – economic opportunity	Percent of residents who work more than 40 hours per week in order to meet their basic needs	
	Basic needs – public safety	Crime rate per capita – reported by neighbourhood/reporting district and by type	
	Residents perception of safety	Percent of residents who feel safe	
	Incidents of abuse	- Number of incidents of abuse (domestic, child, and elder abuse) - Percent of cases prosecuted	
	Incidents of discrimination	- Number of reports regarding employment and housing discrimination - Number of cases prosecuted	
	Education/Youth		
	Empowerment	Women, minorities and people with disabilities in leadership positions - Business, - local government, - non-profit organisations	
	Ability to meet basic needs	Percent of residents who perceive that need are being met	

In *italics* – Indicators and sub-indicators at project level.

"City of the Future" Strategy and Indicators (BBR)

Theme	Strategy			
Provident Land Management	Reduction of the increase in built-up area Reuse of urban derelict land and vacant buildings Optimum use of urban density Conservation and connection of climate effective open spaces			
City-compatible Mobility Managemen	Connection residential areas and workplaces to public transport Reduce the space requirements for the individual motorised transport Expansion of the cycle network Increase the quality of stay for pedestrians			
Precautionary Environmental Protection	Energy conservation and increase in share of renewable energies Reduce air pollution and the greenhouse gases Protection and maintenance of groundwater and water resources Strengthen the biogeochemical cycles and reduce the residual waste			
Socially-responsible Housing Supply	Resource efficient and cost effective housing construction Supply of apartment for seekers with special housing needs Promote neighbourhood self-help Assurance of basic provision near the residential area			
Local-securing Economic Development	Guarantee business locations in the urban centre Creation of workplaces reconcilable with residential area Strengthen and develop urban centres Economic development for environmentally friendly businesses			
Theme	**Standard indicators**		**Additional indicators***	
Provident Land Management	Settlement and traffic area	●	Growth of settlements inwards/ outwards	●
	Intensity of land use	●		
	Protective areas	●	Developed sites mobilisation in stock	●
	Re-use of brownfield sites	●		
City-compatible Mobility Management	Kilometres travelled by bus and train	■	Total length of bike paths	
			Use of cars in the city (modal split)	■
	Car density		Public-transport developed urban area	■
			Road safety (traffic victims)	
Precautionary Environmental Protection	Residual waste		Urban CO_2-Emission	●
	Drinking water consumption		Energy consumption	●
Socially-responsible Housing Supply	Moving away into the surrounding		Basic services near dwellings	
	Housing subsidy		Domestic burglary	
Local-securing Economic Development	Unemployment rate		Workstation space	
	Total commuters		Local economic structure	

Development/master plan elements and sustainability indicators

Plan Element	Theme	Indicator	
Land-Use	Urban area footprint	Total community land area in acres per resident	●
	Infill	Percent of building issued annually on property platted more than five years prior to building permitting	●
	Use mix	Dissimilarity among one-acre grid cells containing predominant land use	●
	Land redeveloped	Percent of designated land area redeveloped per year	●
	Jobs/housing balance	Ratio of jobs to dwelling units	
Transportation	Travel density	Distance travel per capita by mode of transportation	■
	Transit service density	Index of miles of transit routes multiplied by the number of transit vehicles travelling those routes each day, divided by total land area	
	Auto use	Auto vehicles miles travelled per capita per day	
	Pedestrianisation	Percent of all person trips made by walk/bike modes	
Environment	Natural areas protection	Percent of total land area protected as natural area or equivalent	■
	Species biodiversity	Abundance of selected key species	
	Agricultural and land conversion	Acres of agricultural land urbanised per year	
	Imperviousness	Percent of total land area covered by impervious surfaces	
	Water quantity	Annual withdrawal of ground and surface water as a percent of total available water	
	Water quality	BOD in water bodies	
	Air quality	Ambient concentration of air pollutants in urban areas	
	Climate change	Emission of greenhouse gases	●
	Ozone depletion	Consumption of ozone depleting substances	
Infra-structure	Water consumption	Residential water use in gallons per capita per day	
	Park space availability	Acres of park and school yards per 1000 residents	
	Waste generation and management	Waste recycling and reuse	
Urban design	Preservation of historic and archaeological sites and buildings	Percentage of historic and archaeological sites and buildings designated for preservation	
	Open space protection	Percent of total land dedicated to open space	●
Housing	Density	Dwelling units per net acre of land designated for residential use	●
	Affordability	Ratio of average house sale price versus an „affordable price“	
	Transit proximity	Average travel distance from dwellings to closest transit stop in feet	●
Energy	Energy use	Intensity of energy use	■
		Share of consumption of renewable energy resources	
Economic development	Economic performance	GDP per capita	
	Level of investment	Inward investment (as per level of output)	
	Employment	Number of employees per net acre of land designated for employment uses Unemployment rate	

