THE NEW CLIMATE ECONOMY

The Global Commission on the Economy and Climate

LSECities

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NCE Cities – Paper 01

CITIES AND THE NEW CLIMATE ECONOMY: THE TRANSFORMATIVE ROLE OF GLOBAL URBAN GROWTH

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The New Climate Economy

The New Climate Economy (NCE) is the flagship project of the Global Commission on the Economy and Climate. It was established by seven countries, Colombia, Ethiopia, Indonesia, Norway, South Korea, Sweden and the United Kingdom, as an independent initiative to examine how countries can achieve economic growth while dealing with the risks posed by climate change. The NCE Cities Research Programme is led by LSE Cities at the London School of Economics. The programme includes a consortium of researchers from the Stockholm Environment Institute, the ESRC Centre for Climate Change Economics and Policy, the World Resources Institute, Victoria Transport Policy Institute, and Oxford Economics. The NCE Cities Research Programme is directed by Graham Floater and Philipp Rode.

ABSTRACT

Urbanisation is one of the most important drivers of productivity and growth in the global economy. Between 2014 and 2050, the urban population is projected to increase by around 2.5 billion people, reaching 66% of the global population. By 2030, China's cities alone will be home to nearly 1 billion people. India, Nigeria and Indonesia will also experience rapid population growth. If managed well, the potential benefits of this urban growth are substantial. The economic potential is driven by raised productivity resulting from the concentration of people and economic activities in cities that leads to a vibrant market and fertile environment for innovation in ideas, technologies and processes. Similarly, well-managed cities in high income countries could continue to concentrate national economic growth, through re-densification and the roll out of innovative infrastructure and technologies.

Disclaimer

However, poorly managed urban growth is likely to have substantial economic costs. Urban sprawl, poor public transport infrastructure and a lack of basic services such as energy, water and waste can hinder accessibility and mobility, increase air pollution and exacerbate urban poverty, reducing the economic benefits of urban concentrations and increasing costs. This growth pathway also tends to lead to unnecessary greenhouse gas emissions, social exclusion and a range of other environmental and social costs.

In this paper, we identify three groups of cities that will be particularly important for the global economy and climate: Emerging Cities, Global Megacities and Mature Cities. When combined, these 468 cities are projected to contribute over 60% of global GDP growth and over half of global energy-related emissions growth between 2012 and 2030 under business as usual. We also review the contribution of small urban areas to economic growth and carbon emissions.

The choices that countries and cities make today about managing urban growth, particularly in these 468 cities, will lock-in the economic and climate benefits - or costs - for decades to come. The life span of capital intensive urban infrastructure such as roads and buildings typically ranges from 30 to 100 years, and the path dependencies created by urban form are sustained over centuries. Over the next decades, this will be particularly important for Emerging Cities and the periphery of many Global Megacities where much of urban growth will take place.

Evidence suggests that the characteristics of poorly managed - or unmanaged - urban growth are increasing worldwide, as part of a business as usual trend. In this paper, we introduce a new, alternative model of urban development - the '3C model'. The 3C model – compact, connected and coordinated – aims to lock-in economic and climate benefits in cities. Three pillars underpin the model:

- Compact urban growth: through managed expansion and/or urban retrofitting that encourages higher densities, contiguous development, functionally and socially mixed neighbourhoods, walkable and human-scale local urban environments, the redevelopment of existing brownfield sites and provision of green spaces.

- Connected infrastructure: through investment in innovative urban infrastructure and technology such as Bus Rapid Transit, cycle superhighways, electric vehicles, smart grids, energy efficient buildings and essential water, sanitation and waste services.

- Coordinated governance: through effective and accountable institutions to support the coordinated planning and implementation of programmes of activity and investment across public and private sectors and civil society, particularly for land-use change and transport.

We explore the potential of the 3C model to maximise the benefits of urban growth while minimising the costs in Emerging Cities, Global Megacities and Mature Cities, and we review examples of cities where elements of the model have already been implemented.

This paper is one of three papers by LSE Cities that form part of the Cities Research Programme of the New Climate Economy (NCE) project for the Global Commission on the Economy and Climate.

The two other contributing papers cover 'Steering urban growth: governance, policy and finance' (NCE Paper 02) where we explore the challenges of delivering the 3C model, examine in more detail the importance of coordinated governance and explore the most promising policy tools for delivering the model in terms of planning policy, pricing instruments and finance mechanisms; and 'Accessibility in Cities: Transport and Urban Form' (NCE Paper 03) where we analyse compact urban growth and connected infrastructure in greater detail.

1 INTRODUCTION

Urbanisation is one of the most important drivers to shape the global economy in the 21st century. For the first time in human history, over half the world's population now lives in urban areas. As a proportion of global population, the urban population is expected to reach 60% by 2030, with urban areas growing at a rate of 1.3 million people every week (UN DESA 2014a). Historically, high income countries have tended to go through rural to urban transitions, driven by dynamic cities that act as regional economic hubs and engines of growth. Consequently, the potential benefits of this urban growth are substantial. Urban growth is rapidly transforming the economic landscape of emerging markets, while the economic importance of cities in high income countries will continue to grow. The 90 largest Chinese urban economies already account for over US$6 trillion in Gross Domestic Product (GDP) – the size of the national economies of Germany and France combined.[1] And while cities in India are home to just a third of the population, they generate two thirds of national GDP, 90% of total tax revenues, and the majority of jobs (McKinsey Global Institute 2010).

Over the next two to three decades, the economic concentration of cities in China, India and other emerging regions will continue to grow rapidly. By 2030, the middle class in China could total one billion people, corresponding to around 70% of China's total projected population (EY 2013). The majority of these middle-class consumers will be concentrated in the country's urban centres. At the same time, the pace of urbanisation is uncertain. Urban population levels could range from 55–78% in China and 38–69% in India by 2050 (O'Neill, Ren et al. 2012), depending on the pace of rural-urban migration, demographics, and policy decisions made by national, regional, and city governments. This makes planning for urbanisation more challenging. Urban growth, particularly in cities, will also play an important role in the economies of high income countries. Analysis for this paper estimates that cities above 0.5 million with income per capita above US$20,000 represent around 37% of global GDP in 2012 and could drive 27% of global urban income growth between 2012 and 2030.

While the potential benefits of urban development are substantial, poorly managed urban growth is likely to have economic costs. The economic potential of urban growth is driven by raised productivity resulting from the concentration of people and economic activities in cities. Concentrated economic and social interactions create a vibrant market and fertile environment for innovation in ideas, technologies and processes (Lucas 1993; Black and Henderson 1999; Rosenthal and Strange 2003; Glaeser 2011). However, poorly managed urban growth can reduce the economic benefits of urban concentrations and increase costs. Poorly managed growth is defined here as urban development that results in economic, social and environmental costs. These costs can arise from, among others, urban sprawl, inefficient public transport infrastructure, energy inefficient buildings, air pollution, social exclusion and a lack of basic services such as energy, water and waste. These characteristics can be seen in many cities worldwide, as part of a business as usual trend.

Poorly managed urban growth also leads to the inefficient use of energy and unnecessary greenhouse gas emissions. For example, urban sprawl and high levels of motorisation can increase urban carbon emissions substantially, both in terms of embedded emissions in the production of infrastructure and from transport operations (IPCC 2014d). Urban areas are associated with around 70% of global energy consumption and over 70% of energy-related carbon emissions (IPCC 2014d). Furthermore, expansion of urban infrastructure on a business as usual trajectory up to 2050 is projected to generate 470 gigatonnes of carbon emissions (IPCC 2014). Key drivers of urban greenhouse gas emissions include population growth, income growth, local temperatures, industrial composition, design and technology, and market failures. Urban emissions from emerging economy cities are converging with those of developed cities (World Bank 2014). For example, per capita emissions in Beijing and Shanghai are comparable to large European and some North American cities (World Bank 2014; Sugar et al. 2012).

The choices that countries and cities make today about managing urban growth will lock-in economic and climate benefits - or costs - for decades to come. The life span of capital intensive, largely irreversible urban infrastructure investments such as roads and buildings typically range from 30 to 100 years, and the path dependencies created by urban form are sustained over centuries. Historical path dependencies can be seen in the widely varying rates of energy consumption and greenhouse gas emissions today among cities with similar per capita income and climate, due to past policy decisions that have shaped their urban form, transport systems and building energy efficiencies. Over the next decades, this will be particularly important for cities in emerging economies. For example, 70–80% of the urban infrastructure that will exist in India in 2050 has yet to be built (McKinsey Global Institute 2010).

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[1] *From analysis by LSE Cities using data from Oxford Economics for this paper.*

In this paper, commissioned by the Global Commission on the Economy and Climate as part of the New Climate Economy project, we examine potential impacts of urbanisation on the economy and climate and the choices that governments face for managing urban growth. In particular, we address a key question facing policy makers at national, regional and local levels: can urban growth in cities over the next two to three decades be managed in a way that improves the economic performance of countries and cities and the quality of life of those who live in them – and at the same time reduce its contribution to climate change?

We start in section 2 by using a new analysis of cities above 0.5 million people (based on the metropolitan area) to examine the business as usual trend in urban growth between 2012 and 2030 and its impacts on the global economy and climate. We identify three groups of cities that will be particularly important over this period: Emerging Cities, Global Megacities and Mature Cities. When combined, these 468 cities are projected to contribute over 60% of global GDP growth and over half of global energy-related emissions growth between 2012 and 2030 under business as usual. In section 3, we review the costs of poorly managed urban growth in different regions of the world, including the costs of locking in sprawl and motorisation. Finally, in section 4, we examine an alternative growth pathway based on a new urban development model – the 3C model. The model has three pillars: compact urban growth, connected infrastructure, and coordinated governance.

The 3C model draws on a range of evidence in the existing literature (e.g. World Bank 2010a, 2014a; OECD 2012a, 2012d, 2014c; UN-Habitat 2013; Gyergay forthcoming and references therein). We define compact urban growth here as relatively dense, proximate development, with high levels of accessibility to local employment and services (OECD 2012a). This is not about urban containment, but rather about how urban expansion is managed to avoid inefficient sprawl and, for cities with existing sprawl, how re-densification and transit policies can increase economic efficiency and reduce environmental and social impacts. Similarly, different cities will have different starting position in terms of connected infrastructure and coordinated governance. Consequently, although the 3C model provides principles for all cities, its implementation will differ from city to city.

We explore the potential of the 3C model to maximise the benefits of urban growth while minimising the costs, and we review examples of cities where elements of the model have already been implemented. While the paper uses the urban transport sector to illustrate the cross-cutting nature of the model, the 3C concept covers many other sectors and types of infrastructure such as buildings, energy, water and waste. Innovation in buildings and energy systems are covered in other parts of the New Climate Economy project for the Global Commission, and a large literature exists for other sectors (Bogner et al. 2007; Swart and Raes 2007; Sattherthwaite et al. 2009; OECD 2011; Hammer et al. 2011; Mees and Driessen 2011; Merk et al. 2012; Licciardi 2012; Viguié and Hallegatte 2012; Hoornweg, Freire et al. 2013; Kennedy and Corfee-Morlot 2013; IPCC 2014a, 2014c, 2014d, 2014e, 2014f).

Urbanisation and urban change – and their associated economic and climate-related effects – represent a vast research area that is beyond the scope of one paper. For this reason the paper, as commissioned by the Global Commission, focuses specifically on the role of cities in the global economy and climate over the next two to three decades, and uses the urban transport sector as an illustrative example.

Evidence on the dynamics of small urban areas is scarce: the recent revision of world urbanisation prospects by the United Nations makes a distinction between cities (with a population above 0.5 million) and other, smaller, urban areas (UN DESA 2014a). We follow this distinction in our paper, and using new analysis show that 468 of metropolitan areas above 0.5 million are projected to contribute over 60% of global GDP growth and over half of global energy-related emissions growth between 2012 and 2030 under business as usual. We briefly review the contribution of small urban areas to economic growth and carbon emissions based on the very limited data available. Many of these small urban areas are in Sub-Saharan Africa where urbanisation is often taking place not through industrialisation but through natural resource endowments. While the process of urbanisation with and without industrialisation is not within the scope of this paper, a range of existing literature can be consulted (see for example, Fay and Opal 2000; Henderson 2003; Gollin, Jedwab et al. 2014 and references therein).

The paper uses a mixed-method approach. First, evidence from the literature has been reviewed and synthesised. Second, a call for evidence in 2014 has been used to gather and synthesise further information on cities, the economy and climate as part of the New Climate Economy project. Third, the paper also draws on a 2012 survey of officials and other key stakeholders in 90 cities worldwide on the green economy (Rode, Floater et al. 2013). Finally, the paper uses new top down analysis to estimate the growth of population, income and carbon emissions of over 700 cities worldwide between 2012 and 2030.

A major challenge for the analysis of carbon emissions at the city level is the lack of robust, comparable data. In a survey of existing city emissions data for this paper, only around 40 cities were found to have published carbon emissions over the last three years, and only 12 of these provided a clear breakdown of emissions for key sectors of the economy. In this paper, we attempt for the first time to use a top down approach to estimate not only the growth in population across over 700 cities with a population above 0.5 million, but also the growth in income and carbon emissions. To our knowledge, this has not been attempted before. A detailed description of the data sources and methods used for analysis are set out in the Appendix, while the results are presented in section 2.3.

This paper is the first of three New Climate Economy papers by LSE Cities for the Global Commission. In the second paper, 'Steering Urban Growth: Governance, Policy and Finance', we examine in more detail the importance of coordinated governance and explore the most promising policy tools for delivering the 3C model in terms of planning policy, pricing instruments and finance mechanisms (Floater, Rode et al. 2014b). In the third paper, 'Accessibility in Cities: Transport and Urban Form', we analyse the importance of compact urban growth and connected infrastructure in more detail (Rode, Floater et al. 2014). The three papers form the basis of the cities chapter of the New Climate Economy Report, which provides conclusions and recommendations on managing urban growth. The papers are aimed at a range of audiences including national policy makers, regional and municipal policy makers, as well as other stakeholders with an interest in the impacts of urban change on the economy and climate.

2 URBANISATION IN THE 21ST CENTURY

Around 3.9 billion people now live in urban areas (UN DESA 2014a). Between 2014 and 2050, the urban population share is projected to increase by around 2.5 billion, reaching 66% of the global population (UN DESA 2014a; Figure 1). In 30 years, the percentage of the population living in urban areas in China has risen from 23% to 55% (UN DESA 2014a). This same process took 100 years in Britain and 60 years in the United States (The Economist 2014). Furthermore, urban growth in China and other emerging and developing countries is set to continue on a large scale and at a rapid pace. By 2030, China's cities alone will be home to nearly 1 billion people or 69% of its population (UN DESA 2014a).

Figure 1
Global urban and rural population, 1950–2050
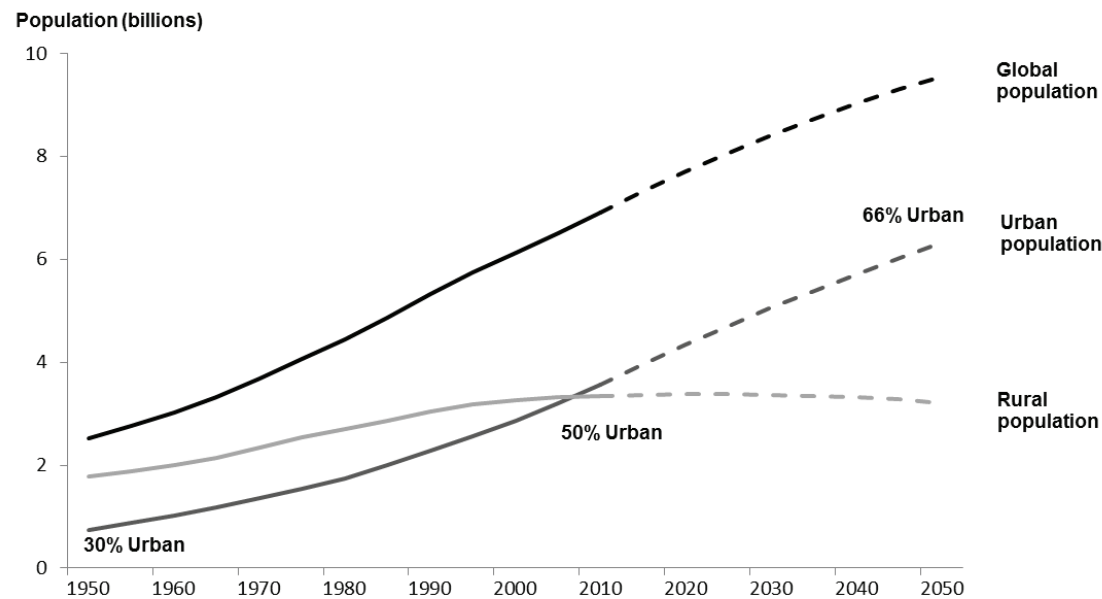
Source: LSE Cities based on United Nations World Urbanization Prospects, 2014 Revision

This rapid urbanisation is also taking place at earlier economic development stages than in previous decades, occurring largely in lower- and middle-income cities in Sub-Saharan Africa, South and East Asia (UN Habitat 2014). Over the next 20 years, the urban population of South Asia and Sub-Saharan Africa, which includes some of the poorest people in the world, is expected to double (World Bank 2010). Nearly 90% of the world's urban population growth will occur in cities in Africa and Asia (UN DESA 2014a). Less developed countries will need to make room for an additional 1 billion urban residents, while developed countries are expected to add 68 million people to their cities by 2030 (UN DESA 2014a). Urban poverty is still a major challenge, with the number of people living in informal settlements projected to rise globally from 1 billion to 2 billion by 2030, primarily in Sub-Saharan Africa, South Asia and Latin America (UN-Habitat 2003). Growing urban poverty will be particularly acute over the next 30 years and further exacerbated by insufficient institutional capacity in cities.

Countries may not capture the benefits of urbanisation equally. Following urban growth in the 20th century, urban areas now account for around 80% of global economic output (Grubler et al. 2007; GEA 2012; IPCC 2014d; World Bank 2014c). However, while some cities and countries have grown strongly, others have stagnated. While the world's largest 150 metropolitan economies represent only 13.5% of the global population, they account for 40% of global GDP.[2] At the other end of the spectrum, the combined economic output of the 220 largest metropolitan areas in low income countries is around US$1.54 trillion, which is lower than that of Tokyo alone at US$1.97 trillion. This suggests that cities and countries that manage urban growth well can benefit from substantial economic gains. However, if urban growth is managed poorly – or unmanaged – countries and cities are likely to miss the opportunities for higher growth and productivity.

[2] From analysis by LSE Cities 2014 using data from Oxford Economics for this paper.

2.2 Urbanisation in rapidly growing regions

Many regions of the world are already highly urbanised. In 2014, urban dwellers represented 81.5% of the population in North America, 79.5% in Latin America, 73.4% in Europe and 70.8% in Oceania (UN DESA 2014a). In contrast, populations in Africa and Asia remain largely rural, with levels of urbanisation in 2014 at 40% and 47.5% respectively (Figure 2, Box 1). These two regions, today representing 90% of the world's rural population, will experience the most rapid rural to urban shift over the next two to three decades, reaching urbanisation levels of 56% in Africa and 64% in Asia by 2050 (Figure 3). In particular, the highest growth rates in urban population will be in China and India, followed by Nigeria and Indonesia (Figure 4). In this section, we discuss the patterns of urbanisation in these rapidly growing regions.

Box 1
Urbanisation Trends in Different Regions and Countries

In July 2014, the Population Division of the Department of Economic and Social Affairs at the United Nations (UN DESA) published its 2014 Revision of World Urbanization Prospects. The latest figures show that the urban populations in Africa and Asia are projected to grow rapidly out to 2050. The countries with the highest rates of urban population growth are China and India, followed by Nigeria and Indonesia. Figures 2, 3 and 4 below summarise the impact that these rapidly growing regions will have on the world's urban population.

Figure 2
Urban and rural population in Africa and Asia compared to Europe, 1950–2050
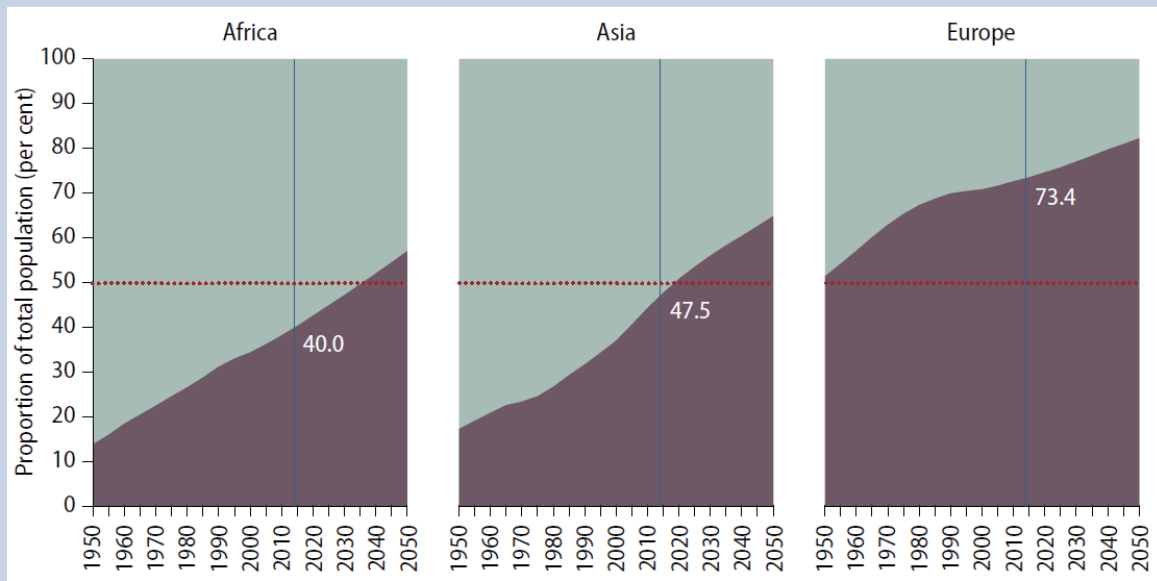
Source: UN DESA (2014a)

Figure 3

Distribution of urban population across world regions, 1950–2050

Distribution of urban population (per cent)

Legend:
- Africa
- Asia
- Europe
- Latin America and the Caribbean
- Northern America
- Oceania
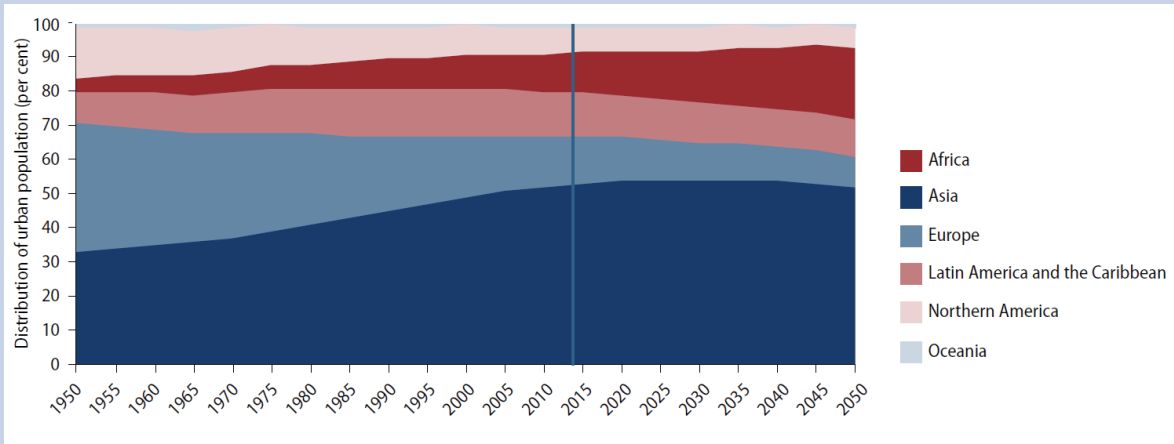
Source: UN DESA (2014a)

Figure 4

Contribution to the increase in urban population by country, 2014–2050

Urban population increase (millions)

nearly 2.5 billion urban population increase by 2050

Other countries

Angola
Viet Nam
Sudan
Iran (Islamic Republic of)
Uganda
Kenya
Iraq
Egypt
Mexico
Brazil
Philippines
Ethiopia
United Republic of Tanzania
Bangladesh

— 50%

Democratic Republic of the Congo
Pakistan
United States of America
Indonesia
Nigeria
China
India
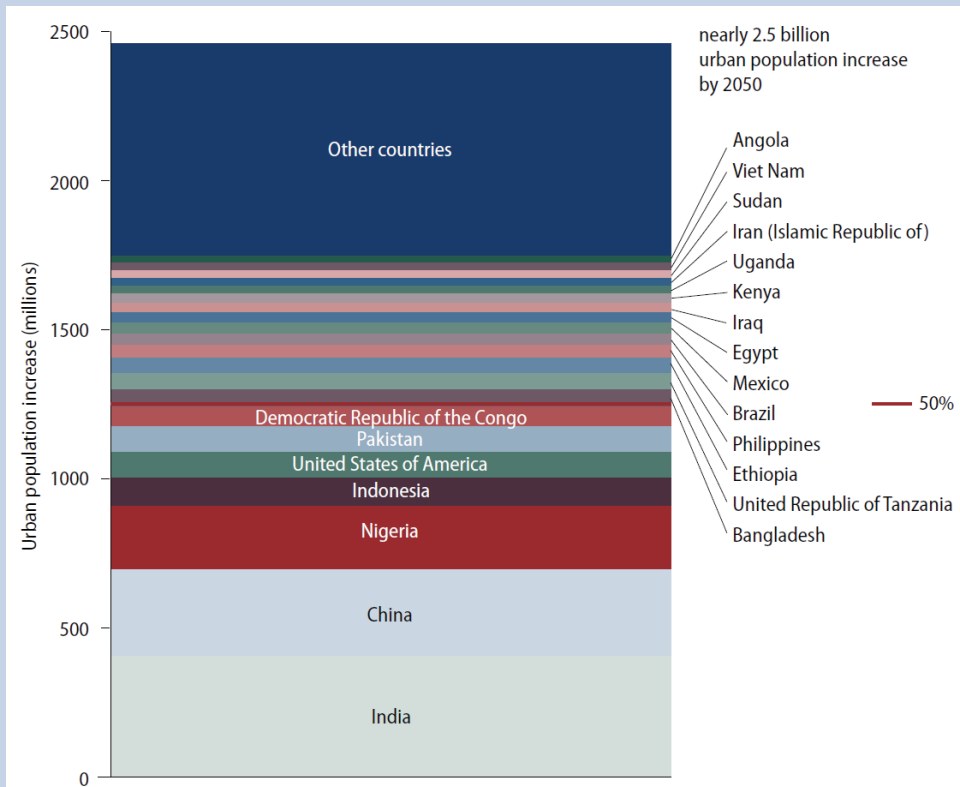
Source: UN DESA (2014a)

2.2.1 China

China's urbanisation represents the largest rural to urban transition in human history, with nearly 500 million people moving into cities in the past 30 years (World Bank 2013a). Over the course of three decades, the urban population of China has nearly tripled, increasing from 23% to 55% in 2014 (UN DESA 2014a). In 2014, the urban population of China is estimated at 758 million – the largest urban population in the world (followed by 410 million in India) (UN DESA 2014a).

