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WORKING PAPER:

Framework Elements for Assessing Urban Environmental Performance

United Nations Environment Programme

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All our colleagues with UNEP, especially:
Francoise d'Estais (UNEP), James Verner (UNEP), Xianli Zhu (UNEP-Risoe)

Special thanks to Mayor Un-Tae Kang and the Metropolitan City of Gwangju and to the Korea Environment Institute for their strong support and sponsorship of this important work.

Cover photo: Tokyo. iStockphoto

Copy editor: Phillip Lyndon, Column Communications Ltd

Design/Layout: Steve Paveley Design

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Executive summary

Effective development of city-regions is a major challenge and requires reliable and pertinent indicators to guide planners' actions and monitor progress. The large number of 'green city' and 'sustainable city' indices that are flourishing today differ in key aspects of methodology and definition, in part because there is no consensus on the main attributes of a sustainable city and the appropriate metrics.

While a range of indicators and reporting systems may be an asset reflecting the unique needs of each community, it also presents a significant challenge to designing a common or standardised sustainability indicator framework and developing database and reporting protocols.

Within the framework of the **Urban Environmental Accords**, the objective of this paper was to examine the opportunities for developing a global consensus on an **Urban Environmental Index** to assess the environmental performance of cities. We analysed a variety of conceptual and actual sustainability and environmental reporting systems at the national and community/municipal level and evaluated their strengths and weaknesses in the face of current challenges.

A first finding of this study is that there is a lack of consensus about the different sectors that need to be monitored. To bridge this gap, we propose a seven-sector framework for assessing environmental performance:

- carbon cycle
- water resources
- solid waste
- pollutants
- biodiversity
- nitrogen and phosphorous (N and P) cycles
- land use change.

A second finding is that the environmental issues are strikingly different at the local and global levels. For cities, the most pressing environmental challenges are the ones that affect the quality of life for urban residents. Water supply and pollution, sanitation and drainage, accumulation of solid waste and air pollution form **the traditional core of local urban environmental issues**. In contrast, **from a global perspective**, the most urgent environmental issues are to reduce: (i) the alarming rate of biodiversity loss; (ii) the emissions of CO_2 and CH_4 into the atmosphere; (iii) the discharge of N and P in water flows.

A two-layered nested model combining local and global assessments is thus proposed to account for these differences:

Local assessment (internal): The urban environment is assessed within the territory boundary with 17 core indicators to monitor carbon cycle, water resources, waste and pollutants. Pressure indicators are favoured as they are the most useful for formulating policy targets and for evaluating policy performance. These indicators are (reasonably) easy to collect and standardise. This list is complemented with two more resource-intensive indicators which could be used by torchbearers for sustainability monitoring.

Global assessment (external): Future research is needed to account for the out-of-boundaries impacts of urban activities, in particular on biodiversity. A complementary set of indicators needs to be developed to cater for externalities which have the most important impacts at the global level, namely biodiversity erosion, N and P cycle and (global) land use change.

These findings and the model lead to a set of recommendations for research and for policy making.

Recommendations for research

How to include mineral resources: Mineral resources do not participate in the functioning of ecosystems and their depletion is traditionally not covered by environmental assessments. However, these are burning sustainability issues and relevant indicators will have to be included in any 'sustainability dashboard'. In particular, recycling rates for key materials are likely to provide a sound basis for such indicators.

Out-of-boundaries environmental impact: It is important to account for the external impacts of urban activities, both distant and global, to address the true imperatives of sustainable development. Whenever possible, assessment of environmental impacts should aim to extend beyond the geographic boundaries of a city. To delineate direct and indirect impacts and avoid double counting, the concept of the three 'scopes' has been developed to account for out-of-boundary GHG emissions. Based on the work done to estimate GHG emissions, it is recommended that a framework be developed to see how this know-how could be adapted to other environmental sectors to account for out-of-boundaries impact, in particular in the case of biodiversity which remains the most daunting challenge and the least monitored. Developing such methodologies is expected to be complex and would perhaps be helped by focused case studies which would trace the impacts of specific resource and waste flows of selected cities.

Integration beyond indicators: To help decision-making on complex and interconnected issues, an exhaustive dashboard is not sufficient to find optimal solutions. Complex systems analysis and modelling of dynamic interactions are dynamic research areas that have brought biology and medicine to an unprecedented level of integration in just a decade. These sciences are now mature enough to model the different parameters of an urban system and their interactions and to apply the dynamics to build evolution scenarios. Urban studies and decision-makers could benefit greatly from such a conceptual and practical revolution.

Sustainability indicators: Although the assessment of the environmental performance of cities is necessary, it is not sufficient on its own to affect sustainability. Future work is needed to integrate the social and economic dimensions and to identify how the interplay between them can be used to maximise the opportunities and minimise the challenges that cities face.

Recommendations for policy making

Indicators: To be practical, indicators should at least be:

- based on data that is comparable over time
- relevant to policy makers (goal-oriented)
- simple and easy to monitor.

In addition, quantitative indicators should be scientifically valid (based on principles of conservation of energy and mass).

Core set of indicators: A list of 17 core indicators is proposed as a framework for local environmental assessment across all sectors. This list has been compiled from the GEO Cities Reports, the UN habitat guidelines for urban indicators and the GCIF and BRIDGE initiatives. These indicators monitor different variables across all sectors relevant to local environmental assessment (see Annexe 4). This set is a tentative one and aims to serve as a basis for discussion. Feedback from practitioners and scientists is needed to establish and test a workable set in the future.

Adaptation to local needs: The specific local context of a city can have an important effect on its environmental concerns and on the priorities and potential for action. Each local authority should be given the ability to define its priorities and select the appropriate pressure indicators according to specific local and regional contexts. In addition to the core set of indicators proposed here, the framework should encourage cities to design and use optional indicators adapted to their current needs. This flexibility is expected to nurture creative policy and favour exchange of best practices.

Urban Environmental Accord – monitoring vs creative policy: Finally, beyond indicators, awareness, political will and sound decision-making remains the best recipe for developing practical and effective solutions. In particular, this study suggests a set of complementary actions to extend the **Urban Environmental Accords** in an effort to reconcile urban lifestyles with environmental priorities.

Introduction

The extent of urbanisation today is unprecedented in human history. Some 90 per cent of global urban growth takes place in developing countries which are projected to triple their built-up urban areas between 2000 and 2030. An estimated 400,000 square kilometres will be constructed in just 30 years – the equivalent of the world's entire built-up urban area in 2000 (Suzuki et al, 2010).

These massive processes of urbanization are inevitably at the centre of our environmental future. Cities and urban areas rely on a wide range of resources from outside their geographical boundaries, including water, food and raw materials for manufacturing. These demands can have significant environmental effects in distant locations. Urban areas also use large amounts of energy and contribute significantly to global greenhouse gas emissions. Locally, inadequate provision of water, sanitation and drainage, and the generation of large amounts of solid waste, air pollution and water pollution, can have major environmental impacts and lead to a severe health burden for urban residents. These issues are particularly acute in low-income countries and coastal areas.

If urban areas are the source of much environmental decay, both directly and indirectly, they are also a stepping stone to the solution of many environmental problems. For instance, the high density of urban settlements makes efficient mass transit systems possible and reduces the energy consumption by households for heating, cooling and lightning. Air, noise, and water pollution can all be partly addressed inside the city, even when the policies involved may originate at the national or regional level (Sassen, 2009).

Addressing the Goldman Sachs 'Top Five Risks Conference' in 2008, Professor Nicholas Stern underlined the importance of regional considerations:

"A few hundred square miles of the Himalayas are the source of all the major rivers of Asia, the Ganges, the Yellow River, the Yangtse where three billon people live. That's almost half of the world's population."

Many regional factors, including geographical location and local environmental conditions, can influence the ability of cities to take action, their development paths, their regenerative options or their resilience capacity. It is now increasingly clear that the ability to define what can be done largely depends on local and regional contexts.

Effective development of city-regions is a major challenge and requires reliable and pertinent indicators to guide actions and monitor progress. Chapter 40 of *Agenda 21* calls on countries and the international community to develop indicators for sustainable development. Such indicators are needed to assist decision-makers at all levels to adopt and monitor adapted sustainable development policies.

As reviewed by Greg Clark recently, the theme of sustainability has emerged – in many cases for the first time – as a prominent feature of some comprehensive city benchmarking efforts, but has yet to be incorporated fully as an indispensable metric. The numerous 'green city' and 'sustainable city' indices proliferating today differ in key aspects of methodology and definition (Clark, 2011), in part because consensus on the main attributes of a sustainable city and the corresponding metric is still lacking.

The search for effective sustainability indicators is usually framed primarily as a technical or scientific problem rather than as a political challenge. Science is clearly needed to develop understanding of the underlying systems, states and processes that indicators reflect. However, indicators are often selected based on our **ability** to measure a particular phenomenon (a technical issue) instead of on the **need** to measure it (a normative issue) (McCool & Stankey, 2004).

This study is focused solely on the environmental impacts of a city – what should be measured and how – and will not cover the economic and social dimensions of sustainable development. The theoretical literature on sustainability provides some elements for a framework, which in turn could be used to define environmental performance.

The objective of this paper is to prepare the foundations of a framework for urban environmental performance assessment:

- **Firstly, scientific literature is analysed to identify which issues need to be assessed and what could be done today.**
- **Secondly, a review of current applications of city indices is undertaken.**
- **Thirdly, propositions are made for improvement in the future.**

Although the assessment of the environmental performance of cities is necessary, it is not sufficient on its own to bring about sustainability. Future work is needed to integrate the social and economic dimensions and to identify how the interplay between these three dimensions can be used to maximise the opportunities and minimise the challenges that cities face.

1 Theoretical elements for urban environmental assessment

Regardless of the precise definition of sustainability, it is safe to say that a sustainable city is a city that has reduced its environmental impacts below certain thresholds. Which impacts? What thresholds?

After introducing the key issues associated with the 'sustainable city' concept, this section will draw up some guidelines from the literature showing which environmental sectors need to be assessed and how. This normative approach will set out a theoretical and idealistic model, which will be compared to the current best practices, with a view to proposing some ways to improve future endeavours.

1.1 Conceptual issues with sustainable cities

1.1.1 Conceptions of sustainable development are diverse

The issue of sustainable development has become a dominant policy paradigm over the last decades. Yet, there is no consensus on the definition of the concept and the types of object to which it applies. The different beliefs regarding what should be sustained, by whom, for whom and how, underlie the various theories of what should be assessed and how (Walton, 2005). Consequently, many different tools labelled as sustainability assessments vary widely in relation to methodology, priorities, target audience, and differ in terms of efficiency and reliability (e.g. Ness et al, 2007; Walton, 2005; Clark, 2011).

Boulanger recognises four different ways of conceptualising sustainable development in terms of:

- domains or pillars (economy, society and environment)
- resources and productive assets (manufactured, natural, human and social capitals)
- human well-being (needs, capabilities)
- norms (efficiency, fairness, prudence, …).

Accordingly, the numerous lists of sustainable development indicators can be whittled down to four major reference classes: socio-natural sectors (or systems), resources, people and standards (Boulanger, 2008).

These different categories are not mutually exclusive: most of the indicator systems constructed within international institutions or countries are inspired by multiple paradigms (Boulanger et al, 2003) and ipso facto important sustainable development keystones are based on different representations. For instance, the inaugural definition of sustainable development outlined in the *Brundtland report* which cites the "needs and aspirations" of present and future generations, clearly refers to human beings and their well-being, while *Agenda 21* refers to systems only.

The lack in consistency of the sustainable development concept has been a major hurdle to the design of performance assessment tools. However, as we will see later, **a shared vision of the environmental issues instructed by science is now emerging. In particular, some priorities between issues at the global and local levels can now be identified, which will inform society's capacity to improve its environmental performance over time.**

1.1.2 What is a city?

In contemporary societies, urbanisation usually extends beyond city limits; as peripheral and suburban zones grow, this creates confusion concerning the limit of city boundaries. It is sometimes difficult to determine the pressure exerted by one particular city amongst a cluster of urban centres. In addition, given the different definitions of cities, comparable areas of reference are required to make international comparisons.

