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Sustainable, Resource Efficient Cities – Making it Happen!

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Acronyms and abbreviations

ADB	Asian Development Bank
BRICs	Brazil, India and China
BRT	Bus Rapid Transit
CNY	Chinese Yuan
CABE	Commission for Architecture and the Built Environment
CCCP	Cities for Climate Protection Programme
CCM	Common Carbon Metric
CCX	Chicago Carbon Exchange
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CO2	Carbon Dioxide
CSP	Concentrated Solar Power
ECA	Economic Commission for Africa (United Nations)
EIA	Environmental Impact Assessment
ESCOs	Energy Savings Companies
EST	Environmentally Sound Technologies
ETAP	Environmental Technologies Action Plan
EU	European Union
FAO	Food and Agricultural Organisation
FHWA	Federal Highway Administration (USA)
GDP	Gross Domestic Product
GER	Green Economic Review
GHG	Green House Gases
GFEI	Global Fuel Economy Initiative
HICs	High Income Countries
HVAC	Heating, Ventilation and Air Conditioning
IEA	International Energy Agency
ICLEI	International Council for Local Environment Initiatives – Local Governments for Sustainability
IET	International Emissions Trading (mechanism)
IPCC	International Panel for Climate Change
ISWM	Integrated Solid Waste Management
KP	Kyoto Protocol
LAC	Latin America and the Caribbean
LCA	Life Cycle Analysis
LDC	Least Developed Countries
LIC	Low Income Countries
MA	Millennium Ecosystem Assessment
MDG	Millennium Development Goals
MLP	Multi-Level Perspective
NGOs	Non-Government Organisations
OECD	Organisation for Economic Cooperation and Development
PCFV	Partnership for Cleaner Fuels and Vehicles
REFIT	Renewable Energy Feed-In Tariff
SBI	Sustainable Buildings Index
SOWCR	State of the World's Cities Report
SSTEC	Sino-Singapore Tianjin Eco-City
StR	Share the Road
TBBP	Toronto Better Buildings Partnership
UES	Urban Ecological Security
UN	United Nations
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
UK	United Kingdom (Great Britain)
USA	United States of America
WWF	World Wildlife Fund

Foreword

Currently, over half of the world's population resides in cities. This urbanization trend is expected to continue and more than 80 per cent of humanity is expected to live cities by 2050. The conditions for city dwellers depend not only on how urbanization is planned and managed but also how cities source, process, and use resources. The choices cities make have far reaching implications on the level of sustainability that is possible in the future.

Cities drive economic growth, the consumption of materials and energy, the production of waste, and the emission of greenhouse gases. If we are serious about conserving our natural resources, reducing climate change, and bringing about the kind of Green Economy we will need in the 21st century to create jobs and alleviate poverty, then clearly change needs to be made at the city level.

This report contributes to the discourse of global environmental well-being by focusing on sustainability and resource efficiency. It is especially useful since it highlights genuine opportunities for city leaders and supports its arguments through a set of inspirational case studies of cities that have successfully improved their transition to sustainability.

In particular, when it advocates the need for city-level participatory management, the report emphasizes the importance of considering pro-poor, pro-people strategies when implementing a city plan. Participatory planning requires time and information but by obtaining the views of citizens, city managers are able to maximize the benefits of new investment.

The report also emphasizes the importance of infrastructure development. Choices made today on building design, waste management, urban ecosystem management, transportation, water, energy and food systems – and how well these choices integrate across sectors – will have critical implications for the future of cities across the world. In order to improve city sustainability, this publication proposes a mix of strategies, incentives, and enforcement measures in a broad range of sectors.

By offering concrete recommendations and examples to city managers, *Sustainable Resource Efficient Cities in the 21st Century: Making it Happen*, makes a strong argument to support its conclusion that integration and coordination across different city sectors and scales is critical to achieving city-level sustainability.

Achim Steiner
United Nations Under-Secretary General
and Executive Director
United Nations Environment Programme

Executive summary

Context

The cities of the 21st century are the largest sites of human settlement today and are increasingly acting as critical nexus points of social, economic, ecological and technological change. This is especially evident in the developing world city context, where growth is most rapid, and where future sustainability challenges will be most severe – all this in the light of growing inequalities, poverty and the pervasiveness of slums and informality. In the face of these challenges, there are genuine opportunities for national and city leaders to contribute to sustainability by focusing on cities' sustainability and resource efficiency.

There is a strong link between quality of life in cities and how cities draw on and manage the natural resources available to them. Resource efficient cities combine greater productivity and innovation with lower costs and reduced environmental impacts while providing increased opportunities for consumer choices and sustainable lifestyles. As such, the transition to resource efficiency rests on a range of factors such as redefining how urban systems are understood at the global level, developing a shared language for evaluating city sustainability and reviewing indices that account for the sustainability of cities.

Resource efficiency also needs to be situated within the context of human development. This publication presents a rationale for socially inclusive urban transitions to sustainable growth and draws on a range of case studies and theoretical and analytical considerations to establish the basis of the argument. It identifies some of the elements that are required to develop a shared language on city transitions to sustainability.

The report is divided into three sections.

- **Section 1** presents the challenges, trends, and pressures facing cities today.
- **Section 2** outlines the sustainability challenges and choices, exploring particularly infrastructure options available for realising sustainable, resource-efficient cities in the building, transport, waste and water sectors.
- **Section 3** examines a number of approaches describing how cities can transition to sustainable, resource-efficient growth.

Key findings

From an overview of recent literature and case study reports, it was found that in order to transition to sustainability, a city needs to harness cooperation, political vision and leadership through thematic and/or iconic programmes and projects that drive specific sustainability agendas around which integration can be achieved.

Second, cities also need to establish sector and institutional strategic intermediaries. These are institutes for education, higher learning, research, policymaking and innovation, funding mechanisms, monitoring and evaluation government agencies, non-governmental organizations's (NGO's), community organisations and other civil society organs; that can play a role in ensuring bottom-up participatory governance in sustainability programmes and projects and bring about cross-sector and inter-institutional coordination.

Third, establishing monitoring and evaluation mechanisms, programmes and projects that focus on intra and inter-sector sustainability were found to be critical to sustainability. Common tools and measures make it possible to assess and benchmark multiple dimensions of urban sustainability.

Finally, cities should make infrastructure choices with the intention of fostering future urban societies that have local resilience and global linkages. It is important for cities to have the capacity to reproduce new and diverse responses to existing, emerging, and new challenges; and to implement these responses at multiple scales and across the urban divide.

Urbanisation in the 21st century – trends and pressures

1.1 Sustainable cities – A new era: Framing the challenges

In the current era of development, urban sustainability is threatened by heightened global uncertainty and change. In broad terms, these changes consist of the following global factors: economic change, scarcity of resources, rapid technological and social change, environmental and climate change effects. These drivers of change have broad reach, and threaten multiple sectors – such as food, water, energy, transport and waste[1] – that are critical for urban sustainability. Cities are key leverage points in the quest for global sustainability due to their high levels of consumption, production and waste. Moreover, developing world cities, which are growing much faster than their developed world counterparts, are particularly vulnerable to lack of resources, poverty, inequality and vulnerability to climate change.

In response, this paper frames city transitions to sustainability – and the role of infrastructures – within its social context, with a focus on developing world cities. Its objective is to help decision-makers and stakeholders frame and develop well-conceived, practical strategies for infrastructure change and upgrade trajectories so that they help bring about city-level sustainability in multiple social, economic and environmental dimensions.

It considers the following questions:

- how to migrate or transition to sustainable, resource-efficient urban development pathways;
- what barriers and opportunities exist;
- and to what extent pro-poor sustainability transitions can be realised, especially in developing world urban contexts?

It also accounts for emerging global trends in the green technology sector and the potential for the creation of green jobs. It is a small but significant step towards conceptualising responses to the often seemingly intractable developing world urban development challenges, and is also useful in developed world urban contexts where the challenges of the urban divide persist.

This paper takes clear positions on; (1) what the key challenge is with respect to transitioning to sustainable, resource efficient urban development, and (2) what can be done to meet these challenges. On the first point, the key position that is adopted is that integration between different sectors and across different scales is required to actualise sustainable, resource efficient urban development trajectories. In respect of (2), the study concludes by making a set of recommendations for improving city sustainability, based on an understanding of the key drivers of change, challenges to city sustainability, available and emerging infrastructure choices and case study evidence – successful and unsuccessful – across the world. These recommendations are not prescriptive and this study acknowledges that no 'one-size-fits-all' solutions exist. The positions that are taken in this paper are hence strategic in nature, and highlight key principles for decision-makers to take into account when formulating urban sustainability strategies, programmes and projects.

It is clear that infrastructure choices that are taken today will have a bearing on city-level resilience in the medium and long term. Yet, infrastructure installations alone cannot bring about the large-scale changes that are required to realise sustainable development in urban contexts. A measure of creativity and originality is required in order to develop urban sustainability solutions that marry successfully with local implementation contexts.

Urban sustainability transitions require extra sensitivity to the social and political contexts in which they are conceived and implemented. This is especially true in developing world contexts where slums[2] and informality constitute significant proportions of the city, and poverty and inequality exacerbate the urban divide. They must also cater for local, contextual factors with great care so that sustainability programmes do not work against these factors but instead utilise these factors effectively in strategy-making, planning and implementation. Bottom-up participation in sustainability programmes and projects is essential, especially in developing world contexts. It is important to recognise that technological solutions alone are not enough to bring about sustainability. The 'rebound effect', for example, describes how financial savings might lead users to increase their actual use. This indicates how important it is to consider to what extent sustainability interventions bring about changes in individual and group modes of behaviour.

For transitions to sustainable development to be successful, the processes of learning, participation, negotiation and coordination[3] need to be present. As such, education, integrated approaches, innovation, participation, funding and leadership and political backing are all important elements of successful sustainability responses in cities. Maintaining the transition towards more sustainable practises and behaviours requires that the institutional capacity and skills – to innovate and implement – are developed in tandem with infrastructure development projects and programs. This requires that networks of niches are incubated and developed over the

1. McKinsey Global Institute (2011)

2. United Nations Centre for Human Settlements (2003)
3. Van Kerkhoff and Lebel (2006)

long term that can act effectively across business, civil society and governance sectors to support the actions, learning and innovations that are necessary for sustainable development. Actualising sustainable, resource efficient urban development requires integration across hierarchies and sectors and greater levels of integration and coordination between urban sustainability programmes. This is perhaps the greatest challenge to realising sustainability in the long term.

In summary, cities are concerned with how to make core infrastructural choices today that will help them transition to more sustainable modes of behaviour in the future.

Making choices about infrastructures that mediate the provision of services such as waste removal, energy and water supply, transportation and recreation require careful consideration of the contextual socio-cultural and political factors that are in play.

This paper identifies the following success factors for city sustainability and resource-efficiency:

- integration (going beyond piecemeal solutions)
- addressing the urban divide
- participatory governance
- employing smart and innovative urban design, logistics and spatial planning
- accessing finance effectively, emphasizing technology and skills development
- stimulating innovation.

In respect of urban infrastructure choices, however, *integration* remains the key challenge. This paper attests to the need for greater integration and coordination between the policies, regulations, governance frameworks, legislature and institutional hierarchies under which cities and city-sectors are governed. Formulating well-integrated development strategies for current infrastructure choices is essential to ensure long-term urban sustainability.

This paper proposes that in order to establish mechanisms for integration that act in support of transitions to city sustainability, three broad strategies can be employed:

1. thematic and iconic programmes and projects
2. the establishment and support of strategic intermediaries [4]
3. establishing multi-dimensional measurement and monitoring programmes.

Developing the institutional capacity to be able to respond to the challenge of integration and strong political leadership will be required to negotiate the urban challenges of the 21st century. Yet in order to achieve this, a shared language for urban sustainability must be engendered. In this respect, locating terms and concepts appropriately is necessary in order to formulate a clear vision for this paper.

Urban sustainability transitions require extra sensitivity to the social and political contexts in which they are concerned and implemented

So what do we mean by 'sustainability' and 'sustainable, resource efficient cities'? Two, complementary definitions of sustainability are employed in this paper. Firstly, sustainability is employed in terms of the broader definition i.e. social, economic and environmental sustainability for current and future generations. Secondly, material sustainability is empirically defined in terms of 'decoupling' growth from resource exploitation and environmental degradation – decoupling[5] is the 'measure' through which material sustainability can be measured. Resource efficiency is a key enabler of decoupling. We maintain that a focus on both levels of definition must be maintained if sustainability is to be achieved.

A *sustainable, resource efficient city* can be defined as a city that is significantly decoupled from resource exploitation and ecological impacts and is socio-economically and ecologically sustainable in the long term. By contrast, a low-carbon growth contributes to achieving sustainability but does not guarantee sustainability in itself. A *low-carbon city*[6] is one where growth is significantly decoupled from carbon emissions. In a sustainable, resource efficient city, it's sustainability programmes may have significant low-carbon outcomes due to the emphasis on resource efficiency but will yield a broader range of outcomes.

4. Hodson and Marvin (2009b)

5. Fischer-Kowalski and Swilling (2010)
6. By contrast, a zero-carbon city produces no emissions on balance and a post-carbon city exhibits carbon-positive growth i.e. it has an emissions deficit on balance.

Suffice to say that realising 'sustainable, resource efficient cities' that yield desirable social, economic and environmental outcomes is the *'vision'* of this paper; realising these mutual trajectories through greater integration is the *'message'* of this paper. To this end, we propose that a vision and message in respect of sustainable, resource efficient urban development, provides an account of infrastructure options and case studies, and concludes with recommendations for decision-makers who are concerned with the urban challenges of the 21st century. As such, this paper seeks to provide a basis upon which decision-makers can formulate strategic frameworks for transitioning to sustainable, resource efficient urban development in this new era.

1.2 Global change trends: pressures and drivers of global uncertainty

Current global urban development is characterised by three fundamental, broad-based changes. Firstly, we have entered an era characterised by the *'second wave of urbanisation'* which has seen more than half the global population now residing in cities. Cities are also playing an increasing role in GDP growth of national economies and as sites of increased employment, competition, trade, consumption, waste and production. Secondly, we are entering an era of *resource scarcity and constraint* where boundless growth strategies that treat resources as abundant have become untenable. Thirdly, we have entered an era of *increased uncertainty*; both *global change*[7] and *climate change effects* combine to exacerbate resource scarcity and increased unpredictability of resource availability (e.g. water, energy, oil, food). This is compounded by the general uncertainty that decision-makers face in a world where increased rates of change and increased inter-connectedness have made organisational navigation more difficult. Malhotra[8] refers to this as "permanent white-waters" for decision-makers. Technological and social (or socio-technical) change plays a key role in generating this uncertainty. Global change factors combine and condense in cities so that medium and long-term predictability becomes difficult due to the sheer complexity of factors involved.

7. The term 'global change' is used here as encompassing global climate change, global economic and financial change, global environmental change and ecological degradation, increased global interconnectedness, social networking, global uncertainty.
8. Malhotra (1999)

1.2.1 The second wave of urbanisation

The global population is expected to reach over 9 billion by 2050. The *'second wave of urbanisation'*[9] indicates that most of these people will live in African and Asian cities where city growth rates are the highest[10]. Migration to cities is also increasing and so are refugees and legal and illegal immigrants.[11] This, 'second wave of urbanisation' is a core driver of change in the 21st century and follows the first wave of urbanisation that took place in developed countries from 1750, lasted 200 years and resulted in the urbanisation of 400 million people.[12] By contrast, the second wave of urbanisation is projected to see over 3 billion additional people living in cities in a time-span of just 80 years, bringing unprecedented challenges to city doorsteps.

The second wave is occurring mainly in Africa and Asia, followed by Latin America and the Caribbean. Africa's city growth rates are the highest in the world while Asia's cities are growing by the highest absolute number of people. Even though Europe's overall percentage of urbanisation is high, it's rate of urbanisation (by major area) is tapering and in some cases even declining in comparison to African and Asian cities.

African city growth rates are the highest but Africa's national rates of urbanisation (i.e. the growth rate of the share of urban population) are not the highest in the world.[13] When referring

9. UN Habitat (2011a) (2010)
10. UN Habitat (2011b)
11. UN Habitat (2011b)
12. Swyngedouw and Kaika (2000): in IPRM (2010) and
13. Potts (2012)

Global population is expected to reach 9 billion by 2050

Resource limitations on availability of materials will significantly affect city growth

to 'urbanisation rates' it is important to clarify what is being counted i.e. urban land area, percentage urban population size increase, or total urban population size increase. By all these measures, however, African and Asian cities are projected to grow significantly, absorbing most of new global growth. It is therefore clear that the challenges faced by developing world cities in particular will intensify as it is mainly African and Asian cities that will struggle to meet the challenges of the second wave. Many of them are unable to meet their current challenges effectively, much less those of the future.

Yet the second wave of urbanisation is a phenomenon that has the potential to "unlock new arenas for thinking and acting on the city"[14] because the rise of the city brings new and existing problems into focus (i.e. social, economic and environmental), where they must be successfully resolved if the city is to become liveable, humane and sustainable in the long term. What considerations must be made in preparation for the second wave, given that the cities of the developing world are central to this phenomenon?

Later, in section 1.3, city growth trends and the expansion of urban slums is discussed in more detail, but first, it is necessary to discuss global resource scarcity, as it is central to the challenges that developing world cities of the future – in particular – will face in maintaining the day-to-day survival of their burgeoning populations. It ascribes the context within which the growth of these cities is unfolding, along with global ecosystem degradation and climate change.

