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William E. Rees [a]
[a] School of Community and Regional Planning, University of British Columbia, Vancouver, BC, Canada

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VIEWPOINT

Is 'Sustainable City' an Oxymoron?

WILLIAM E. REES

Introduction and Purpose

There is general scientific and even political agreement that present global development trends are unsustainable. Since the publication of the so-called Brundtland Report a decade ago (WCED, 1987), there can hardly be a politician or business leader anywhere who has not proclaimed the need for society to make the 'paradigm shift' to a more environmentally benign, economically viable and socially equitable development path. Sustainable development, sustainability, sustainable community, sustainable city and like concepts have become the specific concern of innumerable government task forces and NGOs in various countries around the world. Indeed, it has become commonplace to hear lively discussion of any of these topics at dinner parties among the better informed almost anywhere.

Despite this increase in the level of rhetoric there is as yet no coherent vision of just how 'sustainability' would translate into practice (see, for example Richardson, 1996). Worse, the empirical evidence suggests that in the past few decades the world has become progressively less sustainable, a process that has arguably accelerated since publication of the Brundtland report. Since 1950, real income per capita has more than quadrupled, yet income equity has steadily worsened, (both between North and South and within countries),[1] a billion people still live in abject poverty, fish and grain production per capita may have peaked, and global ecological change is upon us.

One reason for the latter is quite simple. Although environmental concerns were a major catalyst for the sustainable development debate, they seem largely to have been sidelined in recent years. The neoconservative political revolution sweeping the world has effectively confined discussion in the policy mainstream to variations on the theme of 'sustainability-through-growth'. By this model, apparently shared by most government and business leaders, an expanding and increasingly unfettered marketplace will sort everything out unaided. The so-called 'environmental crisis' is thus a passing concern. We have been swayed by the near-doctrinaire belief of economics that, stimulated by rising prices, human ingenuity and technology will be able to substitute for depleted resources. Meanwhile, privatising nature, 'getting the prices right' and 'internalising the externalities' will eliminate pollution concerns. With no serious ecological constraints on the economy, the shortest route to sustainability is to maintain the focus on GDP growth.[2]

Despite the two Habitat conferences (Vancouver in 1976 and Istanbul in 1996) cities—particularly northern high-income cities—have also been given short shrift in the mainstream sustainability debate. The World Conservation Strategy of 1980, which apparently first explicitly used the term 'sustainable development', gave no special attention to accelerating urbanisation. The Brundtland Report did discuss global urbanisation, but the main emphasis was on the "urban crisis in developing countries" (WCED, 1987, p. 8).

This relative neglect of cities is difficult to reconcile with physical reality. Cities are rapidly becoming the principal human habitat. Up to 80% of the populations of industrialised (high-income) countries live in cities and it is said that half of humanity will be urbanised by the end of the century. Moreover, if the wealthiest 25% of the human population consume 80% of the world's economic output, then

William E. Rees, PhD, University of British Columbia, School of Community and Regional Planning, 6333 Memorial Road, Vancouver, BC, Canada, V6T 1Z2. Tel: (604) 822-2937. Fax: (604) 822-3787.

approximately 64% of economic production/consumption and pollution is associated with cities in *rich* countries and only 12% with cities in the developing world. In short, half the people and three-quarters of the world's environmental problems reside in cities, and rich cities, mainly in the developed North, impose by far the greater load on the ecosphere and global commons.

In this paper I revisit both the environmental side of sustainability and the urban question. The major purpose is to enhance current understanding of the ecological impacts of cities and the role they might play in the quest for sustainability. My starting premise is that much of what passes as policy for urban sustainability at present reflects a superficial understanding of the human ecological niche and the role of cities in it. More broadly, I hope to show that the prevailing growth-bound international development model ignores biophysical factors, the inclusion of which would invalidate the model's current policy prescriptions.

The Human Ecology of Cities

Just what is a city? Most people think of 'the city' as a concentration of people in an area dominated by buildings, streets and other human-made artefacts (this is the architect's 'built environment'); some may think of it first as a political entity with a defined boundary containing the area over which the municipal government has jurisdiction; the artistically inclined might see the city mainly as a concentration of cultural, social and educational facilities that would simply not be possible in a smaller settlement; and, finally, the economically minded see the city as a node of intense exchange among individuals and firms and as the engine of economic production and growth. Indeed, Jane Jocobs (1984) famously described cities as the basis for the "wealth of nations".

