THE WEIGHT OF CITIES

RESOURCE REQUIREMENTS OF FUTURE URBANIZATION

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International Resource Panel

Summary for Policymakers

THE WEIGHT OF CITIES

RESOURCE REQUIREMENTS OF FUTURE URBANIZATION

Produced by the International Resource Panel

This document highlights key findings from the report, and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded at http://www.resourcepanel.org/reports/weight-cities.

Additional copies can be ordered via email: resourcepanel@unep.org

Preface

The first International Resource Panel (IRP) report on cities, 'City-Level Decoupling: Urban Resource Flows and the Governance of Infrastructure Transitions', produced back in 2013, provided striking figures in relation to the future of urban development. It highlighted that 60 percent of the built environment required to meet the needs of the world's urban population by 2050 still needs to be constructed.

Inspired by this reality, by the fact that China used more cement in the 2011-2013 period than the USA used during the whole 20th Century and by the absence at conferences related to cities of discussions on the implications of future urbanization on natural resources, 'The Weight of Cities' was developed.

This very timely report calls for a new strategy for 21st Century urbanization, a strategy that allows us to understand its implications, the resources being used and how different tools and interconnected interventions can help cities to better manage their resources.

The findings of the report point out that isolated actions will not result in more resource-efficient urban metabolisms, but rather that there is a pressing need for a transformative and integrated approach. In this regard, 'The Weight of Cities' shows how parallel actions in terms of urban spatial restructuring and human-scale sustainable design, resource-efficient urban components, urban infrastructure planning for cross-sector efficiency and the promotion of sustainable behaviours, would lead to improvements in well-being for all while reducing resource consumption and GHG emissions. The report also presents the entrepreneurial urban governance required to shift urbanization onto a sustainable trajectory.

'The Weight of Cities' contributes to achieving the Paris Agreement and supports the implementation of the New Urban Agenda as well as Sustainable Development Goal 11, to "make cities and human settlements inclusive, safe, resilient and sustainable", and Goal 12, to "ensure sustainable consumption and production patterns". It will also indirectly support many of the remaining Goals since the actions called for in Goal 11 are in many instances the concretization of targets across the

other 16 Goals. In addition, in recognizing that 12 out of the 17 Sustainable Development Goals are directly dependent on natural resources, the report raises awareness of the new challenges related to the scarcity of resources and the environmental impacts associated with their use, including CO2 emissions. Developing resource-efficient cities will not only save resources but lower GHG emissions and contribute to healthier cities.

We are very grateful to Mark Swilling, Maarten Hajer and the rest of the team for what we believe is a valuable contribution to progress towards sustainable and socially just urbanization, and for bringing the resource perspective, which should now become a central policy concern, in addition to other challenges that are already well recognized.

Janez Potočnik
Co-Chair
International Resource Panel

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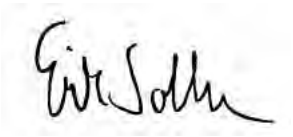
Foreword

With the world population expected to swell by almost two and a half billion people by 2050, new and existing cities must accommodate many of them. Depending on the choices we make, this could exacerbate existing problems like pollution, congestion, lack of infrastructure or public services, and marginalization of the poor. Or, if we rethink urban living and its governance, it could equally be an opportunity to develop the low-carbon, resource-efficient and socially just cities called for in the New Urban Agenda. This assessment report from the International Resource Panel, explores this transition through urban planning, investment in resource efficient infrastructure technologies and entrepreneurial governance.

The report suggests a fundamentally new approach to the way we design cities, so that people live in functionally and socially mixed neighbourhoods with better mobility options, including public transport, walking and cycling. They should have more energy efficient heating, cooling and lighting and more resource efficient components, such as vehicles, infrastructure, buildings and factories. All of which should be complemented by changing habits from consumers and producers of good and services, including better waste management or recycling.

For example, the area of Hammarby Sjöstad in Stockholm, Sweden, has been transformed from an industrial brownfield into a desirable place to live. The redevelopment created a compact area of medium-sized city blocks, small enough to walk around, with a network of green spaces, quays and walkways running through it. During development, a great deal of thought went into how people could move around their community. The use of sustainable transport is encouraged through an education centre, which provides information and promotes environmentally friendly choices and actions.

Around the world, I see more and more towns and cities determined provide such improvements for their residents. This report shows that a different urbanization, one that is sustainable and inclusive, is certainly possible. I hope it will inspire decision makers and provide a practical guide to create innovative cities that have a better relationship with nature and provide a better quality of life for residents.



Erik Solheim
Under-Secretary General
of the United Nations and
Executive Director, UN Environment

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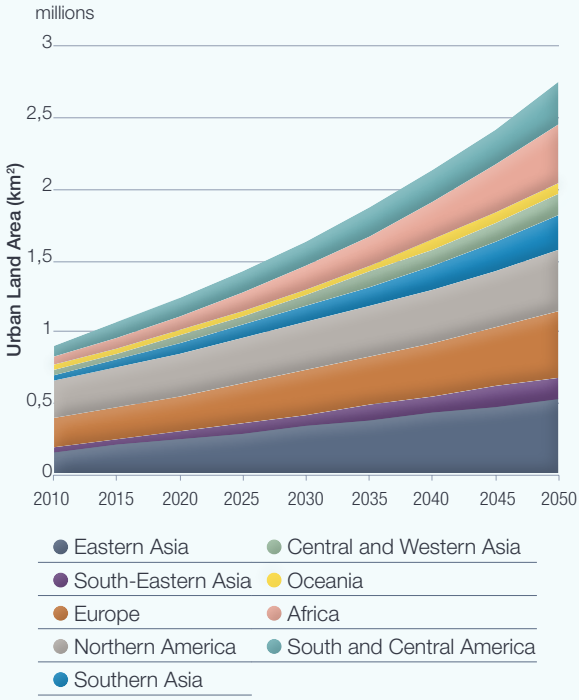
Content

The need to rethink urbanization

Over the next 30 years, an additional 2.4 billion people are likely to be added to the global urban population, meaning a shift from 54 percent of the population living in cities in 2015 to 66 percent in 2050. Most of this transition will take place in the Global South, where nearly 37 percent of this growth is expected to come from only three countries: India, China and Nigeria. Estimations indicate that they will contribute 404 million, 292 million and 212 million urban dwellers respectively (UN-DESA, 2014). At the same time, a third of the current urban population is estimated to live in slums and informal settlements, often without access to proper housing and basic services.

