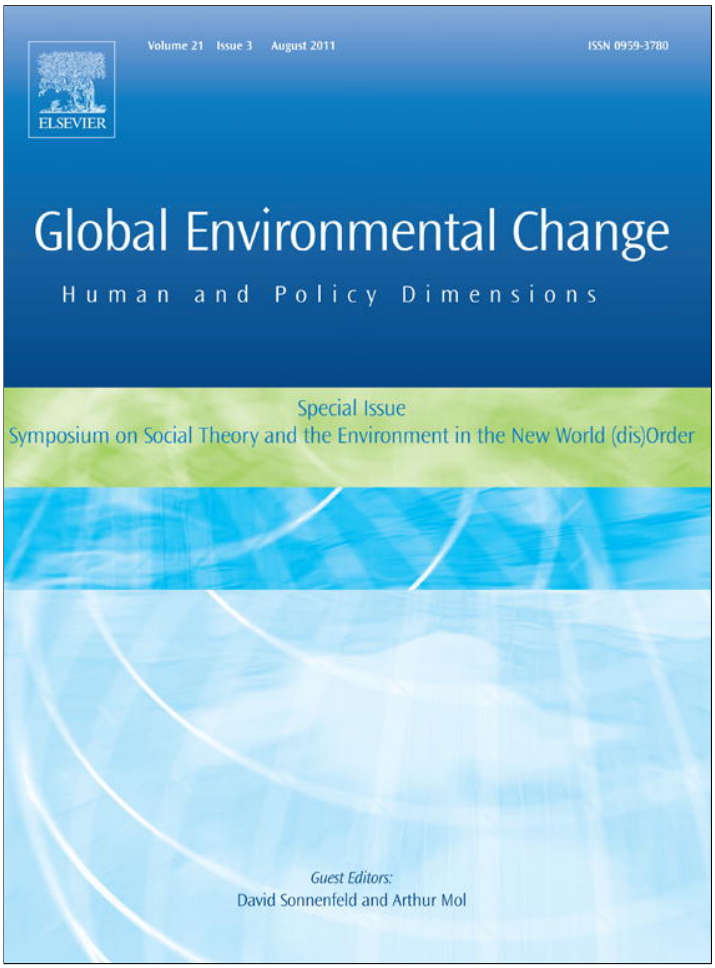

Global Environmental Change 21 (2011) 823–834

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

# Delegating, not returning, to the biosphere: How to use the multi-scalar and ecological properties of cities

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ARTICLE INFO

*Article history:*
Received 1 December 2010
Received in revised form 26 March 2011
Accepted 27 March 2011
Available online 12 May 2011

*Keywords:*
Sustainability
Rupture
Delegating
In-between space
Knowledge
Third natures

ABSTRACT

Our aim is to theorize the shifting relationship between cities and the biosphere in ways that can incorporate vanguard scientific, technical and social innovations. We specify that the city (a) generates third natures – specific new environments – such as heat islands, that today are destructive of the biosphere, and (b) that the city has systemic properties that correspond to those of the biosphere, but today are mostly flattened out of action through the ruptures that dominate today's articulation between cities and biosphere. That is to say, our specific project agrees with the problematizing of the category "nature," which pertains to our presence in the biosphere. But we do not take Harvey's more absolute statement that the city itself is nature nor do we confine our analysis only to Latourian natures–cultures. Our analysis is less centered in the work of correcting a false binary, as is the case with both Latour and Harvey, notwithstanding their different objects of study. We focus on the complex in-between space that is the site of both the transactions between city and biosphere, as well as the site of the ruptures that characterize these transactions.



## 1. Introduction

Cities have multiple articulations with the biosphere. Today these are mostly negative in two major ways. Cities produce ruptures in the biosphere's continuous flows, and their consumption of biospheric resources is "unbiological" in the sense that they take more than the biosphere can replace. Our concern in this paper is to introduce a third element into this dyad of city and biosphere: scientific and technical capabilities that can be used to begin to redress both of the above negatives by activating biospheric capacities in urbanized settings. We name this *delegating back to the biosphere*. A familiar example is the use of algae in combination with a reactor to cleanse acutely contaminated water bodies.

This is, then, not simply a return to "nature" or to the biosphere, but a more complex assemblage of biospheric and scientific capabilities that constitute an intermediate space that is neither fully urban nor fully of the biosphere. Our conceptualization is linked to a second proposition: that *rupture* is increasingly the dominant mode of human transaction with the cycles of the biosphere. Finally, we posit that to enable the proliferation of this type of intervention in complex cities will require using the multi-scalar and socio-ecological properties of cities. One hypothesis we begin to develop here but do not explore fully is that full recognition and activation of these properties of cities could be a key factor for amplifying the positive articulations of cities with the biosphere. *Delegating back to the biosphere* is a framing for an analytics that can take us beyond an emphasis on mitigation and adaptation, today's two dominant approaches.

We situate this project in relation to three broader social science scholarships on the city. We are influenced by all three but want to go in a different direction, armed with different research questions and implications for action. Our proposition about delegating back to the biosphere is not part of these scholarships, and does in some cases, clash with key propositions in some of these texts. There is first an older scholarship in sociology that conceives of the city as a system with a range of diverse socio-physical ecologies, most notably the early Chicago school of urban sociology. A second important, more recent scholarship conceives of the city as a complex multi-scalar system where culture, nature, power and capital are linked (e.g., Harvey, 1996; Latour, 1993). The third type of scholarship, largely in geography (e.g. Swyngedouw and Heynen, 2003), conceives of the city as an urban political ecology, in the sense that power, capital, and the social are the conditions within which we should understand nature. With exceptions (see Mol and Sonnenfeld, 2000), none of these three bodies of scholarship is directly concerned with the question of environmental sustainability. Yet, combining elements of each helps in expanding the analytic terrain within which to explore the issues that concern us in this paper.

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0959-3780/$ – see front matter © 2011 Published by Elsevier Ltd.
doi:10.1016/j.gloenvcha.2011.03.018

While the multi-scalar and ecological properties of cities have received considerable attention in the social science literature, little attention has gone to their utility for the environmental sustainability project. At the same time, cities do not fit easily in existing theories about environmental sustainability and global environmental governance. The environmental burden of cities is often concealed as it is spatially displaced away from an apparently 'clean' and 'efficient' city center (c.f. McGranahan, 2007). And yet there is a clear need for integrating these theories, especially in the context of discussions of any (environmental) new world order (see Sonnenfeld and Mol, this issue).

Our practical aim is to avoid the simplifying assumptions that the only way for cities to contribute to sustainability is through mitigation and adaptation. We also aim to avoid theorization that advocates starting from scratch. We are instead working towards a conceptualization of the shifting relationship between cities and the environment that is rooted in the complexity of already-existing cities. Mitigation and adaptation are not enough to address environmental damage, and most cities *cannot* start from scratch. Abu Dhabi's Mazdar project of a fully self-sustained city, for instance, is not a model for most countries because it is far too expensive; it can though be seen as a laboratory experiment which can help reorient thinking both through its successes and failures. When working from already-existing cities the practical goal becomes changing the negative articulations between cities and the biosphere. This paper is an exploration of these possibilities.

## 2. A larger conceptual landscape

Each of the three dominant strands of social science literature on the relationship between cities and the biosphere emerged from a different mode of theorizing the city.