14. Swyngedouw and Kaika (2000)

1.2.2 Cities, global resource scarcity and the next industrial transition

To add to the growing pressures of concentrated demand that is associated with urbanisation, resource constraint has become a global reality in a number of different sectors threatening to constrain growth. In particular, global resource limitations on the availability of materials for production and construction such as oil, electricity, water, food and transport have the potential to significantly affect city growth (see section 1.4 for more a more detailed discussion). The next *'industrial transition'* – as it is termed – will increasingly be characterised by resource constraints (especially in terms of materials, energy and ecosystem services) instead of resource abundance[15] posing multiple challenges for growth and development in cities, where production activities are often concentrated.[16]

Global ecological changes are also significant as the availability and security of ecosystem services hampers the potential for the growth of human activities. In 2005, the United Nations Millennium Ecosystem Assessment found that 15 out of the 24 key ecosystems that human survival is dependent on were degraded and/or subject to unsustainable use. The consequence is that 1.3 billion people live in ecologically fragile environments, mostly in developing countries.[17] Resource scarcity and degraded ecosystem services may combine to bring about complex challenges in unique ways

15. Fischer-Kowalski and Swilling (2010); Kraussman *et al.* (2008)
16. Swilling and Annecke (2012)
17. Swilling (forthcoming)

in different urban contexts. The next industrial transition is more complex because intricate local, regional and global interdependencies that were taken for granted in the historical construction of cities and urban processes, yet which ensured city sustainability, are now being brought into question.[18]

Global metabolic rates have risen with rising income levels.[19] Thus it is consumption and waste patterns and levels – associated with rising income levels – that lead to higher resource use and environmental degradation. As stated in the Green Economic Review, Cities chapter:[20]

> *"Cities per se are neither drivers of climate change nor the source of ecosystem degradation, but certain consumption and production patterns as well as certain population groups within cities are."*

Rising income levels can be associated with rising global material consumption (and production). Yet rising income levels and greater levels of consumption can also be associated with urbanisation.[21] In turn, as urbanisation levels increase so do ecological footprint sizes,[22] as it is in cities that income levels are higher, and where higher levels of disposable income and access to debt-financing exists. Moreover, cities can consume up to 80% of the global material and energy supply and produce 75% of global carbon emissions (see section 1.4.1). Bringing about global change in levels of consumption and waste output therefore requires a specific focus on cities and their development trajectories. Hence, programmes for resource efficiency in cities have the potential to play a key role in lowering global metabolic rates through influencing the development strategies that cities adopt and the infrastructure choices they correspondingly make. This is especially the case where infrastructures are concerned as they strongly influence the material consumption that results from urban activities.

1.2.3 Global climate change

The Intergovernmental Panel on Climate Change (IPCC) has released several key reports[23] over the past decade that emphasize the dangers that climate change threatens to bring to the globe as a whole and in different regions and locations of the world. At the core of the projected climate change is *increased uncertainty*; that variations are expected to occur at faster rates and more discontinuously than before in both the short and long terms. Global climate change will likely lead to greater variability in local weather extremes and not

18. Krausmann *et al.* (2008)
19. UNEP 2011
20. GER Cities (2011:458)
21. Satterthwaite (2007)
22. GER Cities (2011:458, see Figure 2)
23. e.g. IPCC (2007)

Flooded city in Thailand: decision makers must prepare for greater variability

a general warming. Cities may become subject to increased variations in local climatic conditions with higher extremes in both summer highs and winter lows. Decision-makers and planners must prepare for greater variability than regression allows for, due to the often unpredictable, non-linear nature of the changes that are brought about by climate change effects acting in combination with other changes (e.g. climate-water-energy-food interdependencies).

Where cities are concerned, there are several key factors – that may result from, or work in combination with climate change – that will affect daily life and survival in cities. The increase in energy demands for heating and cooling that result from climate change will be exacerbated by the 'urban heat island effect' where temperatures in cities vary up to ten degrees (Celsius) higher than non-built up urban environments, increasing demand for cooling in summer. Cities are also vulnerable to drought conditions, and where cities draw water from remote sources, drought in those areas will have a direct impact on cities. Price increases in energy and water impact directly upon household budgets and bring additional pressures to family budgets through food and goods price increases related to energy and water price increases.

Cities are also vulnerable to extreme weather events such as cyclonic storms, flooding, water table rise, electrical storms, hurricanes, tornadoes and high wind events that are made worse by the built-up 'corridors' within cities that channel and intensify the effects of wind. Where city infrastructures are only able to cope with a short range of limits in respect of precipitation, temperature and wind, for example, they will be increasingly vulnerable to the greater levels of variation that climate change imposes upon them. Increased global coastal growth trends, mainly within cities located along coastlines, also raise the question of the threat of sea-level rise.[24] The long-term threat of sea-level rise is significant. Even if coastal areas aren't fully inundated in the future they will have to cope with the effects that rising sea levels bring; for example, the effect that saline intrusion will have on water quality, water table levels, soil quality and agricultural industrial production processes. Also in question is how waste will be affected by climate change effects, for example; landfills will release greater amounts of methane under warmer conditions, the cost of waste removal and disposal will increase with increased energy costs, waste-water removal and processing will also be affected by water and energy price increases.

1.3 City growth trends

1.3.1 Growth of cities

A regional overview of urban population growth rates in different regions across the world shows that Africa and Asia have the highest urban population growth rates, followed by Latin America and the Caribbean. Even though Europe and North America have high levels of urbanisation, their rates of urbanisation are very low, and are projected to decline, in comparison to Africa, Asia and Latin America and the Caribbean.

Where the growth of cities is concerned, some key emerging trends contradict the established notions that govern how urban growth is conceptualised. The notion that cities embark upon a purely linear trajectory from "small to big" that inevitably leads to cities of megacity scale is flawed. Contrary to this expectation, 40% of cities in the developing world actually *shrunk*[25] during the 1990s, and 17 large, developing world cities with populations greater than 5 million also shrunk in the 1990s. Developing world cities are growing faster than those in the developed world but only 17% of these cities have high growth rates of 4% per annum, while the majority (36%) are growing between 2-4% per annum.

24. IIED (2008a)
25. UN Habitat (2008: 11)

Africa and Asia have the highest urban population growth rates

There are far more small and intermediate size cities that have resulted from new growth than megacities. Between 1990 and 2000, 694 'new' cities – i.e. containing less than 100,000 people before 1990 – were established. 510 of these cities grew into small cities with less than 500,000 people, while 132 became intermediate cities with populations between 500,000 and 1 million, and the remaining 52 grew into big cities with populations between 1 and 5 million people. A close majority of around 52% of the global urban population currently reside in small cities of less than 500,000.

Projections for city size class distribution in 2025 – based on historical data (starting in 1995) – indicate that more people will live in small cities (of less than 100,000) than in megacities in the medium-term future. Small to intermediate-sized cities are the likely scales at which the challenges of the second wave of urbanisation will become manifest. This indicates that conceptualising city sustainability will require close scrutiny of the scales at which cities are stabilising, and formulating strategies that are appropriate at these smaller levels.

1.3.2 Slums, informality and the urban divide

Even though the percentage of urban populations that are living in slums declined between 1990 and 2010, as the developing world has rapidly urbanised, the proliferation of slums and informal settlements[26] has reached gigantic proportions. According to the United Nations, by 2003, a billion people were living in slums,[27] a figure that is likely to have increased significantly since the global economic collapse of 2008. More than 60% of all urban citizens in sub-Saharan Africa live in slums.[28] Although the actual numbers of slum dwellers are higher in Asia than in sub-Saharan Africa the percentages are lower; ranging between 24-43%, while in Latin America and the Caribbean 27% of the urban population live in slums. Africa has the highest rates of city population growth (3.3.%), and urban populations are projected to increase from 373 million to 1.2 billion by 2050. Slum populations may increase by an additional 800 million inhabitants. The *State of the world's cities report*[29] says that data for slums and informality in European and Organisation for Economic Co-operation and Development (OECD) countries is lacking, making

26. Not all informal settlements are slums. Informal settlements may have access to transport, electricity, piped water and telephone services through conventional infrastructures, for example, whereas in slums this level of access to services may be almost non-existent.
27. UN (2003)
28. UN Habitat (2011a)
29. UN Habitat (2011b)

comparison between developed and developing countries very difficult. Yet the report stresses that the core challenge facing cities is that of the socio-economic "urban divide". The urban divide (i.e. socio-economic divide) is pervasive throughout cities of the developing world in particular but it is also a critical factor affecting cities in the developed world.

Informality itself, however, is broader than slum urbanisation. Informality refers to the broader set of informal activities that urban dwellers resort to in terms of gaining access to services, conducting trade, business, that is; outside of that provided by conventional infrastructures and formal business and trade frameworks. Informality encompasses a wide range of socio-economic and cultural activities that extend beyond informal infrastructures into the formal business areas and conventional infrastructures themselves. People in informal and slum settlements are often unable to access the conventional infrastructure to meet their basic needs and service requirements. What is regarded as 'informal' is really an alternative mode of operation to which people turn when conventional infrastructure provisions become inaccessible to them,[30] for whatever reasons. Linking sustainability agendas to overcome the urban divide is a critical requirement for greening and sustainability programmes and projects. Integrating between social, economic and environmental agendas is a key requirement for long-term city sustainability. These prerogatives must be addressed in a complementary manner, that is; they should be regarded as mutually important and should not be perceived as conflicting visions that are irreconcilable.

30. Bayat (2000)

1.4 Global resource constraints

1.4.1 Materials and energy

Globally, 500 exajoules of primary energy and 60 billion tonnes of raw materials were used annually by 2005, with material extraction having roughly doubled since 1995.[31] Between 60-80% of material consumption can be attributed to cities. As outlined earlier, rising metabolic rates can be associated with higher rates of urbanisation and the higher levels of income that are associated with urbanisation. As material and energy consumers, and producers of waste, cities are overwhelmingly significant players. Up to 75% of global economic output emanates from cities while they may consume up to 80% of global energy supply and produce about 75% of carbon emissions in turn.[32] In general, fossil fuel prices (coal, natural gas and crude oil) have risen steadily since the late 1990s.[33] This raises serious questions about the future sustainability of cities in terms of energy supply, their role in meeting global carbon emission reduction targets and their ability to

31. Krausmann *et al.* (2009)
32. UN Habitat (2011a); OECD (2009a)
33. GER Renewable Energy (2011)

Informal and slum settlements are often unable to access the conventional infrastructure to meet their basic need and service requirements

Fossil fuel prices (coal, natural gas and crude oil) have been rising steadily since the 1990s

participate in the carbon economy. To add to this, the security of electricity supply in cities is mainly dependent on coal-fired power stations that are remotely located – and hence endure temperature sensitive losses on lines that transmit power to the city. This will have to change if carbon emissions are to be significantly reduced.

1.4.2 Oil

The International Energy Agency (IEA)[34] forecasts that the global demand for oil will rise by 45% by the year 2030 and that there is no evidence that new oil discoveries will be able to meet this demand. Heinberg[35] reveals the drastically downward trend in new oil discoveries between 1965 to 2000. At the same time, oil prices have increased significantly since the mid 1980s.[36] Oil peak projections envisage "abrupt and revolutionary" change in the absence of mitigation ten years in advance to oil peak.[37] Whether oil peak as a phenomena is accepted or not, it is critical to note that the IEA[38] projects that the price of oil is nonetheless set upon an ever-increasing track.

The cost of oil impacts upon all extracted, manufactured, grown and transported goods and commodities, and often at multiple points in the value chain. The implications of rising oil prices and the possibility of oil peak in production for cities are dire, as cities rely heavily on 'imported' goods, commodities and services which will undoubtedly be heavily affected. It also affects household budget resilience, and where poorer households may be especially vulnerable to changes in the cost of food and energy (including transportation), oil price increases significantly amplify their vulnerability. In the City of Johannesburg, for example, where 42% of households can be classified as 'food insecure'[39], oil price fluctuations that affect the cost of imported food have severe socio-economic consequences at the household level.

The projected future of cities under conditions of oil constraint may, according to Newman,[40] lead to several different reactions from cities. These include the possibility of collapse of cities, the decentralisation and dispersion of cities into what may be termed "the ruralised city" (where semi-rural activities take precedence), "the divided city", or "the resilient, sustainable, solar city". Combinations of the aforementioned city typologies may also emerge in reaction to peak oil conditions. Central to adaptation efforts will be building cities with "reduced car dependence"[41] yet the motor car is often viewed as a 'sacred cow' to urban developers. As the ex-Mayor of Bogota, Enrique Penalosa puts the question, "are we building cities for cars or for people?". He points out that the great majority of developing world urban citizens do not own cars and building cities primarily for motor car transportation effectively reduces the accessibility and mobility of the majority.

34. IEA (2008)
35. Heinberg (2004): in GER Renewable Energy (2011)
36. GER Renewable Energy (2011)
37. Hirsch *et al.* (2005): in Newman (2007)
38. IEA (2008)
39. Frayne *et al.* (2009:01): in DGE (2010)
40. Newman (2007)
41. Newman (2007)

Demand for oil will rise by 45% by the year 2030

1.4.3 Waste

As existing cities have expanded and new ones have been established, levels of solid and water-borne waste have also grown, increasing demand for land-fill sites and wastewater processing plants. Landfills are significant sources of greenhouse gases (GHGs), such as methane, that can be up to 26 times more powerful than carbon dioxide (CO_2) as a greenhouse gas, and servicing landfills requires large scale transportation of waste, often over large distances. Landfills, where inadequately managed, are also sources of leachate, bacteria and disease which can infect the water table, and bring about environmental hazards. In this respect, it is of interest to note the following:

> *"Waste volumes are not necessarily the most important challenge ahead. Mixed MSW [Municipal Solid Waste], hazardous health-care waste, and industrial waste streams can impose serious health and ecological risks if these wastes remain uncollected or dumped in uncontrolled and unsecured landfill sites. In low income countries, for example, collection rates are lower than 70 per cent, with more than 50 per cent of the collected waste disposed through uncontrolled landfilling and about 15 per cent processed through unsafe and informal recycling (Chalmin and Gaillochet 2009). Given the amount of valuable components in MSW, the mixing of wastes also means a lost opportunity to recover components that could be recycled and used as new resources." (GER Waste, 2011 P297:[Municipal Solid Waste] inserted)*

Waste, whether from domestic or industrial sources, creates externalities (a cost or benefit that is not transmitted through prices) that can be quantified. For example, in the EU, if a low estimate of €21 per ton of CO_2-eq emissions is used, the waste management sector created external GHG costs in the order of €2.7 billion.[42] Methane emission counts contributed heavily to this estimate. In the same year, EU chemical industries produced €3.6 billion in GHG emissions which indicates the scale of the contribution from the waste sector. Yet waste is a valuable resource and cities are major sources of waste output. Waste can be utilised as a critical resource for recycling, waste to gas, waste to energy and waste to fertilizer operations. Solid, waterborne, hazardous and mining waste have re-use and recycling potential.

Where cities are concerned, developing new conceptual frameworks, infrastructures and waste programmes in cities of the future will determine the extent to which the operational costs of the city increase or decrease. In a rapidly urbanising future, it is clear that dealing with waste through conventional means could prove more expensive and environmentally damaging. Newer, low footprint waste disposal, recycling and re-use, re-design of systems and products, and cleaner technology processes and technologies are required if the challenge of waste is to be adequately tackled. Moreover, the developmental trajectories that cities undertake are also important. As outlined in Chalmin and Gaillochet,[43] medium and high income countries produce more waste than low income countries in every class except biomass. Should the aspirations of developing world cities lean towards creating lifestyles constituted of high income, consumption and waste levels their sustainability will prove all the more difficult to achieve.

42. GER Manufacturing (2011:255)
43. Chalmin and Gaillochet (2009): in GER Waste (2011)

Waste can be a valuable resource

1.4.4 Water

The city of Birmingham, Alabama USA, is currently bankrupt due to borrowing heavily (to the tune of US$3 billion) to build a new sewage works in the 1990s. Relying on conventional waste-water infrastructures that utilise large amounts of water and energy – pumping water into cities, and water-borne waste out of them to large plants where they are processed using yet more energy and water – may not be appropriate technologies for the future that cities face, especially in the developing world. It is critical that cheap, easily manageable technologies and infrastructures emerge that can make the capture, use and re-use of water more efficient in terms of water and energy use.

Globally, access to water remains one of the key challenges faced by governments, regions and cities alike. According to the GER report on water,[44] almost 1 billion people do not have access to clean drinking water (i.e. potable water), while 2.6 billion do not have access to "improved sanitations services". Approximately 1.4 million children under five years of age die annually due to the lack of access to proper sanitation and potable water services. The report states that *"the Millennium Development Goal for sanitation will be missed by 1 billion people, mostly in Sub-Saharan Africa and Asia"*. Water supply is growing increasingly scarce and water supply will cater for only 60% of world demand in 20 years.[45] By 2030, people living in Brazil, Russia, India and China (the "BRIC" countries) and the rest of the world[46] will face the most severe water supply challenges.[47] Water supply to cities will prove a continual challenge in the future. Cities are extending their reach to draw water from ever farther sources located outside of city boundaries to meet increasing demands, often with devastating consequences for upstream and downstream activities that depend on water availability.

The implications for increased demand, dams, climate security, production and waste removal are significant. Water use systems (i.e. the transport, storage, wastewater processing of water) will all come under pressure to change in the future. Indeed, many of these systems would be completely different were they to be invented and built today, independently of the influence of traditional, legacy infrastructure systems. For example, flush toilet-based sewerage systems would not be the most likely choice for many new cities were they to be built today. The rates of city growth suggest that concentrated demand for potable water and wastewater abstraction works are set to increase.

1.4.5 Food

The demand for food in cities has also increased with rapid urbanisation yet there are key vulnerabilities emerging at the global scale with respect to the cost and availability of food, and the arable soil and water that is required for the production of food crops. The 2010 OECD-FAO Agricultural Outlook[48] estimates that 1 billion people now live with food insecurity. Where urban residents do not have the ability to draw on locally produced food, their vulnerability to global changes in food prices often proves dire. In respect of global food vulnerability, the GER[49] states that the shock of rising fuel prices between 2007 and 2008, which contributed to rapid

44. GER Water (2011)
45. McKinsey and Company (2009): in GER (2011:20)
46. OECD (2009b): in GER Water (2011:129)
47. OECD (2009b): in GER Water (2011:129) 2030 Water Resources Group (2009): in GER Water (2011:131)
48. OECD and FAO (2010)
49. GER (2011)

Almost 1 billion people do not have access to clean drinking water increases in food and commodity prices, are a reflection of "structural weaknesses and unresolved risks" in the global economy. The IEA[50] views this as an ongoing problem and the GER[51] states that there is currently "no international consensus on the problem of global food security or on possible solutions for how to nourish a population of 9 billion by 2050."

