UNEP

International Resource Panel

CITY-LEVEL DECOUPLING

Urban resource flows and the governance of Infrastructure transitions

Acknowledgements

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International Resource Panel

Summary for Policy Makers

CITY-LEVEL DECOUPLING

Urban resource flows and the governance of infrastructure transitions

produced by the
International Resource Panel.

This document highlights key findings from the report of the International Resource Panel *City-Level Decoupling: Urban resource flows and the governance of infrastructure transitions*. It should be read in conjunction with the full report, which contains full references and additional assessments. An annex to the report also presents a series of case studies that support its findings, providing 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.

Key authors of this Report are:
Mark Swilling, Blake Robinson, Simon Marvin and Mike Hodson

Preface

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. Its 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 achievable. 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, available as an annex to the report, 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 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.

Dr. Ernst Ulrich von Weizsacker
Emmendingen, Germany

Dr. Ashok Khoslar
New Delhi, India

Co-Chairs, International Resource Panel

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

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
Under-Secretary-General and
Executive Director, United Nations
Human Settlements Programme
(UN-Habitat)

Cities as the building

Introduction and overview

blocks for sustainable development

Global economic production and consumption is now concentrated in cities, where some 80% of global GDP is produced on just 2% of the world's land surface.

By 2007 the majority of the world's population of 7 billion lived in urban settlements, consuming approximately 75% of global energy and material flows.

Global economic production and consumption is now concentrated in cities, where some 80% of global GDP is produced on just 2% of the world's land surface, although drawing on resources from beyond the city, within the country and abroad. Cities have been steadily growing over the past 150 years, and by 2007 the majority of the world's population of 7 billion lived in urban settlements, consuming approximately 75% of global energy and material flows. 4 billion urban dwellers are projected to be added to developing world cities between 1950 and 2030, in what might be considered a "second wave of urbanization".[1] Meanwhile, the urban slum population in developing countries grew by 26% from 1990 to 2010, reaching an estimated 830 million people,[2] demonstrating the need to incorporate equity as a foundation for sustainable infrastructures.

Most of the resource flows that support cities are finite, so continuing global economic development will depend on decoupling growth from escalating resource use (Figure 1). This decoupling will require innovation for more efficient management of resource flows to replace traditional approaches to urban development that have implicitly assumed a never-ending supply of resources. The infrastructures that provide cities with transportation, information, sewerage, water, and energy distribution will determine how resources flow through urban systems. The design, construction and operation of infrastructures also shape the "way of life" of citizens and how they procure, use and dispose of the resources they require. City-level infrastructures are therefore key to increased efforts to promote resource efficiency and decoupling at the city level, as well as well-being and access to services of their citizens.

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

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

Cities as the building blocks for sustainable development

In promoting, planning and designing more efficient urban infrastructures, the following approaches should be taken into account:

- Considering infrastructure networks as "socio-technical systems", taking into account human components in addition to the usual focus on the physical construction of infrastructure;
- Examining "urban metabolism", promoting circular flows of resources rather than the traditional input-output models;
- Reducing consumption of finite resources to meet human needs by harnessing the benefits provided by natural systems, otherwise known as "ecosystem services";
- Applying "material flow analysis" that links industrial ecology and urban political economy;
- Recognising the importance of "multi-scale perspectives" when defining urban needs for sustainable resource flows.