### 2.1. The Chicago school

The oldest of these approaches involves a binary split between nature and the city, conceptualized as the rural–urban split. Early American urban sociology emphasized this rural–urban split in the context of functionalist narratives of urban development. For instance, Ernest Burgess's foundational study of urbanization described the city as a metabolic system designed to assimilate immigrants from rural communities (Burgess, 1925). In a mid-century review, Kingsley Davis described a zero-sum relationship between metropolis and countryside, "the one expands and the other shrinks" in a trajectory that points to a future where "'Rurality' would have disappeared, leaving only a new kind of urban existence" (1955, p. 437). Much of this American urban sociology was built on Louis Wirth's definition of an urbanism conceived in opposition to an archaic pre-urban way of life. "Nowhere has mankind been farther removed from organic nature than under the conditions of life characteristic of great cities" (1938, p. 1).

Benet (1963) has identified the Chicago School's emphasis on "rural–urban polarity" as a "leitmotif" of that body of work derived from its intellectual roots in the work of Tönnies and Simmel, "great lovers of polar typologies" (Benet, 1963, p. 2). But this binary approach also appeared at radically different ends of the political spectrum. Murray Bookchin's anarchist engagement with ecological thinking, for instance, emphasized a conflictive relationship between distinct natural and social worlds. "Bourgeois society not only pits humans against each other, it also pits the mass of humanity against the natural world" (Bookchin, 1978–1979, p. 91). This way of thinking, like its Chicago-school opposite, was firmly rooted in a binary logic of society vs. nature.

> The modern city represents a regressive encroachment of the synthetic on the natural, of the inorganic (concrete, metals, and glass) on the organic, of crude, elemental stimuli on variegated, wide-ranging ones (Bookchin, 1978–1979, p. 93).

This type of thinking naturally leads to a mitigation-based conceptualization of the shifting interface between cities and nature. The city and nature are conceived of as distinct systems with a zero-sum relationship – the one grows at the expense of the other. In its simplest form such mitigation-oriented thinking presents itself in narratives of 'return to nature'. Such an approach is inadequate for today's challenges. A simple example is the case of nitrogen-based fertilizer which has enabled the world population to grow 40% beyond what would have been possible using natural methods (Science, 2002; Fryzuk, 2004). A conceptualization that assumes a 'return to nature' would seem to imply a 40% drop in the human population. This is unacceptable – indeed creative (non-millenarian) theory must explain how we will avoid such a crisis.

A move away from binary conceptualizations of the relationship between cities and nature began around the early 1960s with what appears now as an epistemological crisis in urban sociology. As Benet notes, "the fading out of the rural–urban distinctions eliminated the possibility of significant urban research against distinctive rural backgrounds. Urban research was thus conducted *in vacuo*, without a frame of reference" (Benet, 1963, p. 4).[1] The movement away from a binary understanding of urban and rural found a strong expression in Raymond Williams' *The Country and the City* (1973). Reviewing centuries of English literature, Williams revealed that the idealized rural world of innocence, security, peace and plenty, and its dark opposite, the demonized urban world of oppression, crime and squalor were not so much accurate representations of opposite modes of existence as myths "functioning as memory" (1973, p. 43). Williams argued that this dichotomy, which had dominated English literature for centuries – and has infused much of urban sociology – masked the *inextricable* linkages between the urban and the rural.

### 2.2. Space, scale, linkage

The recognition of the deep linkages between cities and biosphere has generated some of the most powerful theoretical scholarship up till now. Harvey (1996) has perhaps given us the most radical formulation, positing that a city does not stand outside the environment, but is in itself a set of environmental conditions. Its built structures and infrastructures, the practices of its inhabitants and users, its socioeconomic configuration, the extent of poverty and disease, each of these is an environmental condition replete with specificities and consequences. For Harvey (1996, p. 186), the created environments of an urbanizing world, their qualities and difficulties, their proneness to new configurations for the development and transmission of new diseases, their extraordinarily difficult problems of sustainability in all senses, "have to move to the center of our attention relative to much of the contemporary preoccupation with wilderness, peripheral peasant movements, preservation of scenic landscapes." Harvey's work has provided the beginnings of a theory where the city is part of nature.

In another major move, Bruno Latour has productively problematized the concept of nature itself. Latour's actor-network theory involves tracing connections between actors – human, non-human, material, and immaterial – in order to recover the complexity of social formations. Latour proposes the concept of nature/culture to move beyond a false dichotomy.

> It is the peculiar trait of Westerners that they have imposed, by their official Constitution, the total separation of humans and nonhumans – the Internal Great Divide – and have thereby

[1] Equally important in this crisis was the discipline's failure to account for the urban unrest of the 1960s.

> artificially created the scandal of the others... But *the very notion of culture is an artifact created by bracketing Nature off*. Cultures – different or universal – do not exist any more than Nature does. There are only natures–cultures, and these offer the only possible basis for comparison (Latour, 1993, p. 104, emphasis in original).

In recent years there has been a significant body of work that draws on Latour's approach. For instance, a June 2006 special issue of *Science as Culture*, organized around efforts to theorize the state of environmentalism, brings together several recent contributions that draw on Latour (see White and Wilbert, 2006).

In his contribution, Swyngedouw (2006) emphasizes circulation and metabolism as entry points for such an analysis. Swyngedouw also highlights the significance of Latour's concept of 'hybrid' and Donna Haraway's discussions of 'cyborg' (c.f. Latour, 2004; Haraway, 1991). In fact some of the contemporary literature on actor-network theory and urbanization has coalesced around these framings.

> If we understand the cyborg to be a cybernetic creation, a hybrid of machine and organism, then urban infrastructures can be conceptualized as a series of interconnecting life support system... The home can be conceived as a 'prosthesis and prophylactic' in which modernist distinctions between nature and culture, and between the organic and the inorganic become blurred (Gandy, 2005, p. 28)

In tracing connections through such cyborg or hybrid cities, authors often come across unexpected connections. For instance in a valuable contribution with important policy implications, Hinchliffe and Whatmore (2006) argue for understanding urban spaces as 'living cities' that accommodate a diverse ecology of human and non-human inhabitants. Despite that dominance of accounts depicting cities as human-only spaces, the authors point to the presence of peregrine falcons in certain urban areas. This leads them to explicitly reject the spatial divisions between "civic and wild, town and country, human and nonhuman." They argue that urban space is often constituted as a public good through the presence of a variety of spaces "including leisure spaces such as parks and allotments; feral spaces such as abandoned railway sidings and derelict land; and remnant spaces such as waterways and woodlands" (2006, p. 123). This understanding of urban space leads the authors to argue for an alternative "politics of conviviality".

In a more recent contribution in this vein, Jean Hillier analyzes the dismantling of large ships that are no longer seaworthy and contain hazardous materials (2009). Hillier brings together the work of Latour, John Law (c.f. 2004) and Michel Callon (c.f. 1998), other main proponents of actor-network theory, as well as Deleuze and Guattari (1987). Hillier traces social and environmental justice issues through a complex set of actants and linkages surrounding the dismantling operations at Graythorp, Hartlepool, in the UK.

There is great value in these contributions in that they preserve a high degree of complexity in analyzing the relationship between cities and the environment. We take our analysis in a somewhat different direction, drawing on Harvey (1996) and on Latour (2004) for their overriding of the nature vs. culture binary, one that can easily lead to zero-sum interpretations of the relationship. Additionally our concept of rupture is consonant with Latour's thinking about crisis and system failures as opportunities for revealing linkages. For Latour "accidents, breakdowns, and strikes" have a special value:

> All of a sudden, completely silent intermediaries become full-blown mediators; even objects, which a minute before appeared fully automatic autonomous, and devoid of human agents, are now made of crowds of frantically moving humans with heavy equipment. (Latour, 2005, p. 81)

The ruptures that we now face in the relationship between cities and the biosphere make visible the connectedness of cities and biosphere, and thereby open new ways to conceptualize urban-ecological cycles. These ruptures are sites where human intervention has dangerously destabilized natural ecological cycles (c.f. below, on interventions into the carbon cycle or the nitrogen cycle). And these ruptures bring to the fore the *transactions* between cities and the biosphere as the key sites for intervening – for delegating back to the biosphere.