This trend in rapid urbanisation in China is set to continue over the next three decades. Between 2014 and 2050, China's urban population is projected to grow by 292 million (UN DESA 2014a). At the end of this period, China will have over one billion urban dwellers, representing 66% of the national population.

These rapid rates of urbanisation have also contributed to a rise in income for millions of Chinese residents. Over the period 2000–2010, the Chinese urban middle class increased rapidly, from almost 3.5% to 19.5% (World Bank 2013a). By 2030, the middle class could total one billion people, corresponding to approximately 70% of China's total projected population (EY 2013). The majority of these middle-class consumers will be concentrated in the country's urban centres.

2.2.2 India

Over the last two decades India's urban population has increased from 217 million to 377 million, bringing the urban share to 31% in 2011 compared to 26% in 1991 (Ahluwalia 2014). While the proportion of India's population living in urban areas is currently lower than many other emerging economies, urban growth is projected to accelerate over the next twenty years, reaching 600 million or 40% of the population by 2031 (Ahluwalia 2014). India already has 53 cities each with a population of over one million, up from 35 in 2011 and projected to grow to 87 by 2031 (Ahluwalia 2014).

The most rapid urban population growth in India is taking place in its secondary cities with populations of between one and five million. Between 2001 and 2011, these cities grew by over 45% and together with other million-plus cities are home to 43% of the urban population (Ahluwalia 2014). Approximately 20% of growth in the urban population can be attributed to rural to urban migration, but a large proportion also comes from internal growth and the annexation of small neighbouring towns and urban outgrowths (Ahluwalia et al. 2014). Besides these secondary cities, rapid growth is taking place in the urban periphery and in census towns. Overall 2,774 new towns were added between 2001 and 2011, of which 91% were 'census towns', defined as towns lacking the statutory status of a municipality (Tewari et al. 2014). These towns often have no urban laws or urban budgets. Small cities with a population of over 100,000 are home to 70% of India's urban population and this proportion is rising rapidly (Tewari et al. 2014).

Growth is also substantial on the urban periphery of large cities. These areas are generally not accounted for in urban statistics and incompletely accounted for in rural data. Yet rapid expansion is taking place in these peri-urban areas, much of it unmanaged, ad hoc and outside city codes and byelaws (Tewari et al. 2014). Unlike Chinese peri-urban areas where local governments have been the main drivers of rural land conversion, Indian peri-urban growth is the result of private actors and household decisions rather than government intervention (APN 2010).

2.2.3 South East Asia

Urbanisation rates in South East Asian countries – apart from Singapore and Brunei Darussalam – are low compared to many other regions in the world, but they are growing rapidly. In 2010, the share of urban population in South East Asian countries was 45% (compared to 46% for less developed regions overall), and by 2050 this share is expected to grow to 65%, surpassing the less developed region average (63%) (UN DESA 2014b). In absolute terms, the region will add 100 million new urban residents between 2010 and 2025, and by 2050 the urban population will reach over 500 million, close to double the 266 million in 2010 (UN DESA 2012b). The region displays a lot of heterogeneity, with the highest urbanisation rates in 2010 occurring in Singapore (100%), Brunei (76%) and Malaysia (71%). At the other end of the scale, Cambodia is home to the smallest share of urban population (20%) and several lower- and middle-income countries are clustered around 30%: Vietnam (30%), Myanmar (31%) and Lao PDR (33%). Thailand (44%), the Philippines (49%) and Indonesia (50%) are close to the regional average (UN DESA 2014b).

Urbanisation rates can underplay the importance of cities in some countries. For example, while urbanisation rates are relatively low in Vietnam and Myanmar, roughly 25% or more of the population resides in cities of over 5 million people (UN DESA 2012a). Indonesia is home to the greatest cluster of cities: in addition to Jakarta, it has six cities of between 1-5 million people and 11 cities of between 0.5-1 million people (UN DESA 2012b). Estimates of city sizes based on administrative boundaries (including UN data) tend to underestimate the size of urban areas that are agglomerations of multiple municipalities, rendering estimates based on labour markets and related criteria more useful. For example, according to estimates of metropolitan area populations, greater Jakarta is currently estimated to have 26.8 million inhabitants and greater Manila 22.4 million inhabitants, dwarfing the next largest urban areas of Bangkok (14.8 million) and Ho Chi Minh City (8 million) (Brinkhoff 2014).

2.2.4 Sub-Saharan Africa

In 2014, urban dwellers totalled 346 million people in Sub-Saharan Africa, representing only 37% of the population (UN DESA 2014a). In some African countries the proportion is substantially lower, such as Ethiopia (19%), Malawi (16%) and Burundi (12%). Countries in Western Africa tend to have higher urbanisation levels than other sub-regions south of the Sahara, ranging from 29% in Burkina Faso to 65% in Cape Verde. The largest cities in Sub-Saharan Africa in 2014 are Kinshasa (Democratic Republic of Congo) and Lagos (Nigeria), each with over 10 million people. Other large and growing cities include Dar es Salaam (Tanzania), Johannesburg (South Africa) and Luanda (Angola).

Partly as a result, the highest urban population growth in the world between 2020 and 2050 is expected in Sub-Saharan Africa, with the number of urban dwellers tripling. By the end of this period, Africa (including North Africa) is expected to represent 21% of the world's urban population (UN DESA 2014a). Furthermore, the rural to urban shift is expected to continue beyond 2050 for the rest of the century (Hoornweg and Pope 2014).

2.3 The role of cities in the global economy and climate

In this paper, we use the term cities to mean metropolitan areas above 0.5 million people. This follows the distinction made by the United Nations between cities (above 0.5 million) and urban areas below 500,000 (UN DESA 2014a). However, our analysis is based on the Oxford Economics 750 database of metropolitan areas which has been developed independently of the UN's own database (see Appendix for data sources and methods). Using metropolitan areas results in fewer, larger cities above 0.5 million compared to UN definitions.

The results of the analysis demonstrate that cities play a critical role in the global economy and climate. With a combined population of 2.4 billion in 2012, cities (including their metropolitan regions) represent around 65% of the world's urban population in 2012. They are projected to contribute 34% of population growth, 64% of urban economic growth, and 56% of carbon emissions growth from 2012 to 2030. In this section, we provide the results of analysis that shows the relative importance of cities in the global economy and as sources of carbon emissions.

Figure 5
Contribution to global population of cities above 0.5 million. The cumulative curves for 2012 and 2030 are very similar
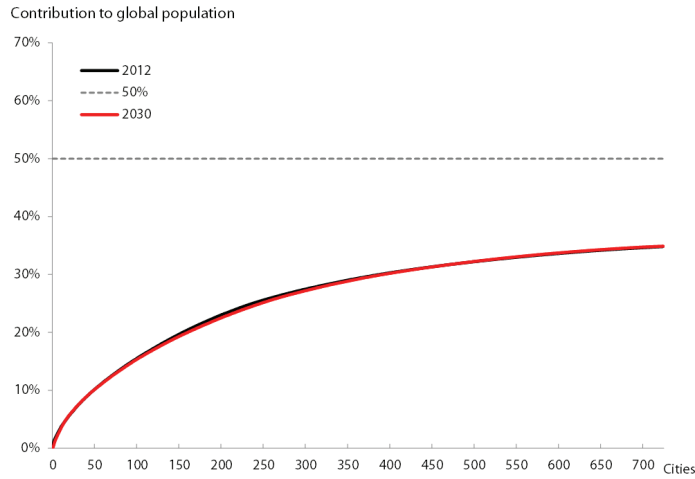
Figure 6
Contribution to global population growth of cities above 0.5 million, 2012–2030

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)
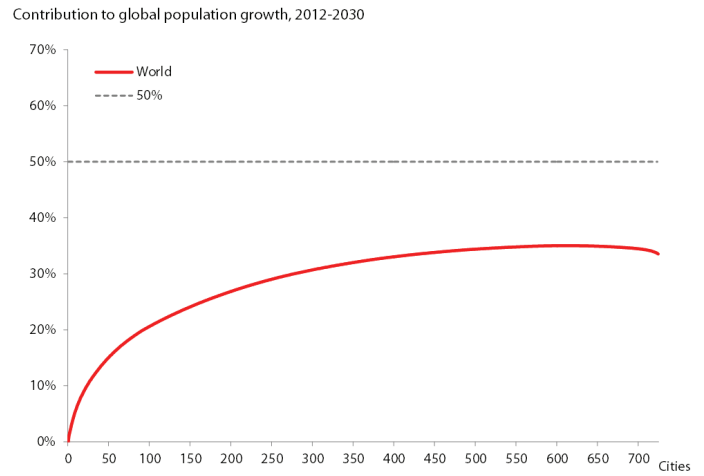
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.3.1 Population growth in cities

In 2012, there were over 700 metropolitan regions in the world with a population of over 0.5 million. Their total population is around one third of the global population; a proportion projected to remain unchanged up to 2030. Figure 5 shows the cumulative population of these cities (by population size, from largest to smallest) for 2012 and 2030 as a percentage of the global population; and it suggests a relatively static pattern of population distribution of cities over the period up to 2030. In 2012, the 50 largest cities had a global population share of 10%, similar to that projected for 2030. The contribution made by cities to global population growth between 2012 and 2030 (Figure 6) indicates that cities are expected to represent around one third of this growth, with the 20 largest cities contributing to approximately 10% and the largest 88 cities to 20% of global population growth respectively.

Figure 7 shows the relationship between population size and population growth (annualised over the period from 2012 to 2030) for all cities. Overall, the range of population growth rates is greatest for cities of a population between 0.5 million and 5 million. This group includes cities with a strong population growth of between 2.5% and 6%, as in the case of Sub-Saharan cities, as well as those with declining populations of up to -1% in several European cities. The larger the city, the more population growth rates converge around a population increase of about 1% annually. In terms of regional patterns, the highest population growth rates of Sub-Saharan cities are followed by those in India and South East Asia. Many Latin American cities, while smaller in size, display higher population growth rates compared to Chinese cities. China has the largest number of cities above 5 million people, with moderate population growth rates of around 0.5%.

Figure 7
Population size (2012) and annualised population growth (2012-2030) of cities above 0.5 million

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 8
Contribution to global GDP of cities above 0.5 million
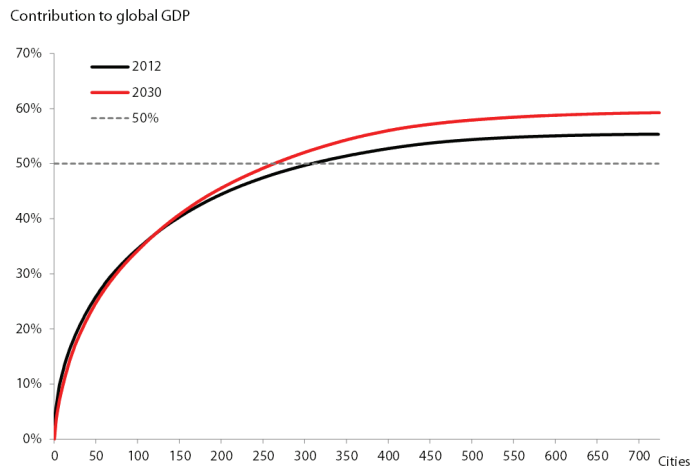
Contribution to global GDP

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 9
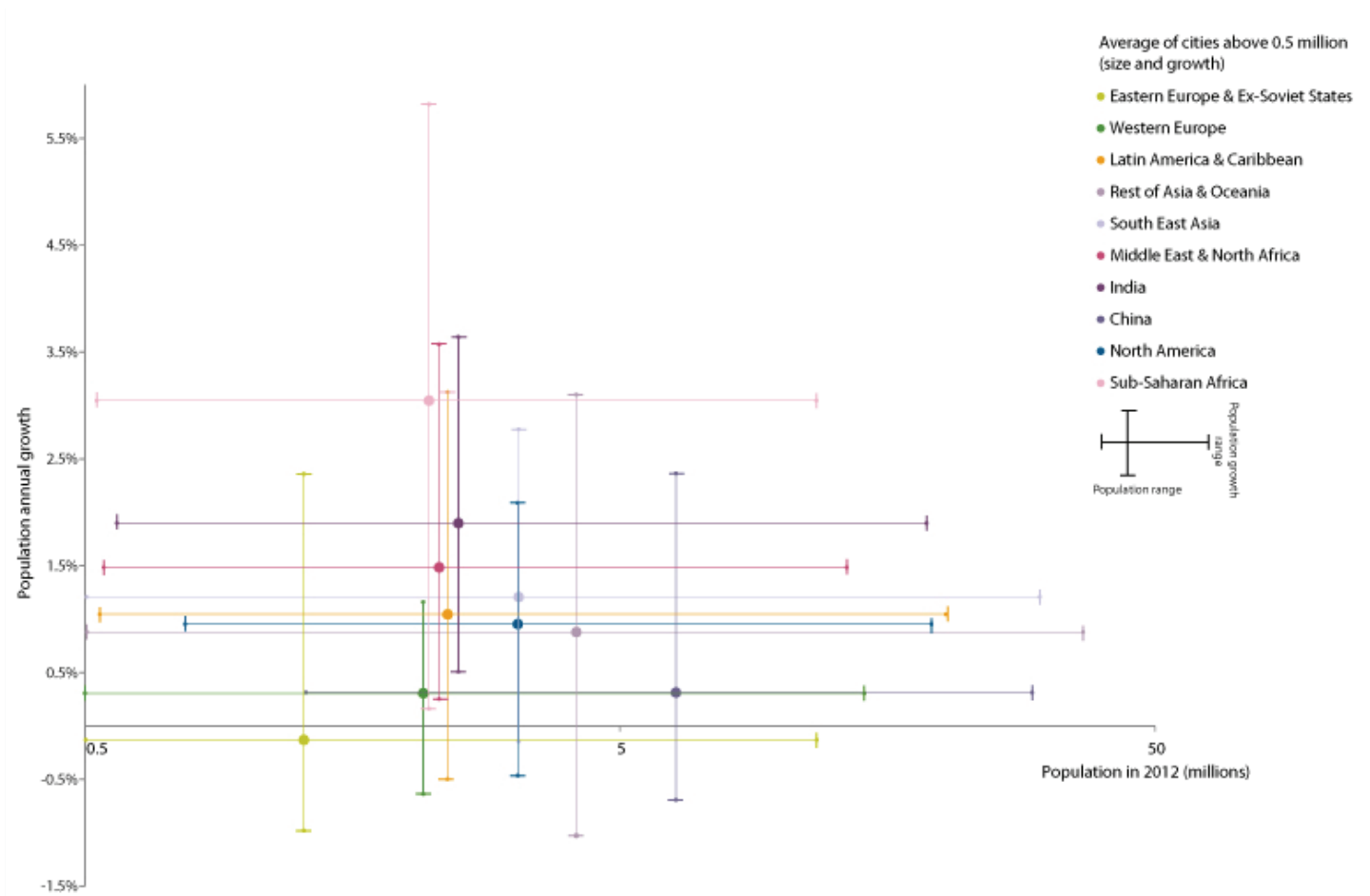**Contribution to global GDP growth of cities above 0.5 million, 2012–2030**

Contribution to global GDP growth, 2012-2030
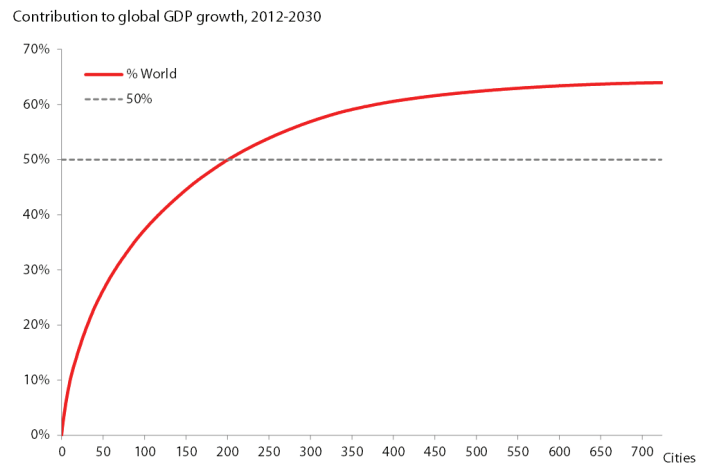
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.3.2 Contribution of cities to the global economy

Cities (metropolitan areas above 0.5 million) have a particularly important role in the global economy. In 2012, cities represented more than 55% of global GDP, a share that is projected to increase to 60% by 2030. At the same time, cities are projected to contribute 71% of urban GDP growth and 64% of total global GDP growth between 2012 and 2030.

Not only do cities play a major role in global GDP levels and growth, but GDP is also concentrated in a small number of these cities. Figure 8 illustrates the cumulative contribution of cities to global GDP and shows that 309 cities alone contributed to 50% of global GDP in 2012, with 71 cities contributing to 30%. Between 2012 and 2030, the relative share of economic output is projected to decrease slightly among the top 50 cities, while the share of the top 250 cities during the same period will increase further. Overall economic growth between 2012 and 2030 is even more concentrated than the total global economic output (Figure 9). Ten cities alone are responsible for 10% of global economic growth during that period, with 31 cities responsible for 20% and 201 cities for 50%.

In terms of the growth distribution of cities across global regions, Figure 10 and Figure 11 illustrate China's substantial concentration of population growth (nearly 70 million people between 2012 and 2030) and GDP growth (US$17.6 trillion over the same period). While other regions display relatively high population growth in cities, their contribution to GDP growth under business as usual is projected to be substantially lower than in China. In Sub-Saharan Africa, while cities are projected to grow by 99 million people, GDP growth is estimated to be as low as US$0.7 trillion. Cities in India are projected to grow by over 70 million, while the Middle East and North Africa and Latin America and Caribbean by over 40 million people each, with GDP growth rates ranging from US$1.1 trillion in India to US$2.3 trillion in Latin America and the Caribbean. A different story is unfolding in North American and European cities; although population growth will be relatively low between 2012 and 2030 (33 million people in North America and 10.4 million people in Western Europe), GDP growth is projected to remain strong (US$7 trillion in North America and US$2.7 trillion in Western Europe).

Figure 10
Population growth of cities above 0.5 million by region, 2012–2030
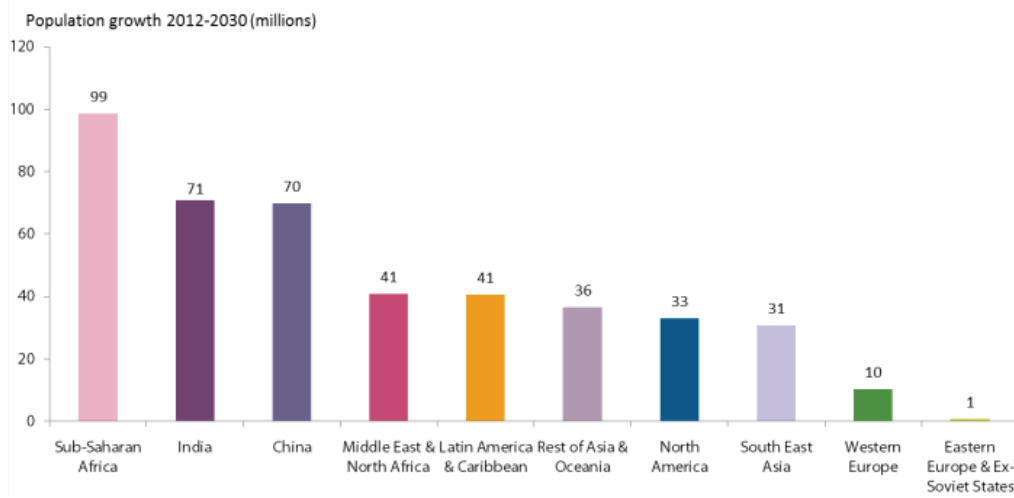
Population growth 2012-2030 (millions)

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 11
Income growth of cities above 0.5 million by region, 2012–2030

GDP growth 2012-2030 (US$ trillions in 2012 prices and exchange rates)
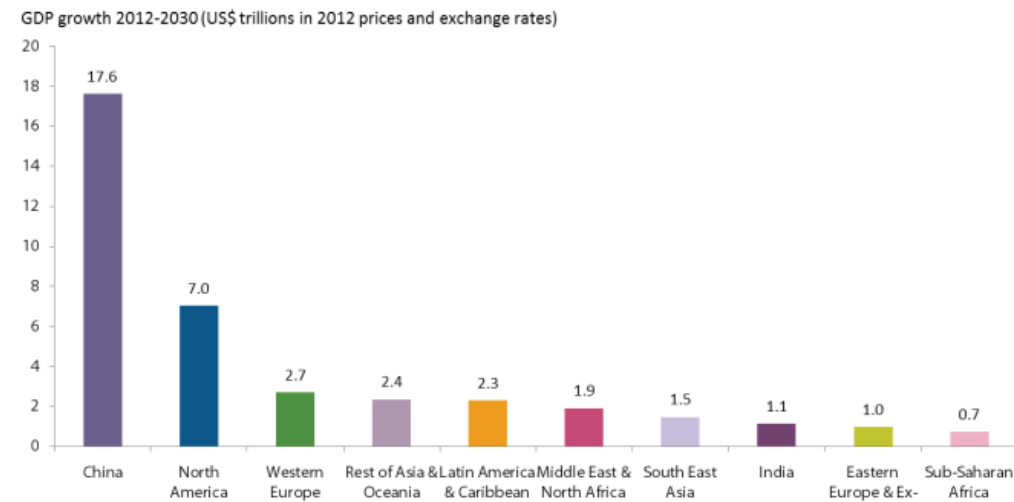
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

It is important to recognise that although cities in lower income regions are projected to contribute less to global GDP growth over the next two decades, the individual growth rates of these cities tend to be higher. The relationship between income levels (GDP/capita) of the world's cities and their projected economic growth rates (annualised over the period 2012 - 2030) is shown in Figure 12. As might be expected, the economic growth rates of cities are highest in cities with lower levels of income. Sub-Saharan African cities lead this group, with economic growth rates typically between 5% and 8%. Indian and Chinese cities both display projected growth rates typically between 6% and 8%. Latin American cities have typical income levels slightly above those of Chinese cities but substantially lower economic growth rates of around 3%. Among higher income cities, North American cities have the highest projected growth of between 2% and 3%, while most Western European cities are projected to grow their economies by between 1% and 2.5%. This illustrates that despite having lower GDP growth rates than Sub-Saharan African cities, cities in China, North America and Europe nonetheless contribute more to global GDP growth due to their higher starting levels of income in 2012.

Figure 12
GDP per capita (2012) and annualised GDP growth (2012–2030) of cities above 0.5 million

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.3.3 Contribution of cities to global carbon emissions

In order to identify key groups of cities across global regions that are of particular importance to a transition towards a new climate economy, this section – in addition to the population and economic analysis above – is based on a carbon emissions study of cities globally (see Appendix). In 2012, cities (metropolitan areas above 0.5 million) were responsible for around 47% of global carbon emissions (Figure 13). Under a business as usual scenario, this share of emissions is predicted to increase slightly to 49% by 2030. Similar to population and economic output, the distribution of emissions is highly concentrated with the 21 highest emitting cities contributing 10% of global energy-related carbon emissions, 64 cities contributing 20% and 139 cities contributing 30%.

An even greater concentration can be observed for carbon emissions growth from 2012 to 2030 (Figure 14). In total, cities are projected to be responsible for 56% of the global increase in carbon emissions during that period, with 10 cities contributing 10% of global emissions growth, 28 cities contributing 20% and 193 cities contributing 50%.