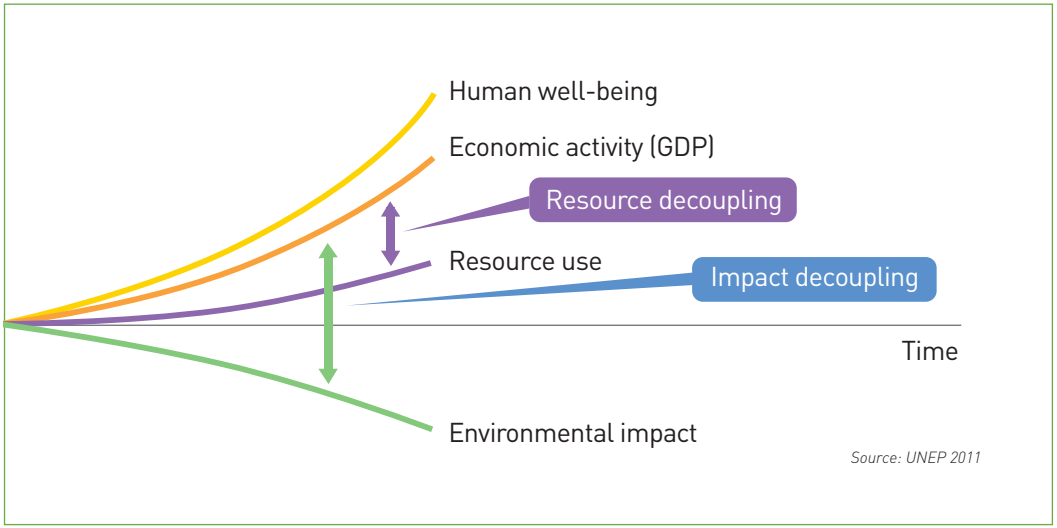
The market and social demand for sustainable and efficient new infrastructures presents an outstanding investment opportunity that can help support economic recovery in many countries. Opportunities exist to foster economic growth without a similar increase in the rate of resource consumption (resource decoupling) and to support the development of urban infrastructure that reduces environmental impacts (impact decoupling). These transitions need to be led by visions for future cities that include all relevant stakeholders and fully address poverty challenges and the need for greater equity. The critical role of intermediaries must also not be underestimated, and in building visions for their cities, policy-makers should enlist support from intermediary organizations that can help mediate among these stakeholders and produce an energised creative society that supports the many initiatives seeking to address the problems posed by unsustainable resource use and environmental degradation in cities. Above all, the innovative forms of infrastructure based on the principles described here can deliver benefits to all, especially in the rapidly growing cities of the developing world. It is essential that these cities avoid locking their populations into obsolete technologies that developed countries are now seeking to replace, often at great cost.

In the rapidly growing cities of the developing world it is essential to avoid locking populations into obsolete technologies that developed countries are now seeking to replace, often at great cost.

Opportunities exist to foster economic growth without a similar increase in the rate of resource consumption.

Figure 1: Two aspects of decoupling[3]

"Decoupling" describes breaking the link between economic activity and the depletion of finite resources and degradation of environments. Two modes of decoupling are resource decoupling that reduces the rate at which primary resources are used per unit of economic output, and impact decoupling that increases economic activity while decreasing negative environmental impacts.



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

Considerations to support sustainable cities

Cities as socio-technical systems

Infrastructure networks must be considered as socio-technical systems, and the social impacts of sustainable infrastructure must be considered.

Social processes and dynamics need to be integrated into any effort to improve the efficiency of resource flows through urban infrastructures. Infrastructure networks must be considered as socio-technical systems, and the social impacts of sustainable infrastructure must be considered, as well as equity issues that will contribute to public well-being as well as ensure broad public support for innovation in decoupling. The social dimension can contribute in many ways because factors such as equity, justice, employment, and accessibility influence the wider social visions and expectations underpinning the initiatives for decoupling. These drivers can also reshape broader pressures, such as global trade, climate change, and energy security, to make them relevant to specific infrastructures and thereby improve the ways in which resource flows become amenable to social intervention.

Innovation can be stimulated by regarding cities as living organisms, with the continuous flow of inputs and outputs as their "metabolism", i.e. complex networks of interlocked infrastructures that bring resources into cities, use the resources to generate wealth and well-being, and dispose of the wastes that are generated by consumption. A typical modern city has a linear metabolism, extracting resources from beyond its boundaries, using them within its boundaries to support urban activities, then depositing the resulting wastes back onto the external environment. Natural ecosystems, by contrast, have a circular metabolism that produces no waste and survives on its immediate environment, though receiving its energy from the sun and its water from regional climate systems. Forms of more circular, location-specific urban metabolism are increasingly recognized as necessary if cities are to survive a future of resource limitations and climate uncertainty.