We specify that the city (a) generates third natures – specific *new* environments – such as heat islands, that today are destructive of the biosphere, and (b) that the city has systemic properties that correspond to those of the biosphere – linkages that are highlighted by the ruptures that increasingly characterize contemporary urbanization. That is to say, our project agrees with the problematizing of the category "nature," which pertains to our presence in the biosphere. But we do not take Harvey's more absolute statement that the city itself is nature, nor do we confine our analysis only to Latourian natures–cultures.

Moving beyond Harvey and Latour, we focus on the complex in-between space that is the site of both the transactions between city and biosphere, as well as the site of the ruptures that characterize these transactions. Our analysis is less centered in the work of correcting a false binary, as is the case with both Latour and Harvey, notwithstanding their different objects of study. Rather, we want to theorize the shifting relationship between cities and the biosphere in ways that can incorporate vanguard scientific, technical and social innovations. Such an analysis entails, for instance, accounting for the deployment of nanotechnology to enhance capacities of the biosphere, but in ways that bridge with the biosphere rather than creating ruptures. Examples include self-cleaning coatings that mimic the surface chemistry of a lotus-leaf and new 'spray-on' photovoltaic technologies (Turney, 2009; Balani et al., 2009; Shin'ichi, 2002; Steinhagen et al., 2009; Panthani et al., 2008). These technologies are characterized by the fact that they enable delegating back to the biosphere some of both the work and the capabilities that need to be activated.

Our theorization aims not only to account for new technology but to account for social innovations as well. An example of such social innovation is the work of Ties Rijcken and a team of researchers at Delft University who have developed a SimCity-like computer game in order to improve stakeholder awareness and participation in water planning for the Rhine delta (www.aorsg.nl). Recalling here Latour's emphasis on the deep linkages between nature and culture, we conceive of this as an intervention in the socio-side of a socio-ecological system – in this case the system is the Rhine delta 'water machine,' an assemblage encompassing the geology, geography, and social practices of that delta.

### 2.3. Marxist urban political ecology

Our project partly, but only partly, corresponds to another branch of thinking about the relationship between cities and nature, Marxist urban political ecology, which emerged from the work of David Harvey and other radical geographers. This scholarship is a power-centered analysis based in the proposition that cities are produced by multiple socio-ecological processes that are linked and involve coincident social and ecological forces. Marxist urban political ecology emphasizes the urban as a site where ecology, economy, and society collapse on one another and must be untangled.

> Under capitalism, the commodity relation veils and hides the multiple socioecological processes of domination/subordination and exploitation/repression that feed the capitalist urbanization process. (Swyngedouw and Heynen, 2003, p. 900)

Urban spaces are conceived as the products of multiple such socio-ecological processes, which produce and are produced by power relations at various, often conflicting, scales; these in turn also offer possibilities for contesting that power, but at another scale (Sassen, 2001, 2005, 2004).

In its most recent form this literature has also embraced a Latourian tracing of connection. For instance, a 2006 collection of papers, "In the Nature of Cities", brings together a series of contributions in the field of urban political ecology (Heynen et al., 2006a,b). In the introduction to this volume the editors point to the field's affinity with the work of Latour (Heynen et al., 2006a,b, p. 1).

The editors of the volume also reiterate that power and politics are central to this body of scholarship. "The central message that emerges from urban political ecology is a decidedly political one" (Heynen et al., 2006a,b, p. 2). The authors give a ten-point manifesto of the central themes and perspectives of urban political ecology (Heynen et al., 2006a,b, p. 11). Many of the contributors to this volume reiterate Harvey's claim that urban ecology is a 'natural' ecology: "In a fundamental sense, there is in the final analysis nothing unnatural about New York City" (Harvey, 1993: 31, 28). Among these contributions Gandy's (2006) is especially worth noting as he extends the discussion to the ideological dimension in positing the existence of an 'ecological imaginary', a cluster of ideologies that have shaped human biases towards and interactions with nature. This approach does bear a strong resemblance to Latour's discussion of natures–cultures mentioned above. For our purposes it also brings to the fore the work of disentangling ideologically and profit-driven conditions from a more-science based understanding, the latter being critical for our purposes.

This scholarship has produced some of the most original theorized case studies on cities and nature. For instance, Swyngedouw and Heynen (2003) describe incomplete construction projects in Jakarta, abandoned in the wake of the 1998 Southeast Asian financial crisis, which had become breeding grounds for malarial mosquitoes after the heavy rainfalls caused by El Niño. This spread of malarial mosquitoes in urban Jakarta is thus the result of a socio-ecological process – the combination of global capital, global climate, local power struggles, and the local environment. Another excellent work in this field is Paul Robbins and Julie Sharp's analysis of the lawn-care chemical economy, which aims to show how the lawn is a produced and deeply structured cultural and psychological system that has motivated the sale of potentially toxic chemicals to urban dwellers. They find that this socio-ecological process is driven by the expansion of low-density urban growth, the aesthetics of suburban development, crises of the chemical industry, and declining margins in the global chemical trade (Robbins and Sharp, 2003).

For the purposes of our project, the value of these types of studies rests both on the findings and on the fact that the condition is an assemblage of very diverse elements. This 'condition' is one version of that critical intermediate space where delegating back to the biosphere can take place – the work of changing the negative valence of an articulation between city and biosphere into a positive one. In the case of these studies the issue at hand is the specification of that assemblage of elements. We want to recode the negative into a space for positive action.

In addition to producing many valuable case studies, urban political ecology has also conceptualized scale in examining socio-ecological processes. This conceptualizing mirrors our own thinking about scale with respect to delegating back to the biosphere. Swyngedouw and Heynen articulate urban political ecology's relationship to scale in evaluating socio-ecological processes.

> These dynamics are embedded within networked or territorial scalar configurations that extend from the local milieu to global relations. The priority, both theoretically and politically, therefore, never resides in a particular social or ecological geographical scale; instead, it resides in the socioecological process through which particular social and environmental scales become constituted and subsequently reconstituted. (Swyngedouw and Heynen, 2003, p. 912).

Scale itself is often a contested issue. This is well illustrated in Kaika's analysis of contests over the scale at which to manage – and privatize – Athens' water systems. The 'natural' water crisis that hit Athens between 1989 and 1991 was socially constructed, both as natural and as crisis. It was the outcome of socio-ecological processes and produced a reconfiguring of power (Kaika, 2003). This sensitivity to the often conflictive and generative interaction between scales mirrors our own approach to understanding scaling and socio-ecological bridging processes (Sassen, 2005, 2004).

Within the scholarship on urban political ecology, the urban environment is generally only of interest insofar as it is the product and stake of contested power relations. Here, our thinking about *delegating back to the biosphere* departs from Marxist urban political ecology which explicitly deemphasizes traditional environmental concerns such as sustainability.

> From these perspectives, there is no such thing as an unsustainable city in general. Rather, there are a series of urban and environmental processes that negatively affect some social groups while benefiting others (Swyngedouw and Heynen, 2003, p. 901).

In contrast, our approach seeks an active engagement with scientific and technological knowledge. This engagement, in turn, should take us beyond the concept of environmental sustainability and its limitations. We want to recover that intermediate space where the work of delegating back to the biosphere takes place. We see this space as one characterized by a relative conceptual autonomy from power relations. In this regard we use "environmental sustainability" with a somewhat more forceful meaning than might be typical in government regulations and international treaties. We draw on Sonnenfeld and Mol's (this issue) proposition of a new world (dis)order. Though power relations are certainly important, they are in a sense orthogonal to our analysis here. Thus *delegating back to the biosphere* constitutes a new mode of theorizing contemporary changes – one based in scale, linkages, and technical, ecological and economic logics rather than traditional Marxist concerns such as power and class.