Figure 13
Contribution to global carbon emissions of cities above 0.5 million

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 14
Contribution to global carbon emissions growth of cities above 0.5 million, 2012–2030

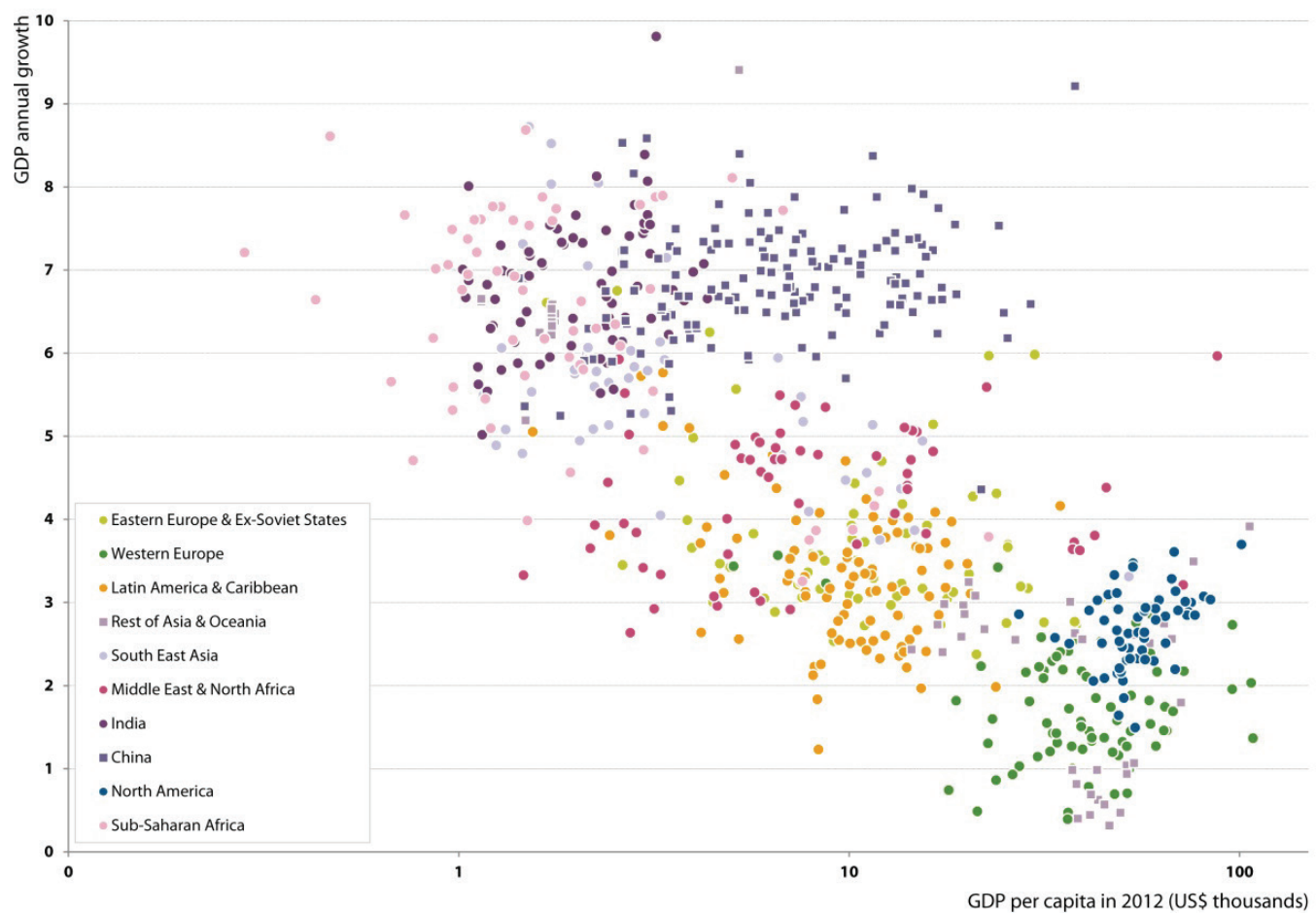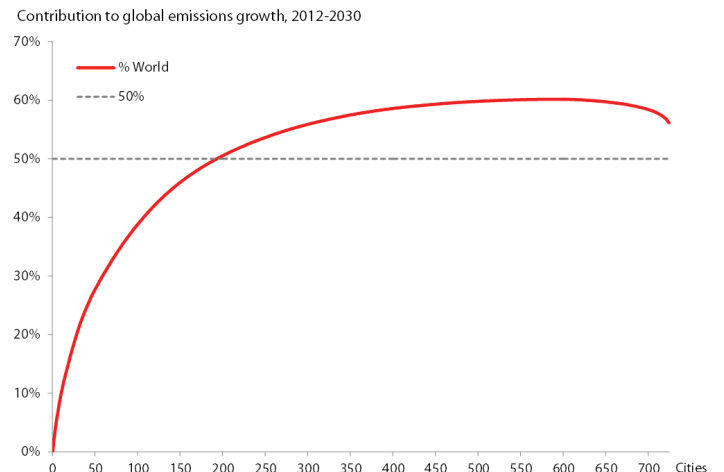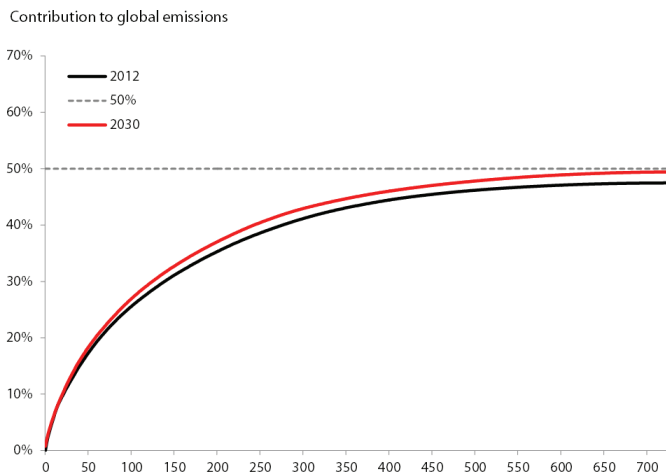Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

In 2012, China had the highest contribution of energy-related carbon emissions from cities at almost 6 gigatonnes. North American cities followed, emitting around 2.9 gigatonnes, with Western European cities emitting 1.1 gigatonnes (Figure 15). The projected carbon emissions growth of cities under business as usual is also dominated by China (Figure 16). With a total projected increase of 2.9 gigatonnes, China is estimated to represent 48% of emissions growth in cities worldwide. However, at 6.3 tonnes in 2012, per capita carbon emissions from Chinese cities are still substantially lower than those in the United States (15.6 tonnes) and Eastern Europe and Ex-Soviet States (9.9 tonnes) but similar to those in Western Europe (6.5 tonnes) and the Middle East and North Africa (5.9 tonnes). Sub-Saharan cities had the lowest per capita emissions (1.8 tonnes) followed by India with 2.8 tonnes (Figure 17).

Figure 15

Total carbon emissions of cities above 0.5 million by region in 2012
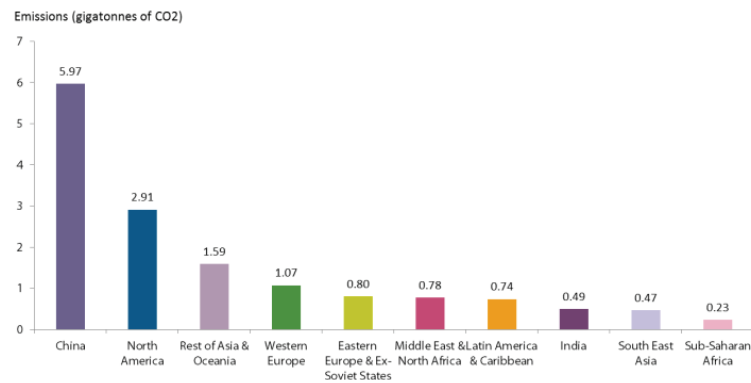
Emissions (gigatonnes of CO2)

Region	Value
China	5.97
North America	2.91
Rest of Asia & Oceania	1.59
Western Europe	1.07
Eastern Europe & Ex-Soviet States	0.80
Middle East & North Africa	0.78
Latin America & Caribbean	0.74
India	0.49
South East Asia	0.47
Sub-Saharan Africa	0.23

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 16

Carbon emissions growth of cities above 0.5 million by region, 2012–2030
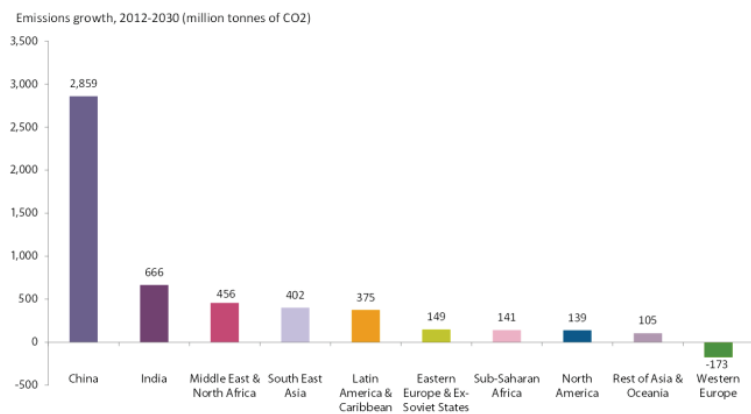
Emissions growth, 2012-2030 (million tonnes of CO2)

Region	Value
China	2,859
India	666
Middle East & North Africa	456
South East Asia	402
Latin America & Caribbean	375
Eastern Europe & Ex-Soviet States	149
Sub-Saharan Africa	141
North America	139
Rest of Asia & Oceania	105
Western Europe	-173

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 17

Average carbon emissions per capita of cities above 0.5 million by region in 2012
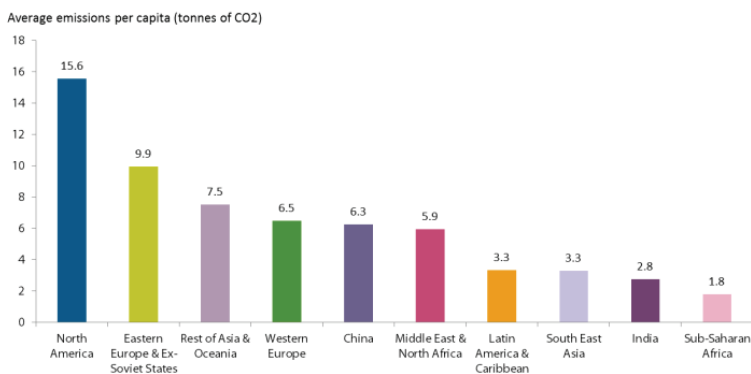
Average emissions per capita (tonnes of CO2)

Region	Value
North America	15.6
Eastern Europe & Ex-Soviet States	9.9
Rest of Asia & Oceania	7.5
Western Europe	6.5
China	6.3
Middle East & North Africa	5.9
Latin America & Caribbean	3.3
South East Asia	3.3
India	2.8
Sub-Saharan Africa	1.8

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 18 shows the relationship between annual growth of carbon emissions for all cities between 2012 and 2030 and emissions per capita in 2012. Under a business as usual scenario, emissions growth is highest (around 4 to 6%) for cities that are the least polluting today. These include cities in India with an average 2.8 tonnes of CO_2 equivalent per capita and many Sub-Saharan cities that have per capita emissions below 1 tonne. Emissions from Chinese cities, already around 6.3 tonnes, are projected to increase by around 2% per year. The highest absolute emissions are registered for most North American cities with around 16 tonnes per capita and growth rates ranging from -1% to about 1.3%.

Figure 18
Carbon emissions per capita (2012) and annualised carbon emissions growth (2012–2030) in cities above 0.5 million

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.3.4 The under-representation of small urban areas

The analysis above suggests that any identification of subgroups of cities of particular relevance to a new climate economy will have to consider the uneven and highly concentrated nature of economic output and carbon emissions in a relatively small number of cities. It is important to note, however, that the key role of cities does not imply that smaller urban areas are not relevant. In absolute terms, small urban areas include a substantial share of the global population, economic activity and carbon emissions (see section 2.4). The latest estimates from UN DESA suggest that almost half of the world's urban population lives in settlements with less than 0.5 million inhabitants, while this share differs, greatly across global regions (Figure 19).

Figure 19
Urban population distribution by settlement size across global regions
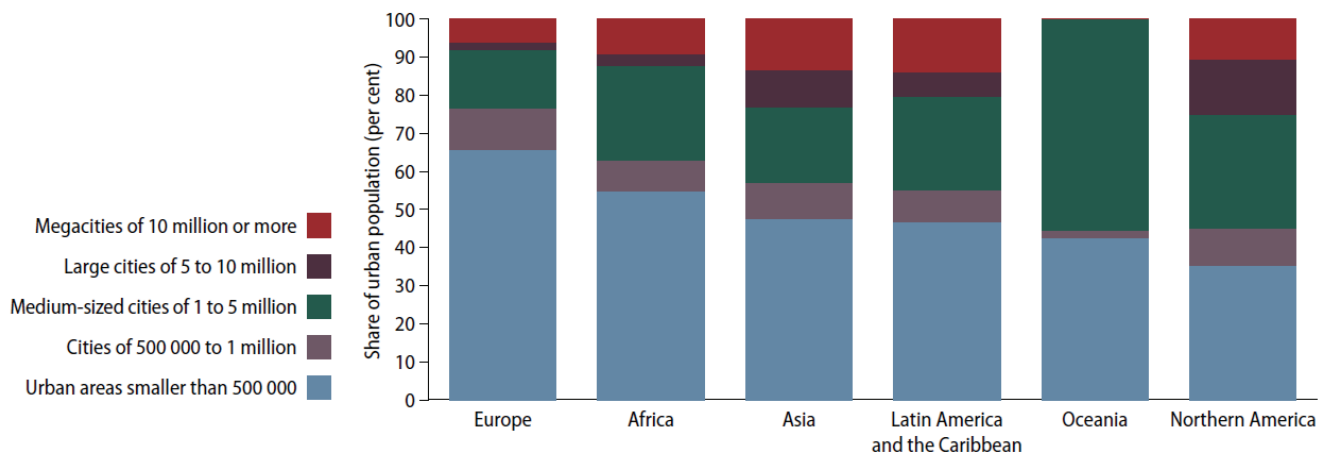
Sources: UN DESA 2014a

However, cities will contribute substantially more to future growth than small urban areas below 0.5 million (including towns, large villages, peripheral industrial zones and other urban areas). The population growth of small urban areas is projected to be around 15% up to 2030 compared to 40% for cities (UN DESA 2014a). As a result, the proportion of the urban population living in small urban areas is projected to decline to about 45% by 2030. Similarly, only about a quarter (26%) of global income and 13% of global carbon emissions growth between 2012 and 2030 will take place in small urban areas.

Furthermore, the shape of the cumulative curves above (see Figures 5, 6, 8, 9, 13 and 14) suggests that there might be little value added in increasing the number of (smaller) urban settlements as part of related analysis, as this would only make a substantial contribution if these places numbered in the thousands rather than hundreds. It might also challenge the city level as the appropriate unit of analysis given the enormous increase in diversity that would result, making comparisons and generalisations more difficult and less meaningful. Little is known about this diverse assemblage of small cities, towns and urban settlements which may include 2,500 smaller 'cities' below 500,000 people along with countless towns and urbanised villages. Analysing small urban areas might instead require a national or even regional level of analysis.

2.4 The new climate economy: three key groups of cities

As the analysis in the previous section shows, a small number of cities will have a disproportionate impact on the global economy and climate over the next two decades. In this section, we identify three broad groups of cities that will be particularly influential: Emerging Cities, Global Megacities, and Mature Cities. These cities are medium to large (above one million in population) and middle to higher income (above US$2,000 per capita). Under business as usual, the 468 cities in these groups will account for over 60% of global income growth and over half of energy-related greenhouse gas emissions growth between 2012 and 2030, rising from over 14 gigatonnes of emissions in 2012 to nearly 19 gigatonnes by 2030. Table 1 shows the distribution of these cities in terms of population size and income per capita compared to all urban areas worldwide.

Table 1
Population size and income per capita of cities above 0.5 million. Numbers refer to the number of cities (metropolitan areas) in each category. Under this categorisation, 291 cities are Emerging Cities, 33 are Global Megacities and 144 are Mature Cities. The number of small urban areas is unknown. Population and GDP are based on metropolitan area

Population	GDP per capita			
	Lower income <$2,000	Middle income $2,000 to $20,000	Higher income >$20,000	
>10m	3	25	8	Emerging Cities
5m-10m	6	101	16	Global Megacities
1m-5m	61	190	128	Mature Cities
0.5m-1m	37	109	40	Other cities
<0.5m	-	-	-	Small urban areas

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.4.1 Emerging Cities

We define Emerging Cities as middle income, medium to large cities (based on metropolitan areas), with populations in 2012 of between 1 million and 10 million and per capita income levels between US$2,000 and 20,000. Sometimes loosely termed 'tier 2 and 3 cities' (being smaller than megacities), these are rapidly expanding middle-income cities in China, India, and other emerging economies. A total of 291 Emerging Cities exist worldwide, with examples including Kunming, Ulaanbaatar, Pune, Puebla and Kuala Lumpur.

One of the defining features of this group is the rapid rate of urbanisation expected over the next two decades. Under business as usual, they will contribute more than any other group of cities to global economic growth and carbon emissions. These 'cities of tomorrow' will account for 15% of global urban population growth, over a quarter of global income growth and over a third of energy-related emissions growth worldwide between 2012 and 2030. Average per capita emissions in these cities are estimated to grow from 5.2 tonnes of CO_2 equivalent in 2012 to 7 tonnes of CO_2 equivalent in 2030.

For example, in India, Chennai is projected to grow by almost 4 million people from today to 2030, while 14 cities in China are expected to grow by 1 million or more. Cities such as Dongguan and Foshan could experience annual GDP growth of 7.7% and 8% respectively, while 20 cities with the highest emissions growth in China are projected to contribute nearly 40% to the country's overall emissions growth, representing a combined increase of over 1 gigatonne of CO_2 equivalent.

Many of these cities will be high-growth industrial economies, requiring major investments in infrastructure along with planning for the connection of residential and industrial areas over the next two decades. By 2030, industry will be valued at US$11.2 trillion in these cities, representing 44-49% of their economies (see Figure 20). Other sectors are also projected to grow strongly, including transport, storage, information and communications at 5.9%, financial and business services at 6.3%, consumer services at 6.1% and public services at 5.4% (see Figure 20).

Figure 20
Income of Emerging Cities in 2012 and 2030 (measured as Gross Value Added)

Gross Value Added (US$ trillions in 2012 prices and exchange rates)

Sector	2012	2030
Agriculture	0.5	0.8
Industry	3.7	11.2
Transport, storage, info & comms services	0.6	1.8
Financial & banking services	1.3	3.9
Consumer services	1.4	3.9
Public services	0.9	2.3

Emerging Cities GVA by sector
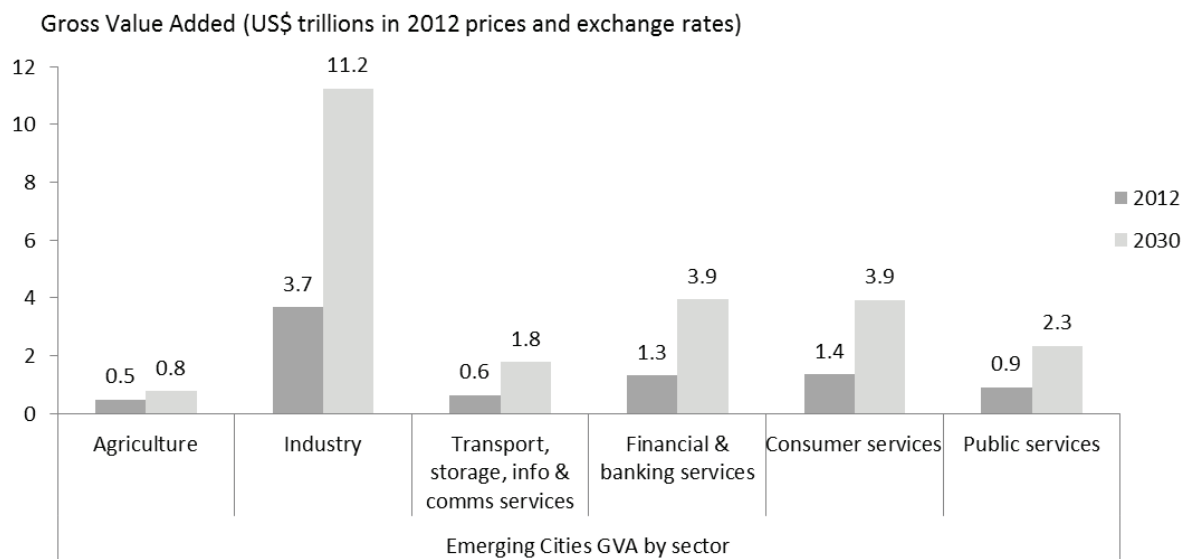
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.4.2 Global Megacities

We define Global Megacities as major economies with populations above 10 million and per capita income of over US$2,000. A total of 33 Global Megacities exist worldwide, with examples including Delhi, Beijing, Shanghai, Bangkok, Rio de Janeiro, Mexico City, Jakarta, London, New York and Tokyo.

While this is a diverse group of cities, they share a number of important features: all are very large economies, often hubs of regional economic growth, and with a strong international outlook. They tend to attract population growth within their urban core as well as on their periphery. Global Megacities also tend to be increasingly services based with strong growth in the financial, business and other services sectors. These urban economies will rely increasingly on agglomeration effects which are greater in denser cities. For example, high-end service jobs and research and development jobs in Beijing are 14 and 12 times respectively more concentrated than the national average (World Bank 2014). In addition, given their size, economic weight and knowledge spill-overs, Global Megacities often act as leaders in innovation, with other cities worldwide following them.

Global Megacities will continue to play a key role in the global economy and climate. Between 2012 and 2030 under business as usual, while these 33 megacities will represent only 8% of the world's urban population growth, they will contribute 16% of global income growth. Furthermore, their share of global urban GDP will remain broadly the same, rising slightly from 17.6% in 2012 to 17.8% in 2030. Under business as usual, these 33 cities will represent 11.5% of global carbon emissions growth and 10.5% of total world emissions in 2030. Average per capita emissions in these megacities are estimated to grow from around 6.2 tonnes of CO_2 equivalent in 2012 to 7.1 tonnes in 2030. Given the large share of carbon emissions in Global Megacities, substantial potential exists for carbon abatement in these cities.

While Global Megacities share common features, they display a range of dynamics from relatively slow to high growth. For example, population growth in these 33 agglomerations ranges from an estimated -0.3% to 4.4%, while economic growth and carbon emissions growth range from 0.6% to 7.9% and from -2.2% to 4.8% respectively. Overall, Global Megacities are projected to display steady growth in financial and business services at 3.6%, as well as industry at 4.3%, transport, storage, information and communications at 3.8%, and consumer services at 3.5% (Figure 21).

Figure 21
Income of Global Megacities in 2012 and 2030 (measured as Gross Value Added)

Gross Value Added (US$ trillions in 2012 prices and exchange rates)
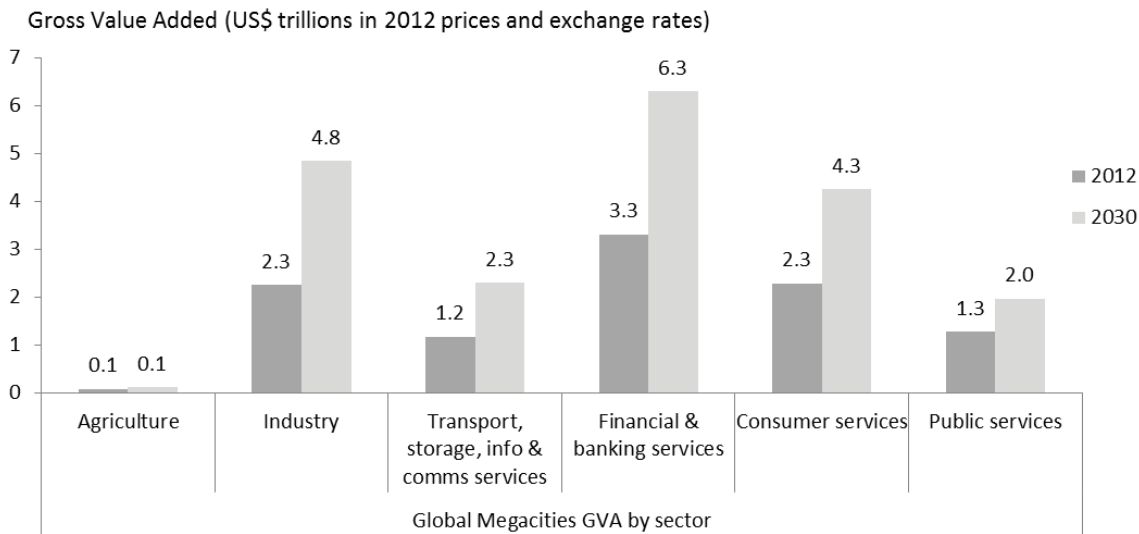
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.4.3 Mature Cities

We define Mature Cities as higher income, medium to large cities, with populations in 2012 of between 1 million and 10 million and per capita income levels above US$20,000. These 'Tier 2 and 3 cities' form the backbone of regional economic networks in countries in North America, Western Europe and OECD countries in other parts of the world. A total of 144 Mature Cities exist worldwide, with examples including Stuttgart, Minneapolis and Hiroshima.
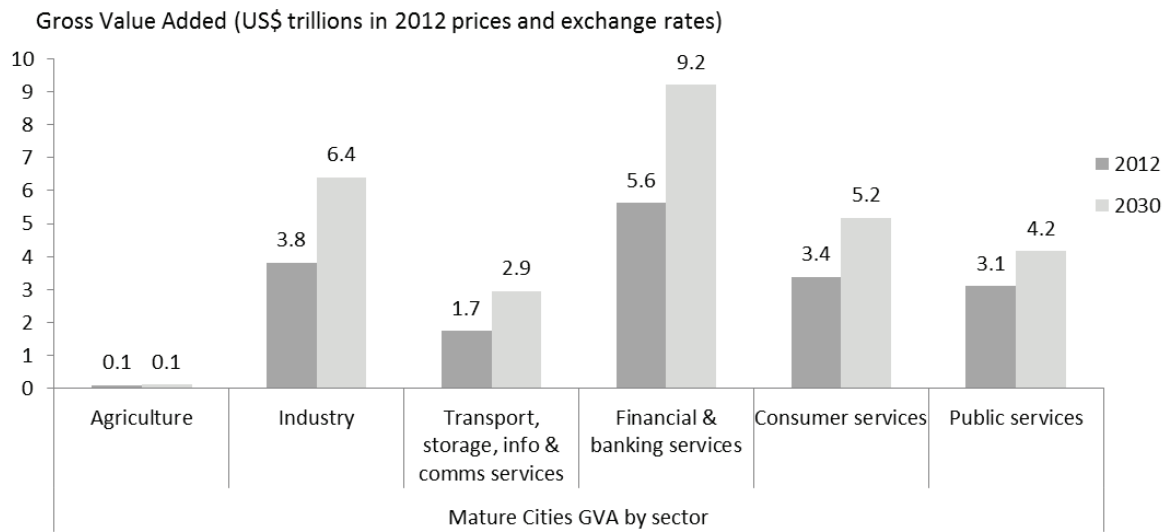
Population growth in Mature Cities will be relatively low over the next two decades. As a group, their contribution is projected to be 4% of global urban population growth, compared to 15% for Emerging Cities. Nevertheless, Mature Cities will continue to experience significant urban change. These changes range from cities that are attracting more populations to their urban core to cities that are experiencing an overall decline in population. This will provide a different set of opportunities and challenges to those faced by Emerging Cities and Global Megacities.

Mature Cities play an important role in the global economy. As a group, they represent around 26% of global GDP and 15.5% of global energy-related carbon emissions. They also contribute the highest per capita emissions of any city group, at an average of 12.5 tonnes of CO_2 equivalent. And while they will not experience the rates of growth shown by Emerging Cities, their contribution to global economic growth will be substantial. Between 2012 and 2030, Mature Cities will drive 17.9% of global income growth. Although carbon emissions growth in Mature Cities is projected to be relatively low under business as usual (4.3%), average emissions levels in these cities are already high. Mature Cities will continue to have substantially higher per capita emissions than Emerging Cities and Global Megacities, projected to be 12.1 tonnes of CO_2 equivalent in 2030.

While Mature Cities share common features of medium to large size and high levels of productivity, the group represents a very diverse assemblage of cities. It includes key innovation leaders such as Stockholm, Copenhagen, Portland, Singapore and San Francisco, as well as economically stagnant cities such as Turin, Detroit and Cleveland. For example, Hong Kong and Seattle's economies are both projected to grow by over 70% between 2012 and 2030, averaging 3% growth per year based on strong service sectors. However, Cleveland is projected to grow by less than 1.5% per year over the same period, while Turin is expected to grow at only 0.4%. These cities tend to have traditional industry sectors that are facing increasing global competition, particularly from high-growth cities in emerging economies.