According to the World Bank,[52] in the period between 2000 and 2007, 27.8% of children under the age of five in low income countries (LICs) were malnourished.[53] Climate change-induced weather variations affect agricultural production and create uncertainty and unpredictability in agricultural practises and production. Energy and oil prices also affect agro-economic activities and food supply significantly; and when variations in other agro-production essentials such as phosphates occurs, double and triple-squeeze effects may occur in the global agricultural sector with serious consequences. This has severe, adverse implications for the food supply and the cost of food in cities.

Building local food resilience in developing countries through boosted local food production and consumption – by incentivising agro-production activities in and around cities – provides 'insurance' against global price changes and climate change effects that may render the global food supply vulnerable, and cities with it. Encouraging local food markets and agro-ecological produce are significant green measures for cities to take as they reduce their food carbon footprint significantly by buying local, seasonal food and building local resilience to global food supply uncertainties at the same time.

50. IEA (2010)
51. GER (2011:14)
52. World Bank (2010)
53. GER Agriculture (2011)

1 billion people now live with food insecurity

1.4.6 Transportation: congestion, air pollution and emissions

Urban sprawl, suburbanisation, private vehicle dependence and inner city decay have left many large cities and megacities with an urban form that will increasingly prove unsustainable in a future characterised by high energy and transportation costs. Emission from air transportation is expected to increase with income growth in developing countries and emissions from shipping is expected to grow by between 150-250% compared to 2007 emission levels.[54] According to the International Energy Agency, transport accounts for 13% of all global GHG emissions and 23% of global carbon dioxide emissions.[55] Transport energy consumption increased by 37% between 1990 and 2005 while carbon dioxide emissions from transport are projected to increase by 57% between 2005 and 2030. Road transport accounted for 89% of energy use attributed to transport in 2005, and grew by 41% between 1990 and 2005, compared to 13% growth in emissions associated with non-road modes of transport. Approximately 60% of total global road transport emissions originate from North America and Western Europe. China ranks third in transport related energy consumption and emissions behind the USA and Europe, and tripled its consumption of transport related energy between 1990 and 2005. In general, growth in transport energy use increased faster in non-OECD countries (>55%), compared to OECD countries (>30%), and can be attributed to increases in personal disposable income margins, higher vehicle ownership numbers and the increased demand for freight transportation.[56]

Fatalities from transport account for 1.27 million yearly and more than 80% of air pollution in developing countries can be attributed to the transport sector. According to the GER report on Transport[57] these costs can account for up to 10% of a nation's GDP. Congestion and air pollution can be linked to lower productivity levels and health threats that impose significant losses and costs upon cities and national economies in turn. Congestion in the USA costs 0.7% of GDP per annum and wastes 5.7 million gallons of fuel.[58] In the European Union the costs of congestion account for 0.75% of GDP,[59] while in the UK it costs £20 billion.[60] In developing countries congestion costs are higher, as in the cases of Buenos Aires, Mexico City and Dakar which amount to 3.4%, 2.6% and 3.4% of national GDP, respectively. Congestion in Toronto costs the city approximately US$3.3 billion per annum in productivity losses, translating to 1.2% of the city's GDP.[61] In

54. GER (2011)
55. GTZ (2010)
56. GTZ (2010)
57. GER Transport (2011)
58. FHWA, 2000; in GER Transport, (2011)
59. World Bank (2002): in GER Cities (2011)
60. Confederation of British Industry (2003): in GER Cities (2011)
61. GER Transport (2011)

80% of air pollution in developing countries can be attributed to the transport sector

developing world cities, such as Lima in Peru, an average of four hours a day are lost by people who live and travel within the city.[62] This translates into a loss of about US$ 6.2 billion or 10% of GDP per annum.[63]

Significantly, the 2011 GER Transport report states that the "traditional approach to tackling congestion – providing more road capacity – has often been counter-effective as the extra capacity induces further demand for traffic." It also suggests that developing countries have the opportunity to leapfrog transportation systems towards greater sustainability and thereby avoid "reproducing the mistakes made by industrialised countries."[64] Cities and city governments have a critical role to play in respect of transportation as they are in the best position to re-envision urban design and bring about large-scale infrastructure changes that address sustainability and liveability concerns. Through the provision of safe, reliable, efficient and low-emission public transportation systems with sufficient non-motorised transport options, cities and states can play a significant role in allowing new values, beliefs, norms and behaviours to emerge.

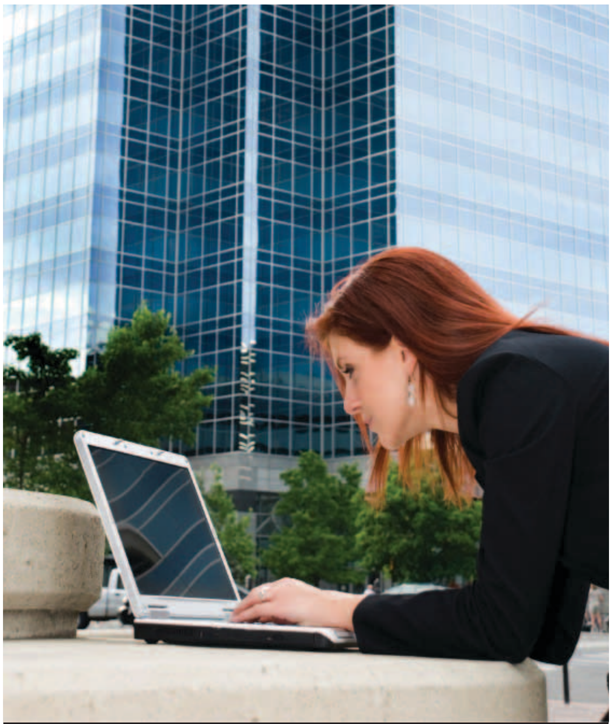
62. GER Transport (2011)
63. UNESCAP *et al.* (2010): in GER (2011)
64. Dalkmann (2009): in GER Transport (2011)

1.5 Emerging trends in global governance

1.5.1 The emergence of a carbon economy

The Kyoto Protocol is a treaty between industrialised and non-industrialised nations that was negotiated in Kyoto, Japan in December 1997 under the United Nations Framework Convention on Climate Change (UNFCCC). The treaty was then opened for signing in 1998, closed in 1999, and became active later in February 2005. Under this agreement, industrialised countries are required to reduce their greenhouse gas emissions by 5.2% compared to 1990 levels of emissions. It is not exhaustive or binding and the treaty has not been ratified by the USA and a few other leading industrialised nations. Nevertheless, the targets for the European Union are set at 8%, the US 7%, Japan 6% and Russia 0%, while increases of 8% has been permitted for Australia[65] and 10% for Iceland. The introduction of the carbon economy has profound implications for competitiveness of cities. The direct implications are that cleaner production,

65. In spite of this, Australia has adopted a carbon tax in order to stimulate a transition to low-energy production and consumption.



Low-carbon growth is required

transport and service provision will increasingly play a role in enhancing the competitiveness of cities. The infrastructure choices that cities make today will largely determine the carbon intensiveness of urban growth in the future. Should the emerging carbon economy establish itself as a permanent global institution, the competitiveness of cities will, in part, be determined by their ability to ensure low-carbon growth.

The post-Kyoto discourse on climate change and the need to reduce GHG emissions has taken many twists and turns. At first, the science behind climate change projections was subject to intense scrutiny by governments which were unwilling to contemplate the large changes that would be required to offset the progression of global climate change effects. The recent United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in 2009 failed to ensure that a legally binding deal was signed.[66] Prior to Copenhagen 2009, the Bali Climate Convention in 2007 agreed that negotiations would occur on two tracks with working groups dealing with long-term cooperative action (LCA) and the Kyoto Protocol (KP).

The LCA working group was concerned with negotiations on long-term reduction targets for developed countries and on the role and potential of developing countries to engage in mitigation and adaption activities through technology transfer and support from developed countries. The KP working group was concerned with deeper emission cut targets for developed countries, potential amendments to KP, and the role of Clean Development Mechanisms (CDM), land use change, forestry etc. in reducing emissions. Both LCA and KP negotiations should have been concluded by the end of Copenhagen 2009.[67] Perhaps the most significant development at Copenhagen was that the accord recognises – for the first time – the need to restrict global warming below 2 degrees Celsius. Yet no binding agreement was obtained, and while a 25-40% reduction in GHGs is required of rich countries according to the IPCC, a World Resource Institute study indicates that commitments by rich countries range[68] between 13-19%.

CASE STUDY

Urban Clean Development Mechanisms: UNEP and the city of Gwangju, Korea

Together with the city of Gwangju (South Korea) UNEP is supporting the development of a global framework to assess the environmental performance of cities and is exploring the feasibility of developing a methodology for a Clean Development Mechanism (CDM) at city level.

A general lack of financial incentives for cities to reduce GHG emissions has been identified by several organizations. So far, existing carbon finance mechanisms such as CDM do not target local authorities specifically. For example, only a small number of examples of CDM projects that could be labelled "Urban CDM" (i.e. CDM projects that have a city-wide approach in one or several sectors) have been identified so far. Such a carbon financing mechanism at local level could provide a key incentive for city authorities to promote green growth among cities in particular in developing countries. Therefore, there is a need to explore CDM mechanisms for cities, including the potentials of setting up a CDM-associated carbon trading mechanism among local authorities and cities. In close collaboration with the city of Gwangju (South Korea), UNEP developed a feasibility study on urban CDM to review existing methodologies and approaches, collecting successful case studies and providing recommendations and a way forward to overcome the inherent challenges of the current CDM system.

66. Ravindranath (2010)

67. Ravindranath (2010)
68. Levin and Bradley (2009): in Ravindranath (2010)

There were many concerns about the situation regarding carbon funding after 2012. Several key responses have emerged. The World Bank recently announced that tranche 2 of the Umbrella Carbon Facility (UCFT2) has been operationalised with 68 million Euros of initial funding, contributed by Deutsche Bank, Gaz de France (GDF) SUEZ and the Swedish Energy Agency. Seventeen projects and programmes are currently under consideration for funding allocations.[69] The tranche will be fully capitalised when it reaches 105 million Euros so there is still space for new applicants. Moreover, five European public finance institutions have started a post-2012 carbon credit fund with the value of 125 million Euros, including the European Investment Bank (EIB), Caisse des Dépôts, Instituto de Crédito Oficial-ICO, KfW Bankengruppe and the Nordic Investment Bank-NIB.[70] The availability of carbon funding in the short to medium terms seems secure, and the World Bank in particular, has sought to make carbon trading more available and easy to implement at city scales. Cities can now start to play a more immediate role in carbon financing schemes.

Box 1: UNEP projects and programmes – climate change:

- Local-global linkages: This programme responds to the impacts of the high rates of urbanisation on the local and global environments and promotes the role of urbanisation in global environmental issues such as climate change and biodiversity and ecosystems. UNEP is busy with initiatives to develop a "Cities and Climate Change Campaign" and has launched a "Global Alliance on Cities and Biodiversity".

- UNEP and International Council for Local Environmental Initiatives (ICLEI) have also collaborated to establish the Bonn Centre for Local Climate Action and Reporting, dubbed "carbonn", which aims to bring climate monitoring expertise to local governments, especially in cities. In addition, ICLEI's Cities for Climate Protection Programme (CCCP), has signed up over 1,100 local governments.

1.5.2 The rapid growth of the green economy

According to a 2008 Worldwatch report,[71] the worldwide environmental products and services market will double between 2008 and 2020 from US$1,370 billion to US$2,740 billion. Energy efficiency constitutes half the market while "sustainable transport, water supply, sanitation and waste management" takes up the other half.

Table 1: New investment in sustainable energy 2004 - 2010

Year	Investment (US$ billions)	% growth from previous year
2004	52	–
2005	76	48
2006	113	48
2007	151	34
2008	180	19
2009	187	4
2010	243	30

(Source: Bloomberg New Energy Finance, 2011; in GER Renewable Energy, 2011 P217, adapted from Figure 5)

The growth of the green technology sector has captured global attention and large-scale investment has followed. Renewable energies showed double-digit growth leading up to 2008, after which it dipped to 4% between 2008-2009 (a consequence of the financial crisis of 2008), and then rebounded to 30% by the end of 2010 (see Table 1). In 2007, investment in sustainable energies – at US$151 billion– exceeded the global investment in coal-based electric power, at US$110 billion. In 2007, investment growth was expected to continue with an additional total injection of about US$450 billion by 2012,[72] but due to the financial crisis in 2008 that estimate was lowered. In 2010, new investment reached US$243 billion. Should the annual growth in new investment remain at a low 30% it will reach around US$410 billion in 2012. By all indications, the growth in new investment in renewable and clean energies appears robust.

Table 2: Global employment in renewable energies

Renewable energy source	Employment (Global, 2006)
Wind	w300,000
Solar PV	170,000
Solar thermal	>624,000
Biomass	1,174,000
Hydropower	>39,000
Geothermal	25,000
TOTAL	>2,332,000

(Source: WorldWatch, 2008; P7: Adapted from Table 2)

69. See: http://siteresources.worldbank.org/EXTCARBONFINANCE/Resources/UCFT2_operational.pdf
70. See: http://www.eib.org/about/press/2008/2008-027-five-european-public-finance-institutions-start-post-2012-carbon-credit-fund.htm
71. Worldwatch (2008)

72. Boeing (2006)

Table 3: Employment projections for renewable energies in 2030

Renewable energy type	Employment (number in 2030)	% employment in 2030
Biofuels	12,000,000	59
Wind	2,100,000	10
Solar PV	6,300,000	31

(Source: Worldwatch 2008, Adapted from Figure 3 P13)

The need to create jobs is especially critical in the wake of the 2008 financial collapse and is a shared concern in cities across the globe. The breakdown of global employment in the renewable energies sector is shown in Table 2. More than 2.3 million jobs exist in the renewable energies sector – China is the dominant employer. Where waste is concerned, China also plays a lead role in employment creation. More than 10 million people are engaged in recycling-related jobs, of which 700,000 are involved in recycling electronic products[73] (this will become an increasingly important sector as global rare earth metal demand rises). Kenya has established a laudable solar market where more than 200,000 systems have been sold since the mid 1980s and where up to 2,000 solar technicians have been trained. Renewable energies, clean technologies and recycling activities are playing leading roles in employment creation in the emerging global green economy. The projections for global employment in renewable energies in 2030 is shown in Table 3, indicating that biofuels, wind and solar technologies will be the main employers in the sector.

1.6 Implications of global change trends for cities

1.6.1 General implications for cities

The resource constraint factors that were raised in section 1.4 (i.e. materials, energy, oil, water, waste, food and transport) can be exacerbated by climate change effects (such as changes in soil, biodiversity, precipitation and temperature that affect the production of food, delays in production due to natural disasters such as flooding or drought, increased energy demand due to heating and cooling requirements, increased requirements for waste management due to drought, heat and water shortages) and broader global changes such as rapid global urbanisation and changes in the global economy. Cities concentrate demand for resources and services and are vulnerable to global price fluctuations and increases, as has been the case with oil and food prices before the global economic collapse of 2008 and its impacts took effect.

73. Worldwatch (2008)

As illustrated in Table 4, resource constraint factors are closely inter-linked. For example:

- The majority of energy consumption in cities–broadly speaking – occurs in transportation and building energy consumption.
- Oil price fluctuations impact upon both the transportation and food sectors and the price of goods in general.
- Water availability and prices affect agro-economic production and food prices whereas water quantity and quality is linked to water pollution levels.
- Solid waste increases contribute to both land-use requirement increases (i.e. for landfills), ecosystem degradation, pollution of soil, water tables, rivers, lakes and coastal ecosystems.
- Air pollution mainly results from the transportation sector while GHG emission can be linked to energy use in buildings that draw on non-renewable energy sources such as coal-fired power stations.
- The rate of material extraction affects the availability of resources and is constrained by resource availability for extraction activities (e.g. water, energy, oil).
- Ecosystem resilience requires that integrated ecosystem functions are ensured i.e. across terrestrial, riparian, wetland, coastal, marine and estuarine habitats and ecosystems. Ecosystem resilience is a consequence of the health and adaptive capacity of social-ecological systems. Human activities such as transport, waste, agriculture, industrial production have multiple, direct impacts upon ecosystems that can combine to bring about unexpected ecosystem collapse. Ecosystem resilience relates to all resource constraint themes and is affected by them (e.g. water quantity and quality) in return.

When taking into account the global change trends that act as pressures and drivers of uncertainty, alongside city growth trends, global resource constraints and clear indications that urban challenges are most likely to intensify in developing world cities, the complexity of designing urban infrastructure responses to these integrated challenges – and ensuring sustainability – becomes apparent. A significant amount of integration will be required, that is; between sectors, institutions, city government departments, civil society, community organisations and the like. Infrastructure decisions affect a range of sectors and meeting the multiple requirements that these sectors impose requires integrated strategies and implementation programmes. Piecemeal efforts to secure sustainable urban development are likely to remain piecemeal in their contribution if they are not coordinated to bring about systems-wide sustainability within broader strategic frameworks.

It is clear that where cities are concerned, key infrastructures will have to be carefully selected in order to ensure

Table 4: Resource constraint conditions and affected sectors

Affected sectors and areas of concern	Resource constraint themes				
	Energy	Oil	Water	Waste	Materials
Buildings	X		X		
Transport	X	X			
Food		X	X		
Water pollution		X	X	X	
Terrestrial pollution			X	X	
Air pollution	X	X			
General material extraction	X	X	X	X	X
Ecosystem resilience	X	X	X	X	X

sustainability, and will be required to meet a range of requirements. A variety of mutually resilient systems are required to ensure city-wide sustainability:

- ***Energy resilience:*** the building and transport sectors are the most important targets for reduced energy consumption. Building energy consumption mainly consists of electrical energy use.
- ***Water resilience:*** will require increased efficiency standards, water re-use and recycling systems, as well as sound solid and liquid waste management practises.
- ***Ecosystem resilience:*** will require integrated waste management practises that keep pollution within acceptable levels for ecosystem absorption, regulate human activities such as road construction, land-use change, the use of ecosystem services such as water.
- ***Food security:*** requires stable water and oil prices and functioning ecosystems within and outside cities. Locally produced food can help alleviate city vulnerability to global price fluctuations.