Metropolitan areas can be larger than the built-up settlement and comprise rural parts with very low-density settlements (e.g. Paris/Ile de France); In other cases, such as with Australian cities, the metropolitan area was administratively defined a long time ago and today is smaller than the actual urban agglomeration (UN-Habitat, 2009).

For city level data, UN-Habitat recommends the use of **urban agglomeration** as the standard area of reference (UN-Habitat, 2009), where the urban agglomeration is defined as:

"the built-up or densely populated area containing the city proper; suburbs, and continuously settled commuter areas. This may be smaller or larger than the metropolitan area."
(UN-Habitat, 1995).

When data for the urban agglomeration is not available, data for the metropolitan area[1] may be used. However, the city proper is not considered as a suitable area of reference as it does not represent the total built-up area of the city (UN-Habitat, 2009).

1.1.3 Different conceptions of a sustainable city

From global to local: From eco-cities to green cities to sustainable cities, how cities can and must become the most environmentally-friendly model for inhabiting our Earth has been widely debated over the past 35 years (see Lehman, 2010 for a historical perspective). Theoretical definitions of a sustainable city have varied enormously, depending on how the relationship between a city and its environmental hinterlands was considered.[2]

Indeed, if sustainable development has historically been a concept developed at a global level, the prominent role of the city in environmental policy has gained considerable traction recently for at least four reasons (Finco and Nijkamp, 2001):

- the majority of human populations and constructed elements are concentrated in urban areas and result in the consequent confinement of natural assets
- decentralisation of environmental and resource policy has become a major device in current policy-making, at least in most western countries
- the city is usually a suitable statistical unit for providing systematic data sets on environmental, energy and socio-economic indicators
- addressing environmental challenges also presents an opportunity to create new jobs (green-jobs or eco-jobs).

From local to global: As early as 1994, the Aalborg charter of *European Cities & Towns Towards Sustainability*[3] recognised that *"the standard of living should be based on the carrying capacity of nature"*. Indeed, the progressive introduction of space as a key parameter for sustainability proved to be a meaningful analytical and policy concept (reviewed in Bithas and Christofakis, 2006).

Today, the expansion of the global economy increases our capacity to annex more and more of the world's land and resources to support a limited number of industries and places. The urban hinterland, once primarily a confined geographic zone, is becoming a global hinterland and many of today's major global governance challenges become tangible, urgent and practical in cities worldwide (Sassen, 2009).

In short, sustainable development concepts elaborated at a global level have been applied to cities at a local scale. The understanding of the nature and interconnections of the environmental issues is now highlighting the problem of scale.

There is a need for an holistic, inclusive and comprehensive conception of the sustainable city, to better monitor its true impacts and to tap into the full range of its transformative capabilities.

1. The **metropolitan area** is the set of formal local government areas which are normally taken to comprise the urban area as a whole and its primary commuter areas.
2. For a detailed description of these models, see Haughton, 1997.
3. Aalborg charter of *European Cities & Town Towards Sustainability* http://sustainable-cities.eu/upload/pdf_files/ac_english.pdf

Accordingly, in this paper we will use the definition of McGranahan and Satterthwaite (2003) for whom sustainable cities are those which:

"…contribute to sustainable development within their boundaries, in the region around them, and globally. (…) Sustainable cities not only consider the needs of the population within the geopolitical borders, but also the needs of all people on a global scale and in the future."

1.2 In search of good indicators

1.2.1 Key challenges in defining good indicators

Proper responses to environmental issues can be formulated when the causes and the impacts of the resulting pressures on the system are known. The principal objective of indicators is to inform public policy-making. They must show whether things are getting better or worse.

The literature on the topic is plethoric and many different sets of guidelines have been established to define good indicators. Here we present two different approaches which are sympathetic and complementary. In practical terms, the main functions of indicators are to:

- assess conditions and trends
- compare places and situations
- provide early warning information
- anticipate future conditions and trends (SCOPE, 1997).

In addition, they should be calibrated in the same terms as the policy goals or targets linked to the indicator (Hammond et al, 1995).

For stakeholders, indicators should be:

- appropriate within the theoretical framework (science issue)
- useful for the governing bodies (political issue)
- legitimate within the territory/the institution (democratic issue)
- easy to monitor (availability, cost, expertise) (Boulanger, 2008).

If these two sets of recommendations can work together then building an ideal set of indicators which comply fully will be beneficial. However, the more the indicators are detailed and comprehensive, the more expensive and less practical they become.

1.2.2 The DPSIR Matrix

The Drivers-Pressures-States-Impacts-Responses (DPSIR) matrix is the reference used today by United Nations agencies and programs and the European Environment Agency to describe the interactions between society and the environment (Kristensen, 2004). In particular, the DPSIR matrix is used by the GEO Cities Reports.

According to the DPSIR framework there is a chain of causal links starting with *'driving forces'* (economic sectors, human activities) through *'pressures'* (emissions, waste) to *'states'* (physical, chemical and biological) and *'impacts'* on ecosystems, human health and functions, eventually leading to political *'responses'* (prioritisation, target setting, indicators) (Kristensen, 2004).

The DPSIR is a detailed and useful framework for monitoring environmental issues and for designing goal-oriented policies. Its use has been recommended for the assessment of urban environmental performance.[4] Describing the causal chain from driving forces to impacts and responses is a complex task, and tends to be broken down into sub-tasks, e.g. by considering the pressure-state relationship (Kristensen, 2004).

In particular, as illustrated in Table 1 (overleaf), the same pressures can lead to different impacts (here water-borne diseases and coastal eutrophication) and a response can have positive effects on different sectors simultaneously (here investment in water treatment and distribution systems). In addition, the driving force/pressure indicators provide direct feedback on whether policies meet stated goals: Are emissions increasing? Or decreasing? Are hazardous conditions improving? Or worsening? etc.

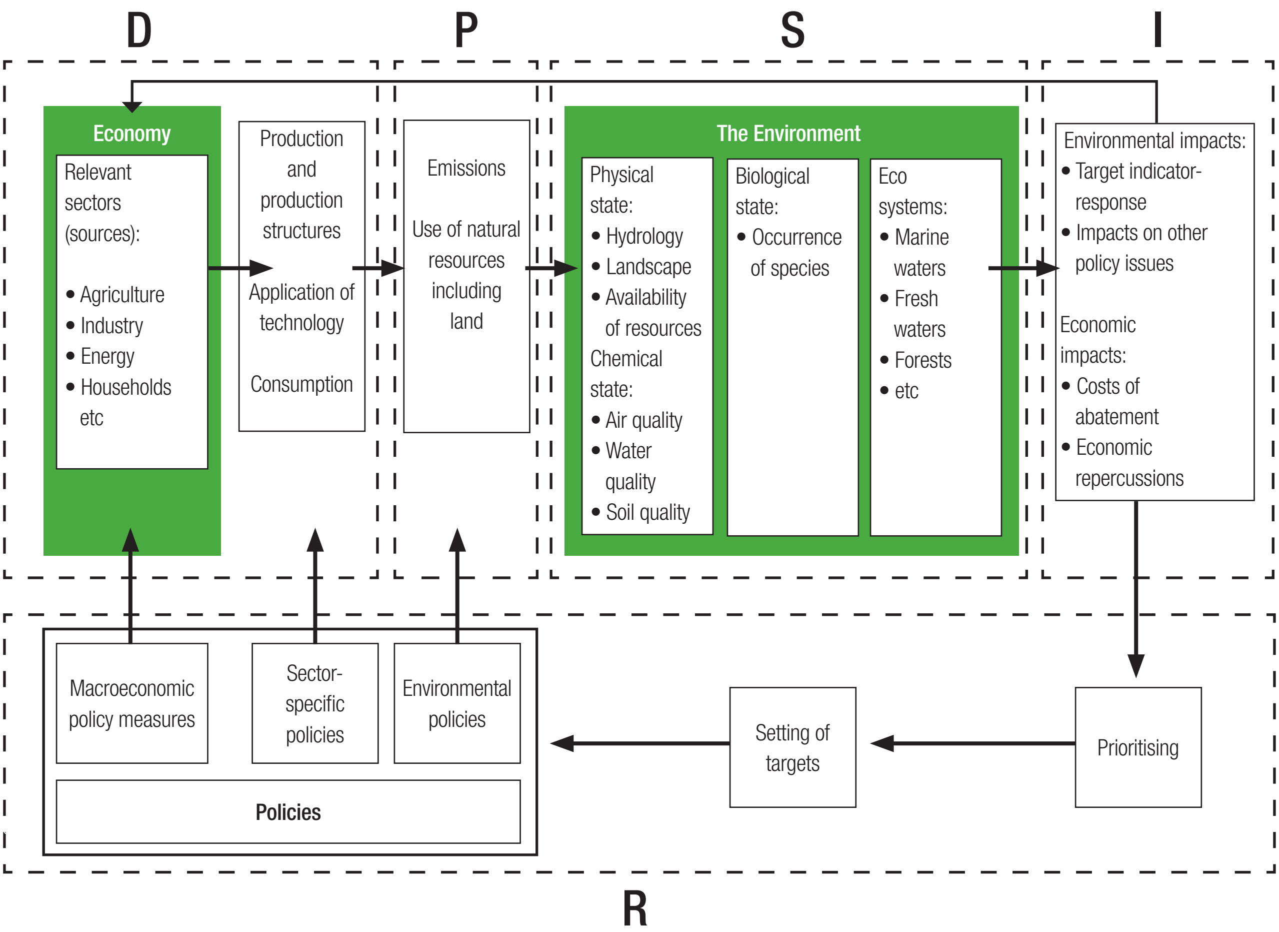
Pressure indicators are thus most useful for formulating policy targets and for evaluating policy performance.

4. Caribbean coral reef ecosystems are damaged by poor wastewater treatment of coastal cities (Sutherland et al, 2011)

Table 1: **Example of logical integration between indicators in the DPSIR matrix for a typical coastal municipality (modified from the GEO Cities Reports)**

Sectors	Drivers	Pressure	State	Impact	Response
Water	Population: sewage system	Total volume of untreated domestic sewage	Water quality Index Concentration of faecal material in water	Increase in water-borne diseases	Investments in water treatment and distributions systems
Air	Transport, Energy use etc.	Atmospheric emissions	Air quality	Incidence of respiratory pathologies	Control of emissions
Land	Waste management	Solid waste production	Polluted sites	Incidence of poisoning and contamination	Investment in solid waste management
Biodiversity	Population: sewage system	Total volume of untreated domestic sewage	Nutrients and pathogens in effluents[5]	Riverine and coastal eutrophication, coral bleaching	Investment in water treatment and distributions systems

Figure 1: **integrated environmental assessment in a DPSIR framework (Kristensen, 2004)**



5. www.unep.org/dewa/africa/docs/en/AEO_cities_manual_en_Nov05.pdf

Guideline: DPSIR is the gold standard but can be too demanding in practice. If the set of indicators is limited in such a way that only one indicator can be used to assess a particular sector, a pressure indicator is recommended.

1.3 Defining key environmental sectors

1.3.1 Standard Matrix of environmental indicators

Environmental sustainability involves a wide range of issues that are highly interconnected and thus difficult to define and compartmentalise in an operative way. For the sake of practicality, most efforts to develop environmental indicators have chosen to focus on a limited set of key environmental issues. Core lists of environmental issues and of relevant indicators tend to differ from one organization to another but are usually derived from the initial work performed by the OECD and UNEP (Hammond, 1995). This initial matrix identified 13 issues and categorised the most common indicators according to the PSR matrix, the ancestor and simpler version of the DPSIR matrix used today (see Table 2, below). In this study, we will refer to this set of environmental issues as the Standard Matrix. Emitted pollutants, defined as substances that are not easily assimilated by the environment, are depicted in **bold**.