On average, all major sectors in Mature Cities are projected to grow strongly. This includes average annual growth rates of transport, storage, information and communications at 3%, financial and business services at 2.8%, consumer services at 2.4% and public services at 1.7% (see Figure 22). However, given the diverse range of cities in this group, sector-specific growth (and decline) will vary widely from city to city.

Figure 22
Income of Mature Cities in 2012 and 2030 (measured as Gross Value Added)

Gross Value Added (US$ trillions in 2012 prices and exchange rates)

Sector	2012	2030
Agriculture	0.1	0.1
Industry	3.8	6.4
Transport, storage, info & comms services	1.7	2.9
Financial & banking services	5.6	9.2
Consumer services	3.4	5.2
Public services	3.1	4.2

Mature Cities GVA by sector

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

2.4.4 City groups compared

Overall, the combined contribution of Emerging Cities, Global Megacities and Mature Cities to economic output and carbon emissions is considerable. While representing around 29% of the global population, these 468 cities contributed an estimated 52.4% of global GDP and 45% of global energy-related carbon emissions in 2012 (Figure 23). Mature Cities were the highest contributors to the global economy at 25.7%, followed by Global Megacities at 14.9% and Emerging Cities at 11.8%. In contrast, the remaining 256 cities above 0.5 million contributed only 3% to global GDP in 2012, and 3% to global emissions.

The three groups of cities will have an even more pronounced impact on economic and carbon emissions growth over the next two decades. Overall, the 468 cities will contribute 61% of global GDP growth and 51% of global energy-related emissions growth between 2012 and 2030 (Figure 24). Emerging Cities are projected to have the greatest impact, with 27% contribution to the global economy. This is followed by Mature Cities with an 18% contribution and Global Megacities with 16%. Emerging Cities will also contribute the most to global energy-related emissions growth at 35%, followed by Global Megacities at 11.5% and Mature Cities at 4%. In contrast, the remaining 256 cities above 0.5 million are projected to contribute only 3% of global GDP growth, and 5% of growth in energy-related emissions.

These results strongly suggest that a unique opportunity exists to concentrate policy interventions on a relatively small number of cities which at the same time will have a disproportionate effect on the global economy and climate. As discussed in section 2.3.4, it is important to note that although small urban areas will contribute considerably less to GDP and emissions growth than the 468 cities identified above, policy makers should not ignore their development over the next two decades. This assemblage of small urban areas represents a vast number of small entities, ranging from prosperous large towns/small cities such as Aberdeen to small groups of houses in Sub-Saharan Africa, industrial areas outside city boundaries to large village communities. Shaping the future development of these areas will in many cases require national or regional level policy intervention at an aggregate scale, rather than focused policies directed at individual cities. This is a particular challenge in low income countries.

Figure 23
Contribution of different settlement types to global population, GDP and energy-related carbon emissions in 2012

Global contribution in 2012
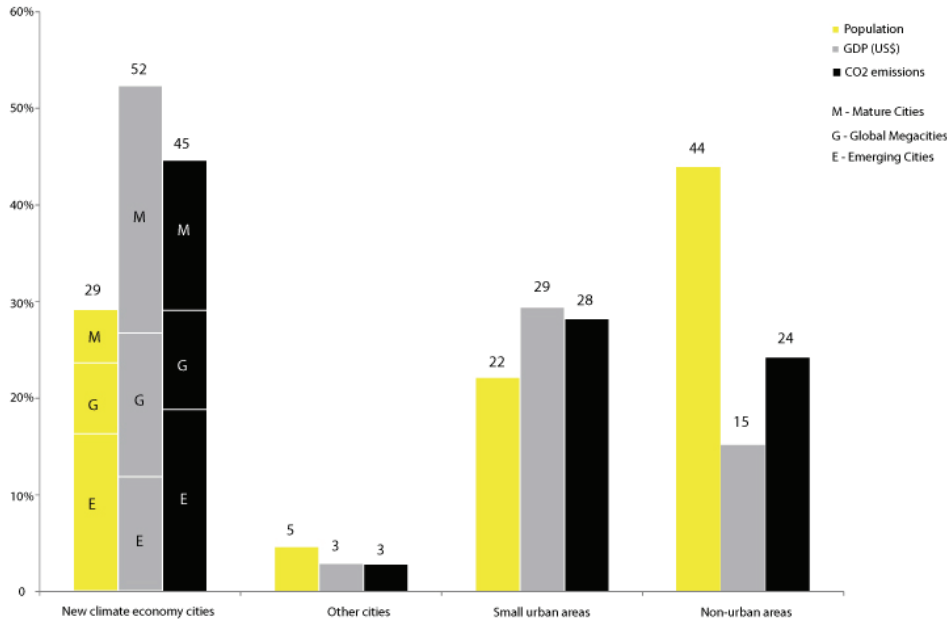
Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Figure 24
Contribution of different settlement types to growth in population, GDP and energy-related carbon emissions, 2012–2030

Contribution to global growth, 2012-2030

Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)
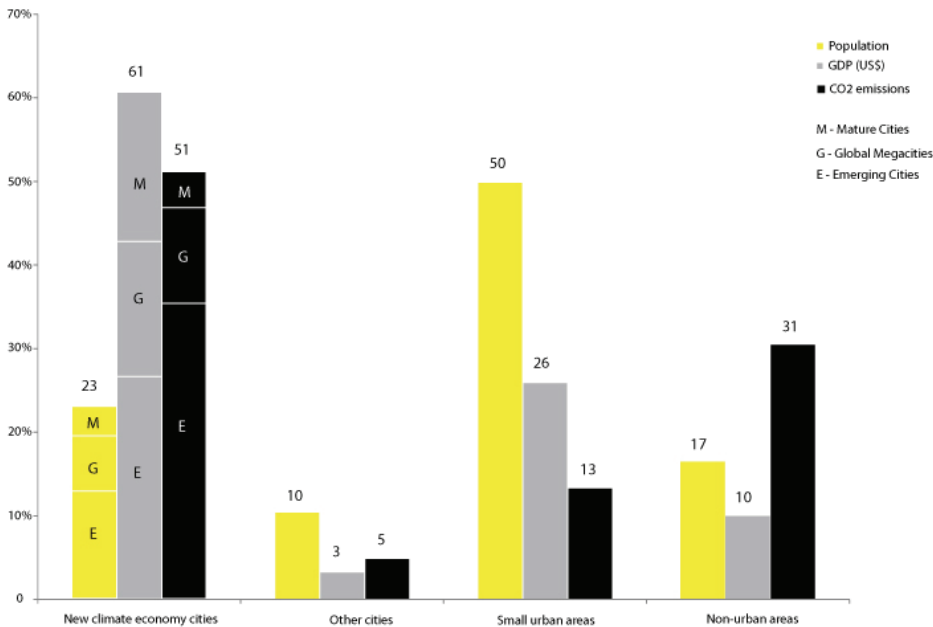
3 THE RISING COSTS OF POORLY MANAGED URBAN GROWTH

While the potential benefits of urban growth through agglomeration effects, concentrations of innovation and knowledge spill-overs are substantial, poorly managed urban growth can not only reduce these economic benefits, but can also have significant negative impacts on the environment and the quality of life of urban citizens. Where markets operate effectively, efficiently and equitably governments should not intervene. However, a number of market failures can hinder productivity and overall economic growth. Among these market failures are congestion and longer travel times, negative externalities of pollution and carbon emissions, network externalities, reduced agglomeration effects on innovation and skills matching, and imperfect and asymmetric information. These market failures are explored in NCE Cities Paper 02 (Floater, Rode et al. 2014b).

In the short-term, poor resource efficiency can increase economic and social costs substantially, while pollution and reduced biodiversity can potentially lower productivity through, for example, decreased health of the population and depletion of natural resources. For many cities, these costs are likely to increase substantially over the coming years, as resource constraints (including energy, water, raw materials and food commodities) continue to deepen in the face of growing demand from rapidly industrialising countries. As centres of energy demand and industrial production, urban areas are associated with around 70% of global energy consumption and over 70% of energy-related carbon emissions. This not only has consequences for the environment, but also creates negative impacts on long-term economic growth (Stern 2006; IPCC 2014d).

Furthermore, the costs of poorly managed urban growth are already being experienced in cities today. In China, Prime Minister Li Keqiang described the smog in Chinese cities as a warning "against the model of inefficient and blind development". The rush to develop has left urban sprawl spreading into rural areas and municipal governments with mounting debt (World Bank 2014a). In many low income countries, including Sub-Saharan Africa, urban poverty and informal settlements are growing as urbanisation increases, with the provision of infrastructure and services such as sanitation, clean drinking water, and provision of energy and waste disposal unable to keep pace with population growth (UN-Habitat 2010a).

3.1 Costs of business as usual

While an abundance of cheap energy, land, capital, labour and resources has supported the economic growth of cities in past centuries, a growing range of market failures and heightened social polarisation, combined with increasing resource constraints and the huge scale of urban population growth today at earlier stages of economic development, mean that the business as usual trend of poorly managed urban growth in cities is leading to substantial costs. The economic and social costs include:

1. **An increase in the urban infrastructure investment gap and the failure of many cities to deliver basic urban infrastructure and services.** According to the OECD, US$50 trillion is required for investment in global infrastructure out to 2030 (OECD 2007). This includes investments in road, rail, and basic energy and water infrastructure. Capital requirements for buildings are as high as US$7 trillion over the next 20 years (World Economic Forum 2013). At the same time, the deficit in investment for global infrastructure is estimated at around US$1 trillion annually (Boston Consulting Group) – much of this in ever more sprawling cities where infrastructure provision is not keeping pace with excessive, and unnecessary, urban expansion. While these estimates of global infrastructure investment requirements are broad estimates, they demonstrate the order of magnitude of the challenge and suggest that urban sprawl could lead to a substantial reduction in resources available for investment in basic urban infrastructure and services, as well as public transport. This should be a major research priority.

    The investment gap is particularly acute in developing countries and emerging economies, where the urban infrastructure deficit is estimated at US$6.3 trillion to 2030 (Parry 2009). In India alone, the gap in urban infrastructure investment is estimated at US$827 billion over the next 20 years, with around 67% of this needed for urban roads and traffic support. Under business as usual, 2.5 billion square metres of roads will need to be paved in India - 20 times the capacity added in the past decade (McKinsey Global Institute 2010). Business as usual urbanisation in China will require 5 billion square metres of roads to be paved by 2025. Furthermore, new estimates for this report suggest that the incremental costs of subsidising sprawl in the United States amounts to around US$400 billion per year (Litman 2014).

2. **Growing financial and welfare costs related to traffic congestion.** The costs of lost time and increased transport costs are estimated at 2–5% of GDP in developing countries in Asia and Latin America (ADB 2012), as high as 3.4% of GDP in Buenos

Aires, 2.6% in Mexico City (World Bank 2002), and 10% of city GDP in São Paulo (ADB 2012). In the largely urbanised European Union these costs are only 0.75% of GDP (World Bank 2002). The social costs of urban transport in Beijing range between 7.5 and 15% of GDP (Creutzig and He 2009). Globally, road transport is estimated to be associated with indirect costs ranging from 5 to more than 40 cents a kilometre (Proost and Van Dender 2011). A more extensive review of urban transport costs under business as usual can be found in NCE Cities Paper 03 (Rode, Floater et al. 2014).

3. **Escalating economic and social costs due to air pollution.** Urban air pollution is projected to become the top environmental cause of premature mortality by 2050 (OECD 2012): in 2012 alone, air pollution resulted in around 7 million premature deaths (WHO 2014). In Asia, several cities exceed annual WHO air pollution guidelines by 5 to 15 times. New analysis conducted for this project, covering 311 cities and over 1.5 billion people, suggests that business as usual has resulted in 86% of these cities exceeding WHO air quality guidelines for outdoor air pollution and led to 730,000 premature deaths (Kuylenstierna, Vallack et al. 2014). Pollution-related health costs amount to 2–3% of GDP in some cities in developing countries (Bank 2002). While cutting CO_2 emissions has additional health impacts, recent analysis suggests that global average monetised co-benefits of avoided mortality from reduced air pollution are around US$50 to 380 per tonne of CO_2 (West et al. 2013). Tackling air pollution in cities has significant economic benefits through its direct impact on human health and funded health systems (hospital/doctor visits, lost work/school days, critical illness, physical/mental wellbeing) and indirect impacts associated with the levers to reduce air pollution.

4. **Lock-in of inefficiently high levels of energy consumption.** A study of 50 cities worldwide estimates that almost 60% of growth in expected energy consumption is directly related to urban sprawl - more than the consumption related to increases in GDP and demographic changes (Bourdic, Salat et al. 2012). This leaves many cities vulnerable to volatility in global energy prices.

5. **Increasing social exclusion through growing income and wealth inequalities in rapidly urbanising countries.** While urbanisation has led to cities becoming concentrated centres of wealth, at the same time societies experiencing extremely high levels of inequality and poverty do not reap the benefits from economic growth (UN-Habitat 2009). If cities are not well-managed, inequality and urban poverty will remain major challenges; under business as usual growth, the number of people classified as urban poor is likely to increase (Ravallion, Chen and Sangraula 2007). The combined effects of urban sprawl, motorisation, growth of informal settlements and gated communities are increasingly creating socially divisive cities (UN Habitat 2010).

6. **A wide range of other economic and social costs** including those related to road safety, community severance, low activity levels with health implications, reduced ecosystem services and food security. Globally, road traffic deaths are projected to double from 1.2 million to 2.4 million between 2011 and 2030, with almost 50% of them taking place in urban areas (WHO 2013; EMBARQ 2013).

In addition to the economic and social costs, poorly managed urban growth will lead to a substantial increase in global carbon emissions through:

7. **The over production of construction materials needed for more sprawling cities.** Concrete and steel are particularly energy-intensive to produce, while cement production is also responsible for emissions from its industrial chemical process. If developing countries expand their infrastructure to current global average levels, the production of infrastructure materials alone would generate around 470 gigatonnes of cumulated CO_2 emissions (IPCC 2014), much of this concentrated in sprawling cities. Under scenarios of continued expansion of infrastructure, cumulative emissions would reach 3,000 to 7,400 gigatonnes of CO_2 between now and the end of this century (Davis, Caldeira et al. 2010). The World Business Council on Sustainable Development estimates that 30 gigatonnes of concrete alone were used in 2006, compared to 2 billion tonnes in 1950 (WBCSD 2009). Due to the energy intensity of its production process, cement production accounts for 5% of global carbon emissions (WBCSD 2012). Overall, global resource consumption has increased more rapidly than the population, particularly the consumption of non-renewable construction materials (UN-Habitat 2012). The construction sector accounts for over 30% of global resource consumption (UNEP 2011b). Between 1900 and 2005, material resource use in the world increased eight-fold, which is almost twice the rate of population growth (UNEP 2011a).

8. **Lock-in of higher operational emissions from buildings and transport for decades and centuries to come.** Once a sprawling urban footprint has been created, it tends to be locked in, along with its associated costs. The Intergovernmental Panel on Climate Change (IPCC) estimates that under poorly managed urban growth, carbon emissions from transport alone, of which a large proportion is conventional motorised transport in cities, are projected to almost double by 2050 (IPCC 2014b).

3.2 Urban sprawl and motorisation

The dominant growth pattern currently being pursued by many cities worldwide is characterised by urban sprawl and conventional motorisation. This particular form of urbanisation leads to many of the costs associated with business as usual urban growth. Here, we define urban sprawl as the excessive expansion of urban development, characterised by low density, segregated land use and insufficient provision of basic infrastructure. Sprawl can also take the form of leapfrog development, whereby development leaps over undeveloped land (OECD 2012a).

In most developed countries, cities are growing more rapidly on the fringes than in the urban core, and in many developing countries urban development is characterised by expansion on the periphery that is insufficiently served by public infrastructure. Land expansion in 292 city locations over three decades (1988–2008) shows that cities are expanding more rapidly than their populations are growing; urban areas have quadrupled over a period of thirty years, while urban populations at the national level have doubled (Seto et al. 2011). Some estimates suggest that, under business as usual urban development, the area of urbanised land will triple between 2000 and 2030 (Seto, Güneralp et al. 2012), while the number of privately owned motorcars may increase from 1 billion today to 2 billion in 2030 (Dargay, Gately et al. 2007; Dargay, Gatley et al. 2007).

Income elasticity of demand for additional residential space, coupled with revenue gains to city governments and land developers from appending adjacent rural land to urban centres, have contributed significantly to urban sprawl in China and the US (Seto et al. 2011). Over the last ten years, population densities in Chinese cities have declined on average by 25% (Bank 2014). The continuation of sprawl at that level would require developing an area the equivalent of the Netherlands over the next decade and a tripling of urban land in China by 2030 (Bank 2014). In the OECD, the majority of growth on the periphery of metropolitan areas exceeds that of the urban core (OECD 2012d, 2013b). Moreover, the floor-to-area ratio of African cities is relatively low near the city centre, in contrast with the majority of cities in other regions where density tends to peak near the centre and the floor-to-area ratio decreases as distance increases from the centre (Malpezzi 2006).

Urban sprawl and motorisation are already leading to substantial costs. In China, Prime Minister Li Keqiang described the smog in Chinese cities as a warning "against the model of inefficient and blind development". The rush to develop has left municipal governments with mounting debt and urban sprawl spreading into rural areas (Bank 2014). In many low-income countries, including those in Sub-Saharan Africa, informal settlements are growing as urbanisation increases, with the provision of infrastructure and services unable to keep pace with population growth (UN Habitat 2010). High unit costs of infrastructure construction are one reason for this; for example, the cost of constructing one kilometre of road in lower-income African cities is around 30% higher than in the OECD (Collier, Kirchberger and Soderbom 2013). Urban economies in the developed world also face challenges. In the lead up to the 2008 global economic downturn, sprawling urban areas in the US were impacted by a speculative real estate market and high energy prices.

3.3 Locking in the costs of unmanaged urban growth

The choices that countries and cities make today about managing urban growth will lock-in the economic and climate benefits - or costs - for decades and centuries to come. The life span of capital intensive, largely irreversible urban infrastructure investments such as roads and buildings typically range from 30 to 100 years, and the path dependencies created by urban form are sustained over centuries. Historical path dependencies can be seen in the widely varying rates of energy consumption and greenhouse gas emissions today among cities with similar per capita income and climate, due to past policy decisions that have shaped their urban form, transport systems and building energy efficiencies. Over the next decades, this will be particularly important for Emerging Cities which are at an early stage of their infrastructure development (Unruh and Carrillo-Hermosilla 2006; Shalizi and Lecocq 2009);). For example, 70–80% of India's urban infrastructure that will exist in 2050 is yet to be built (McKinsey Global Institute 2010).

Above all, the spatial distribution of densities and land use in combination with strategic urban infrastructure will determine the level of economic prosperity, social wellbeing and environmental sustainability in individual cities. Energy intensities related to transport and buildings (Lefèvre 2009; Rode, Keim et al. 2014), the size of agglomeration effects (World Bank 2014a), the costs for operating and maintaining urban infrastructures, and social equity related to employment, housing and transport will all be affected by urban form and infrastructure.

The risk of lock-in also applies to more mature cities that will need to be upgraded and retrofitted over the coming decades. High capital costs, network externalities and increasing returns of urban infrastructure make it difficult to alter the outcomes of infrastructure choices made today (Unruh 2000; Unruh 2002). Due to the long life span of buildings, some have argued that a significant risk exists of locking in around 80% of 2005 global energy use in buildings by 2050 (Ürge-Vorsatz, Eyre, et al. 2012). These major lock-in effects in turn lead to a change-averse culture and political equilibrium far beyond the initial investment and impact on the spatial system.

3.4 Costs of business as usual urbanisation in rapidly growing regions

3.4.1 China

In China, unprecedented economic and social transformation has been accompanied by rapidly increasing growth in energy and other resource use. Primary energy consumption increased more than five-fold between 1980 and 2012 (EIA 2009), and the number of motor vehicles increased from 56 million in 2000 to 240 million in 2012 (Ministry of Public Security 2013). Nearly two billion square metres of newly constructed floor space was built in urban areas in 2011, accounting for around half of the world's total new construction area (CEIC 2011).

Rapid urbanisation and industrialisation in China have also given rise to increasingly severe environmental problems. China is now the world's largest emitter of greenhouse gases. The majority of these emissions (63% – one of the highest shares in the world) can be attributed to manufacturing industries and construction. Furthermore, analysis for this paper suggests that between 2012 and 2030, business as usual urban growth in China could lead to a 48% increase in greenhouse gas emissions - a growth rate of 2.9 gigatonnes (see Figure 16). Per capita emissions average around 6.3 tonnes of CO_2 equivalent and are expected to grow to 8.6 tonnes by 2030. China is one of the few countries where emissions per capita are projected to increase significantly, among countries and regions such as the Middle East and North Africa (from 5.9 to 7.2 tonnes), India (from 2.8 to 4.7 tonnes) and Latin America and the Caribbean (from 3.3 to 4.2 tonnes). In addition, air pollution, soil, ground and surface water contamination have become serious public health issues in many Chinese cities. Air pollution has resulted in an increase in premature mortality from 418,000 to 514,000 between 2001 and 2010 (Cheng et al. 2013). The economic costs of these are estimated to be US$100–300 billion or more per year (World Bank 2014a).

Urban forms that have developed over the past 10 to 15 years exhibit excessive zoning and poor connectivity, locking in a dependency on private cars and resulting in more carbon intensive, polluting and congested development. China is projected to build two and a half cities with a population size of Chicago per year in the near future and to have a total of 221 cities with more than 1 million residents by 2025 (Heck and Rogers 2014). In the past ten years, China has surpassed the US as the world's largest automobile market. In 2011 alone, 18.5 million vehicles were sold there, compared with 12.8 million in the US (Energy Foundation for Chinese Cities 2014). Traffic congestion has become a large scale challenge: in 2010 for example, one traffic jam on the outskirts of Beijing stretched out for over 90 km and lasted nine days (Energy Foundation for Chinese Cities 2014).

Estimates suggest that between 20 and 30 trillion yuan (about US$3.5 to 5 trillion) are required for urban infrastructure in China. This could lead to an investment gap for infrastructure of 10 to 20 trillion yuan (about US$1.6 to 3.5 trillion) (Liu et al. 2012). To finance the delivery of public services, and especially infrastructure, local authorities have used land acquisition from adjacent rural areas as a revenue raising measure. Land is purchased cheaply from local farmers and landowners, designated for urban expansion, and revenues raised from subsequent development (World Bank 2013b). The expansion of urban boundaries has led to urban sprawl. Between 2000 and 2010, average population densities in China have decreased by over 25% (World Bank 2014a), demonstrating that urban territorial expansion has greatly outpaced the growth in population. Furthermore, as the revenues raised by municipal governments from land expropriation have been outpaced by spending, government debt has risen to unsustainable levels in many cases.

Urban sprawl has reduced productivity gains from agglomeration and specialisation, and to counteract this effect even higher capital accumulation is necessary to sustain growth (World Bank 2014a). Research from 261 Chinese cities in 2004 suggests that labour productivity would rise by 8.8% if employment density doubled (Fan 2007). In addition, poor accessibility and permeability in spatial layouts has led to a loss of street life and local community. This has been exacerbated by lack of attention to cultural assets and vernacular tradition, lack of diversity in built form and poor integration of green space.

3.4.2 India

The unprecedented growth of towns and cities in India has left municipal governments with critical infrastructure shortages and service gaps to fill. Over 65 million of India's urban residents now live in informal settlements, up from 52 million in 2001 (Census of India 2011). On average – in cities such as Ahmedabad – 25% of the population live in informal settlements, while in some larger metros such as Mumbai over half the population, or 54%, live in informal settlements with precarious conditions (Ahluwalia et al. 2014). Over 44% of households in informal settlements live with open drains, 30% have no access to piped water, and about a third lack access to any form of household sanitation (Census of India 2011). The government projects that India will need to raise at least US$640 billion in public and private funds over the next 20 years to address the basic urban infrastructure gap (HPEC Ahluwalia 2011). There are, however, important co-benefits to this investment. Investing in alleviating the urban housing shortage for instance, could raise the country's GDP growth rate by 1–1.5% (High Level Task Force 2008).

Poorly managed urban growth could undermine India's economic growth trajectory. Indian cities account for less than a third of the population, but generate two thirds of GDP, nearly half of which comes from the districts where India's 53 largest cities are located (Ahluwalia 2014). By 2031 the urban share of GDP is projected to increase to 75% (Ahluwalia 2014). India's urban population contributes over 90% of the government's total tax revenues and concentrates the majority of non-agricultural jobs. By 2031, Indian cities are expected to create 70% of all net new jobs (HPEC Ahluwalia 2011; McKinsey Global Institute 2010). The middle class share of the Indian population, currently at roughly 50 million people, is projected to reach 200 million by 2020 and 475 million by 2030 (EY 2013). In terms of employment and productivity, with 60% of the country's population of working age in 2013 and with projections for this share to continue to rise until 2040, there are significant challenges associated with creating productive employment in India's cities (Ahluwalia 2014). Estimates suggest that the country will need 700–800 million square metres of commercial and residential space by 2030 to accommodate this growth, which is roughly equivalent to building a new city the size of Chicago every year (McKinsey Global Institute 2010). Without strategic and innovative planning, Indian cities run the risk of locking in costly investment in long-lasting but poorly planned urban assets.

Indian cities not only face severe infrastructure bottlenecks and urban service deficits that undercut urban productivity and economic performance, but they are also currently on an economic growth path that is increasingly carbon and energy intensive. India's net greenhouse gas emissions were estimated at 1.7 gigatonnes of CO_2 equivalent in 2007 (Tewari et al. 2014). Of these, 44% had urban origins (MoEF 2010). Like other Asian cities, especially in China, Indian cities have a high share of carbon emissions from manufacturing industries (between 30 and 50%). Other sources include transport (8.2%), urban buildings (2.5%) and waste (3.3%) (Tewari et al. 2014). Under business as usual, these shares are likely to rise as India's economic and urban growth escalates. In just one decade, from 2001 to 2011, India's share of global emissions rose from 4% to 6% (Tewari et al. 2014). In addition, a business as usual scenario has important public health cost implications. Urban pollution in the country has caused 620,000 premature deaths in 2010, up more than six fold from 2001, and a recent survey of 148 Indian cities by the Indian Central Pollution Control Board (2009) found only two cities with passable air quality. Recent estimates show that the cost of environmental degradation is enormous, reducing India's GDP by 5.7%, or about US$80 billion (World Bank 2013c).

India's relatively high-carbon urban economic growth is largely due to a range of factors. These include: the country's energy-intensive industrial composition in urban areas; a severe lack of public transport systems combined with a high degree of reliance on polluting private vehicular transport; a lack of well-functioning land markets, particularly for affordable housing; and an absence of transparent regulations for developing and re-developing land or property more strategically (Tewari et al. 2014).