Cities are all of these things, of course, but the description remains incomplete. The city is also an ecological entity. This fact is generally ignored, perhaps because it is obscured by the very process of urbanisation itself. Living in the city distances people both spatially and psychologically from the land that supports them. Urbanisation thus reinforces the Cartesian dualism that permeates industrial society, creating a mental barrier between people and the rest of nature. The denizens of our modern cities rarely think of themselves as ecological beings.

In an effort to overcome this cultural bias, I adopt an explicitly ecological perspective in this paper. After all, 'the city' is a physical manifestation of human (bio)ecology. Human ecology starts from the premise that people are an integral component of the ecosystem(s) that sustain them. From this perspective, we would study humans much the same way we would any other plant or animal species. The important question is: what are the critical material relationships between people and the other components of their supportive ecosystems? In short, understanding human ecology requires measurement of the material, energy and information flows between the human sub-system and the rest of nature. What important functional and structural relationships are revealed by these flows?

Economic Production is Consumption

Economists and ecologists would agree that human beings function as consumer organisms in both the economy and the ecosphere. In fact, in today's increasingly market-based society people are as likely to be called 'consumers' as they are citizens, even when the context is a non-economic one. Ecologists would actually refer to people as *macro*-consumers with reference to their place in the global food web. In general, macro-consumers are large organisms, mainly animals, that depend on other organisms, either green plants or other animals, which they consume directly to satisfy their metabolic needs. There is of course one major material difference between humans and other macro-consumers. In addition to our biological metabolism, the human enterprise is characterised by an industrial metabolism. All the artefacts of industrial culture—buildings, equipment, infrastructure, tools and toys (the human-made 'capital' of economists)—are "the exosomatic equivalent of organs" and, like bodily organs, require continuous flows of energy and material to and from 'the environment' for their production and operation (Sterrer, 1993).

Economists and ecologists also both see humans as producers. However, there is a fundamental difference between production in nature and production in the economy. In nature, green plants are the factories. Using the simplest of low-grade inorganic chemicals (mainly water, carbon dioxide and a few mineral nutrients) and an extra-terrestrial source of relatively low-grade energy, light from the sun, plants assemble the high-grade fats, carbohydrates, proteins and nucleic acids upon which most other life forms and the functioning of the ecosphere are dependent. Because they are essentially self-feeding and use only dispersed (high entropy) substances for their growth and maintenance, green plants are called *primary* producers.

By contrast, human beings and their economies are strictly *secondary* producers. As noted, the production and maintenance of our bodies, our human-made capital, and all the products of human factories require enormous inputs of high-grade energy and material resources from the rest of the ecosphere. That is, all economic output requires the consumption of a vastly larger quantity of available energy and material *first produced by nature.* As little as 1% or 2% of the material extracted for the economic production process actually winds up in the final product (Hawken, 1997), and 100% of the energy and material involved is ultimately dissipated back into the ecosphere as waste. Such flows through the economy are unidirectional and irreversible (Figure 1).

Cities and the Second Law

Because the economic process is a secondary process, the entire human enterprise in all its diversity and complexity is a dependent subsystem of the ecosphere. The structural hierarchy implicit in this relationship is critically important to urban sustainability in light of modern interpretations of the second law of thermodynamics (see Table 1 for a detailed explanation).

The second law states that all complex, self-organising systems are subject to forces of spontaneous disintegration. That is, any *isolated* system becomes increasingly unstructured and disordered in an inexorable slide toward thermodynamic equilibrium. (This is a state in which "nothing happens or can happen" [Ayres, 1994].) However, *open* systems, like cities, can maintain themselves and grow by importing high-grade energy and material from their host environments and by exporting entropy (degraded energy and material) back into those environments.[3] Our cities can produce 'the wealth of nations' only by consuming the products and services of the ecosphere. This interpretation shows that in thermodynamic and spatial terms, cities are nodes of intense material consumption and waste discharge within a diffuse and increasingly global human ecosystem.

The Ecological Footprints of Cities

If cities are the nodes of consumption in a spreading human net, just how much productive land/water (ecosystem) area is required for the corresponding production? My students and I have developed an approach to answering this question. Many of the resource and waste flows necessary to sustain urban populations are produced by natural and domesticated land and water ecosystems. It is therefore possible to estimate the ecosystems area required to produce sustainably the quantity of any resource or ecological service used by a defined population and specified technology. The sum of such calculations for all significant consumption items would provide a conservative area-based estimate of the land/water area effectively appropriated by that population. We call this aggregate area the population's true 'ecological footprint (EF)': the total area of productive land and water required on a continuous basis to produce the resources consumed, and to assimilate the wastes produced, by that population, *wherever on Earth the land is located.*

We should note that the ecological footprint of a city/country is, in effect, a solar collector. It is the photosynthetic surface needed continuously to recharge the city's ecological batteries. Cities are entropy generators (Figure 1 and Table 1). The ecosystems 'appropriated' by the eco-footprint replace the low entropy biomass energy and material necessarily dissipated by the city in the normal course of life.