Including ecosystem services into future visions of the city can increase the options for resource decoupling. Nature provides "ecosystem services" through processes such as "bio-utilisation" (using parts of ecosystems or organisms as raw materials), "bio-assistance" (the domestication of organisms, from herding sheep to using

Cities as socio-technical systems

The current rapid growth of cities creates new opportunities for reconfiguring urban infrastructures through applying material flow analysis to the assessment of stocks and flows.

nature-based renewable resources such as earthworms for composting), and "biomimicry" (learning from and then emulating nature's genius to solve design challenges and create more sustainable designs). Maintaining functioning ecosystems can be a cost-effective way to meet human needs over the long term, and in some cases is the only way to provide irreplaceable ecosystem services (for example water supplies from rivers or aquifers essential to cities).

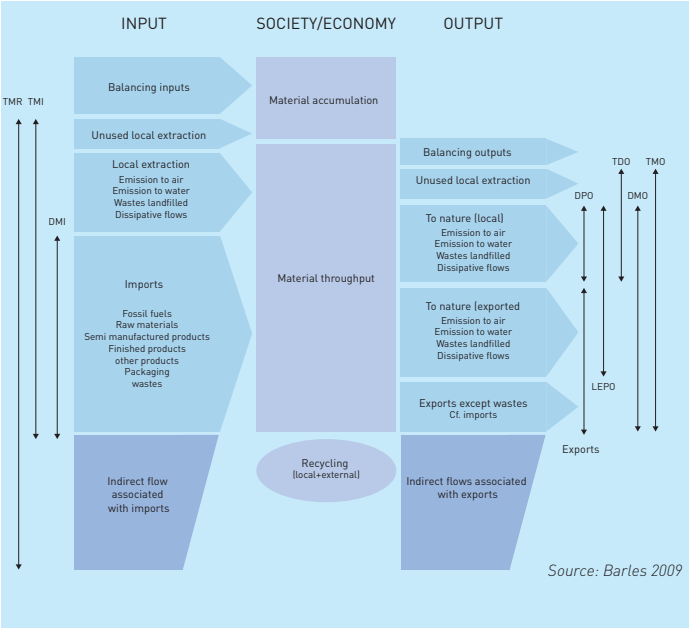
The negative consequences of unsustainable global material flows make decoupling an urgent priority for all cities. The current rapid growth of cities creates new opportunities for reconfiguring urban infrastructures through applying material flow analysis to the assessment of stocks and flows. Stocks include the resources available within the city (such as buildings, infrastructure, and intellectual capital), while flows involve resource inputs and outputs from within and outside the city.

Material flow analysis has generated some sophisticated frameworks for assessing the dynamics of resource flows in cities. The methodology is mature and could prove extremely useful in informing decisions about the building of new or retrofitted urban infrastructures that take into account the long-term flows of strategic resources through the city. Applying such analysis to cities links urban systems to the wider regional flow of ecosystem services (including water supplies, flood protection, and air quality) and natural resource extraction (such as fossil fuels or building materials). Existing analyses demonstrate how urban decoupling will depend on linking cities to their surrounding landscapes (often called "bioregions"). However, thus far this tool is insufficiently applied in supporting policy-making.

Different resources flow at different scales, that can be distinguished as three significant interrelated scales: the **landscape** or macro scale; the **regime** or meso scale; and the **niche** or micro scale.

Cities have multiple infrastructures and resource flows that have national and international reach. "Landscapes" include the broad conditions, environments and pressures for transitions that affect cities. Issues such as political cultures, economic growth, macro-economic trends, land use, utility infrastructures and so on are best addressed at this scale. Landscapes

Figure 2: Urban material flows[4]



Explanation of indicators and abbreviations used in Figure 2	
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

provide the external context and the setting where actions happen at smaller scales. 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).

Research on these landscape-scale flows can inform policies addressing how these can be acted upon at the city scale.