This increase in population will result in **a significant expansion of existing cities and the construction of new cities**. Consequently, material consumption is predicted to grow faster than urban populations. Quantitative analysis of the global resource requirements of future urbanization shows that without a new approach to urbanization, **material consumption by the world's cities will grow from 40 billion tonnes in 2010 to about 90 billion tonnes by 2050**. In their construction and operation, and to support urban lifestyles, cities use billions of tonnes of raw materials, from fossil fuels, sand, gravel and iron ore, to biotic resources such as wood and food. The high demand for such raw materials far exceeds what the planet can sustainably provide. **Resources should now become a central policy concern**, in addition to concerns over CO_2, which are now well recognized. Furthermore, the long-term historic de-densification trend of 2 percent per year (i.e. that cities are becoming less compact) threatens to increase global urban land use from just below 1 million km^2 to over 2.5 million km^2 in 2050, putting agricultural land and food supplies at risk (cf. 'Food Systems and Natural Resources' IRP report, 2015).

Figure 1: Growth in urban land area by region and globally, 2010-2050, if historic de-densification trend of -2% per annum continues



'The Weight of Cities' calls for a new strategy for 21st Century urbanization: resource efficiency and social inclusion must become the focus of urban development strategies if we want to stand a chance of achieving the 2030 Development Agenda as well as the New Urban Agenda.

Goal 11 of the Agenda's Sustainable Development Goals (SDGs) – to 'make cities and human settlements inclusive, safe, resilient and sustainable' – represents recognition of the importance of addressing the links between urbanization and sustainable development. Without attention to this Goal and to the urban implications of the other 16 Goals, none of the SDGs are likely to be achieved. At the city level, all goals matter, and action at this level will be critical. SDG 12 – to 'ensure sustainable consumption and production patterns' – will be relevant to achieving resource-efficient cities, will have implications for climate change action and will draw attention to the currently unsustainable use of resources. Most consumption and production is already happening in cities, and as such, some of the targets of Goal 11 are a direct concretization of Goal 12 targets for action at the city level.

The new strategy based on resource-efficient urbanization presented by the International Resource Panel (IRP) aligns with the goals of the New Urban Agenda, adopted by the United Nations Conference on Housing and Sustainable Development in October 2016 in Quito, Ecuador. The New Urban Agenda provides a Roadmap for sustainable urbanization, with three transformative commitments to 'leave no one

behind', 'sustainable and inclusive economies' and 'environmental sustainability'. Moreover, it contains multiple references to resource efficiency, alongside low-emission and resilient housing, infrastructure and basic services.

We have a once-in-a-lifetime opportunity to shift the expected urbanization onto a more environmentally sustainable and socially just path. Decisions made today on urbanization and land use models, as well as on critical infrastructure, will determine whether our investments are future-proof or whether they in fact lock us into an unsustainable path. Calculations for climate benefits and resilience are relatively well established by now, but resources encompass much more than climate effects alone. What is more, the costs of resource use are often overlooked. Yet such resource ignorance can be costly. Policymakers, at the city, regional and national level, would be well advised to monitor key resource indicators to get a better understanding of the current flows of resources on which both economic development and human well-being depend. In order to carry out an assessment of current and future resource dependencies, it is of paramount importance to get data on resource use in order and to monitor it regularly.

How to rethink urbanization in terms of urban metabolism

Urban metabolism is a framework for modeling the flows of complex urban systems (water, energy, food, people, etc.) as if the city were an ecosystem. It can be used to analyse how urban areas function with regard to resource use and the underlying infrastructures, and the relationship between human activities and the (natural) environment. What is more, it can be used to shape the urban environment in a more sustainable way.

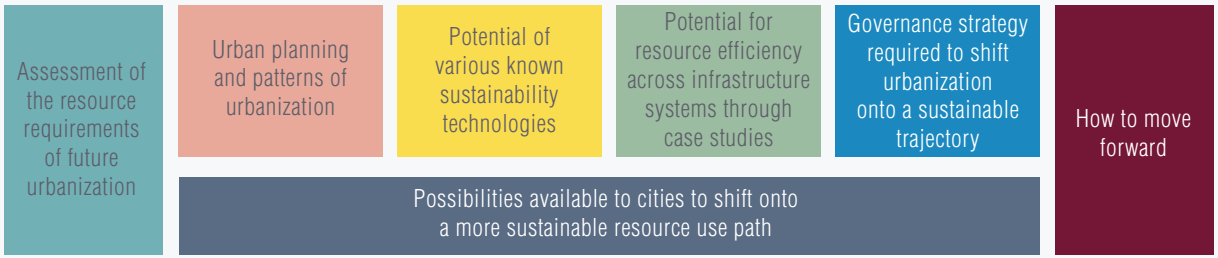
'The Weight of Cities' seeks to address the complex interrelationships between cities and the wider ecosystems in which they are embedded, and presents urban resource flows as being key to understanding what it will take to promote a transition from resource-intensive and polluting cities towards alternatives that manage resources more carefully for the benefit of all citizens. It presents the first assessment of the resources required at a global scale for the wave of urbanization that is already under way, and presents the possibility of an alternative;

a strategy to transition towards low-carbon, resource-efficient and socially just cities, which would be highly relevant to policymakers looking for practical actions to advance the SDGs and break away from current unsustainable routines.

'The Weight of Cities' combines quantitative estimates of the resource implications of business as usual (BAU) and sustainable alternatives, as well as reflections on the governance needed to shift towards better resource management in cities. The report brings different disciplines together to monitor and understand resource consumption patterns and to identify areas for intervention that can help cities to meet sustainable levels of resources. It is argued that we **need to integrate the urban metabolism into a wider understanding of which resources are being used where, by whom, and for what purpose** if we want to connect the increase in resource efficiency to the overall goal of environmentally sustainable and socially just cities. If we want 'resource-efficient' urbanization, this will require a very astute rethink of our urban development and an aggressive deployment of resource-efficient technologies. The report suggests the **need to invest in creating new visions of good city life for all urban inhabitants**, combined with more technical notions of the component parts of such a resource-efficient strategy. This could be realized by an enhanced sharing of good examples and investing in the innovation and governance capacity of cities.

