SUSTAINABLE CITIES

Assessing the Performance and Practice of Urban Environments

Edited by
Pierre Laconte and Chris Gossop

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CHAPTER 6

ECOLOGICAL FOOTPRINT ANALYSIS: ASSESSING URBAN SUSTAINABILITY

William E. Rees

Half the human family already lives in cities and the United Nations projects that urban populations will increase by an additional 2.9 billion in the next four decades.[1] *This increase alone is equivalent to the total accumulation of people on Earth in the entire history of Homo sapiens up until 1957! This greatest of all human migrations underscores the fact that there can be no global sustainability without urban sustainability.*

The purpose of this chapter, therefore, is to suggest a framework to examine prospects for urban sustainability. In particular, the author explores ecological footprint analysis as an essential tool for assessing the sustainability of cities. His main focus is unapologetically on the biophysical dimensions of urban futures for two reasons. First, until relatively recently, most urban scholarship dealt with cities solely as cultural, social, economic or engineered environments. The fact that cities are also complex biophysical systems subject to natural laws has been all but ignored. Second, despite this scholarly vacuum, biophysical sustainability is essential for, and arguably prerequisite to, social, cultural and economic sustainability. It is possible to envisage fully functional ecosystems without cities but there can be no cities in the absence of functional ecosystems[2]

Biophysical sustainability: not that difficult a concept

Despite the endless debate on the definition and meaning of sustainability, on one level the concept is quite simple. Something (e.g. an individual, a city, an ecosystem, the entire human enterprise) is sustainable if it can continue to function in its present state and existing configuration indefinitely.

From this perspective, the human enterprise, as presently configured, is clearly *un*sustainable. Agriculture depletes arable lands 10–30 times faster than soils regenerate; fishers are overharvesting 75 per cent of the world's fish stocks; the oceans are acidifying; agricultural and urban run-off have created large ocean dead-zones that are expanding in number and area; climate change is upon us and greenhouse gases continue to accumulate – the list goes on. What all such data indicate is that the growth of the human economy is currently being funded, in part, through the liquidation of so-called 'natural capital', the self-producing, replenishable and non-renewable natural resources that constitute the material basis of human existence.

Because of the sheer volume of the original endowment of natural capital, humanity can remain in an unsustainable state of overshoot for a considerable period of time. But there are limits. Humans are depleting in decades various natural capital stocks, ranging from tropical forest to petroleum, which required thousands or millions of years to accumulate in the ecosphere. Since reliable supplies of natural capital are pre-requisite to the growth and maintenance of the human enterprise, it is clear that the latter cannot continue 'to function in its present state and configuration indefinitely'. Ominously, while the biophysical and material basis of civilisation is in decline, both the human population and *per capita* material demands are increasing.

Let's be clear. From the biophysical perspective the proximate driver of unsustainability is energy and material consumption. Of course, some consumption is necessary. As biological entities, all people are 'obligate consumers' – a minimal amount of material throughput is necessary merely to maintain any complex system. The problem is that we have 'socially constructed' a global, capitalist, economic system that assumes continuous manufactured capital accumulation and is therefore dependent on continuous material growth. The resultant resource scarcity (depletion) and pollution are therefore merely the symptoms of a greater malaise – gross human ecological dysfunction exercised through the economic process. Material demands stemming from the sheer scale of the human enterprise threaten permanently to undermine the functional integrity of the ecosphere. This is the context from which we must consider prospects for urban sustainability.

Cities as dissipative structures

Both cities and the economic process are subject to natural laws, the most critical of which is the second law of thermodynamics. The second law states that any process occurring in an *isolated* system (one unable to import energy or matter from its environment) increases the entropy of that system. By this we mean that each successive change in an isolated system depletes its resources, reduces internal gradients, simplifies its structure and otherwise increases the 'randomness' of that system. In effect, isolated systems cannibalise themselves – they slide inexorably toward a homogenous state of thermodynamic equilibrium, a state of maximum entropy in which nothing further can happen.