Technological development co-evolves with social functions and interests, and are therefore shaped by "socio-technical

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

Cities as socio-technical systems

regimes" and a broad constituency of engineers, policymakers, business interests, NGOs, or consumers. Regulations, policy priorities, consumption patterns, and investment decisions hold these regimes together and influence the way they develop. Changes at the regime level can be the outcome of historical processes (such as a gradual shift in consumer choices or evolution of new technologies) or driven by a strategic coalition among regimes with a shared vision and capacity to implement. City governments can influence the way regimes change over time, either directly due to their control of the service delivery agencies or indirectly through policy influence and regulatory authority. The combination of regime transitions, governance processes and adaptive capacity leads to a great variety of possible pathways toward transitions to sustainable infrastructures.

Micro-level "socio-technical niches" encompass small networks of actors that add new technologies to the agenda, promoting innovations and novel technological developments. Social learning from niches can be applied at the city scale to help reshape the existing infrastructure regime (often located at other governmental levels). The best examples come from the energy sector, where 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 – can be configured as local generation enterprises that are locally controlled and accountable. Small-scale innovations at the niche level 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.

Approaches that rebundle infrastructures and resource flows at the scale of new buildings or districts governed at the local level (by niches) can be compared with others (often regimes) that seek to develop a metropolitan vision for a reconfigured infrastructure and its wider relations with landscapes. For example, many of the eco-developments are creating relative self-reliance from resource flows at the scale of a new enclave. The diversity of initiatives provides an opportunity to compare the relationships between different scales (at the landscape, regime and niche levels) and the impacts of decoupling, thereby helping to ensure that the costs and benefits of decoupling are shared equitably.

Reconfiguring urban infrastructures can change the flow of resources through cities.

Figure 3: Six themes to guide the transition to more sustainable urban development

1. Reconfiguring urban infrastructures can change the flow of resources through cities, following a dynamic process of negotiating purpose, experience and learning rather than adopting any single formula or model.

2. Multiple visions of urban futures are guided by coalitions of interests that are context-specific in what they aspire to achieve.

3. Visions capture innovation in the relationships between cities, infrastructural systems and resource flows in different ways. Some may address systemic urban infrastructure transitions over 20 years and more while others operate over a few months or years. These innovations develop incrementally through projects and initiatives building up over time.

4. Innovations need to be part of a coherent network that coordinates the various interventions and projects, facilitating learning between them at various times, and deciding how and whether they should be integrated.

5. Broader coalitions that integrate relevant expertise with the interests of key stakeholders will be needed to support more sustainable and environmentally-sensitive infrastructure, replacing the visions that were dominated by narrow coalitions of interests.

6. The future of urban infrastructure systems and resource flows will depend on positive responses to pressures for change on behalf of existing infrastructure regimes, which may prefer to defend the status quo.

Investing in the transition

Promoting investment in sustainable urban infrastructure

to sustainable cities

Rapid urbanisation has placed a burden on municipalities in both developing and developed countries. In particular, the rapid influx of predominantly poor people to under-prepared cities of the global South challenges city managers to provide this mass of new arrivals with opportunities for a better quality of life. Improving the way resources are used will enable more to be achieved with what is available (resource decoupling), while creating less environmental damage (impact decoupling) and supporting the interests of greater equity. However, building a link with infrastructures and resource flows will require answering the following questions:

What is the demand for investment in urban infrastructures? Sustainability-oriented infrastructures can be built rapidly, driven by the economic demand for more viable urban infrastructures and the ecological demand for more sustainable use of natural resources. If policies can be put in place to provide greater certainty for investors, investment in infrastructure rather than fiscal or monetary interventions could well bring the global economic crisis to an end. Retooling the world's cities for the next long-term development cycle is emerging as a key strategic opportunity for many investors.

How much will be invested in urban infrastructures? A global consulting firm estimated that US$41 trillion is required to refurbish the old and build new urban infrastructures over the period 2005–2030.[5] About $22.6 trillion would be required for water systems, $9 trillion for energy, $7.8 trillion for road and rail infrastructure, and $1.6 trillion for air- and sea-ports. Their report warns that "Sooner or later, the money needed to modernise and expand the world's urban infrastructure will have to be spent.... 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 $40 trillion.... But perhaps the money can be spent proactively and innovatively, with a pragmatic hand, a responsive ear, and a visionary eye. The

5 Doshi, V., Schulman, G. &Gabaldon, D. (2007). Light! Water! Motion!. Strategy and Business.

potential payoff is not simply the survival of urban populations, but the next generation of great cities."

