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Issues Paper on

Science, Technology and Innovation for Sustainable Cities and Peri-Urban Communities

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Foreword

The Commission on Science and Technology for Development (CSTD), in its 15th session held in May 2012, selected "Science, Technology and Innovation (STI) for Sustainable Cities and Peri-Urban Communities" as one of its priority themes for the 2012-2013 inter-sessional period. The CSTD Secretariat will hold a panel meeting in Lima, Peru, from 7 to 9 January 2013 in order to facilitate, inter alia, an exchange of views on this theme.

As a contribution to the work of the Commission in its inter-sessional panel, this Issues Paper has been prepared by the UNCTAD Secretariat in order to identify key sectoral planning challenges posed by rapid urbanization particularly in developing countries and propose practical guidelines to city planners and other decision makers for addressing these challenges through the use of science, technology and innovation.

Introduction

The importance of cities to the overall global sustainable development agenda was first recognized in Agenda 21, adopted at the United Nations Conference on Sustainable Development held in Rio in 1992, and the HABITAT Agenda, adopted in 1996.

The World Expo 2010 that took place in Shanghai, China, from May to October 2010 focused on "Better City, Better Life". Sub-themes of Expo 2010 included blending of diverse cultures in the city, economic prosperity in the city, innovations of science and technology in the city, remodelling of communities in the city and interactions between urban and rural areas.

During Expo 2010, the Municipal Government of Shanghai, the Bureau of International Expositions and the United Nations collaborated to produce a "Guide for Sustainable Urban Development in the 21st Century", also known as the "Shanghai Manual". The guide outlined issues in each of the key urban sectors, reviewed success stories and presented policy options for improving cities.

The UN Conference on Sustainable Development (Rio+20), held in June 2012 in Rio de Janeiro on the occasion of the 20th anniversary of the Earth Summit, concluded with an outcome document entitled "The future we want". This document raised the political importance of sustainable cities and human settlements. Member states confirmed that cities, if well planned and developed, could promote economically, socially and environmentally sustainable societies. In this context, member states recognized the need for integrated urban planning, urban regeneration, adequate basic services and affordable housing for all. The outcome document also reaffirmed the importance of implementing the Habitat Agenda, which was adopted in the United Nations Conference on Human Settlements (Habitat II) held in Istanbul in 1996 and has "Adequate shelter for all" and "Sustainable cities" as two key priorities.

This Issues Paper builds on the sectoral analysis of the Shanghai Manual and brings a fresh perspective to the sustainable cities discussion, drawing on current research and cases around the world. It analyzes those sectors of urban management where developing countries face the biggest challenges. These are also the key sectors where progress is needed in the follow-up to Rio+20. Improvements in spatial planning and mobility can play a role in poverty eradication. Energy, waste management and buildings are sectors that can address resource depletion. Increasing resilience in cities is a cornerstone of adaptation to climate change. Finally, integrating peri-urban zones into urban planning can bring benefits in terms of food security, water and employment opportunities.

Chapter I reviews global urbanization trends and the case for sustainable urban development. Chapter II examines challenges in key sectors and proposes science, technology and innovation options with examples to policy implementation on the path towards sustainability. Chapter III discusses the issues of peri-urban areas. Finally, Chapter IV summarizes key points of the Paper and emphasizes the need to follow a cross-sectoral approach in urban planning to make cities more liveable and sustainable.

I. Urbanization and sustainability

Trends of urbanization

Urbanization has accelerated in the last 50 years both as a result of high fertility rates and migration to cities from rural areas. In 2010, for the first time ever, more than half the global population lived in urban areas. By 2050, urban areas will be home to more than two-thirds of humanity. More than 90 per cent of the world's urban population growth is already taking place in developing countries.

Urbanization is mainly stimulated by economic factors, but also occurs as a result of political events. Most new investment and economic opportunities are located in cities and other urban zones that represent epicenters of economic growth. 60 per cent of the increase in global GDP between 2010 and 2025 is expected to come from 600 cities (Gapper 2012). Meanwhile, in Africa, urbanization is driven more by political necessities than industrialization. Already 40 per cent of Africa's one billion people are located in urban areas, of which more than half live in informal settlements where water supply and sanitation are severely inadequate. Slums absorb around three-quarters of sub-Saharan urban population growth. It is expected that the urban population of sub-Saharan Africa will double to reach almost 600 million by 2030 (UN-DESA 2012b, Satterthwaite 2007, FAO 2012).

Urbanization is contributing to global environmental problems. Today, cities account for 52 per cent of the world population and generate four-fifths of global GDP, while they cover only about 2 per cent of the earth's surface (UN-DESA 2012b). At the same time, they account for more than two-thirds of global energy demand, resulting in up to 80 per cent of global greenhouse gas emissions. The scale of the next wave of urbanization represents a key challenge in terms of tackling climate change and addressing energy, water and food scarcity.

The urban planning and investment choices that a few large developing countries will make represent the most important environmental issue of the 21st century. In the next 10 years, more than 10 trillion US Dollars will need to be invested in urban infrastructure in Asia and Latin America (UNESCAP et al. 2011). In order to answer the needs of growing urban populations in terms of jobs, housing, basic services and infrastructure, cities will have to make major investments. Cities around the world, and especially rapidly growing cities in Asia, Africa and Latin America, need to find ways to decouple urban economic growth from resource consumption.

Sustainable urbanization

The economic, social and environmental effects of uncontrolled, rapid urbanization are increasing the awareness of the need for sustainable practices. Mega-events such as Olympics are now measured on whether they incorporate so-called "legacy projects" that plan the reuse of facilities following the event. New "ecocities" are being planned and constructed that fully rely on sustainable technologies. Cities are increasingly setting goals and measuring their sustainability by using indicators such as urban density, public space as a percentage of the urban area, share of renewable

energy sources, energy efficiency of buildings, access and proximity to mass transit, road traffic fatalities, availability of shelter, safe drinking water, wastewater treatment, solid waste management and recycling (UN-HABITAT 2012c). New York City has launched "PlaNYC", a comprehensive agenda that includes long-term targets for enhancing infrastructure, environment, quality of life and economy to accommodate an additional 1 million people until 2030. PlaNYC measures 29 sustainability indicators in categories including housing, parks, public transport, water supply, energy efficiency and air quality through a dedicated Office of Long-Term Planning and Sustainability[1] (Green Media 2012: 32).

The Rio+20 Conference outcome document ("The future we want") emphasized the importance of implementing policies for sustainable urban planning and design in order to respond effectively to the expected growth of urban populations in the coming decades. It included a commitment towards improving the quality of human settlements with a view to eradicating poverty and providing access to basic services, housing and mobility to all people. The document underlined UN member states' commitment to affordable and sustainable transport and energy. In this context, it identified the most critical elements of sectoral action for sustainable urbanism, such as "energy efficiency programmes in building management and developing sustainable, locally appropriate transport systems" as well as "the importance of mixed-use planning and of encouraging non-motorized mobility, including by promoting pedestrian and cycling infrastructures".

The outcome document also stated the need to follow an integrated approach to planning, public-private partnerships and public participation in decision-making as key factors for success towards sustainable cities. The analysis of sectoral issues in the following chapter will show why integrated and multi-stakeholder management is necessary to address interlinked challenges of modern cities.

II. Challenges and opportunities in key sectors

This Chapter identifies key challenges posed by urbanization and explains how science, technology and innovation can contribute to sustainable urban development. As outlined in the Rio+20 Conference outcome document, the challenges cover a wide range from urban sprawl and traffic congestion to inefficient buildings and unplanned informal settlements. Several cities around the world are already using innovative planning, technology and governance models in sectors ranging from spatial planning to mobility, from energy to waste management and from the built environment to disaster resilience in order to address these complex challenges.

II. a. Density, land use and spatial planning

The sectoral analysis of sustainable urban development starts with spatial planning because it is a cross-cutting theme that affects all other sectors. Current research in urban planning points towards more compact and dense spatial planning for cities. The following section explains why increasing density can be beneficial for cities with growing populations and provides alternatives on how to achieve this.

[1] http://www.nyc.gov/html/planyc2030/html/theplan/sustainability.shtml

Key issues

Urbanization in developing countries is taking place with little long-term spatial planning and driven by short-term profitability expectations of the real-estate sector. Even planned development strategies sometimes underestimate the pace of urbanization. For example, the Shanghai 1995 Plan estimated a population of 15 million by 2020, but the city had already reached 16 million people in 2000.

Unplanned urbanization often results in 'urban sprawl', which is commonly defined as single-use, low-density urbanization and has several negative dimensions. Whereas urban sprawl was previously associated with North American cities, it is rapidly extending to cities across the developing world (UNESCAP et al. 2011). The density of urban areas in terms of number of people per hectare is decreasing across the world due to uncontrolled urban sprawl. Lower density makes it more challenging and expensive to provide adequate public services such as transport and utilities (UN-HABITAT 2012c: 32). Unplanned urbanization results in investments that dictate future urban land and resource consumption patterns. It is costly to replace such investments with more sustainable infrastructure later on since they "lock in" the options of urban planners (UN-HABITAT 2012c).

As a result of unplanned urbanization, millions of people live in informal settlements in the periphery of cities without access to basic services, water and sanitation due to the lack of funds to carry out important infrastructure projects. For example, large shortfalls in water supply have increasingly been experienced in Lagos, Nigeria, where official supplies barely meet half of demand due to population growth, insufficient infrastructure, illegal connections, poor maintenance and inadequate access to limited supplies (World Watch Institute 2007: 46).

Urban sprawl is also damaging the environment and affecting the livelihood of communities located in the immediate vicinity of cities by covering land that could otherwise be utilized for agriculture, tourism and recreational activities. For example, significant damage has been caused to environmentally sensitive areas in Latin America around the cities of Caracas, San Jose, São Paulo and Panama City (UNESCAP et al. 2011).

Technology and innovation

Cities can accommodate growing populations in accordance with their land use, spatial design and density plans by combining several regulatory instruments. Below are examples of regulatory instruments for land use and spatial planning that can contribute to sustainable growth in cities.

Table 1. Selected regulatory instruments for land use and spatial planning

Urban growth boundaries	Establishing clear limits to any form of building development around cities to limit urban sprawl; creating green corridors that protect existing ecosystems.
Land-use regulation	Introducing zoning regulation that prioritizes development of inner-city, previously developed (brownfield) land over greenfield development at city-wide level - closely linked to *infill development*, which refers to new construction within existing urban areas as opposed to urban expansion.