The following sections will show where we stand on resource use and what will be required for cities to make the transition towards becoming low-carbon, resource-efficient and socially just urban centres:

Figure 2: Following sections of the Summary for Policymakers



Measuring the weight of cities

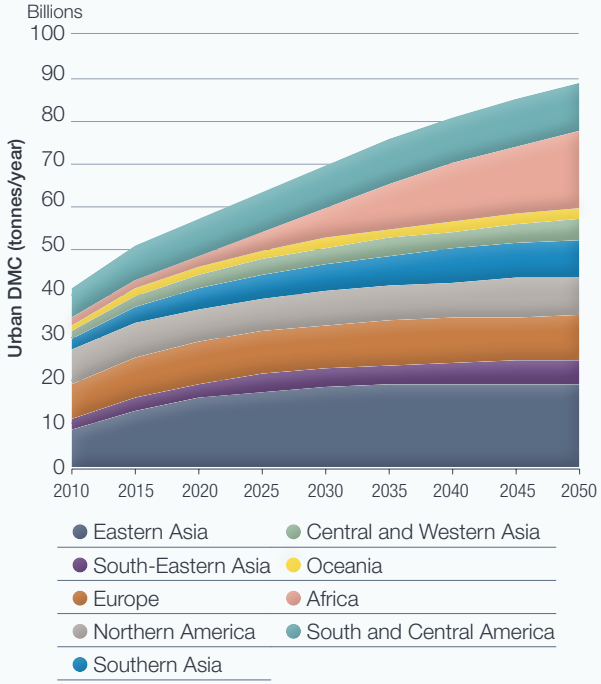
Cities account for about 60 percent of total global 'domestic material consumption' (DMC) of raw materials (including sand, gravel, iron ore, coal and wood). DMC, expressed in tonnes per capita per year, is used in this report as a metric for estimating direct resource use at the city level. 'The Weight of Cities' shows that DMC is likely to be in the range of 8–17 tonnes per capita per year at 2050, assuming material use per capita will stabilize in developing countries at lower levels than today's developed countries.

Domestic material consumption (DMC) measures the material flows consumed within a territory in a given time (often annually). DMC is defined (Eurostat 2001) to be equal to domestically extracted raw materials, plus imported materials, minus exported materials.

A DMC range of 6–8 tonnes per capita per year has been proposed as an indicative target for sustainable resource consumption (UNEP, 2011) and could be used by cities seeking to limit the resource and environmental impacts of their inhabitants. Reducing urban DMC from the projected 2050 baseline range of 8–17 tonnes per capita per year to a range of 6–8 tonnes per capita per year implies that we must think about developing a suite (portfolio) of strategies that yield a 50 percent reduction in DMC across the world's cities.

A first-order estimate of what would be achieved if cities were to be more resource-efficient and achieve the 50 percent saving of resources mentioned above, would be a saving of some 44 billion tonnes of materials per year by 2050 (given that the baseline projection in this report is 90 billion tonnes per year by 2050).

Figure 3: The composition of global urban DMC by aggregate world regions



(Source: Historical data from the CSIRO Material Flows Database West and Schandl, 2013)

Attention should be paid to the broader resource issues relating to building materials such as sand, steel and cement, and to the resource requirements of new infrastructure (asphalt, steel and sand). Moreover, choices available, particularly in the spatial layout of cities, come with major repercussions in terms of the resources needed. The current trend towards de-densification (of 2 percent per year) implies more costs for infrastructure, and much higher 'running costs' for the urban population to commute between activities.

Cities are complex 'sociotechnical systems' that are not easy to change. Policy, lifestyle, political economy and resource use interrelate in complex ways. Yet there are numerous opportunities to change track and to improve urban resource efficiency by a factor of ten. This is known as 'urban productivity'. It is the design of cities that constitutes the greatest potential source of savings at zero or negative cost. Well-structured networks of high-density nodes make for denser, better-connected cities designed to be more open to light, the sun and wind. In this way cities will improve well-being and social and economic exchanges, while economizing on the square kilometres of asphalt and the concrete, electricity and water that are currently used in the overly long and scattered networks of our sprawling contemporary cities. **By increasing the productivity of the urban system by as much as a factor of ten, we may be able to urbanize in a way that creates wealth and eliminates poverty while reducing the pressure exerted on the planet. However, given contextual specificity, productivity improvements by factors of between four and ten could also achieve similar outcomes.**

Embedding resource efficiency in spatial planning to improve urban productivity

Strategic intensification: creating a well-articulated networked hierarchy of high-density nodes (approx. 15,000 people per km^2) that are interconnected by efficient and affordable mass-transit systems (e.g. light rail, rail, Bus Rapid Transit (BRT)), foster a richer mix of housing, jobs and amenities at the neighbourhood level, and are surrounded by medium-density areas (7,500 to 10,000 people per km^2)[1].

The present focus on introduction of resource-efficient infrastructures and buildings will not result in more resource-efficient urban metabolisms if we do not also address the long-term trend of de-densification. Densification, however, must not be simply an increase in average densities. While densities of at least 15,000 people per km^2 or 150 people per hectare should be pursued, the analytical and policy focus must be on what will be referred to in this report as 'strategic intensification'. **It is essential to integrate land use and transport planning in order to have peaks of density corresponding to peaks of transit accessibility.**

Improvements to human well-being depend on a more 'productive' and socially inclusive urban configuration. This can be achieved by applying four **reinforcing interventions**:

- **spatial restructuring** of the urban morphology **to achieve strategic intensification**;
- **human-scale sustainable design** that creates liveable conditions for functionally and socially mixed neighbourhoods, with a

1- It is worth noting that an increase in average densities across a given space economy may be the outcome of successful strategic intensification, but it must not be the analytical and policy focus. Increases in density should be balanced by the need in some excessively dense cities in the developing world (e.g. Indian cities) to provide enough land per capita to achieve sustainable goals for living space per capita, connective streets and social infrastructure.

rich mix of housing types and social amenities for different income groups; a good jobs/residents balance in the neighbourhood providing job opportunities near homes; dense and connected grids of streets defining small perimeter blocks, which create conditions for soft mobility (e.g. walking, cycling) at the city/neighbourhood level and passive heating, cooling and lighting at the building level;

- **resource efficiency of all urban components**, such as vehicles (e.g. vehicle sharing, , electric vehicles and charging point networks), infrastructures (e.g. efficient energy, waste and water systems, street lighting technology and smart grids, cycle paths), buildings (energy-efficient buildings with innovative designs, new heating, cooling and lighting technology) etc.;
- **the promotion of sustainable behaviours**, specifically the separation of waste at source for recycling, the use of public transport, walking or cycling, the use of public spaces, etc.