3.4.3 South East Asia

To understand the economic and social costs associated with urban environmental challenges in South East Asia, it is necessary to examine how cities in the region are expanding. Cities in the region tend to expand with minimal public planning and with spatially segregated, low-density developments on the urban fringe. Urban expansion tends to outpace population growth, although this may be necessary in some cities to correct historically high densities in some cities. Development in Jakarta is

occurring most rapidly on the urban fringe and tends to be characterised by low-density developments in communities that are gated or otherwise characterised by restricted access. This can limit options for public transport services and encourage the use of personal vehicles. Hanoi and Manila are also characterised by the rapid growth of segregated communities on the urban fringe.

In Kuala Lumpur, the core urban areas have experienced strong growth (77% between 1980 and 2013), but the suburban areas are still growing more quickly (280% between 1980 and 2013), and are characterised by low-density, car-based communities (Cox 2013). While the city of Kuala Lumpur has a similar population density to that of the City of San Francisco in the US (6700/km^2), the density of suburban areas of Kuala Lumpur are more similar to the low density suburbs of Los Angeles (2600/km^2) (Cox 2013).

Urban growth in South East Asia tends not to be strongly guided by urban development visions or plans, which makes it difficult for the public sector to align urban form with environmental or economic goals (OECD 2014b forthcoming). In many cities in the region, the public sector has little authority over land development decisions, which tend to be driven by the private sector (McGee 2005; Porio 2009; Percival and Waley 2012). In the Jakarta Metropolitan Area, some private developers manage urban development rather than municipal authorities, and private neighbourhoods provide urban amenities and services that are more likely to be provided by municipal governments in OECD countries (Firman 2004b; Zhu 2010).

In Indonesia, land permits are easily obtained, even when they are for developments that conflict with existing urban plans and encourage speculation by developers who may not be in a position to actually develop the land (Firman 2009). This results in 'leapfrog' development, where urban land 'leaps' over undeveloped land. Development and building permits tend to be used as revenue-raising tools rather than mechanisms for managing land use (Firman 2004a). In Hanoi, the lack of strategic urban planning has contributed to the location of industrial zones in the rural fringe of the city and irregular expansion of housing development into suburban villages (Quang and Kammeier 2002). New developments that result from unplanned, private sector-driven urban expansion do not internalise the costs of extending infrastructure or the impact on the environment (including increased vulnerability to climate change and higher rates of air and water pollution). These costs are instead borne by the public sector and by inhabitants throughout the urban area.

Cities in South East Asia are more vulnerable to flooding. While 34% of cities with over 750,000 inhabitants worldwide are at high risk of flooding, 63% of such cities in South East Asia are at high risk (UN DESA 2012c). South East Asian cities' exposure to flooding and economic losses associated with flooding events are expected to increase. This is in part due to expected rises in sea level caused by climate change and in part due to land subsidence, which is a problem particularly in Bangkok, Ho Chi Minh City and Jakarta (Hallegatte et al. 2013a). Looking at future risks, under a 2050 scenario that takes into account socio-economic change, subsidence, a 20cm sea-level rise by 2050 and adaptation measures that maintain 2005 flood defences and constant flood probability, three South East Asian cities (Ho Chi Minh City, Jakarta and Bangkok) are among the top 20 port cities globally in terms of flood risk (in terms of absolute average annual economic losses). Among these cities, Jakarta is expected to experience a 54% increase in average annual losses compared with 2005, ranking it among the top 10 coastal cities in terms of average annual losses (Hallegatte et al. 2013b). Three South East Asian cities are also among the top 20 cities at risk in terms of annual losses as a share of city GDP - Ho Chi Minh City, Palembang and Hai Phòng.

Unmanaged urban expansion can also lead to costly levels of air pollution. Urban air pollution rates in the region are lower than in China and India, but all except Brunei Darussalam are still higher than WHO guidelines for outdoor air quality. While comparable data on the costs of outdoor air pollution are not available at the city level, the OECD has estimated the costs to countries of air pollution, based on calculations of the value of a statistical life derived from surveys of individuals' willingness to pay to reduce the risk of death from air pollution (OECD 2012c, 2014c). Using this methodology, the costs of outdoor air pollution from all sources in 2010 was nearly US$50 billion in Indonesia, over US$27 billion in Thailand and over US$20 billion in Vietnam (OECD 2014b forthcoming). Finally, unmanaged urban expansion can result in the growth of informal settlements, which are often characterised by insufficient access to water and sanitation services and present a drag on economic growth and environmental quality of life. In South East Asia, the share of urban informal settlement dwellers has declined greatly, from 50% in 1990 to 31% in 2010, a slightly larger decline than in developing regions overall (46% in 1900 to 33% in 2010) (UN-Habitat 2010c). Within the region, there is wide variation in the percentage of urban dwellers living in informal settlements. Lao PDR and Cambodia, which have the lowest overall urbanisation rates, have the highest share of urban population living in informal settlements (OECD 2014b forthcoming; UN-Habitat 2010c).

The share of access to improved water and sanitation in urban areas varies greatly within the region; less than 80% of the urban populations of Indonesia and the Philippines, for example, have access to improved sanitation (WHO and UNICEF 2014). Low access to sanitation has direct economic costs. The World Bank (2008) found that Cambodia, Indonesia, the Philippines and Vietnam lose US$9 billion annually (based on 2005 prices) due to poor sanitation. This corresponds to 1.3% of GDP in Vietnam, 1.5% in the Philippines, 2.3% in Indonesia and 7.2% in Cambodia (World Bank 2008).

3.4.4 Sub-Saharan Africa

Urban informality and urban poverty have continued to increase in Sub-Saharan Africa due to uneven distribution of economic growth and high levels of inequality. Urban poverty is widespread in the region; the majority of urban people are poor, with the proportion growing since the 1980s. In 2010, the poverty rate in the region was 48% (World Bank 2013d). In some countries, the poverty rate has declined, but still remains high compared to other regions. For example, the proportion of people in extreme poverty fell from 62% in 1990 to around 30% today (World Bank 2013d). The negative impact of urban poverty on urban livelihoods has been exacerbated by a prevailing economic insecurity, due to the high degree of informality in the urban economy in cities in the region (Potts 2013).

Informality also exists in the provision and consumption of essential services such as housing, water, waste management and transport (Potts 2013). While Sub-Saharan Africa continues to have the lowest proportion of urban population on the continent at around 35%, the region has the highest proportion of informal settlement dwellers at around 65% (Ncube 2012). Informal settlements are temporary housing structures without legal status as residential dwellings, which tend to have poor sanitary conditions and to lack access to public services such as running water and regular waste collection (UN-Habitat 2009). Most cities in this region are characterised by insufficient or inadequate and outdated basic infrastructure, especially in low-income areas; only 20% of the region's population, for example, has access to electricity (Ncube 2012). Although 42% of the urban population in Sub-Saharan Africa has access to improved sanitation, informal settlements in the cities still suffer from low access levels, which can lead to higher risks of diseases (De Silva and Marshall 2012). An estimated 1.5 billion people in the region lack access to safe drinking water and as a result at least 5 million deaths a year are attributed to waterborne diseases (WHO 2010).

The growth rate of informal settlements in Sub-Saharan Africa is around 4.5%, compared with 2.2% in South Asia (UN-Habitat 2006), while the number of informal settlement dwellers has decreased by 17 million or 5% worldwide (UN-Habitat 2010a). Ghana, Senegal and Uganda are the only countries to have reduced informal settlements by more than 20% (UN-Habitat 2010a). In Kenya, for example, at least 5 million people live and work in informal settlements in the country's major urban centres (State House 2007), 2.5 million of whom are in the capital Nairobi (Ministry of Housing 2010). While Kenya's urban population share is still below the world average of 50% (Kenya National Bureau of Statistics 2009), it is expected to become a predominately urban country by 2035 as a result of rural-urban migration (World Bank 2011). Nairobi's population alone is projected to grow by 47–50% in the next five years (UN-Habitat 2010a).

In many parts of Sub-Saharan Africa, urbanisation is occurring without industrialisation. In these cases, the process of urbanisation is associated with natural resource exports rather than industrial development. Consequently, a rise in urban poverty and the associate expansion of informal settlements needs to be understood within the context of the wider national economic growth model. For a discussion of urbanisation without industrialisation, see Fay and Opal 2000 and Gollin, Jedwab et al. 2014.

With a rapid rate of urbanisation projected for the next two to three decades, cities in the region face the challenge of growing informality and increased numbers of people without access to services and resources. Millions of people could find themselves in informal settlements as they migrate to the city. Furthermore, with a lack of legal rights and recognition, the majority of the urban poor are extremely vulnerable (Potts 2013). For example in Dar es Salaam, Tanzania's rapidly urbanising capital city, 80% of buildings are located in unplanned, informal areas (UNICEF 2012).

Local governments in the majority of African countries are ill-equipped, in terms of well-trained personnel, infrastructure capacity and specific urban management policies and instruments, to address these problems effectively (UN-Habitat 2006). In addition, the large percentage of informal dwellers and workers within the city limits leads to a low tax base, reducing the revenue raising potential of these cities (UN-Habitat 2006).

4 TOWARDS THE 3C MODEL OF URBAN GROWTH

In the longer term, if countries and cities are to capture the productivity benefits of urban growth while minimising the costs, cities will need to shift to a more economically and environmentally sustainable pattern of growth (Stern 2006). In particular, urbanisation will need to be managed to avoid inefficient urban design, infrastructures, governance, financing mechanisms and institutions (Yusuf 2013).This will involve investment in public transport-oriented spatial development, smart infrastructures and technology, walkable and human-scale local urban environments and functionally and socially-mixed urban neighbourhoods.

Addressing the market failures associated with poorly managed urban growth will require a new urban development model for many cities. In particular, three pillars are crucial: compact urban growth, connected infrastructure and coordinated governance. The three pillars are overlapping and mutually reinforcing, requiring integrated policy programmes to capture their benefits fully. For more details on integrated policy and governance under the 3C model, see the second New Climate Economy paper on cities (Floater, Rode et al. 2014b).

Pillar 1: Compact urban growth through managed expansion and/or urban retrofitting that encourages higher densities, contiguous development, functionally and socially mixed neighbourhoods, walkable and human-scale local urban environments, the re-development of existing brownfield sites and the provision of green spaces. Compact growth represents relatively dense, proximate development, with high levels of accessibility to local employment and services. This type of development is not about urban containment or solely about high density, but rather about how urban expansion is managed to develop dense, transit-oriented urban forms.

Pillar 2: Connected infrastructure through investment in innovative urban infrastructure and technology that connects and captures the economic benefits of more compact urban forms. This includes investment in:

- **Transport systems** that connect employment, housing, and commercial clusters, such as Bus Rapid Transit systems, cycle superhighways, vehicle sharing, pedestrianisation, smarter traffic information systems, electric vehicles and charging point networks;
- **Urban utilities** that deliver more connected, resource-efficient public services such as efficient energy, waste and water systems, street lighting technology, and smart grids;
- **Buildings** with innovative and resource-efficient designs, new heating, cooling and lighting technology, and building control systems;
- **Low-carbon, climate resilient, basic infrastructure** in Emerging Cities, where the priority is to connect growing populations to essential water, sanitation, waste and transport services.

Pillar 3: Coordinated governance through effective and accountable institutions to support the coordinated planning and implementation of programmes of activity and investment across public and private sectors and civil society, particularly for land-use change and transport.

This 3C model – compact, connected and coordinated - is already embodied in a few cities such as Copenhagen, Stockholm and Singapore. Also, many other cities are pursuing some elements of the 3C model, for example Bogotá, Colombia, Cebu Metropolitan Area in the Philippines and Durban in South Africa. And while the specific policies used in these cities will not necessarily be directly transferable to others, the general 3C approach and the associated options for policy intervention should be relevant for cities at different stages of development and different starting positions.

4.1 Benefits of Compact, Connected and Coordinated Cities

The 3C model of urban development is ultimately about harnessing the growth potential of cities by reinforcing their central function: facilitating access to other people, goods and ideas. Throughout history, cities have been dynamic centres of economic specialisation and cultural expression. By enabling density – the concentration of people and economic activities in a small geographic space – these economic and social interactions create a vibrant market and fertile environment for innovation in ideas, technologies and processes, spurring innovation and productivity (Lucas 1993; Black and Henderson 1999; Rosenthal and Strange 2003; Glaeser 2011).

A number of cities are already showing that compact, connected and coordinated urban pathways can go hand in hand with strong economic growth. While Stockholm reduced transport, heating and electricity emissions by 35% between 1993 and 2010 from a low starting point, the city's economic output grew by 41% over the same period – one of the highest growth rates in Europe (Figure 25). The World Economic Forum ranked Stockholm fourth in the world for competitiveness – higher than any North American city. Similarly, Hong Kong and Copenhagen have delivered strong and stable growth while reducing carbon emissions in the transport sector. In another example, car ownership in London decreased by 6% between 1995 and 2011, while the city's economy grew by around 40% (Rode, Floater et al. 2013).

Most cities do not have the starting positions or knowledge-led economies of Stockholm, Copenhagen and Hong Kong. For example, carbon emissions in rapidly growing, industrialising cities will inevitably increase in the industrial sector in the short-term. However, the reduction in carbon emissions in the transport and heating sectors in leading green economy cities suggests that a combination of compact urban growth and connected public transport and non-motorised transport infrastructure could be used by other cities as part of a lower carbon growth pathway in these sectors.

Figure 25

Divergence of economic growth and city carbon emissions in Stockholm, Copenhagen and Hong Kong. Carbon emissions are for the transport, heating and electricity sectors alone and do not include direct industrial emissions
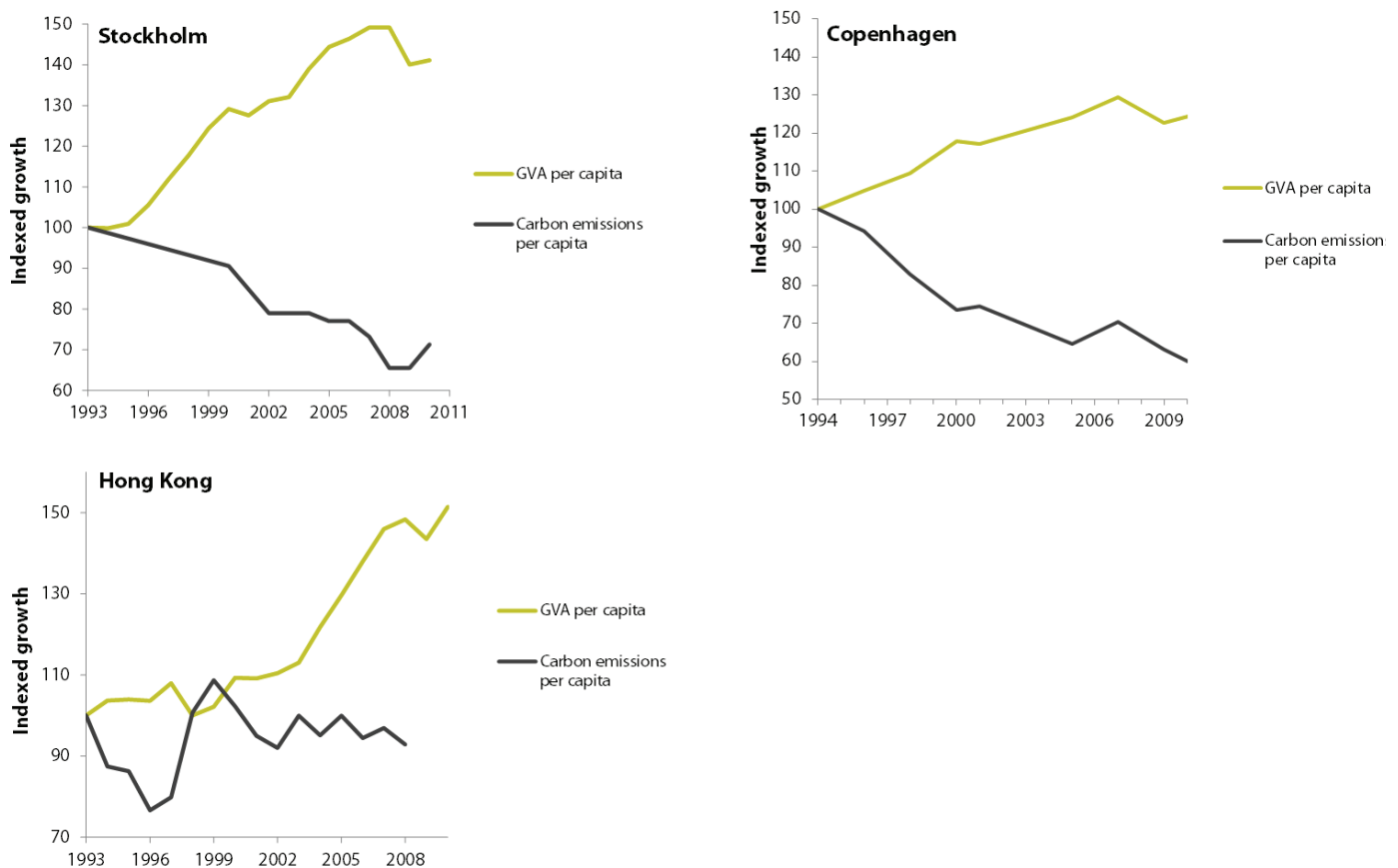
Sources: Floater, Rode et al. 2013; Floater, Rode et al. 2014a; Rode, Floater et al. 2013

Shifting towards a more compact, connected and coordinated urban pathway at scale would provide many cities with a range of economic and social benefits. These include:

1. **Raising productivity and growth through agglomeration effects.** For example, the World Bank (2014a) estimates that in China, a more compact urban development pathway would lead to higher economic growth and urbanisation, greater total factor productivity, and a larger tertiary industry share by 2030. Coordinated governance can also raise productivity. Evidence suggests that a doubling in the number of municipalities within a metropolitan area is associated with a 6% reduction in productivity, while almost half of this effect can be mitigated by the presence of a metropolitan level governance body.

2. **Improving the efficiency of capital deployment and closing the infrastructure gap.** According to analysis commissioned for this project, the incremental external costs of sprawl in the United States alone are around US$400 billion annually. Of this, an estimated US$200 billion per annum could be saved by the US if smarter, more compact growth policies were pursued, primarily through savings in the incremental costs of providing public services and capital investments such as roads (Box 2). The cost savings as a result of containing sprawl in the United States are an estimated US$12.6 billion for water and sewerage infrastructure and US$110 billion for road infrastructure (Burchell 2002). According to the World Bank, China could save up to US$1.4 trillion in infrastructure spending – equivalent to 15% of China's GDP in 2013 – if it pursued a more compact, transit-oriented urban model; and this could reduce China's estimated investment gap of US$160 billion (Zhang et al. 2013; World Bank 2014a).

Box 2
Reducing the Costs of Subsidising Urban Sprawl

Urban sprawl refers to dispersed, single-use, car-oriented, urban-fringe development. This contrasts with 'smart growth', which favours more compact, mixed, multi-modal, infill development in cities.

The subsidising of urban sprawl describes the extent to which current public policies and planning practices in cities unintentionally encourage more dispersed urban development patterns than would otherwise be the case. Examples of planning and market distortions include zoning codes and development requirements that discourage compact development in existing urban areas; excessive parking requirements; and transportation planning and funding practices that favour car-oriented improvements to the detriment of other more sustainable travel modes.

Sprawled development often imposes significant economic, social and environmental costs, and many of these are external and therefore economically inefficient. New analysis commissioned by the LSE Cities New Climate Economy project identifies the various costs associated with urban sprawl and thus the potential benefits from pursuing smart growth policies. The results suggest that the incremental external costs of sprawl in the United States alone are around US$400 billion annually. Of this, an estimated US$200 billion per annum could be saved if smarter, more compact growth policies were pursued.

Costs associated with urban sprawl include:

A rise in per capita vehicle motor travel due to reduced accessibility. Sprawl increases the travel distance required to reach services and activities and reduces the efficiency of walking and public transit.

Increased road and parking costs and subsidies due to more per capita vehicle travel.

Increased traffic congestion imposed on others.

Increased crash risk imposed on other road users.

Higher costs per passenger-mile due to reduced transit service cost efficiency.

Environmental costs associated with a reduction in the amount of open space (farms and wild lands); and increased pollution emissions as a result of increased fuel consumption/vehicle use.

Increased costs of providing public services, due to more infrastructure required to serve longer distances and sprawled areas, including roads, schools, utilities, healthcare and emergency services.

Reduced community cohesion, because of decreased neighbourhood walking and fewer local services.

These costs tend to reduce economic productivity and competitiveness. For example, higher infrastructure costs increase manufacturing costs, and higher traffic crash rates increases the chance that employees will lose work time due to injuries. A rise in vehicle ownership and travel increases various transportation costs including per capita costs of owning and operating motor vehicles, road and parking facility costs, traffic accidents, energy consumption and pollution emissions. The analysis suggests that smart growth development policies can reduce per capita land consumption by 60–80%, utilities and public service costs by 10–30% and sometimes more, and motor vehicle travel and associated costs by 20–50%, whilst at the same time helping to create more liveable, healthy and affordable urban communities.

Source: Litman (2014) commissioned by LSE Cities on behalf of the New Climate Economy

3. **Delivering substantial cost savings in the transport sector.** Estimates for the United States suggest that transit-oriented urban development could decrease per capita car use by half, reducing household expenditures by 20% (Arrington and Cervero 2008). In 1995, transport costs in transit-oriented Singapore were US$10 billion less than in car-oriented Houston, a city of similar population size and wealth (Laconte 2005). Even with significantly lower fuel prices, transport costs in Houston with a sprawling urban footprint spends are around 14% of its GDP compared to 4% in the relatively compact city of Copenhagen and typically around 7% in many Western European cities (Laconte 2005). In New York, density-related transport cost savings amount to around US$19 billion per year (Cortright 2010). The roll-out of connected infrastructure such as Bus Rapid Transit (BRT) in many developing countries has also delivered substantial benefits. Travel time savings from BRT have been estimated at 20 to 50% in Buenos Aires, while commuter cost savings are up to 50% in Lagos (Turner and Pourbaix 2014).

4. **Delivering a wide range of co-benefits related to public transport, walking, and cycling infrastructure.** Co-benefits include greater accessibility to low-cost transport and jobs, reduced congestion, improved public health and safety, as well as greater energy security (Jacobsen 2003; Hultkrantz et al. 2006; Saelens et al. 2003; Heath et al. 2006; Sallis et al. 2009; Creutzig et al. 2012). These benefits have a disproportionately positive impact on the urban poor.

5. **Generating substantial health benefits from improved air quality and physical activity.** A study of Ho Chi Minh City, for example, demonstrates that compact urban growth could reduce transport sector CO_2 emissions by 27% and fine particulate matter (PM2.5) by 44%, as well as achieve a 12% reduction in indirect CO_2 emissions and a 16% reduction in indirect PM emissions from reduced electricity use (Clean Air Asia 2013). Some of the historically most polluting cities – such as London – have reduced air pollution to close to WHO guidelines. The benefit to the national health service of more active lifestyles associated with walking and cycling has been estimated at £17 billion per year in the UK (Jarrett 2012).

In addition to the economic and social benefits, more compact, connected and coordinated urban development will also have significant climate benefits through:

6. **Lower carbon emissions from transport, buildings and other operations.** The IPCC estimates that a 20 to 50% reduction in greenhouse gas emissions from urban transport is possible between 2010 and 2050, compared to business as usual urban development (IPCC 2014b). New analysis for this project shows that if all cities reduced car ownership to levels of the best performing cities in their region, and combined that with compact urban growth, carbon emissions could be around 1.4 gigatonnes lower in 2030 compared to business as usual urbanisation (Box 3). A range of studies across cities in the UK, India, Indonesia, and Peru suggests that cities in both the developed and developing world have opportunities to introduce cost-effective investments at scale that would not only reduce costs but also reduce energy use by around 15-25% (Gouldson et al. 2014). Furthermore, substantial reductions in carbon emissions could result from lower global demand for infrastructure construction materials in turn resulting from more compact urban footprints (IPCC 2014d).

Box 3
Potential for Global Emissions Reductions in the City Transport Sector

As part of the carbon emissions analysis undertaken for this paper, a 'what if' scenario was used to assess the potential for carbon abatement in the city transport sector. Two scenarios were run for 724 cities with a population above 0.5 million based on metropolitan area. The baseline scenario assumed carbon emissions growth for the cities under business as usual urban economic growth from 2012 to 2030. An alternative pathway, based on more compact, connected cities, aimed to explore the potential impact on city emissions of more efficient urban land use (using reduced rates of physical urban expansion as an indicator) and a shift towards more energy efficient transport modes (using lower levels of fossil fuel car ownership as an indicator).

The compact, connected scenario resulted in a 35% reduction in city transport carbon emissions worldwide; a saving of 1.4 gigatonnes a year by 2030. Between 2012 and 2030 this represented a cumulative saving of 14.4 gigatonnes. This 'what if' scenario depends on the assumptions of urban expansion rates and fossil fuel car reductions relative to business as usual. Under the alternative scenario, urban land area growth was assumed to grow at the same rate as population growth in cities in developing countries, and at a rate of zero for cities in developed countries (Western Europe, North America and Oceania).

The scenario also assumed that fossil fuel car ownership in cities did not exceed the level of a benchmark city in the same world region. Benchmark cities were selected on the basis of low car ownership levels and above average income levels in their respective region projected for 2030. Fossil fuel car ownership here is used as a proxy for a range of potential disruptive adjustments cutting across all forms of new urban mobility, including a shift towards public transport, increases in cycling rates, shared mobility, as well as technological innovations that result in a greater proportion of electric vehicles in cities.

Definitions and methods for determining baseline and alternative pathways are set out in further detail in the Appendix.

Source: LSE Cities using data from Oxford Economics (see Appendix).

4.2 Compact urban growth

Compact form supports the primary function of cities: facilitating access to other people, goods and ideas. Compact growth represents relatively dense, proximate development, with high levels of accessibility to local employment and services (OECD 2012a). This type of development is not about urban containment or even high density per se, but rather about how urban expansion is managed to develop dense, transit-oriented urban forms. Accessibility is generated by different combinations of urban form and transport that ultimately create economies of scale, agglomeration effects and networking advantages. Physical proximity is the first principle of achieving accessibility in cities. To a degree, it can be substituted with high speed travel, facilitated by rapid, motorised modes of public and private transport. However, in many cities this substitution has reached excessive levels, leading to the negative externalities outlined above and threatening economic competitiveness.