Promoting mixed-use settlements	Designing neighbourhoods that include residential, service and local employment elements and are adequately covered in terms of basic services and infrastructure.
Density regulation	Providing minimum rather than maximum density standards; establishing clear density standards at city-wide level (such as Floor Area Ratios, FAR[2]) in support of compact city development with a hierarchy of higher density, mixed-use clusters around public transport nodes.
Density bonus	Providing development bonuses that allow increased development rights (for example, extra floor area with respect to standard planning regulations) for green projects that support city-wide and local sustainability.
Special planning powers	Establishing urban development corporations or urban regeneration companies to promote and enable green projects.
Vehicle and traffic regulation	Regulation for vehicle types, emission standards, speed limits and road space allocation that favours green transport and especially green public transport.
Parking standards	Providing maximum rather than minimum parking standards; reducing private car parking standards to a minimum (for instance, less than one car per household) especially in areas of high public transport accessibility.
Car-free developments	Providing planning incentives for car-free developments in higher density areas with high public transport accessibility.
Minimum emission standards	Regulating minimum carbon emission and energy efficiency standards at the local level for buildings and vehicles.

Sources: UNEP (2011: 481), Wheeler (2010: 107)

City planners can use simulation, modeling and visualization technologies to aid long-term planning and investment decisions (Dogdson and Gann 2011: 107). Geospatial tools can be used to identify infill zones like abandoned land or buildings that are suitable for redevelopment and to plan for their reallocation. Geospatial data can also be used for scenario planning to envision future urban development that is in cohesion with a city's historic and current development path. Geospatial tools, with their ability to display multiple layers of information on a map, can combine statistical information with satellite maps to run analyses such as poverty targeting, urban infrastructure and transport planning and socioeconomic analysis like crime statistics and tracking illegal settlements (UNCTAD 2012a).

Case studies

Spatial design

Portland, USA, is a city that experiences relatively stable population growth. Therefore, it based its spatial design on increasing density. It established an urban growth boundary and prioritized infill development by regenerating brownfield areas and replacing degraded buildings with new ones that have higher capacity.

When cities are growing faster than 1-2 percent a year, infill development may not be sufficient and extending the city at its fringes may be required. New York's

[2] FAR is the most common density measure for planning purposes. It is calculated by adding all the area of residential and business floor space and dividing it by the entire area of the development site (UNEP 2011: 481).

Manhattan Commissioners' Plan of 1811 was a far-sighted extension plan that foresaw gradual expansion.

For cities with even higher growth rates, establishing so-called satellite towns in the vicinity of major cities may be an appropriate solution, as envisaged in the Comprehensive Plan of Shanghai, which includes nine satellite towns that will receive migration from rural areas (UN-HABITAT 2012c: 27).

Densification
Rapid low-density development in Cape Town, South Africa created a number of challenges such as long travel distances, loss of agricultural land and operational inefficiencies. The City Council of Cape Town adopted a Densification Policy in February 2012 to address these challenges. The policy supports the increase of average gross density from 10-13 housing units to 25 units per hectare across the city, which corresponds to 100 people per hectare with an average household size of 4 people. The policy is based on subdivision or consolidation of plots in order to make room for redevelopment at higher densities. It takes into account factors such as priority for mixed land use areas, compatibility with built heritage, infrastructure capacity to accommodate more people, socioeconomic compatibility with the local community as well as the surrounding natural environment. The Densification Policy's objectives include efficient use of infrastructure, development of public transport, protection of the environment, revitalization of city life through mixed land uses and the development of attractive and safe urban environments (UN-HABITAT 2012c: 33, www.capetown.gov.za).

Regional integration
The city of Seoul has strong intercity links in its urban design that also includes joint financing, sharing infrastructure with other towns, and joint regional governance mechanisms to manage transport, waste and water resources (6th Urban Research and Knowledge Symposium-Rethinking Cities: Framing the Future, Barcelona, 8-10 October 2012).

Policy considerations

Developing spatial plans in early phases of urbanization based on the political consensus of stakeholders, support from the private sector and outside assistance or investment can prevent wasting financial resources later on. Spatial plans are strategic decisions of cities on spatial design and density that take into account population growth estimates, topographic characteristics and capacity to implement these changes (UN-HABITAT 2012c).

The main spatial design options to accommodate population growth are:

1-Increasing density;
2-Extending the city;
3-Multiplying nodes by building satellite towns.

Spatial planning can optimize the density of cities according to urban development goals and enable public services that achieve economies of scale. Increasing urban density can save costs arising from the provision of basic services to scarcely

inhabited and extended city outskirts. It can also be beneficial in terms of encouraging public transport. Central Hong Kong's high density allows 85 per cent of all trips to be made by using public transport (UN-HABITAT 2012c: 48). At the same time, too much density is also not advisable since it can result in overuse of public infrastructure that will depreciate early. Research in 247 large counties in the United States identified that public spending first decreases with higher density, but then can increase after a tipping point (UN-HABITAT 2012c: 32).

Densification policies can be coupled with innovative models of urban development. In high-value public land that is covered by slums, local governments can implement slum-upgrading programs to the benefit of all stakeholders. They can propose improved housing for occupants of slums in higher, modern buildings on parts of the same land. The private sector can construct these buildings free of cost in return for development rights in other zones of the city. As a result, the city can upgrade infrastructure at no cost, optimize land use and create open space on valuable land with the help of vertical resettlement (Gill and Bhide 2012).

Spatial plans can include regional integration aspects. Cities are located in regions and should undertake metropolitan strategic planning for integration with their region, and not just the jurisdiction area of the metropolitan zone to which they belong.

II. b. Mobility

This section analyzes the issues resulting from inadequate transportation infrastructure in cities, including economic losses. It provides examples of technologies that can improve urban mobility and reviews their application in different cities. Last, the section identifies policy approaches that can be useful in facilitating sustainable mobility planning.

Key issues

Rapid migration to cities and population growth make it harder to predict and plan potential public transport routes that can answer the needs of inhabitants. As mentioned in the previous section, in low-density cities, it is more difficult to introduce cost-efficient public transport due to increased distances and decreased number of people per trip. It takes years to reverse transport strategies that do not answer the needs of citizens due to the cost and scale of the underlying investments. Investing in car infrastructure causes lock-in that multiplies investment needs for switching to means of public transport later on. Moreover, low density results in higher per capita transport energy consumption.

Mobility based on fossil-fuel powered cars is increasingly becoming a liability for the world's cities. In many cities, car ownership is too costly for the majority of inhabitants. For example in Nairobi, only 1 in 7 inhabitants have a car (UN-HABITAT 2012c). Prioritizing car travel leaves out most of the population from adequate means of transport. The car is the most spatially inefficient transport mode, as it can only carry 2000 people per hour on a 3.5 meter-wide lane in the city, in

comparison to 20,000 people for a single lane bus rapid transit system (ADB and GIZ 2011: 55).

Traffic congestion causes economic damage to cities. For example, Bangkok is losing 6% of its GDP to congestion - a percentage comparable to the tourism sector of the city which produces 7% of GDP. In Mexico City, the average daily commute time is 2 hours 30 minutes, creating a loss of 2.6% of GDP (Glaeser 2011). While the cost of traffic congestion is 10% of Lima's GDP, in Buenos Aires, the loss is 3.4% (UNESCAP et al. 2011). Most of this economic loss originates from the value of time lost by car drivers and passengers. Moreover, congestion worsens carbon emissions and air pollution, resulting in negative effects on health.

Car travel requires vast land for roads and parking areas. New sprawling suburbs require high infrastructure costs and cause the loss of productive agricultural land as well as loss of urban land to asphalt. Roads also make it harder to absorb storm water due to their hard surface.

While fossil-fuel powered car travel is increasingly becoming less sustainable, public transport is also facing the challenge of lack of interest. Especially public transport projects that are undertaken without sufficient public consultation are likely to misread local demand on transit routes. Meanwhile, despite its drawbacks, car ownership is continuously increasing. The global private motorcar fleet is expected to grow from 1 billion in 2002 to 2 billion in 2022, mainly driven by motorization in Asia. In Delhi, it is estimated that the number of vehicles in 2030 will be five times that of 1990 levels (ADB and GIZ 2011: 9). Since the car is seen as a status symbol that ensures convenience and personal freedom of travel, citizens are by default biased towards using this mode of transport.

Technology and innovation

Cities can make use of technology to promote the use of public transport and ease traffic. Below are some examples to current and upcoming technologies that can help in moving to cleaner fuels in transport vehicles, improving the flow of traffic and enabling regulatory measures.

Table 2. Technology options for sustainable mobility	
Use of alternative fuels and advanced technology for transport vehicles	**LPG, natural gas or biofuels** such as biodiesel or ethanol may be used in cars. They produce less pollution and lower emissions than gasoline.
	Hybrid vehicles, which represent a combination of electric vehicles and the use of other fuels such as diesel, natural gas, LPG, ethanol, biodiesel or common gasoline.
	Electric automobiles that work by means of rechargeable batteries.
	Hydrogen fuel cells, which produce electricity directly from a reaction between hydrogen and oxygen. They are still expensive and not yet applicable to commercial vehicles.
Public transit	**Mass rapid transit** represents urban rail systems known as metros or subways that require high investment. They are most suited for high-density districts alongside other transport modes.

	Light rapid transit has lower capacity and speed than metros. They are electric rail cars that use dedicated lanes. Integration with other transport modes is critical for their success.
	Bus rapid transit is a variation of the conventional busway, with dedicated lanes, prepaid fares and fast boarding platforms. It has high potential as a relatively low-cost and sustainable transit option.
Technologies for automated traffic control	**Personal rapid transit** systems that work by means of a mechanical system of small booths, which travel safely and rapidly on specialized guide ways. They can help accelerate traffic, for instance by carrying people between airports and cities, and also reduce carbon emissions.
	Advanced driving assistance systems that consist of automated vehicles guided by computerized control systems can help reduce the number of accidents, commuting time, fuel consumption and environmental pollution. They can also improve traffic control without the need for new high-cost infrastructure investments.
Transit control systems	**Global navigation satellite systems**, such as the Global Positioning System (GPS) use radio signals emitted by satellites to locate transport vehicles and improve transport control.
	Electronic Road Pricing represents an electronic system of payment used on highways and roads to reduce congestion.