It is worth noting that the depletion of mineral resources, such as ore or oil fields, was not covered by the standard matrix. Today, such sectors would have to be included in any 'sustainability dashboard' and how to do so remains a burning and open question.

Table 2: **Standard matrix of environmental issues and relevant indicators Adapted from Hammond et al (1995)**

Issues	Pressure	State	Response
Climate change	**GHG emissions**	CO_2 concentration	Energy intensity
Ozone depletion	**Halocarbon**	Chlorine concentration	Protocol sign Fund contribution
Eutrophication	**N, P.**	Concentration	Treatment connection, investments
Acidification	**SO_x, NO_x, NH_3**	Deposition, concentration	Sign. Agreements, investments
Toxic contamination	**POC, heavy metal**	Concentration	Recovery hazardous investments
Urban Env Quality	**VOC, SO_x, NO_x**	Concentration	Expenditures, transportation policy
Biodiversity	Land conversion, fragmentation	Species abundance	Protected area
Waste	Waste generation	Soil/groundwater quality	Collection rate; recycling investments
Water resources	Demand/use intensity	Demand/supply ratio; quality	Expenditure, water pricing
Forest resources	Use intensity	Area degradation, growth ratio	Protected area Sustainable logging
Fish resources	Fish catches	Sustainable stocks	quotas
Soil degradation	Land use changes	Top soil loss	Rehabilitation/protection
Oceans/coastal zone	Oil spills, deposition	Water quality	Coastal zone management/ocean protection

The Standard Matrix provides a list of key environmental issues and corresponding indicators which have been broadly used. However:

- **all the issues are on the same footing and cannot serve directly to prioritise action at local and global levels**
- **this matrix has been designed for national accounting and is not directly adaptable to cities.**

These two issues will now be examined.

1.3.2 Setting global priorities: the Rockstrom approach

Recently, a representation of the natural environment as a set of nine key biophysical subsystems or processes of the Earth has been proposed. For most dimensions, boundaries have been defined as thresholds which are expected to trigger non-linear, abrupt environmental changes if crossed. **This set of boundaries is proposed to define the safe operating space for human activity, i.e. the necessary environmental conditions for sustainable development. This model was recently adopted by the High-level Panel on Global Sustainability of the United Nations.**[6]

The dimensions and their respective boundaries are presented in Annex 1. Briefly, three of the Earth-system processes – **rate of biodiversity loss, climate change** and **interference with the nitrogen cycle** – have already transgressed their boundaries. Humanity may soon be approaching the boundaries for **global freshwater use, change in land use, ocean acidification** and **interference with the global phosphorous cycle** (see Figure A, Annex 1). Thresholds for atmospheric aerosol loading and chemical pollution have not yet been quantified.

The key element in this planetary boundary framework is the provision of numerical target values for the different variables, leading to the proposal of three priority sectors at the global level.

6. In 2011, the High-level Panel on Global Sustainability of the United Nations changed its mission statement into: *"To eradicate poverty and reduce inequality, make growth inclusive, and production and consumption more sustainable while combating climate change and respecting the range of* ***other planetary boundaries****."* www.un.org/wcm/webdav/site/climatechange/shared/gsp/docs/GSP2%20meeting%20report.pdf

In particular, erosion of biodiversity is seen as the most pressing global issue. Indeed, ecosystems are characterised by thresholds, feedback or temporally delayed effects that can lead to relatively rapid shifts in biodiversity and associated ecosystem functions and services. These shifts are often driven by complex interaction between human, ecological and biogeophysical systems and lead to lasting degradation of biodiversity, ecosystem services and human well-being. Being difficult to reverse, these shifts represent real tipping points (Scheffer, 2009; Leadley et al, 2010). Over the past 50 years human activities have changed ecosystems more rapidly and extensively than at any comparable period in our history with more than 60% of the world's ecosystems already degraded (Millennium Ecosystem Assessment 2005). **The analysis of plausible trajectories of biodiversity reveals that several major tipping points are likely to be reached in the next several decades** (e.g. Pereira et al, 2010).

1.3.3 Adapting the Rockstrom approach to cities

The nine subsystems are not independent. Different impacts can be due to the same drivers, and undermining the resilience of a specific subsystem can increase the risk of crossing thresholds in other processes.

Carbon cycle: In particular, ocean acidification and climate change are both driven by CO_2 accumulation. If they correspond to two separate systems, both issues are largely driven by the same pressure factor (namely CO_2 and CH_4 emissions) and can be tackled jointly through anthropogenic GHG emission curbing policies.

We will thus combine ocean acidification and climate change into a new category called Carbon cycle.

Pollutants: The **atmospheric aerosol loading** and **chemical pollution** categories are too broad to be used directly and are partly redundant when linked to other sectors:

- Example 1: Chlorofluorocarbons (CFCs) and other halogenated ozone-depleting substances (ODS) are man-made pollutants that are mainly responsible for **stratospheric ozone depletion**.

- Example 2: Many substances released into the environment by human activities impact both on freshwater resources and biodiversity loss (e.g. organic pollutants, micro-plastics, heavy metals, endocrine disrupters, etc).

These categories are confusing. In fact, sensus stricto, 'chemical pollution' corresponds to produced substances that are not easily assimilated by the environment; they run into many different sectors (they are depicted in **bold** in the Standard Matrix on Table 2).

We propose to abandon these categories and use instead an extended category, Pollutants, combining all of the micro-pollutants generated by city activities (air, land, water) with the exception of CO_2 and CH_4 which are included in the carbon cycle. This category can be subdivided into air, land and water pollutants depending on the type of dispersion of the substances.

Note 1: **Urban Environmental Quality** from the Standard Matrix is not based on a physical object or biological system. Instead it refers to various local pollutants. We propose to combine it with the **"sector pollutants"**.

Note 2: The **Waste** and **Pollutant** groups are distinguished by their size. The former and the latter correspond to macroscopic waste and molecule/ particulate respectively. We propose to keep **Solid Waste** as a bona fide category.

Ozone depletion: This issue is no longer considered a priority by Rockstrom et al and has been removed from the list accordingly. Incidentally, this downgrading results from international, national and local policies which were successful in phasing out the production and use of ozone-depleting substances.

Biodiversity: Rockstrom et al identify the rate of biodiversity loss as the most pressing issue. Indeed, understanding the dynamics of biodiversity loss represents a major challenge since biodiversity is an essential foundation of ecosystem services and human well-being (MA, 2005; DIVERSITAS, 2009). However, this sector is too highly aggregated to be translatable into indicators. A more disaggregated approach, which would potentially have significance at the local level, is highly desirable.

In this study we will keep 'biodiversity' as a category to compare the different indices but, in doing so, recognise that this sector is far too broad to be useful. In particular this is because **many other categories, if not all, have their ultimate impact on ecosystem health and resilience and contribute to biodiversity erosion** (see Table 3 for examples).

Further research is needed to disaggregate the 'rate of biodiversity loss' category into meaningful and workable categories. A classification by ecosystems[7] may be useful to assess the impact of the urban drivers.

1.3.4 Proposal for environmental sectors

Comparing the Rockstrom model and the Standard Matrix leads to the establishment of seven key environmental sectors:

1. **Rate of biodiversity loss**
2. **N and P cycles**
3. **Carbon cycle**
4. **Water resources**
5. **Land use change**
6. **Solid waste**
7. **Pollutants**

The planetary boundary framework is instrumental in setting priorities and providing numerical target values for the different variables. From a global perspective, the most urgent issues are:

- **to reduce the alarming rate of biodiversity loss**
- **to reduce the emissions of GHGs in the atmosphere**
- **to reduce the discharges of N and P in water flows.**

7. Which has been partly adopted in the Standard Matrix, namely Forest resources, Fish resources, Oceans/coastal zone and Land use change

1.4 Territorial dimensions of urban performance measurements

"The case of ozone holes illustrates the scale-up. The damage is produced at the micro level of cars, households, factories and buildings but its full impact becomes visible and measurable only over the poles where there are no cars and buildings."
(Sassen, 2009).

1.4.1 Local, distant and global impacts

If cities occupy only about three per cent of the Earth's surface then their inhabitants use 75 per cent of the natural resources. To maintain these levels of consumption above what is locally available and sustainable, municipalities import resources and export wastes. If local gains in economic or social well-being come at the expense of accelerating ecological damage and social disintegration elsewhere, then local prosperity represents a cost to global sustainability. It is critical that we consider the different scales within which sustainability should be assessed.

The impact of human activities on the environment operates on different geographic spaces and scales and at least three cases can be distinguished:

- **Local effects:** local pollution, waste accumulation, groundwater consumption and land use change, for instance, can occur within the strict boundaries of the city. Deforestation due to urban extension can have a significant impact on biodiversity loss and carbon emission.
- **Distant effects:** Cities' activities induce local effects but in a remote location; e.g. consumption of food or goods that contribute to environmental degradation at the site of production or extraction. Other examples include fishery collapse, toxic contamination, eutrophication, land use change and deforestation etc.

Table 3: **Local, distant and global impacts of urban activities by sector**

Sectors	Local	Distant	Global
Biodiversity loss	Habitat destruction Local pollution Brownfield remediation	Consumption of food and goods Distant pollution[8]	Disturbances of C/N/P/ Hg cycles
Carbon Cycle	Local deforestation Local reforestation	Deforestation due to consumption Reforestation	Induced CO_2 emissions (scopes 1,2,3)
N, P cycles	Local waterways pollution, Eutrophication	Waterways, coastal and land pollution, Eutrophication	NO2 accumulation: Climate change
Pollutants	Local air, land and water pollution	SOx particulate	Hg global contamination[9]
Water resources	Pollution/ exhaustion of local streams / ground water	Consumption: Pollution/ exhaustion of upstream resources / ground water	
Land use change	Urban extension Brownfield rehabilitation	Conversion of lands for food and goods production	
Solid Waste	Local pollution	Downstream pollution Coastal degradation	

8. For example, Caribbean coral reefs are threatened by poor wastewater treatment of coastal cities (Sutherland et al, 2011)
9. Mercury accumulates in different ecozones via diffuse loading on land and water and complex chemical cycles in the atmosphere (Canuel et al, 2009).

- **Global effects:** Cities' activities generate diffuse effects with global and remote impacts. Typical examples are climate change, ocean acidification or ozone depletion.

Table 3 shows some environmental impacts of urban activities in a selection of sectors. Each row presents examples of urban activities that have environmental impacts. These impacts can be local, distant or global. Not all of the impacts are necessarily negative; examples of urban activities having positive impacts are given in **bold**.

Table 3 illustrates how different categories are highly interrelated. Land use change, for instance, is at the same time **a sector** of the safe operating space, **an effect** of city activities and **a cause** of degradation for other categories. In particular, changes in land use exert the most significant effects on terrestrial biodiversity loss.

According to §1.3.2, the three boundaries that have been transgressed are Biodiversity loss, Carbon and Nitrogen cycles. These three global systems are severely impacted by city activities – albeit distantly. In the case of the Nitrogen cycle, major impacts occur outside the geographic boundaries of cities even though they are directly driven by food consumption in urban areas. More generally, consumption of food and goods within the city exerts significant distant impacts on many sectors.

Bridges exist between the local and global levels. The city has been recognised as a key scale for implementing a broad range of environmentally sound policies, and for acting as a focal point for creative environmental strategies (e.g. Finco and Nijkamp, 2001; Satterthwaite et al, 2007). For instance, air, noise, and water pollution can all be partly addressed inside the city, even when the policies involved may originate at the national or regional level (Sassen, 2009).

Guideline: It is important to study the external impact of urban activities, both distant and global, to address the real imperatives of sustainable development. Whenever possible, assessment of environmental impacts should try to extend beyond the boundaries of a city.