By contrast, complex living systems, from individual body cells to entire cities, are self-organising *open* systems that maintain themselves and thrive in a far-from-(thermodynamic)-equilibrium, dynamic, steady-state. Living systems are able to 'defend' themselves against the second law by importing available energy and matter from their environments and using these resources to reproduce themselves and grow. Moreover, systems ecologists now recognise that all living systems exist in overlapping nested hierarchies in which each component subsystem ('holon') is contained by the next level up and itself comprises a chain of linked subsystems at lower levels (think 'Russian nesting dolls'). This organisational form is the basis for 'SOHO' (self-organising holarchic open) systems theory.[3] Every sub-system (or holon) in the hierarchy grows and develops by extracting usable energy and material (negentropy) from its host 'environment' one level up and by ejecting its wastes back into its host. In short, living entities maintain their *local* organisation at the expense of increased *global* entropy, particularly the entropy of their immediate host system.[4] Because all self-organising systems maintain themselves far-from-equilibrium by continuously degrading and dissipating available energy and matter, they are called 'dissipative structures'.[5]

SOHO theory has critical implications for urban sustainability. Both cities and ecosystems are self-organising far-from-equilibrium dissipative structures. However, while the ecosphere evolves and maintains itself by 'feeding' on an extra-terrestrial source of energy (the sun) and by continuously recycling matter, cities grow and maintain themselves by feeding on the rest of the ecosphere and ejecting their wastes back into it. In short, cities (indeed, the entire human enterprise) are open, growing, dependent sub-systems of the materially closed, non-growing finite ecosphere – they can grow and increase their internal order (negentropy) *only* by 'disordering' the ecosphere and increasing global entropy.

This relationship is not necessarily problematic. Ecosystems self-produce and maintain themselves far-from-equilibrium indefinitely empowered by solar energy. They constantly recycle critical nutrients and dissipate their entropic waste heat back into space. Production marginally exceeds respiration and consumption in the non-humanised ecosphere, so biomass slowly accumulates. Indeed, throughout the whole of evolutionary history, net primary production by producer species (mostly green plants) has been more than adequate to sustain the world's entire complement of consumer organisms, including pre-industrial humans, and to evolve new species.

The sustainability conundrum has emerged largely because of the sheer scale of the human enterprise. Our increasingly urban global culture is thermodynamically positioned to consume the ecosphere from within and the accelerating pace of global ecological change suggests that humanity has, in fact, grown to become maliciously parasitic on its planetary host.[6] Certainly the burgeoning human demand for self-producing resources already exceeds annual production and natural waste sinks are filled to over-flowing (e.g. eutrophication of fresh waters, greenhouse gas accumulation).[1]

Quantifying sustainability using ecological footprint analysis

If humanity is serious about sustainability, the world community must begin to scale its material demands to the supply of productive biocapacity. Ecological footprint analysis (EFA) provides a well-developed tool to approach this issue.[7] EFA provides a partial answer to what should be the first question of human ecology (or ecological economics): 'How much of the earth's productive biocapacity is required to support any specified human population at a defined material standard of living with prevailing technology.'

EFA acknowledges that whether we acknowledge it or not, modern human beings are integral components of the ecosystems that support them and that they are therefore still very much dependent on 'the land'. The method also recognises: (a) that whether we consume locally produced products or trade goods, the land connection remains intact, however far removed from the point of consumption some of the productive ecosystems may lie; and (b) that no matter how sophisticated our technology, the production/consumption process requires some land-and water-based ecosystems services. Ecofootprint analysis thus incorporates trade and technology factors simply by inverting the standard carrying capacity ratio: rather than asking what population can be supported by a given area, ecofootprinting estimates how much productive area is needed to support a given population, regardless of the location of the land or the state of technology.