Sources: Adapted from Hernandez-Moreno (2009: 129-131), ADB and GIZ (2011)

Information and communication technologies (ICTs) can be used to improve mobility. There are various applications such as traffic management systems, open access and multimodal trip planning services. Several cities including New York, San Francisco and London are opening up core city data to the outside world and enabling the development of applications that help citizens make more informed decisions in terms of travel, like finding the closest bike share or car-share station (World Watch Institute 2012: 68). ICTs can also be used so that citizens can look up how to plan a door-to-door journey by integrating different modes of public transport such as walking, biking, buses, trains and car sharing. Online commercial tools are already available in the United States that provide multimodal routing services, like Open Trip Planner[3] and Moovel[4]. Last, ICT tools that combine geospatial mapping with crowdsourcing data collected from mobile phones or transport tickets can play a role in relieving traffic and optimizing transport efficiency.

Technology can reduce the need to commute to main office buildings every day. Especially in megacities, new private businesses known as "smart work centers" are renting out offices in close proximity of a residential community to other companies or individuals. They include access to collaboration technologies and other services such as child day care, catering and financial services. Meanwhile, introducing work-from-home policies represents a complementary measure for companies as well.

Case studies

Combination of measures

Cheonggyecheon, a river running through downtown Seoul in South Korea, was used as a sewer after the arrival of immigrants in the 1950s, and then covered by an

[3] http://opentripplanner.com/
[4] https://www.moovel.com/

elevated motorway in the 1970s. The motorway became very congested in the 1980's and at the same time created an urban fault line hampering the livelihood of the middle of the city. In 2003, the metropolitan government removed the motorway and restored the river. As a result, 300 thousand jobs were created through the Cheonggyecheon project, which brought environmental benefits and turned the area into a tourist attraction. The project was accompanied by improvements to Seoul's public transportation system, which was made possible with a consensus-based decision-making model that promoted intermodal transit, incorporating dedicated bus-lanes and a unified fare system. The key to success was the formation of a consultative group called the "Citizens Collaborative Council" which ensured that no party would be disadvantaged by proposed transport solutions (UN-HABITAT 2012c).

Intermodal transport planning

Several good examples exist for cities that reclaimed road space in parallel to improving intermodal public transport networks such as new rail links. Nürnberg is a case in point. In fact, in cities across Germany, from small historic towns to large metropolises, modern light rail systems accompany pedestrian zones in city centers, reducing the need for cars.

Portland and Vancouver are medium-sized cities that have successfully undertaken comprehensive land use and transportation planning to balance auto traffic, public transport and pedestrians (Vuchic 2008).

Toronto, known as one of the most liveable cities in North America, has an intermodal transport network. It includes a metro that is surrounded by high-density land use developments, an extensive tramway network, and buses with weather-protected metro transfer stations for severe winters (Vuchic 2008).

Toyama city in Japan is another successful example of transport planning. It integrates land use and transport integration strategies. Toyama built the first light rail transit (LRT) system in Japan by converting old railway lines. At the same time, it adopted a transit-oriented development approach by concentrating residential and commercial developments within walking distance of public transport stations. This helped more than double the average number of LRT passengers from 2006 to 2011 (Puppim de Oliveira et al. 2012: 25).

Use of technology

Bus Rapid Transit

The city of Curitiba in Brazil pioneered public-transport oriented spatial design based on Bus Rapid Transit (BRT). Although Curitiba's population grew from 400 thousand to 2 million people in 50 years, it did not suffer from pollution or congestion thanks to its BRT system that uses dedicated lanes allowing it to function like a low-cost metro. It also has a special design for stops that facilitates quick payment and easy transfer. Starting with 25 thousand daily passengers in 1974, the system grew to serve 2.2 million passengers in 2007. Curitiba's BRT was the first of its kind in the world, and similar systems were introduced in more than 83 cities globally (World Watch Institute 2007, UN-HABITAT 2012c: 35).

ICT tools

Singapore is using geospatial data and information collected from transport tickets to plan future transport services, recommend routes and provide additional services like the location of taxis during rain. Singapore also uses mobile phone data to map the current traffic situation and propose alternate travel routes to drivers in order to reduce congestion (State of the World 2012, p. 66).

OpenPlans, a non-profit organization, has developed a real-time traffic crowdsourcing application for Cebu, Philippines in cooperation with the World Bank. Once deployed, the application will collect real-time traffic data from 500 Android phones deployed in taxicabs. This data will provide citizens with up-to-date information about traffic conditions and the historical archive will help inform planners and transport engineers[5].

Smart work centers
The City of Amsterdam is cooperating with Cisco to create smart work environments. South Korea is also establishing 500 smart work centers around the country. As a result, employees do not need to undertake long commutes every day and workspaces require fewer buildings in the city center (World Watch Institute 2012).

Innovative regulation
Road pricing in Singapore and London
Singapore was one of the first cities to apply physical, regulatory, and pricing measures to coordinate the use of different modes in a balanced intermodal transport system. The city pioneered road pricing in the city center to reduce congestion. In parallel, it built a state-of-the art metro system and optimized its bus system with many transfer points and major terminals at metro stations. The Land Transport Authority (LTA) comprehensively plans and coordinates all modes of mobility in Singapore. London is another city that implemented congestion pricing in the city center. While the scheme faced resistance at the beginning, after reducing traffic levels by 15-20 per cent and congestion by over 20 per cent in the first three years of operation, it gradually gained more public acceptance (Banister 2007, Vuchic 2008).

Regulation and programs that encourage biking and walking
London has recently introduced a rewards system through which users can accumulate points as they bike or walk. The system works with the help of a mobile phone application that uses the phone's GPS signal to track movement[6]. Points can be redeemed to obtain different kinds of services, such as haircuts and shopping. Likewise, in Switzerland, the "bike to work" initiative encourages participants to commute up to 50% of the time by bike and gain the chance to win prizes like holiday weekends.

Policy considerations

Mobility in cities can be improved through the combination of three strategies entitled "Avoid, Shift, Improve" that can transform behavior and influence technology choices (UNEP 2011: 387, ADB and GIZ 2011: 85).

[5] http://openplans.org/2012/09/dc-help-us-test-our-traffic-crowdsourcing-app/
[6] https://www.recyclebank.com/reroute

Table 3. Avoid, Shift, Improve

Strategy	Technology and Innovation
1. Avoiding or reducing the number of journeys taken.	Urban planning, traffic demand management
2. Shifting to more environmentally efficient forms of transport.	Public transit (mass and light rapid transit, bus rapid transit, ultralight and demand-responsive transit) Non-motorized transit (walking and biking)
3. Improving vehicle and fuel technology to reduce adverse environmental effects such as pollution and resource depletion.	Low emission vehicles and alternative fuels

The Avoid-Shift-Improve model is based on a combination of incentives, disincentives and the use of technology. For example, regulators can aim to overcome automobile dependence through a combination of measures like the ones outlined below (Wheeler 2010: 123, 125-126):

Traffic calming to slow auto traffic and create more humane urban environments better suited to other transportation modes.
Improved transit, such as prioritizing biking and walking as genuine options to the car.
Improved land use, for example by establishing so-called "urban villages" that are self sufficient in terms of employment and recreational activities and thereby reduce the need to travel by car.
Growth management to prevent sprawl and redirect development into urban villages.
Economic incentives such as taxing transportation better.

Traffic calming techniques include altering road layout and design such as narrowed entries to streets, planting trees, variable street surfaces, speed-restricting devices and visual signs for cautious driving. On busier roads, it can be done by reclaiming road space for other uses and reducing the speed of traffic. Measures like traffic calming can reduce congestion, thereby saving fuel wasted in traffic jams and preventing the loss of time. They should be implemented in coordination with schemes that make public transport more attractive in the same areas.

Spatial planning that includes public transport networks from the very beginning is a key factor to help prioritize public transport. Cities can be designed by locating mixed-use developments and jobs near intermodal public transport connections, thereby minimizing dependence on cars and reducing the distance that people need to travel. Likewise, spatial design should plan for integrating the incoming population into the public transport system. Each mode of public transport requires a minimum density to be economic, so the choice between buses, trams and light rail can be identified accordingly. For example, a density of 20 persons per hectare generally makes urban zones dependent on the car. As of 60 persons per hectare, public transport starts to be economic, and with 150 persons per hectare, walking and biking can be considered as practical transport modes.

Cities can accompany public transport infrastructure investments with innovative regulatory mechanisms and incentives. Optimizing urban mobility entails striking the right balance between different modes of transportation (Vuchic 2008). Regulation such as public transport incentives and auto disincentives can be introduced in order

to reach a compromise between personal freedom to choose transport modes, "social optimum" modes that minimize travel cost and time for travellers across the urban area, as well as environmental concerns such as reducing air pollution. Measures can include both soft incentives and hard regulation (Vuchic 2008, Banister 2007).

Traffic demand management regulation more suited for higher-income countries includes low emission zones in city centers, increased fuel taxes, road pricing and parking zone charges. Road pricing may be a solution for traffic calming in larger cities, but the investment in the technical infrastructure necessary to operate it (such as sensors that automatically deduct tolls from units inside vehicles) may not be worthwhile in smaller cities as the scheme may not raise enough funds to cover operational infrastructure costs, and political acceptance by the public may be a more significant issue.

In all countries, possible measures and incentives are as varied as traffic calming, promoting walking and biking, shared car programs and reallocating open space to public transport. One important element of success for such schemes is to gather public support by engaging stakeholders, communicating and sharing information. When launching biking incentives such as electric bicycle promotion campaigns, it is just as important to establish a legal framework on the status of such vehicles within city traffic as making the vehicles available and putting physical infrastructure in place. For instance, bike-sharing programs, which are already available in around 200 cities of the world, require infrastructure such as parking spots and tracks as well as a legal framework that protects the rights of cyclists. Otherwise, people would not feel safe to bike in the city.

II. c. Energy for cities

Energy is one of the most important sectors for sustainability in cities. The section identifies why the future of energy supply for large metropolitan areas increasingly needs to be decentralized. It also looks at innovative energy solutions that work best in crowded urban environments. It concludes with policy options for local government that can stimulate the application of clean energy solutions.

Key issues

Cities are major consumers of energy, and therefore vulnerable to energy scarcity and energy price increases. Adequate energy supply for growing urban zones is increasingly becoming a challenge. It is largely expected that in cities of emerging countries, demand will continue to exceed capacity in the coming years. This brings up questions such as how to improve energy efficiency, regulate the electricity market, involve the private sector and revise the mechanism of subsidized energy pricing (Globescan and MRC McClean Hazel 2007: 37).