1.4.2 The inclusion of regional dimensions when selecting priorities

An indicator framework generally addresses a particular institutional perspective on sustainable development and focuses on a given issue within a spatial scale.

The importance of each single environmental issue can vary greatly by region or country, precluding a one-size-fits-all strategy. Cities from different regions and of different sizes do not share the same environmental problems, nor must they address the same needs in terms of human development. In low-income areas, inadequate provision of water, sanitation and drainage, and the generation of large amounts of solid waste, air pollution and water pollution, can have major environmental impacts and cause a severe health burden for urban residents.

Coastal cities that damage their local ecosystems can render themselves particularly vulnerable to storms and natural disasters. By overexploiting the seas as a source of food and as a location for waste disposal, cities can compromise the benefits offered by their location.

In addition, as a substantial set of data can be taken from national or regional statistical offices, cities from different parts of the world do not have the same ability to monitor the same sectors in the same way.

The age, size and wealth of a city, its regional location and cultural dimensions are all important factors affecting environmental concerns and priorities and potential for action. It is now increasingly clear that the ability to define what can be done largely depends on local and regional contexts.

Local authorities should be empowered to select their own priorities and appropriate indicators to guide their action.

2 Urban environmental assessment: a review of practices and gap analysis

Our analysis of the literature has led to the identification of the urban impacts which would need to be assessed from an environmental point of view and – to a lesser and still theoretical extent – how these impacts could be monitored.

To compare with current practices, we have analysed a range of existing environmental assessment tools with a specific focus on:

- which environmental sectors are monitored
- which indicators are used
- whether local dimensions are taken into account, and if so, how.

The assessment tools and the literature analysed are presented in Annex 2. A synopsis of the sectors and indicators of the most comprehensive indices is given in Table 4.[10]

In the following, the findings are combined to propose:

- a tentative list of environmental sectors which are relevant to cities
- a potential core set of indicators in these sectors
- some ideas on how regional differences could be accounted for.

A gap analysis between the theory and the practice will follow to clarify the differences between what should be done, what is done and what could be done and some proposals for a way forward.

2.1 Sustainable cities: different conceptions, different tools

As pointed out by Clark, when it comes to city performance monitoring, sustainability is a newcomer and is still in the process of being integrated into comprehensive city benchmarking efforts. He recognised that the numerous 'green city' and 'sustainable city' indices proliferating today differ in key aspects of methodology and definition, in part because there is no consensus on the main attributes of a sustainable city and the appropriate metrics (Clark, 2011).

Our analysis confirms these views:

- Most quality of life indices and economics-focused city benchmarks do not currently include environmental or sustainability considerations
- Different indices have different interpretations of environmental performance and sustainability
- Very few tools undertake comprehensive environmental assessment by considering multiple types of ecological impacts.

However, the GEO Cities Reports established by UNEP, UN-Habitat and Parceria 21 provide a comprehensive and detailed methodology. It is the only tool to propose a systematic PSIR approach based on 52 indicators. In particular, a pressure indicator is given for each sector relevant to environmental urban issues (See Annex 2. A.1).

10. Other monitoring tools for cities not described by Clark and presented in the following section are also included in this table.

2.2 Urban Environmental Assessments: Core sectors and indicators

There is no consensus today on the sectors that need to be included in an urban environmental assessment tool. In the first part of this study, we proposed the recognition of seven sectors. A synopsis of how these sectors are covered by the most comprehensive indices developed today is given in Table 4 (see Annex 2). GHG emissions and the energy sector are the most common. The other environmental sectors that are assessed – also to a lesser extent – are: waste recycling, water supply and quality, air quality and green spaces.

From a city point of view, the most pressing environmental challenges are the ones that affect the quality of life of the urban residents. Water supply and pollution, sanitation and drainage, accumulation of solid waste and air pollution define a **core of local urban environmental issues** for local authorities (See Figure 1).

2.2.1 Carbon Cycle

Environmental assessment tools are often geared towards, and sometimes limited to, carbon-reduction and energy efficiency parameters. This limitation reflects the tight links between energy consumption and carbon emissions and illustrates that the issue of climate change has started to be successfully carried into policy making. Indeed, substantial work has been developed in quantifying and understanding GHG emissions (and CO_2 in particular) in cities and obtaining clear indicators that facilitate strategies to compare and monitor policy effectiveness (Hoornweg et al, 2011).

The estimation of major GHG emissions is now routinely done and can be included in a core set of indicators.

However, many different organisations have established different and inconsistent approaches to reporting urban GHG emissions and GHG inventories; so much so that it is almost impossible to compare them (Bader and Bleischwitz, 2009).

In response to the global need for consistency when measuring and reporting GHG emissions, several organisations are developing an open, global and harmonised protocol for quantifying the GHG emissions attributable to cities and territories. This **Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC)** is seen as a critical requirement to support policy and access to finances.

GPC[11] is based on the *International Standard for Determining Greenhouse Gas Emissions for Cities*[12] developed by UNEP, UN-HABITAT and the World Bank. This standard recommends that GHG inventories for cities should follow the principles and methods developed by the IPCC (see Annex 3). It also **advocates that inventories be as complete as possible in order to be consistent with regional and national compilations** (UNEP, UN-HABITAT, World Bank, 2010).

This initiative provides the necessary theoretical ground for harmonisation of indicators in this particular sector and the GPC appears to be a likely candidate for benchmarking in the near future. The cost and feasibility of monitoring GHGs with this protocol will need to be substantiated.

2.2.2 Water resources

This sector is already included in most assessment tools and, as recommended by UN-Habitat, the indicator in use is **water consumption per capita** (UN-Habitat, 2009). This appears to be a common and standardised practice.

The SIEMENS-GCI (Annex 2, §A.2) follows three other parameters in a composite indicator made of two quantitative and two qualitative (water, consumption, water system leakages, water quality policy and water sustainability policy). Share of treated wastewater is also included (in the sanitation sector) following UN-Habitat guidelines. There is no monitoring of water quality.

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11. The Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) is a multi-stakeholder, consensus-based protocol for developing internationally recognised and accepted community-scale GHG accounting and reporting standards. It is the result of a collaboration between ICLEI – Local Governments for Sustainability and C40 Cities Climate Leadership Group; Other core partners that participated in the development of GPC include the World Bank Group, United Nations-HABITAT, United Nations Environment Program, the Organization for Economic Cooperation and Development and the World Resources Institute.
12. www.unep.org/urban_environment/PDFs/InternationalStd-GHG.pdf

The Water Impact Index (Annex 2, §B.1) considers both direct and indirect influences of an activity on water resources.

The Water Impact Index **is the most comprehensive assessment of the impact of human activity on water resources to date and could be used on a voluntary basis for leading municipalities willing to set the scene.**

2.2.3 Solid waste

Solid waste disposal is one of the world's principal urban problems. Improper solid waste disposal puts great polluting pressure on the land; it contaminates aquifers and is harmful to humans. Mitigating its negative impact can prevent atmospheric, water and soil pollution and reduce the incidence of disease.

The water resources sector is also usually included in assessment tools and already standardised. Most tools monitoring this sector follow the UN-Habitat recommendations, namely **solid waste disposal** (UN-habitat, 2009).

2.2.4 Pollutants: Air quality

In addition to CO_2, GEO-CR recommends the monitoring of NOx, SOx and NH_3 emissions.

Air pollutants cause harm to both health and the environment. In particular, SOx, NOx and NH_3 produce acid rain and affect the chemical composition of the soil and of surface water. The main urban sources of air pollution are the burning of fossil fuels (electricity generation, transport, industry and households), industrial processes and solvent use and waste treatment.

Different cities face different issues. For instance, in Europe, the emission of many air pollutants has fallen substantially since 1990, though particulate matter, nitrogen dioxide and ozone in the air have not shown much significant improvement. Air pollution sources are local and priorities differ from one region to the other.[13]

However, air pollution is also a trans-boundary issue. Air pollutants released in one country may be transported in the atmosphere and harm human health and the environment elsewhere. For this reason we have included the relevant indicators in the core set.

Based on GEO-CR, GCIF and BRIDGE initiatives, Annex 4 offers a tentative list of the main atmospheric pollutants that could be monitored by local authorities to guide their actions.

2.2.5 Land use

Land use change has impact on the carbon balance of ecosystems. Land cover types affect energy and water consumption as well as waste and traffic production and GHG emissions (Pauleit and Duhme, 2000).

Three indicators for cities have been identified to monitor soil artificialisation and remediation; land use change from non-urban to urban, green space areas and brownfield remediation.

2.2.6 Nitrogen (N) and phosphorous (P) cycle

This sector has been identified as one of the three key environmental issues at the global level. However, to our knowledge, there is no urban assessment tool that is monitoring the N and P flows in cities despite the important opportunities offered by an urban context. For instance, Beck and colleagues have estimated that as much as 1,700 tonnes of "resourceful" P and 16,600 tonnes of N could be recovered each year in Atlanta's raw wastewater, with a combined annual market value of US$ 22 million as fertiliser (Beck, 2011).

We propose that N and P monitoring in downstream water of cities be part of the core set of indicators.

2.2.7 Biodiversity

When available, biodiversity assessment is often limited to the extent of 'green space area' which is a concept too loose to be useful as it does not refer to suitable habitats. Only three methods evaluate impacts of city activities on urban biodiversity: GEO-CR, Sustainable Cities Index (Forum for the Future, UK) and Corporate Knights – Sustainable Cities (Canada). The Corporate Knights – Sustainable Cities' method addresses the question with a qualitative

13. www.eea.europa.eu/themes/air/intro

and indirect approach. It monitors whether the city has a comprehensive urban biodiversity monitoring program.

Apart from the SCI, which uses the highly aggregated Ecological Footprint concept, the distant impacts are never assessed. In particular, the consumption patterns of city inhabitants form a black hole: the reports which are concerned with consumption monitor local food production, suggesting that the choice of the indicator is more driven by the reduction of GHG emissions than distant impacts on threatened ecosystems.

At the local level, the City Biodiversity Index being developed by the CBD may offer cities a comprehensive dashboard to monitor local impacts on biodiversity. For distant impacts, research is needed to establish a practical approach (see 3.1.3).

2.3 Environmental assessment: Proposal for a two layered nested model

In summary, we have seen that a comprehensive definition of sustainable cities are those which "*contribute to sustainable development within their boundaries, in the region around them, and globally. (…) Sustainable cities not only consider the needs of the population within the geopolitical borders, but also the needs of all people on a global scale and in the future.*"[14]

From a global point of view, the impacts of urban activities outside the boundaries of the territory should be considered to address the true imperatives of sustainable development on a global scale (§1.3). These external impacts correspond to the distant and global impacts described in Table 3. **From a global perspective**, the most urgent environmental issues are to reduce:

- the alarming rate of biodiversity loss
- the emission of GHGs into the atmosphere (in particular CO_2 and CH_4)
- the discharge of N and P in water flows.

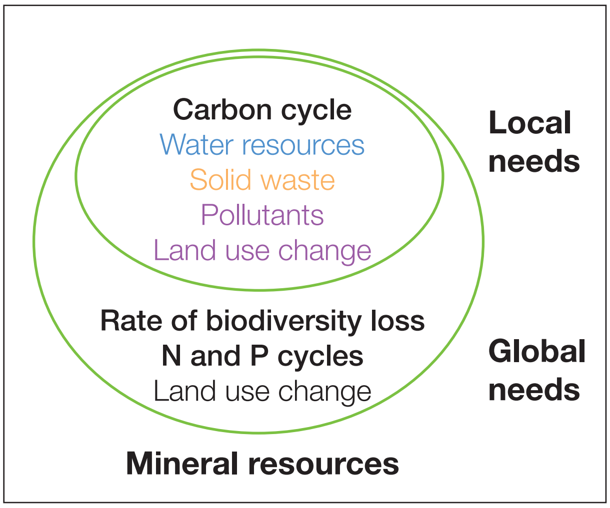
14. McGranahan and Satterthwaite (2003).

