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International Resource Panel

CITY-LEVEL DECOUPLING

Urban resource flows and the governance of infrastructure transitions

United Nations Environment Programme

Acknowledgements

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CITY-LEVEL DECOUPLING:

Urban resource flows and the governance of infrastructure transitions

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Preface from the Panel Co-Chairs

Progress in terms of economic and social development over the last century has been largely achieved through the extensive use of our planet's finite resources. Resource exploitation already exceeds the Earth's biological capacity, endangering the fundamental economic, social and environmental systems on which our development relies. However, significant potential exists for improved resource productivity through technological innovation and demand changes over the whole resource life cycle, from the extraction and use of raw materials to end of life disposal. While this will require enormous political commitment and financial investment, if the situation is not addressed, actual costs to nations at a later stage are likely to be much higher.

The International Resource Panel (IRP) was established to support the framing of policies for sustainable resource management through providing independent, coherent and authoritative scientific assessments on the use of natural resources and their environmental impacts over the full life cycle. It assessments are solutions oriented, examining examples of innovation from both a technological and institutional perspective. The Panel's assessment on *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*, launched in 2011, clearly demonstrated that "absolute decoupling", whereby a greater level of well-being can be created using the same or fewer amounts of resources, or with fewer negative environmental impacts, is theoretically achievable but hardly happening. While technologies are available, as are examples of successful policies, this potential remains untapped. The report also highlighted the key role of cities in contributing to decoupling, as societal 'nodes' in which much of the current unsustainable use of natural resources is socially and institutionally embedded - but also as centers for knowledge, financial, social and institutional resources, where the greatest potential exists for sustainability-oriented innovations. This issue was therefore a natural next step for the Panel's Decoupling work stream.

While the topic of sustainability within cities is currently attracting a large amount of attention, this report examines the issue from a new angle – addressing the key role of infrastructure in directing material flows and therefore resource use, productivity and efficiency in an urban context. In doing so, it makes the case for examining cities from a material flow perspective, presenting the city as a living organism with a dynamic and continuous flow of inputs and outputs as its "metabolism", while also placing the city within the broader system of flows that make it possible for it to function. The report highlights the way that the design, construction and operation of infrastructures, such as for energy, waste, water, sanitation and transport, create a socio-technical environment that shapes the "way of life" of citizens and how they procure, use and dispose of the resources they require. Its approach is innovative in that it frames infrastructure networks as socio-technical systems, examining pressures for change within cities that go beyond technical considerations. The importance of intermediaries as the dominant agents for change is emphasized, as well as the fact that social processes and dynamics need to be understood and integrated into any assessment of urban infrastructure interventions. Innovations in and of themselves do not suffice if they are not integrated into larger strategic visions for the city.

A set of 30 case studies provide examples of innovative approaches to sustainable infrastructure change across a broad range of urban contexts that could inspire leaders of other cities to embrace similar creative solutions. Of course, each city is unique, and interventions need to be tailored to set the challenges and opportunities present in each case.

Given the complexity and breadth of the topic, it has not been possible to cover the whole range of city-related issues in this report, and there are a number of topics which would merit further analysis. The Panel's Working Group on Cities will continue to explore the theme, addressing some of these issues in more detail.

We would like to thank Mark Swilling, as Lead Author of the report and Coordinator of the Cities Working Group for his dedication, as well as the authors of the case studies and all contributors to the report. We would also like to extend our appreciation to Lea Kauppi for serving as peer review coordinator for the report as well as the anonymous peer reviewers who have dedicated their time to helping us enhance its quality.

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Dr. Ashok Khosla, New Delhi, India
Co-Chairs, International Resource Panel
March 2013

Foreword

For up to half the world's population, cities are home. Urban areas currently account for 60-80 per cent of global energy consumption, 75 per cent of carbon emissions, and more than 75 per cent of the world's natural resources.

The trend towards urbanization, reflected in all corners of the world, has been accompanied by increased pressure on the environment and growing numbers of urban poor. And, as this movement towards cities is expected to continue in the coming decades with 70-80 per cent of the global population expected to reside in urban areas by 2050, the pressures are likely to increase.

But while the biggest challenges can be found in cities, the most exciting opportunities for sustainability can be found there, too. UNEP's Green Economy Report, launched in 2011, clearly showed that unique opportunities exist for cities to lead the greening of the global economy, by increasing resource productivity and innovation while creating major financial savings and addressing environmental and social challenges.

Cities are the powerhouses of economic growth, with 80% of global GDP being produced within them. But they are like living organisms too with appetites for resources that are currently consuming three-quarters of what nature makes available to humanity to support lives and livelihoods while emitting wastes and greenhouse gases that are challenging global sustainability targets including keeping under a 2°C temperature rise this century.

It makes sense, then, that the solutions to our global challenges focus on cities given that the decisions and actions required to drive society towards more sustainable patterns of consumption and production will have to be made, to a large extent in urban centres. For the people who live in these burgeoning urban areas, their employment opportunities, health, education, leisure, environment and overall quality of life will depend on how urbanization is planned and managed, and how cities source, process and use resources.

Cities must be seen as the building blocks for sustainable development and many are seizing that challenge. in Lingköping, Sweden, public transport is fuelled by waste; in Chennai, India, rainwater is harvested to enhance the city's water supply; in Cape Town, South Africa, low-income housing is being retro-fitted for energy efficiency; Medellin, Colombia, is building social inclusion with cable cars and San Jose, in the United States with its 15-year plan to address climate change and promote economic growth while enhancing citizens' quality of life, through ambitious and concrete targets.

But what we lack still, is a holistic vision for sustainable cities of the future. This timely and relevant report from the International Resource Panel, on decoupling at the city level, is a step towards that vision.

I would like to express my appreciation to the International Resource Panel under the leadership of its Co-Chairs, Ashok Khosla and Ernst Ulrich von Weizsacker, for its pioneering work. I would also like to extend a special thinks to UN Habitat for their important contribution to the report and their valuable partnership with UNEP on urban issues.

Achim Steiner
UN Under-Secretary General and Executive Director, UNEP

Foreword

City-Level Decoupling: Urban Resource Flows and the Governance of Infrastructure Transitions

We already live in an urban age. Still, 60 per cent of the built environment required to accommodate the earth's urban population by 2050 remains to be built. For most, higher fuel prices, climate change and limits to fresh water will present a major challenge to urban growth. At the same time, these challenges constitute an opportunity to demonstrate that growth can occur at lower rates of environmental degradation. This is the essence of decoupling. The innovations required to deliver decoupling will almost certainly arise from the concentration of institutions, people and infrastructure that cities naturally provide.

When sensitively planned and appropriately supported by sustainable infrastructure, compact cities constitute the world's most efficient settlement pattern. Densification reduces spatial footprint and makes shared infrastructure viable. These in turn reduce emissions and resource use. Compact cities also allow new technologies to be tested and implemented more competitively. Over the long term, cities can strengthen resilience by reducing dependence on carbon intensive growth, stimulating efficiency in resource use, and expanding skills for work in a green economy. Metropolitan areas, from Johannesburg to Portland to Singapore, offer inspiring examples.

Whereas older cities may have to retrofit and replace inefficient infrastructure into which they have been locked for decades, newer and expanding cities have the advantage of flexibility. They can 'get it right' the first time. In an era of rising energy prices, an early transition to patterns and systems that consume increasingly-cheaper renewable energy sources will pay off quickly.

Cities are also the critical spatial platform for the formulation and implementation of policies across sectors. They can catalyse a modal and efficiency shift by targeting investment at well-planned greener transport infrastructure that meets the needs of all users, especially those using non-motorised transportation. Such a shift will go a long way towards addressing resource limits and climate change. Incentives and regulations in the building and construction sector offer opportunities for cities to promote green building materials and technologies. In this regard Lagos, Medellín and Sofia have their own success stories.

To make an effective green transition, cities must ultimately integrate green technology and design innovations into statutory urban planning and development control systems. Partnerships between government, industry and communities will be essential. Above all, by harnessing the advantages of concentrated populations, cities can optimize their infrastructure in ways that reduce excess mobility and provide basic services with greater efficiency. In fact, this is precisely what the successful city of the future must do. UN-Habitat and its global community of partners stand ready to help.

Dr Joan Clos
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CITY-LEVEL DECOUPLING:

Urban resource flows and the governance of infrastructure transitions

Compiled for the Cities Working Group International Resource Panel

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Abbreviations and acronyms

BRT	Bus Rapid Transit
CDM	Clean Development Mechanism
DMC	Domestic Material Consumption
DMI	Domestic Material Input
DMO	Domestic Material Output
DPO	Domestic Processed Output
EMR	Extended Metropolitan Regions
ECLAC	Economic Commission for Latin America and the Caribbean
ESCAP	Economic and Social Commission for Asia and the Pacific
EU	European Union
EDAP	Energy Descent Action Plans
G20	Group of Twenty Finance Ministers and Central Bank Governors from 20 major economies
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IBNET	International Benchmarking Network for Water and Sanitation Utilities
LAC	Latin America and the Caribbean
LED	Light-Emitting Diode
MFA	Material Flow Accounting/Material Flow Analysis
MIT	Massachusetts Institute of Technology
MLP	Multi-Level Perspective
MT	Material Throughputs
NAS	Net Addition to Stock
NGOs	Non-Governmental Organisations
OECD	Organisation for Economic Cooperation and Development
PUI	Sustainability-Oriented Innovations
SOIs	Peri-Urban Interface
TMC	Total Material Consumption
TMR	Total Material Requirements
WWF	World Wildlife Fund

Units

CO_2	Carbon Dioxide
kg	Kilograms
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt

1 Introduction

This report applies the International Resource Panel report, *Decoupling Resource Use and Environmental Impacts from Economic Growth* (henceforth the *Decoupling Report*) to cities. The core argument of the *Decoupling Report* was that a transition to a green economy will depend on finding ways to sustain economic growth rates without escalating rates of resource use. To achieve this decoupling, appropriate sustainability-oriented innovation will need to be initiated, promoted and applied on a large scale.

Because the majority of the world's population now live in cities and because cities are where most resource consumption takes place, the pressures and potentials to find ways to reconcile economic growth, well-being and the sustainable use of natural resources will be greatest in cities. Indeed, many significant sustainability-oriented innovations are already being applied at scale in cities throughout the world. This should not be surprising because cities connect a wide range of actors, networks, infrastructures, resource flows, cultures, social processes, and histories within specific biophysical and ecological contexts. Spurred on by a wide range of socio-economic and ecological threats, cities provide fertile ground for innovation and creativity. As Hajer put it:

> *"Cities are crystallisation points within society – important entities within which people live, work and travel. ... Cities create cohesion and synergy between individuals and businesses. It is in cities that inspiration is found for innovation, renewal and new levels of comfort."*[1]

The report discusses some emerging trends within cities that demonstrate that it is possible to decouple urban development and rising rates of resource consumption, in other words resource decoupling. These trends are generated by factors that combine in unique ways in each context, including market forces, policy-driven action by various stakeholders, and both top-down state-centric and bottom-up local modes of governance. These trends also show regional differences in the ways in which sustainable resource use challenges are being approached. The magnitude of the challenges calls for approaches that encourage continuous learning, improvement and tapping into the resources that are available to bring about change. These can lead to an 'energetic society'[2] that recognizes, catalyses, supports, extends, trusts and reproduces the myriad of initiatives that bubble up from below as coalitions of households, communities, businesses and networks respond to the problems posed by unsustainable resource use and environmental degradation. This shift goes beyond the familiar call to 'do more with less'; cities also need to aspire to do more with more renewable and sustainable resources that will need to replace unsustainably used resources. This celebration of potential is becoming possible in cities that either provide spaces for creativity and innovation, or impose from above a new set of performance requirements that force those involved to break away from tried, tested and tired approaches to development.

The report proceeds from the following points of departure:

- Global economic production and consumption is now concentrated in cities: 80% of global GDP is now produced in cities, with 60% produced in 600 of the most productive cities where one fifth of the world's population now lives.

- A second major wave of urbanisation is underway: since 2007 the majority of the world's population of over 7 billion people has been classified as living in urban settlements, with a projected growth of 4 billion urban dwellers taking place in developing world cities between 1950 and 2030.

- Global resources consumption is concentrated in cities: by the year 2005, approximately 75% of global energy and material flows were consumed in cities, which covered just 2% of the land.

Given that many of the resource flows on which cities depend are finite, it follows that continuing global economic growth will depend on the decoupling of this growth from escalating resource use. However, resource flows through modern cities have typically assumed a never-ending supply of resources, so decoupling will require innovation for more efficient management of resource flows. The cases reported here confirm that this can be done with active support for sustainability-oriented innovations, including the re-organisation of governance institutions.

This report builds on the insights of many previous reports that found cities to be an important dimension of the transition to a green economy. Its strategic focus *is on the resource flows through cities and the infrastructures that have been – or should be - configured to conduct these flows*. Because this theme has not been addressed in most reports on sustainable cities, inadequate attention has been paid to the economics of reconfiguring urban infrastructures whose construction and maintenance are, in turn, often the largest expenditures at the city government level. Traditionally, sustainable cities reports have focused on spatial factors (e.g. densities, mobility), energy supplies and energy efficiency, congestion, greening, pollution, wastes, and consumption behaviour. Insufficient attention has been given to the fact that the design, construction and operation of energy, waste, water, sanitation and transport infrastructures create a socio-technical environment that shapes the 'way of life' of a city's residents and how they procure, use and dispose of the resources they require.

Environmental education and pricing mechanisms aimed at changing consumer behaviour are helpful, but when people are locked into infrastructures that influence certain behaviours, such as the absence of a separated waste recycling system, or alternatives to commuting via private vehicle, significant change is unlikely. Where much of the population is poorly serviced by infrastructure networks, as is the case in many of the fast-growing cities in developing countries, opportunities exist to design and build new infrastructures that avoid the resource- and energy-intensive approaches typical of many cities in developed countries. Indeed, continuing a business-as-usual approach in cities in developing country may well result in rising costs that will reinforce the exclusion of the urban poor even more than is the case today.

As cities have grown, mainstream thinking on urban development and planning has increasingly acknowledged the link between human and natural environments. These issues have been explored in a range of 'City Reports' that have sought a synthesis of current thinking about the relationships between urbanisation and ecological change (Box 1.1).

Although they had different emphases, all the recent mainstream reports recognise the links between urbanization, urban development, climate change, urban infrastructure, ecosystem services and natural resources. They call for interventions that achieve a balance between urban economic development, long-term ecological sustainability and social justice. The challenge is how to facilitate such city transitions. This report assesses socio-metabolic flows and the urban infrastructures that conduct these flows, leading to advice on how to meet this challenge in practical ways.

This report proposes six areas of focus to guide the content and pace of urban transitions:

- First, demonstrating how the reconfiguration of urban infrastructures can change the flow of resources through cities. This is a new field of research, requiring learning from activities that suggest new possibilities. The solution is not a single formula or model, but rather a dynamic process of negotiating purpose, experience and learning.

- Second, showing that multiple visions of urban futures are formed by coalitions of interests that are context-specific. These visions are guided by what they aspire to achieve.

- Third, pointing out that visions of sustainability capture innovation in the relationships between cities, infrastructural systems and resource flows in different ways. Some may address systemic urban infrastructure transitions over long periods of time (20 years and more) while others operate over a few months or years. Innovation in relations between cities, infrastructure systems and resource flows can best be understood through projects and initiatives building up over time.

Box 1.1 Significant recent reports on cities

- UN-Habitat's 2009 Report on Human Settlements was entitled *Planning Sustainable Cities: Policy Directions*. It set out a compelling series of arguments for the re-appreciation of planning for sustainability after two decades of free market thinking.

- The World Bank's 2009 *Eco^2 Cities* report emphasised the importance of synergies between ecological and economic interests as an important component of the World Bank's new urban strategy. It included resource efficiency with extensive discussion of urban infrastructure systems and how these can be reconfigured.

- The OECD's 2009 report on *City Competitiveness and Climate Change* is generating further studies and high profile political roundtables on this issue. It promoted the idea that competitiveness involves more than offering the most attractive conditions for financial investment; it must also offer a desirable living and working environment that is managed in accordance with sustainability criteria.

- The World Bank's 2009 *World Development Report* made a strong case for government policies to focus on city-regions as significant scales of development action.

- UNEP's 2011 *Green Economy Report*'s chapter on sustainable cities demonstrated how the diverse sectorial dimensions of the emerging green economy agenda are anchored in urban centres and linked through a variety of global resource flows.

- WWF published an undated report in collaboration with the global consulting firm Booz Allen Hamilton entitled *Reinventing the City: three prerequisites for greening urban infrastructures*.

- The European Commission's Director-General for Research 2010 report entitled *World and European Sustainable Cities: Insights from EU research* discussed social inclusion, integrated planning and environmental consequences of urban sprawl.

- A 2011 report entitled *Are we building competitive and liveable cities?* by UN-Habitat, ECLAC, UN-ESCAP and the Urban Design Lab made a bold case for investments in eco-efficient and socially inclusive infrastructures.

- Fourth, suggesting that innovations need to be networked into movements of strategic coherence. Coordinating the different interventions and projects, facilitating learning between them at various times, and deciding how and whether they should be integrated will become key challenges for the future.

- Fifth, finding that understanding the dominant agents of change is essential, particularly given the narrow coalitions of interests that dominate different visions and the attempts to achieve them. Such agents may be businesses, urban or national political elites, or configurations dominated by community interests and local forms of expertise. Developing socially robust urban infrastructural responses require the creation of broader coalitions that integrate relevant expertise with the interests of key stakeholders.

- And sixth, showing that the future of urban infrastructure systems and resource flows will depend on how existing infrastructure regimes in energy, water, sanitation, solid waste, transport, and other sectors respond to pressures for change given that these regimes tend to be comfortable with their own habitual behaviours and ingrained routines.

The implication of these six themes is that social processes and dynamics need to be understood and integrated into any assessment of urban infrastructural interventions and the reconfiguration of resource flows. These include the dynamic processes of negotiating purpose, experience and learning; the variability of visions possible in relation to each context; the relationships between time envisaged and required, and the effect intended and achieved; extended coalitions of social interests that contribute to the possibility of these issues being addressed in a socially robust way; and effective appreciation of the context-specific strengths and weaknesses of each city.

Chapters 2-5 consider urban sustainability through infrastructure, and examine options for more sustainable approaches to the issue. These scene-setting chapters start with an overview of the decoupling concept, and explain why it is a suitable lens through which to address the challenges of approaching resource limits, new potentials, and the 'second wave' of urbanisation. In order to understand how this can be practically applied, material flow accounting (MFA) is introduced as a means of quantifying urban resource flows in the pursuit of more sustainable infrastructures. This section concludes that each city is unique, and that sustainable infrastructure interventions need to be tailored to the set of challenges and opportunities present in each context.

Beginning with Chapter 6, the paper considers planned transitions towards more sustainable infrastructure, and how they can unfold. It starts by framing infrastructure networks as socio-technical systems, extending the argument beyond technical solutions to consider how different visions of the future can shape the choices of infrastructure. A four-quadrant model is introduced as a means of broadly understanding infrastructural transition typologies, and distinguishing between newly built and retrofitted infrastructures, as well as between specific infrastructure networks and more integrated cross-network changes toward urban sustainability. The four transition types are analysed and compared, drawing on examples from the case studies in the Annex of the report. These insights are used to formulate a set of considerations for assessing progress toward urban decoupling, and lead into conclusions and recommendations as to how decoupling can be encouraged.

The Annex presents a set of 30 case studies that support the perspectives presented in the report. These cases were selected to showcase innovative and visionary approaches to sustainable infrastructure change across a broad range of contexts, and are intended to demonstrate the abundance of options available that could inspire leaders of other cities to embrace creative solutions. While the approaches adopted in the case studies are not necessarily recommended for implementation in other contexts, they can be used to inspire new thinking about infrastructural solutions that leverage existing strengths and resources to address social and environmental needs in an innovative manner. Furthermore, due to the fact that quite a few of these cases have not been properly documented, not all the case studies are based on independently verified information. When read together, the case studies may not in and of themselves amount to much from a quantitative perspective. Nevertheless, their significance lies in the fact that they are concrete expressions of widely circulated ideas that have begun to be put in practice, with learnings that loop back into networks that the next generation of innovators will benefit from. To this extent they are the 'writing on the wall' – the portents of future trends embedded within the constraints of existing socio-technical systems. However, the case studies are also fundamentally limited. Due to the absence of relevant documented evidence they are not written in a way that directly demonstrates in quantitative terms the link between infrastructure change and more sustainable resource flows through cities/ urban systems. The case studies are descriptive overviews that confirm that there are many examples of initiatives aimed at managing resources more sustainably (e.g. water, solid waste) or at minimising environmental damage (e.g. primarily by reducing greenhouse gas (GHG) emissions). It is going to take some time to train enough researchers (especially in the developing world) to master the tools of material flow analysis so that more case studies can be compiled that relate directly to the core argument of this report.

Unfortunately, it was not possible to cover all urban-related issues in-depth in this report. The rural-urban nexus with respect to a wide range of resource flows into cities that originate in rural areas, such as biomass, water, energy, building materials, industrial minerals and metals will not be addressed here. This is a subject for further research, but it is logical to assume that when cities make more efficient use of the resources they require from outside their boundaries, their pressures on the various sources and sinks will be reduced.

2 Decoupling, material flows, and infrastructure

2.1 Introduction

The existing literature on cities demonstrates that many things need to be done differently if urban poverty and inequalities are to be reduced within a context of finite resources. The rapid influx of predominantly poor people to under-prepared cities of the global South raises questions as to how this mass of people will access the goods and services associated with a better quality of life in the city. Resource- and energy-intensive approaches to the provision and extension of services are not sustainable, and a significant change in the way resources are used is required so that more can be achieved with what is available in the interests of greater equity and lower environmental impact.

This chapter summarizes the concept of decoupling as a means of addressing this challenge. Following a basic explanation of the two types of decoupling, it considers the role cities could play in facilitating reductions in global resource use in line with planetary limits. It introduces 'urban material flows' as a useful method for identifying areas for potential intervention on a city level, and emphasizes the need for investment to change the way cities function in relation to natural resources.

2.2 Material flows and decoupling

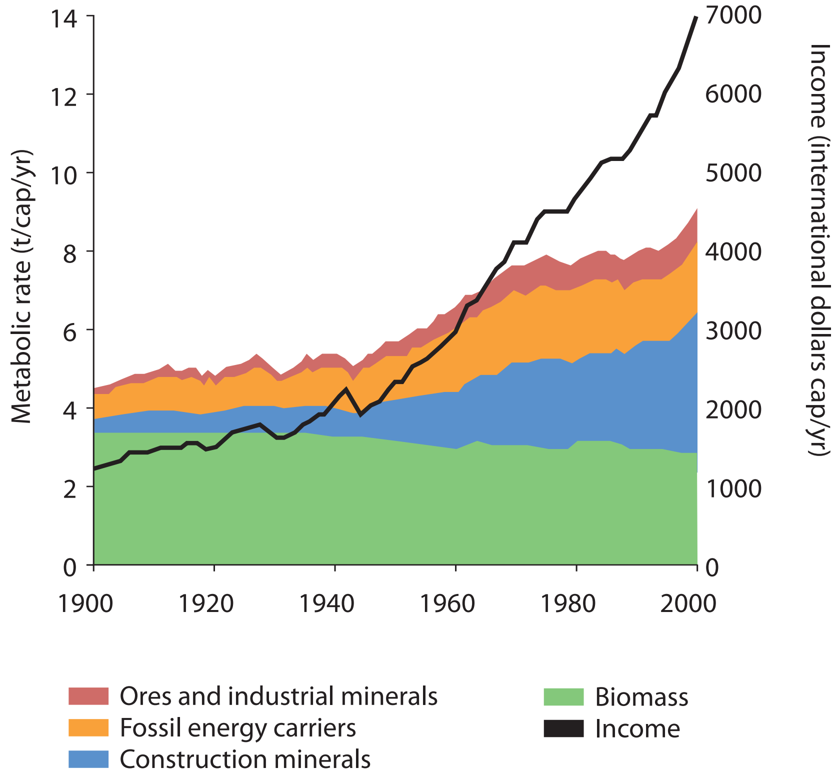
At the start of the 21st century, total raw material extraction is estimated to have been between 47 and 59 billion metric tons per annum.[3] Between 1900 and 2005, global material resource use increased by a factor of 8, almost twice as fast as the rate at which the global population grew. Construction materials increased by a factor of 34, while industrial minerals and ores grew by a factor of 27 and fossil fuels grew by a factor of 12. Despite a fourfold increase in population over the period, biomass extraction only increased 3.6 times (though from a higher baseline). Biomass's share of total material use has dropped significantly from three-quarters to one-third, indicating a significant growth of non-renewable resources over the past century (Figure 2.1).

Average per capita resource consumption around the world is currently around 8 tons per annum, about 22 kg per person per day; extraction increases to about 40 kg of resources per day if that which is extracted but goes unused is included. This average figure masks significant variation in the quantities and types of resources extracted and consumed across continents and countries, and between individuals within countries. Considering extraction alone, Oceania extracts the most resources per capita, equating to 158 kg per day in 2000. This is followed by North America with around 68 kg, Latin America with 41 kg, Europe with 36 kg and Africa and Asia with around 15 kg per day.[4]

UNEP's International Resource Panel has been promoting the term 'decoupling' as a way to describe the efforts to break the causal link between economic prosperity and the depletion of finite resources and degradation of environments. The term

Figure 2.1

Global metabolic rates and income, 1900-2005[5]



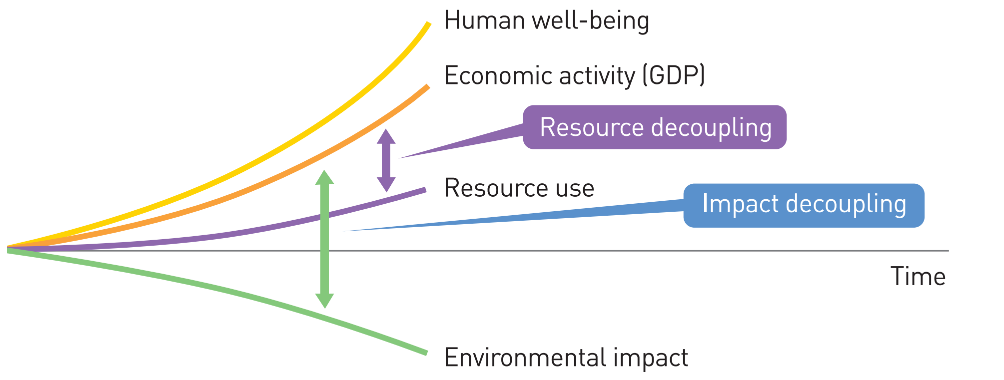
Source: UNEP 2011

can also be used as a lens through which to envision the reconciliation of human and environmental interests in rapidly growing cities. UNEP describes two modes of decoupling. **Resource decoupling** or 'dematerialisation' involves reducing the rate at which primary resources are used per unit of economic output, while **impact decoupling** means increasing economic activity while decreasing negative environmental impacts like pollution, CO_2 emissions or the destruction of biodiversity.[6] Both are illustrated in Figure 2.2.

Global material intensities have declined substantially in the past few decades; energy intensity is 33% less than it was in 1970, and CO_2 intensity has dropped by almost 25% since 1980.[7] Global resource decoupling has occurred spontaneously at a rate of 1-2% per annum, mainly because markets for bulk infrastructures, buildings and other resource intensive economic activities have been saturated in the advanced nations.[8] In order to make the transition to a greener and more socially inclusive global economy, absolute reductions in resource use will be required in industrialised economies, while developing economies will need to face the challenge of relative decoupling (making sure that resource consumption rates are lower than economic growth rates over the long term).[9]

Reductions in overall resource consumption and poverty can only be achieved if radical changes are made to systems and technologies in pursuit of decoupling. New standards are required that promote higher quality of life for all through contextually relevant, low-impact solutions in both the developed and developing world.[10] Even if everyone agreed on the

Figure 2.2
Two aspects of decoupling[11]



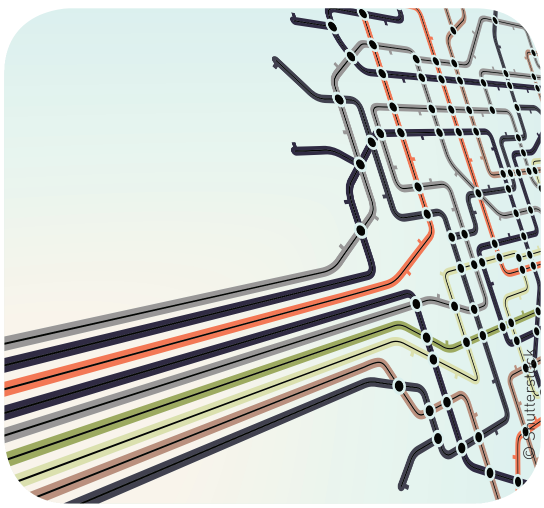
Source: UNEP 2011

need for absolute resource reduction in developed economies and relative decoupling in developing economies, the actual pace of change would be determined by the level of investment in innovation for decoupling along the entire value chain.[12]

2.3 Urban flows and infrastructure

The best way to understand how cities can provide a context where various catalysts for decoupling emerge and thrive is to view them in terms of the flows of resources that pass through them. Cities are complex networks of interlocked infrastructures that have been built over many years to manipulate vast and varied flows of resources that they require to support of human prosperity. Ravetz likens the city to a living organism, describing the continuous flow of inputs and outputs as its 'metabolism'.[13] Similarly, Girardet likens the city to a 'superorganism' with roads, railways and watercourses for veins, food markets for stomachs, and waste dumps for digestion systems.[14] Studying the patterns of matter and energy moving through cities is critical for finding solutions to optimise them in the pursuit of sustainable resource management,[15] and is an important starting point for identifying opportunities for decoupling.