The actual improvements in energy and resource productivity of each of these interventions are not simply the sum of each intervention, but are multiplicative if they are implemented in mutually reinforcing ways. Evidence indicates that:

- **higher densities and compact urban forms** can reduce greenhouse gas (GHG) emissions by a factor of two or more (Salat *et al.*, 2017),
- **human-scale functionally mixed neighbourhoods** could reduce energy consumption by a factor of two or more,
- **energy-efficient buildings** could reduce energy demand by a factor of two or more,
- **efficient systems** could achieve a further 20 percent energy saving and
- **behavioural changes** could reduce energy demand by a factor of two (Salat, 2009).

Altogether, this would result in a tenfold reduction in energy use, which significantly exceeds the factor 5 target that is usually referenced (von Weizsacker *et al.*, 2009). Optimizing densities and reducing sprawl also improves the sharing of resources (e.g. shared walls and roofs in apartment blocks) and reduces the distances that need to be covered by infrastructure networks (e.g. shorter pipes), allowing for savings in the materials and costs associated with service provision.

Compactness of urban forms refers to the shape and size of urban footprints. A city can be compact and dense or compact and not dense.

Key principles of integrated sustainable urban planning:

- Land use and transportation efficiency: Strategic distribution of higher resident and job densities along transit corridors (as opposed to only increasing average density in a homogeneous way) encourages the use of public transportation, reduces infrastructure costs, associated material resources use and embedded energy;
- Connectivity through geographical scales (inter-city connections, intra-metropolitan connectivity and local level) ensures urban and regional markets economic integration with a seamless flow of people and goods;
- Economic efficiency: Agglomeration of economic density (spatial concentration of firms and GDP creation) in nodes with several central business districts (as opposed to agglomeration in a single area) reduces transportation energy and increases market access and productivity;
- Market responsiveness: Flexibility in planning adapts to market demand and market cycles, allows value created by public investment in infrastructure to be captured and avoids oversupply of housing and offices;
- A human-scale, highly walkable, dense, and connected network of medium-width streets (occupying at least 30 percent of the developed land area with at least 18 km of street length per km² and between 80 and 100 street intersections per km2) makes walking access, and not speed of travel, a priority;
- Small street blocks (about 100 m per side) with buildings aligned on the street side (and visually active facades with ground floor activity) provide flexibility and adaptive change of functions (the super block approach to land division should be avoided and small urban blocks should be further divided into a few dozen urban plots with diversified uses);
- Functional mixed-use planning should be applied from the district scale down to the building scale with a balanced mix of housing buildings, office buildings, shops and urban amenities (at least 40 percent of floor space should be allocated for economic use in any neighbourhood, and single function blocks should cover less than 10 percent of any neighbourhood);
- A vibrant public realm fosters identity, social interaction, liveability and economic competitiveness (a continuous landscaped public realm should not lock landscaping into privatized blocks);
- Adapting designs and layouts of buildings, green spaces, squares and streets to the local climatic conditions reduces energy use for space conditioning.

Policies to develop polycentric spatial formations are as follows:

1. Support new, more efficient **public transportation networks between centres** to allow them to better exploit their aggregate urban size, leading to a greater development of agglomeration economies;
2. Enhance the **complementarity among centres** on the metropolitan scale in terms of economic sectors, occupations, and urban functions through promoting transit-oriented development (TOD) and compact city development;
3. Support new, more efficient **public transportation networks between centres and their neighbouring areas** to stimulate activity in centres and increase nearby residents' access to the agglomeration benefits.

Transit-oriented development (TOD): public sector development strategies aimed primarily at urban regeneration and transformation centred on public transport. Unlike transit-related development (TRD), TOD uses public-private partnerships to capture a portion of the improved land values to contribute towards the costs of the public transport infrastructure.

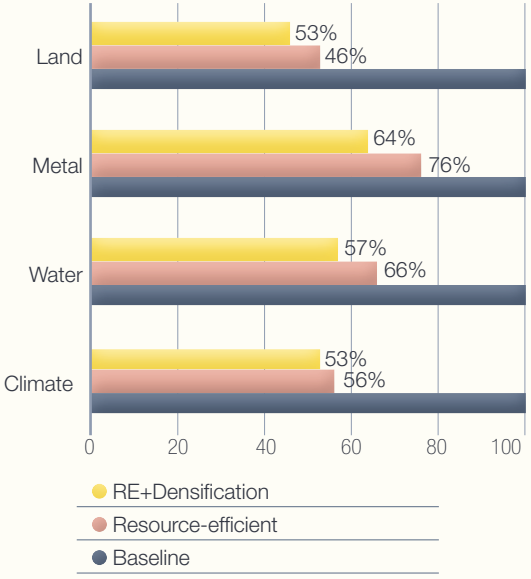
Investing in infrastructure technologies that save resources

As included in the four interventions mentioned in the previous section, one element of a wider process of urban restructuring aimed at fostering more equitable and resilient cities is the **deployment of resource-efficient technologies that can potentially help cities reduce their resource consumption and contribute to mitigating global environmental challenges**.

High penetration of resource efficient infrastructure technologies (e.g. bus rapid transit instead of passenger cars, green commercial buildings instead of conventional office blocks, and district energy instead of boilers and air-conditioners) can achieve a **24-47 percent reduction in impacts on water, energy, land and metals by 2050** in comparison with a baseline for these sectors.

When combined with strategic intensification, another intervention mentioned in relation to urban planning, this is likely to result in a 3-12 percent additional reduction in resource impacts, that is, **resource efficiencies** from 36-54 percent **compared to business as usual in the transportation, commercial buildings and buildings heating/cooling sectors**. This means that **existing sociotechnological systems are capable of taking us into the future world of resource-efficient and liveable cities**, and when combined with strategic intensification, from an extrapolation of the three sectors studied, can create the type of cities needed to achieve urban DMC per capita in the order of 6–8 tonnes per year.