However, in practice, none of the tools analysed assess indirect and distant impacts, with the notable exception of GHG emissions. Climate change is the only global issue that is integrated into city performance assessment tools via indicators for carbon-reduction and/or energy efficiency parameters. The environment is thus implicitly perceived as the **local urban environment**, within the boundary of the city, influenced by human activities and impacting on human health.

As illustrated in Figure 2 below, distinction can be made between:

- **Local assessment (internal):**
  The urban environment is assessed within the territory boundary with core indicators to monitor carbon cycle, water resources, waste and pollutants.
- **Global assessment (external):**
  A complementary set of other indicators which would account for the most pressing global issues which are not captured by the core indicators, namely biodiversity erosion, N and P cycle and (global) land use change. This set could be developed and used for pioneering cities that would like to be torchbearers for sustainability monitoring.

Figure 2: **A two-layered nested model for environmental assessment**



3 Recommendations

3.1 Recommendations for future research

3.1.1 Target priority

The seven-sector framework presented here is based on priorities and boundaries that are expected to evolve in the future. These thresholds are rough first estimates, surrounded by major uncertainties and knowledge gaps and are expected to evolve due to scientific progress (Molden, 2009). In particular, the ;pollutant' sector today regroups tens of thousands of chemicals some of which may become priorities tomorrow and/or need dedicated monitoring in specific areas. Research is required to follow these issues and adapt the framework regularly.

3.1.2 Missing sectors

The traditional assessment tools do not cover non-renewable mineral resources such as metals or fossil fuels. Indeed, mineral stock depletions do not contribute to the functioning of ecosystems per se and are beyond the scope of this study.[15] However, because of the broad environmental impacts associated with mineral resource extraction, these issues are key priorities in terms of sustainability and relevant indicators will have to be included in any 'sustainability dashboard'.

In particular, recycling rates of metals are in many cases far lower than their potential for reuse.[16]

Specific research is needed to analyse which indicators would be suitable for monitoring the sustainability of material flows. Recycling rates for key materials are likely to provide a sound basis for such indicators.

3.1.3 Biodiversity, a thorny issue

- If the erosion of biodiversity is the most pressing environmental issue, most of the urban impacts are indirect and distant, through consumption of goods and food, and today there is no approach that can monitor these impacts.

For practical reasons, we have used 'biodiversity' as a category to compare the different indices. However, many other categories, if not all, have their ultimate impacts on ecosystem health and resilience and contribute to biodiversity erosion (see Table 3 for examples). Ocean acidification, land use change, water and air pollution, eutrophication, overfishing or coastal pollution are all human-induced impacts that ultimately degrade ecosystems and contribute to erode biodiversity.

The two main problems are:

- **biodiversity is too aggregated to be a useful concept**
- **distant effects can be very difficult to trace.**

A classification by ecosystem is likely to be useful to assess the impacts of the urban drivers. Partly because most urban activities impact ecosystems rather than affect specific species, and also because the IUCN is working on a Red List of Ecosystems which will provide a useful instrument for macro-economic planning (Rodríguez et al. In press). The RLE may help establish the required mapping of distant impacts.

Developing such methodologies is likely to be complex and would perhaps be helped by focused case studies that trace the impacts of specific resource and waste flows of selected cities on selected ecosystems which are particularly at risk.

15. It is worth noting nonetheless that SCI uses an aggregated indicator on the percentage of waste that is recycled (§ A.7).
16. Less than one-third of the 60 metals studied by the International Resource Panel have an end-of-life recycling rate above 50 per cent and 34 elements are below 1 per cent recycling (UNEP, 2011).

3.1.4 Accounting for out-of-boundary impacts

The external impact of urban activities, both distant and global, will need to be monitored in the future.

The conceptual tools that are available today are essentially limited to GHG emissions. GHG accounting is the most advanced methodology that accounts for out-of-boundaries impacts, both in terms of current practices (and indeed most indexes include one or several indicators on carbon emissions) and theoretical analysis. While it is impractical to quantify all of the emissions associated with the myriad of goods and materials consumed in cities, several out-of-boundary emissions can now be reported in urban GHG inventories including GHG emissions embodied in the food, water, fuels and building materials consumed in cities (UNEP, UN-HABITAT, World Bank, 2010).

To delineate direct and indirect impacts and avoid double counting, the concept of 'scopes' has been developed to track out-of-boundary GHG emissions:[17]

- **Scope 1:** Direct emissions, i.e. all GHGs that are directly emitted within the territory, such as stationary combustion, mobile combustion, process and fugitive emissions
- **Scope 2:** Indirect emissions which are a consequence of activities of the territory such as emissions due to the generation of electricity, district heating, steam and cooling
- **Scope 3:** All other indirect and embodied emissions, such as landfill or compost emissions.

Based on the work done to estimate GHG emissions, it is recommended that a framework be developed to see how this know-how could be adapted to other environmental sectors to track out-of-boundaries impacts, in particular on distant ecosystems.

Here is a proposal for an extended and generic application of the scope concept:

1. *Scope 1:* Direct environmental impacts, i.e. all impacts that are directly caused by the activity within the territory, such as local water and air pollution and destruction of habitat.
2. *Scope 2:* Indirect environmental impacts which are a consequence of activities in the territory, such as the downstream degradation of river and coastal ecosystems resulting from lack of sewage treatment.
3. *Scope 3:* All other indirect and embodied environmental impacts, such as biodiversity loss resulting from the import of food or manufactured goods.

3.1.5 Integration

Environmental sustainability involves a wide range of issues that are highly interconnected and thus difficult to define and compartmentalise in a useful way. Beyond sectors and indicators, there is a need for integrated tools to design a consistent set of targets. These tools would be instrumental in guiding decision-makers through the analysis of synergistic and contradictory effects.

To help decision-making on complex and interconnected issues, an exhaustive dashboard is not sufficient to find optimal solutions. Complex systems analysis and modelling of dynamic interactions are dynamic research areas that have brought biology and medicine to an unprecedented level of integration in just a decade. These sciences are now mature enough to model the different parameters of an urban system and their interactions and to apply the dynamics to build evolution scenarios. Urban studies and decision-makers could benefit greatly from such a conceptual and practical revolution.

In particular, urban metabolism studies are well positioned to deliver a robust framework for local environmental issues. Section B.2 presents the BRIDGE modelling tool which is currently being tested in five European cities. This style of approach has the potential to evaluate urban planning alternatives through several case studies and support sustainable planning strategies based on these evaluations.

17. WRI / WBCSD: The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard: Revised Edition. www.ghgprotocol.org/

3.2 Recommendations for policy making

3.2.1 Indicators: the ideal, the good and the practical

Choosing good indicators is a compromise – the more detailed and comprehensive the indicators are, the more expensive and less practical they become.

Good indicators are not necessarily ideal indicators and indeed most tools reviewed in this study do not follow all the recommendations of §1.2.1. We have selected four criteria as the minimal requirement for indicators to be practical. Indicators should at least be:

- **based on data that is comparable over time**
- **relevant to policy makers (goal-oriented)**
- **simple and easy to monitor**
- **quantitative indicators should be scientifically valid (based on principles of conservation of energy and mass).**

Based on these principles, we propose a list of 17 core indicators (see Annex 4) which are (reasonably) easy to collect and are standardised. This list is complemented by two more resource-intensive indicators which could be used by municipalities at the forefront of sustainability. Figure 3 below gives a schematic representation of how these indicators are distributed along the two layers nested model (§2.3).

3.2.2 Adaptation to local needs

The specific local context of a city can have an important effect on its environmental concerns and on the priorities and potential for action.

For pollutants in particular, local authorities should be offered the appropriate pressure indicators according to their priorities, depending on the local and regional contexts (e.g arsenic contamination in ground water or PM^{10} in the atmosphere).

Several indices account for local parameters via two different approaches:

- The Siemens Green City Index prioritises an adaptation of the sectors and indicators by region. The global set of indicators is slightly different from Europe to North America to Asia. However, within a region all the cities are analysed using the same indicators. **This strategy is best for benchmarking.**
- The GCIF, the GEO-CR, the BRIDGE and the GUO have favoured a more bottom-up approach by designing two sets of indicators – a core set and an optional set. It is for the city to decide which optional indicators correspond best to their needs. **This option is best for the evaluation of individual progress.**

In particular, **the GEO–CR encourages participants to include or create indicators that**

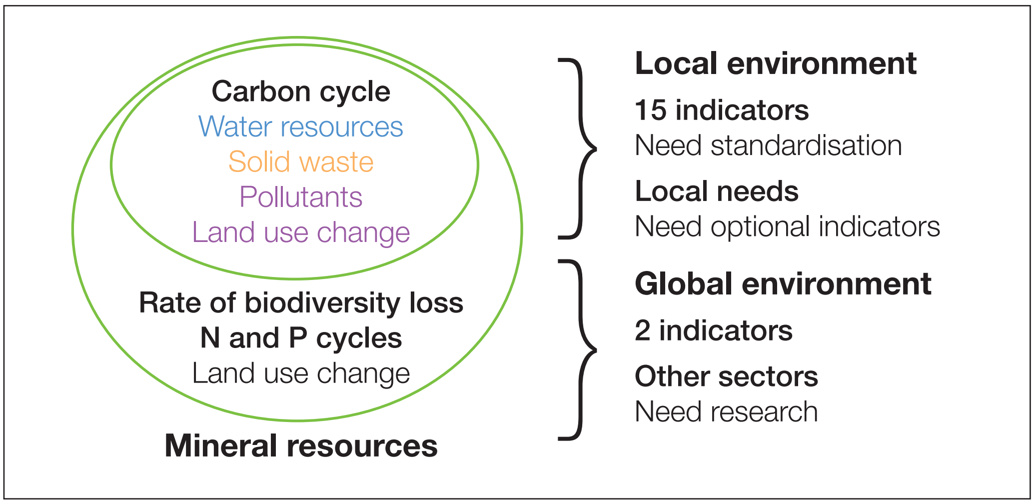


Figure 3: **a schematic representation of how 17 core indicators are distributed along the two layers nested model**

reflect local environmental characteristics so that the report more clearly shows those that are specific to the locality.

The use of such indicators should adhere to the following two general principles:

1. **They should be completely necessary for the report.** *Using many indicators is not recommended as this might confuse users. Being bombarded with information will not help them to understand the phenomenon and might make it more difficult for them to adopt a practical attitude when dealing with the problem.*

2. **They should be clearly described.** *Their use has to be justified, the way they are calculated precisely defined, and an indication should be given about to which urban-development model they belong: pressure, driving forces, state, impact or response.*

This flexibility would be a welcome asset for a generic environmental assessment. In addition to the core set of indicators proposed here, cities should be encouraged and helped to design and use optional indicators adapted to their current needs.

3.2.3 Matching cities

Most municipalities already dedicate significant effort and resources to tracking performance. The Global City Indicator Facility (A.5) is developing a MetroMatch project to share data between similar-sized municipalities in different countries using a common set of indicators, providing a wider context for comparison and exchange of ideas.

As best practices for benchmarks and performance measurements are evolving, this kind of initiative can help cities to lower the costs of their assessment. In particular for global issues, distant effects and comprehensive indexes, matching mechanisms can help local authorities to get a first rough estimate based on similar studies conducted in other cities.

3.2.4 From monitoring to policy making: The Urban Environmental Accords

The Urban Environmental Accords (UEA) is a set of 21 objectives designed to achieve an *"ecologically sustainable, economically dynamic, and socially equitable"* urban future (See B.4). The UEA objectives are based on existing best practices and applied to seven sectors: **energy, waste reduction, urban design, urban nature, transportation, environmental health and water**.