Integral to studies of urban metabolism is an analysis of stocks and flows. Stocks include the resources available within the city (buildings, roads, infrastructures), whereas flows involve resource inputs from within and outside the city and outputs from the city to areas within and beyond its borders.[16] Haberl and colleagues refer to the build-up of 'socio-economic stocks' within the city, consisting of material stocks (e.g. buildings and infrastructural systems) and the resources that go into maintaining and using these stocks (e.g. energy and water). Studying the patterns of matter and bayabasenergy moving through cities is critical in finding solutions to optimise



them in the pursuit of sustainable resource management.[17] While a complete study of urban metabolism should include cultural, social, political and ethical issues[18], the primary focus in this report is on flows of matter and energy from a resource use and social equity perspective.

The design, construction and operation of urban infrastructures to provide key services such as piped water, sanitation, waste removal and processing, electricity for light, warmth and productive activity, and mobility for people and goods, will directly determine how resources in the form of water, nutrients, materials and energy pass through the system, and in what manner. For example, in developing country cities that lack formal networked sanitation systems, nutrients and water from sewage will not circulate through the urban system in the same way as in cities that have a formal networked sanitation system. Similarly, cities that are not hardwired with fibre-optic cables will not be populated by businesses that depend on high-speed, low-cost connections to global information flows 24 hours a day.

Each infrastructure system is associated with a particular set of flows, as illustrated in Table 2.1.

In this report, 'infrastructure' refers to primary networked infrastructures (energy, solid waste, transport/roads, water and sanitation) as they have evolved in developed country cities and most developing country cities. However, it is recognised that between 20% and 80% of the residents of cities in the developing world may not be legally connected to some networked infrastructure grids. But they are connected to informal services of various kinds (from informal sector water and energy vendors through to the ecosystem services supplied by rivers to access water and open ground used for defecation).[19] The greater the number of people who are not connected to networked infrastructure grids, the greater the quantity of material flows that remain unmanaged by these service delivery systems. The consequences of unmanaged material flows can often have negative environmental impacts, including pollution of water bodies, poor public health, uncollected solid waste, and so forth. However, the local community-managed projects can mitigate these negative impacts (see Orangi Pilot Project in the Annex). In other words, although the focus of this Report is on networked infrastructures, it is not presumed

Table 2.1

The set of socio-technical systems and associated socio-metabolic flow

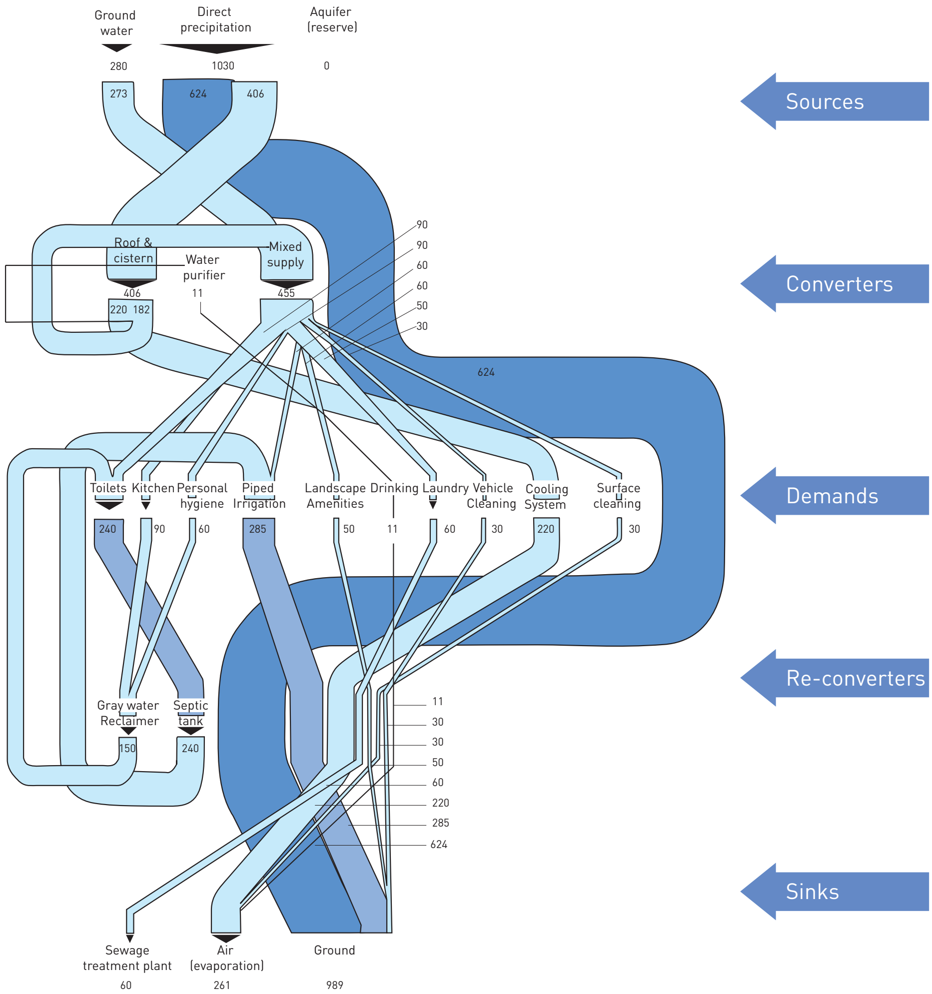
SYSTEMS	FLOWS
Technologies, regulatory frameworks and financial processes for supplying water (including dams, pipes, water treatment works, desalination plants, pump stations) and sanitation (in particular sewage treatment works).	Water from catchment areas/aquifers/seas (via desalination processes) and re-used water (including reclaimed water from sewage plants). Sewage flows into large treatment works (noting that sewage includes useful ingredients such as nutrients, methane and water). Outflows into natural systems.
Technologies, regulatory frameworks and financial processes for supplying energy (from various sources), including generators and grids, passive systems such as solar PV, liquid fuel infrastructures, natural gas infrastructures, bio operations and maintenance.	Energy generated usually from fossil fuels, hydro, nuclear, biomass, solar and other forms of energy.
Technologies, regulatory frameworks and financial processes for supplying mobility, such as railways, air- and sea-ports, roads, and pipelines.	Bodies and goods in automobiles, motorcycles, trains, buses, airplanes, ships, plus flows through pipelines such as oil, natural gas, etc.
Technologies, regulatory frameworks and financial processes for supplying solid waste, including the landfills, transfer stations, incinerators, etc.	All kinds of solid waste, including nutrients, recyclables, and biogas.
Technologies, regulatory framework and financial processes for supplying communications infrastructure, including the full range from traditional land-lines, to fibre optic cables and satellite systems.	Data, voices, images, etc.

that solutions lie only in replicating the technologies that form the centre of conventional networked infrastructures; the informal sector may also be an important source of innovation.

Sankey diagrams, a type of flow diagram in which the width of the arrows indicates the proportion of the quantity of the flow, can be used to depict the way urban infrastructures direct resource flows through cities. Drawing on the World Bank's Eco[2] Cities Report which provides the most advanced practitioner guidelines for assessing urban materials, Sankey diagrams can distinguish between five stages in the flow of resources through

Figure 2.3

Water flow (litres / day) for a new upper income detached home in New Delhi, India[20]



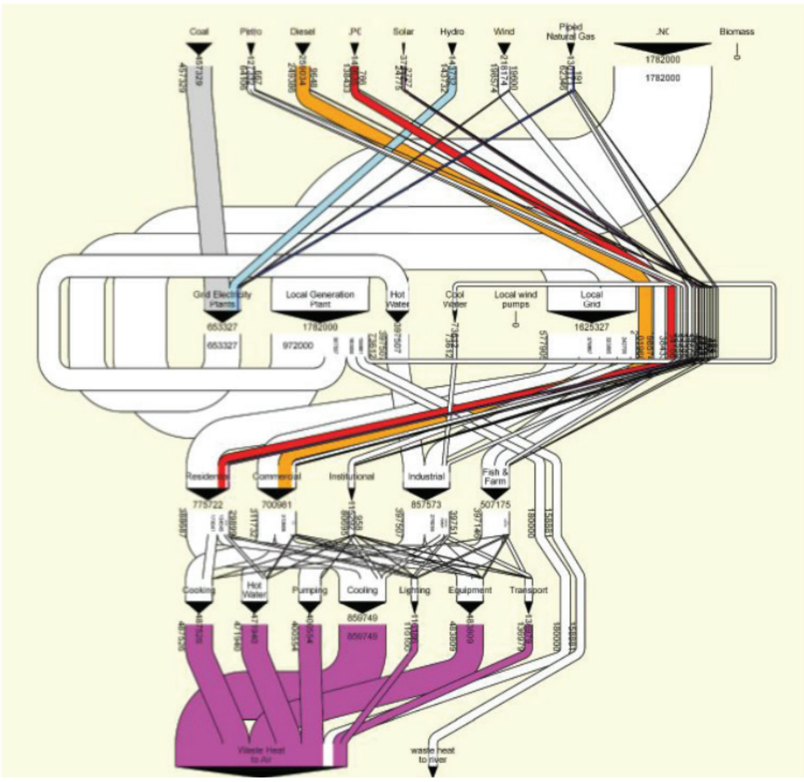
Source: World Bank 2010

an urban infrastructure system: sources, converters, demands, reconverters, and sinks. This is illustrated using a simplistic example in the Sankey diagram for a sustainable water system in a New Delhi home (Figure 2.3).

A diagram like this helps to identify the opportunities for reconfiguring three distinct sets of technologies that affect both sources and sinks: the converter technologies (water tank on roof, water purifier), the demand technologies (from the toilet to the washing machine), and the reconverter technologies (septic tank to grey water reclaimer). Replacing these converter and reconverter technologies with connections to the city's water and sanitation grids will have very different impacts on the sources and sinks on which a household is dependent. The same

Figure 2.4

Two different models of energy flows through Jinze Town, Shanghai[21]



Source: World Bank 2010

applies to the demand technologies: resource-efficient systems could reduce water demand by up to 80%.

The same logic applies to neighbourhood and city-wide systems. Figure 2.4 shows two different ways of configuring the energy system of Jinze Town, Shanghai. The figure on the left represents the current system, and the figure on the right shows what a more sustainable resource flow could look like if the urban infrastructure were reconfigured to decouple the use of coal-based electricity supplied via the national grid from economic growth and improvements in wellbeing. In the more sustainable system, emissions and financial costs are reduced, more local jobs are created and energy security is enhanced. The key technology innovation is a local electricity generation facility powered by natural gas.

These Sankey diagrams are a useful simple demonstration of the principle that infrastructures can be reconfigured to create more sustainable metabolic flows.

Linking material flows and infrastructure analysis demonstrates the economic benefits of infrastructure alternatives that conduct the flows of resources through urban systems in a more sustainable way. In other words, as resource depletion drives prices higher, it will become economically counterproductive to ignore the need for alternative socio-technical systems that both to do more with less and actively restore degraded ecosystems and reduce GHG emissions.

3 The second urbanization wave

3.1 Dimensions of the second urbanisation wave

The increasing demand for resources in the second half of the 20th century is largely attributable to rising incomes of increasing numbers of people made possible largely by urbanisation (migration of rural populations to cities) and natural growth of urban populations, with the latter now the most significant driver of urban population growth. Although cities only occupy 2% of the earth's land surface, 75% of all natural resources are consumed within cities, and as of 2007 more than half of the world's population lived in cities.[22] In the 200 years leading up to 1950, just over 400 million people migrated to the world's cities in what is often referred to as the 'first wave' of urbanisation. Current projections suggest that by 2050 more than 6 billion people (almost 70% of the total world population) will live in urban areas,[23] in a 'second wave' of urbanization. The 3 billion people expected to be added to the global population between 2005 and 2050 will land up mainly in Asian and African cities.

The bulk of growth will be in cities in developing countries, which are expected to grow by an additional 1.3 billion people by 2030, compared to 100 million in developed country cities.[24] The highest growth rates are found in Africa, concentrated in Eastern,

Central and Western Africa (with annual rates of urban population growth higher than 5% in countries such as Malawi, Eritrea and Burkina Faso)[25] (see Figure 3.1). Europe has the world's lowest rates of growth, especially in Eastern Europe where the annual rate of urban population growth was -0.26% between 2005 and 2010, led by negative growth rates in some urban areas in the Russian Federation, Ukraine, Bulgaria and Poland.[26] Stabilising growth rates in more developed regions poses a stark contrast to the exponential growth in the urban populations of less developed regions.[27]

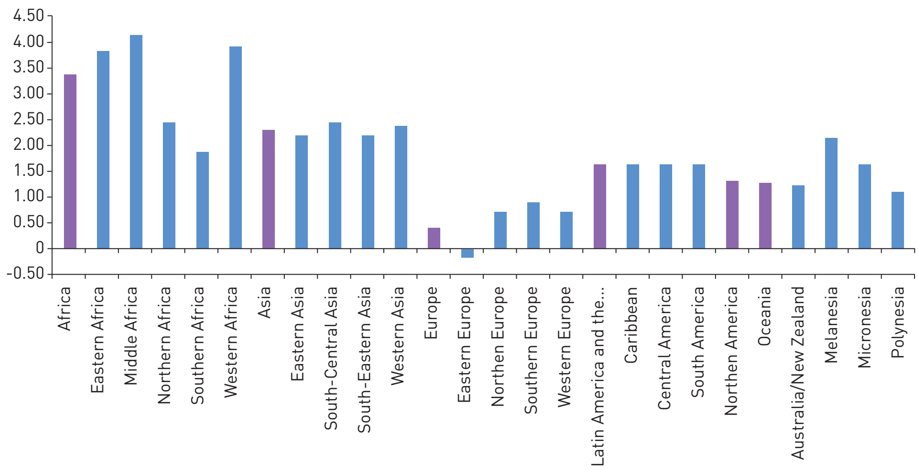
Marked contrasts also characterize the distribution of absolute numbers of urban inhabitants in different regions. Although most of the urban dwellers live in Asian cities,[28] this region's proportion of urban population is lower than in North America or Europe. However, while urban population growth rates are stabilising in regions that are already predominantly urban (such as Europe, North, South and Central America, and Oceania), regions with a higher proportion of rural population (such as Asia and Africa) may experience exponential rates of urban population growth in the coming years (see Figure 3.2).

A significant shift in economic power from cities of the developed world to those in emerging economies is expected in the next 15 years.[29] A third of the developed world cities currently on the list of the top 600 in terms of gross domestic product (GDP) may no longer make this list in 2025 and 136 new cities from developing countries like China, the Democratic Republic of Congo, Nigeria, Indonesia, Pakistan and India are predicted to make it onto the list for the first time. By 2025, middleweight cities (i.e. those with populations between 150,000 and 10 million) in emerging markets are projected to contribute to 40% of global growth, outperforming all the megacities (with populations exceeding 10 million) of the developed and developing world combined. Population growth in 13 current middleweight cities is likely to see them transforming into megacities; 12 of these cities are in emerging markets, and seven are in China alone.

As cities grow, demographic shifts and behavioural changes are leading to a reduction in urban household sizes in many countries. Average household occupant numbers are expected to drop from 3.2 people to 2.7 people by 2025, resulting in a growth in the number of households that is 2.3 times the population growth rate in the world's top cities.[30] This will

Figure 3.1

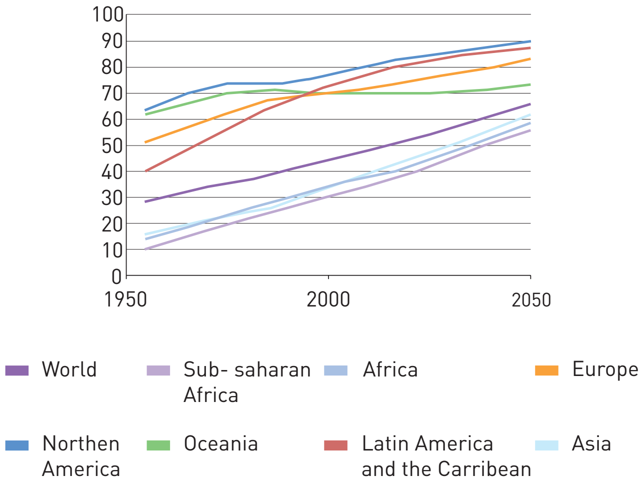
Growth rates 2005-2010 for selected regions (main regions in red)[31]



Source: UN 2010

Figure 3.2

Percentage of population living in urban areas in different regions (1950-2050)[32]



Source: UN 2010

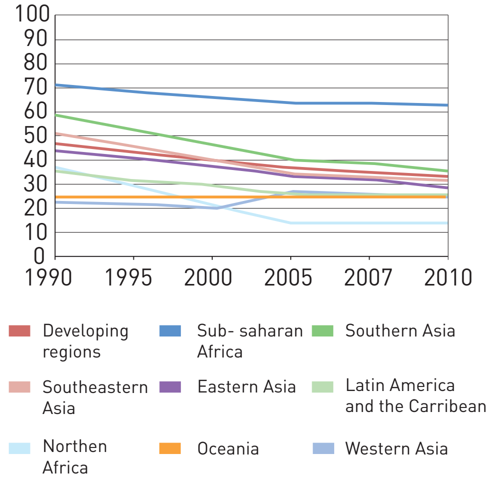
have a dual impact on demand for resources by increasing the number of housing units requiring land and building materials, and reducing the efficiency of resource use per capita compared to that achieved by sharing resources in larger households.[33] Around 85% of demand for housing will be in the cities of emerging economies, and 50% will be from China's cities.[34] Considering that the global construction industry currently consumes around 40% of water, 70% of timber products and 45% of energy,[35] this construction boom is likely to have a major impact on resources.

As cities continue to attract investment and skilled workers, rising income levels are expected to be a more significant driver of economic growth than population. Between 2010 and 2015, an additional 460 million people will enter the middle class from cities in China, India, Russia, Indonesia, Brazil, Turkey, Mexico and South Africa.[36] By 2025, the number of households in emerging economy cities earning over US$20,000 per year at purchasing power parity will be 1.1 times greater than the number in developed region cities currently among the top 600 in terms of GDP.[37] Consumption driven by choice as opposed to need is expected to increase substantially in these emerging markets as higher incomes raise demand for material possessions. In the 10 years leading up to 2010, the percentage of private automobiles sold in emerging market cities rose from 8 per cent to 37 per cent, providing a preview of the kind of consumption growth likely to be experienced across a range of products from decor and household appliances to clothing and luxury goods.[38] It is estimated that India could potentially increase its aggregate urban consumption sixfold between 2005 and 2025, and that consumption could increase more than sevenfold in China.[39]

Many cities will also be challenged by growing numbers of urban poor, who, as individuals, are forced to consume less than the much smaller middle class households to survive, but who add substantially to (potential) resource demand due to their numbers. The 2011 UN-Habitat State of the World Cities Report concludes that while Millennium Development Goal 1, which deals with extreme poverty, has succeeded in reducing the percentage of the urban population living in slums worldwide, the absolute number of people living in slums continues to grow. While the proportion of urban dwellers living in slums decreased from 46.1% to 32.7% between 1990 and 2010, the total urban slum population in developing regions grew by 26% (totalling an estimated 830,000,000 people in 2010) (Figure 3.3).

Figure 3.3

Percentage of urban population living in slum areas for selected regions (1990-2010)[40]



Source: UN-Habitat 2011

As urban slums continue to expand, urban inequality becomes more structurally consolidated. Local governments struggling to cater for expanding demand often resort to outsourcing services through private-based models, which have often reinforced disparities in service quality and costs determined by established jurisdictions and operational areas.[41] Although comparative data on inequality within cities is limited, it appears that while urban inequality grew in developed countries between 1985 and 2005, it grew at an even faster rate in the developing world.[42] This highlights the importance of addressing the manner in which poor immigrants are integrated into developing world cities in particular.

3.2 Heterogeneous urbanisation

The second urbanisation wave is not a uniform process. Each region has distinct patterns and processes that reveal the emergence of a lumpy 'rural-urban continuum' in which rural-urban links are highly heterogeneous between and within countries. Furthermore, some cities are rapidly evolving into 'global cities' while at the same time massive new peri-urban peripheries of under-serviced, urbanised populations continue to grow in both globalised cities and in cities that remain entrenched in their national and/or regional economies. In light of such heterogeneity, the ways in which cities relate to their hinterlands and to more long-distance resource flows for sources and sinks become important considerations when analysing the way in which infrastructural networks are configured.

In regions where the urban population is stabilising or even decreasing, the reduction of demand may undermine the maintenance of infrastructures. The decline or recomposition of urban populations can also result from de-industrialisation or economic restructuring, which may change the demand for services from both industry and citizens. For example, de-industrialisation in Berlin since the 1990s has led to a 40% reduction in demand for water,[43] resulting in redundant infrastructure with additional maintenance requirements and increased costs for consumers. Maintaining redundant infrastructures creates 'artificial demand' that may use clean water resources for purposes that would otherwise use gray water. Similar problems emerge in other 'shrinking' cities, found mainly in Europe, North America and Japan, thereby slowing the potential rate of both resource and impact decoupling.

On the other hand, the astonishing rates of urban population growth found in other parts of the world also pose great challenges in terms of managing limited resources and providing adequate services for all urbanites. Since the 1990s, urbanisation in Asia has resulted in high-density rural or semi-urban areas formed as a result of the expansion and influence of metropolitan economies. McGee[44] has coined the term '*desakota*' (a combination of the Indonesian words *desa* or village and *kota* or city) to encapsulate this phenomenon, also referred to as extended metropolitan regions (EMR).[45] These terms refer to a process of region-based urbanisation (as opposed to city-based urbanisation) and mark the changing international divisions of labour, international networks and regional spill-over from one mega-urban region to another within South and East Asia.

The *desakota* constitutes the spatial by-product of high-tech production spilling out of a heavily congested metropolis (such as Jakarta, Manila and Bangkok) into nearby cheaper but still easily accessible rural areas. The EMR landscapes still appear to be predominantly rural with vast areas devoted to cultivation, and while a large proportion of household income is derived from non-agricultural activities, the provision of services is less secure than in urban areas. The emergence of EMRs and similar spatial phenomena as a result of new articulations to the global economy "...are accompanied by rising incomes and improved quality of life for some groups of inhabitants, but often at the expense of the immiseration of others in both these new cores and peripheries..."[46]

In Latin America and the Caribbean (LAC) recent urban transformations have been closely linked with economic growth, but also with economic disparities. Globalization has influenced the development patterns and structure of major Latin American cities (i.e. Buenos Aires, Lima, São Paulo, and Mexico City) into a polycentric form, where growth concentrates in hot-spots - smaller towns and secondary cities - within wider metropolitan regions.[47] For example the Monterrey Metropolitan Area in Mexico is an urban agglomeration structured into industrial centres (Monterrey, Escobedo, Guadalupe, Apodaca), which allows for the increased decentralisation of service provision. However, this structure creates institutional difficulties when it comes to coordinating service provision across different public and private institutions and tends to reinforce spatial fragmentation which, in turn, can exacerbate resource inefficiencies. This phenomenon is often referred to as 'urban archipelagos', associated with diffuse boundaries between the urban and the rural.[48]

In Sub-Saharan Africa, urban development is characterised by the uneven geography of rural-urban interactions. The highly urbanised, extended, low-density, metropolitan, Johannesburg-Pretoria region in South Africa, contrasts with the so-called 'close-settle zones' like Kano in Nigeria - dense but extended areas evolved together with high intensity farming systems. The challenge in many of these areas is to support high population densities with appropriate services while maintaining soil fertility to guarantee food security. With the exception of South Africa, urbanisation and peri-urbanisation in Africa are not necessarily driven by economic development, as many African cities tend to be marginalised in the global economy and growing despite poor macro-economic performance and without significant direct foreign investment.[49]

3.3 Interactive urban-rural flows in developing countries

Contemporary urbanisation trends affect the way in which rural and urban households and individuals straddle their rural and urban worlds.[50] Decisions about health, fertility, mobility, production, infrastructure, services and so on are increasingly affected by the urbanisation process, both spatially and through informational spill-overs and social networks. Given the key role played by infrastructure in supporting the sustainable development of multiple urban transitions, a key question is whether such transitions will lead to reciprocal relations between urban and rural areas.[51] Urbanisation is not a one way flow of people from rural to urban areas, because a key condition (together with the deterioration of rural livelihoods) that has made rapid urbanisation possible is disappearing fast – namely cheap oil. Rising oil prices that make everyday living in core urban areas increasingly expensive may slow down urbanisation rates or – more likely – significantly reinforce interactive relations between urban and rural areas as people reduce costs by living less oil-dependent lives in small rural towns or rural areas. This has major implications for the understanding of future trends, on the growth of secondary and tertiary urban centres, and on the likelihood of more self-reliant bioregions that depend less and less on imported food, energy and materials.

An historical approach to urbanisation and development shows a swinging bias that favours either urban or rural areas as the engines of development. An urban bias in development theory emerged during the 1950s and 1960s, seeing rural areas as sources of economic surplus to subsidize industrialising urban areas from where future economic growth was expected to diffuse back to the rural peripheries. In other words, the role of urban areas was to grow and expand at the expense of rural areas that were seen, in turn, as developmental dead ends. In the 1970s and 1980s, development thinking shifted to a 'rural bias' ensuing from an acknowledgment that this 'trickle-down' effect was not materialising. This, in turn, gave rise to a negative view of urbanisation and of rural-urban links.

The focus has shifted over time from a spatial definition (assuming a central urban point surrounded by a de-densifying periphery), to a more functional and relational focus on diverse flows between the rural and urban sectors. Recent developments point to the need for a reassessment of the changing nature of the rural-urban divide that has been transformed by new global-local forms of economic organisation and technological change. A regional networks or cluster approach may provide a better understanding of the flows and links between rural and urban areas, and of the potential for combining their mutually positive impact by promoting reciprocal interactions.[52] This approach acknowledges the multiple ways in which contemporary urban transitions are both shaping and being shaped by a complex web of bio-physical, socio-economic and political relations through which infrastructure change might be driven from multiple and often distant needs and decisions, often by-passing the immediate hinterland surrounding a city.

Flows of natural resources, waste and pollution affect both rural and urban areas but can be better appreciated in light of the peri-urban interface (PUI) context, where many changes in urban-rural flows lead to problems and opportunities for both peri-urban communities and the sustainable development of adjacent rural and urban systems.[53] These flows include the carrying capacity and ecological footprint of a city; health and environmental problems experienced by the poor; infrastructural and service deficiencies; and changing patterns in the use of natural resources. The latter includes changes in land use as a result of land conversion and commercialisation; the use of renewable and non-renewable resources to supply food, water, energy and construction materials; and changes in waste generation as the PUI is often the backyard of urban waste disposal.

A wider look at urbanisation from this perspective shakes many of the assumptions that have underpinned the understanding of such processes for decades. Still, urban, rural and regional planning continues to be isolated from each other, with few initiatives specifically harnessing such links for the purpose of reciprocal development, and ultimately decoupling.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4 Urban material flows in cities in the developed and developing world

4.1 Applying material flow analysis to cities

The negative consequences of unsustainable global material flows make decoupling an urgent priority. Most of these flows are converted into buildings and physical urban infrastructures or they are transported through cities by these infrastructures. Decoupling can, therefore, be achieved by retrofitting cities or building new ones. The second urbanisation wave creates new opportunities for reconfiguring the urban infrastructures that must still be designed and built in the rapidly expanding cities of the developing world, through the application of material flow analysis to urban systems. Although this is a new approach, it confirms that this kind of analysis is both viable and strategically important from a policy perspective.