In brief, while we partly align with urban political ecology's emphasis on the artificiality of the nature-culture split and its embeddedness in power relations, we depart from it in significant ways. We take as one key starting point the existence of material and chemical cycles in the biosphere which predate human industry and continue to be responsible for the maintenance of homeostasis on earth. We also factor in the limits of this capacity for maintenance given current economic and social logics. The non-biological consumption of resources by cities, industries, and so on, has caused *ruptures* (see, for instance, our discussion of ruptures in the nitrogen cycle later in this paper). The concept of *delegating back to the biosphere* is also a practical project that aims at contributing to the unmaking of these ruptures. The focus is more on the articulation of the city and the biosphere than on the power relations that are manifested there. We do not deny those power relations; on the contrary we have analyzed how they can be dismantled (Sassen, 2005, 2004, 2010a, b).

## 3. Delegating back to the biosphere

Our understanding of delegating back to the biosphere is partly based also on research outside the social sciences. In the next two sections we use some of this research to develop our argument.

One of the issues that concerns us is the imbalance between the biosphere and what has been described as the unbiological consumption of inputs in our large cities (Bettencourt et al., 2007; Bettencourt and West, 2010; West, 2010). With an astonishing degree of regularity, biological processes exhibit economies of scale; that is, material and energy flows in biological systems tend to proportionally diminish with increasing size. For instance, an elephant requires less energy per pound than a mouse. But large cities today exhibit the opposite behavior – costs, wages, income, employment, resource consumption, rates of invention, etc. all *accelerate* with increasing urban size (Bettencourt et al., 2007). This has fundamental implications for the concept of delegating back to the biosphere and points to the specificity of our concept. The above-mentioned work on comparing 'biological' scaling behavior – i.e. economies of scale – with 'non-biological' scaling behavior – i.e. systems that exhibit linear or increasing resource needs with increasing size, can be graphically represented (see Fig. 1).

The central problem arises when cities consume and produce waste in a 'non-biological' manner while still relying on systems with 'biological' scaling properties for waste remediation, energy production, etc. This has a special relevance to the notion of an environmental new world order around which this Symposium (Sonnenfeld and Mol, this issue) is organized. The current world order is perhaps above all characterized by explosive urbanization and the emergence of megacities. These cities also are a source of instability – latent crisis potential. And Bettencourt et al.'s (2007) finding that cities can exhibit non-biological scaling behaviors applies most strongly to megacities. Reconciling the ecological contradictions of this explosive urbanization is a crucial step in any new environmental world order. Delegating back to the biosphere entails a shift to a different mode of production and consumption. It not simply a technical imperative; the technical innovations we discuss below are merely illustrative of a different mode of thinking about the relationship between cities and the biosphere.

The changing relationship between cities and the biosphere cannot be characterized as a simple return to nature. What is necessary is to activate that in-between space with multiple biosphere capacities and multiple human-made technical and knowledge innovations and instruments. Nor can we simply posit the need for consuming less energy. Rather the point is to consume differently, both as process and as content – and to delegate back to the biosphere, at least partly, what are now "man-made" capacities for supplying and manufacturing resources. This implies, in our reading, and perhaps at its most extreme and therefore clearest, that particular kinds of socio-ecological processes delegated back to the biosphere *must* be managed or accelerated in such a way as to keep pace with the urban material and energy flows that exhibit non-biological scaling behavior, that is to say, processes that accelerate with growing urban scale. This contrasts, with the biosphere's tendency to decelerate with growing scale. Reducing this unsustainable gap marks the specificity of 'delegating back' to the biosphere, in contrast to a simple return to nature.

Delegating back implies management and human intervention in the formation of *novel* socio-ecological bridges with positive valence. For instance, the rate of waste production accelerates with urban scale whereas natural processes for waste removal would tend to decelerate with scale. So delegating waste management back to nature must involve novel socio-ecological transactions that incorporate natural methods in novel ways; for instance, using algae rather than chemicals, to process wastewater – it is the same process as in nature, but accelerated. In this sense these processes are *wrapped* in technology at the moment they are delegated back to the biosphere.

Two decades ago there was a body of critical analysis on the "return to nature" as a viable option. Thus Harvey (1996) notes that at best traditional environmental ecologists can offer some return to an earlier form of urbanization regulated by the metabolical constraints of a bioregional world "as it supposedly existed in the past," a world that for Harvey never really existed. At that time, and perhaps still in much of the world, much of what passed as ecological among social scientists studying cities actually dealt with quality of life issues for middle and high income people and neglected the needs of the poor (Satterthwaithe, 1999).

Though less so today than in the past, the range of issues posed by urbanization goes beyond those typically addressed by environmentalists. For many, the whole notion of "sustainable cities" is faulty in that it fails to name what are the actual dynamics and causalities that are at issue (see Simone, 1997), i.e. the actual processes that cause environmental damage. The articulation of environmental and urban research has long lacked a clear definition of key categories such as environment and sustainability. One difficulty is that environment has many different meanings, depending on ideology, politics, situation, positionality, and economic and political capacities; to this we can add the sort of theoretical issues discussed in the prior section. Nonetheless, there is a whole range of ecological issues central to how we should be thinking about our rapidly urbanizing world. How we respond to some of the large global scale issues (warming, ozone, emissions) will have profound implications for urbanization processes (Girardet, 2008). But these may not be the issues of concern to most people in cities in the South, a difference that goes back decades (e.g., Pathak, 1999; Safi, 1998; Mol and Sonnenfeld, 2000).

With all these ambiguities and differences in the analytical categories and in the position of diverse social strata, we can nonetheless posit that the foundational condition cities share is that the entire energy and material flux coursing through the human economy returns to the ecosphere in altered form as pollution and waste. This is the radical difference between cities

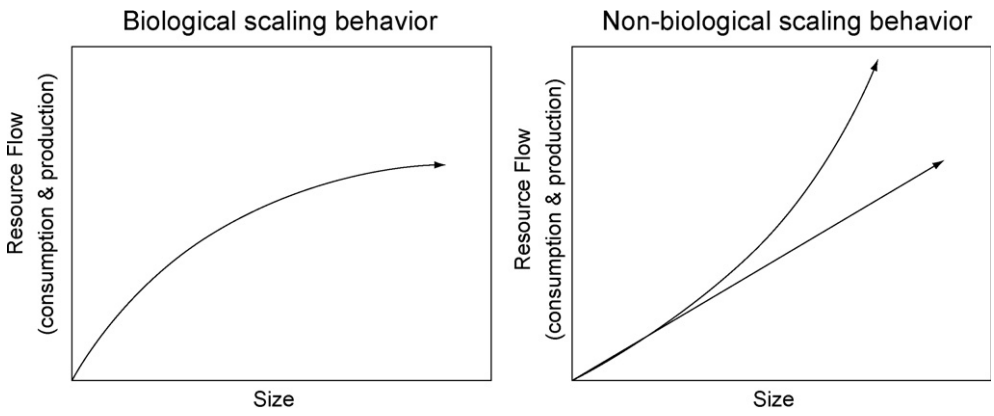


**Fig. 1.** A schematic representation of 'biological' and 'non-biological' scaling behaviors.

and the biosphere: multi-scalar dynamics and horizontal eco-shifts enable the biosphere to avoid that rupture and thereby avoid producing "waste" and "pollution". The rupture at the heart of this set of flows in our cities is *made* and can, thus, be unmade. Addressing this rupture will require instruments and changes that go beyond adaptation and mitigation. This rupture is present in just about all economic sectors, from urban to non-urban. Cities are today a source of much direct and indirect environmental damage, and some of the most intractable conditions that feed that damage. Nevertheless, it is also the complexity of cities that is part of the solution.[2] Thus it is in cities where environmental damage has its most complex interactions and cumulative effects, two systemic properties that are significant and should be made into capabilities with positive environmental valence. We need to use and build upon those features of cities that can re-orient the material and organizational ecologies of cities to positive interactions with the biosphere's ecologies.