As implied above, EFA is based on two critical premises: most human impacts on ecosystems are associated with energy and material extraction/consumption and many energy and material flows can be converted to corresponding productive or assimilative ecosystems areas. A typical ecofootprinting study therefore begins by quantifying all the material and energy associated with final consumption by the study population. Analysts then convert these data to the corresponding ecosystem areas required to produce the goods/services and assimilate critical wastes (usually carbon dioxide). Summed up, this total ecosystem area represents the biocapacity effectively 'appropriated' by the study population to support itself. We therefore formally define the ecological footprint of a specified population as: the area of productive land and water ecosystems that the population requires, on a continuous basis, to produce the resources it consumes and to assimilate its carbon wastes, wherever on earth the relevant land/water may be located.

A complete ecofootprint analysis therefore includes the population's demand on domestic ecosystems, plus any area it effectively 'imports' through net commodity trade, plus its demands on the global common pool for free land- and water-based services (e.g. fish stocks and the carbon-sink function). The area of a population's eco-footprint depends on four factors: the size of the population, the people's average material standard of living, the productivity of the land/water base, and the technological efficiency of resource harvesting, processing and use. Regardless of how these factors interact, a population's ecofootprint represents much of that population's demand on global biocapacity, including ecosystems located half a planet away.

It is important to acknowledge that ecofootprints represent ecologically exclusive areas. The productive capacity used by one human population is not available for use by another. Since there is a measurable, finite area of productive land and water ecosystems on Earth, all human populations are in competition for the available biocapacity of the planet.

We obtain production, productivity and trade data for ecofootprint estimates from national statistical agencies and such international data sources as the Food and Agriculture Organization's Corporate Statistical Database (FAOSTAT). To facilitate comparisons among populations and countries, the results of population EFAs are usually normalised and published in terms of global hectares (hectares of global average productivity or gha). For fuller details of the method see WWF[8] and the Global Footprint Network on-line by following the links at http://www.footprintnetwork.org.

Urban biophysical reality

To some analysts, accelerating urbanisation implies that people are becoming less connected to the land. For example, many economists believe that, because of a declining GDP to resource use ratio, the economy is decoupling from 'the environment', that the human enterprise is dematerialising.

These beliefs are illusion. As consumer organisms, not only do humans remain an integral part of the ecosystems that sustain them but, because of higher incomes and purchasing power, urbanites make significantly greater demands on the ecosphere than do typical rural dwellers, particularly impoverished peasants. In other words, despite being spatially separated from 'the land', urbanites' functional relationship to ecosystems remains intact (albeit extended and corrupted). City dwellers necessarily continue to satisfy their bio-metabolisms by consuming the products of natural and managed ecosystems and by disposing of their wastes back into surrounding ecosystems.

There is a further consideration. In addition to their human bio-metabolism, cities have an enormous 'industrial metabolism' based largely on the use of fossil fuels. The construction, operation, and maintenance of buildings and urban infrastructure account for 40 per cent of the materials used by the world economy;[9] in the US, almost 39 per cent of total energy consumption and 38 per cent of carbon dioxide (CO_2) emissions can be traced to buildings.[10] Indeed, Levin et al. and Levin (1997)[11] show that buildings in the US account for between 15 per cent and 45 per cent of the total environmental burden in each of eight major categories of impact used for life-cycle assessment. Much of the remaining 55–85 per cent of urban consumption can be attributed to urbanites' personal consumption.

The migration of people to cities has major eco-functional consequences. Global urbanisation has converted local, vertically integrated, nutrient-recycling human ecosystems into global, horizontally disintegrated, self-consuming unidirectional throughput systems. For example, instead of being re-deposited on farmland, Vancouver's daily appropriations of mineral nutrients in food from as far away as Saskatchewan, Ecuador and Thailand are flushed straight out to sea. Ecological result? Arable lands are being depleted, critical nutrients dissipated and the oceans over-fertilised.

Urbanites like to think of their cities as cultural incubators, centres of intense economic activities and producers of wealth. All true, but the forgoing data emphasise that, in strictly biophysical terms, cities are also massive 'dissipative structures'. All cities great and small are *necessarily* nodes of intense energy/material consumption and waste production; they are also dependent subsystems of the planetary SOHO hierarchy. Cities' ever-increasing scale and complexity (distance from equilibrium) therefore inevitably imposes an ever-greater entropic load on the ecosphere.