The application of material flow analysis (MFA) to the global economy and national economies is now quite well established.[54] This section reviews the application of MFA to the city-region, based on two approaches: industrial ecology; and urban political economy (led by the 'urbanists').

The systematic application of MFA from an industrial ecology perspective to the city-region has generated some sophisticated frameworks for assessing the empirical dynamics of resource flows through mainly developed world cities.[55] Many cases also demonstrate the robustness of the urban metabolism methodology.[56] Urbanists interested in sustainability have in recent years integrated the general concept of resource flows into their analyses of urban infrastructures and economies.[57]

While industrial ecologists are interested in empirical quantifications of resource flows, the urbanists are more interested in the socio-technical systems (and related governance arrangements) that conduct these flows through urban systems. From a policy perspective, the two approaches are complementary. Whereas the empirical analysis of flows highlights the dependence of cities on specific sources and sinks for the resources and wastes they require, the analysis of socio-technical systems addresses the regulatory, institutional and knowledge systems that conduct these flows. This research enables policy makers who want to promote more sustainable cities, to make decisions about the building of new - or retrofitting of existing - urban infrastructures that take into account the long-term flows of strategic resources into and out of the city.

The most significant outcome of the application of MFA to the city-region is that it facilitates the re-embedding of urban systems within the wider nexus of local-regional ecosystem services (e.g. water supplies, soils, air quality, landfill space) and natural resource extraction (such as fossil fuels or building materials that can be drawn from local, regional, national and/or global sources). This effectively recognises that decoupling urban growth from increasing resource use will depend on a conceptual 'recoupling' of urban systems to their 'bioregions' in a way that accepts that it is no longer possible for the former to grow and develop at the expense of the latter. Indeed, 'recoupling' suggests that urban systems need to find ways to develop by restoring their bioregions and the eco-system services they provide to humans and non-humans.

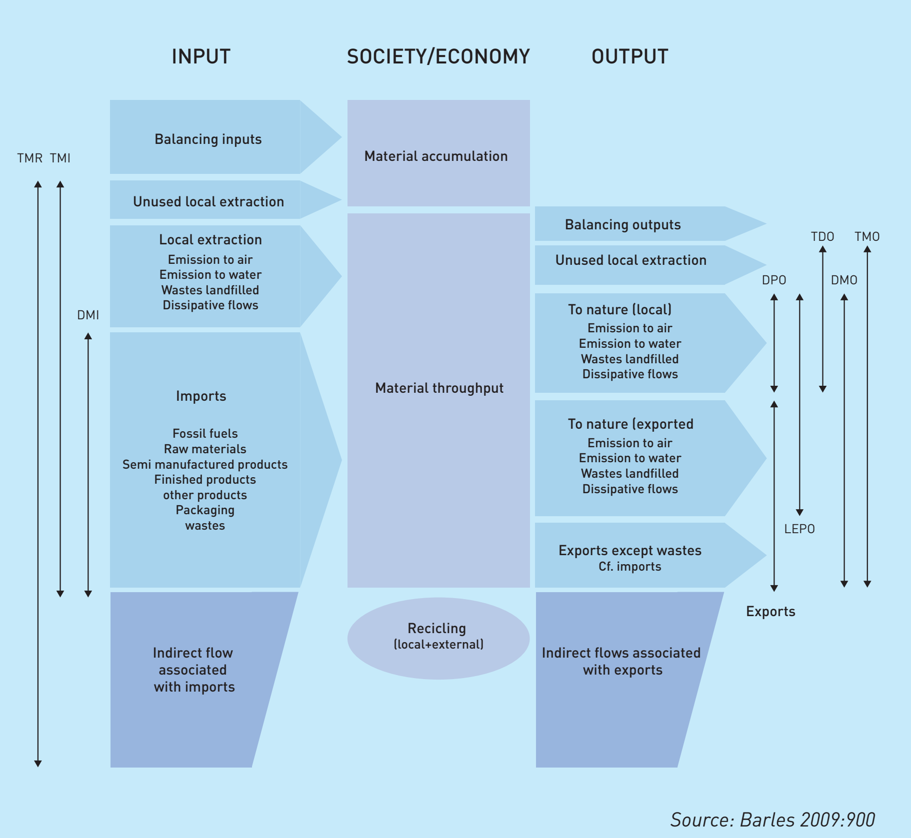
4.2 Adapting the material flow analysis methodology

Applying material flow analysis to city-regions requires modifying the framework that is normally adopted at the national and global level. The most sophisticated framework has been developed by Barles based on the Paris city-region.[58] This is described in some detail here because it provides a template for what could be a future global assessment of a broad sample of the world's cities selected from all regions.

Using standard Eurostat data, Barles has slightly modified material flow analysis in order to develop an approach that is suitable to cities. The difference between countries and cities is that the latter are open systems that will always require sources (of resources) and sinks (for wastes) that are located outside their borders. For example, a substantial proportion of the wastes generated by the city are eventually exported out of the city into the wider region. Reading Figure 4.1 and Table 4.1 together leads to the following conclusions about material flows:

- Domestic Material Consumption (DMC) of resources in a city is equal to Domestic Material Input (DMI) minus what is exported out of the system. (DMI comprises both locally extracted and imported materials.)
- A proportion of materials that flow into the city accumulate in buildings and infrastructures, referred to as Net Addition

Figure 4.1
Urban material flows[59]



Source: Barles 2009:900

to Stock (NAS). In mature cities (located largely in developed countries) inhabited by a large established middle class, a relatively small proportion of materials entering the city system annually will end up as NAS while the bulk of materials will be consumables (pumped through the city by ever-rising energy use). The opposite applies to fast growing cities in developing countries where foreign and local investments are going into the rapid construction of new stock (buildings and infrastructures). That said, ageing districts or redundant infrastructures can become the focus of regeneration initiatives that give new values to some lands, while economic shocks can overnight make entirely new districts redundant as businesses close down or property values collapse.

- Materials that do not result in NAS will be processed as material throughputs (MT) that enable the city's economy to operate (e.g. fuels, food, water), ending up as either locally deposited wastes (landfills), exported wastes (from CO_2 to sewage), or some form of recyclable waste (the large bulk of these wastes being a cause of environmental degradation).
- The most significant outputs are Domestic Material Output (DMO) which includes the domestic wastes deposited into nature *locally* (Domestic Processed Output - DPO), plus the *exported* wastes that are eventually deposited into *non-local* natural systems, in addition to exported materials (minus wastes).

This approach makes it possible to distinguish between the direct and indirect flows that obtain resources from within and beyond the city, then flow through the city with some ending up as NAS, and other flows moving into or beyond the city as wastes, goods and services. Urban infrastructures conduct these flows. For example, the domestic material input per capita (DMI/cap) for a city

Table 4.1

Explanation of indicators and abbreviations used in Figure 4.1[60]

INDICATOR/ ABBREVIATION	EXPLANATION
BI	balancing inputs
BO	balancing outputs
DMC	domestic material consumption = DMI - exports
DMC_{corr}	corrected domestic material consumption = DMI - imported wastes - exports except wastes
DMI	direct material input DMI + BI = NAS + DMO + BO
DMO	direct material output
DPO	domestic processed output
LEPO	local and exported processed output = DPO + exported flows to nature
NAS	net addition to stock
TDO	total domestic output
TMI	total material input TMI + BI = NAS + TMO + BO
TMO	total material output
TMR	total material requirement

Source: Barles 2009:901

where mobility is dominated by the private automobile will be very different to the DMI/ capita in cities that have an excellent public transport system. Similarly, cities with a large manufacturing base will have a DMO that includes a much higher proportion of exports than a city dominated by the services sector. Likewise, a city that is going through a phase of extensive investment in new infrastructures (urban regeneration) will have a much higher proportion of domestic material output per capita (DMO/cap) remaining fixed in NAS than a mature city where on average growth in NAS could be as low as 1 per cent per annum.

Barles applied this approach to three scales of Paris: the core city of Paris itself (2.2 million people); Paris plus its surrounding suburbs (6.3 million people); and Paris, its suburbs plus the surrounding region (known as the Ile-de-France region) with 11.2 million people.

The results are reflected in Table 4.2. Note that the DMC and 'DMC (corrected)' for core Paris are quite different because the common understanding of DMC is misleading when applied to cities. When the large bulk of solid waste is exported and exports are quite high, a low domestic material consumption per capita (DMC/cap) will result. This is obviously misleading. In the case of Paris for example, DMC is 2.2 t per capita, but all of the waste treatment facilities (both solid and liquid) are located outside the city. With the classic method, the related flows would be considered as exports, even if these flows are mostly flows to nature resulting from urban consumption. It seems more accurate, when calculating DMC, to consider exports minus exported wastes: for Paris the result becomes 5 t per capita. In order to avoid double counting and to give coherence to the MFA, it is then necessary to take into account DMI minus imported wastes (i.e. coming from outside the city, possibly to benefit from treatment facilities located within the city), even if they often equal zero in dense urban areas. The resulting DMC is called DMC (corrected).

Table 4.2

Results from a 2003 MFA of Paris and the surrounding region[61]

	Paris (2,166,000 inhab.)		PPC (6,321,000 inhab.)		IdF (11,259,000 inhab.)	
	kt	t/cap	kt	t/cap	kt	t/cap
INPUT						
Local extraction						
Fossil fuels	0	0.0	0	0.0	540	0.0
Minerals	0	0.0	0	0.0	16,990	1.5
Biomass	0	0.0	30	0.0	6,010	0.5
Total local extraction	0	0.0	30	0.0	23,540	2.1
Imports						
Fossil fuels	3,910	1.8	13,050	2.1	26,100	2.3
Others	15,240	7.0	56,450	8.9	88,350	7.8
Total Imports	19,160	8.8	69,500	11.0	114,450	10.2
DMI	19,160	8.8	69,530	11.0	137,990	12.3
OUTPUT						
To nature						
Emissions to air	6,710	3.1	24,470	3.9	53,840	4.8
Waste landfilled	0	0.0	2,500	0.4	20,010	1.8
Emissions to water	0	0.0	10	0.0	40	0.0
Dissipative flows	150	0.1	440	0.1	2,400	0.2
DPO	6,860	3.2	27,410	4.3	76,209	6.8
Exportations						
Exported flows to nature	4,100	1.9	9,160	1.5	69	0.0
Exports exluding wastes	8,380	3.9	40,410	6.4	58,500	5.2
Total exports	12,480	5.8	50,020	7.9	58,570	5.2
DMO	19,340	8.9	77,430	12.2	134,860	12.0
LEPO	10,960	5.1	37,020	5.9	76,360	6.8
RECYCLING						
Local	0	0.0	4,210	0.7	7,320	0.7
External	1,850	0.9	440	0.1	0	0.0
Total recycling	1,850	0.9	4660	0.7	7,320	0.7
Wastes exported	5,950	2.7	10,050	1.6	70	0.0
DMC	4,830	2.2	19,070	3.0	79,420	7.1
DMC_{corr}	10,780	5.0	29,120	4.6	79,490	7.1
BI oxygen (combustion)	6,560	3.0	24,010	3.8	52,650	4.7
BO water (combustion)	3,280	1.5	12,010	1.9	26,330	2.3
NAS	3,100	1.4	4,110	0.7	29,460	2.6

Source: Barles 2009:905

Whereas the DMI per capita for Paris was 8.8 tons in 2003, it was 11 tons for Paris and its suburbs and 12.3 t for Paris plus the region. DMC (corrected) per capita was 5 t, 4.6 t and 7.1 t for each region respectively. Thus more than half the DMI from all three regions are returned to local natural systems. Also, the recycling rate of 0.7-0.9 t per capita is a fifth of DMC (corrected) which sets an interesting benchmark for comparative studies.

This kind of detailed quantification of urban material flows makes it possible to define what decoupling could mean for a particular city in quite specific terms. To retrofit or design new urban infrastructures so as to achieve the goals of decoupling for resource efficiency or resource productivity, the focus will need to be on the 'converter', 'demand' and 'reconverter' technologies (discussed in later chapters). However, wider spatial and economic factors play roles that are unrelated to these specific technologies. The most important will be the stage of development. During the early stages of development, relative decoupling with a focus on materials will be the strategic focus, but later on as NAS becomes less important the focus will shift to rising energy demands as income levels rise.

The unique configuration of cities can give rise to very different levels of DMC/cap even with similarities at national level evidence.[62] For example, DMC/cap was 20.8 t per year for Lisbon, 18 for Singapore, 7.6 for Geneva, 5 for Paris, 3.6 for London, and 3.3 for Cape Town (these figures are for direct flows and ignore indirect flows). The energy requirements for mobility are determined primarily by population density. Where high densities are correlated with good public transit systems and deterrents to private car use, energy requirements for mobility can be lowered dramatically. Similarly, the operational energy requirements of buildings (which far exceed the energy embodied in the constructed building) could be reduced by as much as 80% by changing the way they are designed and operated. Although there may be some rebound effects (if there are no recessionary conditions), in general the energy requirements for urban living are less than similar standards of living across all income categories in rural areas, but urban material and energy use will vary with the context, based on such factors as urban form, especially density; the efficiency of the built structures and related 'green building' standards and regulations; advanced industrialised versus newly industrialised; high or low per capita income; the effect of the urbanisation rate on the likelihood of infrastructure backlogs and related infrastructure investment levels (e.g. India/China vs North America/Europe); income and/or spatial inequalities (e.g. more egalitarian European cities tend to be more dependent on public transport than North and South American cities that tend to be highly dependent on the private car); effectiveness of urban planning (limited in African cities versus high in European, US and Chinese cities); and geographical and topographical differences that will directly affect the requirements for infrastructures such as storm water drainage, energy for heating/cooling, what densities are possible (e.g. steep inclines are generally not useful for high rise buildings).

Urbanisation per se does not seem to result in increased material and energy use per capita. Based on direct flows only, material and energy use per capita in cities is usually lower than rural areas for the same level of income. Rising household income and therefore levels of resource consumption per capita increase material and energy use, so when urbanisation is correlated with rising GDP per capita, then upwardly mobile households will tend to concentrate in cities. At the same time, the capacity for innovations in cities could encourage the decoupling of rising income (up to a point) from rates of resource use.

4.3 Comparative material flow analysis of cities

The Building Technology Programme at Massachusetts Institute of Technology (MIT) has been applying urban MFA to a variety of architectural and urban planning challenges (see http://bt.mit.edu/). One of their recent studies has produced the first global comparative analysis of 155 cities from various parts of the world,[63] presenting data in the following categories:

- Total energy consumed per capita (all sources of energy)
- Total electricity consumed per capita measured in kWh
- A ll fossil fuels consumed per capita measured in tons
- Industrial minerals and ores per capita measured in tons
- Construction materials meansured in tons
- Biomass per capita in tons
- Water per capita measured in cubic metres
- Total material consumption (TMC) associated with domestic production and consumption activities, including indirect flows that are imported but less exports and associated indirect flows and exports.
- Carbon dioxide emissions per capita.

This study used as its point of departure the country-level MFA data for 175 countries available from the Institute for Social Ecology in Vienna. The city-level material flow analyses of the above factors, excluding water, were then derived from the country-level data using a formula developed by Bettencourt and colleagues.[64] Water data for the 155 cities was obtained from the International Benchmarking Network for Water and Sanitation Utilities (IBNET) and overlaid with population, population density, GDP, HDI and climate data. The cities were then ranked as a Low, Medium or High per capita consumer of energy, electricity, fossil fuels, industrial minerals and ores, construction minerals, biomass, water, TMC, and total CO_2, and as a Low, Medium and High per capita emitter of CO_2.

With some exceptions, these two more or less coincide, i.e. cities with a low level of Total Material Consumption (TMC) are more or less fairly low emitters of CO_2.

Figure 4.2 clusters the 155 cities by level of resource consumption as measured in terms of TMC (vertical axis) and by their *pattern* of resource consumption (horizontal axis). So, for example, although they come from vastly different economic and developmental contexts, Johannesburg, Guangzhou, Shanghai, Tashkent, Tel Aviv, Cape Town and St. Petersburg all display a similar *pattern of resource consumption* and so are clustered together in a typology labelled as Type 12.

On the vertical axis (consumption levels 1-7):

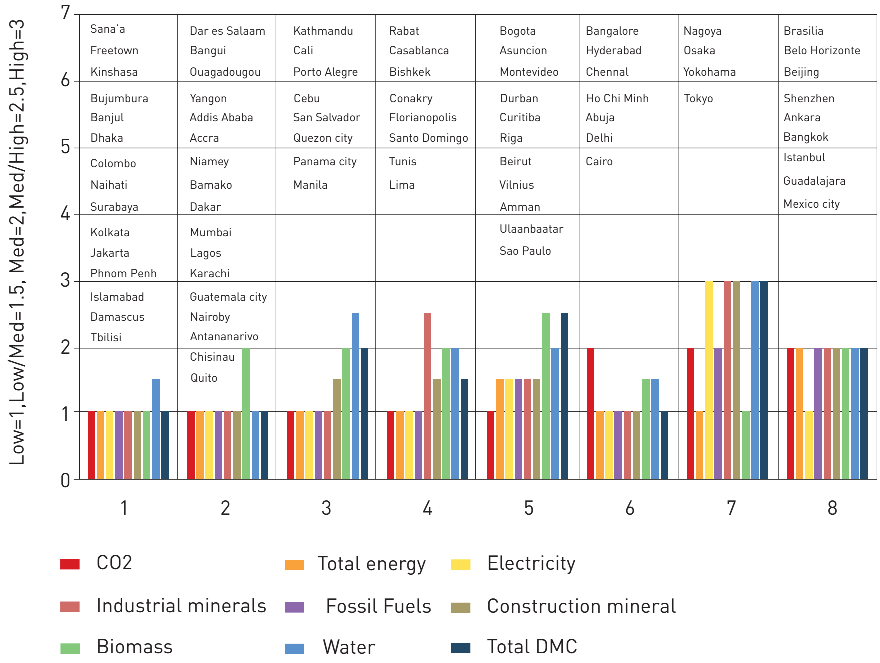
- Consumption level 1: Low resource consumption (TMC range from 2.09 to 4.5 t per capita)
- Consumption level 1.5: Low/Medium resource consumption (TMC range from 4.5 to 7.6 t per capita)
- Consumption level 2: Medium resource consumption (TMC range from 8.04 to 11.5 t per capita)
- Consumption level 2.5: Medium/High resource consumption (TMC range from 11.5 to 14.96 t per capita)
- Consumption level 3: High resource consumption (TMC range from 15 to 43.22 t per capita)

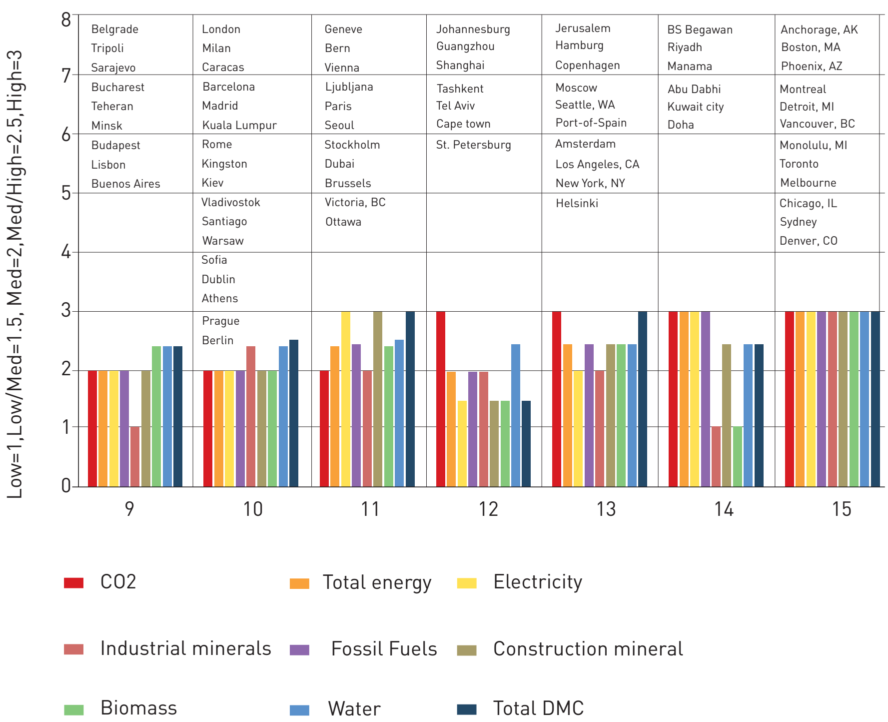
On the horizontal axis (types 1 to 15):

- Types 1 and 2: cities in low to lower-middle income developing countries where resource consumption per capita is low, except for water which is low/medium and biomass which is medium. Type 1 corresponds to a low standard of living for the majority residing in these cities.
- Types 3 to 6: these are cities in countries going through an industrialisation process. For Type 3, the first 5 components are low, but an increase in construction minerals and biomass (low/medium), water (medium or more), and TMC reaches

Figure 4.2

Typology of urban metabolic profiles[65]





Source: Saldivar-Sali, A.N.D. 2010

medium. This profile reflects cities within societies making the transition from an agricultural to an industrial mode of production but where construction lags behind overall consumption driven by industrialisation. Type 4 cities are all medium to high with respect to the consumption of minerals/ores, with medium consumption of biomass and water, and low consumption of construction minerals. CO_2 emissions, total energy, electricity, and fossil fuel consumption are all low. Type 4 cities are typically located in resource-rich environments dominated by mining and light manufacturing, but where biomass-based industries are still prevalent. Type 5 cities are similar in that biomass still dominates resource consumption, but construction and infrastructure have kept up or exceeded the pace of industrialisation. The result is that Type 5 cities are all at the low/medium level with respect to energy, electricity, fossil fuels, minerals and ores and construction minerals. CO_2 emissions are still low because of the dependence on hydropower and oil rather than coal. Type 6 cities are in countries at the early stages of industrialisation. Biomass consumption is therefore higher than construction materials and industrial minerals and ores. TMC and energy-related resources are low. CO_2 is high due to a heavy dependence of the industrialisation process on coal and oil.

- The bulk of the cities in Type 7 are in Japan. Unsurprisingly, their TMC levels are high and they are high consumers of industrial minerals and ores and construction minerals. Biomass consumption is correspondingly low. Japan's history of investment in energy efficiency and regulation of dirty heavy industries is reflected in relatively low CO_2 emissions and fossil fuel consumption (medium), while total energy consumption is low. Electricity consumption is high, but the relatively clean energy mix keeps CO_2 levels at the medium level.

- Resource consumption in Type 8 cities is medium, with the exception of electricity which is low. These are industrialising cities where the low electricity consumption indicates relatively low living standards. Biomass-based production and light manufacturing explains the medium levels for biomass and minerals/ores. Construction minerals are medium, suggesting significant investments in construction and infrastructure.

- Type 9 cities are located in countries that are making the transition from command economies to more market-based economies (not just in Eastern Europe). Biomass-based industries remain significant in these economies (hence medium/high levels of biomass consumption), and investments in construction and infrastructure to stimulate industrialisation are also taking place (hence medium consumption of construction minerals). These are carbon and energy intensive economies; hence the medium level scores in these categories.

- Type 10 cities are located in highly developed and some transitional economies that have diversified into services. Although TMC levels are high, carbon and energy related categories are medium because of a diversified energy mix and lower energy intensity of service sectors compared to secondary industries.

- Type 11 cities are characterised by high levels of personal affluence and associated high energy consumption in the residential and commercial sectors. Nevertheless, CO_2 emissions and total energy consumption levels are medium. Biomass consumption is high due to role played by wood, paper, food and textile industries. Industrial minerals and ores are medium due to manufacturing industries in these cities. Hydropower, nuclear power and energy efficiency help keep the CO_2 levels low relative to energy consumption.

- Type 12 cities are are energy intensive economies with high carbon emissions. Although total energy consumption is high, electricity consumption is relatively low because significant populations of these cities are earning low personal income.

- Type 13 cities are in countries which are technologically advanced producers of coal, cement, food and beverages, and textiles. Construction plays a major role in these economies. As a result, TMC and CO_2 emissions are very high, and biomass and construction minerals are medium/ high. Relatively low electricity and industrial minerals/ores reflects the modest large heavy industrial base.

- Type 14 cities are located in the world's oil producing countries. TMC, water and construction minerals consumption is very high due to the affluence in these cities, with low levels of consumption of biomass industrial minerals and ores due the absence of industries that require these inputs and the arid regional conditions. Unsurprisingly, energy and CO_2 levels are high.

- Type 15 cities are located in the advanced low density industrial nations. The energy and material intensity of these economies plus high levels of personal affluence explain the high resource consumption levels in their cities. Their low density compared to European cities also plays a role here.

This analysis reinforces the overall argument of the report. Business as usual will mean that the cities clustered under Types 1-6 plus 8 will go through a conventional process of modernisation (industrialisation, urbanisation) that will result in their TMC rising from between 2 and 4 t per capita to the same level as the most unsustainable cities in the world (Types 10 to 15) where TMC is between 15 and 40 t per capita. The challenge is for cities in the developed world to reduce their TMC per capita, and for cities in the developing world to find ways of managing the urban development process in ways that do not result in TMC levels of 15 to 40 t per capita.

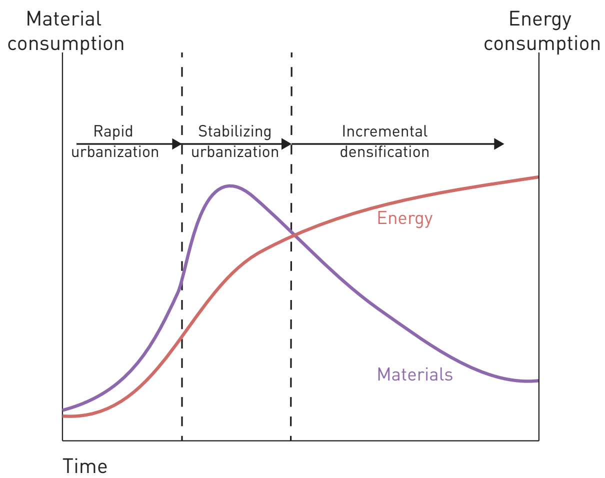
The MIT study only deals with flows through the urban system and not with net addition to stocks (NAS). A similar comparative study for NAS does not exist, but a projection of how an NAS analysis could relate to energy consumption is presented in Figure 4.3.

The figure projects that demand for materials to add to stocks would spike after a period of rapid urbanisation (assuming the necessary economic preconditions are in place to support these investments). At the core of this is a massive increase in demand for construction materials, the bulk of which are Net Addition to Stocks (NAS) (buildings, infrastructure). As urbanisation stabilizes over time and average income levels steadily rise, the demand for construction materials tapers off and the demand for energy rises (with, of course, an associated rise in emissions). The rising energy curve as urbanisation stabilises and incomes rise is directly related to the type of infrastructures that are designed and implemented in cities. This helps illustrate the core conclusion of this report: *infrastructures can be designed in such a way that the materials consumption curve peaks at a lower level of consumption, and that the subsequent energy requirements will be reduced accordingly because the infrastructures and buildings have been appropriately designed to achieve the same level of well-being with less resource consumption and lower CO2 emissions (resource and impact decoupling, respectively).*

While helpful to illustrate a particular ideal type that has really only been manifested to the full extent in developed countries, Figure 4.3 ignores what has been referred to as heterogenous urbanisation and the peri-urbanisation of the urban poor in cities in the developing world. In these cities the materials curve may not rise and fall in this way, but may instead reveal a constant gradual increase as net additions to stocks constantly lag behind economic growth due to the absence of resources for major infrastructure works and building construction. However, the energy curve may look similar albeit at lower levels. It also ignores the fact that a large number of cities around the world are now going through a fourth stage: a stage of de-densification through suburbanization and 'exurbanization'. A fifth stage is also possible, where re-densification through revitalization and regeneration is taking place (the so-called 'new urbanism'). These potential additional stages will probably have different energy and material consumption patterns from the earlier stages depicted in Figure 4.3.

Figure 4.3

Conceptual representation of typical material consumption and energy consumption patterns over the life cycle of the development of a typical city[66]



Source: Fernandez 2007

5 Decoupling through urban infrastructure

5.1 Infrastructure investments, economic recovery and green growth

The central role of urban infrastructure is reflected in many of the financial 'rescue packages' that have been introduced since 2007-2008 to mitigate the impacts of the financial crisis. A significant proportion of the publicly financed investments to stimulate a global recovery seem to be targeted at investments to refurbish or extend the ageing urban infrastructures of cities in the developed world, and the under-serviced, over-burdened urban infrastructures of the burgeoning cities in the developing world. While this is reflected in policy intentions such as, for example, US President Obama's proposed Infrastructure Bank, China's decision to accelerate what was already a large infrastructure construction programme, and the African Union's pan-African infrastructure investment programme, and the increasing number of reports from influential consulting firms advocating investment in infrastructure as a major new financial opportunity,[67] the economic, environment and social impact of policies and programmes merits a detailed assessment.