How can "rebound effects" be addressed? The economics of infrastructure decoupling also need to consider the issue of rebound effects, the unintended outcomes of investments that result in more efficient use of resources but can also stimulate increased consumption if savings encourage people to consume more material resources. For example, encouraging commuters to use public transport instead of private vehicle transport might reduce carbon emissions per commuter, but increase the number of commuters and ultimately increase overall carbon emissions. A key mechanism to counteract the rebound effect is to link improvements in efficiency to increased taxes on activities that harm the environment and that effectively capture the savings for re-investment in public goods ("eco-taxes") rather than recycling savings into increased private consumption. Rebound effects might also be less of a problem in developing country cities were a significant number of people need to move out of poverty or where incomes are declining due to recession or inflation (which could be driven in part by rising resource prices).

Urban material and energy use will vary with the context and the sustainable development policies that are put in place.

How can the demand for material consumption be reduced? Different cities have very different levels of domestic material consumption per capita, often generally irrespective of their level of development; for example, Lisbon consumes nearly 21 tons of material per person per year, while London consumes under four tons per capita. Where high population densities are correlated with good public transit systems and disincentives to private car use, energy requirements for mobility can be lowered dramatically. And the operational energy requirements of buildings could be reduced by as much as 80% by changing the way they are designed and operated. In general, the energy requirements for urban living are less than for similar standards of living in rural areas, but urban material and energy use will vary with the context and the sustainable development policies that are put in place.

Innovations for sustainability will need to become the operating systems for a new generation of vibrant, expanding and socially inclusive urban economies.

What are the key issues in promoting sustainable infrastructures? Sustainable cities have infrastructures designed for a sustainable socio-ecological metabolism. They create the basis for greater equity, reduce levels of poverty, build a sense of community, and use infrastructure designs that can respond to the rising cost and changing flow of resources through cities. While some spontaneous decoupling is already taking place in cities, the decoupling needed to achieve sustainability will require purposive intervention to stimulate broad, systemic (including behavioural) changes. A combination of resource productivity improvements, increased use of local renewable resources and ecosystem services, and re-use of waste products can allow cities to better manage the flows passing through them and achieve decoupling. For whole-system efficiencies to be realised at the city scale, strategic coalitions with a shared vision for decoupling will need to be created.

What are the characteristics of sustainable innovations in infrastructure? Urban development will result in new settlement patterns, resource flows and social dynamics that influence the viability of infrastructure investments. Innovations for sustainability 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, but most innovations have been motivated by the pursuit of economic growth with relatively little attention given to social or environmental considerations. Sustainable innovations are inspired by goals that also address social inclusion (specifically poverty reduction in developing countries) and sustainability (most often reduced negative impacts but also improved resource productivity).

What are the characteristics of an "energetic society"? The recent rise of active civil societies supported by the power of internet-based communications has resulted in the emergence of the "energetic society" whose articulate citizens have an unprecedented reaction speed, learning ability and creativity. Such energetic societies can take full advantage of the new opportunities provided by more efficient infrastructures in a green economy. They

Investing in the transition to sustainable cities

At a time when most people live in cities and the bulk of economic activity is concentrated in urban areas, cities should be given priority as the building blocks for sustainable development.

can also provide a source of intellectual energy when encouraged by appropriate government incentives. An innovative, vital society founded on sustainability will take advantage of the new scope for action and initiative, and ensure that the best improvements are identified and distributed rapidly. This calls for governments that set clear objectives, implement regulations to help promote promising initiatives, and create the institutional frameworks within which citizens, organisations and entrepreneurs can develop and directly benefit from sustainable innovation in infrastructure.

What is required to bring about a transition to sustainable cities?