Large, centralized energy production facilities require costly distribution systems that are vulnerable to misuse and natural disasters. In rapid-growth urban environments, low-density sprawl causes per-capita distribution and line maintenance costs to increase rapidly. In many countries, distribution lines are subject to siphoning as well. Moreover, centralized energy production follows a supply-driven approach,

prioritizing the sale of energy over saving energy, creating no incentives for energy efficiency practices that can reduce consumption. With rapid urbanization, it will be more and more challenging to provide access to electricity in a centralized manner for growing cities.

Technology and innovation

Various clean, low-carbon energy technologies compatible with use in cities are available to improve energy efficiency and enable the transition to renewable energy sources in cities. Each of them faces technical, market, institutional, political, social and environmental challenges on the way to mainstream usage. Cost competitiveness with fossil-fuel energy sources is a major issue. Technical limitations of clean energy technologies, such as battery efficiency of solar photovoltaic technology, and issues such as lack of infrastructure or trained workers as well as lack of public acceptance also need to be overcome (OECD 2012: 127-128).

Below are some examples of innovative energy technologies that could be considered for densely populated urban areas (UN-HABITAT 2012b).

Table 4. Energy technology options

Solar	Solar thermal storage	Solar thermal power plants have the ability to gather heat from the sun and boil water into steam to generate electricity by running a turbine. Energy can thereby be temporarily stored and used when needed during peak hours.
Hydro	Micro hydropower systems	They can complement intermittent wind or solar energy by pumping water to an upper reservoir when excess energy is produced and letting it down when more energy is needed (Totty 2011b).
Kinetic	Converting kinetic energy from walking	Purpose-made slabs installed on pavements can harvest renewable energy from the footstep. The technology developed by Pavegen converts kinetic energy to electricity that can be stored and used for powering off-grid applications such as pedestrian lighting, way-finding solutions and advertising signage.[7]
Heating	District heating	District heating systems can distribute heat and power from a centralized location. The heat often comes from combined heat and power plants (CHP) and therefore has the ability to achieve higher efficiencies and lower emissions than separate heat and power production (UNEP 2011: 344).
Electric grids	Smart grids	They are intelligent electric systems that have three major components: demand management, distributed energy generation, and transmission and distribution grid management (Villa and Mitchell 2010).
	Vehicle to grid	Once the number of electric vehicles in urban traffic reaches a critical mass, it will be possible to benefit from bi-directional connections between the battery of such vehicles and smart electricity grids. At peak times of the grid, when the vehicle is

[7] www.pavegen.com

		not in use, it will have the ability to feed energy from its battery back into the grid (UN-HABITAT 2012b).
Lighting	LED lights	Smart, networked LED street lighting technologies can generate relatively effortless and immediate savings in electricity. Partnerships between ICT networking and lighting companies are making smart, ICT-based LED lighting possible.
ICT	Carbon footprint applications	ICT applications can help encourage more sustainable energy consumption patterns for individuals, for example by proactively tracking and distributing information on personal carbon footprints and consumption patterns (Robinson 2012, Mitchell and Casalegno 2008).

Case studies

Regulatory support for renewable energy

The Government of India formulated a "Solar Cities Programme" in order to reduce demand for fossil-fuel energy sources by at least 10 per cent in sixty cities between 2007 and 2012. The programme allocates financial assistance to local governments that show commitment to implementing renewable energy projects through master plans, governance structures and project proposals (UN-HABITAT 2012b: 106).

The local authorities of the city of Rizhao in China provided strong political and financial support for the development of a local solar panel industry. As a result, solar technology became widespread, with 99 per cent of Rizhao's households in the central districts using solar water heaters and almost all traffic signals, street lights and park illuminations powered by solar energy. In addition, solar cooking facilities are common in households and solar panels are used to heat greenhouses, reducing overhead costs for farmers (UN-HABITAT et al. 2009a: 20).

Shanghai envisages a total of 13 wind farms with an installed capacity of 2.1 gigawatts by 2020, which will provide electricity to more than 4 million households. The plan includes China's first offshore wind farm, which is also the world's first major wind farm outside of Europe. It will provide around 1 per cent of the city's total power production (UN-HABITAT 2012b: 109).

In several cities across Eastern Europe that had district heating infrastructure dating back to the socialist period, modernization efforts driven by EU directives as well as national energy programs are taking place that could generate 15-30 percent savings in heating energy (UNECE 2011: 43). Since district heating can use renewable energy sources such as biomass, geothermal and solar energy with biomass, it harbors great potential for countries that already have infrastructure for this technology in place.

ICT tools for optimizing energy management

Cisco is partnering with the cities of San Francisco, Amsterdam, Seoul as well as Birmingham, Hamburg, Lisbon and Madrid to provide integrated city data for use in improving traffic, public transportation, energy efficiency, and self-management of carbon footprints by residents (Villa et al. 2010: 7).

Use of innovative technology

Pavegen's slabs that convert kinetic energy from footsteps were installed at a metro station of the London 2012 Olympic facilities. The technology is best suited to high-footfall urban environments and represents a good example to how clean technologies can also be enjoyable, which is an important aspect for general public awareness and adoption.

Off-grid energy generation

Sunlabob, a company in Laos, started operations by providing solar electrification to homes on a rental basis. It established an innovative public-private-partnership (PPP) business model whereby local public authorities covered part of the investment cost by owning the solar lamps rented out to households. Sunlabob itself owned charging stations. It created a national network of franchises and trained them on marketing, installation and maintenance. Following its initial success, Sunlabob diversified to offer a full range of renewable energy solutions, such as solar water pumps and heaters, water purification systems, street lighting solutions, cooling units for health posts, and solar lanterns (Bolay and Kern 2012: 315).

Another off-grid solution provider is M-KOPA, a start-up located in Kenya that has designed a solar lamp solution consisting of a base station with a solar panel, three lamps and a charging kit for phones. Users can pay part of the system upfront as they acquire it and the rest via small installments that they transfer by using mobile phones ("Lighting the way" 2012). They can thereby replace kerosene lamps that are not only expensive but also dangerous to health.

Integrated energy and waste management

The Hammarby Sjöstad district of Stockholm, referred to as the "Hammarby Model" in urban planning circles, is an ecological district that used brownfield industry space for development. It minimizes energy usage while optimizing water usage and waste management with the help of recycling, energy and waste treatment plants. Buildings send waste and wastewater to heat/water/treatment plants that then produce heating, biogas and electricity for them. The district plans to produce 50% of its energy requirements locally ("Hammarby Sjöstad: Integrated sustainability as a main focus" 2010).

Policy considerations

Although energy policy is a national issue, cities of developing countries can lead the way in leapfrogging to advanced renewable energy sources and efficient transmission technologies through local regulation, incentives or subsidies. Cities can pioneer the transition to renewable energy by making use of national incentives as well.

The use of new technologies in cities can reduce the burden of rapidly increasing energy demand. For instance, implementing smart grids increases flexibility of energy production/distribution by making it possible for decentralized, individual energy producers, for example households with solar panels on their roofs, to feed surplus energy back into the electricity grid (Cosgrave 2012). They provide real-time information to utility companies with the help of sensors, enabling them to respond to changes in power demand, supply, costs and emissions and prevent major power outages. Smart grids can drive cross-sectoral cooperation, enable decentralized energy generation and encourage more efficient energy consumption patterns.

Smart grid investment should be prioritized in large cities that face frequent peaks in electricity demand and also have high potential for decentralized generation capacity (like suitable weather conditions for installing solar panels on buildings). Local governments can establish regulatory frameworks for local energy marketplaces that make use of smart grid technology. These marketplaces would make it possible for individuals to trade excess power generated by their private facilities, such as micro wind turbines or solar energy panels located in homes (Robinson 2012). The deployment of smart grids could generate up to 4 trillion US Dollars of savings until 2050 in Europe, mainly due to the reduced need to invest in new electricity generation capacity (OECD 2012:10).

Off-grid energy production based on renewable sources can also reduce the need to invest in new centralized production and distribution systems. Cities can provide incentives to companies that specialize in off-grid solutions.

Last, designing integrated energy and waste management infrastructure can optimize energy efficiency and generate significant savings.

II. d. Solid waste management

This section examines possible options to deal with the waste problem that is growing at an even faster rate than urbanization itself. Two main paths are highlighted. One is integrated waste management, which requires considerable infrastructural investments. The other is to launch waste collection initiatives through partnerships with the private sector, NGOs and local citizens at large.

Key issues

Uncontrolled solid waste is growing faster than urbanization and represents a serious issue for the sustainability of cities. Growing cities generate higher amounts of waste per inhabitant. Rates of solid waste growth are fastest in China, other countries in East Asia, parts of Eastern Europe and the Middle East (Hoornweg and Perinaz 2012). The amount of solid waste generated in rapidly growing cities of developing countries is a serious health risk for their populations. Using landfills reduces the attractiveness of cities. Landfills produce methane, which heavily contributes to greenhouse gas emissions, and do not decompose easily. Incineration of solid waste is also not preferable as it can cause air pollution. Although waste is an energy source that could be reused, it is not seen that way in many countries.

The cost of solid waste management can be very high, reaching up to half of the total municipal budget of medium-sized cities in lower-income countries. Global solid waste generation is due to increase from 1.3 billion tons per year to 2.2 billion tons by 2025. It is especially an urgent priority in lower-income countries, where serious increases in solid waste management costs are expected (Hoornweg and Perinaz 2012).

Technology and innovation

Integrated Solid Waste Management (ISWM) is a waste management approach that refers to a shift from less preferred waste treatment and disposal methods such as incineration and different forms of landfilling towards the 3R's: Reduce, Reuse and Recycle.

Activities under ISWM can include:

- Resource conservation, which avoids excessive resource consumption;
- Waste reduction through resource use optimization;
- Waste collection and segregation, ensuring appropriate waste treatment;
- Waste reuse, which circulates waste and avoids the use of new resources;
- Waste recycling, which converts waste into useful products;
- Energy recovery, which harnesses residual energy from waste - for example waste and wastewater can be used for producing biogas, synthetic gas and synthetic construction materials;
- Landfill avoidance, which conserves land and avoids risks of contamination;
- Construction and maintenance of infrastructure for waste collection, recovery of materials from waste streams (collection and segregation) and application of 3R technologies and associated activities.