The first estimates of what this will cost globally are already being published. The global consulting firm Booz Allen Hamilton, which depends heavily on world-wide contracts to build infrastructures for its US$4.5 billion turnover, has compiled a detailed estimate of the investment required to meet demand for urban infrastructure over the next 25 years for all the cities of the world. It estimates that a total of US$41 trillion is required to refurbish the old (in mainly developed country cities) and build new (mainly in the developing country cities) urban infrastructures over the period between 2005 and 2030.[68] Over 50 per cent (US$22.6 trillion) would be required for water systems, US$9 trillion for energy, US$7.8 trillion for road and rail infrastructure, and US$1.6 trillion for air- and sea-ports.[69] The Boston Consulting Group independently arrived at a similar estimate when it argued that US$35–US$40 trillion will need to be invested in infrastructure by 2030.[70]

The report warns that:

> *"Sooner or later, the money needed to modernise and expand the world's urban infrastructure will have to be spent. The demand and need are too great to ignore. The solutions may be applied in a reactive, ad hoc, and ineffective fashion, as they have been in the past, and in that case the price tag will probably be higher than US$40 trillion. After all, infrastructure projects are notorious for cost overruns. But perhaps the money can be spent proactively and innovatively, with a pragmatic hand, a responsive ear, and a visionary eye. The potential payoff is not simply the survival of urban populations, but the next generation of great cities."* [71]

Significantly, Booz Allen Hamilton recognises that the grand retooling of the world's urban infrastructures will mean finding new designs and technologies that will make it possible to use natural resources more sustainably:

> *"... [C]ities that ignore environmental impact will find themselves facing another collapse of infrastructure 30 or 40 years from now, and our children and grandchildren will bear a much higher price tag."* [72]

mistakes made by economic policy-makers during the decades leading up to the start of the crisis in 2007. Signalling the economic policy emphasis of their presidency of the G20 in 2012, the Mexican government noted the need for 'economic stabilization' and 'structural reforms'. However, these measures "have to be enclosed by a renewed political commitment to sustainable development and green growth."[74] The subsequent Communique

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The fact that investments in urban infrastructure have become a key element of fiscal stimulus packages should be unsurprising. These are usually large investments with relatively low transaction costs (a few big investments cost less than a large number of small ones) that create the kinds of public goods that build the confidence needed to stimulate knock-on investments by the private sector. Less obvious is the economic rationale for the kind of investments in sustainability-oriented infrastructures that are needed to prevent infrastructure from collapsing a few decades down the road. It is necessary, in other words, to avoid what the Green Economy Report described as the 'gross misallocation of capital' which the Report cited as the real underlying cause of the global economic and ecological crisis.[73] Fortunately, the G20 is becoming more aware of the need to avoid repeating the

from the February 2012 meeting of Finance Ministers and Central Bank Governors recognised "the importance of 'green growth'" and called on the OECD, the World Bank and the UN to "provide options for G20 countries on inserting green growth and sustainable development policies into structural reform agendas, tailored to specific country conditions and level of development."[75]

Investments in infrastructures that reduce carbon emissions and improve resource productivity can unlock unspent investment funds because they can go to scale rapidly and they will be responsive to credible multi-year policy interventions that limit uncertainty and build confidence over time.

> *"It is precisely the overwhelming and growing long-term need to address numerous market failures [such as*

climate change] through transformational investment and innovation that has the potential to make the opportunity from intervention so credible. 'Green' investment is also large-scale and offers potentially profitable markets for decades. It can therefore leverage in serious private money. As a result, much of this private investment should be additive (rather than displaced from elsewhere), helping to break out of the deflationary confidence spiral, much as Roosevelt's New Deal did in the United States from 1933."[76]

Thus future investments in sustainability-oriented urban infrastructures have two primary drivers: the economic demand for more viable urban infrastructures as the second urbanisation wave takes its course, and the ecological demand for more sustainable use of natural resources (both sources and sinks). If the necessary policy frameworks can be put in place to provide greater certainty for investors, investment rather than fiscal or monetary interventions could well bring the global economic crisis to an end.

Economists look back on the investments in automobiles, roads, petro-chemicals and mass production systems made from the 1930s through to the post-World War II period, including the Marshall Plan in Europe, as the investments that 'resolved' the 1929–1933 economic crisis and paved the way for the post-WWII long-term development cycle. In much the same way, in 20-30 years researchers may look back and regognize that the debt-based investments that helped 'resolve' the crisis that began in 2007 were, in fact, investments in networked urban infrastructures such as using 'Web 2.0'-type information and communications technologies (ICTs) as their operating systems (for instance, smart grids, telecommuting, virtual shopping, remotely controlled intelligence systems, and digitalisation). *Retooling the world's cities for the next long-term development cycle is emerging as a key strategic opportunity for many investors.*

The key question is what kind of networked urban infrastructures will be built? Will cities be designed for sustainable socio-ecological metabolisms, or will they continue to draw down nature's resources and ecosystems? Will they reinforce the stark techno-apartheid that is splintering cities around the world or will they create the basis for greater equity, reduced levels of poverty and greater opportunities to build a sense of community? Will more sustainable modes of resource use reinforce or undermine the search for greater equity and a sense of place? And will infrastructure designs and investments take into account the changing nature of urbanisation patterns in response to the rising cost and changing flow of resources through cities? In other words, will infrastructure investments 'sink in concrete' urbanisation and settlement patterns that may well be superseded by patterns of urban development that are still to emerge in highly unpredictable ways? This, in turn, may suggest modular approaches that apply the flexible specialisation pioneered in the production sphere to the infrastructure sphere, but social behaviours will also need to change if the intended outcomes are to be realised in practice.

5.2 Economic Implications

The recessionary conditions that currently afflict most OECD countries and many (but by no means all) developing countries result from a combination of low levels of consumer demand, too much household debt, fiscally weak governments and a massive surplus of unspent corporate savings. Rising resource prices push up inflation and reduce consumer demand even further. While economists debate the merits of austerity, the consensus is that global economic growth is required. For some this will come from low interest rates, low inflation and debt reduction, while for others Keynesian fiscal stimulus is needed, together with higher interest rates and higher inflation. The large bulk of the most significant economic activities are concentrated in cities (large, medium and small ones), which are configured and operated in many different ways. In other words, the geography of economic space matters when it comes to implementation.

Material flows, the infrastructures that conduct these flows, and (in Section 2) the governance dynamics of infrastructure transitions, provide the practical context for implementing economic policy. Most cities lack access to the funds needed to address the infrastructure challenges they face. At the same time public policy has failed to create the kind of investment climate that can unlock the massive unspent corporate savings. The result is growing recessionary conditions broken by occasional growth spurts that, in turn, are undermined by rising resource prices (in particular oil prices). Recent work by Stern and Zhengelis[77] and McKinsey[78] suggests that the answer is to create incentives for this unspent capital to be directed into resource efficiency and low carbon economic activities. Cities are in a unique position to do just this because they usually have sufficient executive and legislative autonomy to create investment climates that build up the confidence that investors require. While infrastructure is a significant investment opportunity, much will depend on whether a balance can be achieved between the institutional arrangements that will satisfy investors, the fiscal capacity of the city governments and the willingness to regulate the kind of privatisation of assets that frequently results in rising costs that have a negative impact on the urban poor. Public-private partnerships that are attractive to investors in infrastructures that deliver affordable services in resource efficient ways are the kind of economic approach that is envisaged in this report. A greater understanding of material flows and infrastructures from a sustainable and equitable development perspective will assist in this endeavour.

5.3 Pursuing decoupling and the restoration of eco-system services through urban infrastructure

While some evidence indicates that relative decoupling is taking place (mainly in developed country cities), absolute resource reduction is unlikely to happen without deliberate intervention to stimulate broad, systemic changes, including behavioural changes. The decoupling argument may be perceived to focus on reducing environmental degradation and the consumption of limited resources such as fossil fuels, fresh water, rare metals, but the human needs for food, shelter and mobility are still not fully met by a significant percentage of the world's population. Efficiency and resource productivity improvements can at best prolong the lifespan of limited resources, but without a complementary commitment sufficiency existing inequalities could persist. A combination of resource productivity improvements, increased use of local renewable resources and re-use of waste products can allow cities to better manage the flows passing through them in pursuit of decoupling.

5.3.1. Improve resource efficiency

Improvements in resource efficiency are often considered to be a first step towards sustainable resource management.[79] This means achieving more material output with less material inputs, and investments in improving productivity are easy to justify by their economic rationale. Typically, this involves engineering and/or institutional solutions to fine-tune the components of existing systems to reduce the amount of water, electricity or fuel wasted in meeting human needs. However, achieving resource sustainability needs a 'whole system' design perspective that can facilitate more radical system changes. Indeed, sometimes-substantial savings can be generated by simply operating existing technologies in far more efficient ways.

The approaches to improving resource efficiency cover a range of technical complexities and scales. While improving resource efficiency can be interpreted as a demand-side management measure, it can also influence the manner in which certain services are supplied. Electricity interventions typically focus more on reducing demand from end users by encouraging efficient lighting and appliances, and reducing the need to use electricity for heating by insulating buildings and making use of waste heat. In the case of potable water, demand and supply-side measures can be effective; in particular the maintenance of water delivery systems to repair leaks and reduce unaccounted water losses. Similarly, reducing fossil fuel use per capita in transport infrastructure often requires the provision of cycling paths and shared modes of transport as alternatives to private vehicles, and can extend to the planning of cities to reduce commuting distances.

Examples of resource productivity improvements from the case studies include:

- Fitting new buildings with high-tech computer-controlled lighting and temperature control systems to minimise energy wastage in Songdo, Republic of Korea;

- Improving the energy efficiency of buildings to reduce CO_2 emissions in Finnish municipalities;

- Retrofitting government housing with low-energy light bulbs and ceiling insulation in Cape Town, South Africa;

- Replacing street lighting with LED lights connected via a smart network to reduce energy use in San Jose, California;


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- Reducing per capita water usage through water efficiency improvements and leakage prevention programmes in Singapore; and

- Shifting commuters from private cars to shared public buses on Lagos' BRT-Lite, and to trains in Bangkok, Thailand.

Building on the earlier work on 'Factor 4' improvements in resource productivity that result in the same or increased output while using 80% less resources, von Weizsäcker *et al.* now propose 'Factor 5' improvements across a wide range of key economic sectors that have already been developed and can be more generally applied as the basis for a new green economy.[80] Given the escalating pace of technological innovation and compound effects of efficiencies, in the near future it may be possible to move beyond Factor 5. This is reflected in the goal of 'Factor 4-10' resource productivity improvements which have been proposed for industrialised countries in the next 30-50 years[81] and is the focus of the *Decoupling 2* report.

Improvements in resource efficiency can be described as a relative decoupling strategy as fewer resources are used to achieve the same goals, or the same amount is used to achieve greater results. However, it does not fundamentally eliminate dependence on limited resources, and runs the risk of being pursued without understanding the impact on total resource consumption. In the case of non-renewable resources, efficiency measures alone can suffer from the 'rebound effect,'[82] effectively cancelling out net environmental benefits with consumption increases that have been encouraged by the efficiency gains.[83]

5.3.2. Use renewable resources and ecosystem services

As a stand-alone strategy to manage non-renewable resources, improvements to resource productivity in the context of a growing population can only help to prolong the status quo until limits are reached. A certain amount of material is required to support a good quality of human life, so reducing per capita consumption of resources can only be pursued up to a certain point. However, a switch from consumption of finite resources toward sustainably managed renewable resources like sunlight, wind and biomass opens up the possibility of being able to meet the needs of more people. (Some distinguish this decoupling strategy as 'transmaterialisation' or switching to materials that deliver a service with a lower impact per unit).[84] This shifts the focus from reducing damage to generating new alternatives, and broadens the scope of innovation for sustainability beyond the status quo.

Examples from the case studies include:

- 'Positive energy' houses that contribute to grid electricity in Vauban's solar settlement in Freiburg, Germany;
- The installation of photovoltaic panels on the roof of the town hall in Totnes, England;
- Retrofitting government housing with solar water heaters in Cape Town, South Africa;
- Harnessing solar and wind power to generate electricity in Masdar, Abu Dhabi, and positioning buildings to funnel cool winds through the city;
- Harnessing rainwater to replenish depleted aquifers in Chennai, India; and
- Diverting stormwater and processing used water to augment the potable water supply in Singapore.

Similarly, the use of finite resources in meeting some human needs can be reduced by harnessing and maximizing the benefits provided by natural systems, otherwise known as 'ecosystem services'. The 2005 Millennium Ecosystem Assessment showed that human wellbeing is dependent on ecosystem health, and divided the ecosystem services on which socio-economic systems depend into four categories:[85]

1. Provisioning services: food, water, fibres, natural medicines, pharmaceuticals, genetic resources and bio-chemicals.
2. Regulating services: air quality, water regulation, water purification and waste treatment, pollination, erosion regulation, climate regulation, disease regulation, pest regulation, and natural hazard regulation.
3. Cultural services: spiritual and religious values, aesthetic values, ecotourism, and recreation.

4. Supporting services: soil formation, nutrient cycling and primary production.

In the long term, maintaining functioning ecosystems can be a cost-effective way to meet human needs over the long term, and in some cases it is the only way of meeting human needs for irreplaceable ecosystem services such as water supplies from rivers or aquifers essential to cities. By identifying, understanding and incorporating the benefits that nature provides into future visions of the city, planners, educators and managers can increase the number of alternatives to finite resource use that can facilitate decoupling.[86] While it may not be possible to increase earth's absolute carrying capacity, nature's ability to improve the provision of ecosystem services can be supported so that the quality of everyday living can improve, resilience can be enhanced and future options expanded and reinforced.[87] The well-known case of New York's investment in its regional river system is in some ways the iconic case that demonstrates this argument, with lesser known examples in other cities, such as Rio's investment in reforestation to re-establish its aquifers or Johannesburg's investment in its urban forest.

Factoring the planet's multi-trillion dollar ecosystem assets into policy-making can help cities and regional authorities save money while boosting the local economy, enhancing quality of life, securing livelihoods and generating employment. For example, when considering options for reducing pollution, many waste streams such as human and organic household waste can be rendered harmless (and in some cases useful) by natural systems powered by solar-based photosynthesis and the nutrients and moisture contained in the waste itself. While, most conventional pollution control equipment is capital-intensive and expensive to operate, natural systems tend to be much cheaper to maintain as they make use of abundant ecosystem services.[88]

Using nature to provide ecosystem services is known as 'bio-utilisation' or 'bio-assistance'. Bio-utilisation involves the use of parts of ecosystems as raw materials, a house made of wood, or a 'living roof', that provide insulation and other green building benefits are both examples of bio-utilisation. Bio-assistance refers to the domestication of organisms - anything from herding sheep to using nature-based renewable resources such as earthworms for composting or algae for biofuels. These strategies can also be applied to green design, and are sometimes used in combination. For example, 'living machine' sewage treatment systems use live plants and microbes which are selected and arranged to imitate a natural ecosystem. Living machines are not only more environmentally friendly than standard methods of sewage treatment, they turn what is normally a hidden eyesore into a vibrant greenhouse, and in some installations they have become architectural features.[89]

For most cities, each hectare of developed land equates to the loss of almost a hectare's worth of ecosystem services. Roofs and pavements reflect sunlight rather than capturing it for energy; CO_2 is released into the atmosphere rather than sequestered in vegetation or soils; buildings and streets shed rainwater into storm sewers that rush it away rather than letting it filter through wetlands or seep through soils to replenish ground water and support life. Instead of relying on urban green spaces to provide all beneficial ecosystem services, attention is now being paid to the role that buildings and infrastructure can play in giving back to the surrounding area, over-and-above meeting the needs of their users. Although cities may look very different from the native ecosystem, they could mimic natural systems, making use of locally available resources and emitting zero wastes.[90] Biomimicry is the practice of learning from and then emulating nature's genius to solve design challenges and create more sustainable designs. The vision is to create products, processes, systems, organisations, and policies that are well adapted to life on earth over the long haul, and it is a useful lens through which to envisage cities that are decoupled from finite resource use.[91]


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5.3.3. Re-use wastes

Human settlements have always generated waste. The metabolism of a typical modern city can be described as 'linear' in that it extracts resources from beyond its boundaries, makes use of them within its boundaries to support urban activities, and then deposits the resulting wastes in high concentrations back onto the external environment.[92] In this way, the modern city's metabolism is fundamentally different to the circular metabolismthat of a natural ecosystem which produces no waste and survives off its immediate environment.[93] Modern cities require a continuous supply of resource inputs and an unlimited capacity of nature to absorb the concentrated wastes they produce.

Returning to forms of more circular, location-specific urban metabolisms is increasingly recognized as necessary if cities are to survive a future of resource limitations and climate uncertainty.[94] Ravetz explains that "...a city or region which contains its own eco-cycles would tend to be less vulnerable and damaging, or more 'sustainable'...."[95] Growing cities have traditionally expanded the boundaries of the hinterlands on which they depend for survival as a means of accommodating growth, but green cities show signs of a trend toward re-localisation and attempts to create more autonomous circular or 'closed-loop' metabolisms.[96]

'Biomimetic systems' are closed-loop lifecycles where outputs and by-products become inputs for something else, where 'waste equals food'.[97] Achieving a circular metabolism at the scale of the city is challenging due to the many different resources and wastes that circulate through it, so it requires connecting complex webs of interdependency. This may be where nature has the most to teach; everything alive is part of multiple complex webs of predator/prey, waste/fertilizer, parasite/host, symbiant, and scavenger, only a few of which have precise equivalents in modern cities.[98] Biomimicry or biomimetic design provide the potential for buildings and cities to act "...as closed-loop ecosystems that, like a forest or savanna, draw their energy from the elements and produce no net waste - and perhaps even improve the surrounding environment."[99]

'Recycling' runs the risk of being limited to the separation and collection of household packaging wastes, but can include considering all 'waste' generated by urban production and consumption activities as valuable inputs to useful processes. Even the built fabric of the city has potential to be re-used as buildings are retrofitted instead of being replaced, salvaged bricks and other materials from demolitions are re-used as inputs into construction, and rubble is processed for use in road surfacing and other projects. Although an emphasis on recycling is perhaps more applicable to saturated cities in the developed world, even cities where material stocks must still be built up often generate a significant amount of building rubble from new construction as old structures are demolished or rapidly replaced; this resource could be recycled into new construction.

Similarly, organic wastes in the form of food, sewage or animal wastes contain valuable nutrients, gases and water that can be re-used to meet the needs of the city. Instead of viewing waste organic matter as something offensive to be dumped and buried as quickly as possible, the city of Stockholm has built a large-scale municipal sewage treatment systems that captures methane to power its bus fleet, while reducing greenhouse gases released into the atmosphere; the remaining biomass can be composted and used to enhance the fertility, water retention and even CO_2 absorption of soils. Wastewater is a potential

source of water for non-potable uses and the nutrients it contains can be reclaimed and used as affordable natural fertilisers.

Examples of the re-use of resources from the case studies include:

- The selling of 'waste' products from one industry as inputs to another in Kitakyushu Eco-Town, Japan;
- The separation, collection and recycling of household wastes in Curitiba, Brazil;
- The collection, drying and grinding vegetable peels to produce nutritious animal feed in Kampala, Uganda;
- The generation of biogas from crop residues, manure and slaughterhouse waste to run public buses in Linköping, Sweden;
- Fuelling district heating with waste woodchips from nearby logging activities in Växjö, Sweden;
- The use of wastewater to irrigate urban farms in Accra, Ghana;
- Treating waste water on-site for re-use in toilet-flushing, irrigation and other applications in Beijing, China;
- The use of methane for energy generation and processed leachate for irrigation and dust suppression at Mariannhill Landfill site in Durban, South Africa;
- The collection of solid and liquid waste from waterless toilets as a source of nutrients for agriculture in Lilongwe, Malawi; and
- The collection of food scraps for conversion to compost at municipal composting facilities in Portland, Oregon, USA.

Every city has a unique configuration of interests and changing conditions bring unpredictable new configurations, alliances and strategic initiatives. As resource prices rise, new technological options become commercially available to those in the public, private and non-profit sectors seeking new opportunities for tackling old problems. However, this will depend on the existence of appropriate know-how and the capacity for innovation within each specific city. More efficient usage of limited resources, improved management of renewable resources and the re-use of wastes are becoming the focus of new initiatives that could well bring about the decoupling of rates of resource use from well-being and economic growth. For whole-system efficiencies to be realised at the city scale, strategic coalitions with a shared vision for decoupling will need to emerge. The following section describes how transitions toward sustainability at the city scale might look, in order to formulate an agenda for facilitating transitions toward decoupling in different contexts.

6 Transitions toward sustainable cities

6.1 Introduction: approaches to transitions

The critical questions that follow from the preceding discussion of the role of infrastructure in city-scale decoupling and ecosystem restoration are:

- To what extent can decision-makers at the city level govern and shape transitions in infrastructure systems and the resources that flow through them?
- How might the relationships between cities, infrastructure systems and the organisation of resource flows need to change in order to realise more sustainable outcomes?

To answer these questions, the following addresses three key challenges:

First, sustainability-oriented innovations (SOIs) will need to become the operating systems for a new generation of vibrant, expanding and socially inclusive urban economies. Investments in innovation have long been important generators of economic value. However, to date most innovations have been motivated by the pursuit of economic growth with relatively little attention given to environmental considerations. SOIs are inspired by goals that go far beyond economic growth to include social inclusion (specifically poverty reduction in developing countries) and sustainability (most often reduced negative impacts but also improved resource productivity). The increasingly well-known Multi-Level Perspective (MLP) helps understand the relationships between the macro-context of structural change, the logic and structure of existing socio-technical regimes, and niche innovations.[100]

Second, in order for SOIs to become a driver of urban economies, the relationship between government (in particular local government) and society will need to evolve. Historically, many governments acted upon society in accordance with masterplans generated by specialists who tended to downplay the role of citizens. The recent rise of active civil societies supported by the power of internet-based communications has resulted in the emergence of the energetic society: "[a] society of articulate citizens, with an unprecedented reaction speed, learning ability and creativity."[101] As Hajer argues:

> *"It will become important in the coming decades to govern by mobilising social energy. There is a future for an innovative, vital society founded on sustainability. Innovations mean scope for action and initiative, accepting the fact that mistakes will be made, and making certain that the best improvements are identified and distributed rapidly. This calls for a different type of government. Such a government sets clear objectives before going on to create room for other parties, implements knowledge, know-how and regulations to help promote promising combinations of initiatives, and creates the institutional frameworks within which citizens, organisations and entrepreneurs can develop and directly benefit from sustainable innovation."*[102]

From this perspective, cities can be understood as energetic societies comprised of potentially articulate individuals, communities and companies with actual or potential fast learning curves "...who themselves form a source of energy. It is up to the government to create the right conditions to make this possible..."[103]

Third, heterogenous urbanisation patterns and complex interactive flows between rural, urban and peri-urban regions will persist. Urban development patterns could well result in new settlement patterns, resource flows and social dynamics that could shape and influence the viability of particular infrastructure investments and systems. These may not always serve human wellbeing. For example, the converging peri-urbanisation of urban poverty, waste flows and food production must avoid creating divisions and exclusions that infrastructure investments may unintentionally exacerbate and reinforce. Interventions such as Medellin's cable cars that link the urban poor to the city should be favoured over the exclusionary impacts of costly public transit systems such as those found in Bangkok, Thailand and Gauteng, South Africa.

6.1.1. Socio-technical infrastructure transitions and cities

The multi-level perspective (MLP) provides an ambitious attempt to develop an understanding of 'system innovation'[104] or 'sustainability-oriented innovations' (SOIs), based on an interrelated three-level framework of landscape (macro), regime (meso) and niche (micro).

The concept of **'landscape'** in the MLP helps understand the broader conditions, environment and pressures for transitions. Landscapes operate at the macro level, focusing on issues such as political cultures, economic growth, macro-economic trends, land use, utility infrastructures and so on[105] and apply pressures on existing socio-technical regimes creating windows of opportunities for responses.[106] Landscapes have the potential to affect the constitution of regimes (meso) and niches (micro) by providing an external context that makes some actions easier than others. They do not determine niches and regimes, but landscapes need to be considered as the setting where they function.[107]

'Regimes' are seen as socio-technical because technologies and technological functions co-evolve with social functions and social interests. Technological development is potentially shaped by a broad constituency of engineers, policymakers, business interests, NGOs, consumers and so on. Regulations, policy priorities, consumption patterns and investment decisions, among other things, hold these inerests together to stabilise socio-technical regimes and their existing trajectories.[108] The emphasis on regimes – the meso level - therefore, highlights the challenge that "...reconfiguration processes do not occur easily, because the elements in a socio-technical configuration are linked and aligned to each other. Radically new technologies have a hard time to break through, because regulations, infrastructure, user practices, maintenance networks are aligned to the existing technology...."[109]

Adrian Smith and colleagues[110] characterise regime change as being driven by shifting pressures impinging on a regime and the extent to which responses to these pressures are coordinated, both from inside and outside the regime. They see governance interventions (rather than government interventions) facilitating regime transformation. Landscape pressures can be articulated either in very general terms (e.g. demographic change) or in relation to specific regimes (e.g. impact of climate change on the fossil fuels industry). The articulation of these pressures and the adaptive capacity of the regime (its relationships, resources and their levels of coordination) constitute a response to these pressures. Creating space for the 'energetic society' to take its course can be seen as the governance of regime transformation. This can be the outcome of historical processes (e.g. a gradual shift in consumer choices or evolution of new technologies) or driven by a strategic coalition with a shared vision and capacity to implement. The combination of regime transitions, the governance processes and adaptive capacity leads to the great variety of possible transition pathways.

'Socio-technical niches' operate at a micro level in 'protected' spaces that usually encompass small networks of actors learning about new and novel technologies and their uses. These networks mobilize to add new technologies to the agenda, promoting innovations and novel technological developments.[111]

In working through these issues, Smith and colleagues characterise four types of transition (see Figure 6.1) as a means of stimulating regime changes.

1. 'Endogenous renewal' is characterised by highly co-ordinated responses of incumbent regime actors to perceived pressures on the regime, drawing upon resources from within the regime and changing it incrementally.

2. A 're-orientation of trajectories' refers to regimes which encounter radical re-orientation, either from inside or outside the regime, through what they term a 'shock' or a radical shift "...where governance focuses on internal regime functions, under situations in which pressures are poorly articulated and responses uncoordinated..."[112].

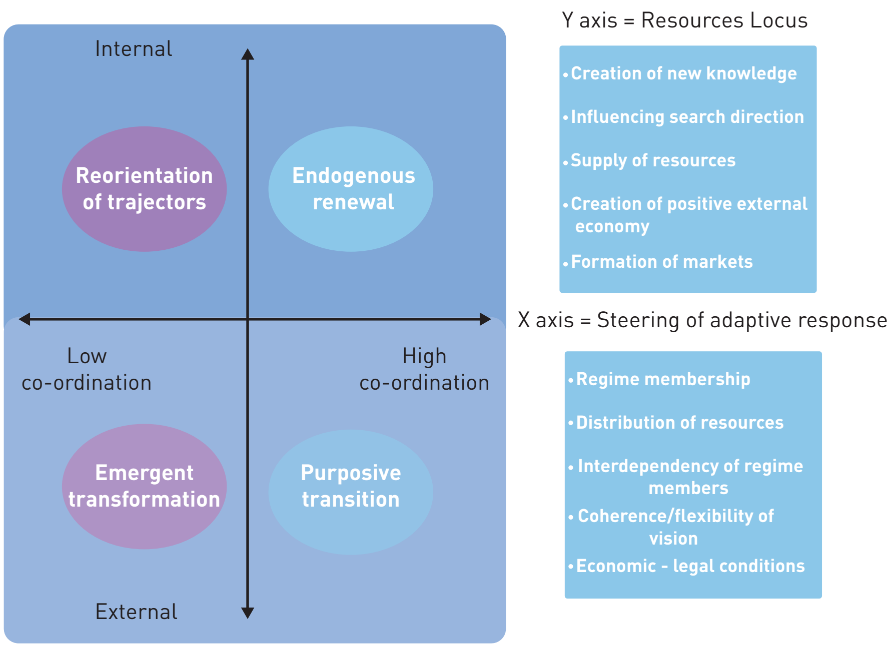
3. 'Emergent transformations' occur through uncoordinated pressures for change and responses external to the incumbent regime. From a governance perspective, "... an emergent transition corresponds in an analytical sense to situations where poorly articulated selection pressures meet with uncoordinated responses..."[113].