More compact growth reduces the costs of service and infrastructure provision and the scale of conversion from agricultural to urban land. It also increases the viability of connecting public transport and other forms of basic urban infrastructure. Moreover, the components of this system are self-reinforcing, generating a virtuous circle: more compact urban centres can help to concentrate urban innovation and job creation, helping to attract talent and capital for investment in smarter infrastructure and technology and widening the skilled labour pool to boost the capacity of municipal authorities.

Compact cities come in many forms, but are characterised by a human-scale built environment with higher density, mixed-use urban form and high quality urban design. They include the European city model, transit-oriented development, new urbanism and polycentric urban development (Gehl 1987; Kelbaugh 1989; Calthorpe 1993; Jenks, Burton and Williams 1996; Thomas and Cousins 1996; Gertz 1997; Urban Task Force 1999; Burgess 2000; Rogers and Power 2000; Williams, Jenks et al. 2000, Burton 2002; Cervero 2003; OECD 2012a; UN-Habitat 2012). Compact urban development typically focuses on urban

regeneration, the revitalisation of urban cores, the promotion of public and non-motorised transport, and high standards of urban management (Williams, Jenks et al. 2000; Breheny 2001). Market forces in de-industrialising Global Megacities and Mature Cities generally reinforce strategies to support re-densification and mixed-use development. But compact urban form in more industrial Emerging Cities will require appropriate integration of their manufacturing, residential and other areas.

Relationships between population, economic output and CO_2 emissions in urban areas have been the focus of extensive study. By identifying a scaling relationship between population and CO_2 emissions for US metropolitan areas, studies have found that a 1% increase in population is associated with a 0.93% increase in carbon emissions (Fragkias et al. 2013) and a 1% increase in economic output with a 0.79% increase in emissions (Lobo et al. 2009). These results suggest that larger metropolitan areas are more energy efficient and that increasing metropolitan economic output is associated with decreasing energy consumption. However, further research on urban scaling is required before conclusions can be drawn definitively (see Bettencourt, Lobo et al. 2013).Compact urban growth will also require accommodating some urban expansion. Expansion can be compact if new developments are proximate to existing developed land and serviced by infrastructure. However, if expansion in Emerging Cities is excessively restricted, the result could be development that 'leapfrogs' over urban growth boundaries or the growth of informal settlements on the urban fringe due to high housing prices. Either case would result in an increase in urban sprawl.

Studies on urban land expansion have shown evidence of a global pattern of declining urban densities over the last 10 years. Despite rapid urbanisation, many cities in the world have become less dense and less compact, generating sprawl, congestion and informality over the last few decades (Angel 2011; Reid et al. 2005 in UN-Habitat 2012; Seto et al. 2011). A study by the Urban Land Institute (2010) found that doubling densities can reduce vehicle miles travelled by 5–12%; and in combination with increased mixed-use land development and improvements to the transit system, it can be reduced by as much as 25% (UN-Habitat 2012).

Development in Global Megacities and Mature Cities can largely be accommodated on existing urban land. This implies retrofitting existing neighbourhoods and former industrial sites whilst re-allocating road space and car parking to a greater mix of alternative transport and non-transport related uses. Successful examples of this include London, Copenhagen, Seoul, Bogotá and Berlin. In China, Guangzhou could accommodate more than 4 million additional residents if its density was adjusted to the levels of Seoul (World Bank 2014a). For cities already affected by substantial sprawl, including Houston, Sydney and Johannesburg, concentrating new development in denser, urban blocks, served by safe and reliable public transport systems that also connect to outlying areas will eventually enable compact city pockets and a diversification of their economies. This can be complemented by the regeneration and revitalisation of urban cores on existing brownfield sites.

Re-densification is already occurring in some leading, well-managed cities. Over the last decade, re-densification has been taking place in a range of Mature Cities and Global Megacities (OECD 2010), including London, Brussels, Tokyo, Hamburg and Nagoya. Beijing is reversing the trend of sprawling cities in China: population density in its core has already increased by 50% (World Bank 2014a). Since 2000, population growth in London has been concentrated within a 10 km radius of the city centre and 53% of all newly constructed floor area between 2004 and 2011 was located within walking distance of a rail or underground station (Rode 2014). In other cities, population densities are already high. Here, the challenge is to provide more efficient, connected infrastructure to service the population as well as managing urbanisation at the periphery of the city.

4.3 Connected infrastructure

Cities can use connected, integrated infrastructure to capture the economic benefits of compact urban growth. Connected infrastructure means integrated infrastructure systems that are cost efficient, energy efficient, low carbon, climate resilient and socially inclusive. In the context of Emerging Cities, connecting growing populations to basic infrastructure will be the primary focus and the challenge will be to invest in infrastructure that is low-carbon, climate-resilient and inclusive. At the same time, cities will need to integrate their strategies for compact urban growth and connected infrastructure to maximise the benefits (see Box 4 for a discussion on population density and the provision of low carbon energy).

Box 4
Low Carbon Infrastructure Strategies for Cities

The urban development strategies that cities can pursue to grow with low carbon trajectories differ depending on urban form, climate, and technological factors. Among the most important determining characteristics are the carbon intensity of electricity supply and the population density of the urbanised area (see Figure 26 below). Cities where the carbon intensity of power grids is below ~600 tonnes of CO_2 equivalent/GWh can broadly pursue electrification and alternative space-heating strategies for low carbon development e.g. adopt electric vehicles, or use heat pumps instead of natural gas furnaces. Above ~600 tonnes of CO_2 equivalent/GWh electrification becomes self-defeating; overall emissions rise due to the high carbon content of electricity supply. Other strategies are, broadly speaking, only viable at medium to high urban densities – above ~6,000 persons/km². Widespread use of district energy systems or substantial public transportation systems only becomes more economically viable at higher densities. Primary strategies for low carbon development may thus be different for cities such as Denver, Toronto, Rio de Janeiro and Beijing, as shown in Figure 26.

In cities expected to undergo rapid growth and with a commensurate need for increased electricity supply, such as Dar es Salaam, the future expected greenhouse gas intensity of electricity supply needs to be considered. In many fast growing cities, potential future hydro-electric opportunities may be exhausted and the carbon intensity of new supply could vary markedly (e.g. likely mix of coal, natural gas, nuclear, renewables).

Figure 26
Examples of low carbon infrastructure strategies tailored to different cities. Prioritisation according to urban population density and the average greenhouse gas intensity of existing electricity supply
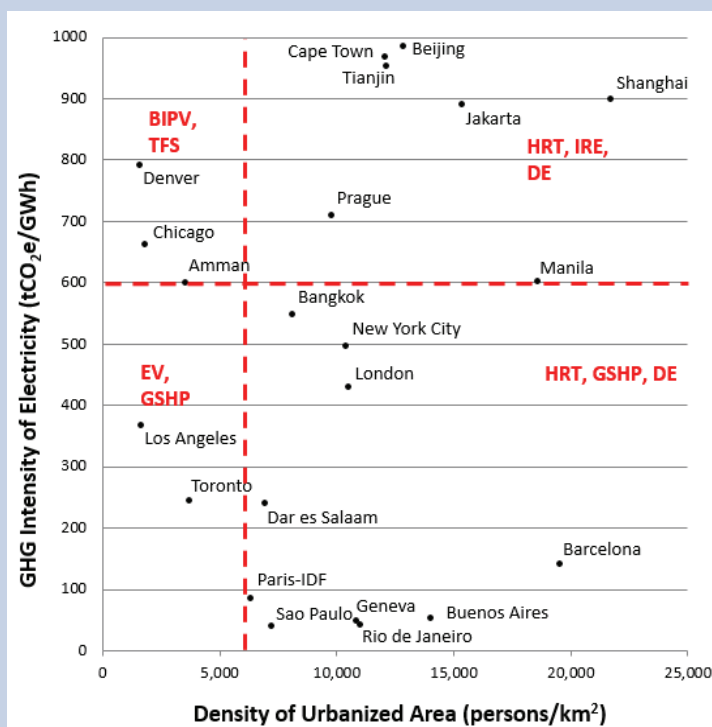
*Source: adapted from Figure 4 in Kennedy et al. 2014*

BIPV: Building Integrated Photovoltaics; DE: District Energy; EV: Electric Vehicles; GSHP: Ground Source Heat Pumps; HRT: Heavy Rapid Transit; IRE: Import Renewable Electricity; TFS: Transportation Fuel Substitution.

Connected infrastructure should draw on an appropriate mix of low and high tech solutions. In transport, this includes systems and technologies such as Bus Rapid Transit, cycle superhighways, car and cycle sharing, smart grids, information systems, charging points and electric vehicles. In the building sector, it cuts across innovative designs, heating and cooling networks, lighting technology, building control systems, smart meters and new construction materials. Smart urban utilities cut across more efficient energy, waste and water infrastructure.

Connected infrastructure delivers wider economic and environmental efficiency both at household and city levels. Smarter transport choices have the potential to reduce national traffic levels by 11% or 21% of peak period urban traffic (Cairns, Sloman et al. 2008; Sloman, Cairns et al. 2010). Incentivised by price mechanisms and the provision of cleaner, more efficient vehicles, behaviour change towards public transport, walking or cycling in city centres can help meet long-term carbon targets (Bristow, Thight et al. 2008). At the same time, a strong economic rationale exists for these smart choices, with the cost-benefit ratio in some cases being higher than 10:1 compared to conventional transport projects (Gyergay forthcoming).

Investments in public transport have been increasing over the last decade, indicating some shifts away from the traditional model of primarily investing in roads (Owens 1995; Goodwin, Hass-Klau et al. 1998). Currently, over 160 cities globally have implemented BRT. Urban rail networks in China will total 3,000 km in system length in 2015 and double by 2020, equivalent to over 4 trillion yuan in investment (World Bank 2014a). At the same time a range of sustainable and smart transport systems have taken off in numerous cities worldwide since 2000 (Hidalgo and Zeng 2013) (Figure 27).

Figure 27
Global adoption of sustainable transport systems
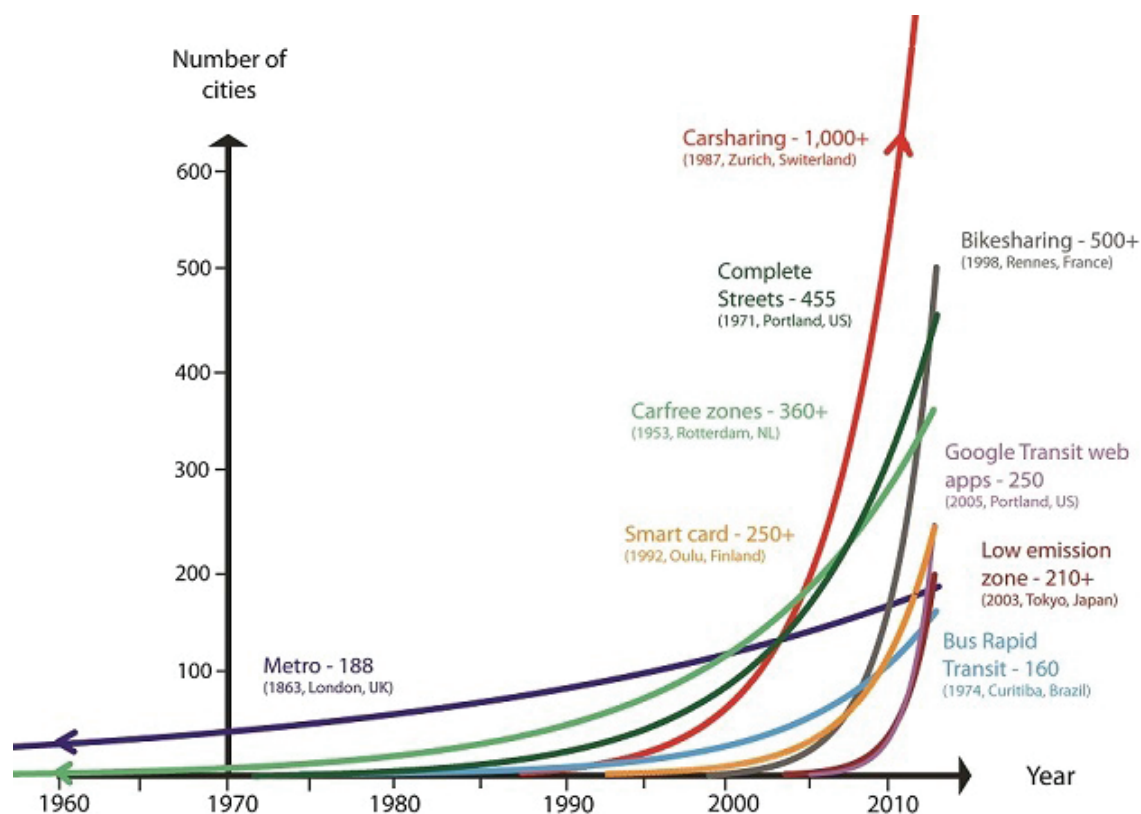
Source: Hidalgo and Zeng 2013

Bus Rapid Transit systems (BRT) are transforming cities in many developing countries, increasing productivity and land value whilst reducing carbon emissions and air pollution. Over three years, Bogotá's TransMilenio BRT infrastructure cost US$5.8 million per kilometre (US$0.34 per passenger), compared with estimates for metro rail of US$101 million per kilometre (US$2.36 per passenger) (Menckhoff 2005; UNEP 2011b). At the same time, the TransMilenio has reduced carbon emissions

by 350,000 tonnes per year. Residential proximity to interstate rights of way within a tenth of a mile decreases property value by US$6,379 on average, whereas proximity to a BRT station increases its value (Department of Transportation 2009). Curitiba was among the first cities to implement BRT successfully and it has been followed by many other cities such as Ahmedabad and Jakarta. In Guangzhou, the BRT system was launched in 2010 and is already serving over one million passengers every day, while in Jakarta, the TransJakarta BRT has reduced carbon emissions by 120,000 tonnes per year.

The city of Lagos developed a BRT system in order to relieve congestion, shorten commuting time, and reduce urban transport-induced emissions. The 'BRTLite', as it is called, modified and adapted the BRT model to make use of the existing urban road network by creating a dedicated lane but narrowing the width of carriageways to ensure that road widths remained largely unchanged. As a result, savings in construction costs meant that the project cost US$1.7 million per km, compared to an average of US$6 million per km for other well-known BRT systems. The Lagos BRT was completed in just 15 months and now serves 195,000 passengers on an average weekday. Studies have estimated that BRTLite has contributed to a 13% reduction in urban transport CO_2 emissions and a reduction in average journey times of more than 50%. The success of BRTLite is due partly to the holistic approach adopted, going beyond the provision of infrastructure to include a re-organisation of the bus industry, leveraging financing from the private sector for new bus purchases, and the creation of an institutional structure and regulatory framework to support the BRT (UN-Habitat 2012).

The upgrading of cycle infrastructure has demonstrated the benefits of cycling for many local economies, the urban environment and individual health. Initiatives range from city-wide upgrades in Copenhagen, cycle superhighways in London and cycle hire schemes combined with ICT in cities as diverse as Hangzhou, Paris and New York. Infrastructure innovations for surface-based public and non-motorised transport may have most impact in Emerging Cities and Mature Cities, as they rely less on costly underground rail and rapid rail systems that are more common in Global Megacities. The Netherlands, Denmark and Germany have all managed to create urban environments that are cycle friendly, based on the combined policies of providing rights of way, ample parking facilities and integration with public transport (Pucher and Buehler 2008). Bicycle boulevards are emerging in US cities such as Minneapolis, Palo Alto and Portland. Cycle sharing schemes are evolving rapidly following the success of the Velib scheme in Paris and the publicity surrounding the London scheme. In China, Hangzhou implemented a vast cycling network integrated with the city bus system and Changwon offers financial incentives to promote cycling. In Indonesia, Yogyakarta promotes an accident insurance scheme to encourage cyclists.

Car sharing has increased significantly in recent years, including both city and individually run schemes. Over 1.5 million members are registered to car sharing schemes in 27 countries globally; and between 2006 and 2012 the market had an average annualised growth rate of over 20% (Cohen 2013). Brazil has been at the forefront of such schemes among developing countries, while support from local authorities in Mexico has enhanced the success of such schemes there. Car pooling is a similar concept that is emerging throughout Europe but which has traditionally applied in developing countries. Taxi use and sharing through smartphone apps has been on the increase, particularly in developing countries where use of a chauffeur is more commonplace. Examples include eHi in Shanghai or Yongche in Beijing. All shared mobility schemes benefit from new advances in communications technology and smart infrastructure, particularly the use of electric vehicles.

Widespread use of electric vehicles requires a constant supply of electricity, preferably through the national grid, as well as a strategically dispersed and reliable network of charging stations. Brussels and Gothenburg are acting as test-beds of such technology in Europe, since coordinating energy demand with residential usage can be managed better through smart grids that take advantage of real time information.

Smart, energy efficient buildings and materials are cost-efficient, high-value solutions. Buildings concentrate a large proportion of global energy demand. In the developed world approximately 40% of energy end-use takes place in buildings, while in the developing world the figure is still significant at 20% (Hoornweg, Freire et al. 2013). Buildings are responsible for 30% of greenhouse gas emissions globally (IPCC 2014c) with 80% of a building's carbon footprint accruing during the 'use' phase of its life-cycle (UNEP 2009). As a result, substantial potential exists for improving the energy efficiency of buildings through better insulation, temperature control, automated lighting systems and the use of renewable building materials. Establishing smart material condition control systems, for example, can vastly reduce expenditure on monitoring and reconstruction of concrete developments (e.g. roads, tunnels and bridges). Introducing integrated and interconnected urban systems facilitated through the increasing use of ICT can enhance the effectiveness of smart grids offering low carbon energy to households and industry; and use of smart grid systems could save up to 30% of a building's energy consumption (US Department of Energy 2014).

Urban developments around the world are increasingly acting as critical test-beds for innovation, integrated technology, smart networks and behaviour change (see Box 5 for case studies). Stockholm, Copenhagen and Singapore have all integrated clean technology innovation and development projects within their cities (Floater, Rode et al. 2013; Floater, Rode et al. 2014a; Bosch 2011; Siemens 2010). Examples include combined heat and power, electric vehicle and smart grid integration and decentralised energy and building technologies. China has also designated at least eight and has plans to roll out up to 100 more low carbon cities as demonstrators to help shift the direction of urban development (World Bank 2012; Energy Foundation for Chinese Cities 2014). Furthermore, a range of ex-ante modelling commissioned for the New Climate Economy project suggests that early investment in connected infrastructure can have short-term benefits both for the city's economy and for the climate (see Box 6).

Information and communications technology is playing an increasing role in lower income cities. For example, the M-Pesa system, which operates in Kenya and Tanzania, facilitates trade and payments through telecommunication infrastructure, ICT and social networks. Investments in this type of initiative often have lower costs than large, physical infrastructure projects and may have a substantial impact on the development of cities that are severely constrained financially.

Box 5
Case Studies of Clean Tech Clusters in Cities

Singapore
Singapore's Green Test Bed is an initiative to develop the city's clean-tech sector. Led by the Singapore Government, it operates in partnership with the private sector. The planned clean-tech sector is expected to create 18,000 jobs and a turnover of approximately US$2 billion by 2015. International companies can apply for government support and are able to use the city as a test bed for developing sustainable technologies before rolling them out more widely on a commercial basis. For instance, since June 2011, Bosch Software Innovations has been working on a five-year test bed project for electric vehicles and charging technology prototypes, as well as developing new business models. Another tech company, JTC, is building Singapore's first 'green' business park and a smart electricity grid with 5,000 smart electricity meters installed.

Stockholm
Stockholm has been developing eco-districts on former industrial sites at Hammarby Sjöstad and Royal Seaport. These are internationally recognised clean-tech demonstrator projects delivered through public private partnerships. Projects within these eco-districts focus on four areas of innovation: (a) Smart Communication; (b) Smart Grid; (c) Smart Waste Collection; and (d) Smart ICT for living and working in Stockholm. These project areas are directly linked to energy, transport, climate adaptation, eco-cycle solutions, and lifestyle. The intention is to use these eco-districts to test and demonstrate new low-carbon technologies before scaling up and rolling out.

Baoding
The city of Baoding, in the Hebei Province of China, is a major hub for renewable energy production and deployment. This followed a transformation of the city which was traditionally known as a manufacturing centre, with concentrated textile and automobile industries. Over 200 Baoding-based producers of renewable and energy efficient technologies have created over 20,000 jobs and turnover of more than $US1 billion in 2009. As a result of securing low-interest loans and a High-Tech Development Zone designation from the national government, the city has been dubbed 'power valley' or 'green electric valley', emulating the industrial cluster model of California's Silicon Valley.

Sources: Bosch (2011), Siemens (2010); Floater, Rode et al. (2013); UNSCD (2012)

Box 6
Benefits of Investing in Connected Infrastructure

While Emerging Cities have an opportunity over the next 10 to 20 years to influence their urban form for the future, Global Megacities and Mature Cities will need to develop a compact, connected and coordinated model based on the urban footprint of the city that already exists. For these cities, reinventing their accessibility and efficiency will depend heavily on the implementation of connected infrastructure – effectively to retrofit their cities.

Smart infrastructure
Analysis by Siemens for the New Climate Economy suggests that if the world's largest megacities rolled out a package of 30 existing low carbon technologies, it could deliver 3 gigatonnes of reductions in carbon emissions, and lead to the reduction of 3 megatonnes of local air pollutants by 2025. The total cost of the investment is estimated at US$2.5 trillion. The 30 measures include market-ready technologies such as energy efficient building technologies, electric buses and LED street lighting. These measures would need to be implemented in parallel with decarbonisation of the electricity supply to have the greatest impact on carbon emissions.

Low carbon districts
Analysis by McKinsey on Mature Cities in the United States, China, and Middle East suggests that implementing an integrated programme of infrastructure and technologies in low carbon districts could deliver savings in annual operating costs of US$250 to 1,200 per resident. Measures include dedicated bus and cycling infrastructure and more efficient buildings. The estimated incremental capital costs are US$35 to 70 million per square kilometre, and the investment would break even between 3 and 5 years, with internal rates of return ranging between 18 and 30%. The technologies could also reduce annual energy costs by 24–36% and reduce carbon emissions by 28–49%.

Urban energy efficiency measures
An analysis of five cities at different levels of development (Leeds, Kolkata, Lima, Johor Bahru, and Palembang) suggests that substantial potential exists for energy efficiency improvements across the transport, energy and building sectors. Savings in energy consumption are estimated to be around 15-25% compared to business as usual, with pay-back periods of less than five years.

Sources: Gouldson, Colenbrander et al. (2014) Siemens (2014); McKinsey (Call for Evidence, 2014)

With the rising incidence of climate related hazards affecting urban areas, cities will also need to invest in infrastructure resilience. An ongoing study shows that 136 port cities have around US$3 trillion worth of assets at risk from climate-related events, and this figure is likely to reach US$35 trillion by 2070 (Nicholls et al. 2008). The cost of damage in Asian coastal megacities has been estimated as high as 2–6% of GDP (World Bank 2010b). In New York, Hurricane Sandy led to damages of US$19 billion (City of New York 2013). The majority of global adaptation costs (up to 80%) will be borne by cities, which could amount to as much as US$49–171 billion per year by 2030 under business as usual (World Bank 2010a). Moreover, out of the rapidly growing urban areas with populations greater than 5 million, almost two-thirds are located in coastal zones with low elevation, and they will require a set of adaptation and mitigation strategies to cope with climate change (McGranahan, Balk and Anderson 2007).

4.4 Coordinated governance

Cities will need strong leadership, effective institutions and integrated policies to deliver the new urban development model. City-level governance is a critical scale for collective decision-making and action (OECD 2010; UN-Habitat 2013; World Bank 2010a), particularly for the integrated policy intervention needed for infrastructure development and spatial planning.

While many megacities have skills and resources to deliver the new urban development model, many other cities lack capacity. Institutional strengthening is particularly important in small and medium sized developing cities, where transparency,

democratic decision making and corruption-free infrastructure procurement are often lacking (UN-Habitat 2013). Furthermore, coordinated governance will be needed if the increase in urban poverty and informal settlements is to be reversed local and national governments.

Five elements of urban governance are essential: (a) multi-level governance with effective coordination of national, regional and city policies; (b) city leadership and financial authority; (c) transparency and accountability; and (d) horizontal policy integration at the local level. As well as these elements, municipal governments can use international and regional networks of cities to transfer knowledge and innovation. See NCE Cities Paper 02 for a more extensive discussion of these elements of coordinated governance (Floater, Rode et al. 2014b).

Depending on how they are designed, national policies can enable or constrain cities' ability to pursue compact growth, improve connectedness and increase coordination. For this reason, policy coherence between national and local levels of government is critical, as is taking a holistic approach at the national level in order to anticipate the potential distributional consequences of policies for compact urban growth or improving infrastructure (OECD 2013a). Fragmented governance and lack of coordination between national and local policy frameworks for urban form and transport are extensive. However, India has developed a National Urban Transport Policy, integrating transport and land use planning as a single strategic goal (Gakenheimer 2011), while South Africa has used national legislation to create an Integrated Development Plan that coordinates national, provincial and local government policy (Rode, Wagner et al. 2008).

Coordination at the metropolitan level is essential for achieving compact urban growth, connected infrastructure and coordinated governance. Nearly all urban areas are made of multiple municipalities, but how these municipalities coordinate on the activities that affect economic growth and climate change can vary widely. For urban areas to develop more effectively and address climate change, coordination across municipalities (and regions, if applicable) is needed, particularly on land-use and urban expansion decisions, on transport planning and service delivery, and on the planning and delivery of basic services such as drinking water, sanitation and solid waste collection. Failing to coordinate land-use planning and transport investments effectively across metropolitan regions can lead to inefficient use of land, gaps or duplications in infrastructure investment, and increased traffic congestion (OECD 2012d, 2014c).

National or regional/provincial governments often need to encourage or require metropolitan coordination, as municipal governments often do not have sufficient capacity or incentive to coordinate across a metropolitan area on long-term planning and on expansion plans (OECD 2014a forthcoming). To integrate policy programmes at the metropolitan level, many countries have implemented sector specific metropolitan-level agencies that can oversee strategic objectives and appraise required expenditure transparently (Cervero 2013). Integrated, multi-modal transport authorities play a particularly important role. Transport for London is a single agency that oversees all urban transport modes ranging from non-motorised transport, public transport, and road traffic with the authority to take decisions across local administrative boundaries.
Cities need a critical level of autonomy and financial authority to deliver infrastructure and services effectively. Greater fiscal autonomy is already a trend in higher income cities, with expenditure at the sub-national level in OECD countries having reached 33% in 2005 (IPCC 2014d). However, many cities - particularly in developing countries - are often constrained in accessing funding. This has been exacerbated by the global economic downturn that has led to reduced national government spending, including on local development. Meanwhile, few cities can access private finance at scale. Only 4% of the 500 largest cities in developing countries are rated as creditworthy in international financial markets, rising slightly to 20% in local markets (World Bank 2013e). Yet US$1 invested in raising creditworthiness of these cities can leverage more than US$100 in private sector financing for smart infrastructure (World Bank 2013e). More details of raising creditworthiness can be found in our second New Climate Economy paper on cities, 'Steering Urban Growth: Governance, Policy and Finance' (Floater, Rode et al. 2014b).