Cities are vulnerable to global price fluctuation

- ***Oil resilience:*** the transport sector is the most important sector to consider where cities are concerned as it contributes to the majority of petroleum (and diesel) fuel use.

At the city scale, green economic development strategies have become particularly important to city mayors and managers, because the demands for materials and energy and waste output are of the highest magnitude and heavily concentrated within cities i.e. the challenges of sustainable economic growth are highest in cities. Compact city development, large public transport infrastructure developments, decentralised smart grid energy supply and savings management developments, city-level carbon banks (such as the Gwangju Carbon Bank), waste recycling and waste to energy projects are all playing a key role in city-scale green economic development strategies. Cities across the world have embraced diverse strategies for greening their economic development trajectories which are often designed to suit their particular local contexts. The United Nations Global Compact Cities Programme[74] is a support mechanism for cities that seek to embrace development that negotiates the often conflicting demands of social, economic and ecological sustainability.

1.6.2 Implications for cities in the developing world

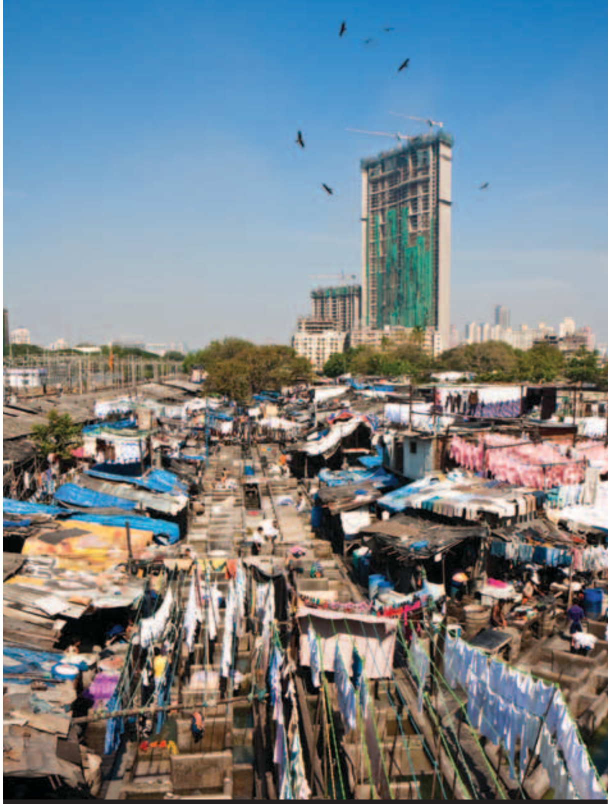
Cities in the developing world face the greatest future pressures emerging from global resource constraint and climate change effects and the rapid growth of urban populations. They are also where the need for transitioning to low-footprint, low-carbon growth in a way that simultaneously addresses pressing social and economic challenges is most urgent. Most existing city infrastructures in developing world contexts aren't adequately equipped to cope with the pressures under which they are now placed, so it is difficult to envisage how these cities will cope with the global and climate change effects.

74. See http://www.citiesprogramme.org/

The general poverty of households and the poverty of women-headed households was highlighted by data reported by the Global Urban Observatory in 2001.[75] In comparison to the averaged household measures, women-headed households in poverty fare worse. Household budgets in the developing world are critically dependent on the price and availability of energy, water and food, which renders households in developing world urban contexts especially vulnerable to how exogenous and endogenous changes may combine to confound the sustainability of household budgets. An investigation of access to services in developing world cities indicates that the scale of the challenges that cities in the developing world typically face is large.[76] High levels of inequality also persist in cities of the developing world according to Gini coefficient data.[77] The balance between sustainability, social equity and socio-economic well-being must be simultaneously realised in the developing world if sustainability interventions are to prove successful. In this respect, there is a need to develop strong participatory governance processes for sustainability and the predominant focus of NGOs on maintaining 'asset security' is inadequate.[78]

Urban ecological environments suffer greatly in cities of the developing world where slums and informality are significant or dominant factors in the urban landscape. In developing countries characterised by slum urbanisation, ecosystems such as wetlands, river and riparian habitats, coastal and estuarine ecosystems, are put under heavy pressure to act as sources (water, fuel wood, subsistence gathering, artisanal fisheries) and sinks for solid waste and bio-waste. Ecosystems are therefore rendered more vulnerable to exploitation and misuse, and the health of life-supporting ecosystems is severely degraded. In this case, ecological vulnerability is driven by the need to survive under difficult conditions of poverty and lack of access to services. As such, social and environmental justice are necessarily inter-linked in the developing world urban context which requires development that meets the demands for both social and environmental justice at the same time. Matching the liveability needs of cities with environmentally sustainable activities will be required.

However it is important to acknowledge that, at a global scale, it is the consumption patterns of the developed world – and a global economic system of consumption-driven growth that reproduces these consumption patterns across the world – that are largely responsible for the destruction of critical life-supporting ecosystems such as rainforests, and for the production of the GHGs that influence the global climate. The developing world has played a negligible role in bringing about the larger-scale, global changes, yet remains more vulnerable to these changes than the developed world. This is especially so in the cities of the developing world where urban vulnerability is magnified by the levels of poverty, unemployment, slums and informality.



High levels of inequality persist in cities

Developing countries, and their cities, are extremely vulnerable to climate change effects. In Africa between 75 and 250 million people will be exposed to increased water stress by 2020 and in some countries that depend on dryland agriculture, agricultural yields may decline[79] by up to 50%. Soil degradation in Africa – estimated at 65% by the International Food Policy Research Institute in Washington[80] – will be exacerbated by spatio-temporal vegetation changes and temperature, humidity and precipitation changes. By 2080 the land area coverage of arid and semi-arid land is projected to increase[81] by between 5-8%. This has severe consequences for food security in Africa which already has significant pre-existing vulnerability to drought and famine. In India, a mean surface temperature increase between 3.5-5 degrees Celsius is projected for the end of the century which may result in an increase of 10-15% in monsoon precipitation in some areas, and, at the same time, a decline in precipitation of between "5-25% in drought prone central India". This will likely impact upon wheat and mustard crops, and consequently, food security.[82]

Megacities such as Pune (50 million population), Delhi (30 million) and Kolkata (20 million) are keenly affected by the urban heat enclave effect with cooling and refrigeration costs expected to increase.[83] "Composite multi-hazards"[84]

75. See Table 19 in UN Habitat (2001)
76. See Table 12 in GUA (2009)
77. See Table 19 in GUA (2009)
78. IIED (2008b)

79. IPCC Fourth Assessment Report (2007): in Swilling (forthcoming)
80. Swilling (forthcoming)
81. Swilling (forthcoming)
82. Revi (2008)
83. Revi (2008)
84. Revi (2008)

Table 5: Cities with disaster management and environmental planning by region

Global regional breakdown	Percentage cities with disaster management and environmental planning (%)					
	Building Controls	Hazard Mapping	Disaster Insurance	Compulsory Insurance	Strategic Planning	Environmental Planning
Africa	69	48	69	24	79	48
Arab states	86	71	36	21	50	43
Asia-pacific	65	65	53	29	88	82
HIC	100	89	78	67	67	67
LAC	65	75	59	17	58	33
Transitional	79	76	71	18	88	79
Developing	71	68	61	21	73	54

(Source: Adapted from Table 22 in UN Habitat, 2001)

may result from the vulnerability to drought, river and inland flooding, cyclonic storms, storm surge and coastal flooding, mean and extreme sea-level rise and environmental health risks. An indication of the broader threat this poses is that 14% of the world's poor, and 21% of urban residents in developing countries, are located along vulnerable coastal zones.[85] Around 150 million urban inhabitants are likely to be placed at risk from severe coastal flooding and sea-level rise and most of these are likely to be poor urban residents in cities of the developing world.[86] For Africa's large coastal cities, adapting to these changes is projected to cost between 5-10% of GDP. [87]

An indication of the state of readiness of developing world regions can be gleaned from Table 5 which shows the poor state of the developing world's disaster response and management capabilities. The state of readiness of developing world cities mirrors these regional inadequacies very strongly. The state of affairs in cities may well be even worse than these statistics indicate due to their concentrated and intensified challenges within cities that are characterised by large and growing slum settlements.

It is therefore problematic to assume that all cities in the world are set upon a linear path to developed world modernity[88] and can be treated as if they were the same. In developing world urban contexts – that are characterised by severe, pressing challenges such as poverty, inequality, unemployment and slum urbanisation – pursuing the developmental trajectories adopted by developed world ('world class') cities may not be appropriate, and indeed, may even prove detrimental. In particular, the often techno-centric and technocratic approaches that are adopted in developed world cities, can be waylaid in the developing world by socio-cultural factors, funding limitations, the high costs of technologies, the lack of available skills and education, corruption and institutional malaise.

Top-down implementation strategies that may work in developed world cities where strong institutional capacity exists to manage and regulate implementation, may not work in developing world contexts where the institutional capacity (and/or funding bases) to implement top-down solutions does not exist. In the developing world, the value of low technology solutions and innovations, rethinking design and planning in relation to informality, building participatory governance capacity, utilising indigenous knowledge and practises, emphasizing education, creating new small to medium scale business opportunities and employment, and working closely with communities are critical factors for developing successful sustainability solutions.

The emergence of the carbon economy, green economy and a new focus on urban ecosystem management practises, provides many opportunities for cities in the developing world to re-think their urban design principles and infrastructure upgrade trajectories. Developing world cities generally suffer a lack of conventional infrastructure amidst high rates of informality and slum urbanisation. They therefore lack the 'lock-in' to conventional infrastructures and urban forms that cities in the developed world are subject to, yet face intense challenges such as poverty, inequality and informality instead. If large-scale infrastructure development pathways are to be undertaken in developing world cities, adopting a sustainability-based approach that mutually addresses the social and economic prerogatives of development alongside ecological priorities will be required. This is also increasingly the case for cities in the developed world as well where the impact of the 2008 global economic climate has increased the urban divide, threatening socio-economic and political stability.

In the next section, we frame the key areas where both developed and developing countries can respond to the need for more sustainable urban growth.

85. McGranahan *et al.* (2007): in GER (2011:19)
86. Nicholls *et al.* (2007): in GER (2011:19)
87. Swilling (forthcoming)
88. Pieterse (2011)

City infrastructures: sustainability challenges and choices

2.1 Rethinking city infrastructure themes

According to Pieterse[89] rethinking city sustainability, and how urbanisation and the environment are linked, requires going beyond the Brundtlandt conception of sustainability. Pieterse[90] stresses that although the Brundtland conception raises the need to consider the mutual social, economic and ecological sustainability of systems, in reality, ecological and economic concerns often over-ride social and political concerns in implementation. In developing world contexts in particular, where slums and informality constitute significant proportions (sometimes the majority) of the city, sustainability transitions require extra sensitivity to the social and political conditions in which they are conceived and implemented. Instead of merely adopting techno-centric and technocratic approaches towards achieving green growth and sustainability, there is a growing need to rethink sustainability in terms of the human dimension. The challenges faced in the developing world have made it increasingly important to create programmes of action that emerge from social justice considerations (e.g. *pro-poor* visions) for achieving sustainability in cities and at city-region scales. This requires a shift away from the predominant emphasis on techno-centric and technocratic schemes that focus purely on asset security towards smart design and planning that is people-centred.

Box 2: Integrating environment into urban governance

UNEP recognizes the growing need to address global environmental concerns from an urban perspective and to integrate the urban dimension of global environmental issues. More specifically, UNEP aims to promote the link between global agenda and local action.

In order to respond to the needs of an increasingly urbanizing world, UNEP supports cities in emphasizing interventions that have both local and global benefits. Areas of focus include, among others, buildings and infrastructure, transport, air pollution, waste and water management, biodiversity and ecosystems. In cooperation with partners, UNEP supports cities across the world in addressing environmental impacts and in integrating the environment into their long-term strategic planning.

The emphasis of UNEP's activities is on supporting developing countries to develop and implement policies, through capacity building, technology and knowledge support. This includes policies supporting low-carbon, resource efficient and green growth as well as policies on mitigation and adaptation to a changing climate.

89. Pieterse (2011)
90. Pieterse (2011)

Public transport systems play a major role in overcoming elements of the 'urban divide'

Where urban ecology is concerned, traditional ecological theory is challenged by the need to incorporate and model human communities as integral components of ecosystems.[91] Hodson and Marvin[92] interrogate the notion of "urban ecological security" which aims to protect ecological resource flows, services and infrastructure in cities by reconfiguring cities and their infrastructures in ways that help ensure their "ecological and material reproduction". Their concern over this new paradigm under which city sustainability strategies are being framed might "selectively privilege particular urban areas and particular social interests over others". As they put it, the authors are concerned that the urban ecological security paradigm might serve as a foundation for "a new strategy of accumulation".

Hodson and Marvin[93] are concerned with the role that "world cities" (or world-class cities) are playing in developing solutions and responses to the challenge of urban ecological security with the intention of exporting these solutions on a global scale. They argue that the urban ecological security paradigm imposes the quest for a "bounded autonomy" of cities, and that this runs contrary to the fact that cities themselves are "never truly bounded or autonomous spaces". The need to realise circular metabolic flows within cities is not in question. But Hodson and Marvin[94] argue that the responses that stem from the urban ecological security paradigm are characterised by "an increasing metropolitanization of ecological resources and infrastructure networks", where cities stake their futures on greater control of resources.

At a more local level, however, cities are concerned with how to make core infrastructural choices today that will help them transition to more sustainable modes of behaviour in the future. Making choices about infrastructures that mediate the provision of services such as waste removal, food, energy and water supply security, transportation and recreation requires careful consideration of the socio-cultural and political factors that are in play, especially in the developing world. In this respect, some key infrastructure themes are introduced in the next section.

Emerging global response trends, such as the carbon economy, green economy and urban ecosystem management programmes give an indication of what options are available to city governments that wish to ensure sustainable, decoupled growth that increases their resilience to adverse global changes. The key question facing decision-makers, in this respect is, *"how to integrate and coordinate sector-oriented strategies and implementation programmes, and what technologies should underlie their core infrastructure choices?"*. UNEP has identified five key thematic areas for informing city infrastructure choices, each of which integrates across a range of sectors and resource constraints that may be affecting them. These include:

91. Collins *et al.* (2000)
92. Hodson and Marvin (2009a)
93. Hodson and Marvin (2009a)
94. Hodson and Marvin (2009a)

Building energy efficiency alleviates pressure

- ***Building energy efficiency:*** Energy efficiency in buildings has large potential to contribute to decreased electricity use, thereby alleviating pressure on the energy sector.

- ***Waste management:*** Solid waste management has the potential to contribute to decreased landfill demand, reductions in green-house gases e.g. methane emissions from waste or waste-to-gas conversion, decreased terrestrial and aquatic pollution levels, and reduced energy use (electricity and oil) in the transport and disposal of waste. Recycling and reuse of waste has the potential to create jobs and to reduce dependence on material imports for production.

- ***Sustainable urban transport:*** Sustainable urban transport systems target reduced dependence on the energy sector (i.e. oil and petroleum), reduced congestion and increased productivity, and reductions in air pollution levels. Public transport systems employ large numbers of people and can help create employment. Lastly, public transport systems play a large role in increasing access and mobility of the urban citizenry and can play a major role in overcoming elements of the 'urban divide'.

- ***Water and wastewater:*** Water availability is critical for industrial and agro-ecological production as well as for sustaining daily household activities. Water quality is also important for sustaining health, agricultural activities and ecosystem services. Large amounts of water are used in the production of energy (approximately 1 litre of water for every 1 kg of coal used). The food sector depends on water availability and precipitation patterns.

- ***Urban ecosystem management:*** Urban ecosystem management consists of the integrated management of environmental impacts of urban activities. The integrated impacts of air, water and terrestrial pollution are systemically tackled in urban ecosystem management practises, which aim to address the critical linkages between ecosystem components. Land-use change, water quantity and quality, air quality, pollution levels, resource exploitation levels and waste management practises all have significant impacts on ecosystem resilience.

Each theme is a cross-cutting response to the need for ensuring energy, water and oil supply, food security and greater ecosystem resilience that was outlined in section 1.6.1 as the systems between which mutual resilience is desirable at city-scale. The rationale for each theme is outlined in more detail in the next section.

2.2 Rationale for selected infrastructure themes

2.2.1 Energy efficiency in the building sector

The energy efficiency of buildings in cities is a major concern as buildings consume one third of global energy (end use) and are hence the largest contributing sector to global GHG emissions.[95] Residential and commercial buildings are responsible for nearly 60% of global electricity supply.[96] Through demand for heating, ventilation and air-conditioning, refrigeration and manufacturing buildings contribute heavily to the energy consumption profile and carbon footprint of cities. They also contribute to the urban heat enclave effect, channel and exacerbate wind speeds in the city, while contributing little to the ability of the city to capture and store water and energy. The construction industry consumes a third of global resource consumption and generates 40% of the total global volume of solid waste. The total energy footprint of buildings is even higher if one considers their construction. The building sector is therefore a critical sector where global GHG reductions is concerned. The IPCC study of 80 cases in 2007[97] in 36 countries suggests that a 29% reduction in projected baseline emissions can be achieved at zero cost in this sector.

Due to rising energy costs and the increased vulnerability of energy security in many cities, building sector energy efficiency programs have emerged in both developing and developed world urban contexts. They typically involve retrofitting programs and smart new design programs. Building retrofits for improved water and energy efficiency are of high importance for cities where established infrastructures already exist in the form of buildings and supporting infrastructures. Breaking this 'lock-in' to high footprint legacy infrastructures requires retrofit technologies and processes. In turn, introducing retrofit technologies has the potential to create new opportunities for small, medium and large enterprises, and to boost employment levels in the city as a result. A wide variety of retrofit technologies is

95. GER Buildings (2011)

96. GER Buildings (2011)
97. IPCC (2007): in GER Buildings (2011)

Residential and commercial buildings are responsible for nearly 60% of global electricity available for buildings, ranging from low energy light bulbs, to solar panels, solar water heater geysers, wind energy, bio-bin composting and bio-gas systems, insulation and cooling products, devices for energy savings management through appliance load shedding and roof-greening.