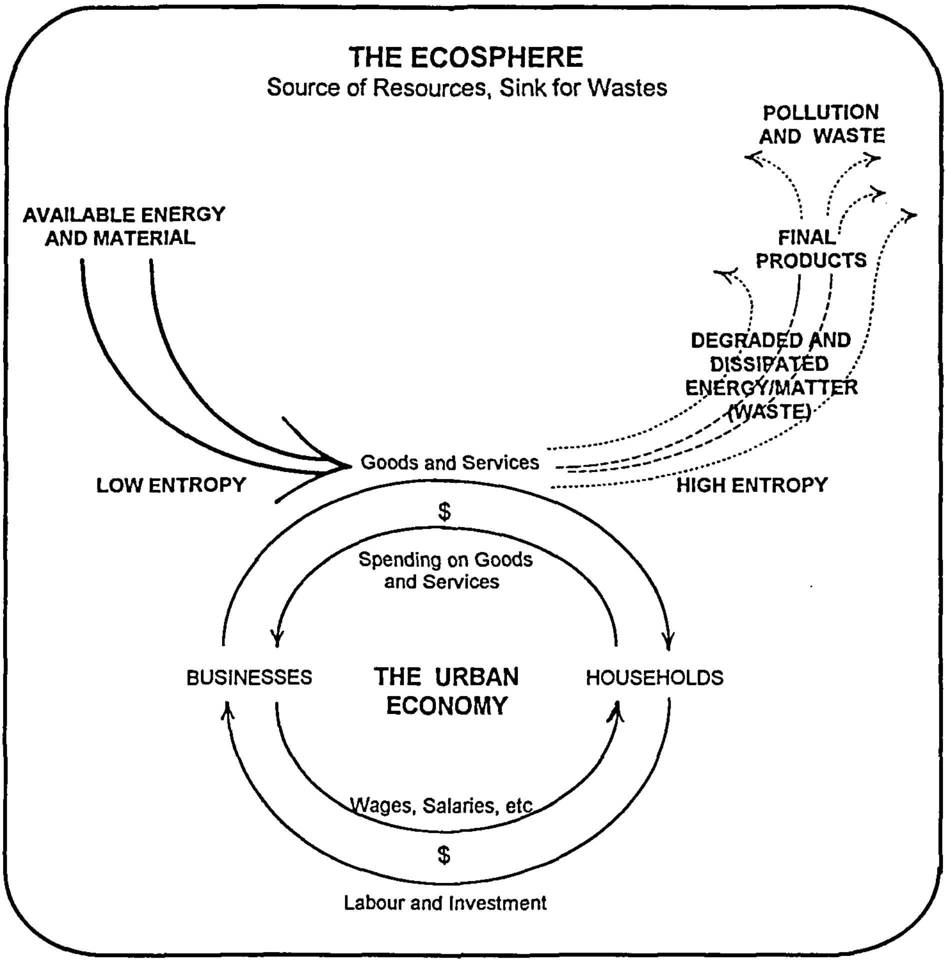

FIGURE 1. The linear throughput of energy/matter. *Note:* Economic output is measured by the 'circular flows of exchange value' (lower part of diagram). However, conventional monetary accounting is blind to the linear throughput of available energy and matter (upper part of diagram) which makes economic activity possible and connects the economy to the ecosphere.

Our results show that the citizens of high-income countries typically use the output of between three and seven hectares of ecologically productive land per capita.[4] It is a simple step from there to estimate the true ecological footprint of a whole city, region or country (for details see Rees, 1992, 1996; Rees & Wackernagel, 1994; Wackernagel & Rees, 1995).