The ecological footprints of cities

Production is a prerequisite for consumption and production must take place somewhere. For every urbanised consuming 'node' there is a corresponding – but vastly larger and increasingly global – network of ecosystems that generates bio-resources (negentropy) and life-support functions essential for the survival and sustainability of the city.

This is where ecological footprint analysis comes in – we can use it to estimate the area of any city's productive hinterland. Recent EF studies reveal that the average residents of high-income, mainly urban countries such as the United Arab Emirates, the United States, Canada, Australia, Western Europe, and Japan each require the biophysical output of 4 to 10 global average hectares (10–25 average acres) *per capita* of productive land and water to support their consumer lifestyles. Wealthy urban elites throughout the developed world therefore boast oversized ecofootprints. Note, for contrast, that the citizens of the poorest, mostly rural, nations get by on the productivity and sink capacities of as little as half a gha.[12]

Some of the world's great cities have population densities of several tens to hundreds of people per hectare. However, EFA shows that each city dweller is functionally 'attached' by trade, commerce and waste flows (economic production and consumption) to several hectares of productive land and water scattered around the world. We should therefore not be surprised to learn that the EFs of high-income cities typically exceed their geographic or political areas by two to three orders of magnitude.[13] For example:

- With a *per capita* EF of approximately 7.0 gha (based on the Canadian national average), the 600,000 citizens of the author's home town, Vancouver, effectively occupy an ecosystem area 368 times larger than the city's 114 km^2 (11,400 ha). Even the metropolitan population of 2.2 million, living at lower average densities, has an extraterritorial eco-footprint 55 times larger than the metropolitan region's 2,787 km^2 (Rees 2010,[14] but see also note 5).
- Folke et al.[15] estimated that the 29 largest cities of Europe's Baltic region require the biocapacity of forest, agricultural, marine, and wetland ecosystems 565–1,130 times larger than the area of the cities themselves;
- Warren-Rhodes and Koenig[16] estimated that the almost 7 million people of Hong Kong (EF = 5.0-7.2 gha/capita) have a total eco-footprint of 332,150 to 478,300 km^2. Thus, the residents of Hong Kong ecologically 'occupy' a space on the planet *at least* 3,020 times the built-up area of the city (110 km^2) or about 303 times the total land area of the Hong Kong Special Administrative Region (1,097 km^2).
- At 6.6 gha/capita, London's ecological footprint in 2000 was almost 49 million global hectares (gha) – 42 times its biocapacity and 293 times its geographical area.[17] If cut off from global supply chains, the UK could not support even its capital city on the country's domestic biocapacity.
- Similarly, assuming the Japanese average *per capita* EF of 4.7gha, metropolitan Tokyo, the world's largest city (population: 33 million) has a total eco-footprint of 155,100,000 gha. Since the entire domestic biocapacity of Japan is only about 89,000,000 gha,[18] Tokyo, with only

26% of Japan's population, lives on an area of productive ecosystems 1.7 times larger than that nation's terrestrial biocapacity![19]

The Global Rural Urban Mapping Project reported in 2005 that 'roughly 3% of the Earth's land surface is occupied by urban areas' and that this represents an increase of 'at least 50% over previous estimates that urban areas occupied 1–2% of the Earth's total land area'[20]. As impressive as this apparent increase may seem, the foregoing shows that it is ecologically meaningless. Three per cent represents only the area of Earth 'occupied' by urbanised land, what planners call the 'built environment'. By contrast, EFA confirms that 100 per cent of the bioproductive land and water area on Earth has been functionally 'occupied' in support of human, mainly urban populations. Indeed, global biocapacity is being severely overused. There are only 1.8 gha of ecologically productive land and water *per capita* on the planet, yet the average human ecofootprint is 2.7 gha. The human enterprise has exceeded the long-term carrying capacity of Earth by 50 per cent. We are in overshoot, currently using an entire years' worth of bioproduction in about eight months.[21]

(Re)assessing urban sustainability

EFA results suggest several properties of cities that should be central to urban sustainability assessment and planning. First, in biophysical and thermodynamic terms, contemporary cities are entropic black holes sweeping up the productivity of a vastly larger and increasingly global resource hinterland and (necessarily) spewing an equivalent quantity of waste back into it.[22] From this perspective, cities have become as much the engines of global entropic decay as they are the 'engines of national economic growth'.