Urban transitions depend on a shared understanding between a wide range of urban policy-makers and those who manage the various infrastructure regimes. **"Visions"** form a central part of transition management and offer the potential to present a shared understanding of citywide and regime interests (without implying in advance that everyone must reach consensus). In terms of urban infrastructure, a vision-building process may involve representatives of utilities, municipal governments, regulators, developers, businesses, citizens, and "users". 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. Although visions will change over time with the variety of social interests that become involved, the ideal outcome often stems from a vision-building process that brings new external knowledge into socio-technical regimes that have the internal capacity to manage a transition.

What is the role of intermediary organizations? Purposive urban socio-technical transitions aim to mutually transform both urban governance arrangements and socio-technical regimes, which is no simple task. Producing a vision provides a framework for such a purposive transition but it says little about how this will be done. It therefore needs to be followed up by building an effective capacity to convert vision into action. Coordinating

Cities are where the major global and national resource flows connect as resource inputs, stocks and outputs (goods, services and wastes).

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. Intermediaries often play a critical role by helping to learn from innovations and build capacity for managing the changes that convert visions into reality.

At a time when most people live in cities and the bulk of economic activity is concentrated in urban areas, cities should be given priority as the building blocks for sustainable development. Dependent on their infrastructures, cities are where the major global and national resource flows connect as resource inputs, stocks and outputs (goods, services and wastes). They are also where ecology meets the energetic society, making them sites of social debate and innovation in support of a green economy.

Typologies of urban

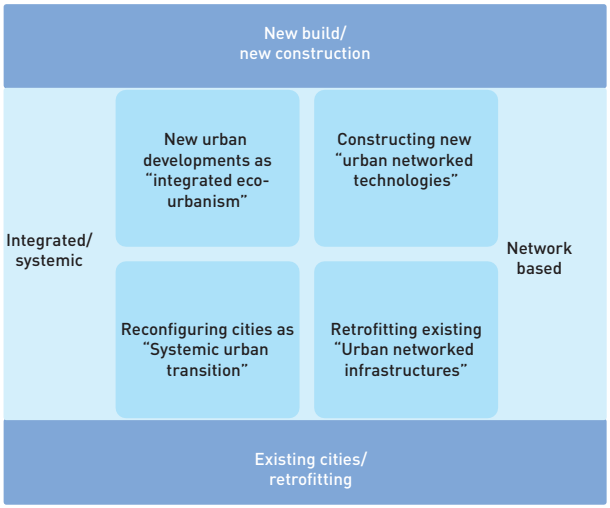
Applying the emerging concepts to urban infrastructure decoupling issues

"Integrated eco-urbanism" are entirely new developments (eco-town, eco-house or eco-neighbourhood) where the design includes integrated infrastructure networks to achieve high sustainability goals.

Four types of green urban networks can be distinguished, as outlined in Figure 4, on the basis of two dimensions: 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; and the horizontal axis indicates whether urban responses are concerned with integrated (systemic) change or mainly concerned with a particular category of infrastructure network. Each type has its strengths and weaknesses, as indicated by the 30 case studies included in the annex to the full report of the IRP on City-level Decoupling.

"Integrated eco-urbanism" is new development (such as an eco-island, new town, cluster development, or eco-village). The design includes infrastructure networks that have been integrated to achieve high-level sustainability goals, cutting across multiple infrastructure networks that are rebundled together at particular scales in the design of new buildings, neighbourhoods, towns, blocks and cities. They usually focus on either entirely new 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

Figure 4: Four types of green urban networks



"Urban networked technologies" is where new construction projects focus on the development of one particular technology or infrastructure.

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. In other words, they are working toward a more circular urban metabolism.

The development of visions for integrated eco-urbanism frequently involves commercial architects, international organizations, national officials and programmes, regional and local authorities, residents and local groups. The configuration of these intermediaries 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.

Formal evaluations of "integrated eco-urbanism" experiments are scarce, making it difficult to assess their impact on resources. Many integrated eco-developments have faced cancellations and delays in implementation. Where they are being implemented, commercial constraints may reduce the innovative technologies or existing standards may have been raised in support of greater sustainability. Despite the challenges, these experiments with a protected niche provide settings for the development and potential testing of innovative responses within a protected experimental niche that may threaten established utilities, social interests and technological practices.