The long-term vision under ISWM is to establish a circular economy in which the use of materials and generation of waste are minimized, any unavoidable waste is recycled or remanufactured, and any remaining waste is treated in a way that causes the least damage to the environment and human health or even creates value by recovering energy (UNEP 2011: 294-295, Totty 2011b)

Case studies

Integrated solid waste management

In Kalundborg, Denmark, companies located in an industrial zone started selling waste products as raw materials to each other as of 1961. Later on, the network grew to include more than 30 exchange pipes. Surplus heat, steam and other residue generated from a 1500 MW coal-fired power plant are all reutilized by nearby businesses, reducing the ecological footprint for the plant and involved companies (Jastrup and Drique 2012: 60, UN-HABITAT 2012b: 121).

São Paulo implemented a landfill emissions control program that renovated two solid waste landfills. Methane-rich biogas from decaying waste was used to generate electric power on site. The program both reduced the amount of methane released into the atmosphere and supplied energy to 7 per cent of households in São Paulo. It was also approved as a Clean Development Mechanism (CDM) project of the United Nations Framework Convention on Climate Change (UNFCCC). In 2008, the program was generating a number of carbon credits that was close to the sum of all other certified projects in Brazil. The city used the proceeds of these credits to fund urban and environmental improvement projects in surrounding areas (Goldenstein 2008).

Public-private partnerships and community initiatives

Surabaya municipality in Indonesia partnered with Unilever and organized a competition to award villages for effective waste management systems. Surabaya also built 16 compost houses to reduce organic waste by producing compost that is used for urban farming in order to maintain parks and beautify the environment. Similarly, in Yogyakarta, the village of Sukunan developed a community-based solid waste management system whereby each family started separating household waste into categories like plastic, paper, glass and metal, and organic. As a result, the village was able to raise funds by selling part of the waste, reduce solid waste by 92 percent through recycling and create employment through the initiative (Puppim de Oliveira et al. 2012b).

Recycling plastic (PET) bottles presents another opportunity for waste management. Mauritius established a deposit-refund system to encourage reuse of plastic bottles. Within the framework of this system, a private recycling company purchases used bottles from citizens and organizations and recycles them into plastic pellets for export to South Africa. The collection rate of plastic bottles reached 34% in 2009 thanks to this system.

In Bangladesh, where the city of Dhaka's organic waste was transported to a landfill before, Wasteconcern, a local NGO, launched a PPP for waste collection with the logistical support and program coordination of public authorities. Local communities collected waste that complied with minimum quality benchmarks of Wasteconcern and sold it to private fertilizer companies. The PPP model of Wasteconcern, which started in 1998, was replicated in several other cities and towns of Bangladesh, servicing a total of 130,000 people in 15 cities. Wasteconcern's project was also registered under CDM, since collected waste avoided the production of methane gas that is released when organic waste is deposited at a landfill (Municipal Government of Shanghai et al. 2011: 115).

The city of Matale in Sri Lanka established an integrated center to treat organic waste and produce high-quality compost with the assistance from Waste Concern and the United Nations Economic and Social Commission for Asia and the Pacific – UNESCAP (UNESCAP et al. 2011: 159). The project is now being replicated by UNESCAP in ten Asian cities. In Peru, Ciudad Saludable, a local NGO, organized more than 6500 waste collectors who collected close to 300 thousand tons of recyclable material per year and thereby helped increase the rate of recycling from 40 to 80 percent in over 200 cities (UN-HABITAT 2012c: 80).

Policy considerations

Following the Hammarby and Kalundborg examples described previously, cities can make use of technologies to convert certain types of waste into energy as mentioned in the ISWM approach. Many governments in Europe are promoting "eco-industrial parks", also referred to as "industrial symbiosis systems". Emerging country cities are also implementing projects based on ISWM and the 3R's.

PPP's as well as joint initiatives of local communities and NGOs can be effective in launching waste management initiatives. In several countries, PPPs between

municipalities and the private sector as well as organized initiatives of citizens are already actively participating in solid waste management.

Solid waste should be handled in an integrated manner with spatial planning. Spatial planning can help optimize energy consumption and waste management in cities (UN-HABITAT 2012c: 76-85). For example, the location of landfills can minimize negative effects, and providing sorting and recycling space close to locations where waste is generated can help reduce the size of disposal sites.

II. e. Resource-efficient buildings

There is a multitude of available technologies that can improve resource efficiency in buildings. Although startup costs may be higher, in the long term, buildings that have a smart design, generate energy and conserve water can save costs. This section explores ways to stimulate the adoption of technology for the built environment.

Key issues

The built environment poses a challenge of resource efficiency. Buildings account for 40 per cent of global energy use, 38 per cent of global greenhouse gas emissions, 12 per cent of global potable water use and 40 per cent of solid waste streams in developed countries (UNEP 2012a). The lack of resource-efficiency measures for existing or new buildings is resulting in a missed opportunity, carrying the resource burden, environmental damage and social inequality into the future. Since new buildings are long-term investments and the housing stock of cities is gradually replaced, policies requiring resource-efficiency standards can combine affordability with sustainability in the long run.

Especially in cities of developing countries, the built environment is a cause of concern in terms of the current and upcoming housing shortages. There is high demand for affordable housing in cities of rapidly urbanizing countries of Asia, Africa and Latin America as well as a lack of space for newcomers. In China, it is estimated that as much new building floor space will be built until 2030 as the entire existing building stock of the US (UN-HABITAT 2012a: 6). Due to the fact that the supply of affordable housing, infrastructure and services is not able to catch up with the rate of urbanization in developing countries, informal shelter is being built with no infrastructure, little sanitation and no compliance with planning or building regulations.

Technology and innovation

Resource-consuming buildings harbor the greatest potential for resource and emissions reductions. Sustainable houses can be built by using a range of techniques and practices that improve resource-efficiency and contribute to healthy indoor living conditions at a reasonable cost. Solutions differ according to the type of house, the climate zone and the available infrastructure around the building (such as access to district heating or not). Using sustainable technologies in new buildings could achieve a 30-50 per cent reduction in energy use, 35 per cent reduction in greenhouse gas

emissions, 40 per cent reduction in water use and 70 per cent reduction in waste outputs (UNEP 2012a). Retrofitting existing buildings can also bring about significant efficiencies. Below are examples of sustainable practices for building or retrofitting houses.

Table 5. Technology options for sustainable buildings

Design	Design	Design for sustainability can dramatically reduce energy consumption and create settings that encourage inhabitants to be more physically active.
	Windows	Windows provide views and daylight, passive solar energy and natural ventilation to buildings. By optimal orientation and use, windows can provide net energy to buildings. Automated shading is essential in warmer climates to keep out heat from the sun. Natural light is beneficial to productivity, well-being and health.
	Orientation towards the sun	Homes can be placed with large facades facing east and west, letting in morning and evening sun. Offices can have large facades north and south, letting in high quality daylight (with shielding from direct sun to avoid overheating).
	Green roofs and walls	Adding plants to rooftops, walls and balconies offers many benefits: added insulation, reduced runoff of water during heavy rainfall, aesthetic qualities, noise reduction and reduced heat island effect.
Energy generation	Solar power	Photovoltaic cells can deliver clean energy to the building on site, eliminating transmission losses. Combined with a heat pump, solar power can also generate heating. Falling prices of photovoltaic cells have rendered them more feasible in many parts of the world.
	Solar window blinds	They keep buildings cool by blocking sunlight and at the same time produce electricity via photovoltaic technology.
	Solar shingles	They are based on photovoltaic technology like solar panels, but can absorb more light and their durability makes it possible to use them as roofing material.
	Micro wind turbines	Generating energy from wind by placing turbines on top of commercial or residential buildings can cover a large percentage of the structure's energy needs.
Heating and cooling	Solar heating	Solar heating systems can provide heat and hot water and can be combined with heat pumps to create heat depots in hot periods for use when the weather gets colder.
	Insulation	From mineral wool to aerogel, insulation materials are essential in every climate for keeping heat either in or out of the building.
	Natural Ventilation	Techniques which use natural convection currents within air flow to direct air into and out of buildings in order to replace rising warm air with cooler air can function with no or minimal mechanical parts or energy consumption. For example, air ducts can be designed to allow air to enter low in the building via underground ducts, while simultaneously allowing air to escape high from the building and provide for natural ventilation.
	Heat pumps	Earth to water or air to water heat pumps can draw thermal energy from the surroundings into buildings, multiplying the energy used. 1 kWh of electricity can deliver 2-4 kWh of heat.
	Ambiators	They can cool interiors by using thermodynamic technology

		based on evaporation at a fraction of the energy consumption of conventional air conditioning. They first process air through a pump that recuperates heat and reduces temperature. The pre-cooled air then passes through an evaporative cooling module that uses limited amounts of water to cool the air further[8]. Ambiators are more suitable for low-humidity locations.
Water	Reusing water	Reusing water from wash basins or showers for water closets can reduce water consumption.
	Rainwater retention and collection	Rainwater can be held in fascines or tanks, reducing runoff during heavy rainfall. It can then be reused in water closets.
	Reducing covered ground	Reducing the amount of ground covered in buildings, pavements, roads, parking lots etc. reduces both the local heat island effect and the pressure on sewerage and drainage, as the earth can soak up more rainwater under heavy rainfall.
ICTs	Smart homes	Monitoring and controlling energy demand in buildings can reduce energy consumption by 5-10 per cent.

Sources: Jastrup and Drique (2012: 88-89), UN-HABITAT (2012b), UN-HABITAT (2012e)

Buildings can employ either "passive" or "active" environmental design strategies. Passive design techniques such as improving insulation, natural ventilation and day lighting take advantage of the building site or climatic characteristics to improve resource efficiency. According to energy consumption guidelines in the UK, the introduction of natural ventilation can save 55-60 per cent of the energy used in fully air-conditioned and fully glazed office buildings (UNEP 2011: 343). The potential of passive strategies is larger in tropical regions due to the priority of blocking heat rather than generating it efficiently (Municipal Government of Shanghai et al: 135). On the other hand, active systems employ technologies such as solar panels or energy efficient appliances to improve efficiency (UNEP 2012a). A study in the U.S. of more than 5000 commercial buildings showed that in new buildings, employing energy-efficient lighting, heating, ventilation, air conditioning and shading can achieve a 64 per cent reduction in energy use (UNEP 2012a).