4. 'Purposive transitions' show a strong degree of intention in pursuing regime transition, and involve coordinating actors and resources largely from outside the regime. This type has significant internal capacity to manage change, drawing on new ideas from external learning networks.

Although these models of the four main regime-change modes make sense at a general level, they cannot be easily applied to a city because a 'city' cannot be equated to a 'regime'. Instead, a city is a *space* where a

Figure 6.1

Transition contexts as a function of degree of coordination to selection pressures and the locus of asaptive ressources[114]



Source: Smith et. al.

multiplicity of energy, water, waste, mobility and food 'regimes' co-exist in ways that can be both functional and dysfunctional at the same time. City governments are notional 'managers' of the spaces within which these 'regimes' operate, so they are implicated in the way these regimes change over time, either directly due to their control of the service delivery agencies or indirectly as key policy actors with some degree of policy influence and/or regulatory authority. However, some cities, mainly in developing country have networked infrastructures that service only a minority of citizens and their governments have very limited capacity to either extend or operate these infrastructures. In these contexts bottom-up initiatives by households, streets, neighbourhoods and associations, such as taxi drivers who invest in road maintenance, fill the gaps in ways that could over time build new kinds of governance capacities for infrastructure transitions.

Nevertheless, the discussion that follows aims to reinforce 'purposive transitions', with significant capacity to manage transition (which in most cases must still be built up) and a willingness to draw on knowledge and learning from outside agencies, whether or not they are controlled by city governments.

6.1.2. The absence of cities in multi-Level transition approaches

Despite an impressive breadth of focus on substantive areas as varied as transport, energy, water, waste and food systems, and governance,[115] the MLP has thus far neglected the spatial dynamics of cities. This raises the issue of where cities 'fit' within the MLP and how do cities manage the landscape-regime-niche hierarchy? This calls for exploring how innovative activities within cities interrelate with wider national and societal transitions by seeking answers to questions like:

- To what extent are cities conceived of as 'receiving' national transitions that are then 'implemented' in their own local context?

- To what extent can different configurations of social interests at the urban scale mediate national transitions – that is 'accelerate', 'reshape' or even 'disrupt' the implementation of national transitions in their local context?

- If cities can mediate national transitions, to what extent can they then develop further capacity and capability to envision and enact their own locally developed transitions that are relatively distinct from national transitions?

- Depending on the answers to these questions, can cities develop transition initiatives that are 'taken up' by the national context and re-incorporated into new national transitions that are then cascaded back downwards onto cities?[116]

Central to this potential is the relative positioning of cities in terms of their location in governance hierarchies, implying that cities have differentiated capacities to either be shaping or shaped by national transitions.

In order to understand the role of cities in a multi-level perspective, multi-level governance[117] and different scales of action must also be considered. Agency at the level of the city cannot be reduced to understanding the variety and coalitions of actors (e.g. local authorities, mayors, universities, local and economic actors) expected to work at this scale. It also involves the influence of actors at national and supranational scales of action who influence, both intentionally and through unintended consequences, action at a city scale.[118] Considering the way decisions at the national and regional scales cascade downwards leads to seeing cities as both the recipients and generators of urban transitions.

6.1.3. Understanding purposive urban infrastructure transitions: a framework

The relative neglect of cities in discussions of transition to sustainable development can be corrected by developing a framework for understanding the distinctiveness of purposive urban infrastructure transitions. This raises questions as to who is driving the transition and who is claiming to speak on behalf of cities. Priorities at the scale of the city – such as economic growth targets, carbon emissions reduction aspirations, resource security – are becoming strategically intertwined with the new socio-technical infrastructure systems that may or may not be organised at the scale of the city. In other words, urban social interests (municipal and local policymakers and officials in particular) may sit outside of socio-technical infrastructure regimes, but still need to gain degrees of influence and control over these regimes in order to achieve their city's objectives.

The issue here is the degree to which policy agendas are separated or aligned with the power to manage urban infrastructure regimes. To use the language of the MLP, it is the extent to which the priorities of an urban governance network – and the social interests that produce them – are able to actively manage socio-technical regime change.

Urban responses to these pressures will vary. Cities will experience these challenges differently and have historically organised infrastructures that may differ as well as variable capacity to respond to the emerging pressures. The key issues are the degree of regime change required, the leadership capability to enact such changes, and the ways of building common understanding of the outcomes.

6.1.4. Shared visions of urban infrastructure transitions

Urban transitions depend on a shared understanding between a wide range of urban policy-makers and those who manage the energy, water, waste and transport infrastructure regimes. 'Visions' form a central part of prospective transitions management approaches[119] and offer the potential to present a shared understanding of city-wide and regime interests (without implying in advance that everyone *must* reach consensus). The need to consider the 'vision' for a city arises from the fact that cities have become major consumers of organisational change that is packaged and delivered by the strategies of the global consulting industry. Most major cities regularly engage consultants – and/or use their own internal strategy units – to review and set the 'vision' for the city. These activities can include city-wide multi-stakeholder initiatives, strategy formulation processes led by top city politicians and their officials, and departmental or even neighbourhood levels. In South Africa, for example, national legislation prescribes that every town and city sets a vision and drafts an 'Integrated Development Plan' on an annual basis. In this case, all these processes – stakeholders, top leadership, departments – take place separately and then merge into the final integrated plan. Many cities around the world follow this format to some extent, with major multi-national donors funding some of these processes, such as the World Bank's *City Alliance* initiative which promotes 'city development strategies' for every city, though without providing the funding to enable them to do so.

In terms of urban infrastructure, a vision-building process may involve representatives of utilities, municipal government, regulators, developers, business, citizens, 'users' and so on. Visions and the goals they outline provide a reference point through which networks can be built, gaining commitments to participate, orienting the actions of potential participants and constituencies, and persuading potential participants of the desirability of transition.[120] Although visions are not fixed and will change over time with the variety of social interests who become involved, the ideal outcome often stems from a vision-building process that procures new external knowledge into socio-technical regimes that have the internal capacity to manage a transition. Low capacity and dependence on institutionally internal knowledge is often the worst combination from a transition perspective.

6.1.5. Translating visions: intermediary organisation

Visions of 'purposive' urban transitions (i.e. those that demonstrate a strong degree of intention in pursuing regime transition by largely involving coordinating actors and resources from outside the regime) represent a transformative view of the relationship between cities and socio-technical regimes. Both urban governance networks and socio-technical regimes are relatively stable. Purposive urban socio-technical transitions aim

to mutually transform both urban governance arrangements and socio-technical regimes, no simple task. The production of a vision provides a framework for a purposive urban socio-technical transition but it says little about *how* this will be done. It needs to be followed up by building an effective capacity to convert vision into action. Coordinating and mobilising capability requires the creation of new intermediary organisations that constitute a space outside of the vested interests of both existing urban governance regimes and existing socio-technical regimes.[121] This creates a context for the discussion of competing priorities, helps to access fresh external knowledge into a particular regime, and either provides capacity that is lacking or helps mobilise untapped internal capacity. Intermediaries encompass a wide variety of different organisational priorities and motivations, funding streams and organisational capabilities which are predicated on the pursuit of different political priorities aligned with interventions. Institutions acting as intermediaries in cities include consulting companies, university-based research units, NGOs, citizen-based coalitions (often with strong political links), international lobby groups such as the Clinton C40 league, international associations such as the International Council for Local Enviornmental Initiatives, major development institutions such as the World Bank and UN agencies, formalised urban development agencies (constituted either by the municipal government or the private sector, or both as a partnership), or even relatively autonomous internal strategy units. Interestingly, technology providers are also becoming intermediaries – from Cisco systems and Siemens to providers of solar or wind power, like General Electric, technology providers are intervening to reshape markets to favour their new product lines. Intermediaries, excluding now the technology providers, can be characterised in terms of three aspects of their mediating function.

- First, intermediaries often mediate between production and consumption rather than focusing solely on production or consumption issues.[122]

- Second, they can also mediate the different priorities and levels of different funders, 'stakeholders', policy interests, social interests and regulators.

- Third, they mediate between different priorities in the production of a vision and in their application. 'Smart cities' are a battle ground where many different actors try to impose their view of what a 'true' green city should look like, some of which may not be appropriate to the context.

6.1.6. Intermediaries: developing capacity and capabilities for action

The different types of intermediaries are of such critical importance because they are usually brought into change processes by key players to provide knowledge and/or capacity. Knowledge services involve a wide spectrum of activities, including purely descriptive or rapid short-term scoping analyses, through to in-depth research, innovation and long-term strategic guidance/management. Capacity refers to skills and staff time to help (co-)manage some or all aspects of a transition, from scoping through to research and innovation, and even into application and implementation over the long-term. University-based research units, for example, will tend to focus on knowledge services, while large consulting firms will tend to span knowledge and capacity services (preferring, of course, the lucrative implementation contracts). It follows that the perspectives of these intermediaries directly affect the nature and outcome of the transition. They enjoy significant power when it comes to defining what is possible.

The organisational basis within which these social interests, their expectations and forms of knowledge are crucial to the development of active capacity and necessary capability to translate a vision into social and material action. Analysis of European intermediary practices[123] indicates six issues that are particularly important in constituting capacity and capability:

1. Funding: In order to develop a longer-term systemic programme of activities to address the approved 'vision' (no matter how wide or narrow the social base may be), it is necessary to secure sustained broad-based financial support for the work of the intermediaries. Although some intermediaries, like NGOs or multi-lateral agencies, fund their own involvement in transitions, most will need to be funded in some way for their skills and time. Consultants will normally be the most expensive, but often have the skills to demonstrate future value. If key players lack the financial resources to secure the services of the intermediary, the result will be ad hoc stop-start funding that will limit the capacity of the intermediary to contribute meaningfully. A secure long-term financial commitment reduces the risk of the priorities of the intermediary being dictated by the reactive chasing of funding.

2. Staff: Implementation requires creating staff posts within the relevant institutions before the benefits of the envisaged changes are fully realized. Funding is needed to provide the stability and resources that will be required for staff to be motivated, trained, and feel rewarded throughout the transition. Without this long-term funding, the basis for an organisational commitment to the full cycle of transition will be compromised.

3. Trust and shared vision: Stability of organisational resources and commitment within the intermediary organisations and the participating city-level and non-local partners then provide the basis for mutual trust. To manage (potential) conflicts between stakeholders, intermediaries must be able to effectively 'plug in' to the networks of partners to enhance capacity from a shared organisational view.

4. Learning: The key to success is the mutual learning that takes place as stakeholders engage with one another to deal with the problems and challenges they face. Often developers, utilities, companies, communities, environmental or social justice NGOs, local governments, and researchers interact in ways that can over time generate new knowledge about what is possible. The adaptability and learning required by the intermediaries, means that they must constantly work at developing and re-developing their knowledge base. In addressing long-term, systemic and strategic issues a wide variety of technical, policy and local forms of knowledge and social interests need to be constantly negotiated and effectively integrated.

5. Networks: Intermediaries often establish 'communication forums' that make it possible to negotiate and effectively integrate the different knowledge sets and priorities associated with multiple sets of social interests. They tend to cultivate a local presence and effective local networks and develop effective relationships with existing socio-technical regimes, national policymakers and potentially social interests at a supranational level as well.

6. Communication: The role described above requires that intermediaries carefully

represent what they do with their variety of different partners, thereby communicating credibility and building trust with partners who in other aspects of their work and business may have competing interests. Symbolic visibility in the local and national media is important as is symbolic exemplification through demonstration and showcasing. This is part of the positioning of the intermediary as distinctive, as 'first mover' and the people to turn to.

These six aspects of building capacity and capability for are all important in embedding the intermediary within a specific urban context and facilitating the development of the resources, relationships, forms of knowledge and communications and, thus, visibility, to be able to demonstrate a credible influence. Addressing these six critical issues facilitates the formation of the type of organisational context necessary for active and effective intermediary intervention in purposive urban socio-technical transitions.

While this report embraces the idea of an 'energetic society' that creates space for intermediaries to facilitate innovations that bubble up from below, not all societies are configured this way. In societies where the state plays a strong economic role using interventionist planning instruments, innovations can be imposed from above, complete with a set of performance requirements. The evidence suggests that both can work – China's eco-blocks, Abu Dhabi's Masdar and Republic of Korea's Songdo emerged in contexts where strong states imposed the requirement to break from mainstream approaches, sometimes by copying innovations pioneered elsewhere.

6.1.7. Consequences: outcome and process

The issue of outcomes acknowledges the importance of intermediary organisations as agents of change. It requires assessing the extent to which the initial vision of urban socio-technical infrastructure transition was achieved over time, with respect to aims, objectives, timings, material and and social change. Having engaged with the different social interests in the process, intermediaries may still be confronted with difficult issues and problems. This might include, for example, controversies such as where a technology development is located, difficulties with funding streams, and lack of political support. How these issues are addressed and who subsequently becomes involved and with what expectations is critical to the process. This broadens the constituency of the process of urban socio-technical infrastructure transitions. A controversial location for technology development, for example, may involve technology developers engaging with local residents, funding difficulties may require dialogue with different funding bodies, or a lack of political support may require discussions with political interests at different levels. Each of these social interests potentially brings different sets of expectations to the process of urban socio-technical transitions.

6.2 Four types of urban change

To assess how initiatives from around the world are contributing to the reconfiguration of cities, infrastructure systems and resource flows 30 case studies are analysed using a fourfold framework: 1) pressures and visions; 2) intermediary organization; 3) responses and outcomes; and 4) consequences. This creates a context in which to bring together the quantitative assessments of material flows (set out in Chapter 2) with the socio-technical contexts of their development. Material from the case studies is illustrated and analysed in the sub-sections below. The full, referenced case studies are presented in the Annex. They are:

1. Auroville, India – restoring ecology and building social unity;
2. Bangalore, India – building green gated communities;
3. Masdar, Abu Dhabi – envisioning a sustainable city in the desert;
4. Songdo, Republic of Korea – constructing a hi-tech eco-city;

5. Treasure Island, San Franciso, USA – developing a mixed-use eco-island;
6. Vauban, Freiburg, Germany – living sustainably in a low energy, low car district;
7. Accra, Ghana – utilising wastewater for urban agriculture;
8. Bangkok, Thailand – investing in public transport;
9. Beijing, China – recycling water with on-site wastewater treatment;
10. Durban, South Africa – closing loops in solid waste management;
11. Kampala, Uganda – re-using organic waste to reduce landfill impact;
12. Karachi, Pakistan – collaborating with the poor to extend sanitation services;
13. Lagos, Nigeria – rapidly implementing a public bus system in Africa;
14. Lilongwe, Malawi – developing waterless sanitation solutions for informal settlements;
15. Medellín, Colombia – building social inclusion with cable cars;
16. Finnish municipalities – pursuing carbon neutrality;
17. Kitakyushu, Japan – collaborating to achieve zero waste;
18. Melbourne, Australia – strategising for a carbon neutral future;
19. Portland, USA – preparing for climate change;
20. San Jose, USA – building a green vision;
21. Singapore – doing more with less water;
22. Totnes, United Kingdom – transitioning towns towards sustainability;
23. Växjö, Sweden –using renewable resources to provide heat and electricity;
24. Buenos Aires, Argentina –growing food locally to feed the city;
25. Cape Town, South Africa – retrofitting low-income housing for energy efficiency;
26. Chennai, India – harnessing rainwater to enhance water supply;
27. Curitiba, Brazil – incentivising citizens to get involved in recycling;
28. Ho Chi Minh City, Vietnam –encouraging cleaner urban environments;
29. Lingköping, Sweden –fuelling public transport with waste; and
30. Seoul, Korea – reintroducing nature to address city problems.

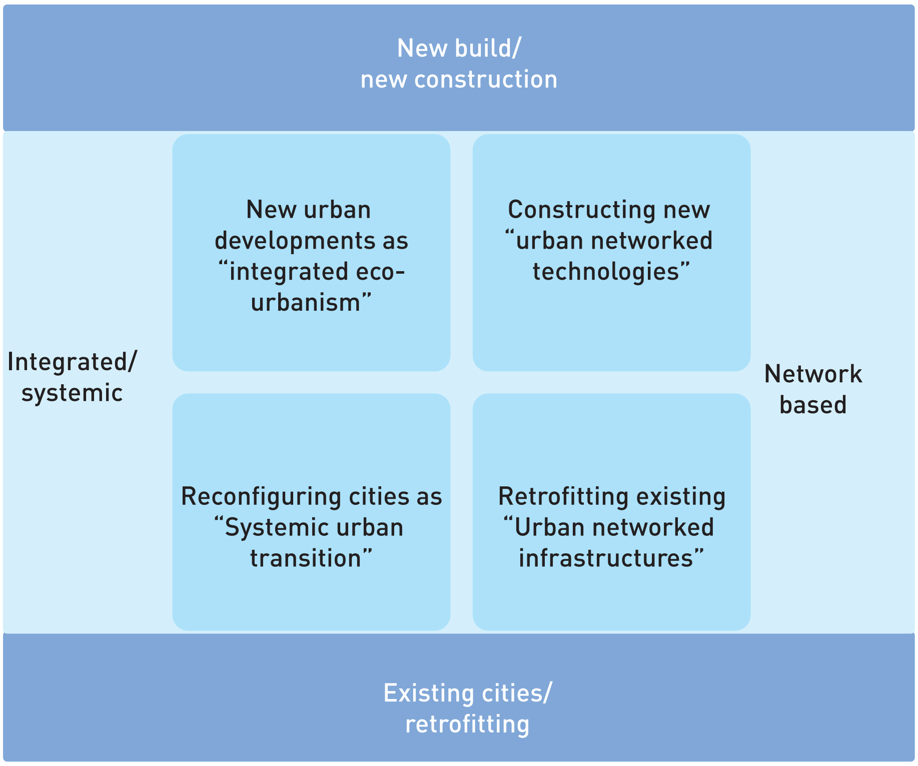
The case studies are used to provide examples of initiatives that are responding to the need to manage resources more sustainably or limit environmental impacts (such as CO2). Anecdotal evidence and some common trends reinforce and illustrate rather than 'prove' the importance of decoupling. The case studies have not been compiled to 'prove' the core argument of this report, which is that more sustainable resource flows will depend on the reconfiguration of infrastructures. Currently, no case study research exists that will prove this. What currently exists, are case studies of infrastructure reconfigurations without a quantitative analysis of the consequences for the socio-metabolic flows through the urban system. Nevertheless, it remains valid to refer to these infrastructure reconfigurations as examples of how stakeholders are responding to the need for more sustainable resource flows through urban systems.

Figure 6.2 organises the 30 case studies into four types of urban networks, on the basis of two dimensions. The first dimension, aligned on the horizontal axis, indicates whether urban responses focus on new construction and new networked infrastructure or are concerned with the 'retrofitting' of existing cities and already installed networked infrastructures. The former is much easier for introducing innovations because it can start with a clean slate; the latter presents more complex problems of vested interests and higher costs. The second dimension, on the horizontal axis, indicates whether urban responses are concerned with the development of integrated (systemic) change or mainly concerned with a particular category of infrastructure network, such as water, or energy or transport.

Network-based solutions focus primarily on either shifts in the socio-technical configuration of existing infrastructures, or on the development of entirely new infrastructures located within the city. These tend to be concerned with narrower

Figure 6.2

Four types of rebundled green urban networks[124]



Source: Hodson & Marvin 2010

technical changes primarily steered and led by infrastructure service providers and developers. The integrative and systemic responses to integrated/systemic developments at the scale of new developments are designed to achieve a more autonomous and self-reliant set of approaches to resource management. Reconfiguring the built fabric and infrastructures by mobilising stakeholders and social interests around wider visions of systemic socio-technical change implies a much more ambitious, challenging and complex process of managed socio-technical and behavioural change, with much more blurry boundaries between different resource flows and social interests that cross multiple scales.

Systemic change within a highly distributed infrastructure system is much more difficult to achieve, whether this involves the installation of new networks in congested cities or the reconfiguration of existing systems. These two dimensions – retrofit or new construction, network or system – create a matrix with four models which can be summarized as follows:

- **'Integrated eco-urbanism'** refers to new (large or small) development (e.g. an eco-island, new town, or cluster development, or eco-village) that takes place normally on a (semi-) greenfields site. The design includes a wide range of different network infrastructures (water, energy, waste, and sanitation) that have been integrated to achieve high-level sustainability goals. Examples of intentional integration span capital intensive elite enclaves like Masdar, Abu Dhabi on one extreme to bottom-up socially more complex grassroots eco-villages on the other, and both can be found in all regions.
- **'Urban networked technologies'** are also about new construction on a (semi-)

greenfields site, but here the focus is on one particular technology rather than an integrated approach. Examples include an ecological approach to water or energy management to deal with supply constraints. Alternatively, the new construction might not refer to a new property development per se, but rather to an entirely new infrastructure. An example is replacing the highway through Seoul with the river it had previously displaced.

- **'Systemic urban transitions'** refers to retrofits of existing urban infrastructures and/or buildings using an integrated network approach where new investments in low- or declining-value environments drive the application of new technologies. This can include the regeneration of central business districts, the conversion of underused industrial zones into new mixed use zones, the conversion of previously low density suburban environments into high-density uses, or even the upgrading of low-income or informal settlements. Examples include the Barking Riverside development along the Thames in London, England, the Honeysuckle Urban Renewal Project in the Australian city of Newcastle, and the redevelopment of Western Harbour in Malmö, Sweden. Systemic urban transitions can also refer to urban movements, such as the Transition Towns Movement, the Low Carbon Cities movement, the movement of towns and neighbourhoods that would like to be fossil fuel free zones, or shackdweller movements in developing country cities.

- **'Urban urban networked infrastructures'** refers to retrofits that focus on a particular technology. This can include interventions like the Bus Rapid Transit (BRT) systems that have become popular in Latin America, investments in rapid urban rail (like in Mumbai, India, and the Johannesburg-Pretoria complex in South Africa), or major new water efficiency infrastructures such as the Catskills development in New York.

Each of these four ideal models has variations developed predominantly by environmental and/or community groups. These usually are outside the more corporate and policy oriented solutions, generally have a less technologically focused emphasis, or tend to be more focused on demand-side management and localised and small scale production technologies. These responses tend to give greater emphasis to social, cultural and behavioural change than technological solutions and a more household or local focus. Examples include the 'transition towns' movement, the 'global eco-village' movement, and some of the more grassroots oriented local government initiatives.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6.3 New urban developments as 'integrated eco-urbanism'

Most of these models aim at *integrated* responses to infrastructure that cut across multiple infrastructure networks – energy, food, water, waste and so on – and that are rebundled together at particular scales in the design of new buildings, neighbourhoods, towns, blocks and cities. They usually focus on new developments, either entirely new Greenfield developments such as an eco-city or eco-town, or new stand-alone developments that are located adjacent to or within existing cities such as an eco-house or eco-neighbourhood. The approach is much more concerned with integration at the scale of the development than with the wider transformation of the existing city or its existing infrastructure networks. These responses have at their core the vision that they can transcend conventional responses to climate or resource constraint because they build ecological security by internally producing their own food, energy and other critical resources, reusing wastes as resources and reducing reliance on external infrastructures. The case studies draw upon the most 'exemplary' illustrations of this new style of urbanism that are claimed by their developers to offer new and replicable models of development.

6.3.1. Objectives and visions

Assessing a range of case studies enables the identification of some common objectives that underpin these initiatives: first, to reduce carbon emissions from new development projects to meet national targets or establish new more ambitious standards; second, to secure energy, water and food resources, and to manage waste flows within the boundaries of a new development; third, to provide a test-bed for the development of new technologies and solutions that can be viewed as exemplary and or replicated in other contexts; and finally, to address a set of wider social issues associated with employment, social justice and quality of life which vary across different urban contexts.

These general objectives manifest themselves in particular ways in relation to different initiatives.

In responding to these objectives across a range of case studies, responses are aiming to solve multiple problems. These include addressing housing shortages and doing so in ways that integrate buildings with strict energy standards, green spaces, dense urban design, public transport and schools as in Vauban, Germany and Treasure Island, USA. Yet often underpinning these developments is a vision of integrated eco-urbanism as developing, commercialising and implementing technologies to address climate change as in Masdar, Abu Dhabi and, conceptually, Songdo, Republic of Korea. In this sense the relationship between economic development and ecological change is critical to the problems being addressed. This can include government-led attempts to address a housing shortage - as in Vauban - or as a response to market demand for enclaves of high quality ecologically-conscious housing as observed in the 'Towards Zero Carbon Development' initiative in Bangalore, India. Thus different initiatives may have goals as different as addressing a housing shortage or creating exclusive housing.

The objectives of integrated eco-urbanism initiatives are often explicit in their visions of new buildings, parkland and green spaces, waterways, transport links and systems and retail development. The claim is that such initiatives can meet a collection of ambitious targets. This is the case in Songdo, Republic of Korea, where 40% of the city is planned as parkland and waterways, with shops, green spaces and access to transport no more than a 12.5 minute walk away for anybody, and that it will be significantly less resource intensive than cities of a similar size. Standards and targets are set in relation to buildings and the flows of energy and water resources. The solutions developed in some cities (such as Masdar, Vauban and Songdo) are sometimes represented as experimental test-beds for new technologies or new life-style solutions that can be replicated elsewhere.

Yet many of these initiatives have been a long time in the making, with, for example, Auroville planned as a settlement of 50,000 people in 1968 and the Vauban quarter of Freiburg planned in 1993. The consistent vision is that integrated eco-urbanism is long-term in orientation. Many of these initiatives, while planned at a particular time and aiming for completion by a particular year (Vauban's goal for completion by 2006) continue to evolve over time. Given the long timescales of these developments, they often get overtaken by wider economic pressures (financial crises and new standards) which may delay them, leading to their being overtaken by even newer innovations. Decoupling is a continuing and evolving process.

6.3.2. How intermediaries are involved

The development of visions for integrated eco-urbanism frequently involves commercial architects, international supranational bodies such as the UN and the EU, national officials and programmes, regional and local authorities, residents, and local groups. The configuration of these interests – or indeed the involvement of all of them – varies with the initiative. Each set of interests comes with its own expectations of what are the main objectives of an initiative, and the dominant interests often change over the long process of development

Narrowly constituted involvement usually sees private interests, developers or commercial architects, adopt a view of integrated eco-urbanism with them as a commercial interest, linking various technological possibilities and the construction of the built environment. The scale of development, which is bigger than individual houses but smaller than a city, means that private interests seek to develop methodologies for bringing different elements, (technologies, buildings, regulations, materials and their costs, benchmarking, maintenance, green consumers), together to test, adapt and re-test in pursuit of market opportunities. This can also result in the development of enclaves that are separate from existing urban and community systems, as in Masdar, Abu Dhabi.

A broader form of response will often have a local or public authority as an important intermediary organisation that not only provides funding but also builds broader networks. For example, the Vauban eco-city development was initiated by the city of Freiberg, Germany, when it bought a former army barracks in 1993 to address a housing shortage. Rather than being driven primarily by a profit motive, the city leaders were motivated by the need to provide housing with a range of accompanying energy, green space and design standards. They built a three-way relationship between public authorities, experts working to provide a set of plans for the development, and public groups or representatives. Utilities that invested in network provision and in public aspects of the infrastructure were supported by local and regional funding.

6.3.3. Responses and outcomes

Integrated eco-urbanism initiatives present new visions of a changed relationship between infrastructure networks, geographic locations and resource flows. These are often intended to be low-carbon, zero-, post- or beyond carbon, and to create greater self-sufficiency, security of resource flows, and economic activity. These concepts are usually the subject of master plans or vision documents with time horizons of a decade or longer. Integrated eco-urbanism is frequently characterised as experimental, as in the case of Bangalore, India, Treasure Island, USA, and Masdar, Abu Dhabi. The bringing together of different goals with plans, technologies, schemes, regulations and buildings is often presented as being a form of laboratory or incubation that supports the development, up-scaling and replicability of developments.

Emblematic projects are a feature of integrated eco-urbanism and are usually seen as attempts to experiment with new technologies, forms of regulation and standards. The Solar Settlement of 50 houses in Vauban for example, demonstrated 'plus energy' houses based on high energy efficiency and the use of large photovoltaic panels that generate more electricity than the residents consume. The city of Auroville recycles 86% of its total generated waste, has 20 community-level sewage treatment facilities experimenting with wastewater treatment methods, is powered by renewable energy from 200 photovoltaic panels, and circulates water using 140 solar water-pumping units and 30 windmills.