For example, the Canadian city of Vancouver had a 1991 population of 472 000 and an area of 114 km^2 (11 400 ha). With a per capita land consumption rate of at least 4.3 ha, Vancouver's residents require (conservatively) 2 million ha of land to support current consumption levels. However, the area of the city is only 11 400 ha. This means that the city's population uses the productive output of a land area nearly 180 times larger than its political area to maintain its consumer lifestyle. If we add the aggregate marine footprint associated with seafood consumption (0.7 ha capita), the total

TABLE 1. The second law, cities and the ecosphere

- The second law of thermodynamics states that the 'entropy' of any isolated system spontaneously increases. That is, concentrations of material are dispersed, available energy is dissipated, gradients disappear, and structural order and integrity break down. Eventually, no point in the system can be distinguished from any other
- Open systems are subject to the same forces of entropic decay as isolated systems. However ...
- Complex self-organising, self-producing systems can maintain or increase their internal order by importing available energy/matter (essergy) from their host environments and exporting degraded energy matter back into them. That is...
- Complex systems develop and grow "at the expense of increasing the disorder [entropy] at higher levels in the systems hierarchy" (Schneider & Kay, 1994, abstract and p. 2)
- Systems that maintain themselves in dynamic non-equilibrium through the continuous dissipation of essergy extracted from their host systems are called 'dissipative structures'
- Cities are prime examples of highly-ordered, far-from-equilibrium dissipative structures. As major components of the human economy, they are also sub-systems of the materially closed ecosphere. In thermodynamic terms, cities (indeed, the entire human enterprise), exist in a quasi-parasitic relationship to the rest of nature
- It follows that with continuous population and material growth of urban economies, a point *will* be reached when the disordering of the ecosphere (e.g. biodiversity loss, ecosystems collapse, climate change, toxic contamination, ozone depletion, etc.) becomes unsustainable, perhaps irreversible.

becomes 2.4 million ha or over 200 times the size of the city.

These results are fairly typical. The UK's International Institute of Environment and Development estimates that London's ecological footprint for just food, forest products and carbon assimilation to be 120 times the surface area of the city proper (IIED, 1995). (By this measure, and assuming the British landscape could produce suitable substitutes for the current array of imports, the entire productive land base of Great Britain would be taken up to supply London alone.) Similarly, Carl Folke and his team at Stockholm University report that the aggregate consumption of wood, paper, fibre and food (including seafood) by the inhabitants of 29 cities in the Baltic Sea drainage basin appropriates an ecosystem area 200 times larger that the cities themselves (this study did not include an energy component) (Folke *et al.*, 1995).

In light of these data, it will come as no surprise that most high-income countries in Europe have ecological footprints several times larger than their domestic territories (Wackernagel & Rees, 1995). Even those countries with trade and current account surpluses are running massive 'ecological deficits' with the rest of the world and imposing a massive burden on the global commons (Rees, 1996).

Cities and Sustainability

These studies reveal several dimensions of the sustainability crisis that are transparent to conventional perceptions and analyses. First they show that as a result of enormous technology-induced increases in energy and material consumption per capita, and growing dependence on trade, *the ecological locations of urban regions no longer coincide with their geographic locations.* Without taking anything away from cities as economic engines and cultural hotbeds, we must recognise that they also resemble entropic black holes, sweeping up the output of areas of the ecosphere vastly larger than themselves. In this respect, cities are the human equivalent of cattle feedlots. Perhaps the most important insight from this result is that *no city or urban region can be sustainable on its own.* 'Sustainable city'—at least as we presently define cities—is an oxymoron.

Regardless of local land use and environmental policies, a prerequisite for sustainable cities is the sustainability of the global hinterland.

Second, our ecological analysis poses several challenges to the conventional 'sustainability-through-growth' approach. Mainstream analysts believe that technology frees humans from ecological constraints and that trade increases local carrying capacity. By contrast, eco-footprinting suggests that while technological gains have expanded the scope and efficiency with which we exploit nature, the material effect has been steady increases in gross material consumption (in part because efficiency gains lead to rising incomes and falling prices). Meanwhile, trade may appear to increase carrying capacity but actually only shuffles it around. Food and fibre imports, for example, may sustain Europe's inflated population, but the corresponding exports reduce carrying capacity somewhere else (both by reducing local food supplies and through accelerated soil erosion, chemical contamination of soil and water, and trade-related nutrient loss). In fact, "by encouraging all regions to exceed local limits, by reducing the perceived risk attached to local natural capital depletion, and by simultaneously exposing regional surpluses to global demand, uncontrolled trade accelerates natural capital depletion, *reducing* global carrying capacity and increasing the risk to everyone" (Rees, 1994, p. 43). Thus even as GDP goes up, general long-term welfare declines.

Toward Urban Sustainability

Self-reliance, once a noble virtue, has become anathema to the free-trading world of today. However, in an era of real or incipient ecological change, it may be time to reconsider our development values. Cities are increasingly vulnerable to the potentially disastrous consequences of over-consumption and global ecological mismanagement. How economically and socially secure can a city of 10 million be if distant sources of food, water, energy or other critical resources are threatened by accelerating ecospheric change, increasing competition and dwindling supplies? Does any development pattern that increases inter-regional dependence on vital but vulnerable resource flows make ecological or geopolitical sense? If the answer is 'no', or even a cautious 'possibly not', circumstances may already warrant consideration of the potential benefits of greater ecological independence and intra-regional self-reliance.[5] At least there should be a restoration of balance between the forces of local cohesion and globalisation. The increase in welfare from enhanced food security, improved environmental quality and increased local control will offset any loss in gross economic product.