Plan Element	Theme	Indicator	
Population	Human health	Years of healthy life expectancy	
	Poverty	Percent of population living below poverty line	■
	Education	Literacy rate	
	Social inclusiveness	Percent of the poor children, women and disabled people that have access to community facilities and services. Percent of deprived people that participate in decision making	■

Planning outcomes indicators (RTPI)

Objective	Indicators	
Making suitable land available and its efficient use for development	Making commercial floor space developed Additional new homes completed Percentage change in derelict land stock Percentage of appeals against refusal of planning permission Change in inter- and intra-regional transport infrastructure capacity and connections	■
Suitable economic development	Percentage change of working age people in employment Percentage change in the total number of VAT registered businesses Change in job density Change in the level of community interdependence	
Protecting and enhancing the natural and historic environment	Loss of protected area Percentage of residents surveyed satisfied with their neighbourhood as a place to live Change in area of parks an green spaces per 1,000 head of population	● ● ●
High quality development and efficient use of resources	Change in carbon footprint (CO_2 emission per capita) Change in commuting mode (public transport) Congestion: average journey time per mile during the morning peak Percentage of residents surveyed finding it easy to access key local services	● ●
Inclusive and liveable communities	Percentage change in total resident population Percentage of population who live in the 10% most deprived areas Percentage of households that can afford to purchase the average first time buyer's property in the area Change in supply-side over qualification index value	■

Sustainability indicators - multi-layered urban typologies

Level	Theme	Indicator	
Physical structure - Housing structure	Compactness (Density + Structure)	Floor area, height (storeys)	●
		Built up ratio	●
		Block size and shape	●
		Structure of the street network	●
		Location of the metropolitan area	
		Multi-functionality /mixture of usage	●
	Informality	Informal settlement rate	■
	Accessibility	Low income people accessibility to housing	■
Urban land use – urban/environ. land use pattern	Land resource	Land use structure	●
	Green area	Green area (trees, grass, waters)	●
	Community space	Community space	
	Green area	Distribution of green areas	●
	Underground water	Quality of underground water	
	Underground water	Intensity of exploitation	
	Surface water	Quality of surface water	
Use pattern – public infrastructure services	Sanitation (accessibility)	Clean water supply	
		Sewage system	
		Waste collection system	
	Water pollution	Waste water treatment	
	Disposal/collection	Domestic waste generation/collection	
	Treatment	Volume of treated waste	
	Transportation modes	Density/ratio/efficiency of public transportation	
	Energy	Consumption of energy	
Social System – social sciences and human geograph	Density	Population density	■
	Population change	Migration/natural growth rate	
	Economic structure	Income	
	Poverty	Population living below poverty line	■
	Unemployment	Unemployment rate	

INDEX Indicators

Theme	Indicator		Indicator	
Demographics	Population (residents)		Employment (employees)	
	Population density (residents/gross area)			
Land use	Study area surface (total area)	●	Average parcel size (average area)	●
	Use mix (scale 0 to 1)	●	Use balance (scale 0 to 1)	●
	Development footprint (net area/1000 residents)			●
Housing	Dwelling density (DU/gross area)	●	Dwelling unit count (total Dwelling Units)	
	Residential footprint (net area/1000 R)	●	Single-family parcel size (avg. area)	
	Single family dwelling density (DU/net area)	●	Multifamily dwelling density (DU/net area)	●
	Single family dwelling share (% from total DU)		Multifamily dwelling share (% from total DU)	●
	Amenities adjacency (% pop w/i user buffer)		Amenities proximity (avg. walk to closest)	
	Transit adjacency to housing (% pop w/i user buffer)		Transit proximity to housing (avg. walk distance to closest stop)	
	Waste water generation (volume/day)		Solid waste generation (weight/day)	
	Structural energy use (/year/capita)	●	Residential water consumption (volume/day/capita)	
Employment	Jobs to housing balance (jobs/DU)		Employment density (emps/net area)	
	Commercial building density (avg. FAR)			
	Transit adjacency to work (% pop w/i user buffer)		Transit proximity to work (avg. walk distance to closest stop)	
Recreation	Park/school yard/space supply (area/1000 residents)			
	Park/school yard adjacency to housing (% pop w/i user buffer)		Park/school yard proximity to housing (avg. walk distance to closest park/school)	
Environment	NO_x pollutant emission (weight/cap/yr)		HC pollutant emissions (weight/cap/yr)	
	CO pollutant emissions (weight/cap/yr)		GHG emissions (weight/cap/yr)	
	Open space share (% total net area)		Open space connectivity (0-1 scale)	
	Storm water runoff (volume/area/yr)		Nonpoint pollution (weight/area/yr)	
	Imperviousness (% total net land area)	●	Floodplain encroachment (% study area w/i floodplain)	●
	Land suitability (% net vacant land developable)			●
Transportation	Internal street connectivity (cul-de-sac/intersection ratio)		External street connectivity (avg. distance between ingress/egress streets)	
	Street segment length (avg. length		Street centreline distance (total length)	
	Street network density (centreline length/area)		Transit service coverage (stops/area)	
	Transit service density (vehicle route length/area)		Vehicle route length/area)	
	Transit-oriented residential density (DU/net area w/i user buffer of stops)		Transit-oriented employment density (emps/net area w/i user buffer of stops)	
	Light rail boarding (avg. person/day)		Pedestrian network coverage (% of streets w/sidewalks)	
	Pedestrian crossing distance (avg. curb-to-curb length)		Street route directness (walk distance/straight line ratio)	
	Street route directness (walk distance/straight line ratio)		Pedestrian setback (avg. commercial building setback length)	
	Pedestrian accessibility (% origins w/i		Bicycle network coverage	
	Residential multimodal access (% DU w/ 3+ modes w/ i1		Home-base vehicle miles travelled (distance/day/capita)	
	Nonhome-base vehicle miles travelled (distance/day/capita)		Home-based vehicle trips (trips/day/capita)	
	Nonhome-based vehicle trips (trips/day/capita)			
	Personal vehicle energy use (yr/capita)		Park requirements (total space required)	