A comparison between new-build and retrofit opportunities for different global regions was explored by Nelson.[98] Whereas European and North American cities have a higher potential for retrofits, developing and emerging regions such as China, India, South Korea, Russia, Indonesia and Turkey show greater potential for new builds. Schemes for retrofitting existing buildings for energy efficiency are numerous yet it should be emphasised that this may involve high and low-tech solutions. Low-tech solutions are likely to be more suitable in the developing world. In the Philippines, the Isang Litrong Liwanag (A litre of light) project has brought a low-cost solution to the problem of lighting up informal shacks and slum settlements. The Solar Bottle Bulb is simply a recycled 2 litre soda bottle containing water, salt and chlorine that is installed into the rooftop of an informal shack where it can capture solar radiation in the visible spectrum and transmit it as light into the dark, often un-electrified rooms (albeit during the daytime only). It was developed by the Massachusetts Institute of Technology under a program that seeks to make technologies available that are easily replicable, cheap and can address developing world challenges. Likewise, solar cookers, fuel-efficient wood burning cookers and wind-up radios have been developed and implemented in the developing world where the need for cheap, reliable solutions is required. Where new buildings are concerned, the opportunity for employing smart, low-footprint design exists and may go beyond simply implementing high-tech architectural solutions. Bio-mimicry and making use of indigenous and traditional knowledge of heating and cooling of buildings has become more popular in architecture and design circles.

The economics of a global roadmap for building transformation for reduced energy consumption and emissions output is presented in Houser.[99] Developed countries in Europe and North America face the largest expense in this respect as these regions have high existing emission counts. The potential gains through improving building energy efficiency are worth mentioning. Investments in the range of US$300 million to US$1 trillion per annum can, under some scenarios, result in a saving of one-third of building energy use by 2050.[100] This itself would result in a significant level of global GHG emissions reduction. Up to 3.5 million new jobs could be created in Europe and the USA alone through boosted investment in building energy efficiency.[101]

98. Nelson (2008): in GER Buildings (2011)
99. Houser (2009): in GER Buildings (2011:345, Table 3)
100. GER Buildings (2011)
101. GER Buildings (2011)

Photo courtesy of South South North Projects Africa

CASE STUDY

Kuyasa, South Africa

The Kuyasa Project, located in the Khayelitsha informal settlement in Cape Town, South Africa is the world's first gold standard CDM system. South South North – an NGO – stepped in to expedite the ability of poor recipients of government houses to access carbon development mechanisms, working closely with the city of Cape Town and the residents of Kuyasa in a participatory-based approach, eventually registering as a CDM project in 2005. The South African Export Development Fund (SAEDF) helped to develop a business plan, underwrote the project and oversees it in partnership with a resident manager in Kuyasa (Goldman, 2010; Kuyasa CDM, 2011). Skills development and employment creation were realised through strong community involvement and participation in the installation of solar water heater geysers, energy efficient lighting and insulated ceilings in 2,309 homes. Income from the carbon emission reductions through the CDM project allows for the expansion of installations for the ongoing employment of local residents to provide maintenance for solar water heater geysers over the long term (Kretzmann, 2009; Kuyasa CDM, 2011). Households involved in the first phase have enjoyed savings of around R150 per month on energy; respiratory illness has decreased by 76%; 87 jobs were created and 6,580 tons of carbon were saved per annum in total for the first phase. The cost of the project was low, at around R36 million (Ndamane, 2011), or US$4.87 million.

Lastly, the need for housing in the developing world offers up an opportunity to embark upon new build programmes that accommodate building energy efficiency goals from the outset, and to avoid the often higher costs of retrofitting.[102] India, for example, has a housing shortage of around 24.7 million homes.[103] Between 2000 and 2020 the office space in China is projected to double.[104] In the US, the retrofit market for non-residential buildings is expected to increase from US$2.1 to US$3.7 billion in the period from 2010 to 2014. In light of China's keen adoption of energy efficiency technologies and practises, an even larger retrofit market may yet emerge in

102. GER Buildings (2011)
103. Government of India (2007) and Roy *et al.* (2007): in GER Buildings (2011)
104. WBCSD (2009): in GER Buildings (2009)

Box 3: UNEP projects and programmes – sustainable buildings:

The UNEP Sustainable Buildings and Climate Initiative (UNEP-SBCI) is a partnership of major public and private sector stakeholders in the building sector, working to promote sustainable building policies and practices worldwide. The initiative presents a common voice for building sector stakeholders on sustainable buildings and climate change.

The UNEP-SBCI undertakes a range of activities with its partners. These activities are guided by four key goals:

1. Provide a common platform for dialogue and collective action among building sector stakeholders to address sustainability issues of global significance, especially climate change.
2. Develop tools and strategies for achieving greater acceptance and adoption of sustainable building practices throughout the world.
3. Establish baselines which are globally recognized and are based on a life-cycle approach. Focus has initially been concentrated on establishing baselines for energy efficiency and Greenhouse Gas (GHG) emissions but is now expanding to account for additional indicators such as materials and water.
4. Demonstrate through pilot projects and inform policy developments of the important role buildings have to play in mitigation and adaptation to climate change at local, national and/or global levels.

Specific activities include the development of a Common Carbon Metric (CCM) which will establish baselines, enable measurable, reportable and verifiable (MRV) reporting; and, help unlock the potential for significant reduction in GHG emissions in the building sector; creation of the Sustainable Building Reporting Protocol to establish globally recognized baselines based on a life-cycle approach and frame a common language for the performance assessment of energy efficient and low carbon buildings; and, implementation of pilot projects such as the Sustainable Social Housing Initiative (SUSHI) and Sustainable Building Policies for Developing contributes to UNFCCC negotiations and national policy development through support to policy-makers and research. It is producing a series of country and region-specific reports to establish baselines based on a life-cycle approach.

Chinese cities, boosting global growth in this sector. The costs at which savings can be obtained range from a 10% saving at a cost of US$1 per square foot, while a 40% saving can be achieved at a cost of US$10-US$30 per square foot.[105]

2.2.2 Waste management

The global waste market (not including the informal sector in developing countries) has an approximate value of US$410 million per annum.[106] Five per cent of global GHG emissions result from the 11.2 billion tonnes of solid waste that is collected globally. Waste management challenges in cities (i.e. solid waste, electronic waste, biomass waste, hazardous waste, medical, packaging waste and marine litter) are amplified by the high rates of urbanisation. The costs of maintaining landfill operations are increasing as available landfill capacity is being stretched (and have to be developed further away from cities) and increasing transportation and management costs combine to take their toll on city governments. City governments are increasingly recognising and attempting to deal with the polluting effects of landfills upon surrounding areas and the water table where landfill sites are improperly managed. This is especially the case in the developing world where the governance capacity for landfill management (i.e. leachate, bacteria and disease) is inadequate, or may not exist due to shortages of skills, funds and technologies.

Recycling programmes for glass, plastic, biomass and hazardous waste have been adopted by many cities in response to the challenge of dealing with waste material. According to the 2011 GER Waste report, the global waste to energy market was valued at US$19.9 billion in 2008, and 30% growth was projected in the sector by 2014. The global market for recycled plastics and glass is also favourable and previously informal recyclers such as the Zabbaleen in Cairo (a Coptic Christian minority) – who have implemented sophisticated recycling systems[107] – have managed to access this global market. Accessing local and global markets for recycling can transform the waste sectors of many cities and generate new employment opportunities that would otherwise remain untapped. In respect of creating new employment, the role of informal recyclers who generally work under unsafe and unhygienic conditions (with devastating health consequences for recyclers[108]), are often overlooked in green waste strategies,[109] and expensive, techno-centric schemes

105. Pike Research (2009): in GER Buildings (2011)
106. GER Waste (2011)
107. GER Cities (2011)
108. GER Waste (2011)
109. Medina (2000): in GER cities (2011)

CASE STUDY

Mariannhill, South Africa

The Mariannhill landfill site is located 20km outside the city of Durban/Ethekwini on the east coast of South Africa. It receives approximately 450 tons of waste per day from the city which was once the fastest growing city in the world. It continues to grow at a significant rate (as the province continues to urbanise and will reach 62% urbanisation by 2020) although significantly decreased by smaller family sizes and the impact of HIV. The Mariannhill landfill site is a CDM project that enjoyed community involvement through a monitoring committee that the community set up when the landfill was being planned. The landfill site captures methane gas for electricity generation (SAGoodNews, 2007), generating between 450,000 and 650,000 kWh of electricity per month (Wright, 2011) and R200,000 (or US$27,086) per month in income. The cost of the gas to electricity project is around R130 million, with R10 million in operational costs per annum (Wright, 2011). It captures, treats and re-uses leachate as polished leachate to settle landfill dust (Strachan, 2007). It also captures toxic substances through constructed wetlands (Moodley, 2007) and has a program for preservation of indigenous vegetation (i.e. a plant rescue unit that is located onsite), as well as alien clearance management. The site was registered as a national conservancy in 2002.

are adopted instead.[110] Rethinking waste management from a social perspective requires grappling with this challenge.

Waste management programmes can be implemented at different urban scales, ranging from the whole city-scale down to neighbourhood level. Often, recycling activities are undertaken by members of the poorer urban underclass and waste recycling jobs are low-paying, unhygienic and hazardous. In some cases, such as that of Zabbaleen in Cairo, recyclers have an historical and traditional role as waste removers and recyclers that go back through centuries of history. Dealing with the different scales of recycling activities and the social conditions that prevail amongst recyclers is key to successful city-scale waste management. In developing world urban contexts, characterised by slums and informality, waste collection through conventional waste management systems can prove challenging, yet diverse responses are emerging. The Green Swap programme in Curitiba (see later in section 3.2.1), where food is exchanged for waste, provides an alternative model for the socialisation of waste management that is both humane and can stimulate behavioural change for the same cost as landfill programmes, except that the destructive effects of landfills are negated. Variations on the approaches taken in all our case studies can be found or developed in different regional and local urban contexts. What is clear, is that successful programs rely on high levels of public and community participation and engages across the governance, business and civil society sectors in both the planning and implementation phases of waste interventions.

Where CDM is concerned, it is clear that most local authorities require the support and assistance of civil society and/or other agencies that can help expedite and manage the processes that are required to access carbon finance from the World Bank, the United Nations and other institutions. The 2011 GER Cities report states that many European cities recycle close to 50% of their waste. The city of San Francisco diverts 72% of its waste away from landfill and is aiming to be a zero-waste city by 2020.[111] The city of London drafted a waste management plan in 2011 that sets a 45% target for recycling and composting municipal waste by 2015.[112] At the high end of the scale, in Copenhagen, only 3% of waste from Copenhagen ends up in landfills[113] where waste is incinerated for energy production. Zero-waste programmes, such as that undertaken by San Francisco, do not employ incineration as an acceptable method. By undertaking this low-emission strategy, about 20% of San Francisco's waste currently goes to landfill and the city aims to be a zero-waste city by 2020. One of the key challenges in recycling in developing world contexts is migrating largely informal recycling activities into a more formalised system that provides safe and decent working conditions for recyclers and adequate remuneration for their efforts at various levels in the

One of the key challenges in recycling in developing world contexts is migrating largely informal recycling activities into a more formalised system that provides safe and decent working conditions for recyclers and adequate remuneration for their efforts at various levels

110. Wilson *et al.* (2006): in GER Cities (2011)

111. See http://www.spur.org/publications/library/article/toward_zero_waste
112. GER Waste (2011)
113. C40 Cities (2010)

value chain. Most importantly, however, Integrated Solid Waste Management (ISWM) practises are critical to the success of waste management programmes as they enable the integration programmes and projects for waste management into broader themes and sectors such as health, ecosystem resilience, habitat protection, carbon efficiency and water quality.

Box 4: UNEP projects and programmes – waste management:

In 2005, UNEP International Environmental Technology Centre (IETC) developed a full-fledged portfolio on waste management which initially comprised two focal areas: resource augmentation by utilizing waste and Integrated Solid Waste Management.

After the successful implementation of an initial set of activities, there was strong demand to address specific waste streams such as Waste Electrical and Electronic Equipment (WEEE/e-waste), waste agricultural biomass, health care waste, waste oils, waste plastics and disaster debris. Numerous projects have been carried out in Asia, Africa, and Latin America.

In 2010, UNEP IETC launched the Global Partnership on Waste Management (GPWM) to enhance international cooperation among stakeholders, identify and fill information gaps, share information and strengthen awareness, political will and capacity to promote resource conservation and resource efficiency. With the GPWM, UNEP provides a coordinating forum for international organizations, partnerships, governments, private sector and other non-governmental entities, to build synergies, to assist in avoiding duplication of efforts and to increase cooperation among stakeholders (see http://www.unep.org/gpwm).

2.2.3 Sustainable urban transport

"Of the various channels through which investment can flow into green transport, investment in infrastructure offers the greatest potential for economic growth, by encouraging government investment and stimulating new business opportunities. Investment in green transport technology is also likely to benefit the overall economy, particularly through its potential to stimulate government investment." GER Transport, see Table 3, P387).

The need for sustainable urban transport that improves access and mobility while decreasing congestion and increasing productivity is self evident in many cities (see section 1.3). The sheer numbers of employment seekers that are converging upon cities and the increase in the number of privately owned vehicles place concentrated pressures upon city infrastructures. These problems manifest in both developed and developing world cities. A variety of responses has emerged. In some cases, private vehicle owners are penalised and public transport use is incentivised. The degree to which penalties and incentives are used varies from city to city. In other cases, promoting the switch to cleaner cars (e.g. electric or hybrid cars) or cleaner fuel use (e.g. bioethanol, biodiesel, hydrogen) forms the core of city strategies for making urban transport more sustainable. Pedestrianisation has also been undertaken at large scales in some cities.

The economic impacts per million US dollars spending in transport is shown in Chmelynski.[114] Where the need for green transport is concerned, the study illustrates the potential for green economic development through investment in infrastructure and stimulating government investment.[115] What is clear is that public transport programmes have the

114. Chmelynski (2008): in GER Transport (2011:388)
115. GER Transport (2011:387)

CASE STUDY

Kampala, Uganda

Despite 40% of Kampala's annual budget being allocated to waste management, waste collection and disposal in landfill conducted by the city lies at a maximum of 45% of all waste (Kanyonyore, 1998; KCC, 2000; Mugabi, 1998). The solid waste management model adopted by the city is oriented towards conventional, formalised city infrastructures, leaving informal settlements un-serviced and neglected. A partnership between the Kampala city council and the Kasubi-Kawala community, civil society organisations and Makerere University was created under the "Sustainable Neighbourhood in Focus" program, to target the 11-25 tons of waste that was produced per day in the neighbourhood. 75% of waste in Kampala is organic and originates from vegetable and fruit peels such as sweet potatoes, potatoes, cassava and bananas, with significant consequences for pollution and landfill leachate production (UN Habitat and ECA, 2008). Some households were already making use of organic waste to produce energy briquettes, compost and animal feed so the university conducted a risk and feasibility assessment of expanding the practises. It found that significant GHG reductions (e.g. methane) could be achieved and that peel re-use could reduce the volume of neighbourhood waste by 40% (Buyana and Lwasa, 2011), while recycling valuable nutrients through the human and agro-production urban systems.

potential to address a wide range of needs in the city that go beyond sustainability and deal with the greater issues of liveability.

The potential for reducing GHGs in the transport sector is staggering, and the 2011 GER report on transport states that "(s)everal scenarios show that a green, low carbon, transport sector can reduce greenhouse gas emissions by 70 per cent without major additional investment". The challenges involve shifting investment towards projects that respond to the principle of "avoiding or reducing trips through integrated land-use and transport planning and enabling more localised production and consumption."[116] It also involves shifts towards more environmentally efficient modes of transport (e.g. public transport, non-motorised transport options) and to more environmentally efficient vehicles and fuels.[117] It is critical to appreciate the long-term impact of investments in sustainable urban transport systems in terms of infrastructure lock-in (due to transport mode choices, road infrastructure development and land-use change plans for cities).

In short, urban transportation generally contributes highly to the carbon footprint of cities, their fuel consumption, air pollution, congestion and noise pollution. It also contributes significantly to health disorders and fatalities. The transportation sector is therefore a popular choice for sustainability interventions, both in developed and developing countries alike. Yet transportation has other dimensions that require equal consideration alongside environmental

116. GER Transport (2011)
117. GER Transport (2011)

Reduction in greenhouse gas emissions involves shifts towards more environmentally efficient modes of transport

Bogota, Colombia

Bogota's BRT system is estimated to have reduced per passenger emissions by 14% (Rogat et al.,2009; in GER Cities, 2011). Yet there is more to creating parallel mobility systems. In Bogota, Colombia a public bicycle scheme was introduced and large scale 'pedestrianisation' measures were taken to improve non-motorised and foot traffic as part of the transport-oriented measures undertaken by the then Mayor Enrique Penalosa as part of his programme to improve the liveability, accessibility and mobility of Bogota and help the poor and marginalised overcome the restrictions of the drastic urban divide within the city. As already outlined earlier in section 1.3, core to his approach was asking the question, "are we building cities for cars, or for people?" and responding to the specific needs of Bogota. To get pedestrians and cyclists out onto the streets at night, a 'take back the city at night' initiative was undertaken to engage citizens in the spirit of performing acts of reclaiming the spaces within the city. Bogota, Mexico City and Rio de Janeiro have car free days or weekend street closures (Parra et al., 2007; in GER Cities, 2011).

considerations; primarily that transportation systems largely determine the level to which access, mobility and liveability is realised at the city scale. Public transport systems play a large role in shaping the daily experience of the urban citizenry. Two case studies of public transport systems are discussed in this section. Bogota's approach to transport systems and public access and mobility is outlined in the first case study. The importance of switching to cleaner fuels and vehicles is highlighted in the second case study on Linkoping.