Second, cities *per se* are incomplete human ecosystems. As previously noted, what most people think of as 'the city' is merely the resource-consuming and waste-generating core of the total human urban ecosystem. The latter also comprises a productive/assimilative hinterland that may be several hundred times larger than the core and is increasingly dispersed all over the earth. (In this singular respect, cities are ecologically analogous to livestock feedlots – both are intense concentrations of a single macro-consumer species spatially segregated from their supportive ecosystems.) The critical point is that both the built-up core and the more extensive supportive countryside are *essential* components of the complete urban-centred human ecosystem. It is virtually meaningless to plan for urban sustainability without 'hinterland sustainability'.[23]

Third, no individual city, region or country within the global SOHO hierarchy can be sustainable if its host system(s) higher in the hierarchy are decaying unsustainably. Vancouver or Tokyo – any modern city – could become an exemplar of local sustainability planning in conventional terms but this would be to no avail if its supportive ecosystems fail due to climate change or other form of eco-degradation (or, for that matter, if the city is simply cut off from its sources of supply).

Fourth, it follows that virtually all modern cities are currently unsustainable. Cities are subsystems of the human enterprise and, as previously established, the entire human enterprise is in an unsustainable state of overshoot. In the event of increasingly probable large-scale climate change, significant food or other resource shortages, and any resultant geopolitical turmoil, even wealthy cities are at risk – the first class suites on the *Titanic* sank just as quickly as the third class steerage cabins.

Fifth, from the perspective of EFA, most contemporary efforts toward urban sustainability or 'greening' the city may increase urban 'livability', but they are too narrowly focused to be effective in achieving sustainability. The new urbanism, smart growth, green buildings, living roofs, hybrid vehicles, improved public transit and similar approaches to more efficient urban design make only marginal contributions to reducing cities' ecological footprints. The science is clear – if your development project or urban sustainability plan does not produce a substantial reduction in *per capita* energy and material throughput (up to 80 per cent in North American and other high-income cities) it is part of the problem.

Toward resolution

None of this means that human urban culture cannot, in theory, become sustainable. However, true sustainability requires that policy analysts and planners both think in 'whole systems' terms and consider the global context. In fact, it should be apparent that in today's interdependent world, sustainability is a collective problem requiring unprecedented international cooperation and globally coordinated solutions.

Regrettably, it does not seem likely that these policy conditions will be met in the foreseeable future. Individual cities can, in theory, go it alone, but in the absence of global sustainability planning, the best any city can achieve in isolation is a state of quasi-sustainability. A city would be 'quasi-sustainable' if its residents were living at a level of energy/material consumption *per capita* which, if extended to the entire human family, would result in global sustainability (Rees 2009).[24] This assumes general equity as a moral prerequisite and starting point for sustainability planning as there is no *prima facie* reason why some people merit a greater share of the world's ecological output than others.

As noted, there are presently only about 1.8 gha of productive land and water ecosystems *per capita* on Earth.[25] This 1.8 gha represents each person's equitable share of global biocapacity. Equitable global sustainability therefore implies that the eco-footprints of rich and poor alike should converge on 1.8 gha. If the basic science is correct, failure to achieve an average human ecofootprint within global biocapacity implies the collapse of major ecosystems and life-support functions and, with them, prospects for global civilisation. Equitable sustainability on a finite planet requires large reductions in the material demands of rich consumers simply to create the ecological space required for justifiable growth in developing countries.[26]