Symbolically at least, initiatives frequently seek to limit private car use and to promote public transportation. The controversial issues involved with transport and mobility infrastructure are often addressed through the design of pedestrian-friendly streets, widely accessible public transport, car sharing schemes, and shorter distances between residential areas and local amenities, as in Treasure Island. Vauban has 'parking free' residential streets and a 'car-free living' scheme. These combinations of design, regulations and policies also include the development of new lifestyles and community organising (see also the Seoul and Portland cases for examples of new transport alternatives).

These plans for integrated eco-urbanism present a model for the development of sustainable urban futures. Often these are highly contested, the balance between the more regressive and progressive elements differs, and the ways in which they have come to be seen as exemplary and emblematic is less than clear.

6.3.4. Lessons learned

Formal evaluations of 'integrated eco-urbanism' experiments are scarce, making it difficult to assess their impact on resources. Even so, the cases represented in this report provide some insights into outcomes.

- Many of the integrated eco-developments have faced significant challenges, even cancellations and delays, in their implementation. Where they are being implemented, commercial constraints may reduce the innovative technologies used or existing standards may have been raised in support of greater sustainability.
- At the same time, they provide innovative contexts for the development and potential testing of innovative responses within a protected experimental niche that is concerned with established utilities, social interests and technological practices.
- The protected nature of the eco-development means that the solutions may not be socially robust or they create premium ecological enclaves. The appropriateness of premium green enclaves in contexts where large sections of the population have limited or no access to existing infrastructure threatens to undermine the sustainability of these projects by overlooking the social context. Only a few have had to engage with established communities and socio-technical network technologies.
- The internal relative self-sufficiency of the integrated developments has not been as contested as the issues of how they are connected to the city and highway network and the consequences this has for the transport systems.

6.4 Constructing new 'urban networked infrastructures'

This section examines alternatives to conventional energy, water, waste and transport networks through the construction of new infrastructure systems and the creation of new or restructured resource interdependencies. These developments, particularly in developed world cities, build more resilient resource flows at the scale of the city, under conditions of climate change and resource constraint. The strategic interest in the development of new energy networks at the urban scale and beyond drives district heating systems for the distribution of heat and cooling, and alternative fuels such as hydrogen, biofuels, and other gases. Parallel water systems distribute grey water and recycled water alongside potable water systems. Public transport, pedestrian walkways, cycling networks, and the use of electricity, biofuels and hydrogen in vehicles also reduces energy consumption. Underlying all these responses is the vision to construct new or parallel infrastructures within the city.

6.4.1. Drivers and visions

The drivers that shape the development and implementation of alternative or replacement infrastructure systems are responses to problems with the operation and performance of conventional infrastructures that do not provide sufficient access or quality of service, or even produce negative environmental consequences to local users.

In the case of Accra, Ghana, urban farmers were unable to afford the additional costs placed on water used for irrigation in the context of competing demands for urban water supply. Building on local experience of using water from liquid effluent streams, urban farmers started to informally construct an alternative supply network to the main water network despite the initial absence of official support or formal policy to develop this alternative system.

In contrast, the conventional solid waste management model, shaped by assumptions about the viability of conventional waste management systems, was not a feasible option in the high density, fine-grained informal settlements of Kampala, Uganda. Consequently less than 45% of existing waste was collected and accumulated organic household wastes, causing serious problems in the city's neighbourhoods. In this case, the collection and use of organic waste to produce animal feed significantly reduced the need for conventional solid waste management systems, and created entrepreneurial opportunities for local residents.

In Orangi, Pakistan, inadequate sanitation in low-income areas led to neighbourhood pollution, health problems and building damage. Existing sewage networks only covered some sections of these areas and were in many places degraded to the point of being useless. The government was unable to afford universal service delivery, so a component-sharing model was developed to allow homeowners and government to assist each other in achieving their shared goal of connecting poor households to sewage mains.

In Beijing, China, water supply pressures led to the implementation of new legislation that made it compulsory for all new hotels and public buildings over a certain size to install on-site water treatment systems so that waste water could be re-used for non-potable applications like irrigation and toilet flushing. In Lilongwe, Malawi, the problem of inadequate access to piped water and sanitation was addressed in a novel way with the development and installation of 'Skyloos', which are independent of piped water infrastructure and facilitate the collection and re-use of nutrients from human waste for agriculture. A bus rapid transit (BRT) system was developed in Lagos, Nigeria, in the context of serious problems with the city's transportation network. The existing system was characterized by highly congested roads and highways, very high levels of fuel consumption, poor air quality as a result of engine emissions and unreliable and time consuming transport for the city's residents. The existing inefficient system of infrastructure involved many different stakeholders and social interests, including 100,000 private operators. Consequently a new infrastructure system needed to be fitted into the city to provide a better quality, cheaper, more reliable and less polluting service.

Similarly, planners in Bangkok, Thailand, realised that adding more highways was worsening rather than reducing the city's chronic traffic congestion. This led to the consideration of alternatives to private vehicle ownership that ultimately led to constructing of the Bangkok Mass Transit System. This has had a noticeable impact on the spatial structure of the city, slowing both the pace and scale of suburbanization. While the core areas of Bangkok have always been vibrant, those areas with access to the transit stations have gained greater advantages than others, and new investment in the city centre has been stimulated. The same has been observed in Medellín, Columbia, where a cable car system has helped to connect poor communities living on mountain slopes to the opportunities of the city, and the areas around stations have become loci for urban renewal.

In the Mariannhill landfill site in Durban, South Africa, the focus was on a new approach to landfill management that was less disruptive to neighbours and less damaging to the environment. Communities living near the site objected to waste leakage, poor air quality, and damage to local ecosystems, and consequently, a new approach was developed to address these issues.

In all of these cases existing infrastructure networks were unable to operate effectively for a wide range of economic and social reasons that also had damaging ecological consequences. These drivers produced serious problems but also stimulated innovative responses to new infrastructure networks and dynamics. But who reshapes the infrastructure and what sorts of knowledge and capabilities do they use to make changes in the social-technical organization of new infrastructures?

6.4.2. Intermediaries involved

A common theme across these cases is the ways that new social interests, sometimes external to the conventional system, are involved in shaping the development of new infrastructure options. Are new intermediaries developed to create new infrastructure, or can existing intermediaries with existing responsibilities for the stressed infrastructure reshape the development of new replacement or alternative infrastructure?

The case studies provide examples of new intermediaries that were created specifically to support the development or acceleration of the infrastructure. In the case of Accra, the use of waste water began as an innovation developed by users and has not yet been translated into a formal policy at city level. However, a 15-partner intermediary has been formed, the Accra Working Group on Urban and Peri-urban Agriculture, involving representatives of universities, farmers, and national and urban government representatives through their joint recognition of the potential of water reuse. Initially the intermediary focused on education and training of farmers to reduce the risks of contamination, but more recently shifts have focused on formally recognizing the relevance of the practices, especially the ecological benefits of circular metabolisms, despite the lack of official support.

Similarly, in the Kampala waste project a specialist intermediary was created, called 'Sustainable Neighbourhood in Focus'. The partners involved in this were an international research project, the city council, local universities, civil society organizations and the pilot community of Kasubi-Kawaal. The overall aim was to identify projects that could alleviate poverty and promote ecological resilience.

The intermediary worked with the community through 'learning by doing' over a three-year timeframe to reshape the waste stream. This involved working with 15,000 households enrolled into the project to collect and re-use organic waste.

In other cases, the transition to a new infrastructure system involved an established intermediary with a commitment to existing infrastructure developing a new style of working to create new socio-technical systems. In the case of the BRT in Lagos, the Lagos Metropolitan Area Transport Authority played an important role in partnership with the Lagos state government. Critical to this was an initial feasibility study and the involvement of key overseas partners: workers and employers of bus rapid transit schemes in Latin America. Subsequent funding was provided by the World Bank, Lagos state and the private sector. Stakeholder engagement was critical in building political and community support for the scheme.

The Mariannhill landfill project involved Durban Solid Waste and the local municipality who sought to change the way they developed landfill sites. The main aim was to prevent contamination and to restore the site while reducing greenhouse gas emissions through the capture of methane and the sale of electricity and carbon credits. Working with Enviros, a French development bank, and the South African government, they redesigned the way in which the landfill would operate to provide power, reduce water consumption and protect indigenous vegetation. They also worked with community interests on employment, skills development and education programmes, and the development of a community centre.

One conclusion is that interventions that focus on a particular infrastructure always require an intermediary of some sort, in particular to reduce the social risks of a costly long-term capital investment. However, in under-funded environments, intermediaries play a crucial role in translating social capital into system viability and financial capital.

6.4.3. Responses and outcomes of change

The understanding of the consequences of these schemes is highly variable, based on the effectiveness and efficiency of the processes and how these were monitored and evaluated. In the Accra example, the benefits are not well understood but are estimated to include over 1,000 farmers involved in the production and recycling of water because they believe that the initiative lessens demand for water, reduces chemical usage, and reduces sewer use and contaminated water downstream. State reluctance to institutionalize these activities has made it harder to quantify the consequences.

Waste reduction is well understood in Kampala through the use of an action research method. University evaluation measured the weight, feed yield value, economic benefits and nutrient value. Although motivated by the ideal of 'zero waste', in practice this initiative resulted in levels of waste collected that were 30 to 40 tons per month, with reduced costs of 36% and reduced waste volumes of 40%.

The BRT development in Lagos took only 15 months to complete and was delivered at a much lower cost than premium BRT projects. Passenger numbers and improvements in CO_2 emissions, journey and waiting times are all well understood. The major limitation is that the BRT cannot cope with peaks of demand.

The performance of the Mariannhill landfill site is audited bi-annually, and its gas-to-electricity production is quantified each year. The closed-loop approach avoids environmental contamination by toxic leachate, and the initiative generates power, creates jobs, protects indigenous biodiversity, and saves the municipality the costs of new plants for landscaping public spaces.

6.4.4. Lessons learned

Four key conclusions arise from the case studies on urban networked infrastructures:

1. The Accra project shows the potential fragility of bottom-up, user-driven responses. Despite the creation of an intermediary to develop training and education to reduce food contamination, the practices and solution are not yet officially recognized. Benefits for food security, water savings and reduced demand for wastewater treatment are not well quantified and are difficult to prove conclusively. Continued urbanization and land encroachment are squeezing space for urban farming, and fertile lands are being seen as nothing more than transitional spaces awaiting development. If this project is not continued or is abandoned, then the sewage system may produce harmful wastes that are currently intercepted.

2. The Kampala example is well documented and understood, but despite the community continuing to run it after its official end point, the future of the activity is unclear. While other interested users have learned about it, no mechanism is in place for up-scaling, accelerating and repeating the lessons in other relevant contexts. The re-use of organic waste for animal feed can provide a relevant alternative to conventional solid waste management practices, but it is likely to remain an isolated experiment without further resources to capture and transfer lessons to other areas.

3. The Lagos BRT example shows that existing intermediaries can develop new networked technologies. They were given the capacity necessary to achieve this, and had the required buy-in to pursue an integrated approach that included the reorganization of the bus industry, financing from the private sector and the creation new institutional and regulatory structures. Strong management was instrumental in achieving swift implementation.

4. The Durban case also shows the potential of existing intermediaries to provide financial and technical support, as well as how local communities can be involved to develop local sustainable solutions. However, the wider external clean development mechanism framework and internal financial obligations contributed little.

These case studies demonstrate the potential benefits of unconventional infrastructure projects, and the critical roles and limitations of intermediaries working in a multi-level framework to develop and implement these in a systemic way.

6.5 Reconfiguring cities as 'systemic urban transitions'

In contrast to the development of new networks, cities around the world are embracing systemic responses to the reconfiguration of their intertwined infrastructure systems under the banner of over-arching city objectives like reducing emissions, preparing for more expensive oil or improving sustainability. Such developments represent attempts to implement purposive urban transition in the socio-technical organization of cities and existing infrastructure systems, focusing on the overall outcome rather than a specific intervention. Critically this means mobilizing the social, institutional, political and technological complexity to reshape the existing urban networks.

City reconfigurations are often led by groups of city leaders and decision-makers, researchers, developmental and international agencies. An example is the C40 (funded by the Clinton Foundation), which is working with coalitions of the world's largest and most powerful cities and some of the world's most influential businesses to reduce greenhouse gas emissions. It aims to achieve this by developing common procurement strategies, sharing common emission measurement tools, establishing baselines and tracking reductions, and promoting information exchange and mutual learning among member cities.

Such strategies encourage systemic socio-technical change in the organization of cities in order to prepare for climate change and resource constraint. They are usually underpinned by wider social visions about the type of city that is being constructed and wider forms of engagement with stakeholders about the construction of the vision, although the depth and scope of this may be variable. The cultivation of a strategic orientation for the reconfiguration of socio-technical systems – infrastructure, buildings, and social relations – also requires the purposive, strategic development of new forms of knowledge, capacity and capability to translate these into action.

6.5.1. Pressures and visions

Promoting systemic urban transitions is often undertaken in pursuit of ambitious targets adopted in reaction to city concerns. Many cities have recognised their contribution to greenhouse gas emissions and have set ambitious targets for reducing this at the city scale. For example, Portland, Oregon, USA, has long-term aspirations to reduce the carbon emissions of the city and the wider region by 80% by 2050, the city of Melbourne, Australia, aims to be carbon neutral by 2020 and Finnish municipalities belonging to the Carbon Neutral Municipalities project aim to reduce their emissions by 80% between 2020 and 2030. Some cities have set targets, like Växjö, Sweden's aim for a 55% decrease in carbon emissions per capita by 2015, and a 100% decrease per capita by 2030. While emission reductions have become an important goal, a combination of sustainability goals can also be incorporated into city strategies. Singapore, for example, aims to achieve a 35% improvement in energy efficiency from 2005 levels, a recycling rate of 70% and a reduction in domestic water consumption to 140 litres per person per day by 2030.

In order to achieve these ambitious targets, most of these cities have developed plans to systematically apply new technologies to their existing critical energy, water, waste, transport, and food systems. While most responses focus primarily on the role of technologies, alternatives include localised efforts to undertake social and cultural change in the use of resources that are driven and developed from within communities.

The development of these urban targets is a response to a complex set of ecological and economic pressures that become intertwined against a context of competitive pressures between cities. For example, the transition of the Japanese city Kitakyushu to sustainability was driven by public outcry over excessive pollution of land, air and water by the city's industries, and Singapore faced significant increases in the cost of water when its purchasing agreements with Malaysia expired.


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Melbourne faces serious problems associated with rising temperatures and changing rainfall patterns that could lead to potential drought and flooding. Existing power supplies and food and water sources are vulnerable to local risks and the challenges posed by increasing oil prices. These ecological pressures potentially affect the ability of Melbourne to ensure its continued economic development – particularly maintaining its high levels of international tourism. Melbourne has positioned itself in the international race between cities to be a 'first mover' in the development of low carbon responses which could support the development and implementation of new technologies and the economic and commercial possibilities these can create. These economic drivers and the competitive race are challenges faced by most cities.

Frequently the aims of systemic urban transitions are multiple: to secure economic competitiveness, to develop more efficient and reconfigured resource flows of energy, water, waste, and food; and to address new vulnerabilities by building resilience to the challenges posed by climate change. The response of individual cities usually involves a suite of ambitious targets and technologies to address these multiple issues. By 2006, San Jose's carbon emission figures were still high relative to California's carbon emission reduction targets, and city leaders were growing concerned that it was 'falling behind'. The response was to reduce carbon emissions significantly through the development, commercialisation and implementation of cleaner forms of technology. The 2007 Green Vision for the city was based on 10 goals that had the aim of making the city the "world capital of clean technology innovation and leader of urban sustainability".

Alternatives to these exemplary modes of systemic urban transition are being developed by localisation groups that may question the premise of more growth and an intensification of economic competition between places. Rather they promote plans for a different type of society and economy that requires less dependency on current resources through, for example, the development by Transition Towns of 15-20 year Energy Descent Action Plans (EDAPs) that are locally specific working plans for moving towards a robust, sustainable, energy efficient urban future.

Both dominant and alternative approaches to systemic urban transitions are long-term in their aims and aspirations. For cities this can mean plans and roadmaps that may have 2020 or 2050 as their target. Similarly, the Transition Towns approach is not prescriptive and rigid in its timeframes; rather the expectation is that the development and realisation of an EDAP is long-term and likely to take around 15 years. These plans remain dynamic documents. Melbourne's plan, for example, was published in 2003 and updated in 2008. Other plans are considered as broad statements that are expected to be revised in the light of changing circumstances.

6.5.2. Intermediaries involved

Converting the targets and plans for systemic urban transition into reality is complex, dynamic and takes place over a long period of time. It involves a wide range of institutions, social interests, technologies, policy interventions, experiments, and financial mechanisms configured in many ways. It requires central leadership by city leaders, and the intermediary organisations they mobilise or create to translate the plan into practice.

In undertaking transitions, representatives of cities often seek to lead by example with the opportunities this affords them through the city's property portfolio, vehicles and policy instruments. Further capacity must be developed and engaged to undertake an effective transition, including the role of national governments or their agencies as funders of transition initiatives and as legislators and regulators – usually the setters of standards and codes. It also includes roles for international organisations and networks, such as the C40 League of Cities, and for academics and other public agencies, with private businesses providing contexts for technological development and innovation, the production of green products and the implementation of technologies and services.

Utilities, i.e. the existing providers of energy, water and transport resources, are important interests both in terms of their existing assets and their organisational connections to households and businesses, but also to the extent that as institutions they are adaptable and can (potentially) engage with the city's transition. Yet in many conventional systemic urban transitions, a gap separates the strategic visions prepared by coalitions of city, private, and utility interests from the general public. Even in Transition Towns and localisation movements that have significant, fundamental local deliberation, the connections between this local capacity and formal city, private, and utility interests are often weak and poorly developed.

6.5.3. Responses and outcomes

The possibilities and constraints in systemic urban transition through leading by example can be seen in interventions that have been subject to assessment or evaluation. Melbourne, for example, recorded a 41% reduction in city operation emissions between

1997 and 2008, driven by a mandatory requirement for improved energy performance codes, the implementation of energy efficiency measures in public buildings and lighting, and wider public engagement initiatives such as the Postcode 3000 programme that encourages people to move back to the inner city by providing financial incentives, as well as technical and street-level support, the implementation of a house auditing programme, and the CitySwitch Green Office alliance, which works with commercial building tenants. The use of reclaimed water for irrigation purposes and use of extensive mulching to improve water retention has been widely promoted. A free showerhead exchange initiative reduces the amount of water used by the average person by approximately 13,500 litres each year.

In Portland, recycling and public awareness campaigns have sought to minimise solid waste flows as has a food-scrap collection programme that transforms food waste into compost to enrich the soil in urban farms and gardens. Standards for household and business recycling collection are currently being developed. By 2010, the city had decreased total wastage by 8% from 2008 figures. Substantial investment has also been made in solar energy options for homes, neighbourhoods and businesses with up-front financing provided for purchasing and installation, as well as incentives for conversion to less carbon intensive energy sources and reduction of energy usage in homes. The city generates five MW of renewable electricity from sunlight, and is in the process of doubling this capacity. A 279 kW solar electric system has been installed at city premises, and reductions in energy consumption have saved around US$3.5 million from the city's energy bill. To receive 100% of its electricity from renewable sources, the city is promoting solar energy by supporting power purchase agreements and public-private partnerships. San Jose aims to add 25,000 jobs in the clean tech sector by supporting start-up and existing companies through grant support, permit assistance, networking, and offering city land and buildings for demonstration projects. Energy consumption is being reduced by partnering with residents and organisations to measure energy use and implement efficiency measures.

The Transition Towns movement seeks to integrate communities, resource flows and organisation. Local resilience and community is built through a 12-step, tool-oriented process that engages with a range of community interests. Totnes in the United Kingdom is the oldest transition initiative, and has 10 active groups and 32 transition projects underway. These include a Totnes Renewable Energy Society (TRESOC) that has formed a community-owned company with four energy projects in development: a 4.5 MW wind farm, an aerobic digestion scheme, a biomass boiler, and four potential solar farms with 30-50 kW peak capacity. A Transition Homes Group has set up a trust that aims to provide low-cost housing and neighbourhood infrastructures for water, sanitation and food production, based on ecological principles of metabolic flows. Local, non-toxic materials will be used for construction, and residents will participate in the physical building process, learning useful skills for future developments. The Transition Streets project has so far formed 59 neighbourhood groups of 6-8 households each (50% low-income). These groups are working collectively to implement energy changes (behavioural and technical) to reduce household carbon emissions and energy bills by 2.1 t per year and 600 Great Britain Pounds - £ - per year respectively (US$910[125]). An interim goal of a 40% reduction by 2030 has been set with emissions being reported on annually. The plan will be evaluated every three years and rewritten every ten. The 2010 annual status report indicates that carbon emissions decreased by 15% between 2000 and 2010, resulting in emission levels that were 1% below 1990 levels, despite a 24% increase in population over that period.

The Transition Network has thus far not conducted any formal research on the impact of the programme on local resource use and infrastructure transformations. It is, nevertheless, an interesting example of movement that aims to mobilize citizens directly through vision building coupled to actions that ordinary people can initiate. It consciously avoids making local governments the focus of attention, preferring rather to depict citizens and direct action as the key motors of change.

6.5.4. Lessons learned

Five key conclusions can be drawn from the case studies on systemic urban transitions:

1. The race to lead by example and achieve first mover status needs to be understood in a longer historical context. For example, Portland's aspirations to be a low carbon exemplar can be traced back to 1993 when it was the first US local government to institute policy around anticipated global warming. San Jose has a strong history of high recycling rates, water conservation strategies, energy efficiency and alternative energy programmes dating back to the 1980s. Its embedded capacity is significant in that it is located in Silicon Valley with its culture of technological development, innovation and high levels of venture capital investment.

2. Information is often readily available for citizens and businesses wanting to move towards a low-carbon future. This stimulates more forms of partnership working between different public, private and community interests.

3. The financing of this range of schemes involves a complex and emerging regime of direct investments, grants, subsidies, efforts to attract private finance, new mechanisms to recycle investments, long-term payback mechanisms to upfront costs through envisaged savings, and public authority investments from savings made in their own estates through resources efficiencies and savings.

4. Seeing transition as an opportunity for economic growth could result in further growth that is not decoupled from resource use. Another significant problem is the lack of a consistent and concerted way of measuring savings and sharing the learning that transition processes produce. The wide range of interests that are necessary to make radical transformation in decarbonising energy systems need effective coordination and incentives to engage.

5. The impact of Transition Town initiatives and their networked basis has not yet been quantified. This may be one of its strengths, but makes it difficult for consistent shared monitoring of impacts. A significant issue for localisation movements in the global North is how they engage with disadvantaged communities given the time and resource commitments necessary to participate meaningfully.

6.6 Retrofitting existing 'urban networked infrastructures'

This section discusses interventions that reconfigure particular infrastructure systems that address issues such as water security, energy security, food security or flood resilience, and exploit the potential of smart technologies and pricing systems to reconfigure the use of existing infrastructures. These responses seek to systemically reshape existing infrastructure networks in order to reduce vulnerability, increase self-reliance and develop resilience.

6.6.1. Pressures and visions

General pressures for retrofitting existing urban networked infrastructures relate to specific networks and places. For example, recurring food shortages and economic crises, and in particular a 2001 food crisis, generated initiatives aimed at increasing food production and security in Buenos Aires, Arengentina. The country's ProHuerta initiative aims to improve nutrition among impoverished peri-urban and rural populations by encouraging the production of organic food on a small scale (from home gardens, small farms, schools, institutions, and community organizations). This is a nationwide initiative funded by national government with support from international organisations.

In Chennai, India, an acute water crisis in 2003-2004 created pressures for the development of a more sustainable approach to water management in the city. Following the water crisis, in the neighbourhood of Thiruvanmiyur, in southern Chennai, the community-led *Puduvellam* (meaning 'New Water') initiative restored the defunct historic Marundeeswarar temple tank as a means of recharging groundwater. It also strengthened the essence of democracy by creating the foundations for partnerships between state, civil society and community actors, and across class and caste divides.

Significant population growth and changing economic consumption patterns in recent decades in Curitiba, southern Brazil, have resulted in pressures on the city's landfill due to mounting non-organic waste. Working with poor communities, the Curitiba government developed a low cost but effective waste recycling scheme, loosely translated as 'Garbage that is not Garbage' (Lixo que não é lixo). Similar trends have had an impact on other cities, for example in Hanoi and Ho Chi Minh City in Vietnam.

In Cape Town, South Africa, the government's Reconstruction and Development Programme to house people relocated the poor from shacks in Khayelitsha to subsidised housing in the Kuyasa settlement. Although they provided an improvement in living conditions, the houses were energy inefficient and costly to live in. Meeting the occupants' energy needs via conventional methods was difficult for the City of Cape Town due to financial, ecological and energy supply constraints. The Kuyasa project addressed this by providing low-cost, energy efficient services and insulation to individual low-income households to improve their inhabitants' quality of life in a manner compatible with the City's commitment to reducing reliance on coal-fired electricity. At the same time, the project provided sustainable employment and skills development opportunities for the local community.

In Seoul, Republic of Korea, pressures from urbanisation and the frequent flooding of the polluted Cheonggyecheon River underpinned a project to demolish a highway and restore the river that once ran through the site. Objectives included recovering the flow of the river, reintroducing biodiversity into the area, creating a space where people and nature could interact, rehabilitating significant historical and cultural sites, creating a centre for business and finance, and uplifting the area while restoring the balance of development between north and south Seoul. Problems, however, remain: the river needs to be artificially recharged with water and fish because its concrete form has prevented the required natural ecosystems from emerging.

In Lingköping, Sweden, emissions from diesel buses were causing air pollution from smog and soot. A solution that aligned with local economic priorities, did not require extensive fuelling infrastructure, and aligned with national and interest in renewable fuels was to develop an integrated system to generate biogas from waste (and, where necessary, biomass), and to convert the city's bus fleet to run on this clean-burning fuel.

Many of these initiatives to retrofit existing urban networks were schemes and projects with short and medium-term time frames, for example Seoul's Cheonggyecheon River highway conversion took place between 2003 and 2005. Others were longer-term, such as the Curitiba recycling scheme which started in 1984, and the ProHuerta initiative and Lingköping biogas public transport system which commenced in 1991; both have been implemented in phases.

6.6.2. Intermediaries Involved

Many of the projects that retrofit existing urban infrastructure involve various public officials and agencies, private and business interests and community groups. The leadership of city authorities and the support of national government priorities, funding and schemes provide a locus for bringing together different social and institutional interests, as well as for the generation of project funding.

In the Buenos Aires Metropolitan area, for example, a team of 60 field technicians and 1740 'promoters' have been trained to teach organic food production techniques and act as intermediaries between ProHuerta and the urban gardeners. They also facilitate the distribution of inputs required for food production such as seeds, plant cuttings, chickens, rabbits and tools provided free by ProHuerta. The use of agrochemicals is avoided, and the promoters educate urban gardeners on natural methods of pest and disease control that help them to save money.

The Seoul highway-river conversion project was championed by Seoul's mayor. The planning and execution of the project was a collective effort of the Implementation Centre (part of the Seoul Metropolitan Government), the Citizens' Committee, and the Research Support Group from the Seoul Development Institute (sponsored by the Seoul Metropolitan Government).

An outbreak of cholera in Brazil in 1991 caused the consumption of vegetables in Curitiba to drop sharply and the city's green belt produced a surplus of agricultural products. To convert this problem into an opportunity, a program called 'Green Exchange' (*Câmbio Verde*) bought food products from regional producers at a reasonably low price, and used it as a form of remuneration for recycling collectors at distribution points around the city. Initial tests were a great success, and the Green Exchange has now become a permanent program with over 80 distribution points around the city. Currently, 4 kg of recyclable materials can be traded for one kg of locally cultivated seasonal produce, improving access to healthy food for the poor while tidying up the city.

Community groups often play an active and sometimes informal role as intermediaries. 'Socialisation of solid waste management', the term used in Vietnam, indicates the active participation of community groups, cooperatives and independent collectors in managing urban solid waste systems. Syndicates of individual collectors play a critical role in managing the informal system, with collectors participating on a voluntary basis. To become a syndicate member, a collector submits an application and pays a monthly fee for use of the depot, general administration, and cost recovery that is transferred to the public waste agency. The syndicates expand collection services by engaging with local authorities to determine the areas that require additional services, and by quickly mobilizing members to cover those areas once they gain permission from the authority. The syndicates also handle problems and conflicts that arise in the collection processes. Ho Chi Minh City's 3,000 independent collectors are well suited to collecting waste from the narrow streets where vehicles are unable to drive. By using low-skilled workers instead of expensive machinery to collect waste, this community-based system shows that waste collection can improve urban liveability and sustainability with fewer resources and less impact on the environment.