Public transportation overhauls such as those undertaken in Curitiba and Bogota, or even the cable car systems implemented in Medellin and Rio, can be implemented to meet a variety of urban needs and to promote access and mobility of the poor and marginalised urban citizens. Public transport systems are also large employers in cities around the world,[118] and investment in public transport can generate "exceptional economic returns."[119] The 2011 GER report on transport states that "a green, low carbon, transport sector can reduce greenhouse gas emissions by 70% without major additional investment", and that if 0.16% of global GDP were invested in boosting public transport infrastructure the volume of road vehicles could be reduced by a third by 2050. Strong political backing, leadership and diverse consultation and participation are generally hallmarks of successful public transport interventions.

118. GER Transport (2011)
119. GER Transport (2011)

CASE STUDY

Linkoping, Sweden

The city of Linkoping, Sweden, operates a public transportation system that constitutes a circular, closed loop energy and nutrient cycling system. The bus system is run on biogas obtained from wastewater treatment plants, landfill and a biogas production facility that utilises agricultural crop residues and manure and the entire public bus fleet runs on bio-methane by 2002 (IEA, 2005). Fertiliser is also produced as a by-product allowing for valuable nutrients such as phosphates to be recycled through the city metabolism. Landfill loads are also alleviated through the system. The project received sufficient funding, strong political backing and cooperation between the city, Linkoping University, transit authorities and farmers' associations. The profitability of biogas production, however, has been in question and obstacles exist to biogas development at broader, regional scales. Yet the very fact that such a project has been undertaken means that the learning and know-how has been created and the potential for leveraging this knowledge base for improving, adapting and innovating is high. In a future characterised by rising oil prices and the introduction of the carbon economy, systems that convert waste to valuable uses in closed loop systems may yet prove to have a significant advantage over conventional infrastructures.

Box 5: UNEP projects and programmes – transport:

The UNEP Transport Unit supports governments in the development of cleaner and more efficient transport policies and technologies with a focus on urban transport systems in developing countries. Based on the demand for policy advice from governments, UNEP's transport programme focuses on a comprehensive approach to achieving sustainable transport development based on three principal areas of intervention:

(1) AVOID – reduce demand for transport and emissions from transport through better transport/urban planning;

(2) SHIFT – mode shifting to low carbon and mass transit-oriented development by promoting efficient public transport and walking facilities, and

(3) IMPROVE – promoting cleaner and more efficient fuels and vehicles.

UNEP has translated these principal areas in four specific programs (also see www.unep.org/transport):

- *The Partnership for Clean Fuel and Vehicles, PCFV:* assists developing and transitional countries to reduce vehicular air pollution through the promotion of lead-free, low sulphur fuels and cleaner vehicle standards and technologies.
- *The Global Fuel Economy Initiative, GFEI:* aims to facilitate large reductions of greenhouse gas emissions and oil use through improvements in automotive fuel economy in the face of rapidly growing car use worldwide.
- *Share the Road (StR) Initiative:* a campaign to encourage investments in road financing that is dedicated to non-motorized transport infrastructure (pedestrian and bicycle lanes) for safety, environment and accessibility.
- *The promotion of Public Transport infrastructure:* support a shift from high carbon to low-carbon sustainable transport modes in particular mass transit systems through policy, technical, financial and networking support services.

2.2.4 Water and wastewater

Population increase, rising living standards, over-exploitation, pollution, ecosystem degradation and adverse climate change effects all contribute to global water scarcity problems.[120] Ensuring water supply and wastewater treatment in cities has also become a major challenge for cities that are experiencing high population growth levels. Cities are increasingly seeking out water from sources that are located ever further from cities in order to meet demand. Wastewater processing facilities are also under increased pressure in a number of cities and the high cost of moving water-borne waste out to wastewater facilities located far away from the districts where the waste is produced, has become a major consideration for planners who are seeking new ways to address the challenge of wastewater abstraction. In some cities, extensive use of greywater systems has been implemented while other cities have explored making use of bio-filtration processes to manage waste at lower cost.

Ultimately however, there is a limit to the benefits that re-use and recycling can bring to city water metabolism and it is necessary for cities to be actively engaged in catchment scale management in order to improve their access to water in the long term. The rehabilitation of the Catskills catchment – which provides the water supply for the city of New York – is one example where paying attention to catchment activities resulted in significant benefits at the city scale. This has implications for urban ecosystem management.

Water scarcity challenges are not new to cities but the increasing urban population pressures place huge demands on existing potable water provision and wastewater abstraction processing plants. Cities in both the developed and developing world are extending their reach into ever more remote locations to access water to meet the needs of their increased populations and production activities. Simpler and cheaper technologies which aid adaptation may find greater uptake in developing countries; for example; rainwater capture, solar water heater geysers, and bio-bin composting and gas capture technologies. These can play a large role in shedding the load of conventional infrastructure systems.

Waste water treatment has also become a major challenge for cities that are experiencing high population growth levels

In response to water scarcity challenges in Delhi, the Municipal Corporation introduced the requirement for all buildings

120. GER Water (2011)

CASE STUDY

Orangi, Pakistan

In the 1980s in the Orangi informal settlement in Karachi, a sewage absorption crisis was met with a collaborative implementation solution that involved a collaboration where residents built and installed household and street level infrastructure while the government installed the secondary infrastructures. Over 90% of the settlement was then able to enjoy the service provision. Infant mortality rates dropped more than 70% in the first ten years (IPRM 2011). This example highlights the importance of participatory processes in addressing urban water challenges, especially where equipping slums and informal settlements is concerned.

Note, however, that the socio-cultural and political context that existed in the case of the Orangi settlement may not exist in the same form in other contexts. In South Africa, for example, where political redress for the inequalities of Apartheid segregation and disenfranchisement dominates the political spectrum, residents may be reluctant to pick up a portion of the costs of sewerage installation. These sensitivities must be well understood and strong collaborative mechanisms and partnerships need to be in place in order for community level cooperation to flourish in such projects.

(i.e. above 100 square metres and a plot area more than 1,000 square metres) to capture rainwater, with an estimated 76.6 billion litres of water made available for groundwater recharge. These types of schemes are important. In Chennai, groundwater recharge raised water table levels by four metres between 1988 and 2002.[121]

Greywater is non-toilet contaminated water from bathtubs, showers, washing machines, bathtub basins that is, according to municipal guidelines. Greywater permits can be issued to help regulate greywater use. On average, water use at household level is due to toilet flushes, laundry and showers and baths. Industrial greywater use in Austin, Texas, USA, for example, is facilitated through the installation of reclaimed water pumping systems that run parallel to the existing potable water distribution system. They are indicated by blue pipes that run throughout the city and are connected to industrial and commercial irrigated agriculture activities. The system recycles more than 150 million litres per day. Legal and regulatory issues concerned with greywater capture and re-use, for example – in groundwater recharge – can have a significant impact on costs.

Retrofit technologies may involve addressing critical resource constraints such as water supply of cities. Building desalination plants is also an option that some cities must necessarily consider where other alternatives do not exist, despite the high costs associated with desalination due to high energy supply requirements. This has, for example, been undertaken in the city of Adelaide in Australia, under the National Urban Water and Desalination Plan. Recycling of water, and water-borne waste to fertiliser, for example, has already been successfully implemented as retrofits (perhaps not strictly) in a number of cities. There are dangers to exclusively techno-centric schemes however. In South Africa, the city of Johannesburg experienced widespread crises after installing pre-paid water technologies[122] in a bid to cultivate and ensure payment.

Many cities in the developing world exceed or nearly exceed the capacity of their waste-water processing plants, and new, low-cost methods that work with natural, organic systems to break down sewage waste have been implemented with success in India.

In conclusion, water has social, cultural and economic dimensions that rise to significance differently in different contexts. Conflicting preferences for low- versus high-tech solutions to water problems are often based on perceptions of progress and modernity. Failing to recognise these factors, and work with them, generally lies at the core of failed water management schemes. Lastly, in considering the locations from which water is sought out from cities it is clear that cities may need to engage more closely in catchment management activities in order to ensure that upstream and downstream impacts of cities themselves are highlighted within the broader scales that water systems operate at. In this way, cities can move beyond creating bounded solutions to their water challenges and improve their long-term water resilience through both regional and local actions.

2.2.5 Urban ecosystem management

Lastly, urban ecosystem management concerns have gained the attention of city managers for a host of reasons. Many cities that depend on their natural assets for attracting tourism or property investment, for example, have taken up conservation and restoration projects that increase land value and stimulate employment creation. Urban gardens and food markets have also been implemented in clever and unique ways to increase the resilience of cities to external price changes in food that is imported into cities.

Spaces for recreation and business activities can also be stimulated through creative and innovative urban ecosystem management initiatives. The key issues that dominate the debates on urban ecosystem management revolve around the following key issues. The lack of recognition of urban ecosystems as unique ecosystem habitat niches by ecologists and conservation biologists – which has led to a dearth of

Ecosystems management increases resilience

121. Sakthivadivel (2007): in GER Cities (2011)
122. Bond and Dugard (2008)

information and data on urban ecosystems. Thinking of urban ecosystem management strictly in terms of conservation biology is itself a limiting perspective and hampers the development of strategies for urban ecosystem management that address the broader socio-economic and cultural context in which urban ecosystems are located. Lastly, the emphasis on urban ecological security[123] has the potential to remove city ecosystem management from considering how ecosystems that are affected far away from these cities are affected by activities within these cities.

Rehabilitating, extending, maintaining and conserving parks and open spaces with green and blue (water) ecologies plays a critical role in ensuring that city resilience to urban heat enclave effects, storms and flooding, waste absorption, carbon sequestration and storage and habitat loss. According to McPherson *et al.*,[124] increasing tree cover by 10% leads to a reduction in heating and cooling requirements by between 5-10%. In cities located in coastal zones, estuaries, mangrove forests and coral reefs provide high levels of protection from storm surges, tsunamis, hurricanes and extreme wave events. River, wetland, estuarine and coastal ecosystem management in cities requires dedicated monitoring, evaluation, assessment and intervention programmes that are managed by the city, sometimes in partnership with other agencies.

Urban ecologies are unique and offer up distinct opportunities for urban ecosystem management practises and innovations. Developing solutions to ecosystem management in developing world urban contexts requires taking into account the unique circumstances that urban citizens face in the developing world, such as high unemployment, energy poverty, food insecurity, slums and informality. It is unlikely that programmes that target environmental resilience to the exclusion of the social circumstances in which ecosystems are located will prove successful. Indeed, this is the consistent message that has generally been revealed by the case studies that have been presented in this study.

Food: Up to 30% of the ecological footprint of European cities can be attributed to food.[125] Food and agro-production systems fall under the 'urban ecosystem management' theme as it relates to anthropogenic nutrient flow management within the city system that can close the nutrient loops, increase resilience to global and climate change effects on food and lower city-level carbon footprints. Between 15-20% of global food production is produced in urban areas.[126] Food infrastructure retrofit and development can involve the establishment of local market gardens and food markets, and constructing and servicing the supporting infrastructural

123. Marvin and Hodson (2009a)
124. McPherson *et al.* (1994)
125. Steel (2008): in GER Cities (2011)
126. GER Cities (2011)

CASE STUDY

Seoul, South Korea

In the city of Seoul, Korea, the Chonggyecheon River restoration project focused on reclaiming the river from an elevated arterial road that had been built over it in 1961 (Park, 2004) and which was diagnosed with serious structural problems in 2000 that would prove costly to remedy – to the tune of US$95 million (GRN, 2007). The highway was demolished and a 5.84km park on either side was established, re-establishing 1,000 acres of green space (CRP, 2009; GRN, 2007). The project cost US$367 million, social costs were valued at $1,900 million, and an estimated US$3,500 million in social benefits stood to be gained (Lee, 2005; CRP, 2009). Benefits include reduced air pollution levels, up to 5% decrease in high city temperatures, a 50% decrease in average wind speeds, re-habitation with increases in fish species (4 to 25), bird species (6 to 36) (Revkin, 2009) and flood resilience. The major criticisms of the project have revolved around rising property costs (which have doubled, CABE, 2011) that threaten local residents with displacement, retrofitted access for the disabled who were not consulted during the planning phases of the project, and that a nearby river and groundwater reserves are being used to ensure perennial river flow instead of ensuring that the river catchment is adequately restored to ensure water supply.

requirements associated with food production, storage and delivery. Encouraging the growth and purchase of low-carbon locally grown produce is a critical part of many city strategies to lower their ecological and carbon footprints and build local resilience to external price shocks that may affect prices adversely at the global or regional levels. In Milan, Italy, 40% of daily consumption of produce comes from within a four hour travel radius of the city[127] as it is closely located to agricultural regions. In Nakuru in Kenya, up to 35% of households were engaged in urban agriculture in 1998, while in Kampala in Uganda it was closer to 50% in 2003[128] and 90% of Accra's supply of vegetables was grown within the bounds of the city.[129] By rethinking how city food systems work, a broad range of social, economic and ecological benefits can be realised.

127. GER Cities (2011)
128. Foeken (2006) and David *et al.* (2010): in GER Cities (2011)
129. Annorbah-Sarpei (1998)

How cities can transition to sustainable, resource efficient growth

3.1 Distinguishing between different city-level sustainability responses

There are many different ways to classify and discriminate between case studies in sustainability at city level. This suggests the need for a broader conceptual framework for dealing with case studies in order to better understand the range of options that are available to decision-makers, Swilling *et al*[130] identify four different types of emerging responses to the need for higher levels of sustainability (see Figure 1). These can be described under two general systems typologies; networked and systematic (see Table 6).

Table 6: Systematic vs network-based city infrastructure strategies

	INTEGRATED AND SYSTEMATIC	NETWORK BASED
NEW	New urban developments as integrated ecosystems	Constructing new urban networked technologies
RETROFIT – OLD	Reconfiguring cities as systematic urban transitions	Retrofitting existing urban networked infrastructures

(Source: Adapted from IPRM 2010)

In a broad sense, networked base infrastructure technologies are less bounded and more pervasive, even if narrowly implemented within a sector or between sectors, whereas systematic, integrated responses tend to focus on building internal reliance and sufficiency, and are more systemically bounded than networked solutions. Two additional dimensions can be discerned from this taxonomy; a first that addresses *new* developments, and a second that addresses existing *legacy* infrastructures through reconfiguring and retrofitting them. These are outlined below:

New urban developments as integrated ecosystems: These systematic, integrated initiatives refer to entirely new, bounded developments whether at the city-scale (e.g. eco-cities) or sub-city region scales (e.g. eco-towns, eco-blocks, eco-corridors, eco-regions). These types of developments typically aim to reduce the reliance of new developments on existing, conventional infrastructures in order to build internal reliance, adaptive capacity[131] and sufficiency through, for example; producing their own food and energy, and recycling waste, water and other re-usable materials such as construction materials. Integrated, cross-cutting responses are developed to cope with multiple infrastructures that carry, for example; waste, water, energy, goods and food. These responses are then "rebundled"[132] at the required scale. There are a wide variety of 'greenfield' developments that explore the development of bold, new visions for sustainable urban design and management. Eco-islands, such as Treasure Island situated in the San Francisco Bay, eco-villages such as Gaviotas that is located in a desert region in Colombia were founded in the 1930s and 1960s, respectively. New post-carbon and low-carbon eco-cities such as Masdar, that operate at the whole city scale (see section 3.2.2), also fall under this classification. In themselves, these developments are critical incubators of learning trajectories that are undertaken by early adopters who can provide thought and technology leadership in the future.

Reconfiguring cities as systemic urban transitions: These responses seek to develop agendas, often thematic or iconic, around which socio-technical systems can reorganise their existing infrastructures and legacy systems of governance, regulation and management, for example. These are usually developed through multi-stakeholder engagements and participatory processes and may involve a range of key actors and sector representatives from within and without the city. Often the responses at programmatic and project level are thematic and/or iconic in nature, such as the drives towards low-carbon and zero-carbon cities, and liveable or humane cities. This involves 'systemically' driven programmes of action that are oriented at the whole city-scale that can cut across sectors and institutions. They generally aim to realise resilient, self-sufficient cities through decentralised infrastructures and building local resilience and

130. IPRM (2010)
131. Folke *et al.* (2002)

132. UN-Habitat (2011a)

Constructing new urban networked technologies creates relationships among systems in order to render socio-metabolic system flows more efficient with less overall impact

Curitiba, Brazil

Curitiba Integrated Sustainability Strategy: Curitiba has one of the highest per capita income levels in Brazil and its poverty level ranks 8% below the national average. Due to the high use of the public transport system (75% of weekday commuters) it has 25% less congestion and 30% less fuel consumption than other Brazilian cities of similar size. Curitiba's transition towards sustainability and liveability started in the 1960s with the leadership of Jaime Lerner, who was both an architect and urban planner, who became the head of the Institute of Urban Research, and later Mayor of Curitiba in 1971. Today, 1.6 million people reside in the city while 2.7 million people live in the metropolitan area. Curitiba's approach is holistic, involving recycling, coordinated land use and open space management and places emphasis on schools and city services provision, low income neighbourhood upliftment and public transport systems. Curitiba's success is due to a holistic set of measures that target sustainability and liveability by addressing five different spheres; including recycling, a food for recyclables swap programme, the provision of 'citizenship streets' that offer public utilities, 'lighthouses of knowledge' that provide library and internet services as well as feeding schemes and security, open space management and a 15% greenfield Curitiba Industrial City.

adaptive capacity. Cities such as Tianjin (see section 3.2.2), Bogota in Colombia and Curitiba in Brazil (see section 3.2.1) fall under this classification.

Constructing new urban networked technologies: These focus on new urban networked responses to sustainability goals, on developing alternatives to conventional networked infrastructures, and on restructuring resource interdependence. Constructing new urban networked technologies creates relationships among systems in order to render socio-metabolic system flows more efficient with less overall impact footprint. These include for example; alternative fuel and energy systems, water systems, transport systems and construction materials. Parallel network systems are put in place alongside legacy systems with the aim of at first providing supplementary adaptive capacity to absorb growth in the short term, but in some cases eventually replacing conventional infrastructure networks in the long term. Where parallel mobility systems are concerned, new public transport can be 'grafted' onto existing infrastructure to meet congestion and emission-reduction goals. Public transport system introductions in cities has mainly focused on establishing bus rapid transit (BRT), light rail, subway and high speed train systems. BRT systems are particularly popular and have been introduced in many developing world cities such as Bogota, Curitiba (see sections 2.2.3 and 3.2.1), and Johannesburg. Also, city-wide energy transition strategies such as those outlined later in section 3.2.3 also fall under this classification.