Based on this study a set of complementary actions could extend the Urban Environmental Accords to three priority sectors: Land Use, N, P sectors and Biodiversity.

Land use: An action could be targeted to foster brownfield remediation.

Another could aim at the creation or increasing the size of protected areas managed by the city. Protected areas, when integrated into land use plans, offer practical and tangible solutions to the problems of both species loss and adaptation to climate change.

N, P sectors: Recognising the importance of the eutrophication phenomenon, an action could aim at reducing the annual load of N and P in rivers (when applicable).

Biodiversity: If biodiversity erosion does not lend itself to the development of indicators, measures can nevertheless be taken to alleviate some of the pressures exerted by cities and to monitor the impact of policy.

Some UEA 21 actions, for instance, items 5, 16 and 17, aim at changing consumption patterns to reduce toxicity and waste. Similar actions could be designed to encourage sustainable production and consumption and contribute to reducing the distant pressures exerted by cities.

The consumption of food and goods in the city is a major driver that results in deforestation, particularly in tropical regions. If a city cannot monitor today the origin of all the products that contribute to its metabolism, measures can nevertheless be taken to encourage citizens to opt for FSC[18] certified products.

The recent success in banning shark fin products from prestigious hotels and official banquets in China

18. The Forest Stewardship Council is an independent, non-governmental, not-for-profit organisation established to promote the responsible management of the world's forests.

and Hong Kong[19] demonstrates that change of life style is a potent driver for sustainability.

Beyond indicators, awareness, political will and sound decision-making remain the best recipe for developing practical and efficient solutions.

3.3 Conclusion: from environmental assessment to sustainable city

The objective of this paper was to examine the opportunities for developing a global consensus on a method to assess the environmental performance of cities. If a commonly accepted framework for city environmental indicators and reporting systems is still a distant goal, progress has still been significant.

A shared vision of the environmental issues instructed by science has emerged. In particular, priorities between issues at the global and local levels can now be defined to inform society's capacity to improve its environmental performance over time.

In an attempt to synthesise the huge range of literature on the subject we propose a core set of pressure indicators which can serve as a basis for a local urban assessment framework. Much work remains to be done to integrate distant and global impacts of cities' activities.

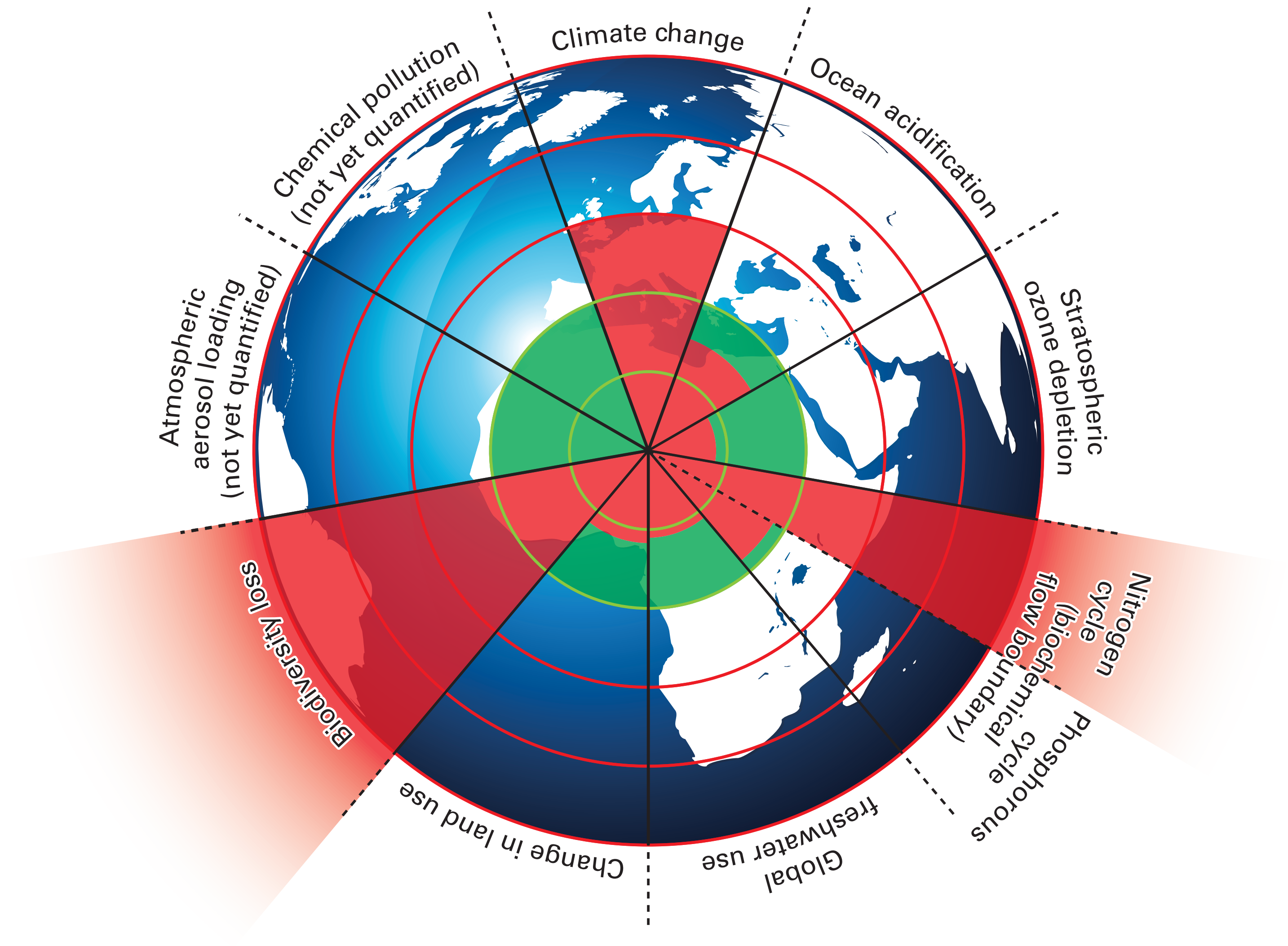
Finally, assessing the environmental performance of cities is necessary but is not sufficient to qualify their overall sustainability. Future work is needed to include the social and economic dimensions and define how their integration can seize the opportunities and address the challenges.

19. www.asianscientist.com/topnews/hongkong-and-shanghai-hotels-peninsula-hotels-ban-shark-fin-products-2011/
http://edition.cnn.com/2012/07/03/world/asia/china-shark-fin/index.html

Annex 1: Planetary boundaries and the safe operating space

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorous cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorous cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5-9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by human (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	To be determined		
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disruptors, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof	To be determined		
Boundaries for processes in red have been crossed. Data sources: ref. 10 and supplementary information				

The green circle represents the proposed safe operating space for each of the nine components of Earth Systems. Red shading denotes an estimate of the current status of each variable, due to human impacts. The rates of biodiversity loss, climate change and human interference with the nitrogen cycle are far beyond the safe operating space (from Rockstrom et al, 2009).



Annex 2: Environmental assessment and sustainability index for cities: a brief review

This annex presents a brief review of how environmental performance is assessed for cities. Among the many different tools available, one should distinguish between:

- **Assessments** which describe the impact of the city
- **Benchmarks** which are designed to compare cities' performance
- **Indicators** which aim at guiding creative policy.

A. Comprehensive tools for cities

Greg Clark has reviewed 65 different reports, composite benchmarks and single-variable rankings which span a wide compass of different outlooks on cities, ranging from a global outlook on cities in the international economy, to micro-studies of individual urban variables (see Clark, 2011, pp 5-6 for the list of the initiatives studied). This work extends its analysis to other comprehensive tools focused on environmental performance of cities which are presented below. Table 4 presents a synopsis of the sectors and indicators used in the eight most comprehensive tools we have analysed.

Table 4: **Synopsis of the sectors and indicators**

	GEO Cities Report	Siemens European GCI	Sustainable Cities (CK)	Sustain Lane (US)	GCIF	Global Urban Observatory	European Smart Cities	Sustainable Cities Index (FftF)
Local Needs								
Carbon Cycle/Energy	2	8 (6)	3 (3)	4	0;1	1	2	.(1)
Water resources	4	3 (1)	1 (1)	1	3;3	2	1	
Solid Waste	2	2 (1)	2		2;5	1		1
Pollutants	4	4 (1)	1	1	1	5	2	1
Land Use Change	3	. (1)	1	2	0;1	1	1	1
Biodiversity loss (local)	2		. (1)	1			.(1)	1
Global Needs								
Biodiversity loss (distant)								.(1)
N and P Cycle								
Land Use Change								.(1)
Mineral Resources								1

In accordance with Figures 1 and 2, Carbon Cycle is regarded as a local need here because the issue is interwoven with energy efficiency, transport and building policies. The qualitative indicators are indicated in brackets when applicable. In the case of the Sustainable Cities Index, the Ecological Footprint is intended to capture all the environmental impacts of the city including the distant ones. A qualitative indicator has been added to carbon cycle biodiversity loss and land use change. For GCIF, the numbers of core and supporting indicators are presented such as: (core; supporting).

A.1 The GEO Cities Reports

The GEO Cities Reports (GEO-CR)[20] developed by UNEP, UN-HABITAT and Consorcio Parceria 21 provide comprehensive guidelines on how to assess the state of the environment and how to prepare periodic state-of-the-environment reports. GEO-CR uses a harmonised methodology and a set of indicators for decision-making by the public authority and other local stakeholders.

Key features:
Sectors: The GEO-CR is the most comprehensive assessment tool. It proposes indicators in all the sectors identified (1.3.4) except the N and P cycles (which is an orphan sector).

Indicators: The GEO-CR is the only tool to propose a systematic PSIR approach based on 52 indicators, (14 for pressure, 8 for state, 15 for impact, 15 for responses, see detailed list pp 87-89). When applicable, these indicators follow the guidelines from UN-Habitat (2009). These indicators are presented in three different tables:

- Basic indicators (pressures and states)
- Impacts indicators (e.g. loss of urban attraction, public health cost etc)
- Response indicators (e.g. environmental education, investment in drainage networks etc).

The relevant indicators for this study are:

- **Carbon cycle:** energy consumption per capita; Motorisation Index
- **Water resources:** total volume of untreated sewage, water consumption per capita, water shortages, quality of water supply
- **Pollutants:** air quality, acid rain producing gas emissions, atmospheric emissions, contaminated sites
- **Solid waste:** solid waste production, solid waste disposal
- **Biodiversity loss**: extinct or endangered species, known species
- **Land use change:** reduction of vegetal cover, land change from non-urban to urban.

Limits: Surprisingly, carbon cycle indicators are indirect and unconventional and GHG emissions are not covered. None of the indicators address distant impacts of the city on the environment.

Regional dimensions: The GEO–CR is a goal-oriented and user-driven tool. It encourages the inclusion or creation of indicators that reflect local ecosystem characteristics so that the report more clearly shows those that are specific to the locality. This model is included in the recommendations.

20. www.pnuma.org/deat1/pdf/Metho_GEOCitiesinddOK.pdf

A.2 Siemens Green City Index

The Green City Indices (GCI) assess and compare the environmental performance of cities **at a regional level**.[21] Six GC indices have been released so far: Asia (22 cities), Europe (30 cities), Germany, Latin America, US and Canada (27 cities) and Africa (15 cities).

The Index is composed of aggregate scores of all the underlying indicators. About half of the indicators are quantitative and measure how a city currently performs – e.g. a city's water leakage or waste production (State and Pressure).

The remaining qualitative indicators assess policies and plans (Response). For example, the 'greenhouse gas (GHG) monitoring' indicator assesses whether cities regularly monitor GHG emissions and publish their findings every one to three years. This indicator seems to be a better measure of aspiration than of performance.