The quasi-sustainable or 'one planet' criterion obviously has enormous implications for urban sustainability planning. Using Vancouver as an example, 'Vancouverites' would have to take steps to reduce their average ecofootprints by 74 per cent (from 7.0 to 1.8 gha *per capita*) to meet the one planet standard under prevailing conditions.[27] This is fairly typical for high-income cities. On the assumption that available biocapacity will decline to only 1.4 gha, by mid-century, the Greater London Authority reported that Londoners will have to reduce their ecofootprints by 80 per cent to become (quasi)sustainable by 2050.[28]

Material contraction by the rich may be necessary, but there is a problem. In today's competitively individualistic growth-oriented global economy, policies to encourage significant reductions in material throughput (e.g. significant carbon taxes or other approaches to true-cost pricing) remain politically unfeasible. Certainly there is little evidence that any wealthy city or country is yet prepared to implement measures to achieve a state of quasi-sustainability. One major barrier to needed action is the so-called public good/free-rider problem. According to conventional wisdom, any city working toward quasi-sustainability (a 'public good') on its own would lose out in today's economy and would eventually succumb to global collapse anyway if other cities (the 'free-riders') did not follow. This conundrum is regrettable since an 80 per cent reduction of high-income ecofootprints seems achievable with no loss of living standards using existing technologies and anticipated increases in resource productivity.[29]

Political inaction by individual states while solutions are at hand underscores the fact that sustainability is a collective problem requiring collective solutions (and helps to explain why a policy paralysed global community is collectively tempting climate chaos and geopolitical turmoil).

Epilogue

Approximately 70 per cent of global energy and material throughput can be attributed to consumption and waste production in support of urban populations, particularly the populations of high-income cities. The production of anything – an email message, your cell phone, an ocean liner, our own bodies – requires the extraction and dissipation of useful energy and material and the ejection of useless waste. These are irreversible processes. The energy consumed is almost immediately permanently radiated off the planet and, while the material may remain in the system, it is often chemically transformed and widely dispersed into the air soils and water. Recapturing such dissipated material is economically impossible. The excessive scale of human economic activity is literally consuming and dissipating the biophysical basis of our own existence.

The 'hard science' of sustainability is well-developed. There is no serious dispute about any assertion in the previous paragraph, for example. Countless scientific studies have helped to scale the problem; climate change analyses, ecofootprinting and related studies agree on the reductions in material throughput needed to create a sustainable steady-state. Yet there is no evidence of the political or popular will necessary for policies that will actually make a difference. Instead, society deludes itself into thinking that minor reform is all that is necessary, that improved efficiency or new technologies can preserve the *status quo*. Indeed, those with vested interests in the *status quo* are spending vast sums on disinformation campaigns to ensure the public remains deluded! We now have an economic sector dedicated to the social construction of denial.

It does not help that urbanites are both spatially and psychologically isolated from the ecosystems that support them and thus doubly blind to the distant land degradation, pollution and social costs incurred to serve their demands. Globalisation and trade further delay signals of imminent danger by providing urban consumers access to remaining pockets of productive natural capital all over the earth. Thus while wealthy urbanites experience a world of glittering lights, techno-gadgetry and expanding economies their consumer lifestyles are creating a parallel world of, degraded landscapes, climate change and depleted resources.

Humans claim to be intelligent, uniquely capable of logical analysis and forward planning, and able to exercise moral judgment. These are precisely the qualities necessary to ensure a smooth transition from contemporary overshoot to an ecologically stable, economically secure and socially more equitable world. Yet the mainstream world seems focused almost exclusively on policies to fuel the growth economy and the root of the sustainability crisis. It is no small irony that when those qualities that make us truly human are most in demand, they seem to be in least supply.