Retrofitting cities as systemic urban networked infrastructures: Infrastructure retrofitting tends to focus on specific infrastructure networks, with the goal of building resilience and adaptability to pressures that city infrastructures may be experiencing (or are projected to experience in the future). These may include floods, drought, fuel and electrical energy supply, and ensuring food, water and energy security and waste production.. In response, non-motorised transport or renewable energy powered transport, market gardens, recycling (see section 2.2.2), local food markets (see section 2.2.5) and unique service provision in slums and informal settlements of the developing world have emerged. Commercial retrofit technologies for greywater re-use and rainwater capture for households and buildings are also available (see section 2.2.4). Where de-motorized transport is concerned, solutions do not always have to be large scale. For example, redesigning rickshaws with a 30% lighter frame has been undertaken by the Indian Institute for Transport and Development Policy, along with a solar-powered rickshaw development project.

3.2 Integrated approaches for city-scale sustainability

The typology that was explained in the previous section (3.1) is useful for making clear distinctions between systematic and networked-based approaches to city infrastructure and technology change. Yet in reality, these distinctions are often blurred when formulating city-level strategies for sustainability. Integrated, systematic approaches to city sustainability, require the integration of new and retrofit network-based technologies and infrastructures. In the next two sections, real-world examples of integrated approaches to city sustainability are discussed.

3.2.1 Liveable and sustainable cities

In most developing world urban contexts, addressing both liveability and sustainability challenges mutually through development programmes is desirable, as coping with high levels of poverty, inequality, lack of access to basic services, shelter, health and education are high priority socio-economic challenges that threaten the current and future fabric of society. Yet very few manage to innovate and implement creative responses that enable them to integrate both social and environmental sustainability concerns effectively. The city of Curitiba in Brazil has become a role model, in many respects, for those seeking to achieve sustainability outcomes that manage to address pressing social problems at the same time.

The Curitiba example illustrates the importance of taking a holistic view on transitions to sustainability and building the capacity for ensuring the continuance of the transition into the long term. Reconfiguring cities as systemic urban transitions requires initiating change from a system-wide

It matters little whether the central theme adopted by a city may be concerned with transport, water, energy or food alone (or in combination), as long as the central theme is located within a broader systems view that adequately addresses the multidimensional nature of the urban challenge

perspective. In this sense, it matters little whether the central theme adopted by a city may be concerned with transport, water, energy or food alone (or in combination), as long as the central theme is located within a broader systems view that adequately addresses the multidimensional nature of the urban challenge, and the core underlying social, cultural, economic and ecological systems needs of the city.

In the developing world context, city-led initiatives geared towards realising liveable, humane and sustainable cities have proved popular. In Latin America, for example, where cities such as Bogota and Curitiba have been strongly influenced by the need and desire to realise these multiple requirements while envisioning their sustainability transitions. It must be mentioned that a strong emphasis on transportation systems was taken in both cities, so in some ways they can also be classified as led by a transportation theme. In both cases, strong leadership at the mayoral level was responsible for driving the changes and institutions that were set up to facilitate the transition through research and policy-decision support continue the drive towards sustainability in the long term.

3.2.2 Low-carbon and post-carbon eco-cities

Post-carbon cities are cities that seek to enable a full transition to zero-carbon living, and perhaps even positive-carbon living. Low-carbon cities seek to achieve less ambitious reduction targets. Cities such as these might, for example, involve adopting carbon trade mechanisms such as developing carbon exchanges and carbon banks to create positive carbon and GHG reduction balances.

China's Low Carbon City Initiative (LCCI) involves developing and implementing measures to move Chinese cities towards low-carbon consumption, especially within China's special economic zones. Shen and Song[133] lists the total number of eco-city projects in China at 168, and at various stages of development, while another report from the Organisation for Cooperation and Economic Development[134] puts it closer to 40. The eco-city concept also has strong support in China, resulting in high profile eco-city projects such as Sino-Singapore Tianjin Eco-City and Cafeidian (Tangshan) that are driven centrally or provincially, whereas others are driven by entrepreneurs or local level agencies. Some examples of low-carbon and post-carbon cities are outlined in the case studies below, in particular, Tianjin City and Masdar City. These three case studies provide an overview of successes and failures in realising the eco-city concept that are useful and instructive in that they highlight specific success criteria.

133. Shen and Song (2010): in ADB (2010)

134. OECD (2009: in ADB (2010)

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CASE STUDY

Masdar City, United Arab Emirates

Masdar City is a planned carbon neutral, zero waste town in Abu Dhabi which is the most important emirate within the United Arab Emirates. Abu Dhabi is the largest owner of the UAE's oil resources (95%) which is significant in a country where hydrocarbons contribute 70% to the national GDP. There is nothing new about establishing a carbon neutral town in particular; what distinguishes Masdar City is the large scale on which it is planned (Reiche, 2009). 'Going big' is what differentiates Masdar City. Masdar City is designed to have the capacity to house 40,000 residents and 50,000 daily commuters. What is clear, is that the Masdar City project will also act as a test-bed for the development of the skills, specialisation, innovation and network base for realising the eco-city concept at large scale. Developing future market competitiveness in green and renewable energy technologies, systems and urban design is the primary aim of the project. In lieu of this ambitious goal, Masdar City has established the Masdar Institute of Science and Technology which is a collaboration with the Massachusetts Institute of Technology (MIT) that involves skills and technology transfer and hosting postgraduate student programmes in green design, clean-tech and advanced energy technologies.

CASE STUDY

Tianjin City, China

Tianjin is the third largest city in China and has a population of around 11.76 million (ADB, 2010). The Sino-Singapore Tianjin Eco-City (SSTEC) project was launched in November 2007 with the milestone for start-up completion by 2013 and full completion by 2020 when it aims to house 350,000 people. It consists of "integrated mixed-use zones in an 'eco-cell' layout" where land uses within the cells span from education, commercial activities and workplaces to recreation. It will also have a light rail system as the main transport mode and green corridors ("eco-valleys") for use as public open spaces and an ecological conservation area. Performance of the SSTEC project will be measured quantitatively and qualitatively. Quantitative measures will focus on: natural environment measures of water and air quality; wetland ecological integrity; noise pollution levels; decoupling from material, energy and carbon dioxide emissions; measures of greening in the built environment (indigenous vegetation, green building percentages, per capita green space); green lifestyle measures (per capita waste, water and energy use, network coverage, etc.); greening the economy (renewable energy use, water use and reuse, research and development activity measures, etc.). Qualitative measures will involve adopting green policy measures, preserving historical and cultural heritage and influencing surrounding regions.

3.2.3 City-level energy strategies for post-carbon cities – future choices

Where energy is concerned, new networked technologies involve decentralising energy production, consumption and savings management; involving the implementation of smart grids, real-time energy savings technologies, energy efficiency technologies and renewable energies at the local scale. Smart grids usually operate at district level and, once introduced, offer up opportunities for new small to medium sized businesses to emerge, similar to those associated with telecommunications. Energy savings companies (ESCOs), for example, can make use of a variety of technology and system management tools to shed loads from the household to large-scale retail and industrial building scale by having direct access and control over non-essential services such as heating, air conditioning and ventilation (HVAC) which is generally responsible for 30-50% of total building energy use. ESCOs can also sell devices that allow household and business owners to self-manage their appliance energy loads and install solar water heater geysers,

New networked technologies involve decentralising energy production, consumption and savings management

Small-scale energy strategies can be effective

solar panels, solar-chargers and solar-battery chargers. The city of Rhizao in China is a solar-powered city where 99% of households within the central districts make use of solar water heater geysers.[135] The 2011 GER Cities Report states that:

> *"Grid-based, decentralised energy system(s), with district heating systems can provide space and water heating for large urban complexes (like hospitals, schools or universities) or residential neighbourhoods. They can significantly reduce overall energy demand. Their efficiency further improves with combined heat and power energy generation systems. Copenhagen's district heating system, for example, supplies 97 per cent of the city with waste heat (C40 Cities 2010d)."*

The introduction of renewable energy feed in tariffs (REFITs) can significantly incentivise the development of zero- or low-carbon renewable energy sources such as wind and tidal power technologies, hydropower and geothermal energy. Geothermal heat, for example, is safe, reliable and low cost and the city of Manila in the Philippines obtains 7% of its electrical energy from it.[136] In Germany, the introduction of a REFIT-led strategy has stimulated large interest in renewable energy technologies even before the decision was taken to end its reliance on nuclear power. In the city of Freiburg, solar photovoltaic systems supply 1.1% of the total city demand and a further 1.3% and 6% of supply is provided by a biomass CHP system and wind turbines, respectively.[137] Household energy consumption has been decreased by up to 80% due to Freiburg's energy-efficient housing standards.[138]

135. ICLEI, UNEP and UN Habitat (2009): in GER cities (2010)
136. ICLEI, UNEP and UN Habitat (2009)
137. IEA (2009): in GER Cities; C40 Cities (2010a)
138. von Weizsacker *et al.* (2009): in GER Cities (2011)

Alternative fuel use is also on the rise. US cities have been particularly active in adopting biofuels. San Francisco's entire vehicle fleet is powered by biofuels and other cities have also moved in this direction. In New York, one third of all heating oil purchased by the city contains biofuel. Biofuels use is incentivised in the US at the federal level through research and tax credit incentives. Hydrogen infrastructure requirements are costly but in countries that are heavily dependent upon external supplies of oil for vehicle intensive cities, the security of hydrogen networks may outweigh the cost factor. Using current technologies, the cost of hydrogen can be 2-3 times higher than that of petroleum.[139] It is not difficult to envisage this gap closing in the future as investment in hydrogen innovation yields efficiency gains and oil price instabilities take effect in the future. Mintz[140] accounts for hydrogen refuelling station costs as being at approximately US$700,000, "including pumps, storage, compression equipment, sensors, etc.", for centralised hydrogen production. Average vehicle fill quantities of hydrogen is about 4kg, at a cost of US$16 per kg of hydrogen.

3.3 Success factors for transitioning to sustainable, resource efficient cities

A range of issues is core to successful sustainability interventions in cities. It is clear that one-dimensional approaches, that seek only to address economic or technological efficiency concerns, often fail to bring about their desired sustainability objectives. It is important to recognise the role that human activities, behaviours and contextual socio-cultural and economic factors play in realising sustainability interventions. These are summarised below in six, short sections:

Integration: Cities that take the need to transition to sustainability to heart, have to go beyond merely conducting environmental impact assessments (EIAs) before going ahead with developments. Instead, they need to embrace the core principles of sustainability. This requires a holistic response rather than a conservation biology-oriented approach towards greening. Where the need for a shared language in achieving transitions to sustainability in cities is concerned, we have discussed the role of socio-metabolic flows in cities which can be quantified in terms of material and energy consumption, and in terms of ecological degradation and damage associated with city growth in population and size. Material flows analysis has a critical role to play in this respect, alongside techniques such as life-cycle analysis, all in service of understanding city socio-metabolisms better, so

139. Mintz *et al.* (2003)
140. Mintz *et al.* (2003)

Cities need to embrace the core principles of sustainability

that comparisons between cities can be standardized to some degree. Yet the demand for coping with social, economic and ecological factors together in the quest for holistic sustainability, requires that both qualitative and quantitative measures be brought together in service of assessing the sustainability of cities. Here the liveability of cities, and the creation of humane, socially just urban living environments is required.

Urban divide: The key challenge facing cities in respect of socio-cultural, political and economic factors is that of the urban divide[141] which acts as a pervasive phenomenon in cities across both the developed and the developing world. The urban divide is significantly more pronounced in the cities of the developing world, however, where the rapid rates of urbanisation and slum urbanisation threaten to overwhelm the urban landscape. Since the financial collapse of 2008, cities in the developing world have been hit by widespread public protests over unemployment, spending cuts, rising prices, service delivery, student and youth protests and unrest. Urban social instability, outbreaks of violence and protests over service delivery and funding cuts, often associated with developing world cities, have recently been experienced in cities of the developed world. What is significant about this development is that it reveals the deep effect that recession and financial crises exert upon social and political stability, especially within cities, and how vulnerable the developed world cities, even the 'world class' cities among them have proven themselves to be.

Governance: Mitigating against climate change, and adapting to the effects of climate change will require more than mere retrofitting of existing infrastructures. As Revi[142] points out, *"Technical, purely economic or even institutional 'fixes' typically will fail to deliver results unless local democratic, political and socio-cultural processes are engaged with around the themes of equity, social transformation, local 'voice' and 'agency'."* The requirement for effective multi-participant participatory processes consistently reappears as a core theme in literature on implementing sustainability visions and strategies at macro and micro-scales alike. Decision-makers, stakeholders, system users, communities and civil society all have critical roles to play in bringing about coordinated multi-sector change.

Smart urban design, logistics and spatial planning: Inclusiveness and low-footprint design that targets public transport, pedestrianisation schemes and cycle lanes and

141. UN Habitat (2011b)

142. Revi (2008)

facilities, urban gardens and food markets, energy and water efficient, low-footprint design of buildings and infrastructure, are all essential elements that, in combination, can be employed for successful urban design and spatial planning. Urban design experts and spatial planners can consider two over-arching dimensions i.e. whether systemic- or networked-based interventions are necessary. Within these dimensions, they may consider whether to establish new infrastructure (leapfrogging) or to upgrade, complement or retrofit legacy infrastructure. Smart logistics systems are required, in terms of design and electronic technologies.[143] Smart information systems for public transport systems, for example, can improve efficiency and use-ability.[144] Ultimately, place-making needs to remain the central aim of urban design and spatial planning as it is through place-making that the liveability and social inclusiveness of urban environments is ultimately ensured. At the city-scale, spatial planning sculpts the socio-spatial urban fabric and plays a critical role in determining whether a more fragmented or cohesive urban form emerges in the future. This has significant consequences for the sustainability of the overall urban form. Stressing compact, multi-use urban development responses for the rapidly growing cities in the developing world is critical for ensuring their future sustainability.

Finance: Cooperation between city governments, national governments, international bodies, inter-city partnerships can all be accessed in order to increase the chances of success where funding for sustainability, resource-efficiency and low-carbon programmes and projects is required. NGOs, development agencies, carbon banks and exchanges, universities and other state-funded research agencies should develop the knowledge bases and provide the support that sustainability and low-carbon projects and programmes require. In addition, price mechanisms such as incentives, tariffs, subsidies can also be utilised instrumentally to stimulate the uptake of green technologies and processes.

Technology and skills transfer and development: Technology transfers must take place within the socio-technical context into which they are introduced. Cultural and socio-economic factors are as important in successful technology introduction as the pure utility of the technology itself. Technology transfers in developing world countries that amount to straightforward purchase and implementation of off-the-shelf technology solutions from the developed world, often encounter key challenges that emerge around not having the appropriate skills and capacity (including management and maintenance skills), nor the commensurate innovation bases and places of learning to produce the knowledge and skills that are required to support long-term development of the institutional capacity that is required. Negotiating technology and skills transfers as packages is critical for developing world cities.

Innovation: Where innovation is concerned, the key requirement is diversity i.e. bringing diverse personalities, intellects, professions, disciplines, orientations, age groups and people with different ways of life together to develop ideas in cooperation. No doubt, plurality and speciality both lie at the heart of innovation. Developing the appropriate educational and higher learning institutional capacity to support innovation-based technology activities, whether high-tech or low-tech is essential. Yet there is more to innovation than technology. It involves innovation in technology, policy, regulation, discursive innovation,[145] conceptual frameworks, processes and engineering standards. Skills, capabilities and networks that span the interpersonal, and across knowledge-oriented, governance and business or civil society actors, are all essential components for realising the milieux of innovation that are sought through building capabilities and competences.

3.4 Enabling integration in city transitions to sustainability – recommendations

The pressures that developing world cities find themselves under are now shared by significant numbers of urban citizens who live within cities of the developed world and their 'world class' cities. Cities are sites where pluralism is mediated, negotiated and contested over. Differences over class, race, ethnicity, gender, sexual orientation and citizen status play out in cities on a day-to-day basis, and are often resolved in cities, whether through formal or informal agreement.

Cities are urban environments where social and community structures are often very varied. Adequately diverse participatory governance processes, involving multi-stakeholder engagements over developmental priorities and service provision needs of communities (whether of urban residents, business, industry, higher learning institutions), are consistently viewed as being critical components of engendering shared visions and re-envisioning as governance is forced to adapt to new and changing circumstances.[146] Cities that do not adequately cater for their communities can become socially unsustainable very quickly and can erupt into social disorder. Catering for the youth, in particular, and conducting processes of participation that involve young people in the processes of governance that affect their future, may yet bring more value to the evolution of cities in the future.

143. WWF/Booz and Co (2008)
144. WWF/Booz and Co (2008)
145. Spath and Rohrracher (2010)
146. Folke *et al.* (2005)

Sector integration, institutional alignment and focus is required. Swilling *et al*[147] identify the elements that are critical for change as;

1. a city based approach, with
2. integrated planning,
3. adequate platforms for wide-ranging collaboration, and
4. engendering values that support sustainability.

Monitoring progress in the transition to sustainability is also important in this respect. The overall goal of successful transitions to sustainability is stimulating and maintaining trajectories towards large-scale behavioural change. New infrastructures alone do not bring greater efficiency and sustainability. Rather, how human behaviours orient around these new infrastructures and technologies plays a critical role. It is important to understand the values, norms and beliefs that govern human behaviour[148] alongside the technical advantages of new technologies and infrastructures. Three broad elements can be identified as a framework for considering city transitions to sustainability. These are delineated along the need to provide *vision and leadership, implementation and coordination capacity, and monitoring and evaluation*, respectively. They are summarised in the next three sub-sections.