Today's mostly negative interactions, and the diversity of domains they cover, are themselves an emergent socio-biospheric system that belongs to both the city and the biosphere. At the same time, the very existence of this hybrid in-between space, invites us to ask whether it contains systemic capabilities that could be extricated and moved to novel in-between spaces where their valence would become positive regarding environmental sustainability.[3]

Besides mitigation of environmental damage and adaptation, we need to identify systemic features of cities that bridge with the biosphere through positive articulations. Key is the diversity of ecologies and multi-scalar capacities of cities. There is here a parallel with the biosphere's features. More theoretically, one can posit that insofar as cities are constituted by various processes that produce space, time, place and "nature" (e.g., the new eco-urban conditions such as heat islands and, at another scale, ozone holes), they also contain the transformative possibilities embedded in these same processes. For example, the temporal dimension becomes critical in environmentally sound initiatives. Thus, ecological economics enables us to recognize that what is inefficient or value-losing according to market criteria with short temporal evaluation frames, can be positive and value-adding, using criteria driven by the biosphere's conditionalities, including uninterrupted flows and multi-scalar shifts.

## 4. Cases that signal capacities to delegate back to nature

We take it as a starting point that, with some exceptions, we cannot return to archaic forms of production. Rather, we see our project at its most synthetic as understanding how current knowledge is increasingly being used to close cycles of the biosphere which have been interrupted by human activities/intervention. One key step that we have observed is the development of practices, scientific knowledge and technologies that better emulate the fully closed cycles of the biosphere. The raw data are the scientific discoveries and applications that contribute to the closing of today's disrupted cycles.

In the discussion below we emphasize the technical aspects of several innovations and their relationship to specific ruptures. This is not to say that social, socio-ecological or socio-technical aspects are unimportant. Rather we aim here to illustrate a specific tendency – i.e. the tendency to delegate back to the biosphere – and must leave deeper discussion of its social, political, and economic articulations for future work. There has though been important work highlighting the role of human users in technical networks.

In a review of the role of infrastructure in studies both from actor-network theory and geography, Kathryn Furlong finds that both have underestimated the significance of user (i.e. human) involvement (2010). Furlong emphasizes the importance of emerging 'mediating technologies', simple, low-cost devices that can be added to infrastructure networks with the goal of modifying their performance often by increasing user awareness and interaction. Furlong's account reveals how new mediating technologies are opening up the 'black-box' of infrastructure networks. This is an important task. In the illustrations that follow, though, we put aside such analysis of mediation and user involvement, despite the fact that these are certainly important.

We are less concerned with opening a black-box than with elucidating a trend which is becoming increasingly characteristic in human transactions with the biosphere. Undoubtedly human interactions with technical systems play an important role. The remainder of this section provides a series of brief sketches of the technologies themselves as vanguard cases of delegating back to the biosphere. We leave it to the reader and further research to explore the intersection between delegating back to the biosphere and the other undoubtedly important analytics articulated in the literature (e.g., Furlong's mediating technologies, Gandy's cyborg cities, Latour's natures–cultures, etc.).

Our understanding of the emergence of *delegating back to the biosphere* is not only informed by the sociological literature discussed above, but is also grounded in more technical literature that relates directly to environmental policy, economics and technology.

### 4.1. Roots in ecological economics

Over the last three decades ecological economists have developed several alternative sub-paradigms within the broader paradigm of ecological economics.[4] In the examples below we tend to align our analysis with H.T. Odum's EMERGY model (Odum, 1971). Rather than emphasizing limits on natural resources, this model traces all environmental products and services to solar energy. This draws the analytical focus to ways in which natural products can be renewed (i.e. using solar energy). It signals the possibility that the natural cycles that sustain human life (e.g., nitrogen cycle and carbon cycle) can grow in size while maintaining homeostasis. This model contrasts with H.E. Daly's model of a "steady state economy", which advocates minimizing 'throughput', that is to say, minimizing the use of materials and energy in the economy (Daly, 1977).

Odum better captures the particular dynamics that concern us here because our empirical cases already contain capabilities that dramatically amplify throughput – to use Daly's term – far beyond what the biosphere alone provides. Currently an estimated 40% of human life on earth is sustained by nitrogen-based fertilizers, a condition that signals we are beyond the point of using archaic techniques. Minimizing waste is crucial and can greatly reduce environmental degradation, but unless the human population on earth stops growing the minimum size of the ecological economy

[2] That it is not urbanization per se that is damaging, but the mode of urbanization, is also signaled by the adoption of environmentally harmful production processes in rural societies. Until recently, these had environmentally sustainable economic practices, such as crop rotation and foregoing the use of chemicals to fertilize and control insects. Further, our extreme capitalism has made the rural poor, especially in the Global South, so poor that for the first time, many now are also engaging in environmentally destructive practices, notably practices that lead to desertification.

[3] For a fuller development of this argument/thesis see Sassen (2008, especially chapters 1 and 9) examining how capabilities produced in a given historical system can switch organizing logics and become constitutive of a novel system. One implication is that systemic change can be furthered by capabilities belonging to the prior regime but on condition that they switch organizing logics.

[4] For discussion of key premises in ecological economics applied to the question of cities and sustainability see (Sassen, 2004, 2010a).

will continue expanding. The key, in our understanding, is to ensure that the throughput is renewable. This means that rather than simply increasing the goods-side of cycles (e.g., amplification of fixed nitrogen suitable for agricultural use) humans must also increase the scale of the waste-recycling processes that had maintained homeostasis before human involvement. The crucial rupture is found at the point where the amplification of natural cycles by human intervention leads to collateral ecological damage. For most of our modern history we have intervened in the biosphere without attention to downstream effects. Ecological economics has drawn attention to this fallacy by providing an alternative to the earlier paradigm of Environmental and Resource Economics (ERE).

ERE considers nature as a resource competitively consumed by human actors. The analytic goal thus becomes optimally distributing a scarce, consumable resource to achieve Pareto efficiency – i.e. maximum aggregate welfare. In contrast, ecological economics (EE) considers a longer horizon and does not see Pareto efficiency as the optimum. We could say that while ERE seeks to optimally consume natural resources, EE seeks to avoid their depletion qua consumption. If ERE seeks to optimally *use up* limited natural resources, EE sees their *using up* as the ultimate failure. EE, unlike ERE, includes stability and resilience of ecosystems and biodiversity in its calculus. There is a substantive rationale for this – namely that we are intervening in complex systems in which interventions will tend to produce unknown effects. This raises the likelihood of catastrophic breakdowns in complex systems, which Charles Perrow has described in the context of organizational sociology as 'normal accidents'.

Here we introduce some examples of the incipient trend that we are identifying – i.e. delegating back to the biosphere as a strategy of undoing man-made ruptures. These examples and illustrations are a first step in specifying an in-between space, a space that combines elements of the biosphere with human innovations allowing us to delegate processes back to the biosphere, but in amplified form. The mix of knowledge of the natural sciences and the fact that cities are complex social systems makes it imperative in our view that the social sciences be a central part of such a project. The social sciences, and in many ways especially sociology, should be in a prime position to develop these facts conceptually, describing, clarifying and contextualizing the innovations made in the natural sciences. This is clearly a collective project given worldwide differences in the conditions of the biosphere and of society.