New "urban networked technologies" also include new construction, but here the focus is on one particular technology rather than an integrated approach. These initiatives promote 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 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

drives systems for the distribution of heat and cooling, and alternative fuels such as hydrogen and biofuels. Public transport, pedestrian walkways, cycling networks and the use of alternative fuels in vehicles also reduce energy consumption. Parallel water systems distribute recycled water alongside potable water systems. Underlying all these responses is the vision to construct new or parallel infrastructures within the city. These 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 for local users.

Unconventional "urban networked infrastructure" projects have considerable potential, but interventions that focus on a particular infrastructure usually require an intermediary of some sort, in particular to reduce the social risks of a costly long-term capital investment. In under-funded environments, intermediaries play a crucial role in translating social capital into system viability and financial capital.

"Systemic urban transitions" are retrofits of existing urban infrastructures and/or buildings using an integrated network approach.

"Systemic urban transitions" are 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. Many cities 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. This requires mobilizing the social, institutional, political and technological complexity to reshape the existing urban networks.

City reconfigurations are often led by groups of city leaders, researchers, and developmental and international agencies, often acting as intermediaries. For example, coalitions of the world's largest and most powerful cities and some of the world's most influential businesses are

working together to reduce greenhouse gas emissions 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 approaches 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 in developing the vision. The cultivation of a strategic orientation for the reconfiguration of socio-technical systems also requires the purposive, strategic development of new capacity to translate these into action.

As the providers of energy, water and transport, utilities have important interests in urban transitions, both in terms of their existing assets and their organisational connections to households and businesses. 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 local deliberation, the connections between this local capacity and formal city, private and utility interests are often weak and poorly developed.

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 public, private and community interests. The financing of these transitions involves a complex system of direct investments, grants, subsidies, private finance, long-term payback mechanisms of upfront costs through envisaged savings, and public authority investments from savings made in their own estates through resource efficiencies.

“Urban networked infrastructures” are retrofits that seek to reconfigure particular infrastructure systems that

"Urban networked infrastructures" are retrofits of infrastructure systems focusing on a particular technology.

address issues such as water security, energy security, food security or flood resilience. They exploit the potential of smart technologies and pricing systems to reconfigure the use of existing infrastructures in order to reduce vulnerability, increase self-reliance, and develop adaptability. They often focus on a particular technology, such as bus rapid transit systems or major new water efficiency infrastructures. They tend to require national funding and long-term programmes, local champions to play a critical initiating role, and traditional forms of resource-use efficiency.

A key issue in these retrofits is equity, requiring that planners ensure that the retrofitting of urban networked infrastructures provide real benefits to the urban poor in the form of low-cost, energy efficient technologies. Providing sustainable employment in building and managing the new infrastructures and skills development opportunities for the local community should also be part of the package.

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, have a less technologically focused emphasis, and are more focused on demand-side management and small-scale production technologies. Examples include the "transition towns" movement, the "global eco-village" movement, and some of the more grassroots-oriented local government initiatives that have equity as a leading concern.

Conclusions and policy recommendations

The way forward

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.

Decoupling in cities depends on a clear vision of ultimate objectives. Such a vision must emerge from interactions among city stakeholders.

The core conclusion of this report is that urban infrastructures can be designed to achieve the same or an improved level of well-being with less resource consumption and lower carbon emissions (resource and impact decoupling, respectively). Urban decoupling links material flows to a socio-technical understanding of the institutions, producers, users and intermediaries involved in effectively organising resource flows through infrastructure networks. Central to this transition is the need to identify the key drivers, distributional inequalities, and ecological consequences of resource flows. This provides the analytical context in which city leaders can apply innovations to existing infrastructures that need to be reshaped to replace obsolete approaches that may reduce wellbeing and hamper decoupling.

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. Many alternatives are available to the traditional resource and energy intensive approaches to urban infrastructures. However, further research is needed to quantify the impact of these alternative infrastructure approaches on actual material flows and their distribution (ultimately an equity issue).