147. UN-Habitat (2011a)
148. Stern (2000); Ehrlich and Levin (2005)

3.4.1 Thematic and iconic projects and programmes

Leadership, vision and political and institutional backing is required for city-scale transitions to sustainability. These play a critical role in introducing elements of a sustainability discourse into the public domain and initiate the process of change in values, beliefs, norms and behaviours by setting new directions and identifying the key sustainability-oriented themes and strategies that will inform development within the city. In this respect, thematic and iconic city-scale or national scale projects can play a critical role in providing focus within the vast realm of pressing concerns that cities are occupied with. They provide a means for orienting networks, institutions, policy-makers and regulators upon thematic areas that act as integrators and help build a shared vision amongst different participants and sectors.

Public transport-oriented city-level programmes and projects can bring higher levels of awareness and focus upon city design, as has been shown in the cases of Bogota and Curitiba. Not only are public transport programmes and projects reliable ways to bring about large-scale behavioural changes in respect

The way people orient themselves around these new infrastructures and technologies plays a critical role. It is important to understand the values, norms and beliefs that govern human behaviour of energy use and emissions, they also relieve congestion (productivity) and air pollution (health), improve access and mobility, create jobs, relieve alienation of the urban poor, and get more people onto the streets of the city rendering it a safer, more liveable and humane urban domain.

Themed approaches such as the low-carbon, zero-carbon and eco-city, are also useful, integrating visions for city-led transitions to sustainability. As has been discussed earlier in case studies of low-carbon and eco-cities, these themed approaches act as broad integrators for a variety of sustainability-oriented developments ranging from urban to building design, large-scale infrastructure changes, technology transfer, innovation, monitoring and evaluation schemes. Cities such as Johannesburg are gravely concerned with energy poverty and security within the city and have adopted a bold, new vision to introduce smart-grid oriented technologies that enable renewable energy, energy savings management and consumption at district scales and perhaps even at smaller scales (buildings, malls). Combined with large-scale public transport improvement programmes that target the existing train system, the development of the above ground high-speed "Gautrain", and introducing a new BRT system, essentially constitutes a low-carbon, low-energy oriented approach that accommodates a wide range of socio-economic concerns such as energy poverty, unemployment, lack of small to medium enterprise growth and access and mobility.

3.4.2 Establishing sector and institutional intermediaries

In their critique of the multi-level perspective[149] on transitioning to sustainability, Marvin and Hodson[150] draw attention to the need for strategic intermediaries at the city scale that can ensure sector-specific focus or cross-sector integration, where it is needed, and broker coordinated action at the implementation level. It is clear that institutional and sector integration around sustainability objectives, that are place-based, must be created in a number of cities where resource management has traditionally occurred within institutional and sector oriented 'silos'. Achieving sustainability in the long term will involve addressing the interstitial, cross-sector relationships and interdependencies where the impacts of activities in one sector are externalised to the other. In this respect some examples of strategic intermediaries would include:

- ***Innovation, higher learning, research and policy institutes:*** As seen in the Curitiba and Masdar case studies, setting up research, policy and innovation mechanisms such as institutes and innovation hubs that support knowledge building, technology development, monitoring and evaluation, network formation and skills development and transfer are critical elements of realising city-scale sustainability initiatives programmes. Cooperation with higher learning institutions such as universities was observed in a number of successful interventions.

- ***Funding:*** A variety of government, private sector and civil society organisations have the skills and knowledge bases that can help sustainability-oriented projects access funding. Carbon banks and exchanges can act as intermediaries that offer greenhouse gas trading schemes. NGOs can also play a key role in helping CDM projects access CDM funding and negotiate bureaucracies and procedural requirements – this was the case in the Kuyasa informal settlement CDM project, where SouthSouthNorth played a key role in facilitating access to carbon funding and the South African Export Development Fund helped develop the business plan and underwrote the project.

- ***Observatories:*** Institutionalised mechanisms are required for monitoring, measuring and evaluating changes in cities and the directions that city transitions are taking. For example, the Global Urban Observatory has been set up to collect data and information, monitor and measure and evaluate global urban trends and patterns.

- ***Urban laboratories:*** Local research and practise-oriented 'laboratories' that perform pilot sustainability interventions and use this learning to participate in mainstreaming solutions at larger scales.

- ***Participatory governance:*** This requires developing and supporting agencies that establish focus groups, institutes and task teams that concentrate on coordinating and improving participation and participatory governance between government, business, research and development and civil society organisations – and within them – and help bring about shared vision and consensus, while holding spaces open for debate and consideration on the range of trajectories that can be embraced in migrating towards sustainability and liveability in cities.

3.4.3 Monitoring and evaluation – the question of indices for city sustainability

Cities are unique ecosystems yet their ecosystem functions often go un-researched and undocumented. Ecologists tend to focus on what they regard as 'pristine', untouched ecosystems, and to avoid ecosystems in which human beings are highly settled. As a result, there is a lack of appreciation, monitoring and understanding of the role of city ecosystems as essential to its metabolism. It is therefore no surprise that the

149. Grin, Rotmans and Schot (2010)
150. Marvin and Hodson (2010)

use of environmental accounting frameworks at city-region level are largely absent; that is, discounting carbon credit schemes (which are more easily quantified and understood). Cities and urban growth are also closely linked to increased coastal growth trends, and correspondingly, increased pollution of coastal and marine environmental systems.

Developing robust monitoring and measuring schemes for evaluating ecological services, that keep cities alive, are critical elements in establishing a knowledge base from which to observe, intervene and adapt along a sustainability transition. Researching, measuring, monitoring and evaluating ecological ecosystem services and ecological resilience are critical for establishing development pathways that aim to improve the ecological condition of the urban environment and those that sustain it, even though they may be far away. Measuring and monitoring the emergence and effectiveness of green interventions, be it through economic, social or cultural dimensions, or through qualitative and quantitative means – whatever is appropriate for the particular case – are all required to evaluate the effectiveness of the green sector in contributing to transition. Mixed methods that integrate quantitative and qualitative analyses are required for assessing transition.

Monitoring and evaluating the success or failure criteria of transitions to sustainability raises many challenges at the city scale and many diverse schemes can be devised to meet the needs of cities that are located in different contexts. Aside from monitoring material sustainability, it is important to be able to assess how the transition to sustainability-oriented values, beliefs, norms and behaviours[151] are progressing at the city scale. Often the latter provide better information and understanding of where failures occur and can help re-align and steer transitions better. Where indicators are concerned, there are no definitive or exhaustive single indicators or sets of indicators for measuring city-scale sustainability. In this respect, the aggregation criteria for indicators are as important as the indicators themselves; and in some cases more important. The reason for this is that indicators often reveal more about the underlying assumptions that have governed the selection of indicators than the behaviours they are intended to monitor. Simply put, indicators are models of understanding based on assumptions and it is as important to interrogate these assumptions alongside data drawn from indicators.

Below, we explore the possibility of establishing indices or a framework for handling city indices for sustainability. What is clear is that both quantitative and qualitative monitoring and evaluation schemes are required for dealing with the challenge of assessing how transitions to sustainability are proceeding and identifying what can be done to adapt to changes as and when the context requires it. While it is possible to construct a universal green index for cities, it must be noted that the underlying assumptions of such an index may not extend to different city and urban contexts. In this sense, it may give false indications where it is applied without appropriately accommodating the changed context. A more suitable approach is to decide upon a flexible basket of measures that can be adapted to different situations. Some core measures (such as domestic material consumption and domestic energy consumption) may be 'fixed' while other more flexible sets of measures can be 'optional' in formulating a city-level green basket of measures. Indeed, as evidenced in the indices formulated by different agencies, baskets of measures are often employed to monitor sustainability transitions, for example; a basket of indicators can be composed choosing from any number of the measures outlined in Table 7 (in Annex), which outlines a range of areas for monitoring and measurement for gauging city-scale transitions to sustainable, low-carbon economic growth.

A comprehensive, but in-exhaustive set of proposed measures, is listed and evaluated in terms of its potential and relevance for (1) improving decoupling, (2) enhancing liveability and (3) catalysing skills development and innovation. The measures proposed in Table 7 (in Annex) are separated into two broad categories, each with sub-categories, as follows:

- ***Measures by infrastructure theme categories*** – i.e. building energy efficiency, waste management, sustainable urban transport, water and wastewater and urban ecosystem management. These measures are theme-specific but also have cross-cutting impacts.

- ***Measures for integration and establishing aggregation criteria*** – city-scale decoupling, qualitative assessments of research, innovation, policy and business. These measures can be aggregated from measures within infrastructure theme categories.

Each measure is classified in terms of whether it contributes to the three broad categories of decoupling, liveability, and skills and innovation. The measures for infrastructure themes typically relate to one or more of the three broad categories and are mainly quantitative, while the measures for integration typically span across multiple categories and include both qualitative and quantitative assessments in equal measure. As aggregation towards city-scale is approached, it becomes necessary to include qualitative assessment as a critical safeguard against losing touch with developmental implementation realities that span from the material to the social.

Lastly, measurements, in themselves, while important, require policy frameworks and institutional arrangements

151. Stern (2000); Ehrlich and Levin (2005)

that take into account these quantitative measures. Qualitative assessments are necessary in order to ensure that frameworks for action exist. Incorporating environmental economics into urban policy frameworks is a simple first step towards enabling urban environmental management. Establishing the departments, programmes and projects is required in order to put in place the institutional arrangements that are necessary.

The measures accounted for in Table 7 (in Annex) do not constitute an exhaustive list of measures that has been formulated from those that exist in the different case study contexts that were discussed in this study. As the measures proceed from quantitative to qualitative, so they have greater 'reach', often affecting decoupling, liveability and skills and innovation development alike. Aggregative indices can be derived for each city to monitor its individual progress but determining an aggregator for comparison between cities should be formulating using a few, core measures. Deciding upon which core measures will be chosen for comparison between cities, might be worth exploring at Rio+20, where the occasion provides the opportunity to establish agreement on them.

A broader framework of integration is required for cities to transition to sustainable resource efficient development

3.5 Summary and conclusions

This paper aims to formulate a broader framework of integration which is required for cities to transition to sustainable, resource-efficient development and to realise green urban economic growth trajectories that are equitable *and* sustainable. It frames the question of urban sustainability in a conceptual foundation and language that places human development objectives at the heart of urban sustainability transitions. It presents a set of policy positions and recommendations within a strategic framework that is derived from this understanding. It argues that in addition to a primary emphasis on integration, other success factors for transition to sustainable, resource-efficient urban development includes:

- addressing the socio-economics of the urban divide
- the inclusion of bottom-up participatory governance processes in infrastructure change programs
- smart urban logistics and spatial planning
- smart design, finance, technology and skills transfer and development
- innovation.

This paper primarily argues that integration and coordination across different city sectors and scales is critical to achieving city-level sustainability. This in turn requires focusing political vision and inter-institutional and organisation. This paper proposes that strategic frameworks for integration of city sustainability visions and agendas can best be derived from considering the role of:

1. cross-cutting thematic (such as the proposed infrastructure themes) and iconic projects and programmes (such as public transport overhauls)

2. strategic sector and institutional intermediaries

3. monitoring and evaluation systems.

In respect of (1), the proposed themes and iconic programmes and projects that were highlighted in this study are in-exhaustive. Their value is their capacity to add value across sectors and satisfy a broad set of measurements i.e. social, economic and environmental. Whatever set of themes and basket of measures a city chooses or adapts, strategic intermediaries will be required to bring about integration and coordination in pursuit of city-level sustainability.

In respect of (2), the role of strategic intermediaries[152] may vary in different contexts but they play a key role in implementation, learning and adaptation. In respect of strategic intermediaries, this paper stresses the importance of research institutions

152. Hodson and Marvin (2009b)

that engage closely with practice and the development of urban practitioners, alongside establishing new governance and regulatory functions within city governments, including establishing new government departments. It may also require establishing research, skills development and innovation competences in higher education and technical institutions, technology incubators, business, industry, civil society and community-based organisations. It may also require establishing sustainability thinking in the school syllabus as an introduction to systems-level conceptualisation of human development challenges.

In respect of (3) measures of city transitions to sustainable, resource-efficient development, two classes – measures by infrastructure theme and measures for integration at city-scale – are proposed. There is a consistency between the measures selected for these classes as they allow for aggregation at city-scale and disaggregation at the sector scale (which is thematically defined). The measures themselves are evaluated in terms of three areas of contribution:

- catalysing decoupling
- improving liveability
- boosting skills and innovation.

While the above-mentioned measures are not exhaustive they provide a useful framework for conceptualising infrastructure choices for city transitions to sustainability across a great set of dimensions.

Cities should make infrastructure choices with the intention of fostering future urban societies that have local resilience to global linkages, the capacity to reproduce new and diverse responses to existing, emerging and new challenges and to implement these responses at multiple scales and across the urban divide.

A sustainable urban world will be a sustainable world. It is achievable. What is left is to start making decisions today that will lead to urban futures that all urban citizens can participate in equally so that they can enjoy services and lifestyles that are sufficient and healthy, and ecosystems that are safeguarded and protected in an adaptive, ecologically aware, resource urban-efficient society.

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Annex

Table 7: Cities Measuring sustainability transitions in cities – variables for decoupling, liveability and skills and innovation

Measures	Decoupling	Liveability	Skills and innovation
Building energy efficiency			
Average and disaggregated building energy use by type and scale	X		
Average and disaggregated per-capita energy use in buildings.	X		
Percentage building energy use by type[153] and scale[154] obtained from:			
– Renewable energies	X		
– Non-renewable energies	X		
Percentage building energy savings by type and scale obtained from energy savings devices, and design practises and other measures that are taken to reduce energy use.	X		
Employment creation through building energy efficiency and green building activities.	X	X	X
Waste management			
Total solid waste output of city.	X	X	
Per capita waste (solid, liquid and hazardous) per annum, or ratio of waste output to GDP per annum.	X	X	
Material re-use and recycling ratios for biomass, plastics, glass, metals, electronics, mine, construction materials and hazardous materials.	X	X	X
Greenhouse gas emissions associated with solid waste output of city.	X		
Greenhouse gas emission savings with programmes, measures to reduce waste-to-landfill.	X		
Number of recycling points per neighbourhood area.	X	X	
Waste separation at source ratios.	X		
Employment creation through green waste management activities.	X	X	X
Sustainable urban transport			
Decline in petroleum fuel use per annum in the city by vehicle type.	X		
Total greenhouse gas emissions from transport sector.	X		
Total air pollution gases from transport sector.	X	X	
Safety measures:			
Ratio of female passengers on public transport systems, compared to city gender ratio.		X	
Mobility and accessibility measures:		X	
– Average travel time to place of work.		X	
– Availability and frequency of public transport systems.		X	
Affordability of city public transport systems.	X	X	
Percentage use of public transport systems.	X	X	

153. Building type: residential, commercial, financial, government, retail, shopping malls, industrial, warehousing, mixed-use, mining, and so forth.
154. Building scale: in terms of square metre space of buildings.

Measures	Decoupling	Liveability	Skills and innovation
Sustainable urban transport (continued)			
Percentage use of private transport systems.	X		
Average ratio of public to private transport use.	X		
Employment creation through public transport systems.		X	X
Employment creation through green transport activities.	X	X	X
Water and wastewater			
Total water use.	X		
Per capita water use.	X	X	
Water use breakdown: residential, industrial, commercial, mining, agriculture, etc.	X	X	
Ratio of GDP growth to water use.	X		
Ratio of water demand to water supply.	X		
Ratio of potable water demand to potable water supply.	X	X	
Ratio of wastewater abstraction demand to wastewater abstraction capacity.	X	X	
Ratio of water re-use due to greywater systems and water recycling activities.	X		X
Water quality.	X	X	
Employment creation through green water programmes.	X		X
Urban ecosystem management			
Biodiversity indices for terrestrial, riparian, estuarine and coastal habitats.	X	X	
Ratio of alien to indigenous vegetation.	X		
Wetland ecological integrity.	X	X	
River water quality.	X	X	
Ratio of river flows to baseline environmental flow requirements.	X	X	
Green space per capita.		X	
Ecosystem degradation.	X	X	
Employment creation through urban ecosystem management activities.	X		X
Food security and improved nutrition.	X	X	
Urban gardens and markets.	X	X	X
Food price stability.	X	X	

Measures for integration: aggregation criteria	Decoupling	Liveability	Skills and innovation
City-scale decoupling			
Ratio of city GDP growth to city material extraction.	X		
Ratio of city GDP growth to ecosystem degradation and ecological services loss:	X	X	
– Ratio of natural capital depreciation to GDP per annum.		X	
– Biodiversity intactness index at city scale.	X	X	
Ratio of city GDP growth to non-renewable energy use.	X		
Ratio of city GDP growth to city carbon emission output.	X		
Material re-use and recycling ratios (e.g. greywater re-use, solid waste reuse).	X		X
Emissions savings (e.g. carbon) and sources of savings (e.g. sequestration, efficiency measures, absolute per capita emissions reduction).	X		
Total decline in petroleum fuel use per capita per annum in the city.	X		
Qualitative assessments: research, innovation, policy and business			
Innovation:			
– Publications, patents, degrees, technical diplomas.			X
– Green technology and design patents.			X
– Pilots, case studies.	X		X
Business and Industry:			
– Number of green project proposals in various stages of evaluation and approval per annum.	X		X
– Total green projects in implementation per annum.	X		X
– Total investment in greening and sustainability per annum (e.g. – renewable energies, cleaner production, conservation).	X		
– Total number of new green businesses established per annum, and existing green businesses per annum.	X		X
Policy:			
– Green policy measures adopted.	X	X	
– Green policy enforcement measures.	X	X	
– Policies and measures for environmental protection.	X	X	
Other:			
– Green skills development: programmes (e.g. numbers of technicians skilled, employed, etc.).	X		X

About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: **climate change, harmful substances and hazardous waste, resource efficiency.**

DTIE is also actively contributing to the **Green Economy Initiative** launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

> **The International Environmental Technology Centre** – IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

For more information,
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This publication aims to formulate a broader framework of integration which is required for cities to transition to sustainable, resource efficient development and to realise green urban economic growth trajectories that are equitable and sustainable. It frames the question of urban sustainability in a conceptual foundation and language that places human development objectives at the heart of urban sustainability transitions. It presents a set of policy positions and recommendations within a strategic framework that is derived from this understanding.

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