While the operational phase of buildings represents the most important opportunity area for resource efficiency, using innovative construction technology can also save costs and resources. New, prefabricated and modular building techniques, making use of local building materials and local know-how can optimize resource efficiency of construction (Kaye 2012). Using building materials without harmful chemicals has a large positive impact on the health of the user. Recycling building materials can reduce the environmental impact of the building process dramatically.

Case studies

Innovative construction technology

In Harare, Zimbabwe, the Eastgate Center, a shopping center and office block, was designed and built with an innovative "passive" cooling system. It stores heat in daytime and the warm air rises in the evening, replaced by denser cool air at the

[8] http://www.hmx.biz/

bottom of the building. The shopping center entirely avoided the need for artificial air-conditioning and saved 3.5 million US Dollars (UN-HABITAT 2012b: 112).

A Chinese company called Broad Sustainable Building is using pre-manufactured structures for more sustainable building construction. This technique has been implemented in the Tower Hotel in Yueyang, Hunan Province. The building has several features like resilience to earthquakes up to 9.0 on the Richter scale, thermal insulation and the ability to produce biogas from sewage and use hot wastewater for heating purposes. 93% of the parts that made up the building were produced in Broad's factory and then shipped to the construction site. There, the building was assembled in only 15 days, by bolting pre-constructed modules together. The construction process required no water, welding or scaffolding, caused minimal dust, and created only 1% of the waste that is common in similar construction sites (Kaye 2012).

In Cuba, which has a programme for low energy and material consumption for housing, more than fifty thousand homes were built in the last 20 years by using alternative building techniques, with so-called "eco-materials" that require less energy and fewer resources. The materials use recycled waste products and special types of tile, cement and concrete blocks. Bio-wastes are used as fuel and bamboo is used in the construction process (UN-HABITAT et al. 2009a: 38).

Innovative building regulation

As of 2016, new residences in England will have to comply with very high energy efficiency standards, with heating energy demand levels corresponding to one-fifth of current buildings and on-or-off-site renewable energy generation for all building-related energy demand such as lighting and ventilation. By 2030, 2-3 million new homes will be built according to these "zero carbon standards" (UN-HABITAT 2012b).

The City of Vienna has an energy efficiency policy that subsidizes new housing projects based on a competitive selection process that includes energy efficiency among its criteria. It also partially subsidizes refurbishment of existing buildings (UNECE 2011: 60).

Stuttgart analyzed weather patterns to develop an urban climatic map and identify "wind paths" that transport clean air into the city and improve air quality by reducing the city's heat island effect. As a result, constructing new buildings that would prevent air flow through these wind paths was prohibited (Robbins 2012).

Sustainable housing initiatives

UNEP is implementing a "Sustainable Social Housing Initiative" that was piloted in São Paulo, Brazil and Bangkok, Thailand in order to build social housing units that are both energy-efficient and low-cost.

Brazil and Mexico both have housing programmes that aim to cover their housing shortages. Brazil's "My house, my life" program provides incentives and subsidies to enable mortgages for low-income households and includes solar water heaters in housing design. Mexico's National Housing Programme subsidizes households to buy homes with pre-approved eco-technologies (UN-HABITAT 2012a).

There are also successful examples of upgrading informal settlements. The Igarapés settlement in Manaus, Brazil is a case in point. It was upgraded through the construction of parks, transport infrastructure and sewerage pipes as well as provision of basic services such as water, sanitation and electricity (UN-HABITAT 2012c: 102).

Policy considerations

Public support and regulation can speed up adoption of green building practices in the construction sector. Innovative building regulation can also improve resilience and environmental quality in cities.

Standard measurement and reporting requirements for building performance in terms of energy efficiency and greenhouse gas emissions can drive the spread of sustainable construction in the real estate sector. They can also make it easier to embed the environmental performance of buildings into their financial value. Towards this end, the UNEP is piloting a "common carbon metric"[9] that will measure emissions from buildings based on energy use, such as heating, cooling, ventilation, lighting and appliances. This metric will allow data-driven comparison between buildings. Moreover, the "Bonn Center for Local Climate Action and Reporting – carbonn", which was established in December 2009 as an initiative of ICLEI and UNEP, facilitates voluntary publication of city commitments, actions and performance in terms of emission reductions[10]. It also provides guidance for emissions reporting. A notable example to voluntary reporting initiatives is the "Greenprint Performance Report", which measures energy consumption and greenhouse gas emissions of assets owned by members of Greenprint Foundation, a worldwide alliance of real estate investors.

Establishing multi-tier building rating systems can guide the real estate sector in terms of adopting comprehensive green building standards. So-called "green building rating systems" that certify environmental building design strategies are starting to be implemented globally. Notable examples are BREEAM in the UK, Singapore's Green Mark, GRIHA in India and LEED in the USA. For instance, LEED certification is provided to buildings that are generally designed to operate at lower cost and higher asset value, reduce waste, conserve energy and water, are healthier and safer for residents and reduce greenhouse gas emissions. Green building rating systems should be promoted first and foremost at the level of municipalities and other local governance structures. Local authorities should thereby also provide transparent information to the real estate sector on green building construction costs, which are normally lower than what is perceived by the public and can easily be recuperated in the long term due to lower operating costs. Local governments could lead by example and implement energy-efficiency measures in new public buildings. The new City Hall of Seoul uses a combination of photovoltaic, solar and geothermal energy for power generation.

[9] See http://www.unep.org/sbci/Activities/CCM_Pilot.asp
[10] See http://carbonn.org/

Green buildings require higher startup costs. Local authorities can provide construction companies incentives (such as cash payments, loans or lower taxes) so that they can benefit from some of the long-term savings resulting from lower resource usage of ecological construction. Otherwise, if the business model of green regulation would pass on resource efficiency savings only to the building owners, construction companies would not be willing to invest. Therefore the introduction of green building regulation should be accompanied with information campaigns that educate builders on the technical aspects of new standards and potential financial incentives such as favourable tax policies or interest rates that may compensate for extra costs of green construction (Municipal Government of Shanghai et al. 2011: 124).

Green buildings need not be confined to cities of high-income countries. Local governments in developing countries can address housing shortages through construction initiatives for affordable, sustainable housing and upgrading informal settlements.

II. f. Resilience against natural risks

A resilient city is one that can predict and react to natural disasters in order to minimize loss of lives and disruption of city utilities and services. Developing country cities will be those most affected by the increased frequency of natural risks induced by climate change. This section discusses ways to increase resilience in the face of these risks.

Key issues

Cities in developing countries undergoing unplanned urbanization are facing the risk of huge economic and human losses from natural hazards. The effects of climate change are exacerbating the issue by instigating more frequent urban climate-related hazards. On the one hand, more and more people are moving into vibrant metropolises that are situated on or close to the coast. On the other, these cities are increasingly at risk due to climate-change induced natural disasters. Especially informal settlements at city fringes and other lower-quality buildings that are products of rapid, unplanned urbanization represent a resilience issue for developing countries, although they play an important role in terms of meeting shelter needs of the urban poor. Their low construction standards and poor drainage result in serious vulnerability to natural risks.

Hurricane Sandy, which developed in the eastern part of the Atlantic Ocean and swept through New York City in October 2012, occurred only a year after Hurricane Irene and served as a reminder of the danger that cities face. New York City is one of several global cities at risk due to the fact that they are surrounded by water and the precautions they can take against risks like sea-level rise are limited. Urban areas in developing countries situated on the coast with a large population exposed to climate-related hazards include Mumbai, Guangzhou, Shanghai, Ho Chi Minh City, Kolkata and Alexandria. In the past 20 years, floods have become the most frequent natural disaster. The average annual number of floods increased at a higher rate than any other natural hazard (Green Media 2012: 139). Below is a list of some of the most

important hazards that will become more frequent and affect urban zones due to increased climate variability.

Table 6. Urban Climate-Related Hazards

Climate-related hazard	Projected impact
Sea-level rise	Erosion and saline intrusion threatens coastal ecosystems: dunes, water tables, river water flows, and wetlands.
Storm surges	Threaten coastal housing and municipal infrastructure - port and trade logistics facilities, highways, power plants, water treatment plants - due to increased runoff contaminant and change in population distribution.
Extreme rain	Higher frequency and intensity of flooding, road washouts, and landslides may occur in urban areas, threatening vulnerable settlements. Heightened risk of infectious diseases exists.
Heat waves / heat-island effect	Very high temperatures affect cities more than rural areas given the heat-retaining built environment (buildings, paved areas) and lower air speeds. This considerably reduces nighttime cooling, and may result in higher-than-average morbidity and mortality, particularly in older persons. Possible impacts include increased energy demand for air conditioning, water contamination, increased road surface damage, increased water demand.
Water scarcity	Changes in precipitation patterns will reduce reservoir supplies and availability for urban use; runoff contamination increases.
Worsening air quality	Air pollutants from fixed and mobile sources, volatile organic compounds (VOCs) and nitrogen oxides (NOx), react to increasing temperatures with the formation of ground ozone, and surface inversion increases. It particularly affects children and older persons' health.

Source: World Bank (2012: 14)

City management in lower and middle-income countries faces challenges in developing and maintaining disaster risk management strategies. They lack an understanding of risk and methodologies to assess risk particularly for urban growth areas and informal settlements. Disaster and climate change risk is not a priority due to lack of financial resources and institutional capacity. Few of them have procedures to mainstream disaster risk management and climate change adaptation into urban planning or monitoring city's performance for risk reduction (World Bank 2012:16).

Technology and innovation

The use of technology plays an important role to improve resilience against natural hazards. Hazard monitoring and surveillance techniques can be beneficial for early warning and land use planning. ICTs that combine data from different departments can enable cities to monitor risks in an integrated manner. Geospatial tools can be beneficial for assessing disaster risk. For example, they were used by the International Organization for Migration in Haiti after the January 2010 earthquake to identify appropriate buildings and sites that could be used as shelter (UNCTAD 2012b: 22). Lower technology solutions such as insulating subway entrances to prevent rainwater from flowing in can also be useful to improve resilience.

Case studies

Monitoring and managing risks

Mumbai has 35 automatic weather stations that measure real-time rainfall intensity, and flow gauges on the Mithi River to monitor water flow. Chacao, Venezuela has a wireless early warning system that connects civil protection and environmental institutions with cameras that monitor four river channels crossing the city. Chacao also provides online real-time hazard information to citizens (UNISDR 2012: 62-63).