Figure 4: Best case reductions in resource consumption for three sociotechnical systems (transport, district energy and green commercial buildings) for 84 cities combined under resource-efficient scenarios in 2050 (compared with baseline in 2050). RE + Densification considers high penetration of resource-efficient technologies in addition to increased urban density, which lowers the demand for passenger transportation



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Saving resources through inter-sectoral infrastructure interventions

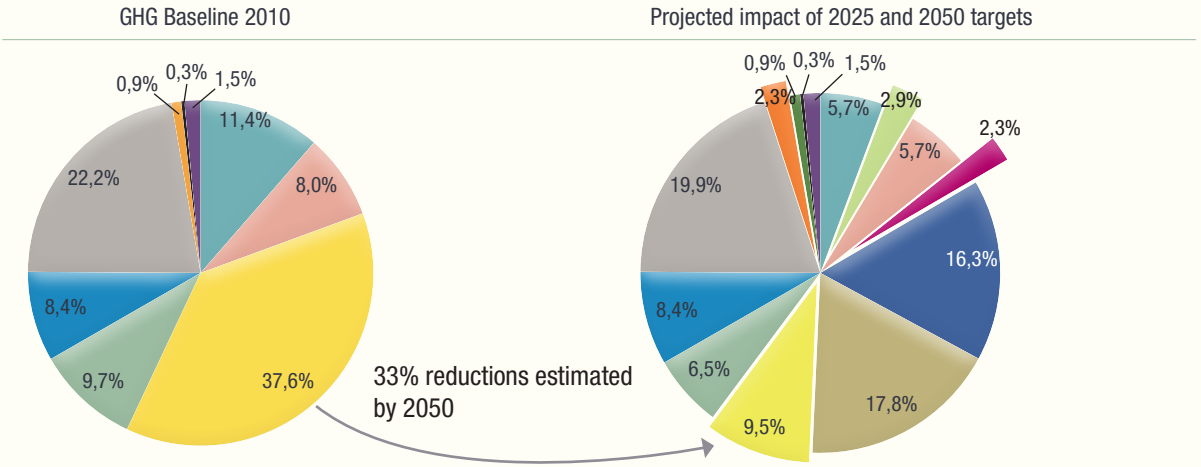
Planning infrastructure projects in isolation from one another misses a number of opportunities to improve the resource efficiency of urban systems. Significant **resource savings of between 30 percent and 60 percent are possible if infrastructure operations become more efficient and can be configured to ensure resource sharing across sectors**. Integrated infrastructure planning can improve efficiency by allowing wastes and by-products of one urban system to be reused in another, reducing the city's resource demands and GHG emissions. The following bottom-up case studies are used in the report to illustrate this:

Credit: Thampapon/shutterstock.com

Established city with stable population growth case study: Minneapolis

By combining existing policy commitments across different levels of government and by focusing on a combination of strategic densification, public transit, building efficiency, district energy systems, timber construction and renewable energy, Minneapolis could reduce the GHG emissions associated with infrastructure provision by up to 33 percent. New timber technologies offer the potential for saving 62 percent of mineral construction materials used in buildings and can offer the potential for carbon sequestration. District energy, in conjunction with use of the sewer system as a heat/cold sink, offers innovation and achieves about a 40 percent reduction in energy use for the heating and cooling of buildings.

Figure 5: GHG emissions baseline and reductions associated with multiple infrastructure provisions in Minneapolis, USA. Year 2010 baseline emissions from Hillman and Ramaswami (2010); efficiency estimates of multiple infrastructure interventions are based on year 2025 and 2050 targets proposed by the city and other policy actors.

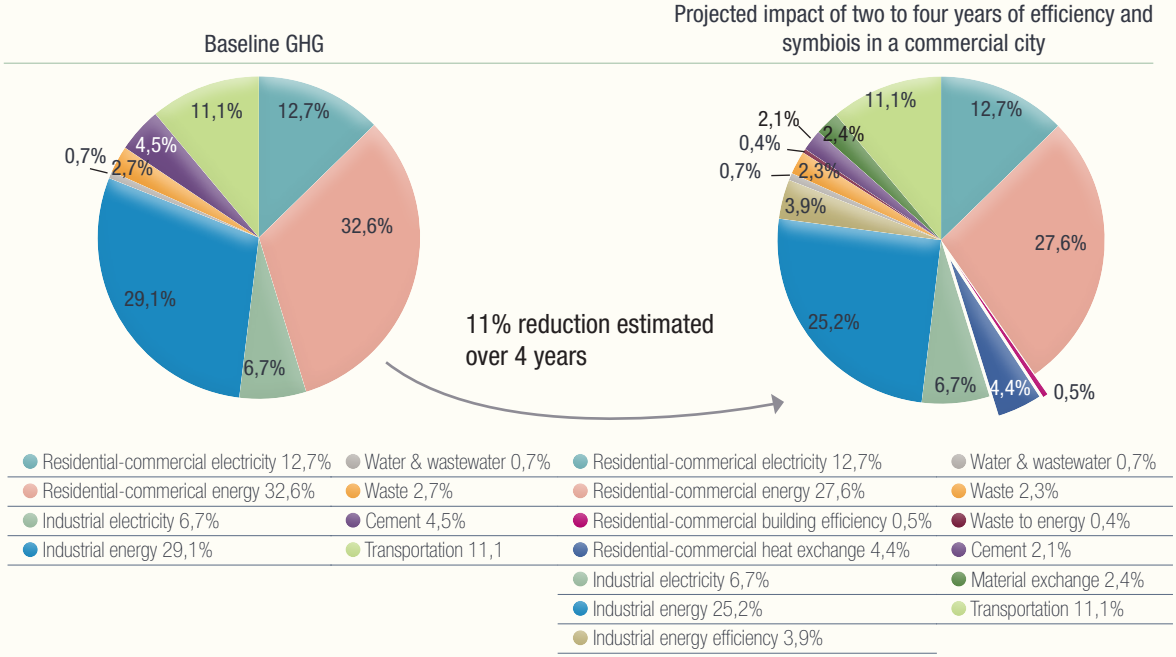


- Residential electricity 11,4%
- Residential natural gas 8,0%
- Commerical & industrial buildings electricity 37,6%
- Commerical & industrial buildings natural gas 9,7%
- Airports 8,4%
- Ground transport 22,2%
- Waste & wastewater 0,9%
- Waste 0,3%
- Cement 1,5%
- Residential electricity 5,7%
- Residential energy efficiency 2,9%
- Residential natural gas 5,7%
- Natural gas reduction from district energy 2,3%
- Reduction from renewable energy 16,3%
- Commercial & industrial buildings electricity 17,8%
- Commercial & industrial buildings energy efficiency 9,5%
- Commercial & industrial buildings natural gas 6,5%
- Airports 8,4%
- Ground transport 19,9%
- Ground transport reductions 2,3%
- Water & wastewater 0,9%
- Waste 0,3%
- Cement 1,5%