Notes

1. United Nations Department of Economic and Social Affairs/Population Division, 'UN World Urbanization Prospects: The 2009 Revision' (New York, 2009).
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7. W. E. Rees, 'Ecological footprints and appropriated carrying capacity: What urban economics leaves out', *Environment and Urbanization*, 4 (1992): 120–30; W. E. Rees, 'The ecological crisis and self-delusion: implications for the building sector', *Building Research and Information*, 37/3 (2009): 300–11; W. E. Rees, 'Ecological Footprint, Concept of', in Simon Levin (ed.) *Encyclopedia of Biodiversity* (2nd edn) (2013); M. Wackernagel and W. E. Rees. *Our Ecological Footprint: Reducing Human Impact on the Earth* (Gabriola Island, B.C., 1996); WWF., 'Living Planet Report 2010' (Gland, 2010); WWF, 'Living Planet Report 2012' (Gland, 2012).
8. WWF, 'Living Planet Report 2008' (Gland, 2008); WWF, 'Living Planet Report 2010'.
9. Worldwatch Institute, 'State of the World 1995' (Washington, 1995).
10. DOE, 'Buildings Energy Data Book', prepared for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, by D&R International (Washington, 2008).
11. H. Levin, 'Systematic Evaluation and Assessment of Building Environmental Performance (SEABEP)', paper presented to 'Buildings and Environment', Paris, 9–12 June 1997 (Santa Cruz, CA, 1997).
12. WWF, 'Living Planet Report 2010'; WWF, 'Living Planet Report 2012'.
13. This holds true despite methodological and data-quality differences. National EFs are based on data routinely collected by government statistical agencies and international (e.g. UN) organisations, but no such agencies monitor trade across municipal boundaries. Some urban EFs are based on original local data-gathering capacity; others use national per capita EF estimates adjusted for local variations in income, energy sources, lifestyles, etc.
14. Rees, 'Getting Serious about Urban Sustainability'.
15. C. Folke, A. Jansson, J. Larsson and R. Costanza, 'Ecosystem appropriation by cities', *Ambio*, 26 (1997): 167–72.
16. K. Warren-Rhodes and A. Koenig, 'Ecosystem appropriation by Hong Kong and its implications for sustainable development', *Ecological Economics*, 39 (2001): 347–59.
17. GLA, 'London's Ecological Footprint: A Review' (London, 2003).

18. The terrestrial area of Japan is actually only 37,770,000 ha but Japan's terrestrial ecosystems are considerably more productive than the world average. This increases the country's biocapacity to about 89,000,000 gha.
19. Rees, 'Getting Serious about Urban Sustainability'.
20. Earth Institute, Columbia University, 'The Growing Urbanization of the World', www.earth.columbia.edu/news/2005/story03-07-05.html.
21. WWF, 'Living Planet Report 2010'; WWF, 'Living Planet Report 2014' (Gland, 2014).
22. Rees, 'Getting Serious about Urban Sustainability'.
23. Rees, 'Getting Serious about Urban Sustainability'.
24. I.e., quasi-sustainability implies a 'one planet lifestyle' or 'one planet living'.
25. WWF, 'Living Planet Report 2010'; WWF, 'Living Planet Report 2012'.
26. Contemplating economic contraction in the face of global change is no longer a taboo subject. Consider the global 'degrowth' movement and such studies as *Managing without Growth* (Victor 2008) and *Prosperity without Growth* (Jackson 2009) by prominent economists.
27. Rees, 'Getting Serious about Urban Sustainability'. A more recent study using local data estimates Vancouver's per capita ecofootprint to be about 5 gha (Moore and Rees 2013). This is less than the Canadian average of about 7 gha largely because the city is blessed by abundant hydro-electricity and thus has a smaller carbon footprint than the rest of Canada. Even so, Moore and Rees show that to achieve quasi-sustainability ('one planet living'), the city's inhabitants should be striving to reduce their energy and material throughput by 66 per cent.
28. GLA, 'London's Ecological Footprint'. Meanwhile, hundreds of millions of people who live below the quasi-sustainability criterion would be able to *grow* their ecofootprints. Average Bangladeshis, for example, could *increase* their material consumption by 200 per cent before exceeding their 2010 fair Earth-share.
29. E. von Weizsäcker, K. Hargroves, M.H. Smith, C. Desha and P. Stasinopoulos, *Factor Five: Transforming the Global Economy through 80% Improvements in Resource Productivity* (London, 2010).