Rio de Janeiro established an Operations Center by partnering with IBM that provides real-time integrated data from 30 agencies on transport, energy, weather and emergency services. The Operations Center has improved coordination between agencies and reaction times. When a 20-story building collapsed in January 2012, the Operations Center alerted the fire and civil defense departments, asked the gas and electric companies to shut down service in the area, closed the subway stop, blocked the street, dispatched ambulances, alerted hospitals, sent equipment to clear the rubble and activated civil guards to secure the site. It also informed citizens over the Internet via Twitter (Singer 2012).

Mainstreaming adaptation into urban planning

eThekwini Municipality of South Africa integrated adaptation planning into its general urban planning and development framework. It involves adaptation at both municipal and community levels. In 2006, a climate change impact assessment was prepared. Following that, a climate change adaptation strategy was put together to identify key interventions in cases such as the urban heat-island effect or sea level rise. It is constantly being extended to include reforestation projects and water, health and disaster management. Finally, an assessment tool was developed to evaluate and compare policies and mainstreaming initiatives were undertaken, such as the creation of a Climate Protection Branch within the municipality (UNEP 2012b: 14-15).

Risk assessments

Sorsogon, Philippines is a city with 152,000 people that is exposed to the Pacific Ocean on both the east and west sides. The city faces on average five tropical storms each year. Sorsogon conducted a vulnerability and adaptation assessment in cooperation with UN-HABITAT, as a result of which it directed urban development plans to safer inland areas. Settlements in high-risk coastal zones will be incrementally relocated through local shelter relocation projects or voluntary resettlement. Inland areas will be incentivized through infrastructure investments, construction of new residential units and new industrial sites for employment. (UN-HABITAT 2012c: 114-115).

Policy considerations

Cities need to invest proactively into infrastructure for adaptation to natural hazards. As oceans get warmer and sea levels rise due to the effects of climate change, they will have to continuously revise their risk assessments and adapt their infrastructure. Many of the policies mentioned in previous sections can help increase resilience. For example, spatial plans can take into account risks of natural disasters, while improved buildings can reduce human losses. In addition to the necessity to save lives when

disasters occur, adaptation has a financial dimension. Investing into adaptation earlier can reduce the scale of economic losses and financing required to repair damage. Considering that the economic damage that New York City suffered due to Hurricane Sandy is estimated at 20 Billion US Dollars, the human and economic cost of inaction in less-prepared cities of developing countries will be massive. In Manila, Bangkok and Ho Chi Minh City, the cost of repairing damage from climate-change related flooding is estimated at 2 to 6 percent of regional GDP (UN-HABITAT 2012c: 107).

Cities can mainstream adaptation into urban planning. Possible measures include building new developments outside of risk areas, upgrading informal settlements, and addressing the lack of infrastructure and the degradation of the environment (UN-HABITAT 2012c: 106-107).

Risk assessments map the areas that are most vulnerable to hazards and help to adjust land use and development strategies. The Urban Risk Assessment, developed by the World Bank, UNEP and UN-HABITAT with the support of Cities Alliance, is a standardized tool to assess urban risk and identify areas and populations that are most vulnerable, which are typically those living in informal settlements. It provides a framework for both qualitative and quantitative assessments that enhances a local government's capacity to identify hazards arising from disaster and climate change risks. It assesses exposure and vulnerability of specific assets and populations, analyzes institutional capacities and data availability, and quantifies city vulnerabilities through the application of a baseline-benchmarking approach to assess progress over time and space (UN-HABITAT 2012c: 106).

Integrating spatial planning with infrastructure can also improve resilience. Dhaka accompanied infrastructure measures such as reinforcing river and canal embankments with efforts to prevent the encroachment of buildings to the vicinity of canals for improved protection against major floods. Similarly, regulatory measures based on risk assessments can guide future developments to avoid disaster risk. Singapore requires new land reclamations to be at least 2.25 meters above the highest level of recorded tides (UN-HABITAT 2012c:109).

III. Sustainability of peri-urban areas

Peri-urbanization is a process that is closely interlinked with urban sprawl. It refers to urban growth into zones that lie between the city and rural zones, sometimes also referred to as "spillover growth", usually without spatial planning and the provision of basic services. Development of the city fringes that undergo peri-urbanization is most often triggered by a real-estate boom that accompanies rapid urban growth. Populations that were previously rural benefit from new economic dynamism in manufacturing and services brought by urbanization, but they do not always enjoy improvements in quality of life. This section discusses potential pathways for more inclusive urbanization that takes into account the needs of peri-urban zones, enabled by science, technology and innovation.

Key issues

People living in peri-urban areas suffer the consequences of unplanned urban growth most intensely, as they face the consequences of environmental pollution, rapid social transformation and poverty. Peri-urbanization also results in conflicts on basic needs and resources such as water. Although peri-urban zones in developing countries are often neglected in the process of urban growth and lack basic services like water and sanitation, they have a key role to play in supplying cities with food, energy, water, building materials and critical ecosystem services. Their success or failure has implications beyond their vicinity. Since there is no return from urbanization and no future in rural poverty, the key question is how to undertake the "right" urbanization for peri-urban zones.

The rules of administrative governance of peri-urban areas are often unclear. Rapid urbanization causes peri-urban zones to undergo fast transformation in land, social structure and economic activity. The extension of cities into peri-urban areas in developing countries is often uncontrolled and can occur along a river or highway, as well as around a single metropolitan area. Due to lack of regulation or planning, peri-urban areas face severe environmental, economic and property-related challenges. For instance, due to the lack of regulation, some cities get away with discharging waste into peri-urban areas without facing any legal consequences. Insufficient regulation can result in peri-urban agriculture not being recognized as legal. Urban sprawl causes property speculation to increase land prices to unaffordable levels for peri-urban residents (UNFPA 2008: 49).

Many cities in developing countries expand with little focus on protecting peri-urban water systems or agricultural areas. Since the peri-urban is not incorporated in city development plans, the effects of urbanization in city fringes are not properly assessed. For example, much of the households in peri-urban zones are involved in agriculture. A lack of understanding of the way peri-urban agriculture is sustained represents a key issue affecting peri-urban farmers. Land acquisition and fragmentation of land caused by urbanization disrupts the livelihood of farmers. Their vulnerability is also increased by industrial pollution and deprioritization of agricultural programmes. In addition to all these issues, opportunities of greater economic return by selling or leasing land are decreasing the attractiveness of future peri-urban agricultural prospects (Marshall et al. 2009: 30).

Peri-urban zones on city fringes compete with urban residential and industry demand for water. Growing urban zones endanger water resources that are critical for agriculture. A study conducted in Chennai, India demonstrated that after a water-use agreement was signed between the urban water management authority and rural farmers for the usage of groundwater, peri-urban farmers were caught up in a vulnerable situation due to increased urban/rural demand and resulting price increases. Moreover, the water-use agreement had counterproductive effects on all parties. As urban water usage increased, excessive groundwater extraction led to longer droughts, thereby also negatively impacting urban citizens due to reduced food production (Thapa et al. 2010).

Water scarcity can turn into a serious health issue for both rapidly growing cities and peri-urban zones. The lack of water is negatively affecting access to sanitation. The number of inhabitants in cities of sub-Saharan African countries without access to adequate sanitation more than doubled between 1990 and 2010, reaching 180 million people (FAO 2012: 14). In Maputo, Mozambique, 20% of the population lacked access to potable water in 2003. Half of Jakarta's 10 million citizens had no access in 2007 (UN-HABITAT 2012c: 70). Meanwhile, water consumption is already excessive according to WHO norms in cities like Bangkok, Nanjing, Porto Alegre, Montevideo, Johannesburg and Tunis, and likely to grow further. Water leakages and abuse are severe problems in many countries. Thus the lack of water can be an inhibiting factor for sound urban growth and peri-urban livelihood.

The lack of healthy nutrition remains an important issue in growing urban areas of developing countries. More than half of urban residents in Africa live in slums, are undernourished and have scarce employment opportunities. Commercial horticulture (production of fresh fruits and vegetables), widely practiced in peri-urban zones especially in Africa, risks becoming unsustainable due to lack of means and support. Horticulture and food production are sources of nutrition and employment for millions of urban Africans, but they receive little recognition, regulation or support from their governments. As a result, an important opportunity for healthy nutrition of urban populations and a source of employment especially for female workers remains underutilized (FAO 2012).

Technology and innovation

Market gardening

As the spread of urban zones results in a lack of space for food production, small-scale peri-urban market gardening can make up for shortages of healthy, fresh food and generate employment. Peri-urban farms can even reuse urban wastewater for irrigation purposes. Production of fruit and vegetables in private, small farms close to cities can be less costly than supplies from rural areas due to lower transport costs. It can also help contain urban sprawl by creating urban green belts.

Water technologies

Since peri-urban communities in developing countries largely depend on agriculture, water is a key resource for their economic well-being. Water storage, irrigation and water lifting technologies can help tackle water shortages. For example Grundfos, a Danish pump manufacturer, developed and implemented a solution to bring sustainable access to water for rural and peri-urban communities in the developing world. The solution, as implemented in Kenya, uses solar energy to activate a pump that extracts groundwater and distributes it through a payment system that is managed locally. The revenue from the pump is used for maintaining the solution. Grundfos is working on introducing it to other countries as well ("A new model for sustainable water supply in the developing world" 2012).

Green roofs

Rooftops cover one-fifth of urban surface areas. Green roofs can be used to provide insulation and thereby reduce heating/cooling costs for buildings, while at the same time absorbing rainwater and filtering pollutants so that the cleaned water can be

reused (Totty 2011b). Green roofs are already common in Europe and spreading to North America.

Phyto-remediation
Another innovative method for reusing urban wastewater is called "phyto-remediation", i.e. the use of trees and plants to clean water. This works with the help of a drainage system that channels wastewater into a catchment that is filled with trees, which then capture the water and hold the waste. The cleaned water is then reused for irrigation purposes.

Case studies

Market gardening
Mozambique demonstrates the best example of policymaking for successful market gardening in Africa. The Government created so-called 'green zones' by organizing horticulture cooperatives in the capital city Maputo and other major cities after the civil war of the 1980s disrupted food supplies and increased urban unemployment. These green zones produce a critical supply of fresh vegetables such as cabbages, lettuce, tomatoes, onions, eggplants, beans and pumpkins. Despite its exponential growth that occurred without planning or administrative control, most of Maputo's green zones were protected by the City Council, sustaining the livelihood of predominantly female farmers. Membership of farmers' associations, which are affiliated with the General Union of Cooperatives, made it possible to protect the land of small-scale farmers from takeover by more wealthy farmers. The cooperative-based structure also supports farmers with financing, technical assistance and market access. The green zones play a key economic role through healthy small-scale food production, the creation of employment opportunities and use of urban wastewater for irrigation purposes (FAO 2012: 71-73).