6.6.3. Responses and outcomes

The sustainability contributions resulting from retrofitting infrastructure networks are both quantitative and qualitative. For example, ProHuerta's approach to food self-sufficiency offered an ideal solution to the 2001 food crisis for the city of Buenos Aires, particularly in the poor areas where the effects were most harshly felt. Local production of fresh fruit and vegetables helped to address issues of malnutrition among the poor whils indirectly providing economic, social and environmental benefits. The Buenos Aires Metropolitan Area (*Área metropolitan de Buenos Aires*, AMBA) ProHuerta technical team now services most of the city, coordinating a network of 1876 promoters consisting mainly of volunteers and teachers. It works with over 200 organizations and institutions to deliver inputs and provide technical support and training, and 323,559 people are now producing food under the program as a network of 50,362 urban gardens and 1048 small farms (providing chickens and rabbits). While the program was initially intended to address the food crisis and malnutrition among the city's poor, bartering and trading at community fairs has provided an additional benefit in the form of strengthened social cohesion in Greater Buenos Aires. Many of these food fairs are held more than once a week, trading mostly fruit and vegetables. The fairs have helped to stimulate local economies and have provided new employment opportunities for the poor. In some cases, municipalities have recognised the value of these fairs and have dedicated municipal land for use as market places.

A conventional approach to the provision of energy services could not have offered the sustainable development benefits of the Kuyasa project in Cape Town. The use of energy-efficient light bulbs, insulated ceilings and solar water heaters has reduced household electricity requirements, and thus the CO_2 emissions and climate impact associated with daily life. Households save on the cost of energy services, while enjoying the health benefits of an insulated home. The community's involvement in the installation and maintenance of this infrasructure has developed skills and provided sustainable employment opportunities to Kuyasa residents, rather than the usual outsourced install-and-go' approach. As a clean development mechanism (CDM) project, income can be derived from the sale of carbon reduction certificates to expand installations and employ local residents to maintain the solar water heaters on a long-term basis. As with other CDM projects, the Kuyusa project is required to produce quarterly monitoring reports by the United Nations Framework Convention on Climate Change.

An assessment of the highway-river conversion in Seoul found an improved quality of life: citizens now have green public spaces where they can interact as equals, exercise, participate in traditional festivals and enjoy cultural events. The project inspired the creation of an informal 'knowledge community' to discuss issues relating to the Cheonggyecheon River and recommend solutions. The public now has access to valuable educational resources through renewed contact with nature, restored historical sites, and the Cheonggyecheon Museum. Ecological sustainability has also improved, although there are reports of system failures with respect to the re-creation of a viable natural eco-system that can sustain the fish population and the water quality. Fossil fuel use has been reduced by removing about 170,000 cars from the arterial road system, improving public transport, and creating pleasant pedestrian routes to encourage walking. This has also reduced air and noise pollution in the city; small-particle air pollution in the area has fallen from 74 to 48 micrograms per cubic meter. High city temperatures have decreased by up to 5 degrees Celsius due to reduced traffic, the proximity of cool water, and a 50% increase in average wind speeds following the removal of the highway. The restoration has re-established lost habitats, and increased the number of fish species from 4 to 25, bird species from 6 to 36, and insect species from 15 to 192. The river has also helped to improve Seoul's resilience to climate change as the open river is better able to cope with flooding than buried sewers. Economic benefits can be seen in an increase in the number of businesses and employment density within 1.2 km of the Cheonggyecheon corridor. Property prices have also increased at double the rates found elsewhere in the city. Single-family residential units are now more likely to convert to high-rise residential, commercial-retail, and mixed units that can lead to resource decoupling.

In Linköping, the transition from a fossil-fuel driven public transport system to one powered by biogas has improved more than just air quality in the city. The use of biogas as a fuel results in very few hazardous emissions and greenhouse gases. The biogas from the plant replaces about 5.5 million litres of petrol and diesel each year, decreasing the need to import fossil fuels substantially. Carbon dioxide emissions have been reduced by more than 9,000 tons per year since 2002, lessening the city's contribution to global warming. The production of biogas turns waste products into a valuable resource, reducing the need for environmentally-destructive landfills and waste incinerators, and creating circular rather than linear resource flows through the city. Specifically, the project has cut the volume of waste sent for incineration in Linköping by 3,422 tons annually. The biogas process produces biological fertiliser as a by-product, which is purchased by the farmers' association to replace energy-intensive, fossil-fuel based fertilisers. Made from waste products, these bio-fertiliers cycle nutrients, such as phosphorus, through the economy and return them to nourish farmlands rather than allowing them to accumulate in toxic concentrations at landfills. The project has also contributed positively to the city's economy by including local farmers in the production of biogas and sale of bio-fertilisers to increase their competitiveness and keep financial flows within the local economy.

6.6.4. Lessons learned

Many lessons can be derived from these initiatives both in terms of what worked well and what challenges remain:

1. National funding and long-term programmes are often essential, as demonstrated by the ProHuerta initiative.

2. Local champions often play a critical initiating role. For example, the mayor of Seoul's championing of the Cheonggyecheon River Restoration Project was crucial to the project's success.

3. Innovation can sometimes be built on traditional forms of resource-use efficiency. For example, rainwater harvesting as a low-

technology solution to the 2003-04 water crisis in Chennai restored pre-colonial infrastructure to recharge the city's depleted aquifers.

4. A continuing challenge is balancing project-scale interventions with sustainability when the ecological costs stretch beyond the boundaries of the project. In the Seoul case, critics have questioned the ecological costs of pumping water from a nearby river and groundwater reserves to keep the Cheonggyecheon flowing all year round.

5. Some seemingly-effective innovations can render existing services unsustainable, where, for example, new informal waste collection services can contribute to the unprofitability of existing formal services through collecting 'their' waste and circumventing regulations.

7 Assessing progress toward decoupling in cities

This section reflects on the lessons learned from the case studies regarding the role of cities in decoupling economic growth rates from rates of finite resource use. It considers what progress is being made in a very diverse set of initiatives and experiments operating at a range of different scales and what they can and cannot show about the future role of cities in decoupling.

7.1 Existing research on decoupling in cities, and areas requiring more attention

Generally the role of cities in shaping systemic changes in the organisation of infrastructure and the level of resource flows is not well understood or researched in an interdisciplinary and comparative manner. In particular, as argued in Section 1, studies of urban resource flows using Material Flow Analysis are poorly linked to studies on more socio-technical analyses of the social organisation and urban political dynamics of resource flows. These two sets of issues need to be brought together in a more comparative and systematic manner. At present the many different initiatives, experiments and demonstrations described here have not been subject to formal evaluation of their efficiency and effectiveness. Instead they provide a partial picture with some understanding of how selected initiatives may shape resource flows but in many cases success is asserted and initiatives have assumed emblematic and exemplary status without rigorous evaluation.

Considerable experimentation and demonstration needs to be assessed to define the limits and opportunities for systemically reshaping resource flows. The main gaps for further research include:

- First, to place cities' resources flows in an existing context requires an **understanding of the current status** of material flows, the social and technical organisation of utilities and infrastructures, the pressures and drivers in individual cities, and finally an assessment of the existing or potential socio-technical capability to shape resource flows.

- Second, while the evaluation of specific initiatives needs to be placed in the wider context of their impacts on resource flows, more research is needed on how the existing social relations, institutions and regulations affect the up-scaling of initiatives.

- Third, research **across different experiments** within the same city (as well as comparisons with other cities) in terms of what second-order social learning from experimentation can help inform the development of intermediary capability. This would contribute to the up-scaling of initiatives and help understand how research results can then be used to reshape the organisation and priorities of infrastructure regimes at other levels. This type of research can build understanding of existing systems, the degree of flexibility and autonomy in developing new configurations and the issues involved in up-scaling and accelerating decoupling.

7.2 The scale of the city and how to conceptualise its boundaries

Difficult issues are involved in the boundaries and the scale at which resource flows are considered. Cities have multiple infrastructures and resource flows that have national and international reach. Research to build understanding of these flows can inform policies on how these can be acted upon at the city scale. The differences between approaches that rebundle infrastructures and resource flows at the scale of new buildings or districts can be compared with others that seek to develop a metropolitan vision for a reconfigured infrastructure and its wider relations with global systems. For example, many of the eco-developments are creating relative self-reliance from resource flows at the scale of a new (and often premium) enclave. Many metropolitan initiatives are promoting citywide changes in urban infrastructure in order to develop low carbon or 'sustainable' cities. The diversity of initiatives provides an opportunity to compare the relationships between different scales (at the landscape, regime and niche levels) and the related impacts of decoupling.

Integrated eco-developments that aim to build greater self-reliance also need to retain links to existing infrastructures. So, in the case of a more self-reliant development, who becomes the infrastructure provider of last resort if internal systems fail or break down? What happens to complex wastes that cannot be recycled or reused within a development and what about the wider implication for offsite transport infrastructures? A sustainable city that exports its unsustainability to other locations cannot be considered sustainable from a multi-level perspective. Nor, for that matter, can a city become more sustainable by exporting or marginalising to the peri-urban periphery those who are unable to meet the


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requirements of new service behaviours or infrastructure protocols. Finally, what lessons from self-reliant developments can be applied to the reconfiguration of existing city-wide infrastructures?

7.3 Total material requirements and rebound effects

Material flow analyses of cities should be more widely promoted. The work by Sabine Barles on Paris can be considered the current gold standard for this purpose.[126] This will complement and extend the kind of global comparative work that has been initiated by MIT.[127] As the understanding of urban metabolism grows, it will become possible to shed much greater light on the Total Material Requirements (TMR) of cities, including both direct and indirect flows. This will reveal how dependent cities are on material imported from other localities within and beyond national boundaries, indicating the environmental impact of cities on other localities. Linking the quantitative approach provided by the material flow analysis with the qualitative social science approaches will:

1) Improve the assessment of indirect flows and urban ecological footprints.[128]

2) Make it possible to better define targets for action. For instance, the final energy consumption of Paris has been stable for ten years, while its primary energy consumption continues to increase. This means that reducing urban consumption is as important as improving downstream energy supply.[129] Another example is that of food, where indirect flows are much more important than direct ones.[130]

3) Show that indirect flows can help assess what is possible to achieve within an intra-urban approach and place the city within the broader system of flows and stakeholders that make it possible for the city to function.

Rebound effects are the unintended outcomes of investments that result in more efficient use of resources per capita. Such rebound effects could cause TMR per capita to increase because savings may encourage people to buy more goods and services. For example, shifting commuters from a private vehicle transport model to the use of public transport might reduce TMR per commuter, but making mobility more accessible to the poor would increase the number of commuters, and may ultimately increase overall TMR per capita. This would be a positive developmental outcome in developing country cities where private car systems exclude the poor. But a negative outcome in developed country cities would, for example, be energy savings from green buildings being converted into increased consumption of imported luxury foods. A key mechanism to counteract the rebound effect is to link improvements in efficiency to rising eco-taxes that effectively capture the savings for re-investment in public goods rather than allowing savings to be recycled via malls into increased private consumption (a topic addressed by the Decoupling 2 Report). However, rebound effects might also be less of a problem where real incomes are declining due to recession or inflation, which could itself be driven in part by rising resource prices.

Along the same lines, if imports into cities are derived from localities that are expected to pay for environmental externalities, then the imports could well be underpriced. This is effectively a subsidy of consumption in the destination city, thus reinforcing the rebound effect. This suggests that the rebound effect cannot be resolved without understanding indirect material flows embodied in regional flows between urban, rural and peri-urban regions and global flows created by trade (which is the subject of a forthcoming International Resource Panel Report). Direct and indirect flows need to be addressed at the urban level, and this may require socio-political changes in the relationships between consuming and producing regions in the interests of better resource management.

7.4 Accounting for wider benefits and contextual appropriateness in evaluations of success

The case studies show how a wide range of criteria, including equity, justice, employment, and accessibility, shape the wider social visions and expectations underpinning the initiatives. Contextual features and locally contingent drivers reshape generic landscape pressures and drivers, such as the economic crisis, climate change, and energy security. Analysing how locally based intermediaries re-interpret these pressures and make them relevant in specific local contexts according to particular issues, problems and opportunities is key to understanding the ways in which resource flows become amenable to social intervention even if the overall environmental impacts are relatively modest.

Three issues are central to an understanding of the potential of managed urban transitions. First, resource flows need to be related to local context so that opportunities can be found for reshaping flows that may be driven by other economic, social and local agendas. Second, these opportunities provide test-beds for designing, demonstrating and testing experiments in re-orienting resource flows that produce positive social benefits - despite the sometimes marginal environmental benefits. Third, in the longer term, intermediaries can learn from their experience and involvement in multiple projects about the success of different types of intermediation, and accelerate these to achieve more significant environmental impacts.

7.5 How decoupling in cities can be assessed and accelerated in the future

The case studies have indicated the types of urban framework required to link material flows to a socio-technical understanding of the institutions, producers, users and intermediaries involved in effectively organising resource flows through infrastructure and mobility networks. Central to this is the need to understand the particular urban dynamics of resource flows – the key drivers, the distributional inequalities, different access, tensions and pinch points and ecological consequences of flows. This provides the analytical context in which city leaders can combine an understanding of the relations between projects or sets of experimental projects with an understanding of how existing infrastructure regimes need to be reshaped to overcome outdated approaches that may hamper decoupling.

Accelerating the wider application of decoupling can follow two main pathways. The first is the development of experimental projects that teach lessons that can then be incorporated into the development of further projects. This requires sufficient flexibility within the existing infrastructure regime to accept, even encourage, innovations. For example, the Barking Riverside development within the wider Thames Gateway development in outer London envisages 10,800 new homes with significant sustainability commitments. As one of the largest housing projects in the UK, it is clearly experimental and high impact. While the learning that will be generated from such a project will be important, its replication will require that the wider urban system is managed in a way that allows such developments to take place. Another example is the self-built housing project described in the Malawi case which was allowed by authorities simply because no alternative was available; this ground-breaking experiment could help inform future urban planning when economic conditions improve, if it is allowed to do so.

The second pathway concerns how social learning from niches and experiments can be applied at the urban scale and used to reshape the existing infrastructure regime – often located at other governmental and governance levels – in order to reshape the regime to accelerate the development of additional niches. This requires that city planners and their partners are able to influence regulatory and political regimes at other levels so that the institutional context within which cities operate can be changed. The best examples here come from the energy sector. Bottom-up sustainable urban developments tend to favour micro-generation (solar, wind, biogas) because the material nature of these systems, and the low barriers for entry from a financial perspective, are such that they can be configured as local generation enterprises that are locally controlled and accountable. However, the dominant fossil-fuel based energy regime that is secured by a tight national regulatory framework may prohibit these kinds of local generation enterprises and a feed-in tariff system may not exist to support this kind of enterprise. If such regime restrictions exist, it is unlikely that local and city-level stakeholders have the capacity to change these restrictions. In such circumstances, it is necessary to develop cooperative rather than antagonistic relationships between niche-level agents and regime-level managers.

8 Conclusions and policy recommendations

At a time when the majority of the world's population lives in cities and the bulk of economic activity is concentrated in urban areas, cities must be given priority as the building blocks of a socially inclusive global green economy. Cities are the spatial nodes where the major global and national resource flows connect as resource inputs, stocks and outputs (goods, services and wastes). They also act as both a major market for those in their surrounding wider region who supply the cities with goods and services and as a major threat because cities pollute the environment. Unsurprisingly, as cities change they may affect their rural environs in both negative and positive ways. One possibility is that demand for goods and services supplied by rural areas may decline as intra-urban food production or recycling building wastes increases. Another more positive possibility is that cities might minimize negative environmental impacts. Finally, cities are where ecology meets the energetic society, making them sites of social debate and innovation.

This general conclusion, however, must be translated into strategies and actions that are aimed at minimizing environmental damage (impact decoupling) and maximising the potential of sustainable resource use (resource decoupling). Cities will undoubtedly be fundamentally restructured over the coming decades in response to many of the macro-dynamics discussed in this report, but also to the micro-dynamics of changes in consumption, cultural behaviours and technologies. To translate this into a practical programme, the focus should be on direct and indirect material flows and how urban infrastructures can be reconfigured to significantly improve resource productivity (by a factor of at least five), as well as on radically reorienting resource use by substituting non-renewables with renewable resources.


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Resource substitution, with regard to resources like metals and food, has its limits. Supplies of metals are finite, which means prices will rise over time as deposits are exploited that are of lower and lower quality. Substitutes for steel, for example, might need to be found. Similarly, the key flows of food are not as conditioned by urban infrastructures as are the flows of water, sanitation, solid waste and energy. Rising transport costs and soil degradation might well force cities to adopt food security as a key goal in the event that long-distance supply chains are disrupted. A substitution strategy would involve resuscitating local (peri-) urban food production.


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The rising levels of investment in urban infrastructures provide a unique opportunity to prepare cities for both inclusive economic development and sustainable consumption of natural resources.

Although the case studies do not specifically apply material flow analysis, they do suggest examples of a wide range of alternatives available to the mainstream resource and energy intensive approaches for the design, construction and operation of urban infrastructures. However, further research will be needed to quantify the impact of these alternative infrastructure approaches on actual material flows. Indeed, material flow analysis of cities is still in its infancy. As these studies expand, so will the capacities of the research community to use material flow analysis to set the design parameters for future infrastructure investments.

The wide range of institutional learning and social change dynamic addressed here lead to the following conclusions:

- Decoupling in cities depends on a clear vision of ultimate objectives;
- The vision to guide the transition to sustainable cities must emerge from interactions among city stakeholders, with each city having its own unique characteristics;
- Small-scale innovations in cities have great potential, especially if they offer viable long-term solutions, and generate strategically important research and development that can be applied to many other contexts;
- Cities in developing countries may have an advantage over many cities in developed economies which are now dependent on out-dated technologies. Cities in developing countries may be able to engage in large-scale investments in alternative urban infrastructure technologies to leap frog towards more sustainable solutions rather than wasting valuable resources to implement what must later on be dismantled;
- The infrastructures being built today will affect city-wide resource flows for decades to come, so urban planners should focus on urban resource efficiency informed by long-term sustainability perspectives and not 'business as usual'; and
- Intermediaries, especially major private sector players and universities, play a critical role by helping to learn from innovations and build capacity for managing change at city-wide scales.

Policy-relevant recommendations include:

- Following the example of Brazil and a handful of other countries, and in line with many of the global sustainable city reports cited in Box 1, national governments should adopt National Sustainable Urban Development Policy Frameworks that support the role of cities in national sustainable development strategies. The National and City-Level Policy Frameworks need to make specific reference to urban infrastructure planning that specifically aims to reduce environmental impacts, especially greenhouse gas emissions (impact decoupling), and drastically improve resource efficiency and productivity (resource decoupling). They should align spatial planning guidelines, infrastructure investment strategies, financial capability (for revenue collection, borrowing, capital and operational expenditure), and long-term sustainability goals. Projecting the desired metabolic flows per capita given the economic and ecological context of any given city will provide a clear-cut and understandable framework for assessing progress towards more sustainable resource use.

- The capacity of city-level governments and their partners, such as universities, to collect and process quantitative data about urban metabolic flows need to be enhanced. Adopting a globally standardised methodology will make performance benchmarking possible (e.g. water use per capita across all cities would make it possible for all cities to identify strategic targets for consumption). A good start would be to adopt the highly systematic methodology developed for the city of Paris discussed earlier.

- Government investments in urban infrastructures should be aimed at creating infrastructures that stimulate urban development and prepare cities for a long-term transition to a greener economy, which, by definition, includes a low-carbon, resource-efficient world. This can be achieved by setting specific resource productivity targets for each infrastructure service (e.g. litres of water per unit of GDP, or percentage of passenger trips by public transport).

- Although national and city-level investments in urban infrastructure either exist or are being considered in many countries, greener growth will require including improvements in resource productivity as a key investment criterion. This will typically mean widening the environmental criteria to include both resource and impact decoupling.

- Relevant niche (micro-level) innovations at city level need to be actively supported and networked in order to stimulate knowledge about viable technology alternatives. This will entail procurement criteria that favour innovation, regulatory reforms that open up markets monopolised by existing infrastructure providers, social processes that encourage and stimulate a culture of innovation, funding flows to support networks of innovators, and protective measures that will create space for innovations to mature to a point where they can compete in the open market. Associations, networks and partnerships that pool knowledge, share risk, mobilize support and instigate innovation will be required.

- Intermediaries need to be formally contracted into the urban transition process and they need a relatively stable operating and funding environment. An appropriate balance between accountability and flexibility will be needed: accountability to prevent ruptures between stakeholders and intermediaries, and flexibility to allow intermediaries to test ideas and develop appropriate innovations.

- In developing country cities that stand to benefit from large-scale investments in new urban infrastructures aimed at poverty eradication, investors need to promote sustainability-oriented innovations at the technical, institutional and relational levels. In many ways, these cities have an advantage because they are not locked into the outdated technologies that many developed country cities are seeking to replace, at great cost.

- More efficient use of limited resources, improved management of renewable resources and the re-use of waste in cities can contribute significantly to decoupling rates of resource use from economic growth and promote impact decoupling as well.

- Private sector players can clearly play key roles as both knowledge brokers and investors in order to take to scale proven niche innovations that could be translated into new city-wide sustainable urban infrastructure demonstration projects.

References

1. Hajer, M. (2011) The energetic society: in search of a governance philosophy for a clean economy. The Hague: Netherlands Environmental Assessment Agency, p. 31.

2. Ibid

3. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 10.

4. SERI Global and Friends of the Earth Europe (2009). Overconsumption? Our use of the World's Natural Resources. Vienna/Brussels: SERI Global.

5. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 12.

6. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 4-5.

7. Jackson, T. (2009). *Prosperity without Growth: The Transition to a Sustainable Economy.* United Kingdom: Sustainable Development Commission. 48-49.

8. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 14-15

9. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.

10. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. xiii.

11. Birkeland, J. (2008). *Positive development – from vicious circles to virtuous cycles through built environment design.* London: Earthscan.

12. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 51.

13. Ravetz, J. (2000). *City Region 2020: Integrated Planning for a Sustainable Environment.* London: Earthscan.

14. Girardet, H. (2004). *Cities People Planet – liveable cities for a sustainable world.* United Kingdom: Wiley Academy.

15. Costa, A., Marchettini, N. & Facchini, A. (2004). Developing the urban metabolism approach into a new urban metabolic model. In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III.* United Kingdom: WIT Press. 32.

16. Ravetz, J. (2000). *City Region 2020: Integrated Planning for a Sustainable Environment.* London: Earthscan. 10.

17. Costa, A., Marchettini, N. & Facchini, A. (2004). Developing the urban metabolism approach into a new urban metabolic model. In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III.* United Kingdom: WIT Press. 32.

18. Ravetz, J. (2000). *City Region 2020: Integrated Planning for a Sustainable Environment.* London: Earthscan. 19.

19. Swilling, M., Annecke, E., *Just Transitions : Explorations of Sustainability in and Unfair World.*

20. World Bank. (2010). *Eco^{2}Cities: Ecological Cities as Economic Cities.* Washington, DC: World Bank. 123.

21. World Bank. (2010). *Eco^{2}Cities: Ecological Cities as Economic Cities.* Washington, DC: World Bank. 126.

22. UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. 42.

23. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

24. Boston Consulting Group (2010). Winning in Emerging Market Cities: A Guide to the World's Largest Growth Opportunity. USA: BCG. 5.

25. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

26. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

27. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

28. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

29. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

30. UN (2010). 2009 Revision of World Urbanisation Prospects, NY: UN Population Division.

31. McKinsey Global Institute (2011). Urban world: mapping the economic power of cities. McKinsey & Company. 12.

32. McKinsey Global Institute (2011). Urban world: mapping the economic power of cities. McKinsey & Company.

33. Liu, J., Daily, G., Ehrlich, P. & Luck, G. (2003). Effects of household dynamics on resource consumption and biodiversity. *Nature*, 421. 530-532.

34. McKinsey Global Institute (2011). Urban world: mapping the economic power of cities. McKinsey & Company.

35. van Wyk, L. (2007). The Meaning of Green Buildings and its Relevance to South Africa. Green Buildings Conference: Pretoria, 8-9 November 2007. Also, Green Buildings Chapter of Green Economy Report.

36. Boston Consulting Group (2010). Winning in Emerging Market Cities: A Guide to the World's Largest Growth Opportunity. USA: BCG. 13.

37. McKinsey Global Institute (2011). Urban world: mapping the economic power of cities. McKinsey & Company.

38. Boston Consulting Group (2010). Winning in Emerging Market Cities: A Guide to the World's Largest Growth Opportunity. USA: BCG. 14

39. McKinsey Global Institute (2011). Urban world: mapping the economic power of cities. McKinsey & Company.

40. UN-Habitat (2011). State of the World Cities Report 2010/2011, Bridging the rural divide, Nairobi: UN-Habitat.

41. Joassart-Marcelli, P. and J. Musso (2005). 'Municipal Service Provision Choices within a Metropolitan Area', *Urban Affairs Review* 40(4): 492-519

42. Un-Habitat (2011). Op. cit.

43. Moss, T. (2010). 'Declining towns', speech at *The City is Alive* seminar, City Factory, Hambourg, 6,7 and 8 April (available at: http://www.lafabriquedelacite.com/en/speech/declining-towns).

44. McGee, T.G. (1991). 'The emergence of the desakota regions in Asia: expanding a hypothesis', in N Ginsburg, B Poppel and T G McGee (eds) *The Extended Metropolis*, University of Hawaii Press, Honolulu, 3-25.

45. Ginsburg, N., B Koppel and T McGee (eds) (1991). *The Extended Metropolis: Settlement Transition in Asia*, Hawaii University Press, Honolulu.

46. Simon, D; D McGregor; D Thompson (2006). Contemporary perspectives on the peri-urban zones of cities in developing countries. In D McGregor, D. Simon and D Thompson (eds) *The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*, Earthscan, London, 3-17. Page 7.

47. Armstrong, W. and McGee, T.G. (1985). *Theatres of Accumulation: Studies in Latin American and Asian Urbanisation*, Methuen, London; Villa, Miguel and Jorge Rodriguez (1996) Demographic Trends in Latin America's Metropolises, 1950-1990. in Alan Gilbert (ed) The Mega-City in Latin America, United Nations University Press, Tokyo; Browder, J, J R Bohland and J L Scarpadi (1995) 'Patterns of development on the metropolitan fringe – Urban fringe expansion in Bangkok, Jakarta and Santiago', *Journal of the American planning Association*, 61 (3).

48. Simon *et al* (2006). Op. cit.

49. Briggs, J. and Mwamfupe, D. (2000). 'Peri-urban development in an era of structural adjustment in Africa: the city of Dar es Salaam, Tanzania', *Urban Studies* 37 (4), 797-810.

50. Tacoli, C. (1998). Rural-urban interactions: a guide to the literature, *Environment and Urbanization*, vol 10 (1).

51. Douglass, Michael (1998) "A regional network strategy for reciprocal rural-urban linkages: an agenda for policy research with reference to Indonesia" Third World Planning Review, Vol 20, No 1, pages 1-33.
Frayne, Bruce (2005) Survival of the Poorest: Migration and Food Security in Namibia, in Luc J. A. Mougeot (ed) AGROPOLIS: The Social, Political, and Environmental Dimensions of Urban Agriculture, Earthscan/IDRC, London, 31-50. Downloadable from: http://www.idrc.ca/es/ev-85401-201-1-DO_TOPIC.html [Last accessed 20 August 2007].

52. Allen, A (2007) Rural - Urban Linkages for Poverty Reduction, Report commissioned by IDRC and UN-Habitat for the State of the World's Cities Report 2008: Creating Harmonious Cities.

53. Allen, A (2003), 'Environmental planning and management of the peri-urban interface (PUI). Perspectives on an emerging field', Environment & Urbanization Vol 15, No 1, April, 135–147.
Allen, A (2006) 'Understanding environmental change in the context of rural-urban interactions', in in D McGregor, Simon, D and Thompson, D (eds), The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use, Earthscan, London.