Indicators for sustainable development for climate change policy and analysis (UN DSD)

Theme/ Subtheme	CSD Indicator	Other Indicator	Related CSD Indicator	
Climate Change Mitigation				
GHG Emission	Carbon dioxide emission (total and by sector)			
	Emission of GHG total and by gas			
	Consumption of ozone depleting substances			
		CO2/GHG emissions per capita / *MDG Indicator*	CO2/GHG emission	
		CO2/GHG intensity of the economy (total and by sector) / *MDG Indicator*	Carbon dioxide emissions/Emission of greenhouse gases	
		Consumption-based GHG emissions	Emission of greenhouse gases	
Energy	Annual energy consumption and by main user category			
	Intensity of energy use, total and by economic activity			
	Share of renewables energy sources in total energy use			
		Carbon intensity of energy use	Carbon dioxide/ Energy consumption	
	Energy intensity of transport (fuel use per km)			
	Modal split of passenger transportation			
	Modal split of freight transport			
		Household energy intensity (Energy use per household and/or per floor area) (Energy Indicators of Sustainable Development)		
Industry and product use	Material intensity of the economy			
	Domestic material consumption			
Waste	Generation of waste			
	Waste treatment and disposal			
	Wastewater treatment			
	Ambient concentration of air pollutants in urban areas			
Agriculture, forests and other land use	Fertilizer use efficiency			
	Area under organic farming			
	Proportion of land area covered by forests			
		Deforestation rate	Land use change	
	Area of forest under sustainable forest management			
		Area under payment for ecological services (PES) schemes		
	Land use change			
	Land use degradation			
Climate Change Adaptation				
Temperatur		Annual mean and variability of temperature		

Theme/ Subtheme	CSD Indicator	Other Indicator	Related CSD Indicator	
e and precipitation changes		Annual mean and variability of precipitation		
Natural hazards	Percentage of population living in hazard prone areas			
	Human and economic loss due to natural disasters			
Fresh water	Proportion of total water resources used			
	Water use intensity by economic activity			
Agriculture		Land productivity in agriculture (FAOSTAT)		
		Agriculture diversification index	Arable and permanent cropland area	
Health		Morbidity of vector-borne disease such as malaria and dengue	Morbidity of major diseases such as HIV/AIDS, malaria, tuberculosis	
		Area in which vector-borne diseases such as malaria and dengue are endemic		
Coastal zones and marine environment	Percent of total population living in coastal areas			
	Proportion of marine area protected			
	Area of coral reef ecosystems and percentage cover			
Biodiversity and terrestrial ecosystems	Change in threat status of species			
	Abundance of invasive alien species			
	Proportion of terrestrial area protected, total and by ecological region			
	Land degradation			
	Land desertification			
Economic Development		Economic diversification indicator	Gross domestic product	
		Infrastructure investment in areas vulnerable to climate change	Investment share in GDP	
Adaptive capacity	Proportion of population living below poverty line			
	Proportion of population using improved water source			
	Under-five mortality rate			
	Gross domestic product per capita			
Climate change financing and technology				
Public and publicly guaranteed transfers		Climate change related official development assistance	Net Official Development given or received as a percentage of GNI	
		Contribution to and receipts from climate change specific funds		
Investment		Climate change related FDI net inflows and net outflows	Foreign direct investment (FDI) net inflow and net outflow as percentage of GDP	

Theme/ Subtheme	CSD Indicator	Other Indicator	Related CSD Indicator	
		Climate change related portfolio investment net inflows and net outflows		
Trade		Exports and imports in emission reduction certificates or similar instruments (measured in CO2 equivalents and in currency)		
		Exports and imports of climate change technologies (goods and services), at commercial and preferential terms		
Technology development		R&D in climate change technologies, domestic and in international cooperation	Gross domestic expenditure on R&D as a percent of GDP	