Fast-growing Chinese cities case study — Beijing and Kaifeng

Energy scenario modeling of Chinese case studies shows that, in the context of rapidly growing industrializing cities, GHG emission reductions of up to 40 percent can be achieved over a short period of time (about four years) by implementing existing building and industrial efficiency targets established in Five-Year Plans (FYPs), and adopting industrial symbiosis approaches across sectors. Reuse of waste heat from industries and material exchange strategies have a particularly large impact in highly industrial cities when compared to more commercial cities, driven by the balance between industries and co-located commercial and residential homes. Design strategies that enable exchange of materials and energy within cities can improve their resource-efficiency strategy, particularly in conjunction with fourth-generation (hot water-based) district energy systems.

Figure 6: Anticipated Scope 1 and 2 GHG benefits in a period of two to four years based on modest policies already included in China's FYP, complemented by urban industrial symbiosis

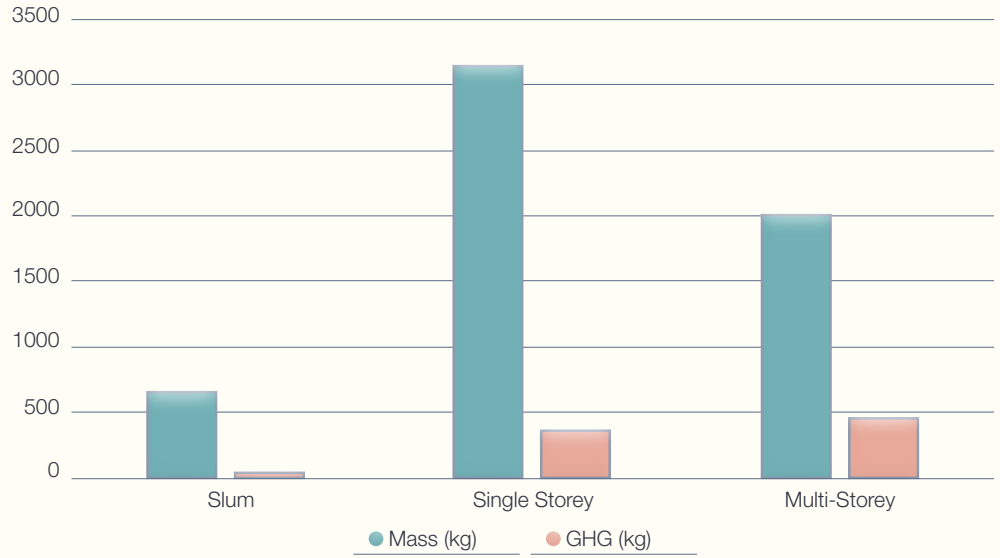


(Data and models from Ramaswami *et al.*, 2017 and Tong *et al.*, 2017).

Inclusive city case study — Delhi and Ahmedabad

In India, as in many developing economies, the urban poor living in slums and informal settlements lack access to durable housing. Effective cases of in situ slum rehabilitation are documented in India, where rehabilitation from slum dwellings to multi-storey housing occurs on site and within the city core, offering benefits of reduced material use (36 percent less than single-storey construction), reduced motorized travel demand and improved access to employment. Innovative financing through incentives offered to developers has seen success in Ahmedabad where in situ slum rehabilitation has been effectively undertaken with the consent of 80 percent of the residents. Providing more equitable access to better shelter and electricity has a significant social impact, but relatively little overall resource impact. For example, if the lower 50 percentile of Delhi's households had electricity access and consumed the per capita median of 40 kWh per month of electricity compared to current consumption, the resulting demand increase would only be 13 percent.

Figure 7: Housing material by mass and by embodied GHG emissions for Multi Family (MF) homes. Single-story and multi-story designs are derived from real-world structurally code-compliant buildings in India.



(Source: Nagpure et al., 2018)

Entrepreneurial urban governance and integrated planning for urban transitions

'The Weight of Cities' showcases alternative options for a radical break away from the unsustainable present situation, and establishes the case for resource-efficient urbanism to become a key policy priority. Accelerating urban productivity by restructuring the morphological form of neighbourhoods, investing in city-wide mass-transit systems, building inclusive renewable energy grids and energy-efficient buildings, reducing wastes to zero and resource sharing will crucially depend on the emergence of appropriate modes of urban governance.

We will need new leadership coalitions to realize the potential of accelerated urban transitions. However, the form this takes will vary greatly depending on the context. In cities of the Global North with well-developed urban infrastructures, city-level leadership will be faced with the challenge of lock-in and sunk costs if they are seriously committed to retrofitting; whereas in cities of the Global South that have not yet sunk in concrete 19th or 20th Century technologies, the challenge will be to secure and build up the necessary institutional capacity for implementation and also, the need to overcome the modernist aspiration to 'be like the West'.

The approximate $90 trillion that is estimated to be spent on new or renewed urban infrastructure between now and 2050 can either reinforce a business-as-usual paradigm of the car-oriented '100-mile city' or, alternatively, promote densities and infrastructure solutions that make it possible to live a good quality of life without emitting more than 2 tonnes of CO_2 per capita per annum, and without using more than 6–8 tonnes of resources per capita per annum.