The wide range of institutional learning and social change dynamics addressed here demonstrate that decoupling in cities depends on a clear vision of ultimate objectives. Such a vision must emerge from interactions among city stakeholders, with each city having its own unique characteristics.

The assessments from this report lead to the following policy-relevant recommendations:

- **Establish national and city-level policies that support sustainable infrastructures.** Following the example of some visionary governments, and in line with many global sustainable city reports, national governments should adopt policies that support the role of cities in national sustainable development strategies. These policies need to make specific reference to urban infrastructure planning that aims to reduce environmental impacts (especially greenhouse gas emissions) and drastically improve resource efficiency and productivity. They should align spatial planning guidelines, infrastructure investment strategies, equity objectives, financial capability, and long-term sustainability goals. City governments should prepare their own

The way forward

Government investments in urban infrastructures to prepare cities for a long-term transition to a greener economy should set specific resource productivity targets for each infrastructure service.

sustainable infrastructure policies, adapting the national policies to meet local conditions.

- **Adopt equity as a fundamental principle in all infrastructure developments.** Equity provides the ethical basis for building public support for sustainable infrastructures and the innovations that will enable them. Governments and businesses should promote greater equity when setting objectives for new infrastructures and link them to practical measures such as new employment and capacity building for the urban poor. Investors should promote sustainability-oriented innovation, especially in developing country cities that stand to benefit from large-scale investments in new urban infrastructures aimed at poverty alleviation. This calls for international support for innovative urban infrastructures that have a strong equity component.
- **Establish challenging but realistic targets for sustainable urban infrastructures.** City governments should adopt targets for desired metabolic flows per capita based on the economic and ecological context of the city. These will provide a clear-cut and understandable framework for assessing progress towards more sustainable resource use. Establishing targets requires enhancing the capacity of city-level governments and their partners (such as universities and businesses) to collect and process quantitative data about urban metabolic flows. Adopting a globally standardised methodology will make performance benchmarking possible. For example, monitoring water use per capita across all cities would enable city governments to identify strategic targets for consumption. Government investments in urban infrastructures to prepare cities for a long-term transition to a greener economy should set specific resource productivity targets for each infrastructure service (for example, litres of water per unit of GDP, or percentage of passenger trips by public transport).
- **Adopt the new approaches to sustainable infrastructures that are being developed.** This report has provided numerous examples of new approaches to sustainable infrastructures. One example is material flow analysis, with Paris providing an outstanding model that has been well quantified; as understanding of urban metabolism grows, it will become possible to shed much greater light on

the total material requirements of cities. This will reveal how dependent cities are on material imported from other localities within and beyond national boundaries, indicate the environmental impact of cities on other localities, and provide the basis for establishing payments for ecosystem services. Supporting innovation in urban infrastructures should include procurement criteria that favour innovation, regulatory reforms that open up markets previously 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 should be encouraged. They may need support from intermediaries who in turn need to be formally contracted into the urban transition process and provided with a relatively stable operating and funding environment.

Associations, networks and partnerships that pool knowledge, share risk, mobilize support and instigate innovation should be encouraged.

- **Promote investment in innovative urban infrastructures.** Investment in sustainable urban infrastructures potentially represent a $40 trillion business opportunity over the next 20 years. Guiding these investments with environmental criteria, taking into account both resource and impact decoupling, while adequately involving relevant stakeholders and intermediaries, can ensure that urban infrastructures meet not only investment potential, but in doing so also contribute to environmental and social well-being.

Of course, each city is unique, and interventions to translate these general recommendations into actions that are aimed at minimizing environmental damage and maximising the potential of sustainable resource use need to be tailored to the challenges and opportunities present in each case. Cities will be fundamentally restructured over the coming decades in response to many of the issues discussed in this report, and to changes in consumption, cultural behaviours and technologies. By considering this restructuring from a material flow perspective, infrastructures can be reconfigured to improve resource productivity and reduce environmental impacts, in a way that can also contribute to the well-being of society.

Acronyms

GDP	Gross Domestic Product
NGO	Non-Governmental Organization
UN	United Nations
UNEP	United Nations Environment Programme

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.

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