54. Eurostat (2002). *Material use in the European Union 1980-2000. Indicators and Analysis.* Luxembourg: Office for Official Publications of the European Communities.
UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.
Giljum, S., Lutz, C., Jungnitz, A., Bruckner, M. & Hinterberger, F. (2008). Global Dimensions of European Natural Resource use. SERI Working Paper. 7. Vienna: Sustainable Europe Research Institute.
Krausman, F., Schandl, H., Fischer-Kowalski, M. & Eisenmenger, N. (2008). The Global Socio-Metabolic

Transition: Past and Present Metabolic Profiles and their Future Trajectoris. *Journal of Industrial Ecology*, 12:637-656.
Krausmann, F., Gingrich, S., Eisenmenger, K.H., Haberl, H. & Fischer-Kowalski, M. (2009). Growth in Global Materials use, GDP and Population during the 20th Century. *Ecological Economics*, 68(10):2696-2705.
National Research Council of the National Academies (2003). *Materials Count: The Case for Material Flow Analysis*. Washington, D.C.: The National Academies Press.
OECD (2008). *Measuring Material Flows and Resource Productivity: Volume III. Inventory of Country Activities*. Paris: OECD.
Rogich, D., Cassara, A., Wernick, I., Miranda, M. & World Resources Institute (2008). *Material Flows in the United States: A Physical Accounting of the US Industrial Economy*. Washington, D.C.: World Resources Institute.
Russi, D., Gonzalez-Martinez, A.C., Silva-Macher, J.C., Giljum, J.C. & Martinez-Alier, J.l.V., M.C. (2008). Material Flows in Latin America: A Comparative Analysis of Chile, Ecuador, Mexico and Peru (1980-2000). *Journal of Industrial Ecology*, 10:133-147.
Steinberger, J.K., Krausmann, F.P. & Eisenmenger, N. (2010). Global Patterns of Material use: Socioeconomic and Geophysical Analysis. *Ecological Economics*, 69(5):1148-1158.
Weisz, H., Krausmann, F., Amann, C., Eisenmenger, N., Erb, K.H., Hubacek, K. & Fischer-Kowalski, M. (2006). The Physical Economy of the European Union: Cross-Country Comparison and Determinants of Material Consumption. *Ecological Economics*, 58:676-698.

55. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913.
Barles, S. (2010). Society, Energy and Materials: The Contribution of Urban Metabolism Studies to Sustainable Urban Development Issues. *Journal of Environmental Planning and Management*, 53(4):439-455.
Costa, A., Marchettini, N. & Facchini, A. (2004). Developing the Urban Metabolism Approach into a New Urban Metabolic Model. In: N. Marchettini, C. Brebbia, E. Tiezzi and C. Wadhwa. (Ed.).*The Sustainable City III*. United Kingdom: WIT Press.
Fernandez, J. (2007). Resource Consumption of New Urban Construction in China. *Journal of Industrial Ecology*, 11(2):99-115
Kennedy, C., Cuddihy, J. & Engel-Yan, J. (2007). The Changing Metabolism of Cities. *Journal of Industrial Ecology*, 11(2):43-59.
Weisz, H. & Steinberger, J.K. (2010). Reducing Energy and Materials Flows in Cities. *Current Opinion in Environmental Sustainability*, 2:185-192.
Kennedy, C., Cuddihy, J. & Engele-Yan, J. (2007). The ChangingMetabolism of Cities. Journal of Industrial Ecology. 11, 43-59
Saldivar-Sali, A.N.D. (2010) A Global Typology of Cities: Classification Tree Analysis or Urban Resource Consumption. Thesis submitted in partial fulfilment of the requirements of a Master of Science in Building Technology, Department of Architecture, Massachusetts Institute of Technology, USA

56. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913
Brunner, P.H., Daxbeck, H. & Baccini, P. (1994). Industrial Metabolism at the Regional and Local Level: A Case-Study on a Swiss Region. In: R. U. Ayres and U. E. Simonis. (Ed.). *Industrial Metabolism: Restructuring for Sustainable Development*. Tokyo, Paris, New York: United Nations University Press.
Burstrom, F., Brandt, N., Frostell, B. & Mohlander, U. (1998). *Material Flow Accounting and Information for Environmental Policies in the City of Stockholm*. Analysis for action: support for policy towards sustainabilty by material flow accounting: Wuppertal. Wuppertal Institute. 11-12 September 1997. Wuppertal. 136-145.
Daxbeck, H., Lampert, C., Morf, L., Obernostere, R., Rechberger, H., Reiner, I. & Brunner, P.H. (1997). *The Anthropogenic Metabolism of the City of Vienna*. Regional and national material flow accounting: from paradigm to practice: Leiden. Wuppertal Institute. 21-23 January 1997. Wuppertal. 249-254.
FaistEmmenegger, M. & Frischknecht, R. (2003). *Métabolisme du Canton de Genève - Phase 1*. Uster: ESU Service.
Hammer, M., Giljum, S., Luks, F. & Winkler, M. (2006). Die ökologische Nachhaltigkeit regionaler Metabolismen: Materialflussanalysen der Regionen Hamburg, Wien und Leipzig. *Natur Und Kultur*, 7(2):62-78.

57. Crane, W. & Swilling, M. (2008). Environment, Sustainable Resource use and the Cape Town Functional Region - an Overview. *Urban Forum*, 19:263-287.
Guy, S., Marvin, S. & Moss, T. (2001). *Urban Infrastructure in Transition*. London: Earthscan.
Heynen, N., Kaika, M. & Swyngedouw, E. (2006). *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism*. London and New York: Routledge.
Hodson, M. & Marvin, S. (2010). *World Cities and Climate Change: Producing Urban Ecological Security*. Maidenhead, UK: McGraw Hill.
Hodson, M. & Marvin, S. (2009). Urban Ecological Security: A New Urban Paradigm? *International Journal of Urban and Regional Research*, 33(1):193-215
Swilling, M. (2010). Sustainability, Poverty and Municipal Services: The Case of Cape Town, South Africa. *Sustainable Development*, 18:194-201.
Swilling, M. (2010). *Sustaining Cape Town: Imagining a Livable City.* Stellenbosch: Sun Media.

58. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913.

59. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913.

60. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913.

61. Weisz, H. & Steinberger, J.K. (2010). Reducing Energy and Materials Flows in Cities. *Current Opinion in Environmental Sustainability*, 2:185-192.

62. Barles, S. (2009). Urban Metabolism of Paris and its Region. *Journal of Industrial Ecology*, 13(6):898-913

63. Saldivar-Sali, A.N.D. (2010) A Global Typology of Cities: Classification Tree Analysis or Urban Resource Consumption. Thesis submitted in partial fulfilment of the requirements of a Master of Science in Building Technology, Department of Architecture, Massachusetts Institute of Technology, USA.

64. Ibid, pp.36-37. See also Bettencourt, L.M.A., Lobo, J., Helbing, D., Kuhnert, C. & West, G.B. (2007) Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences of the United States of America*, 104:7301.

65. Saldivar-Sali, A.N.D. (2010) A Global Typology of Cities: Classification Tree Analysis or Urban Resource Consumption. Thesis submitted in partial fulfilment of the requirements of a Master of Science in Building Technology, Department of Architecture, Massachusetts Institute of Technology, USA.

66. Fernandez, J. (2007). Resource Consumption of New Urban Construction in China. *Journal of Industrial Ecology*, 11(2):99-115.

67. See for example Doshi, V., Schulman, G. & Gabaldon, D. (2007). Light! Water! Motion!. Strategy and Business, 47:39-53 and Airoldi, M., Biscarini, L. & Saracina, V. (2010). The Global Infrastructure Challenge: Top Priorities for the Public and Private Sectors. Milan: Boston Consulting Group.

68. Doshi, V., Schulman, G. & Gabaldon, D. (2007). Light! Water! Motion!. *Strategy and Business*, 47:39-53.

69. Doshi, V., Schulman, G. & Gabaldon, D. (2007). Light! Water! Motion!. *Strategy and Business*, 47:39-53.

70. Airoldi, M., Biscarini, L. & Saracina, V. (2010). The Global Infrastructure Challenge: Top Priorities for the Public and Private Sectors. Milan: Boston Consulting Group.

71. Doshi, V., Schulman, G. & Gabaldon, D. (2007). Light! Water! Motion!. *Strategy and Business*, 47:39-53.

72. Doshi, V., Schulman, G. & Gabaldon, D. (2007). Light! Water! Motion!. *Strategy and Business*, 47:39-53.

73. United Nations Environment Programme, Green Economy Report (2011)

74. http://g20mexico.org/images/pdfs/disceng.pdf

75. http://g20mexico.org/en/news-room/press-releases/235-communique-meeting-of-finance-ministers-and-central-bank-governors

76. Zhengelis, D. 2012. A strategy for restoring confidence and economic growth through green investment and innovation. London: London School of Economics. Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy. Policy Brief, April 20120 P.18

77. See Ibid.

78. McKinsey *Resource Revolution*

79. Hawken, P. Lovins, A. B. & Lovins, L.H. (1999). *Natural Capitalism: The Next Industrial Revolution*. London: Earthscan.
Van Timmeren, A., Kristinsson, J. & Röling, L. (2004). Existing infrastructures: a restriction for real sustainable development? In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III*. United Kingdom: WIT Press. 11-20.
Codoban, N. & Kennedy, C. (2008). Metabolism of neighbourhoods. *Journal of Urban Planning and Development*, March: 21-31.
Von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. & Stasinopoulos, P. (2009). *Factor Five: Transforming the global economy through 80% improvements in resource productivity*. London: Earthscan.
World Business Council for Sustainable Development (2000). Eco-efficiency – creating more value with less impact. Switzerland: WBCSD.

80. Von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. & Stasinopoulos, P. (2009). *Factor Five: Transforming the global economy through 80% improvements in resource productivity*. London: Earthscan. 24.

81. Bringezu, S. (2002). Construction ecology and metabolism – rematerialisation and dematerialisation. In Kibert, C., Sendzimir, J. & Guy, G. (eds.) Construction ecology: nature as the basis for green buildings. London: Routledge. 199.

82. Alcott, B. (2008). The sufficiency strategy: Would rich-world frugality lower environmental impact? Ecological Economics, 64: 770-786.
UNEP (2011). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.

83. Von Weizsäcker, E., Hargroves, K., Smith, M., Desha, C. & Stasinopoulos, P. (2009). *Factor Five: Transforming the global economy through 80% improvements in resource productivity*. London: Earthscan. 277.

84. Azar, C., J. Holmberg, & S. Karlsson (2002). Decoupling – past trends and prospects for the future, Goeteborg

85. Reid, W. V., H. A. Mooney, A. Cropper, D. Capistrano, S. R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A. K. Duraiappah, R. Hassan, R. Kasperson, R. Leemans, R. M. May, A. J. McMichael, P. Pingali, C. Samper, R. Scholes, R. T. Watson, A. H. Zakri, Z. Shidong, N. J. Ash, E. Bennett, P. Kumar, M. J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell, and M. B. Zurek (2005).Millennium ecosystem assessment synthesis report. USA: Island Press.

86. The Economics of Ecosystems and Biodiversity (TEEB). (2011). *Manual for Cities: Ecosystem Services in Urban Management.*

87. Birkeland, J. (2008). *Positive development – from vicious circles to virtuous cycles through built environment design*. London: Earthscan.

88. Heal, G. (2004). Valuing Ecosystem Services: Toward Better Environmental Decision Making. National Academy Study, Columbia University School of Business.

89. Todd, J. & Josephson, B. (1996). The design of living technologies for waste treatment. *Ecological Engineering*, 6:109-136.

90. *The Biomimicry Institute, monthly newsletter, June 2010, section by Janine Benyus, Tim McGee, and Sherry Ritter*

91. *Janine Benyus, Defining the meme, 2009*

92. Costa, A., Marchettini, N. &Facchini, A. (2004). Developing the urban metabolism approach into a new urban metabolic model. In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III*. United Kingdom: WIT Press.
Girardet, H. (2004). *Cities People Planet – liveable cities for a sustainable world.* United Kingdom: Wiley Academy.
Ravetz, J. (2000). *City Region 2020: Integrated Planning for a Sustainable Environment.* London: Earthscan.

93. Girardet, H. (2004). *Cities People Planet – liveable cities for a sustainable world.* United Kingdom: Wiley Academy.

94. Girardet, H. (2004). *Cities People Planet – liveable cities for a sustainable world.* United Kingdom: Wiley Academy.
Costa, A., Marchettini, N. & Facchini, A. (2004). Developing the urban metabolism approach into a new urban metabolic model. In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III.* United Kingdom: WIT Press.

Van Timmeren, A., Kristinsson, J. & Röling, L. (2004). Existing infrastructures: a restriction for real sustainable development? In Marchettini, N., Brebbia, C., Tiezzi, E. & Wadhwa, C. *The Sustainable City III.* United Kingdom: WIT Press. 11-20.
Hodson, M. & Marvin, S. (2009). 'Urban ecological security': a new urban paradigm? *International Journal of Urban and Regional Research*, 33(1):193-215.

95. Ravetz, J. (2000). *City Region 2020: Integrated Planning for a Sustainable Environment*. London: Earthscan. 10.

96. Hodson, M. & Marvin, S. (2009). 'Urban ecological security': a new urban paradigm? *International Journal of Urban and Regional Research*, 33(1):193-215.

97. McDonough, W. & Braungart, M. (2002) *Cradle to Cradle – Remaking the way we make things*. North Point Press, New York.

98. *Biomimicry 101, Jeremy Faludi, Worldchanging.com, 13 October 2005.*

99. *Janine Benyus, HOK/Biomimicry Guild Partnership, 2010.*

100. Hodson, M. and Marvin, S. (2010). Can cities shape socio-technical transitions and how would we know if they were'? Research Policy, 39:.4: 477-485. These arguments are developed further in a special edition of Research Policy (2010) edited by Smith, Grin and Voss).

101. Hajer, M. (2011) The energetic society: in search of a governance philosophy for a clean economy. The Hague: Netherlands Environmental Assessment Agency, p.9.

102. Hajer, M. (2011) The energetic society: in search of a governance philosophy for a clean economy. The Hague: Netherlands Environmental Assessment Agency, p. 10.

103. Hajer, M. (2011) The energetic society: in search of a governance philosophy for a clean economy. The Hague: Netherlands Environmental Assessment Agency, p. 29.

104. Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. Research Policy, 31: 1257-74. Geels, F. (2002) Towards sociotechnical scenarios and reflexive anticipation: using patterns and regularities in technology dynamics'. In: K. Sørensen and R. Williams, R. (eds.). Shaping technology, guiding policy: concepts, spaces and tools, Edward Elgar, Cheltenham. 359-87.

105. Geels, F. (2002). Towards sociotechnical scenarios and reflexive anticipation: using patterns and regularities in technology dynamics'. In: K. Sørensen and R. Williams, R. (eds.). Shaping technology, guiding policy: concepts, spaces and tools, Edward Elgar, Cheltenham. p.369.

106. Geels, F. & Schot, J.(2007). Typology of Socio-technical Transition Pathways.Research Policy, 36(3): 399-417.

107. Geels, F. & Schot, J.(2007). Typology of Socio-technical Transition Pathways.Research Policy, 36(3):404.

108. Geels, F. & Schot, J.(2007). Typology of Socio-technical Transition Pathways.Research Policy, 36(3): 399-417.

109. Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. Research Policy, 31.p.1258.

110. Smith, A. Stirling, A. and Berkhout, F.(2005). The Governance of Sustainable Socio-technical Transitions. Research Policy, 34(10): 1491-1510.Berkhout, F. Smith, A. and Stirling, A. (2003). Socio-technological regimes and transition contexts. Working Paper Series. SPRU, University of Sussex.

111. Hoogma, R. Kemp, R. Schot, J. and Truffer, B. (eds.) (2002). Experimenting for sustainable transport: the approach of strategic niche management. Spon Press, London.

112. Geels, F. (2002). Towards sociotechnical scenarios and reflexive anticipation: using patterns and regularities in technology dynamics'. In: K. Sørensen and R. Williams, R. (eds.). Shaping technology, guiding policy: concepts, spaces and tools, Edward Elgar, Cheltenham. p.369.

113. Smith, A. Stirling, A. and Berkhout, F. (2005). The Governance of Sustainable Socio-technical Transitions. Research Policy, 34(10): 1501.

114. Derived from Smith, A. Stirling, A. and Berkhout, F. (2005). The Governance of Sustainable Socio-technical Transitions.Research Policy, 34(10): 1502.

115. Hoogma, R. Kemp, R. Schot, J. and Truffer, B. (eds.) (2002). Experimenting for sustainable transport: the approach of strategic niche management. Spon Press, London.
Verbong, G. and Geels, F. (2007). The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960–2004). Energy Policy, 35(2): 1025-1037.
Van der Brugge, R. and Rotmans, J. (2007). Towards Transition Management of European Water Resources, Water Resources Management, 21(1): 249-267.
Geels, F. (2005). Co-Evolution of Technology and Society: The Transition in Water Supply and Personal Hygiene in the Netherlands (1850-1930) - a Case Study in Multi-Level Perspective. Technology in Society 27(3): 363-397.
Green, K. and Foster, C. (2005). Give Peas a Chance: Transformations in Food Consumption and Production Systems. Technological Forecasting and Social Change, 72: 663-679.
Elzen, B. Geels, F. and Green, K. (eds.) (2004) System innovation and the transition to sustainability: theory, evidence and policy. Cheltenham, Edward Elgar.
Voß, J-P. Bauknecht, D. and Kemp, R. (eds.)(2006). Reflexive Governance for Sustainable Development. Edward Elgar, Cheltenham.

116. Hodson, M. and Marvin, S.(2009). Cities Mediating Technological Transitions: Understanding Visions, Intermediation and Consequences. Technology Analysis and Strategic Management, 21(4): 515-34.

117. Bache, I. and Flinders, M. (2004). Multi-level Governance. Oxford University Press, Oxford.

118. Brenner, N.(2004). New State Spaces: Urban Governance and the Rescaling of Statehood. Oxford University Press, New York.

119. Kemp, R. and Loorbach, D. (2005). Dutch policies to manage the transition to sustainable energy. In: F. Beckenbach, U. Hampicke and C. Leipertet (eds.) Jahrbuch ökologische Ökonomik: Innovationen und Transformation. Band 4, Metropolis, Marburg. Rotmans, J. Kemp, R. and van Asselt, M. (2001). More evolution than revolution. Foresight 3(1): 1-17.

120. Russell, S. and Williams, R. (2002). Social Shaping of Technology: Frameworks, Findings and Implications for Policy... In: K. Sørensen and R. Williams, R. (eds.). Shaping

technology, guiding policy: concepts, spaces and tools, Edward Elgar, Cheltenham: 37-132

121. Hodson, M. (2008). Old Industrial Regions, Technology and Innovation: Tensions of Obduracy and Transformation. Environment and Planning A, 40(5): 1057-1075.

122. Van Lente, H. Hekkert, M. Smits, R. and van Waveren, B.(2003).Roles of systemic intermediaries in transition processes. International Journal of Innovation Management, 7(3): 247-279.

123. Hodson, M. and Marvin, S. (2009). Cities Mediating Technological Transitions: Understanding Visions, Intermediation and Consequences. Technology Analysis and Strategic Management 21(4): 515-34. Hodson, M. and Marvin, S.(2009) Identification of intermediary practices across countries for assessing piloting. Report for Changing Behaviour Project, Seventh Framework Programme, European Commission.

124. Derived from Hodson, M. and Marvin, S. (2010). World Cities and Climate Change. Berkshire, Open University Press/ McGraw-Hill: 87.

125. Based on the United Nations Exchange rate as at 4th March 2013 (rate of 1.52)

126. Barles, S. (2009). Urban Metabolism of Paris and its Region. Journal of Industrial Ecology, 13(6):898-913

127. Saldivar-Sali, A.N.D. (2010) A Global Typology of Cities: Classification Tree Analysis or Urban Resource Consumption. Thesis submitted in partial fulfilment of the requirements of a Master of Science in Building Technology, Department of Architecture, Massachusetts Institute of Technology, USA.

128. Billen, G., Garnier, J. & Barles, S. (2012). History of the urban environmental imprint. Forthcoming in Regional Environmental Change.

129. Kim, E & Barles, S. (2011). The energy consumption of Paris and its supply areas from the eighteenth century to the present. Regional Environmental Change. 1-16.

130. Chatzimpiros, P. & Barles, S. (2012). Nitrogen food-print: N use and N cascade from livestock systems in relation to pork, beef and milk supply to Paris. Biogeosciences Discuss, (9)1971-2004.

About the International Resource Panel

The International Resource Panel (IRP) was established to provide independent, coherent and authoritative scientific assessments on the use of natural resources and its environmental impacts over the full life cycle and contribute to a better understanding of how to decouple economic growth from environmental degradation. Benefiting from the broad support of governments and scientific communities, the Panel is constituted of eminent scientists and experts from all parts of the world, bringing their multidisciplinary expertise to address resource management issues. The information contained in the International Resource Panel's reports is intended to be evidence based and policy relevant, informing policy framing and development and supporting evaluation and monitoring of policy effectiveness. The Secretariat is hosted by the United Nations Environment Programme (UNEP).

Since the International Resource Panel's launch in 2007, six of its assessments have been published. This first series of reports covered biofuels, priority economic sectors and materials for sustainable resource management, metals stocks in society and their rates of recycling, water accounting, and finally the unsatisfactory state of untapped potential for decoupling resource use and related environmental impacts from economic growth.

The assessments of the IRP to date demonstrate the numerous opportunities for governments and businesses to work together to create and implement policies to encourage sustainable resource management, including through better planning, more investment, technological innovation and strategic incentives.

Following its establishment the Panel first devoted much of its research to issues related to the use, stocks and scarcities of individual resources, as well as to the development and application of the perspective of 'decoupling' economic growth from natural resource use and environmental degradation. Building upon this knowledge base, the Panel has now begun to examine systematic approaches to resource use. While technological innovation and efficiency are important they are not sufficient to achieve the required decoupling between economic growth, resource use and emissions. In many cases, efficiency improvements will need to go hand in hand with institutional innovation in activities that have high resource use and emissions. These include the direct and indirect (or embedded) impacts of trade on natural resource use and flows, and the city as a societal 'node' in which much of the current unsustainable usage of natural resources is socially and institutionally embedded. The sustainable management of land and its related resource nexus considerations, land potential and soil quality are also the foci of upcoming reports. In a similar vein it has become apparent that the resource use and requirements of the global food consumption call for a better understanding of the food system as a whole, and in particular its role as a node for resources such as water, land, and biotic resources on the one hand and the varied range of social practices that drive the consumption of food on the other. The years to come will therefore focus on and further deepen these work streams.

About the Cities Working Group

The International Resource Panel (IRP) has as its main mission to provide independent, coherent and authoritative scientific assessments of policy relevance on the sustainable use of resources and their environmental impacts over the full life cycle, and to contribute to a better understanding of how to "decouple" economic growth from environmental degradation.

The Panel's first assessment on "Decoupling" clearly demonstrated that "absolute decoupling" is possible. Innovation and technology development, in principle, could produce 80% reductions in resource and emission intensity in some crucial activities within the housing, food and transport sector. Of course, investing in resource efficiency is necessary but not sufficient for sustainable natural resource use. Because of the scale of the challenge, resource efficiency needs to be complemented by systems sustainability–oriented innovation.

Cities are home to a majority of the world's population, accounting for an estimated 60-80 per cent of global energy consumption, 75 per cent of carbon emissions, 75 per cent of the world's natural resources, and 80% of global GDP. The concentration of resource use and its environment impact is expected to further intensify as urbanization process proceeds. It is clear that many of those opportunities for decoupling are to be found within cities, both retrofitting existing cities and building new ones. This was therefore naturally a key issue for the IRP to explore in more depth.

In late 2010, the Panel established the Cities Working Group with Professor Mark Swilling as the Working Group Coordinator. Members of the International Resource Panel who have also participated in the Cities Working Group include Maarten Hajer, who also takes a leadership role, Walter Pengue and Lea Kauppi.

This first report from the Working Group explores how infrastructure directs material flows and therefore resource use, productivity and efficiency in an urban context. It makes the case for examining cities from a material flow perspective, while also placing the city within the broader system of flows that make it possible for it to function. It also highlights the way that the design, construction and operation of infrastructures create a socio-technical environment that shapes the way of life of citizens and how they procure, use and dispose of the resources they require. The Working Group on Cities will continue to explore the theme of resource use and material flows within an urban context.

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- sustainable consumption and production,
- the efficient use of renewable energy,
- adequate management of chemicals,
- the integration of environmental costs in development policies.

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

- The International Environmental Technology Centre – IETC (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- Sustainable Consumption and Production (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- Energy (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

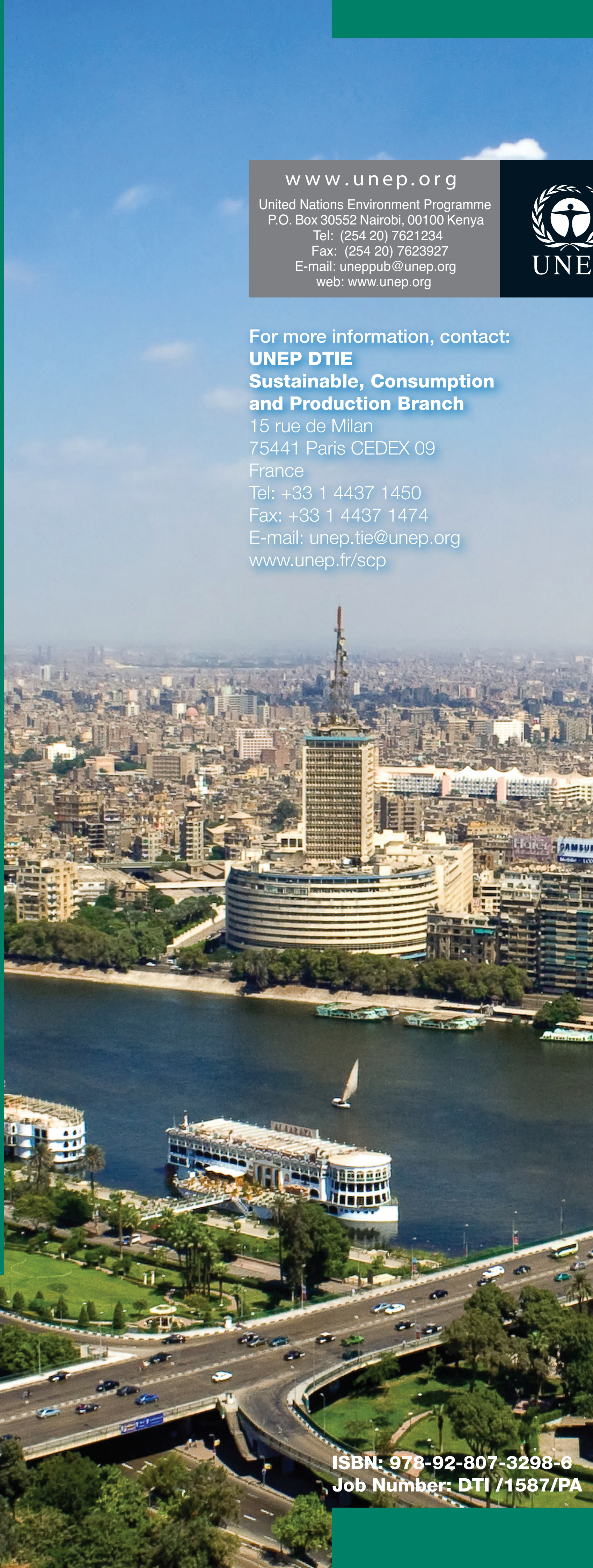
For more information, see www.unep.org/dtie/

Building upon previous work of the International Resource Panel on Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, this report examines the potential for decoupling at the city level. While the majority of the world's population now live in cities and cities are where most resource consumption takes place, both the pressures and potentials to find ways to reconcile economic growth, wellbeing and the sustainable use of natural resources will therefore be greatest in cities.

Analysing the role of cities as spatial nodes where the major resource flows connect as goods, services and wastes, the report's focus is how infrastructure directs material flows and therefore resource use, productivity and efficiency in an urban context. It makes the case for examining cities from a material flow perspective, while also placing the city within the broader system of flows that make it possible for it to function.

The report also highlights the way that the design, construction and operation of energy, waste, water, sanitation and transport infrastructures create a socio-technical environment that shapes the "way of life" of citizens and how they procure, use and dispose of the resources they require. Its approach is innovative in that it frames infrastructure networks as socio-technical systems, examining pressures for change within cities that go beyond technical considerations. The importance of intermediaries as the dominant agents for change is emphasized, as well as the fact that social processes and dynamics need to be understood and integrated into any assessment of urban infrastructure interventions and the reconfiguration of resource flows.

A set of 30 case studies provide examples of innovative approaches to sustainable infrastructure change across a broad range of urban contexts that could inspire leaders of other cities to embrace similar creative solutions. Of course, innovations in and of themselves do not suffice if they are not integrated into larger strategic visions for the city, and as each city is unique, interventions need to be tailored to the set of challenges and opportunities present in each case.



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