Public private partnerships could help to leverage private finance while maintaining project control by the city. For example, the Delhi-Mumbai Industrial Corridor (DMIC) is developing seven new smart, greenfield cities following the example and standards set by the two already developed new cities – Dholera and Shendra (Ahluwalia 2014). India plans to spend €66 billion to develop these seven smart cities by using a mixture of public private partnerships (80% of the funds) and publicly funded infrastructure investment for the rest of the funds (Jerath 2011).

Cities need transparency and accountability in government practices to provide accountability and legitimacy of government actions. Historically, corruption has often stemmed from the substantial value of converting undeveloped land to industrial or

residential use (Brown 2014). Many city governments could use new ICT systems and e-governance to empower citizens to provide feedback to the municipal administration, strengthening their interface with the local government (Ahluwalia 2014). City governments in India are also starting to use GIS mapping systems, which can develop spatial planning strategies and also ensure more effective collection of tax revenues by better identifying individual properties.

Transparency can be strengthened through the collection and publication of urban metrics, such as local government spending on infrastructure, production of carbon emissions at the city level, and air pollution levels. An important first step for cities could be to develop a framework similar to the Standard National Accounting system (UN Statistics Division 2009; Severinson 2010). This would provide a coherent and consistent set of macroeconomic accounts based on common standards. In response to deficiencies in urban data, cities can harness ICT and social media to build effective city metrics at low cost. This has particular potential for lower income cities and those cities with constrained finances. City carbon emissions data are particularly inconsistent, of poor quality and with no common baseline. The Global Protocol for Community Scale Emissions project being developed by ICLEI, IEAP, WRI and C40, and supported by the World Bank, UN-Habitat and UNEP, is helping to address this problem.

Institutional structures at multiple levels of government also need to be capable of delivering integrated socio-economic and environmental policy programmes at the local level. Due to the cross-cutting nature of urban policies and environmental policies, pursuing compact, connected and coordinated urban growth will often involve multiple national ministries, regional governments, and multiple sectors at the local level. To improve policy coherence between different sectors and different levels of government, attention will need to be paid to the interactions among these entities and the degree to which their policy priorities align or diverge (OECD 2013a, 2014a forthcoming).

5 CONCLUSIONS

The results of our analysis suggest that over the next 15 to 20 years, three groups of cities will be key for the global economy and climate: Emerging Cities, Global Megacities and Mature Cities. When combined, the 468 cities in these groups are projected to contribute 60% of global GDP growth and over half of global energy-related emissions growth between 2012 and 2030 under business as usual.

If these cities continue on current trends of urban development, characterised by increasing sprawl and motorisation rates, energy inefficient buildings, and insufficient urban infrastructure and services, the evidence suggests that the benefits of urbanisation will be reduced and the economic and social costs will continue to increase. Poorly managed urban growth will also lead to substantially higher carbon emissions.

The 3C model of urban development provides an alternative pathway for cities to manage urban growth. While the principles of the 3C model are common to all cities, the most effective implementation of its three pillars, compact urban growth, connected infrastructure and coordinated governance, will depend on city-specific circumstances. Table 2 summarises some of the key elements of the model that policy makers could consider in each of the three key city groups in the new climate economy: Emerging Cities, Global Megacities and Mature Cities. Delivering the 3C model will depend on effective and coordinated policy intervention at different government levels, a combination of national, regional and city level policies.

Although implementation of the 3C model in these three groups will be particularly important for the global economy and climate, elements of the 3C model can also be implemented in other cities. At the same time, it is important to consider that every city has a unique combination of characteristics and starting positions, and consequently, integrated policy programmes for implementing the 3C model will need to be tailored to each city. Even the city groups themselves represent a diverse range of cities. For example, the urban development challenges and strategies for Stockholm's existing compact urban form and well-developed public transport systems are different from those of Houston's car-dominated sprawl, despite their metropolitan areas having similar levels of population and income as Mature Cities. As a result, each city will require a tailored strategy within the broad principles of e.g. regeneration of city cores and urban retrofitting.

In the longer term, beyond 2050, cities and small urban areas in low income countries, including many in Sub-Saharan Africa, are likely to grow in importance for global income and carbon emissions as the process of urbanisation continues. In these countries, national economic policy will play a particularly central role in the development of urban areas, including whether the process of urbanisation goes hand in hand with industrialisation or is resource export led.

Finally, it is important that the analysis and conclusions of this paper are not interpreted as a definitive end-point. The areas of smart growth and the urban green economy are relatively young research disciplines, and robust data for assessing the risk-adjusted costs and benefits of urban policy instruments are lacking. Consequently, an urgent need exists for the collection of consistent and comparable economic, social and environmental data at the city level, combined with further empirical research.

Table 2
Implementing the 3C model in different cities

	Compact Urban Growth	**Connected Infrastructure**	**Coordinated Governance**
Emerging Cities	Design in compact city features from the start, including integration of industrial and residential areas, and efficient public transport routes. e.g. Chenggong (China)	Introduce surface-based public transport based on bus and BRT systems and rapid rail where appropriate, along with provision of infrastructure for non-motorised travel. e.g. Bogotá (Colombia)	Build capacity for integrated land use and transport planning, access to private finance and international funds. Policy support from national and regional governments and the international community where appropriate. Develop best practice through city networks. e.g. Curitiba (Brazil), Lima (Peru)
Global Megacities	Redensify through regeneration of existing city cores and multiple hubs, brownfield re-development, and urban retrofitting. Initiate well-managed growth of urban periphery. e.g. Beijing (China)	Expand existing public transport systems and increase share of public and non-motorised travel. e.g. Mumbai (India)	Integrate land use and transport planning with regulatory, fiscal and financial policy instruments across municipalities within the metropolitan area. Policy support from national and regional governments. Provide best practice leadership for other cities. e.g. London (United Kingdom)
Mature Cities	Redensify through regeneration of existing city cores and supporting hubs, brownfield re-development, and urban retrofitting. e.g. Hamburg (Germany)	Major opportunities to introduce cycling and non-motorised travel (in mature sprawling cities redensification also required to make public transport more cost effective). e.g. Copenhagen (Denmark)	Integrate land use and transport planning, including use of regulations. Policy support from national and regional governments. Develop best practice through city networks. e.g. Barcelona (Spain)

6 BIBLIOGRAPHY

ADB (2012). Joint Statement to the Rio+20 United Nations Conference on Sustainable Development by the African Development Bank, Asian Development Bank, CAF-Development Bank of Latin America, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, Islamic Development Bank, and World Bank. June 2012

Ahluwalia, I. (2014). Transforming Our Cities: Postcards of Change. London, Harper Collins.

Ahluwalia, I., R. Kanbur and P. Mohanty (2014). Challenges of Urbanisation in India: An Overview. Urbanisation in India: Challenges, Opportunties and the Way Forward. I. Ahluwalia, R. Kanbur and P. Mohanty. New Delhi, Sage Publication.

Angel, S. (2011). "Making Room for a Planet of Cities". Cambridge, MA: Lincoln Institute of Land Policy. Available from: http://www.lincolninst.edu/pubs/1880_Making-Room-for-a-Planet-of-Cities-urban-expansion.

Arrington, G. and R. Cervero (2008). TCRP Report 128: Effects of TOD on Housing, Parking, and Travel. Transportation Research Board of the National Academies, Washington, DC,. 3.

APN (2010). Peri-Urban Development and Environmental Sustainability: Examples from China and India. Asia-Pacific Network for Global Change Research

Bettencourt, L., Lobo, J. and Youn, H. (2013). The Hypothesis of Urban Scaling: Formalization, Implications and Challenges. Santa Fe Institute Working Paper, 2013-01-004.

Black, D. and V. Henderson (1999). "A theory of urban growth." Journal of political economy 107(2): 252-284.

Bogner, J., A. M. Abdelrafie, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, and T. Zhang. (2007). "Waste Management." In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds. B. Metz, O. R. Davidson, P. R. Bosch, R., and L. A. Meyer. Cambridge and New York: Cambridge University Press.

Boston Consulting Group (2013). Bridging the gap: Meeting the Infrastructure Challenge with Public-Private Partnerships.

Boston, Boston Consulting Group.

Bosch (2011). Bosch eMobility Solution to power electric vehicle infrastructure in Singapore 2011, Bosch. Available from http://www.bosch-si.com/newsroom/news/press-releases/press-releases-3628.html [Retrieved 20 March 2014].

Bourdic, L., S. Salat and C. Nowacki (2012). "Assessing cities: a new system of cross-scale spatial indicators." Building Research & Information 40(5): 592-605.

Breheny, M. (2001). Densities and Sustainable Cities: the UK experience. Cities for the New Millennium. M. Echenique and A. Saint. London: 39-51.

Brinkhoff, T. (2014), "Major Agglomerations of the World", Available at http://www.citypopulation.de, Last accessed 9 May 2014.

Bristow, A., M. Thight, A. Pridmore and A. May (2008). "Developing pathways to low carbon land-based passenger transport in Great Britain by 2050." Energy Policy 36(9): 9.

Brown, A. (2014). City Futures- Planning Sustainable and Inclusive Cities. DFID. London, DFID.

Burchell, R. W. (2002). Costs of Sprawl, Transit Cooperative Research Program.

Burgess, R. (2000). The Compact City Debate: A global perspective. Compact Cities - Sustainable Urban Forms for Developing Countries. M. Jenks and R. Burgess. London, Spon Press.

Burton, E. (2002). "Measuring urban compactness in UK towns and cities." Environment and Planning B: Planning and Design 29(2): 219-250.

Cairns, S., L. Sloman, C. Newson, J. Anable, A. Kirkbride and P. Goodwin (2008). "Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using 'Soft Measures'." Transport Reviews 28(5): 26.

Calthorpe, P. (1993). The next American metropolis: ecology, community, and the American dream, Princeton Architectural Press.

CEIC (2011). China Economic Data Database | China GDP, GNP, FDI, CPI, Inflation Data. Retrieved 3 May, 2014, from at: http://www.ceicdata.com/en/countries/china [Accessed 14 May 2014].

Census of India (2011), Provisional Data. Available at: http://censusindia.gov.in/2011-prov-results/indiaatglance.html

Central Pollution Control Board (2009). Annual Report for 2008-09. Government of India. Available at: http://www.cpcb.nic.in/

Centre for Low Carbon Futures (2014). Call for evidence contribution to the New Climate Economy.

Cervero, R. (2003). "Growing Smart by Linking Transportation and Land Use: Perspectives from California." Built Environment 29(1): 66-78.

Cervero, R. (2013). "Linking urban transport and land use in developing countries." Journal of Transport and Land Use 6: 7-24.

Cheng, Z.; Jiang, J.; Fajardo, O.; Wang, S.; Hao, J. (2013). Characteristics and health impacts of particulate matter pollution in

China (2001-2011). Atmospheric Environment, Volume 65, p. 186-194.

City of New York (2013). New York City Special Initiative on Rebuilding and Resiliency: A Stronger, More Resilient New York. New York, NY.

Clean Air Asia (2013). Annual Report, Philippines, Accessed 20 March 2014, Available at: http://cleanairinitiative.org/portal/sites/default/files/documents/Clean_Air_Asia_Annual_Report_-_FINAL.pdf.

Cohen, A. (2013). "Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis, and Trends - Summer 2013." Retrieved 21st May, 2014, from http://www.innovativemobility.org/publications/Carsharing_Innovative_Mobility_Industry_Outlook.shtml.

Collier P., M. Kirchberger and M. Soderbom (2013). The Cost of Transport Infrastructure in Developing Countries, mimeo, CSAE, Oxford.

Cortright, J, (2010). Driven Apart: How Sprawl is Lengthening Our Commutes and Why Misleading Mobility Measures are Making Things Worse, CEOs for Cities (www.ceosforcities.org); Available at: www.ceosforcities.org/work/driven-apart.

Cox, W. (2013), "The Evolving Urban Form: Kuala Lumpur", newgeography blog, Available at: www.newgeography.com/content/003395-the-evolving-urban-form-kuala-lumpur, last accessed 5 March 2014.

Creutzig, F. and D. He (2009). "Climate change mitigation and co-benefits of feasible transport demand policies in Beijing." Transportation research part D: transport and environment 14(2): 120-131.

Creutzig, F., R. Mühlhoff, and J. Römer (2012). Decarbonizing urban transport in European cities: four cases show possibly high co-benefits. Environmental Research Letters, 2012. 7(4): p. 04404

Dargay, J., D. Gately and M. Sommer (2007). "Vehicle ownership and income growth, worldwide: 1960-2030." The Energy Journal: 143-170.

Davis, S. J., K. Caldeira and H. D. Matthews (2010). "Future CO_2 emissions and climate change from existing energy infrastructure." Science 329(5997): 1330-1333.

De Silva, PM and Marshall, JM. (2012). "Factors Contributing to Urban Malaria Transmission in Sub-Saharan Africa: A Systematic Review," Journal of Tropical Medicine, vol. 2012, Article ID 819563, 10 pages, 2012. doi:10.1155/2012/819563.

Department of Transportation (2009). "Land Use Impacts of Bus Rapid Transit: Effect of BRT Station Proximity on Property Values along the Pittsburgh Martin Luther King, Jr. East Busway" , accessed 20 March 2014 http://www.nbrti.org/docs/pdf/Property%20Value%20Impacts%20of%20BRT_NBRTI.pdf.

EIA (2009). International Energy Statistics - EIA. Retrieved 3 May. 2014, from: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm.

EMBARQ (2013). Financing Needs for Sustainable Transport Systems for the 21st Century. World Resources Institute (WRI) Center for Sustainable Transport. Background paper presented at the 7th Regional Environmentally Sustainable Transport Forum in Asia, 23-25 April 2013, Bali, Indonesia.

Energy Foundation for Chinese Cities (2014). Building Livable Cities in China, Submitted as part of New Climate Economy Call for Evidence.

EY (2013). Hitting the sweet spot: The growth of the middle class in emerging markets. Available from: http://www.ey.com/Publication/vwLUAssets/Hitting_the_sweet_spot/$FILE/Hitting_the_sweet_spot.pdf.

Fan, J. (2007). "Industrial Agglomeration and Difference of Regional Labor Productivity: Chinese." Economic Research Journal 8: 73–84.

Fay, M. and Opal, C. (2000). Urbanization Without Growth: a Not-So-Uncommon Phenomenon. World Bank Policy Research Working Paper Series 2412.

Firman, T. (2009), "The continuity and change in mega-urbanization in Indonesia: A survey of Jakarta–Bandung Region (JBR) development", Habitat International, vol. 33, pp. 327-339, Elsevier.

Firman (2004a), "Major issues in Indonesia's urban land development", Land Use Policy, vol. 21, pp. 347-355, Elsevier.

Firman, T. (2004b). "Large-Scale Housing and New Town Development in Jakarta Metropolitan Area (JMA): Towards an Urban Spatial Segregation". Department of Regional and City Planning, Institute of Technology Bandung, Bandung. Available at www.lib.gla.ac.uk/media/media_132462_en.pdf, last accessed 5 March 2014.

Floater, G., P. Rode, D. Zenghelis, M. M. Carrero, D. Smith, K. Baker and C. Heeckt (2013). Stockholm: Green Economy Leader Report. London, LSE Cities, London.

Floater, P. Rode, D. Zenghelis, M. Ulterino, D. Smith, K. Baker, and C. Heeckt (2014a). Copenhagen: Green Economy Leader Report. LSE Cities, London.

Floater, G., Rode, P., Friedel, B., Robert, A. (2014). Steering Urban Growth: Governance, Policy and Finance. NCE Cities Paper 02. LSE Cities. London School of Economics and Political Science.

Fragkias M., J. Lobo, D. Strumsky, and K.C. Seto (2013). Does Size Matter? Scaling of CO_2 Emissions and U.S. Urban Areas (M. Convertino, Ed.). PLoS ONE 8, e64727. (DOI: 10.1371/journal.pone.0064727).

Gakenheimer, R. (2011). "Land Use and Transport in Rapidly Motorizing Cities: Contexts of Controversy." Urban Transport in The Developing World: A Handbook of Policy and Practice.

GEA (2012). Global Energy Assessment - Toward a Sustainable Future. Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, 1802 pp., (ISBN: 9781 10700 5198).

Gehl, J. (1987). Life Between Buildings: Using Public Space, Island Press.

Gertz, C. (1997). Umsetzungsprozesse in der Stadt- und Verkehrsplanung: Die Strategie der kurzen Wege.

Glaeser, E. (2011). Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier. Penguin Books.

Gollin, D., Jedwab, R. and Vollrath, D. (2014). Urbanization with and without Industrialization. Working Papers 2014-01, The George Washington University, Institute for International Economic Policy.

Goodwin, P., C. Hass-Klau and S. Cairns (1998). "Evidence on the effects of road capacity reduction on traffic levels." Traffic Engineering+ Control 39(6): 348-354.

Gouldson, A., Colenbrander, S., McAnulla, F., Sudmant, A., Kerr, N., Sakai, P., Hall, S. and Kuylenstierna, J. C. I. (2014). The Economic Case for Climate Action in Cities. New Climate Economy contributing paper. Sustainability Research Institute, University of Leeds, and Stockholm Environment Institute, York, UK.

Grubler A., B. O'Neill, K. Riahi, V. Chirkov, A. Goujon, P. Kolp, I. Prommer, S. Scherbov, and E. Slentoe (2007). Regional, national, and spatially explicit scenarios of demographic and economic change based on SRES, Technological Forecasting and Social Change 74 980–1029 pp. (DOI: 10.1016/j.techfore.2006.05.023), (ISSN: 0040-1625).

Gyergay, B. (forthcoming). The use of ICT to provide incentives to change habitual travel patterns. ICT for transport: opportunities and threats. N. Thomopoulos, Givoni, M., Rietveld, P. (Eds.) Cheltenham, Edward Elgar.

Hallegatte, S., C. Green, R. Nicholls and J. Corfee-Morlot (2013a), "Future flood losses in major coastal cities," Nature Climate Change, vol.3, pp. 802-806.

Hallegatte, S., C. Green, R. Nicholls and J. Corfee-Morlot (2013b), "Future flood losses in major coastal cities: Supplementary information" Nature Climate Change, doi: 10.1038/nclimate1979.

Hammer, S., J. Keirstead, S. Dhakal, J. Mitchell, M. Coley, R. Connell, R. Gonzalez, L. Herve-Mignucci, L. Parshall, N. Schulz, and M. Hyams (2011). Climate Change and Urban Energy Systems. In: Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. [Rosenzweig, C., W.D. Solecki, S.A. Hammer, and S. Mehrotra (eds.)]. Cambridge University Press, Cambridge, UK, pp. 85-111.

Heath, G.W., R. C. Brownson, J. Kruger, R. Miles, K. E. Powell, L. T. Ramsey, and the Task Force on Community Preventive Services (2006). The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. Journal of Physical Activity & Health, 2006. 3.

Heck, S. and Rogers, M. (2014). Resource Revolution: How to capture the biggest business opportunity in a century. Amazon Publishing, Seattle. New York, NY.

Henderson, J.V. (2003). The Urbanization Process and Economic Growth: The So-What Question. Journal of Economic Growth, 8(1): 47-71.

Hidalgo, D. and Zeng, H. (2013). "On the move: Pushing sustainable transport from concept to tipping point." Retrieved 25th April, 2014, Available at: http://thecityfix.com/blog/on-the-move-pushing-sustainable-transport-coancept-tipping-point-dario-hidalgo-heshuang-zeng/.

High Level Task Force (2008). "Affordable Housing for All". Report of the High Level Task Force, December 2008.

Hoornweg, D., M. Freire, J. Baker-Gallegos and A. Saldivar-Sali (2013). Building sustainability in an urbanizing world - A partnership report. Urban Development series. Washington DC, World Bank.

Hoornweg, D. and Pope, K (2014). Socioeconomic Pathways and Regional Distribution of the World's 101 Largest Cities. Global Cities Institute Working Paper No. 04. January 2014.

HPEC Ahluwalia. I. J. (2011). Recommendations of HPEC Report. Dr. Isher Judge Ahluwalia. Chairperson, High Powered Expert Committee. 29th September 2011.

Hultkrantz, L., G. Lindberg, and C. Andersson (2006). The value of improved road safety. Journal of Risk and Uncertainty, 2006. 32(2): p. 151-170.

Institute for Health Metrics and Evaluation (2013), The Global Burden of Disease (GBD) Visualizations: GBD compare. Institute for Health Metrics and Evaluation, Seattle. http://viz.healthmetricsandevaluation.org/gbd-compare/.

IPCC (2014a). Climate Change 2014: Mitigation of Climate Change – Chapter 7 Energy Systems. Potsdam, IPCC - Working Group III.

IPCC (2014b). Climate Change 2014: Mitigation of Climate Change – Chapter 8 Transport. Potsdam, IPCC - Working Group III.

IPCC (2014c). Climate Change 2014: Mitigation of Climate Change – Chapter 9 Buildings. Potsdam, IPCC - Working Group III.

IPCC (2014d). Climate Change 2014: Mitigation of Climate Change – Chapter 12 Human Settlements, Infrastructure and Spatial Planning. Potsdam, IPCC - Working Group III.

IPCC (2014e). Climate Change 2014: Mitigation of Climate Change – Chapter 16 Cross-cutting Investment and Finance Issues. Potsdam, IPCC - Working Group III.

IPCC (2014f). Climate Change 2014: Mitigation of Climate Change – Chapter 15 National and Sub-national Policies and Institutions. Potsdam, IPCC - Working Group III.

Jacobsen, P.L. (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury prevention, 2003. 9(3): p. 205-209.

Jarrett, e. a. (2012). "Effect of increasing active travel in urban England and Wales on costs to the National Health Service." The Lancet 379.

Jenks, M., E. Burton and K. Williams (1996). The Compact City: A Sustainable Urban Form?, E & FN Spon.

Jerath, A. (2011). 'Delhi-Mumbai Industrial Corridor to Spawn 7 "smart" cities', Times of India. Available at: http://timesofindia.indiatimes.com/india/Delhi-Mumbai-industrial-corridor-to-spawn-7-smart-cities/articleshow/7288527.cms?referral=PM.

Kelbaugh, D. (1989). The Pedestrian pocket book: a new suburban design strategy, Princeton Architectural Press in association with the University of Washington.

Kenya National Bureau of Statistics (2009). National Population and Housing Census. Nairobi: Ministry of State for Planning, National Development and Vision 2030.

Kennedy, C. and J. Corfee-Morlot (2013) Past performance and future needs for low carbon climate resilient infrastructure–An investment perspective. Energy Policy, 59, 773-783.

Kennedy C. A., N. Ibrahim and D. Hoornweg (2014). Low-carbon infrastructure strategies for cities . Nature Climate Change (2014). Published online 16 March 2014. Available at: http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2160.html.

Kuylenstierna, J.C.I, Vallack, H.W., Schwela, D., Holland, M. and Ashmore, M., et al. (2014). Air Quality Benefits of Climate Strategies. New Climate Economy contributing paper. Stockholm Environment Institute.

Laconte, P. (2005), Urban and Transport Management - International Trends and Practices, in International Symposium "Sustainable Urban Transport and City. 2005, Tongji University and Nagoya University: Shanghai. Lefèvre, B. (2009). Long-term energy consumptions of urban transportation: A prospective simulation of "transport–land uses" policies in Bangalore. Energy Policy 37, 940–953. (DOI: 10.1016/j.enpol.2008.10.036).

Licciardi, G. (2012). "Energy Efficiency in Historic Built Assets." In Sustainable Low-Carbon City Development in China, eds. Axel Baeumler, Ede Ijjasz-Vasquez, and Shomik Mehndiratta, Ch. 17. Washington, DC: The World Bank.

Litman, T. (2014). Analysis of Public Policies That Unintentionally Encourage and Subsidize Urban Sprawl, Victoria Transport Policy Institute (www.vtpi.org), Supporting paper commissioned by LSE Cities (www.lsecities.net) at the London School of Economics and Political Science, on behalf of the Global Commission on the Economy and Climate (www.newclimateeconomy.net) for the New Climate Economy Cities Program.

Liu, Y., Chen, T., and Song, X. (2012). Relationship between Urban Form and Urban CO_2 Efficiency with Policies and Recommendations. Urban China Initiative (UCI) sponsored project 2012.11.

Lobo, J., Strumsky, D., Bettencourt, L.M.A. (2009). Metropolitan Areas and CO_2 Emissions: Large is Beautiful, Toronto: Rotman School of Management, University of Toronto.

Lucas Jr, R. E. (1993). "Making a miracle." Econometrica: Journal of the Econometric Society: 251-272.

Malpezzi, S. (2006). Cross-Country Patterns of Urban Development in R. J. Arnott and D. P. McMillen (eds) A Companion to Urban Economics, Blackwell.

McGee, T.G. (2005), "Distinctive Urbanization in the Peri-Urban Regions of East and Southeast Asia: Renewing the Debate", Jurnal Perencanaan Wilayah dan Kota, vol. 16, no. 1, pp. 39-55, Institut Teknologi Bandung, Bandung, Indonesia.

McGranahan G, Balk D, Anderson B (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization 19: 17–37.

McKinsey Global Institute (2010). India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth, McKinsey and Company.

Menckhoff, G. (2005). Latin American experience with bus rapid transit. annual meeting of the Institute of Transportation Engineers, Melbourne.

Mees, H.P. and P.P. Driessen (2011). Adaptation to climate change in urban areas: Climate-greening London, Rotterdam, and Toronto. Climate Law, 2(2), 251-280.

Merk, O., Saussier, S., Staropoli, C., Slack, E., Kim, J-H (2012). Financing Green Urban Infrastructure, OECD. Regional Development Working Papers 2012/10, OECD Publishing; http://dc.doi.org/10.1787/5k92p0c6j6r0-en.

Ministry of Housing (2010). The Kenya Informal Settlements Improvement Program: Environmental and Social Management Framework. Nairobi: Government of Kenya. Available at: http://marsgroupkenya.org/pdfs/2011/01/Ministry_PDFS/Housing_ministry/Draft_ESMF_KISIP.pdf.

Ministry of Public Security (2013). Available at: http://english.gov.cn/2005-10/02/content_74192.htm.
MoEF (Ministry of Environment & Forests) (2010). Annual Report 2009-2010. Available at: http://envfor.nic.in/publication-reports/annual-report/annual-report-2009-2010.