### 4.2. Case: nitrogen-based fertilizer

The amount of available fixed nitrogen in soil is a limiting factor in food and plant growth. The discovery in 1909 of Fritz Haber's process for chemically fixing nitrogen (known as the Haber or Haber-Bosch process) made it possible to surpass the amount of food that could be grown using traditional nitrogen replenishment techniques such as crop rotation or leaving fallow fields. The Haber process uses heat and the presence of a catalyst to convert nitrogen gas, and methane-derived hydrogen gas, into a useable form of nitrogen – ammonia. The process is still applied all over the world to produce 500 million tons of artificial fertilizer per year which sustains roughly 40% of the population and uses 1% of the world's energy supply (Science, 2002; Fryzuk, 2004).

This constitutes a major rupture and central case in our analysis. There are two key flaws in the current situation: (a) the non-renewable sources of energy (in the form of electricity) used in the production of ammonia, and (b) the negative effects of its uncontrolled diffusion into different environments. This is a clear illustration of humans intervening in one stage of the nitrogen cycle without corresponding interventions at other stages. Delegating back to the biosphere entails closing the cycle – eliminating the interruption or the imbalance in the cycle.

Not addressing this imbalance has serious consequences. Runoff of excess fertilizer leads to accumulation of nitrates in groundwater. This can cause 'blue baby syndrome' – a form of asphyxiation – as nitrates bind to hemoglobin more strongly than oxygen. Nitrate-enriched groundwater gets into lakes and oceans where it causes excessive algae growth, which can kill fish through eutrophication, the formation of 'dead zones'. The use of fertilizers is also becoming an increasingly important source of climate change – nitrous oxide is currently the third most important greenhouse gas.

The nitrogen cycle illustrated in the familiar diagram (Fig. 2) of the US Environmental Protection Agency (2008, in the public domain), illustrates this imbalance. Basically, humans have increased the flows of the left side of this diagram but have not correspondingly increased flows on the right side. This imbalance is the cause of much of the harm done by nitrogen-based fertilizers. New technologies are being developed to compensate for this and many of these can be understood within the framework of delegating back to nature. We briefly describe some of these next.

*Technology #1: Algal Wastewater processing*: One, by now well-established, technology is the use of bioreactors (essentially controlled ponds) that combine bacteria and algae which can clean nitrate contaminated water, and recycle gaseous nitrogen ($N_2$) into the atmosphere. Algae in the bioreactor produce dissolved oxygen through photosynthesis. This oxygen is then used by bacteria, including denitrifying bacteria, in the process of breaking down organic wastewater components. The bacteria, in turn, provide carbon, nitrogen and phosphorus needed for algal growth. Additionally, algal photosynthesis raises the pH of the bioreactor, which causes decomposition of harmful ammonia compounds (by stripping ammonium ions) as well as precipitation of phosphate contaminants, another fertilizer derived pollutant (Garcia et al., 2000).

This process is a controlled acceleration of the right hand side of the nitrogen cycle depicted in Fig. 2: it takes solar energy and waste as the inputs. It thus works towards undoing the rupture caused by our acceleration of the left side of the cycle.

### 4.3. Case: the carbon cycle

The carbon cycle is the primary means through which energy is cycled through ecosystems including the human economy. The burning of fossil fuels releases stored solar energy and carbon gases, including carbon dioxide and carbon monoxide. The carbon cycle is illustrated in the image below (Fig. 3), from NASA (2008, in the public domain).

The numbers next to the arrows in Fig. 3 represent billions of tons of carbon (GtC) released and absorbed. Human burning of fossil fuels liberates 5.5 GtC annually. While human intervention has accelerated the right side of the carbon cycle in the image, there has not been a corresponding acceleration of re-uptake on the left side. This constitutes another rupture that is being tackled by technologies that delegate back to the biosphere.

*Technology #2: Algal Fuel Generation/Carbon Sequestration*: The firm, Algenol Biofuels is developing a process that produces ethanol from genetically modified algae in bioreactors. This process takes sunlight and carbon dioxide (obtained in a concentrated form by capturing carbon dioxide released from fossil fuel burning power plants). The company reports that their prototype strains of algae can produce ethanol at a rate of 6000 gal/acre/year and aim to reach efficiency of 10,000 gal/acre/year (algenolbiofuels.com). This compares to 250–

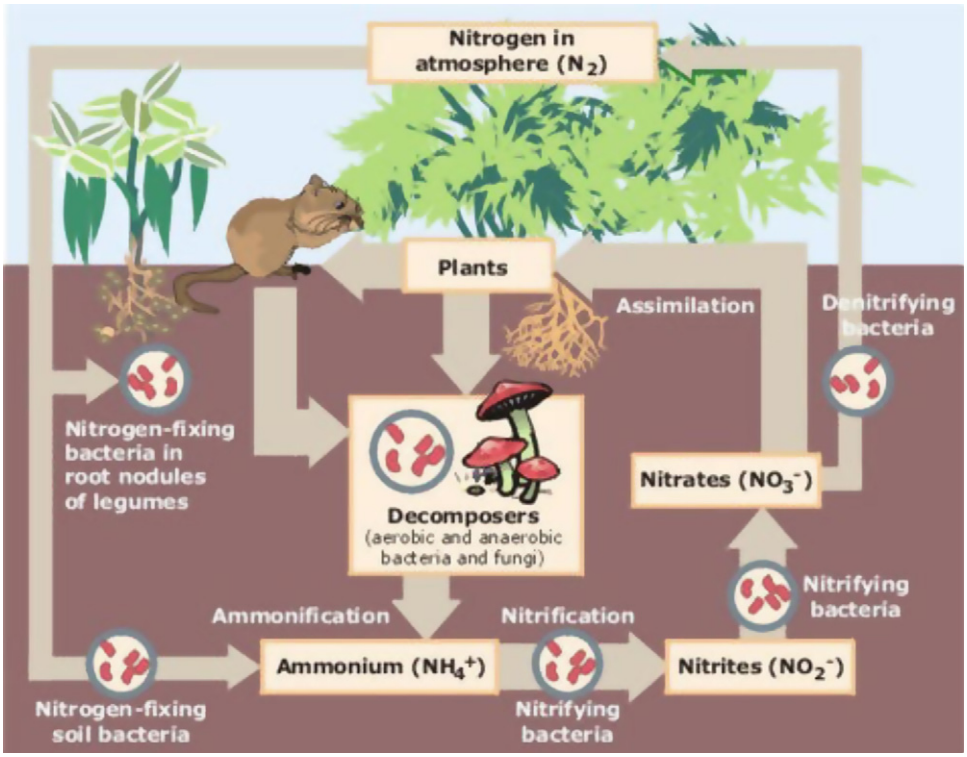


**Fig. 2.** The nitrogen cycle.
*Source*: US Environmental Protection Agency.

350 gal/acre/year generated by growing and fermenting corn (Shapouri et al., 1995; Pimentel, 2005). When coupled to an ethanol-burning power plant, these bioreactors can be thought of as giant biological solar panels. Dow Chemical has partnered with Algenol Biofuels with an interest in using ethanol, rather than fossil fuel, as a raw material in the synthesis of plastics (Wald, 2009). The Chinese firm, ENN is also developing algal biofuel systems in an effort to reduce that nation's reliance on coal (Watts, 2009).