In Table 2, GCI for European cities has been analysed in greater detail. The methodology is based on 16 quantitative and 14 qualitative indicators.[22]

GCI is by far the most comprehensive index on energy efficiency, with no less than 14 indicators directly or indirectly related to energy:

> CO_2 emissions, CO_2 intensity, CO_2 reduction strategy, energy consumption, energy, intensity, renewable energy consumption, clean and efficient energy policies, energy consumption of residential buildings, energy-efficient buildings standards, energy-efficient buildings initiatives, use of non-car transport, size of non-car transport network, green transport promotion and congestion reduction policies.

The other indicators monitor water and waste quantities, air quality (nitrogen dioxide, ozone, particulate matter, sulphur dioxide and clean air policies).

Limits: The GCI is essentially geared towards patterns of energy consumption. Regarding the carbon cycle, it is worth noting that CO_2 is the only GHG analysed. Land use, N and P and biodiversity are orphan sectors. The distant and global impacts of cities are not taken into account.

21. www.siemens.com/entry/cc/en/greencityindex.htm
22. www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_en.pdf

Key features: The Siemens GCI assesses environmental performance of cities with tailored indicators at the regional level. This strategy has the potential to address three key issues:

- different cities are not facing the same challenges
- different cities are not contributing to the same issues
- data availability and monitoring capacities vary enormously from city to city.

How are the regional specificities taken into account? How much do the different GCIs differ?
The number of individual indicators varies slightly between the different GCIs (29 for Asian cities, 30 for European cities, 31 for North American Cities, 25 for African cities) and cities are compared across very similar categories:

Asia GCI	US Canada
Energy and CO_2	Energy
	CO_2
Land use and buildings	Land use
	Buildings
Transport	Transport
Waste	Waste
Water	Water
Sanitation	
Air quality	Air quality
Environmental governance	Environmental governance

Data availability: To be applicable to different regions, the GCIs have been adapted to accommodate variations in data quality and availability and environmental challenges specific to the region. The availability and comparability of data across cities is limited in Asia compared to Europe or North America. The GCI Asia has sought to include the most recent data available for each city even though the comparison points can be several years apart and gaps were filled with estimates.

A.3 Canada's most sustainable cities – Corporate Knights

The study defines sustainability as the *"ability of individuals and communities to flourish without contributing to the progressive degradation of the human and natural systems on which we depend"*. The report ranked 17 cities – the most populous centres in each Canadian province and territory and the ten most populous cities in the country – according to five themes: ecological integrity, economic security, governance & empowerment, infrastructure & built environment and social well-being.[23] The total number of indicators analysed for all categories was reduced from 63 to 28 to avoid overlap and create a manageable amount of data. The Sector **Ecological Integrity** is composed of six indicators: *water consumption, green space, waste diversion (residential), air quality, GHG emission reduction* and *water quality in and out*. This year a new descriptive indicator has been added: urban biodiversity monitoring program.

*Note***:** this methodology includes six different indicators in the carbon cycle sector: three of these are quantitative: GHG emission reduction, density and green transportation use. The three others are qualitative in nature: municipal GHG emission reduction target, green buildings and renewable energy.

A.4 Sustain Lane

The 2008 Sustain Lane US City Rankings provide comprehensive coverage of the greening of the 50 most populous American cities. The report benchmarks each city's performance in 16 areas of urban sustainability,[24] and monitors transportation mode share and congestion, air quality, water quality and supply and green building.

Two indicators in particular distinguish the Sustain Lane initiative as they monitor sectors that are seldom covered:

- **Local food and agriculture:** *Number of community gardens and number of farmers' markets per city.*
- **Planning and land use:** Urban sprawl data and percentage of city land area devoted to parks.

Note: These two indicators do not account for distant impacts.

23. www.corporateknights.ca/report/2011-most-sustainable-cities-canada/methodology

24. www.sustainlane.com/us-city-rankings/articles/the-sustainlane-methodology/JXICFDNN7CF9H7MD7P8USMW9Y78J

A.5 Global City Indicators Facility (GCIF)

The Global City Indicators Program is structured around 22 'themes' organised into two categories that measure a range of city services and quality of life factors.

Environmental assessment: GCIF primarily focuses on the social and economic parameters of the cities. The environmental assessment is composed of the following core indicators: PM10 concentration, percentage of solid waste collection, percentage of solid waste that is recycled, percentage of city population with potable water supply service and domestic water consumption per capita.[25]

GHG emissions and surface of urban green area are also available as supporting indicators. Future indicators currently under discussion include:

- Share of renewable energy use out of primary energy supply
- Residential energy use per household by types of energy
- Total energy use index
- Water quality (relative to national standards and boiled water advisories)
- Water quality index.

Regional component: The GCIF recognises the differences in resources and capabilities between developed and developing world cities. The overall set of 115 indicators is divided into 31 'core' indicators which all cities participating in the initiative are expected to report on, and 43 'supporting' indicators which all cities are encouraged, but not expected, to report on. An additional 41 'profile' indicators provide basic statistics and background information to help cities determine which cities are of interest for comparisons.

A key feature of the GCIF initiative is the high level of standardisation of indicators. This provides a mechanism for municipalities to share technical information on improving performance relative to identified benchmarks. The MetroMatch project will enable willing municipal participants to be listed in a web-based, 'MetroMatch Directory' with information about their position and the expertise that they possess.[26]

25. www.cityindicators.org/themes.aspx
26. www.cityindicators.org/CityMatch.aspx

A.6 Global Urban Observatory

The Global Urban Observatory (GUO)[27] was established by UN-Habitat, governments, local authorities and organisations to develop and apply policy-oriented urban indicators, statistics and other urban information. Urban indicators are regularly collected in a sample of cities worldwide to report on progress in 20 key areas. The areas relevant for this study are: land use, water, waste management and transport. The seven corresponding indicators are planned settlements, water consumption, water price, air pollution*, waste water treatment, solid waste disposal, recycling rate and transport mode share.

* where Air pollution is a composite indicator corresponding to the number of days per annum that WHO standards are exceeded, and average annual measured concentrations for sulphur dioxide, ozone, carbon monoxide, nitrogen dioxide and lead.

Regional dimensions: Indicators are subdivided into key indicators and flexible indicators that allow for some tailoring between cities.

27. ww2.unhabitat.org/programmes/guo/guo_guide.asp

A.7 European Smart Cities

The European Smart City (ESC)[28] is a ranking instrument that targets European mid-sized cities with populations under 500,000. ESC is based on six characteristics: economy, people, governance, mobility, living and environment. In total, 74 indicators are used for the evaluation, 48 of which (65%) are based on local or regional data, the other 26 (35%) being based on national data.

The "Smart Environment" sector assesses the following:

- **attractiveness of natural conditions** (sunshine and green space share)
- **pollution** (summer smog, particulate matter, fatal chronic lower respiratory diseases)
- **environmental protection** (individual efforts on protecting nature, opinion on nature protection)
- **sustainable resource management** (use of water per GDP, use of electricity per GDP).[29]

In addition the 'smart mobility' includes an indicator for green mobility share.

All these indicators are based on regional data except the environmental protection indicators which are national. All of these indicators are user-oriented and most of them relate to urban environmental quality issues. Water per GDP and electricity per GDP are proxies for the carbon cycle and water resource sectors respectively.

28. www.smart-cities.eu/download/smart_cities_final_report.pdf
29. www.smart-cities.eu/download/results_indicators.pdf

A.8 Sustainable Cities Index

The SCI is an annual index developed by Forum for the Future for General Electric to track progress on sustainability in Britain's 20 largest cities. This methodology has also been adapted by the Australian Conservation Foundation. The SCI is relies on a small number of highly integrated indices to *"give an insight into the sustainability of cities rather than an exhaustive representation"*.[30] Indicators were selected for their public availability and comparability across cities. The SCI is composed of 13 indicators along three strands:

- environmental performance
- quality of life
- readiness for the challenges of the future.

Of interest here, the environmental performance is monitored through:

- NO_2 concentration (air quality)
- Ecological footprint (assess the impact of products consumed in the local authority, see B.3)
- Household waste collected per capita
- Biodiversity (percentage of local nature sites that have undergone conservation management).

The future-proofing basket includes:

- A qualitative composite indicator of how cities prepare for, adapt to, and mitigate the impact of climate change
- Percentage of collected household waste reused, recycled or composted.

The oversimplification and hyper-aggregation of the ecological footprint (EF) bring drawbacks. The EF, by (supposedly) capturing all the environ-mental impacts of the city, does so in a complex, aggregated, opaque and qualitative way which makes it difficult to prioritise action and design efficient policies (see § B3).

Nonetheless, the SCI is the only index which measures the distant impacts of consumption within the city. This is a remarkable approach which takes advantage of the fact that a lot of EF data are available for cities in the UK allowing for efficient benchmarking. It is also the only analysed tool that includes a parameter on recycling and monitoring mineral resources.

30. www.forumforthefuture.org/sites/default/files/images/Forum/Projects/Sustainable_Cities_Index/Sustainable_Cities_Index_2010_FINAL_15-10-10.pdf

B. Other methodologies

B.1 Urban Metabolism

Urban Metabolism is a model that facilitates the description and analysis of the flows of materials and energy within cities. A city is a large group of living organisms. As such, it obeys physical and biological laws and the activities of a city – the 'urban metabolism' – generates two different types of environmental impact: the city takes resources from the environment (inputs) and produces different types of waste (outputs) which are variously assimilated by the environment. The inputs can cause depletion of resources and the outputs can generate toxicity and contribute to the depletion of resources (e.g. groundwater pollution). Outputs can also have direct impact on the health and well-being of people (e.g. local air and water pollution). Indeed, Abel Wolman fathered the concept of urban metabolism for practical reasons. He was particularly concerned with air pollution and other wastes produced in US cities (see Kennedy et al, 2011 for a review).

Todays' cities have large linear metabolisms characterised by high flows of energy and materials. The study of urban metabolism quantifies the inputs, outputs and storage of energy, water, nutrients, materials and wastes for an urban region.

This approach provides a sound basis for identifying and monitoring the key parameters of the city's local environmental impacts. By tracing the flows, it also provides a design tool that can be used to close loops, thus reducing the input of resources and output of wastes.

However, today the urban metabolism concept presents several shortcomings:

- Little information is usually provided in terms of how city activities might change aspects of environmental quality or how this might relate to basic concepts of environmental sustainability such as resilience or carrying capacity (Minx et al, 2011).
- Even though considerable information is available at the city level, data availability is fragmented, data are of different types and refer to different delineations of the urban system (Minx et al, 2011).
- In addition, the data situation can vary considerably across countries and a standard classification system for stocks and flows in the urban metabolism is still much needed (see Kennedy et al, 2011).

Finally, though the urban metabolism approach provides a powerful method for modelling the flows of energy and chemical elements, it cannot be used to track the effects on living organisms.

B.2 The Bridge project

BRIDGE is a EU funded research project. Its main goal is to develop a Decision Support System (DSS) which uses a Geographic Information System (GIS) to model land use change and energy, water, carbon and air pollution fluxes and instruct urban planning.

Urban metabolic studies are usually top-down approaches that assess the inputs and outputs of materials, water, energy, etc. from a city, or compare the metabolic process of several cities (see A.8a). Recent advances in biophysical sciences have led to new methods of estimating energy, water, carbon and pollutant fluxes. BRIDGE is a bottom-up approach based on quantitative estimates of urban metabolism components at local scale, considering the urban metabolism as the 3D exchange and transformation of energy and matter between a city and its environment.

Energy and water fluxes are measured and modelled at a local scale. The fluxes of carbon and pollutants are modelled and their spatio-temporal distributions are estimated. These fluxes are simulated in a 3D context and also dynamically and the output of these models leads to indicators which define the state of the urban environment.

The Bridge methodology is currently being tested in Helsinki, London, Athens, Firenze and Gliwice. Preliminary results are available on the BRIDGE website.[31]

This modelling approach offers interesting perspectives for the modelled sectors, namely air pollutants, GHG emissions, water and energy.