To reduce their dependence on external flows, urban regions may choose to implement policies to rehabilitate their own natural capital stocks and to promote the use of local fisheries, forests, agricultural land, etc. In this context, we should remember that cities as presently conceived are incomplete systems, typically occupying less than 1% of the ecosystem area upon which they draw. Should we not be reconsidering how we define city systems, both conceptually and in spatial terms? Perhaps it is time to think of cities as whole systems—as such, they comprise not just the node of concentrated activity as presently conceived, but also the entire supportive hinterland.

Short of so great a conceptual leap, there is much that can be done incrementally to increase the sustainability of our cities. For example, in the domain of land-use planning, planners and politicians should find ways to:

- integrate planning for city size/form, urban density and settlement (nodal) patterns in ways that minimise the energy, material and land use requirements of cities and their inhabitants;
- capitalise on the multifunctionality of green areas (e.g. aesthetic, carbon sink, climate modification, food production, functions) both within and outside the city;
- integrate open-space planning with other policies to increase local self-reliance in respect of food production, forest products, water supply, carbon sinks, etc. For example, domestic waste systems should be designed to enable the recycling of compost back onto regional agricultural and forest lands;
- protect the integrity and productivity of local ecosystems to reduce the ecological load imposed on distant systems and the global common pool;

- strive for zero-impact development. The destruction of ecosystems and related biophysical services due to urban growth in one area should be compensated for by equivalent ecosystem rehabilitation in another.

Land use aside, ecological footprint analysis supports other studies that suggest that we must reduce resource use and environmental impact per unit consumption in high-income countries by up to 90% by 2040 if we are "to meet the needs of a growing world population fairly within the planet's ecological means" (BCSD, 1993; see also Ekins & Jacobs, 1994). Fortunately, the sheer concentration of population and consumption gives cities considerable leverage in reducing the ecological footprints of their citizens. The agglomeration economies and economies of scale characteristic of cities reduce the per capita requirements for and costs of water and sewer systems, waste collection, and related infrastructure; create opportunities for recycling, reuse and remanufacturing unavailable to smaller communities; enable such energy savings strategies as co-generation and district heating, and reduce the need for energy-intensive travel in private cars while facilitating walking, cycling and public transit (Mitlin & Satterthwaite, 1994). Walker & Rees (1997) show that the housing and transportation choices made by urban dwellers can significantly influence their per capita ecological footprints.

Epilogue

The human ecological approach offers one final lesson for consideration by the eco-cities movement. The ecological footprint of any high-income city is attributable largely to final demand, i.e. to personal consumption by its inhabitants. In short, much of the ecological impact that can be traced *to* cities has little to do with the structure, infrastructure, form, or other inherent properties *of* cities *per se*. Rather, it is a reflection of individual values and behaviour and would occur whatever the settlement pattern. For example, if an individual's fixed consumption appropriates the continuous output of 3 ha of land scattered about the globe it does not much matter where that individual resides. This means that efforts to green our cities may gain more from attention to changing personal consumption patterns than from the prevailing focus on city-level factors—post-consumer waste management, public infrastructure, urban greenways, etc. In short, we should focus less on trying to fix our cities and more on fixing ourselves. The best-designed and most sensitively administered city cannot be sustainable if its inhabitants live unsustainable lifestyles.

Notes

1. The top 20% of income earners took home 60 times the income of the bottom 20% in the early 1990s. This gap had more than doubled in 30 years (UNDP, 1994).
2. This conventional growth model actually betrays economic theory by confusing the maximisation of production with the maximisation of general welfare.
3. This means, in effect, that every sub-system in a given hierarchy exists in a potentially parasitic relationship with the next level up in that hierarchy. If a sub-system grows without check, it will reach a point at which its own vitality is purchased at the expense of the vitality of its host. (This may be a sufficient physical explanation for the onset of global ecological change.)
4. These data reflect the growing ecological inequity between rich and poor. There are only about 1.5–1.7 ha of ecological productive land per capita on Earth.
5. This will be difficult for some major city regions. An alternative (or supplement) is to consider more formal and fair long-term relationships (e.g., international treaties) between the consumer regions and producer territories to help ensure reliable supplies of biophysical goods and services.

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