To be both guiding and responsive in ways that allow experiments in sociotechnical change and strategic intensification to

be upscaled, **there must be a balance between informational development, human development and sustainable developmen**t. To this end, entrepreneurial governance of urban experimentation will be needed to envisage an active and goal-setting role for the state, in a way that allows broader coalitions of urban 'agents of change' to emerge and to maximize the potential of new information and communication technologies.

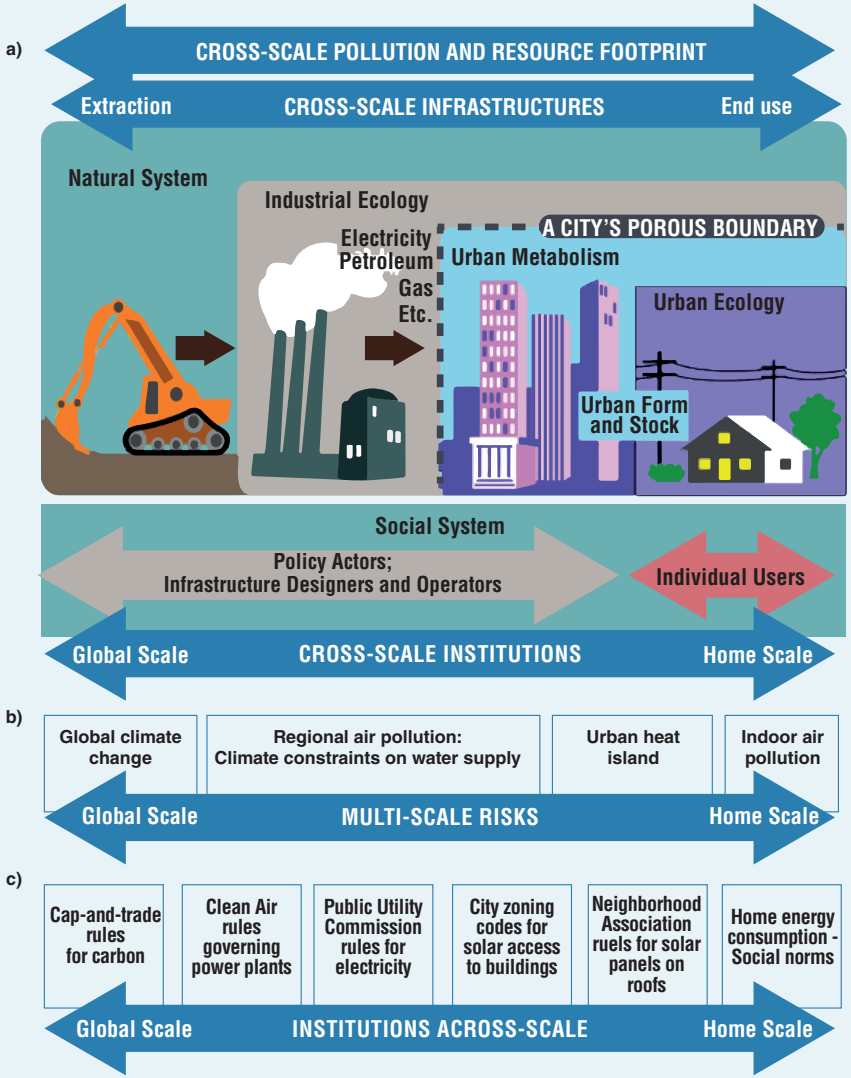
Integrated urban planning holds the key to achieving sustainable urban growth, especially with respect to setting flexible frameworks for guiding the spatial evolution of high-density, mixed-used neighbourhoods with access to affordable and efficient transit and multi-purpose public spaces.

Resource efficiency can never be a matter of cities alone. The sourcing of resources is nearly always international. Similarly, the consequences of faulty resource strategies are often regional or even global in scope. A strategy of resource-efficient urbanization therefore encompasses changes in policy at the international, the national and the local/regional level.

Given the uneven geography of urbanization patterns, **the diversity of urban regulatory regimes must be recognized** when conceptualizing the future of urban governance – these range from the structurally formal, highly regulated regimes in cities in developed countries to the highly informal and unregulated regimes in many poorer cities. Hybridized and diverse urban service delivery systems in Southern cities reflect their heterogeneity.

Finally, **there are a multiplicity of state-led, market-led, technology-led and citizen-led urban experiments already under way around the world** that reinforce the notion that urban experimentation is, indeed, emerging as a mode of urban governance fit for the complexities of the 21st Century. Sharing case studies between cities helps to inspire innovation and facilitate learning.

Figure 8: Pictorial illustration of the socio-ecological-infrastructural systems (SEIS) framework



(Source: Ramaswami et al., 2012)

Credit: Thampapon/shutterstock.com

Recommendations for policymakers

City stakeholders from academia, policymakers, community leaders, designers and the business community need to reconnect and rethink the relationship between cities and the natural environment. This is envisaged as a movement propelled by strong visions of current and possible success, examples that speak to the imagination, as well as by scholarly work that explains why certain results could be achieved, and how other cities may learn from them. It is crucial to capture the productive energy of policymakers, insights from academics, initiatives from civil society, designers, business and finance to rethink existing cities as well as create new ones. Urban metabolism provides a powerful language to facilitate collaboration between different but intersecting world views, as has been done with this report.

The push to really break away from the current rates of material resource consumption and GHG emissions should create a spike of sustainability-oriented innovations. If done well, sustainability will become an aspirational good in itself.

The following recommendations are proposed:

1. **Urban metabolisms must shift from 'linear' to 'circular':** This implies new approaches to managing the movement of resources through the city – both in terms of stocks (e.g. building materials) and flows that service the city (e.g. water, energy and waste). Concepts such as 'urban mining', 'resource cascading', 'industrial symbiosis' and the various manifestations of 're-economy' (reduce, reuse, recycle) will define the new urbanism. Sanitation and solid waste systems will have to shift from being collectors of pollutants for disposal towards being providers of water, energy, materials, nutrients and employment. Businesses and cities will have to focus on offering high value *services* rather than selling *artefacts*;

providing heat instead of heaters, mobility instead of highways and cars, light instead of light bulbs. Most sustainable may be those cities and neighbourhoods that can constantly adapt to new demands.