Green roofs
Some countries (Austria, Germany, Switzerland, Canada and USA) are introducing regulation that makes it compulsory to construct green roofs on all new buildings or allocating subsidies for converting existing roofs (UNECE 2011). Toronto has become the first city in North America that requires green roofs on new buildings (Robbins 2012). Several cities are investing in rooftop gardens and trees that are designed to hold water. For example in Seattle, households are reimbursed for putting in place these "rain gardens". Meanwhile, rainwater harvesting from roofs has been made mandatory in Bangalore, India with the Water Supply and Sewerage Bill of 2009. Existing buildings that do not install rainwater harvesting structures are penalized (UN-HABITAT 2012b: 121).

Ecosystem assessment
Following up from the Millennium Ecosystem Assessment released in 2005, a land and marine ecosystem assessment was conducted in Japan by the Institute of Advanced Studies of the United Nations University (Japan Satoyama-Satoumi Assessment-JSSA). The assessment was divided into five major regional clusters. It identified the root causes of decline in both land and marine ecosystems and possible courses of action to reverse this trend. The most important root causes were land use transformation - largely due to urbanisation - and demographic change (rapid ageing) that made it harder to sustain these landscapes. It has been identified that the decline

of these ecosystems has negatively affected health and well-being in Japan (Duraiappah et al. 2012). The assessment established that the two key challenges for the future are attracting citizens and NGOs to participate in re-establishing land and marine ecosystem services and formulating economic incentives to protect non-economic values in these landscapes.

Ecosystem protection

Suncheon City is a good example to an urban zone that managed to protect its surrounding ecosystems. Located on the south coast of the Republic of Korea, Suncheon, despite being surrounded by cities prioritizing heavy industry, invested in its ecosystems as of the late 1990s and turned Suncheon Bay into an award-winning ecotourism center that attracts more than 2.3 million visitors a year. Although businesses and landowners disagreed with the plan at the beginning, it was implemented with the mayor's strong leadership and a clear vision on how the ecosystem approach would bring economic growth. (UNESCAP et al. 2011: 51).

Policy considerations

Peri-urbanization should take place as a planned, managed transition. Regional governance entities may be set up to establish a framework of equitable regulation that protects the environment, provides basic services to the poor and resolves land disputes that may arise from urban sprawl. It may even be to the benefit of the region as a whole to set city land expansion limits as in the case of Portland in the United States and encourage more concentrated development. Peri-urban areas can benefit from social inclusion programmes that upgrade existing informal settlements and prevent the formation of new informal settlements through adequate spatial planning. They can be integrated into the urban transport network as well. Soweto, a large township in South Africa that was part of greater Johannesburg as a separate municipality was successfully integrated into Johannesburg as a result of a planning and investment effort that improved infrastructure, accessibility, safety, public spaces and provided new economic opportunities (UN-HABITAT 2012c: 86).

Formal means of public participation in decision-making can play a key role in preventing resource conflicts between urban, peri-urban and rural stakeholders during the process of urbanization. Some countries have already managed to establish successful forms of participation in urban decision-making. For example, in Brazil, more than 70 cities have a participatory budget system that allows citizen participation in decisions of resource allocation (Marshall et al. 2009: 44). In Peru, the "Mesa de Concertación para la Lucha Contra la Pobreza" is a Council made up of government, NGO, church and community organisation members. It formulates short, medium and long term priorities for community development in areas of infrastructure, health, education, security, recreation and employment (Marshall et al. 2009: 45).

Horticulture can be supported through policies of urban zoning, building irrigation systems and establishing cooperatives that protect small-scale farming. Agricultural cooperatives can sustain agricultural production and the livelihood of the peri-urban farming community/industry in the face of urbanization. Cooperative structures improve the accessibility of markets and provide logistical support for individual farmers. Furthermore, governments can support peri-urban farming through

regulation. Tax policies can help sustain peri-urban food production for cities, thereby reducing the need for transporting food from other areas that would potentially increase the cost of food.

Water governance of urban and peri-urban zones by a single, unified authority can help resolve water conflicts. Singapore centralized all of its water management in the Public Utilities Board in 1963. In 40 years, two-thirds of Singapore's land surface became a water catchment area by storing water in 17 reservoirs. Singapore also collects wastewater to produce drinking water, which covers 30 percent of the city's needs (Tan 2012).

Peri-urban communities may benefit from regional ecosystem assessments that map their composition, interlinkages and changes induced by urbanization. Assessments can document vulnerabilities of peri-urban zones with quantifiable data so that policies can be developed to maintain landscapes and ecosystems that are important for food production, maintaining biodiversity and tourism.

IV. Summary

This Paper outlines sustainable development challenges faced by cities in key sectors. It proposes sustainable practices that make use of science, technology and innovation in order to produce wider economic, social and environmental benefits for cities. It explains how cities that prioritize sustainable growth patterns can improve employment and competitiveness, enhance social cohesion and create a healthy and liveable urban environment.

In its sectoral analysis, the Paper focuses on those sectors that harbor the greatest potential contribution of STI for positive change. For example, spatial planning goes hand in hand with transport to create compact and adequately dense urban environments with infrastructural cost efficiencies. STI can be used to manage energy, waste, water and buildings more efficiently and avoid resource depletion. Risk assessments and the use of technology can help reduce the effects of natural disasters. Last, synergies between urban and peri-urban areas can provide benefits in terms of food security, water management and employment.

There are common lessons that can be drawn from the analysis of each urban sector:

- First, sectors of urban management are interlinked. The absence of cross-sectoral policies can lead to fragmented governance, which is counterproductive and exposed to unexpected, unwanted outcomes. For example, "rebound effects" can occur in cases where the introduction of technologies that save energy actually lead to increased per capita energy consumption (UNEP 2011). Local governments in developing countries can launch cross-sectoral sustainability goals covering mobility, energy, buildings, water and waste. Science, technology and innovation has an essential role to play in order to address cross-sectoral sustainability challenges. For instance, information and communication technologies can be used to bring together data from different city departments and enable coordinated, simultaneous responses to challenges.

- Second, mainstreaming sustainability into urban development plans right from the start can avoid costly and difficult policy adjustments later on. It is true that developing accurate long-term plans is more challenging in rapidly growing urban environments as opposed to areas with constant populations. Still, new technologies empower urban planners by providing more capability and capacity to plan ahead.

- Third, the case studies from around the world demonstrate the need for cities to form a coalition of public, private and civil society actors and multilevel governance models in their transition to sustainability. Since policy changes such as prioritizing public transport, energy saving and efficient buildings affect all stakeholders that take part in urban life, they require consensus-based decision making to succeed. Cities need to envisage and put in place legal participation mechanisms. Broad public participation can gather input and promote consensus on urban projects, leading to cities that are more socially inclusive.

- Fourth, local governments should put in place a comprehensive regulatory environment and provide incentives to encourage the private sector to participate in urban infrastructure and technology projects. Public-private partnerships can attract investment into sustainability projects. International organizations and business associations such as the World Business Council on Sustainable Development can assist in matching the sustainability needs of cities with possible solutions of the private sector. Municipalities can also receive support from national governments and international organizations to create more favorable conditions so that sustainable practices do not remain expensive, subsidy-dependent options and are turned into real business opportunities (UNESCAP et al. 2011, UNEP 2011).

- Last, sustainability examples from several cities show that applying technology in highly populated urban environments requires a sound business model in order to succeed. Popular adoption of new urban technologies depends on whether they can replace current habits and practices without disruption or economic disadvantage. City departments can increase the potential for entrepreneurs to establish sound business models through regulation, economic incentives and information and awareness campaigns.

In the wake of the Rio+20 Conference, several international bodies will need to combine their expertise in order to implement the outcome document, as well as the Habitat Agenda, adopted more than 15 years ago as the basic framework for sustainable human settlements development. The expertise of international organizations like UN-HABITAT, UNEP, FAO and the World Bank needs to be leveraged to set standards in terms of sustainable policies for cities and peri-urban communities and undertake technical cooperation projects. International local government networks such as United Cities and Local Governments (UCLG), Cities Alliance, C40 Cities and ICLEI will also play an important role to increase awareness on sustainability, make best practices circulate and provide a platform for joint projects. Action at mayoral level is effective since mayors own, regulate or operate infrastructure such as city roads, buildings, public transport, waste collection, land use planning and even streetlights.

Cities and peri-urban areas in developing countries face a diverse range of challenges. At the same time, they have science, technology and innovation at their disposal to become more sustainable. Spatial design is a critical element of urban planning that has long-term effects on mobility and resource efficiency in cities. Decisions on density, land-use and spatial planning play a key role in city energy consumption, traffic, greenhouse gas emissions and building efficiency patterns. Transport-oriented spatial planning can improve mobility in a city. The way buildings are constructed can achieve energy savings. Far-sighted planning can prevent peri-urban zones from environmental degradation and conversion into slums. Local governments should implement sustainable policies first and foremost because they improve the lives of their citizens. Ultimately, cities should be constructed so that they serve their people, and not the other way around.

V. Discussion questions

The following questions are proposed as a basis for discussion during the inter-sessional Panel of the CSTD:

Sectoral questions

1. Do cities in your country have long-term spatial plans?
2. Which technologies and policies have you adopted to address traffic congestion in cities?
3. Can you provide examples of energy and water conservation measures that are being/will be used in cities of your country?
4. Which regulation, incentive and business models can promote sustainable buildings in cities of your country? Where do the commercial opportunities lie?
5. Which policies or governance models did you use to improve the resilience of cities against climate change and natural disasters?
6. Do you have cities where urban agriculture is practiced? How could space for this purpose be created?

General policy questions

1. What are the most pressing urban sustainability issues in your country? Do you set targets and measure progress when addressing these issues with policy responses?
2. What strategies could induce changes in lifestyle and consumption patterns of urban populations to achieve sustainability goals?
3. What financing models could be used to implement innovative policies and technologies that can address sustainability issues?
4. How can the private sector be encouraged to implement sustainable solutions in key sectors?

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