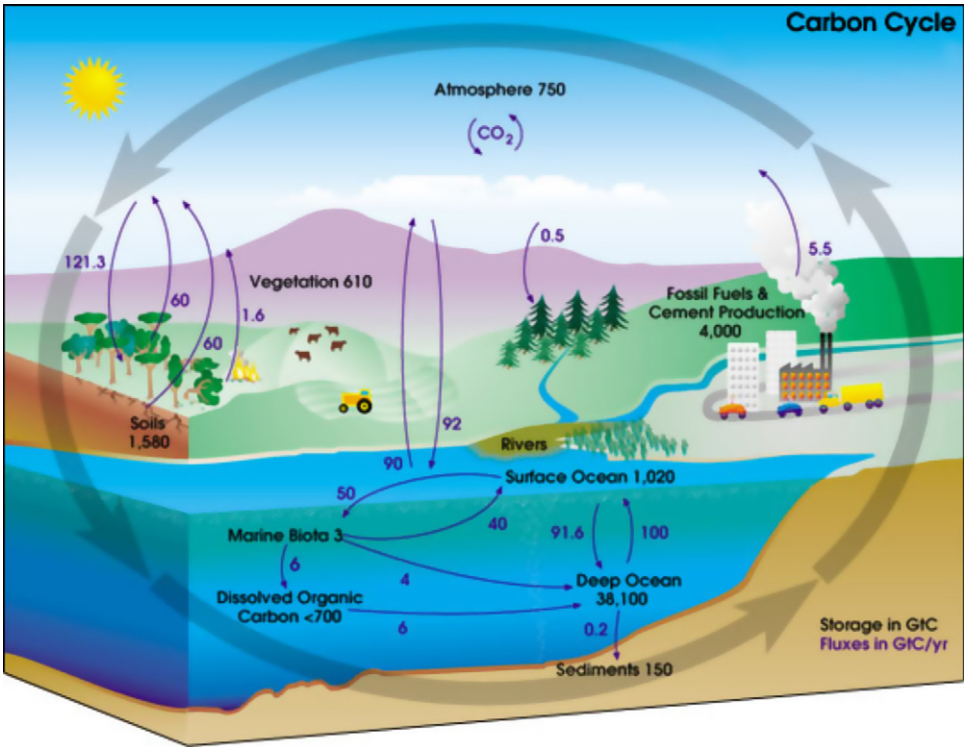


**Fig. 3.** The carbon cycle.
*Source*: NASA Earth Observatory.

This productive recapture of atmospheric carbon, using solar energy as the primary energy input, is analogous to accelerating the reuptake-side of the carbon cycle. By delegating back to nature, these technologies are unmaking ruptures caused by human intervention in the carbon cycle.

### 4.4. Case: reducing throughput/increasing efficiency

While there is a debate and the variability of cities makes it difficult to generalize, it is most likely the case that cities are more efficient and cause less collateral environmental damage per-capita than suburbs or rural areas.[5] Here we describe just one of several technologies with the potential to use the built environment as a platform for delegating back to the biosphere.

*Technology #3: Self-Healing Concrete*: One dramatic technology being developed is self-healing, bacterial concrete. In this technology, bacteria residing within concrete structures seal cracks and reduce the permeability of concrete surfaces by depositing dense layers of calcium carbonate and other minerals. Several groups have demonstrated the feasibility of this approach (Jonkers, 2007). This technology is still under development but early tests show positive results in reducing green house gases. Human-made structures would thus more closely model the self-sustaining homeostatic physical structures found in nature.[6]

### 4.5. Case: diffusion control/constraining cycles

While human intervention in natural cycles is geared towards amplification and harvesting at a certain stage, oftentimes wastes are allowed to diffuse into other natural systems and become difficult to recycle even when adequate recycling technologies are available. This problem of spatial distribution is aggravated by the anisotropic distribution of human activity over the surface of the earth, which can lead to dangerous concentrations and dispersal of pollutants.

*Technology #4: Bio Reactor Landfill*: The problems of concentrated capture and recycling are strongly felt in cities as a result of the extremely high population densities found in many cities. Landfill waste generated by human activity becomes a dangerous pollutant, source of greenhouse emissions, and terminal break in many natural cycles. The development of landfill bioreactors seeks to overcome this. Landfill bioreactors seek to accelerate waste decomposition by improving conditions for aerobic or anaerobic biological processes. This is paired with the capture of byproducts released from these processes, most notably carbon dioxide and methane which is used as fuel known as "landfill gas" or LFG (Yolo County, 2006). This both reduces the uncontrolled diffusion of greenhouse gases and provides a concentrated source of fuel as well as carbon dioxide for use in carbon sequestration and fuel generation. As of December 2008, the US Environmental Protection Agency reported that approximately 480 LFG energy projects were operating in the US, generating approximately 12 billion kW h of electricity per year and 255 million cubic ft. of LFG for direct use.

The applications of scientific knowledge described above are a strategic first step that signal the rise of delegating back to the biosphere as an increasingly characteristic strategy among efforts to create a positive relationship between cities and the biosphere. But cities are not merely about scientific knowledge. They are complex multi-scalar and ecological systems, and they are systems of power and of social relations. It is at this point that forms of knowledge about the social and the political become critical inputs for succeeding in the larger process of delegating back to the biosphere, issues we address in the next, concluding section.

## 5. The next stage: towards a multi-scalar ecological urban analysis of cities

Our initial aim is using science and technology in ways that could enable a better use of the properties of cities in the work of multiplying the positive articulations between cities and the biosphere. Yet it is merely one step in a trajectory that should include, in our view, two other strategic elements. One of these is full use of the complexity of cities – their multi-scalar and ecological features. The technologies described above mobilize some of these features. Still, a wider use of these and other technologies could mobilize the full multi-scalar and ecological potential of cities. We do not think we are close to this point, but under the rubric of delegating back to the biosphere we have identified an incipient mobilization in this direction. This should enable urban experts and scientists to connect far more and this might enable us to move much faster on this potential for delegating back to the biosphere.

The second strategic element concerns the city as a social and power system – with laws, often extreme inequalities, and vast concentrations of power.[7] Urban complexity and diversity are augmented by the fact that delegating back to the biosphere also will require engaging the legal systems and profit logics that underlie and enable many of the environmentally damaging aspects of our societies (Sassen, 2008, Chapters 4 and 5). Any project of delegating back to the biosphere is necessarily implicated in these systems and logics. The question of urban sustainability cannot be reduced to modest interventions that leave these major systems untouched. The actual features of these systems vary across countries and across the North-South divide. While, in some of the other environmental domains, it is possible to confine the discussion of the subject to scientific knowledge, this is not the case when dealing with cities. Non-scientific elements are a crucial part of the picture. Questions of power, poverty and inequality, ideology and cultural preferences, are all part of the question and the answer. One major dynamic of the current era is globalization and the spread of markets to more and more institutional realms. Questions of policy and proactive engagement possibilities have become a critical dimension of treatments of urban sustainability, whether they involve asking people to support waste recycling or demanding accountability from major global corporations that are known to have environmentally damaging production processes.

Cities are multi-scalar systems where many of the environmental dynamics that concern us are constituted and which, in turn, partly constitute what we call the city. Yet, an enormous share of the attention devoted to urban sustainability has been on how people as consumers and household-level actors damage the environment. When measuring cities, inevitably individuals and households are by far the most numerous units of analysis. There are shortcomings in this focus. In matters of policy, it leads to an

[5] The scholarship is large and diverse given the millions of cities that might have served as case studies. For one of the best general overviews, see: ICLEI Climate Program. www.iclei.org/index. For an interesting point of view, see: David Owen, "Green Manhattan", *The New Yorker*, October 18, 2004.

[6] An experimental technology with a similar capacity to be deployed "globally at the local level" is the so-called carbon negative cement (see http://www.novacem.com/docs/novacem_press_release_6_aug_2009.pdf). There are many other such uses of nature's capacity to address the environmental challenge in cities, although none as globally present as the challenge of greening buildings.