2. **Urban metabolisms must be monitored to assist strategic planning at local government level:** Awareness of resource use is a significant driver of change towards resource efficiency. Inputs to cities, such as biomaterials (from fuels to food), and the production of solid and liquid waste and airborne emissions must be understood. Local governments must use this information to develop resource efficiency strategies. A system of 'green accounting' of material flows and environmental emissions could be used as a first step to rethinking the resource balance sheet in business and public service.

3. **The relationship between GDP and material flows, global land use and GHG emissions must be measured, and targets must be set:** The negative externalities of various resource usages must be priced in. Pricing of carbon emissions and scarce resources like water will provide economic incentives for behavioural change. Attention should also be paid to the economics of land, including further investigation into value added tax that helps local governments to recoup the money they spend on maintaining public infrastructure. Ultimately, however, we need to move beyond GDP as the only measurement of progress, and shift to a system that assesses well-being.

4. **City planning 'defaults' must be changed:** Cityscapes need to be designed for people not cars, and must allow the poor in particular to access the opportunities of the city. We recommend a radical change in default approaches to urban planning to prevent uncontrolled sprawl and 1) promote high-density, mixed-use nodes with safe and inviting streetscapes, connected by efficient and affordable mass transit systems; 2) liveable, functionally and socially mixed neighbourhoods; 3) resource-efficient smart buildings and urban energy, waste and water systems; and 4) changing values and behaviour to support this.

5. **Use urban infrastructure as a catalyst for sustainable cities:** In order for cities to shift their defaults towards sustainability, it is crucial that existing infrastructure budgets are channeled in new directions. A low-carbon scenario would require adding only 5 percent to infrastructure spending (Global Commission on the Economy and Climate, 2014). We therefore recommend judging the massive investments in urban infrastructure in the next decades based on a set of criteria and goals that are drawn up to make achieving the SDGs realistic.

6. **Urban infrastructure and land-use policy must be strategically linked to achieve sustainability goals:** Transit-oriented development (TOD) has the potential to significantly change the way people and goods move through the city, thus reducing dependence on fossil fuels and potentially improving quality of life for city inhabitants in a number of ways. Approaching TOD and area development as integrated portfolios is crucial for better accessibility and could help reduce urban inequities.

7. **Develop appealing mixed-use and socially mixed inner-city neighbourhoods:** These should be attractive and therefore remove the incentive to invest in the urbanization of the suburbs, focusing development instead around high-access 'nodes' of the transport network. This requires an integrative approach in which such mixed-use and socially mixed neighbourhoods also house the top schools, cultural amenities, sporting and recreation facilities, and pavements that are safe and clean (avoiding the development of high security residential enclaves for upper-income groups, since this stands in the way of achieving socially inclusive cities). The emphasis would therefore be on mixed-use and socially mixed neighbourhoods not only supporting the SDG of social inclusion, but also helping reduce the resource requirements of urban life by locating activities closer together and avoiding long commutes.

8. **We need new imaginative business propositions to guide strategic planning for vibrant, green and socially inclusive cities.** We recommend using good presentations of successful case studies (e.g. new transport systems, efficient buildings, renewable energy provision in informal settings, planning of metabolic urban flows, industrial symbiosis, etc.) as the driving force of the sustainability transition. Combining these results can create appealing visions of post-carbon, highly resource-efficient and liveable cities that can build the appetite of both investors and politicians for sustainable urban futures. The history of urbanism shows that such imaginaries of new possible worlds can have powerful effects on rethinking and reordering cities. Creating and sharing new 'real utopias' helps to break away from default routines. Visual representations can help make people aware of the choices available.

Imaginaries: Representations of possible futures, often via a combination of images, compelling narratives and calculations. When powerful, imaginaries have transformative capacity and actively shape decisions in the present.

9. **A politics of experimentation can provide hope for a better future:** We recommend approaching cities as agents of change and thinking about ways in which city governments, the business community and local communities can significantly improve their collaboration to shift onto this alternative trajectory. Resource-efficient urbanism can connect to a new politics of experimentation that is seen emerging in cities around the world. Concepts such as 'living labs', city deals, innovation hubs and special zones indicate that cities are now thinking much more in terms of 'learning by doing' than focusing on one solution and trying to apply it everywhere. Most likely it is this politics of experimentation that will provide the inspiration and mutual learning that can really drive a broader transition.
10. **Cities must learn from the experiences of other cities to hasten transition:** We recommend accelerating learning by investing in city networks and 'twin town' or 'sister city' initiatives that function as horizontal communicative and learning platforms. The learning capacity of cities can be enhanced by investing in networks of cities at various scales: nationally, internationally or even globally. Investments must be made to build institutions that help these networks to work better and build solidarity between cities.
11. **Higher levels of government must support city-level innovation for resource efficiency:** Cities are highly dependent on higher levels of government. Collaboration with higher levels of government is essential if cities and networks of cities are to overcome regulatory barriers and access funding for innovation. Reinforcement, inspection and compliance are mostly national responsibilities, and should serve to support cities in achieving resource-efficiency goals. Similarly, prices and taxes set at the national level can contribute significantly to providing incentives and disincentives for behaviours that support resource efficiency.

Each city is unique, so we recommend combining analysis at the global level with constant 'deep dives' into local and regional strategies. We therefore promote an approach that mobilizes local ingenuity in a manner that appreciates local contexts and allows for the creation of new, forward-thinking engines of growth and development.

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The proportion of the global population living in cities and towns is expected to rise from 54 percent in 2015 to 66 percent by 2050; which will result in a significant expansion of existing cities, as well as the construction of new cities. Without a new approach to urbanization the material consumption by the world's cities will grow from 40 billion tonnes in 2010 to about 90 billion tonnes by 2050. Therefore the resource use implications and environmental impacts of urbanization are significant. Resources should now become a central policy concern, in addition to concerns over climate change.

We have a once-in-a-lifetime opportunity to shift the expected urbanization onto a more environmentally sustainable and socially just path. Decisions made today on urbanization and land use models, as well as on critical infrastructure, will determine whether our investments are future-proof or whether they in fact lock us into an unsustainable path.

This report calls for a new strategy for 21st Century urbanization and presents the parallel actions on urban planning, sustainable design, resource efficient components, and infrastructure for cross-sector efficiency that are required for a transition towards low-carbon, resource-efficient and socially just cities. It also presents the new governance model and politics of new imaginative business propositions and experimentation that will make possible such transition.

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