Currently the model does not support other sectors and is restricted to local effects only.

31. http://bridge-fp7.eu/

Strengths and weaknesses of the methodological approach, based on the experiences made in Europe.

Strengths	Weaknesses
There are already many people involved in EF calculations. The methodological approach is becoming well known and there is now also a search for a common methodology. EF has the ability to communicate with the individual, as well as with politicians and environmental managers. It can be used at all levels and in all sectors. EF is well known and its advantages have been documented. EF might also be characterised as a sustainable development indicator, which not only tells us what the demand is, but also in which direction we should be moving. WWFs adoption of EF through the use of the Footprint of Nations calculations (Wackernagel et al) is strengthening the approach. Regional authorities, e.g. Wales in the UK, have also adopted the concept by integrating the perspective in regional development strategies. EF tells us what to do next. It illustrates strategies for change by presenting the key components of consumption, and thereby the potential for change by different efforts. The effectiveness of changes in energy sources, production systems, transportation, dematerialisation, bio-production etc, becomes visible.	EF answers questions that have in fact not yet been posed by the municipalities themselves. On what level should it be used and what is the purpose of having it? The compound approach is trying to compete with economic indicators. This could be a blind alley. The approach does not give any revolutionary new information to the municipalities. Energy is a problem: The consumption of energy is becoming a more and more important question for society, but EF does not point towards specific energy decisions and changes of policy in this area of concern. EF at the regional level: the concept does not focus very much on the possibilities at regional level. This is partly a result of the lack of access to local data. There is a lack of transparency: The calculations are complex and often not accessible for the potential users of the results. The production side of the process is only marginally brought in. Environmental quality or degradation is not treated in the approach. Neither does EF give insights into these matters, nor is it a tool for change. To become an indicator for sustainability, the concept lacks several of the major dimensions of the Sustainable Development perspective. EF does not include social/economical aspects, e.g. the question of poverty. As it is now calculated, rich countries may come out positively on 'national ecological deficit' (comparing national EF with existing national biocapacity), while poor countries in the south might end up with a negative 'national ecological deficit'. This picture turns the focus of the discussion away from over-consumption in the south and represents a weakness of the approach. EF might become a tool for scenario development but never for realistic projections.

Source: Program for Research and Documentation for a Sustainable Society
www.prosus.uio.no/english/sus_dev/tools/oslows/1.htm

B.3 Ecological Footprint

The ecological footprint (EF) was originally conceived as a simple method for comparing the sustainability of resource use among different populations. **EF is thus a benchmarking tool.** EF represents the amount of biologically productive land required to supply the natural resources and to assimilate the associated waste of a given population (Wackernagel and Rees, 1995).

It is a system that can work at a variety of scales, from individual to global, and in particular, EF methods have been applied to cities. The equivalent areas of ecosystems for sustaining cities are typically one to two orders of magnitude greater than the areas of the cities themselves (see Kennedy et al, 2007 and reference therein).

By drawing a direct link between consumption and land, the ecological footprint has been successful in capturing the public's attention and is generally acknowledged as a valuable educational tool.

However, a number of researchers have criticised the oversimplification and hyper-aggregation of the EF. For instance, EF does not reveal where impacts really occur, what the nature and severity of these impacts is and how these impacts compare with the self-repair capability of the respective ecosystem. The original EF has been perceived as too aggregated to explain the specific reasons for unsustainability and to formulate appropriate policy responses (see Lenzen and Murray, 2003 for a review and references therein). Development of and debate about the method is ongoing.

B.4 The Urban Environmental Accords: Environment in practice for Cities

The Urban Environmental Accords (UEA) is a set of 21 objectives designed to achieve an "ecologically sustainable, economically dynamic, and socially equitable" urban future. The UEA objectives are based on existing best practices and applied to seven sectors: energy, waste reduction, urban design, urban nature, transportation, environmental health and water. These sectors, designed for urban policies have some correspondences with the environmental sectors proposed for monitoring (§1.3.4): three of these sectors target GHG emissions reductions (energy, urban design and transportation); two others have direct counterparts (water and waste). An additional sector, environmental health, corresponds in part to the pollutants sector.

C. Comprehensive indices by sectors

C.1 The City Biodiversity Index

The City Biodiversity Index is currently being developed by the Convention on Biological Diversity.[32]

This index aims to quantitatively assess the biodiversity in cities and comprises 23 indicators in three components:

- The first component focuses on different aspects of native biodiversity, in particular what native biodiversity is found in the city, how it is conserved, what are its threats, etc.

The second component concentrates on the ecosystem services provided by native biodiversity in the city, including those pertaining to regulation of water, carbon storage and recreational and educational services.

The third component is concerned with the governance and management of biodiversity, encompassing budget allocation, institutional set-ups, number of biodiversity-related projects, public awareness programmes and administrative procedures, etc.

Regional specifics: Cities in the temperate region inherently have a lower biodiversity than cities in the tropical region. The age of the cities, human intervention and other processes of succession could also be factors affecting the biodiversity richness of cities. City size is also an important factor in determining biodiversity richness. To ensure fairness and reduce bias, it was agreed that the total number of ecosystems and total number of specific species be listed in the profile of each city.

The index has been developed very recently and is not yet finalised. It is currently being tested by more than 100 cities. It is the most comprehensive index developed for urban biodiversity and includes regional dimensions. It does not assess the distant impacts for which a methodology is still to be developed.

32. www.cbd.int/authorities/doc/User's%20Manual-for-the-City-Biodiversity-Index27Sept2010.pdf

C.2 The Water Impact Index

The Water Impact Index[33] is the first indicator enabling a **comprehensive assessment of the impact of human activity on water resources**.

The Water Impact Index expands on existing volume-based water measurement tools by incorporating both resource stress and water quality. It examines the impact of human activity on water resources and provides a methodology for establishing positive and negative implications about how water resources are managed.

The Water Impact Index considers both direct and indirect influences of an activity from 'cradle to grave' – whether managing a textile production facility or a wastewater treatment facility. It incorporates the volume and quality of the water extracted and released back into the environment and adds the Water Stress Index (which accounts for the level of stress on the resource). This index assesses the water impact – and it includes indirect elements from the production chain such as energy, raw materials, chemicals and waste generated.

This tool can help cities plan long-term projects and better understand sustainable approaches to ensure long-term water supplies and healthy water ecosystems.

33. www.veoliawaterna.com/north-america-water/ressources/documents/1/10975,Water_Impact_Index-White_Paper.pdf

Annex 3: IPCC guidelines for carbon

The 2006 IPCC guidelines require national GHG inventories to be transparent, consistent, comparable, complete and accurate (IPCC, 2006):

"Transparency: There is sufficient and clear documentation such that individuals or groups other than the inventory compilers can understand how the inventory was compiled and can assure themselves that it meets the good practice requirements for national greenhouse gas emissions inventories […].

Completeness: Estimates are reported for all relevant categories of sources and sinks and gases. Geographic areas within the scope of the national greenhouse gas inventory are recommended in these guidelines. Where elements are missing, their absence should be clearly documented together with a justification for exclusion […].

Consistency: Estimates for different inventory years, gases and categories are made in such a way that differences in the results between years and categories reflect real differences in emissions. Inventory annual trends, as far as possible, should be calculated using the same method and data sources in all years and should aim to reflect the real annual fluctuations in emissions or removals and not be subject to changes resulting from methodological differences […].

Comparability: The national greenhouse gas inventory is reported in a way that allows it to be compared with national greenhouse gas inventories for other countries. This comparability should be reflected in an appropriate choice of key categories […], and in the use of the reporting guidance and tables and use of the classification and definition of categories of emissions and removals […].

Accuracy: The national greenhouse gas inventory contains neither over- nor under-estimates so far as can be judged. This means endeavouring to remove bias from the inventory estimates […]."

Annex 4: Proposed set of indicators

This tentative list of 17 core indicators (see opposite) has been compiled from the GEO Cities Reports, the UN-Habitat guidelines for urban indicators, the GCIF and the BRIDGE initiatives. They all abide by the four criteria defined at §3.2.1, namely they are:

- based on data that is comparable over time
- scientifically valid (based on principles of conservation of energy and mass)
- relevant to policy makers (goal-oriented)
- simple and easy to monitor.

These indicators monitor different variables across all sectors relevant to local environmental assessment. This list is a tentative one and aims to serve as a basis for discussion. Feedback from practitioners and scientists during the piloting phase will be needed to refine and test a practical set.

This list is complemented by two discretionary indicators (CBI and WII) which are comprehensive but are resource-intensive to manipulate. WII is already available, while CBI is still in development (See Annex 2, section B).

The proposed indicators are organised by sectors and objectives.

Core Indicators

Carbon cycle
Objectives: Mitigate climate change and ocean acidification

1. Emission of CO_2 (tonnes / per capita / per year)
2. Emission of CH_4 (tonnes / per capita / per year)
3. Percentage of energy from renewable energy sources (% KWh of total)

Pollutants
Objectives: Improve air quality

4. Emission of thoracic particles PM_{10} (µg/m^3)
5. Emission of fine particles $PM_{2.5}$ (µg/m^3)
6. NOx (tonnes / per capita / per year)
7. SOx (tonnes / per capita / per year)
8. NH_3 (tonnes / per capita / per year)

Water resources
Objectives: Protect water resources, riverine and coastal ecosystems and reduce urban pollution

9. Water consumption per capita (m^3/ per capita / per year)
10. Wastewater treated: percentage of all wastewater undergoing treatment (% / per year)

Solid waste
Objectives: Reduce urban pollution, protect riverine and coastal ecosystems

11. Total solid waste produced (tonnes / per capita / year)
12. Solid waste disposal. Percentage of solid waste: a) disposed to sanitary landfill; b) incinerated and burned openly; c) disposed to open dump; d) recycled; (% / year)

Land use change
Objectives: Mitigate artificialisation of land, protect biodiversity and remediate soil pollution

13. Land use change from non-urban to urban. Area artificialised per year (km^2 / year)
14. Protected area relevant for biodiversity conservation managed by the city (km^2).
15. Brownfield remediation. Area of brownfield remediated per year (km^2/ year)

N and P cycle
Objectives: Mitigate downstream eutrophication

16. Annual load of nitrates in rivers (tonnes/year)
17. Annual load of phosphorous in rivers (tonnes/year)

Note: the two first indicators (carbon cycle and pollutants) would be combined if the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) were applied (see §2.2.1).

Discretionary Indicators

18. City Biodiversity Index (B.1)
19. Water Impact Index (B.2)

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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.

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Effective development of city-regions is a major challenge and requires reliable and pertinent indicators to guide planners' actions and monitor progress. The large number of 'green city' and 'sustainable city' indices that are flourishing today differ in key aspects of methodology and definition, in part because there is no consensus on the main attributes of a sustainable city and the appropriate metrics.

While a range of indicators and reporting systems may be an asset reflecting the unique needs of each community, it also presents a significant challenge to designing a common or standardised sustainability indicator framework and developing database and reporting protocols.

The objective of this paper was to examine the opportunities for developing a global consensus on a method to assess the environmental performance of cities. For this study, a variety of conceptual and actual sustainability and environmental reporting systems at the national and community/municipal level were analysed. Their strengths and weaknesses were evaluated in the face of current challenges.

This study finds that there is no consensus about the different sectors that must be monitored to assess cities' environmental performance. A second finding is that the environmental issues are strikingly different at the local and global level: for cities, the most pressing environmental challenges are those that affect the quality of life of urban residents. A two-layered nested model combining local and global assessments is thus proposed to account for these differences.

Finally, this study also finds that while a commonly accepted framework for city environmental indicators and reporting systems is still a distant goal, progress has been significant. A shared vision of the environmental issues instructed by science has emerged. In particular, priorities between issues at the global and local level can now be defined to inform society's capacity to improve its environmental performance over time.

DTI/1634/PA