[7] This is a broad subject. For studies that engage a range of aspects, see Sassen (2001, 2005), Satterthwaite et al. (2007), Girardet (2008), Mol and Sonnenfeld (2000), Beddoe et al. (2009), and Morello-Frosch et al. (2009).

emphasis on household recycling activities without addressing the fundamental issue of how an economic system prices modes of production that are not environmentally sound. This type of focus can easily leave out global economic and ecological systems that are articulated with the city, yet cannot be addressed at the level of households or individual firms. For instance, those who insist that greenhouse gas emissions will have to be controlled at the local level are, in many ways, right. However, these emissions will also have to be addressed at the broader macro-levels of our economic, as well as biophysical systems. Further, some recent innovations suggest the possibility of planetary interventions that materialize at the local level. This could be the case with one of the scientific applications described above, "self-healing concrete", a technology that can be used for all concrete buildings, whether they are located in modest neighborhoods or the business districts of global cities, whether in a rich Global North country or a poor Global South town.[8] This would constitute a global scale through multiple local spaces.

These types of issues can be analytically conceived as questions of scale. Scaling can be seen as one way of handling what are now often seen as either/or conditions: local vs. global, market vs. non-market mechanisms, green vs. brown environmentalism. We have found analytic work on scaling by bio-ecologists useful for conceptualizing particular features of cities. Of particular relevance is the notion that complex systems are multi-scalar systems, as distinct from multilevel systems, and that complexity resides in the relationships among scales. Understanding how tensions among scales might be operating in the context of the city can refine the analysis of environmental damages associated with urbanization, and the ways in which cities provide solutions.

Situating diverse types of environmental dynamics in the context of cities and in relation to policy is part of a vast research agenda. There is better understanding of what needs to be done to mitigate and clean-up environmental damage. However, understanding the city as a broader complex system rather than as an array of points of remedial intervention, poses enormous difficulties, precisely because of the multiple scales and ecologies that comprise the city. Its ecologies and scalings make the city a system of vertically and horizontally distributed capabilities, which range from physical to social, politico-economic, and juridical-administrative capabilities. That is to say, the individual household, firm or government office can recycle waste, but cannot address effectively the broader issue of a city or a region's excess consumption of scarce resources. Conversely, an international agreement can call for global level measures to reduce greenhouse emissions, but depends on individual countries, individual cities, individual households and firms to implement many of the necessary steps. A national government can mandate environmental standards, but also has to engage systems of economic power and wealth production.

A key analytic step is to decide which of the many and diversely scaled ecological, social, economic policy processes are needed to explain a specific environmental condition, whether negative or positive, and to design a specific action or response. A second analytic step is to factor in the temporal scales or frames of various urban conditions and dynamics – cycles of a city's built environment, economy, infrastructures, and such items as investment instruments and revenue cycles. The combination of these two steps helps us deconstruct a given situation and locate its constitutive conditions in a broader grid of spatial, temporal, and administrative scales.

The articulation between spatial and temporal scales evident in the biosphere's ecologies may prove useful analytically for the case of cities. What may be negative in a small spatial scale or a short-time frame (e.g., a predator's kill) may be positive in a larger scale or longer time frame. For a given set of disturbances, different spatio-temporal scales may elicit different responses from ecosystems. Using an illustration from ecology, we can say that individual forest plots may come and go, but the forest cover of a region can remain relatively constant overall. This raises a question as to whether a city needs a larger system in place to neutralize the impact of multiple small negative conditions or actions inside the city – for instance, at the level of neighborhoods or buildings. An example of such a larger system is satellite-based traffic information that can be used to alert drivers about points of extreme congestion.

In the social sciences, it is easy to confuse levels and scales. Bio-ecological research can help in clarifying the difference. What is sometimes presented as a change of scales is actually a translation between levels. A change of scale results in new interactions and relationships, often a different organization. Level, on the other hand, is a relative position in a hierarchically organized system. Thus, a change in levels entails a change in a quantity or size rather than the formation of a different entity. A level of organization is not a scale, even if it can have scale or be at a scale. Scale and level are two different dimensions.

One pertinent research finding from ecology is that movement across scales brings about change and is the dominant stabilizing process; it is not only a question of larger or smaller, but rather that the phenomenon itself changes. Unstable systems become stable, bottom-up control incorporates elements of top-down control as it shifts scales upward, and what is competition at a lower scale may become less important and interactions of differences more important at a larger scale. This also would potentially bring to the fore the importance of using the complexity of cities as a key source of solutions to many types of environmental damage. One question then becomes: what are the scales at which a city's diverse components can contribute solutions to the environmental crisis?

Relating some of these analytic distinctions to the case of cities allows us to identify at least three ways in which the city can be conceived of as a multi-scalar system. A first way is to note that when an event takes place in a city, some of its features can be altered in a way that would not be the case in a rural area. Density is a good example. The individual occurrence is distinct from the aggregate outcome. It is not merely a sum of individual occurrences (i.e., a greater quantity of occurrences). It is a different event. $CO_2$ emissions produced by the micro-scale of vehicles and coal burning by individual households become massive air pollution covering the entire city with effects that transcend $CO_2$ emission *per se*, i.e. they can produce a different formation, notably heat islands and ozone holes, whereas a rural area with a few houses burning coal and a few cars would not scale up into a different formation. Air- and water-borne microbes materialize as diseases at the scale of the household and the individual body. But they become epidemics that thrive on the multiplier effects of urban density and are capable of destabilizing the operations of organizations whose physical and technological infrastructures have no intrinsic susceptibility to the disease.

A second way in which the city is multi-scalar becomes evident in the geography of the environmental damages it produces. Some of the damage is internal to the built environment of the city but some of it takes place in non-urban geographies and multi-scalar systems, such as the rain forest (via the demand for wood for furniture and construction). Urban demand for resources engenders a geography of extraction and processing that spans the globe. The fact that it does so in the form of a sequence of confined

[8] This example also illustrates how the complexity of the city expands the meaning of the scientific application. On the one hand, buildings are the largest single source of green gas emissions and on the other, it moves into the social as implementation would create employment, mobilize citizens in their neighborhoods, and allow local governments to get involved by initial small subsidies, especially in modest neighborhoods.

individual sites, albeit distributed worldwide, may help in both addressing and making visible the environmental cost. So might the fact that this worldwide geography of extraction materializes in particular and specific entities (e.g., furniture, jewelry, machinery, and fuel) inside the city. There is an interesting potential here to raise consciousness about the need to reduce geographies of extraction and damage by making visible the multiple components of those geographies. The city is one moment – the strategic moment – in these global geographies, but it is the strategic one for feeding their span and content, and for reducing their damaging effects.

A third way in which the city is multi-scalar is that it incorporates a broad range of policies—supranational, national, regional, metropolitan, and local. Again, the city is one moment in these diverse policies. It gets deployed in specific ways within each policy domain, often not explicitly; for instance, much of the existing global environmental policy framework does not directly address cities; even less so their hinterlands. Policies materialize in particular procedures, regulations, penalties, forms of compliance and types of violations. These in turn can differ from how the actual policies are formulated and implemented in other sites – rural areas, coastal areas, regions, national domains, international domains.

These three entry points into the multi-scalar character of cities – the specificity of urban vs. rural effects, the geographies of environmental damage caused through urban consumption, and the range of policies implicated in the urban policy domain – are also invitations to future research. Each of these is a dimension along which contests over delegating back to nature are played out. They are thus also implicated in pressing issues of power, inequality, and social justice. We will need active inter-disciplinary research in each of these areas if we are to have a fuller picture of the future of delegating back to nature and that in-between space where cities and the biosphere meet – a space of great disruptions, but also great potential.

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