Ncube, M. (2012). Urbanization in Africa. Available at: http://www.afdb.org/en/blogs/afdb-championing-inclusive-growth-across-africa/post/urbanization-in-africa-10143/.

Nicholls, R. J., et al. (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", OECD Environment Working Papers, No. 1, OECD Publishing. doi: 10.1787/011766488208.

OECD (2007). Infrastructure to 2030: Mapping Policy for Electricity, Water and Transport (Volume 2). Paris, OECD.

OECD (2010). Cities and Climate Change, OECD Publishing.

OECD (2011). Towards Green Growth. Paris: OECD Publishing.

OECD (2012a). Compact City Policies: A Comparative Assessment. OECD Green Growth Studies. OECD Publishing.

OECD (2012b). Environmental Outlook to 2050: The Consequences of Inaction. Paris, OECD.

OECD (2012c), Mortality Risk Valuation in Environment, Health and Transport Policies, OECD Publishing. doi: 10.1787/9789264130807-en.

OECD (2012d). Roundtable of Mayors and Ministers - Mobilising investments for urban sustainability, job creation and resilient growth. Issues Paper. Chicago, IL, OECD.

OECD (2013a). Building Sustainable Cities of All Sizes: A National Urban Policy Framework. OECD Publishing, Paris.

OECD (2013b) Green Growth in Cities, OECD Green Growth Studies Series, OECD Publishing, Paris.

OECD (2014a forthcoming). "Chapter 5. A National Strategy for Cities: Taking Ownership of Urban Policy", Regional Outlook 2014, OECD Publishing, Paris.

OECD (2014b forthcoming), Towards Green Growth in Southeast Asia, OECD Green Growth Studies, OECD Publishing, Paris.

OECD (2014c), The Cost of Air Pollution: Health Impacts of Road Transport, OECD Publishing. doi: 10.1787/9789264210448-en.

O'Neill, B. C., X. Ren, L. Jiang and M. Dalton (2012). "The effect of urbanization on energy use in India and China in the iPETS model." Energy Economics 34: S339-S345.

Owens, S. (1995). "From 'predict and provide' to 'predict and prevent'?: Pricing and planning in transport policy." Transport Policy 2(1): 43-49.

Parry, M. L. (2009). Assessing the costs of adaptation to climate change: a review of the UNFCCC and other recent estimates, IIED.

Percival, T. and P. Waley (2012), "Articulating Intra-Asian Urbanism: The Production of Satellite Cities in Phnom Penh", Urban Studies, vol. 49, pp. 2873-2888, Sage Publications.

Porio, E. (2009). "Urban Transition, Poverty, and Development in the Philippines: A Preliminary Draft", Ateneo de Manila University, Department of Sociology and Anthropology, 31 August 2009, available at: http://pubs.iied.org/pdfs/G02570.pdf, last accessed 7 March 2014.

Potts, D. (2013). Rural-Urban and Urban-Rural Migration Flows as Indicators of Economic Opportunity in Sub-Saharan Africa: What Do the Data Tell Us? Migrating Out of Poverty working paper. Available at: http://migratingoutofpoverty.dfid.gov.uk/files/file.php?name=wp9-potts-rural-uban-and-urban-rural-migation-flows.pdf&site=354.
Proost, S. and K. Van Dender (2011). "What long-term road transport future? Trends and policy options." Review of Environmental Economics and Policy 5(1): 44-65.

Pucher, J. and R. Buehler (2008). "Making cycling irresistible: lessons from the Netherlands, Denmark and Germany." Transport Reviews 28(4): 495-528.

Quang, N. and H.D. Kammeier (2002), "Changes in the political economy of Vietnam and their impacts on the built environment of Hanoi", Cities, vol. 19, no. 6, pp. 373-388, Elsevier.

Ravallion, M. and Chen, S. and Sangraula, P. (2007), New Evidence on the Urbanization of Global Poverty (04/01/2007). World Bank Policy Research Working Paper Series, Vol. , pp. -, 2007. Available at SSRN: http://ssrn.com/abstract=980817.

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

Rode, P., J. Wagner, et al. (2008). "Integrated city making: Governance, planning and transport."

Rode, P., G. Floater, J. Kandt, K. Baker, M. Montero, C. Heeckt, D. Smith and M. Delfs (2013). Going Green: How cities are leading the next economy. L. Cities. London, LSE Cities.

Rode, P. (2014). The Politics and Planning of Urban Compaction: The Case of the London Metropolitan Region. The Economy of Sustainable Construction. N. J. Ilka and Andreas Ruby. Berlin, Ruby Press.

Rode, P., C. Keim, G. Robazza, P. Viejo and J. Schofied (2014). "Cities and Energy: Urban Morphology and Residential Heat Energy Demand." Environment and Planning B: Planning and Design.

Rode, P., Floater, G., Thomopoulos, N., Docherty, J., Schwinger, P., Mahendra, A., and Fang, W. (2014): Accessibility in Cities: Transport and Urban Form. NCE Cities Paper 03. LSE Cities. London School of Economics and Political Science.

Rogers, R. G. and A. Power (2000). Cities for a small country, Faber.

Rosenthal, S. S. and W. C. Strange (2003). "Geography, industrial organization, and agglomeration." Review of Economics and Statistics 85(2): 377-393.

Saelens, B.E., J.F. Sallis, and L.D. Frank (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of behavioral medicine, 2003. 25(2): p. 80-91.

Sallis, J.F., Saelens, B.E., Frank, L.D., Conway, T.L., Slymen, D.J., Cain, K.L., Chapman, J.E. and Kerr, J. (2009), Neighborhood built environment and income: examining multiple health outcomes. Social science & medicine, 2009. 68(7): p. 1285-1293.

Satterwhaite, David, Saleemul Huq, Hannah Reid, Mark Pelling, and Patricia Romero Lankao. (2009). Adapting to Climate Change in Urban Areas: the Possibilities and Constraints in Low-and Middle-Income Nations. London: IIED.

Seto K.C., Fragkias M, Güneralp B, Reilly MK (2011). A Meta-Analysis of Global Urban Land Expansion. PLoS ONE 6(8): e23777.

Seto, K. C., B. Güneralp and L. R. Hutyra (2012). "Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools." Proceedings of the National Academy of Sciences 109(40): 16083-16088.

Severinson, C. (2010). The New IAS 19 Exposure Draft, OECD Publishing.

Shalizi, Z. and F. Lecocq (2009). "Climate change and the economics of targeted mitigation in sectors with long-lived capital stock."

Siemens (2010), Green Test Bed- Singapore, in Pictures of the Future. Available at: http://www.siemens.com/innovation/apps/pof_microsite/_pof-spring-2010/_html_en/singapore.html. [Retrieved 20 March 2014].

Siemens (2014) Urban Infrastructure in 2025, The Economic Impacts of Implementing Green Technologies in the World's Megacities. New Climate Economy call for evidence submission. Available on request.

Sloman, L., S. Cairns, C. Newson, J. Anable, A. Pridmore and P. Goodwin (2010). The Effects of Smarter Choice Programmes in the Sustainable Travel Towns: Summary Report: 55.

State House (2007). We are addressing challenges of urbanization, President says. Nairobi Kenya. Retrieved 13 May 2014, from http://www.statehousekenya.go.ke/news/april07/2007160401.htm.

Stern, N. (2006). "Stern Review on The Economics of Climate Change (pre-publication edition). Executive Summary". HM Treasury, London. Archived from the original on 31 January 2010. Retrieved 31 January 2010.

Sugar, L,, Kennedy,C., and Leman, E. (2012). "Greenhouse Gas Emissions from Chinese Cities." Journal of Industrial Ecology 16 (4): 552–63.

Swart, R. and F. Raes, 2007: Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? Climate Policy, 7(4), 288-303.

Tewari, M, A. Goldar, Z. Aziz, I. Ray, S. Ray and V. Unnikrishnan. (2014). "A strategic framework for Indian cities: the quest for high growth, low carbon, climate resilient urban development." Background paper for the NCE, prepared by ICRIER.

The Economist (2014). Building the dream. [online] Available at: http://www.economist.com/news/special-report/21600797-2030-chinese-cities-will-be-home-about-1-billion-people-getting-urban-china-work [Accessed 25 Apr. 2014].

Thomas, L. and W. Cousins (1996). A new compact city form: Concepts in Practice. The Compact City: A Sustainable Urban Form? M. Jenks, E. Burton and K. Williams, E & FN Spon.

Turner, P. and Pourbaix, J. (2014). Actions to reduce emissions, urban innovation and smart technologies, UITP call for evidence response.

UN DESA (2012a), "File 17c: Percentage of Urban Population in Cities Classified by Size Class of Urban Settlement, Major Area, Region and Country, 1950-2025", World Urbanization Prospects: The 2011 Revision, CD-ROM Edition, UNDESA, Population Division.

UN DESA (2012b), "File 17b: Number of Cities Classified by Size Class of Urban Settlement, Major Area, Region and Country, 1950-2025", World Urbanization Prospects: The 2011 Revision, CD-ROM Edition, UNDESA, Population Division.

UN DESA (2012c), World Urbanization Prospects: The 2011 Revision, File 23: Coastal status, Type of drylands ecosystem, Number of multi-Hazards, Risk decile by type of hazard for Urban Agglomerations with 750,000 Inhabitants or More in 2011, CD-ROM Edition, UNDESA Population Division.

UN DESA (2014a). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

UN DESA (2014b). "File 2: Percentage of Population at Mid-Year Residing in Urban Areas by Major Area, Region and Country, 1950-2050", World Urbanization Prospects: The 2014 Revision, CD-ROM Edition, UNDESA, Population Division.

UNEP (2009). Common Carbon Metric for Measuring Energy Use & Reporting Greenhouse Gas Emissions from Building Operations. UNEP SBCI Sustainable Buildings & Climate Initiative.

UNEP (2011a). Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. United Nations Environment Programme, p. 10.

UNEP (2011b). Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. UNEP. Nairobi, UNEP.

UNICEF (2012). Cities and Children: The Challenge of Urbanisation in Tanzania. United Nations Children's Fund (UNICEF) 2012. Dar es Salaam, United Republic of Tanzania.

UN-Habitat (2003). The Challenge of Slums - Global Report on Human Settlements 2003.

UN-Habitat (2006). State of the World's Cities 2006/2007. London: Earthscan and UN-Habitat.

UN-Habitat (2009). State of the World's Cities 2008/2009: Harmonious Cities. London: Earthscan and UN-Habitat.

UN Habitat (2010a). The State of African Cities 2010: Governance, Inequality and Urban Land Markets. Nairobi, UN-Habitat.

UN-Habitat (2010b). State of the World's Cities 2010/2011: Bridging the Urban Divide. London: Earthscan and UN-Habitat.

UN-Habitat (2010c), The State of Asian Cities 2010/2011, UN-Habitat, Fukuoka, Japan.

UN-Habitat (2012). Urban Patterns for a Green Economy: Leveraging Density. United Nations Human Settlements Programme (UN-Habitat). Nairobi, Kenya.

UN-Habitat (2013). Planning and design for sustainable urban mobility: Global report on human settlements 2013. United Nations Human Settlements Programme. New York, United Nations.

UN-Habitat (2014). The state of African cities 2014 - Re-imagining sustainable urban transitions. Nairobi, Kenya, United Nations Human Settlements Programme.

Unruh, G. C. (2000). "Understanding carbon lock-in." Energy Policy 28(12): 817-830.

Unruh, G. C. (2002). "Escaping carbon lock-in." Energy Policy 30(4): 317-325.

Unruh, G. C. and J. Carrillo-Hermosilla (2006). "Globalizing carbon lock-in." Energy Policy 34(10): 1185-1197.

UNSCD (2012) Shanghai Manual: A Guide for Sustainable Urban Development in the 21st Century. Available at: http://www.uncsd2012.org/index.php?page=view&nr=245&type=99&menu=20#sthash.HBw8VJWS.PCm6xOdj.dpu.

UN Statistics Division (2009). System of National Accounts 2008. New York, United Nations.

Urban Task Force (1999). Towards an Urban Renaissance. London, E and F N Spon.

Urban Land Institute (2010). Land Use and Driving. The role compact development can play in reducing greenhouse gas emissions. www.uli.org 7-8.

Ürge-Vorsatz, D., Eyre, N., Graham, P., Harvey, D., Hertwich, E., Jiang, Y., et al. (2012). Chapter 10 – Energy End-Use: Building Global Energy Assessment - Toward a Sustainable Future (pp. 649-760). Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria: Cambridge University Press.

US Department of Energy. (2014). Sensors & Controls | Department of Energy. Retrieved 22 May 2014, Available at: http://energy.gov/eere/buildings/sensors-controls.

Viguié, V. and S. Hallegatte, 2012: Trade-offs and synergies in urban climate policies. Nature Climate Change, 2(5), 334-337.

WBCSD (2009). The cement sustainability initiative: Recycling concrete - Executive summary, WBCSD-CSI.

WBCSD (2012). "About the cement industry."   Retrieved 27th May, 2014, Available at: http://www.wbcsdcement.org/index.php/about-cement.

WEF (World Economic Forum) (2013). The Green Investment Report: The ways and means to unlock private finance for green growth. Geneva, World Economic Forum.

West, J.J., Smith, S. J., Silva, R. A., Naik, V., Zhang, Y., Adelman, Z., Fry, M. M., Anenberg, S., Horowitz, L. W., and Lamarque, J-F. (2013). Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health. Nature climate change, 2013. 3(10): p. 885-889.

WHO (2010). "Urban industrial solid waste pollution", World Health Organization. New York.

WHO (2013), "Global Status Report on Road Safety 2013," World Health Organization. Geneva, Switzerland.

WHO (2014). Air pollution estimates: World Health Organisation, WHO, Editor 2014: Geneva.

WHO and UNICEF (2014), Progress on Drinking-Water and Sanitation: 2014 Update Tables, WHO/UNICEF.

Williams, K., M. Jenks and E. Burton (2000). Achieving sustainable urban form, E & FN Spon.

World Bank (2002). "Cities on the move." Washington DC.

World Bank (2008). Economic Impacts of Sanitation in Southeast Asia: A four-country study conducted in Cambodia, Indonesia, the Philippines and Vietnam under the Economics of Sanitation Initiative (ESI), World Bank, Jakarta, Indonesia.

World Bank (2010a). Cities and climate change: An urgent agenda. Urban Development Series Knowledge Papers. Washington DC. 10: 92.

World Bank (2010b). Costs of adaptation and mitigation in cities. Climate Finance in the Urban Context. November 2010. Issues Brief #4. Available at: http://www.uncclearn.org/sites/www.uncclearn.org/files/inventory/WB72_0.pdf.

World Bank (2011). Turning the Tide in Turbulent Times: Making the most of Kenya's demographic change and rapid urbanization. Kenya Economic Update No. 4. World Bank, Poverty Reduction and Economic Management Unit, Africa Region.

World Bank (2012). Sustainable Low-Carbon City Development in China. February 2012. Default Book Series Sustainable Low-Carbon City Development in China.

World Bank (2013a). China's Next Transformation: Making Urbanization Efficient, Inclusive, and Sustainable. 2013, World Bank, Washington DC.

World Bank (2013b). Urban China: Building a Modern, Harmonious, and Creative Society. (China 2030). 2013, World Bank: Washington D.C.

World Bank (2013c). An analysis of physical and monetary losses of environmental health and natural resources. Vol. 1 of India - Diagnostic assessment of select environmental challenges. World Bank, Washington DC.

World Bank (2013d). Global Monitoring Report 2013: Rural-Urban Dynamics and the Millennium Development Goals. 2013, World Bank. Washington, DC.

World Bank (2013e). "Financing Sustainable Cities: How We're Helping Africa's Cities Raise Their Credit Ratings." Retrieved March 20, 2014, Available at: http://www.worldbank.org/en/news/feature/2013/10/24/financing-sustainable-cities-africa-creditworthy.

World Bank (2014a). Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization and Supporting Reports II. Washington D.C, World Bank.

World Bank (2014b). Sub-Saharan Africa. Retrieved 14 April, 2014, Available at: http://www.worldbank.org/en/publication/global-economic-prospects/regional-outlooks/ssa.

World Bank (2014c). Urban Development Overview. [online] Last Updated: Mar 25,2014. Available at: http://www.worldbank.org/en/topic/urbandevelopment/overview [Accessed 24 Jul. 2014].

Yusuf, S. (2013). Will cities continue driving economic growth? Centre for Development and Enterprise. Paper prepared for the Centre for Development and Enterprise, commissioned for Cities of Hope project, June 2013.

Zhang, G., Li, L., Fan, M., Li, W., Chen, Y., et al. (2013). More Efficient Urban Investment and Financing – Government Debt Security and Reform of Investment and Financing in Urbanisation. Urban China Initiative.

Zhu, J. (2010). "Symmetric Development of Informal Settlements and Gated Communities: Capacity of the State – The Case of Jakarta, Indonesia", ARI Working Paper, No. 135, February 2010, Asia Research Institute, Singapore, available at www.ari.nus.edu.sg/pub/wps.htm

APPENDIX: METHODOLOGY NOTE
**Sources and methods for the estimation of city carbon emissions for the
New Climate Economy project**

INTRODUCTION

As part of the New Climate Economy project, this note sets out the sources and methods used by the collaboration of LSE Cities and Oxford Economics for the estimation of carbon emissions of cities. Within the scope of the project, we have attempted to use the most up to date assumptions for analysis. However, the results of analysis should not be regarded as definitive, particularly as data at the city level are often not as robust as national level data. As data become increasingly robust over the coming years, we expect the assumptions and methods underpinning city carbon emissions to be refined. The purpose of this note is to provide a transparent description of the sources and methods used so that other researchers can use and build on them for the future.

This methodology note has been produced as part of the analytical collaboration between LSE Cities and Oxford Economics for the New Climate Economy project. The methods and analysis have been undertaken using the Oxford Economics 750 Cities database, the LSE Cities urban net population density database, and a range of published data.

Introduction to Global Cities 2030

Oxford Economics' Global Cities 2030 service has been developed to explore markets, trends and opportunities among the world's largest 750 cities. The service provides city (and corresponding national) annual historic estimates (back to 2000 where possible) and forecasts (to 2030) to support business decision making and strategy, research, analysis, urban planning, and client consultation and engagements.

Definition of urban geographies

The Global Cities 2030 service targets a definition of cities on the basis of urban agglomerations and metropolitan areas, which include the built-up area outside the historical or administrative core (i.e. city proper).
As we have defined cities on a broader metro/UA basis the distinction between resident and location-based estimates of indicators becomes less important (e.g. commuting issues associated with employment, retail sales etc.). This is because metros and UAs are (by definition) closer to self-contained entities (e.g. functional economic geographies) than 'city-proper' definitions of cities, in that a large proportion of the resident population are likely to work and spend within the metro/UA boundaries.

Overview of approach

Global Cities 2030 expands Oxford Economics' existing cities and regions services to cover new countries and new geographies within existing countries, and also extends the range of variables to include indicators such as consumer spending by product/service and household income distributions. The number of cities covered is 750 and number of countries covered is 140.

Global Cities 2030 is fully consistent with the estimates and forecasts in Oxford Economics' Global Macroeconomic service, one of the most respected macro level services in the industry. This ensures city level estimates and forecasts are anchored to the most reliable national level figures available.

The service is underpinned by significant work which was undertaken to collect, check and 'clean' data from numerous sources, as no central source of global city data existed previously. Even then a significant amount of city data estimation was required. In many cases data collection involved contacting statistical agencies and government/international organisations. The key data sources are listed below:

- OECD – GDP and employment
- National statistical agencies of each country – most indicators
- Eurostat – most indicators
- UN – population
- Other international organisations – e.g. African Development Bank
- Haver & CEIC (commercial data providers) – most indicators

The Global Cities service makes the fullest possible use of data that were available and collected during the process to develop the service. Where data were not available for a particular series or in particular years we have applied sound economic principles, coupled with analysis of available city and national data to estimate missing data points. At all stages the production of historical estimates has been informed by our understanding of economies at the national and city levels, and the relationship between variables within and between different levels of geography.

Population

750 cities taken directly from the Oxford Economics Global Cities 2030 database

Historical population estimates have been collected or created from national sources on official metro or urban agglomeration definitions where these definitions exist. This was the case in Europe, Japan, Indonesia (half), Chile, Peru, South Korea, Thailand, Brazil, Mexico, Canada and the USA. Where metro/UA definitions did not exist one of four approaches is taken:

1. If the available official estimates for the closest matching geography are close to the UN figures we have adopted the official definition to ensure boundaries are traceable to official sources.
2. If the official estimates for the closest matching geography are significantly different to the UN's then the official estimates have, in cases, been scaled to the UN definition to ensure consistency across countries/cities in the use of metro/UA definitions.
3. If the official estimates for the closest matching geography are significantly different to the UN's then the official estimates have, in cases, been used instead of UN data.
4. In China population according to the official urban geographies (city prefectures) is larger than in the UN definition. This is because official city estimates are reported at the much broader 'prefecture' level. In China we have retained the official prefecture definition of the city to avoid creating fundamentally different urban geographies that may not be traditionally recognised. This decision was also guided by sponsor input and specifically by sponsor staff based in China.

Data for other urban areas in countries included in Oxford Economics Global Cities 2030 database

1. The Global 750 share of total population in each country is calculated from OE data
2. The total share of national population that lives in an urban area is calculated using 2011 UN World Urbanization Prospects database
3. The difference between steps 1) and 2) provides an estimate of the share of each country's urban population that is not included in the Global 750 cities
4. The non-750 urban population share calculated in step 3) is applied to OE national population forecasts to generate a forecast for the non-750 urban population in each country.

In countries where the Global 750 share of population is greater than the total urban population share in the UN database (notably China) it is assumed that the Global 750 cities data include the entire urban population of a country.

Data for other urban areas in countries not included in the Oxford Economics Global Cities 2030 database

Data taken from 2011 UN World Urbanization Prospects database.

Employment (total and by sector)

750 cities taken directly from the Oxford Economics Global Cities 2030 database

National employment by industry is commonly available for almost all the developed and emerging countries covered in Global Cities 2030 and is sourced from various national statistical agencies and other institutions (Eurostat, UN, World Bank, OECD). Employment by industry is always aligned to total employment estimates which tend to be more accurate and up to date. For developing countries the sector employment time series is in some cases incomplete. In these instances we extrapolated the implied productivity trend for the industry from years in which data existed. The extrapolated productivity coupled with GVA gives estimated employment in the missing years.

Regional employment data exist for the majority of developed and emerging market countries. This was collected, sense-checked and made consistent with the national data.

City-level employment data is available for many developed countries and some emerging countries. Where this was the case (e.g. Australia, Europe, Canada, US, Mexico, Brazil) the data was collected, checked and made consistent with the broader regional and national data.

Where available employment data are not granular enough to cover the specific city definition used in Global Cities, it is estimated from broader regional/national data (e.g. Argentina, Colombia, Indonesia, and Malaysia). This is done via population location quotients (LQs) for each industry, which represent the per capita importance of an industry to city employment compared with the region/province/country. For example one would expect consumer services to play a greater role in city employment than at the national level as a whole, while agriculture and mining employment should have far less prominence in cities. The LQs were estimated from an analysis of countries in which city employment existed, to gauge the relative importance of different industries to city employment. This analysis was performed for different groups of countries split according to level of economic development to capture variations in LQs between such groups.

Estimated industry employment was then aggregated to total employment and the resulting city employment rates were checked against regional (where they existed) and national rates.

Data for other urban areas in countries included in Oxford Economics Global Cities 2030 database

1. Global 750 cities total employment subtracted from national total employment for each sector to obtain residual employment by sector in each country
2. For each sector, the residual obtained from step 1 is allocated to rural areas based on the rural share of population in rural and other urban areas, plus an adjustment factor estimated from Eurostat data for employment by sector in 13 European countries for which the Eurostat urban/rural classification is broadly consistent with that used by the UN.
3. Employment in other urban areas is calculated as national employment in sector less Global 750 employment in sector less rural employment in sector.

Total employment in other urban and rural areas is the sum of the six sectors.

Data for other urban areas in countries not included in the Oxford Economics Global Cities 2030 database

National employment by sector taken from OE database for Afghanistan, Bahamas, Bahrain, Barbados, Cyprus, Djibouti, Eritrea, Fiji, Guinea-Bissau, Guyana, Iceland, Liberia, Libya, Maldives, Malta, Mauritania, Montenegro, Papua New Guinea, Suriname, Turkmenistan.

Employment is allocated between other urban and rural areas using the methodology described above (there is no Global 750 cities employment in these countries). Total employment in rural and other urban areas is the sum of the six sectors.

For other countries, the estimation process is as follows:

1. Total national employment is estimated based on the average ratio of employment: population for the respective region of the world.
2. Employment by sector is estimated using the average share of each sector in total employment in the respective region of the world.
3. Employment by sector is allocated between other urban and rural areas using the methodology described above.
4. Total employment in other urban and rural areas is the sum of the six sectors.

GVA (total and by sector)

750 cities taken directly from the Oxford Economics Global Cities 2030 database

National GDP and GVA by industry data (real and nominal) are one of the most commonly available variables and were sourced primarily from various national statistical agencies (e.g. Statistics Indonesia, Instituto Brasileiro de Geografia e Estatística) as well as organisations such as Eurostat, the UN, World Bank and OECD.

Regional level GDP/GVA data is usually available for developed countries as well as some emerging and developing countries. Within the Global Cities service regional (e.g. province or state) GDP and GVA data underpin city level estimates for nearly all developed countries and a significant number of emerging and developing markets (including China and India). In some cases states correspond exactly to city metro geographies, e.g. Lagos in Nigeria.

The geographical granularity of 'regions' varies by country. In Europe data is available down to NUTS3 level, which in many cases corresponds closely with traditional (city-proper) definitions of cities. However in other countries such as Indonesia regional estimates are at the province level (of which there are 34 in Indonesia). Where sub-national data was collected from national statistical agencies it was sense-checked for errors and jump-offs, and made consistent with the usually more up-to date national GDP/GVA data.

Due to different industrial classifications used by different statistical agencies, the industry definitions of data published often vary by country. For example all of Europe uses NACE rev2 classification, most developing/emerging countries use classifications similar to NACE rev1, while the USA uses the NAICS classification. It is partly for this reason we present our data for six 'broad' sectors only, which enable a more direct and consistent comparison across countries. Although we do hold more detailed sector detail outside of Global Cities for many of the cities from Oxford Economics' other city and region forecasting services.

Historical estimates of city level GDP/GVA are consistent with the chosen boundaries of the city as defined by its population. For example New York has been defined according to its official metro population and our GDP estimates relate to the same 'boundaries'.

Where GDP data exist for the relevant definition of the city it has been used directly. Where this data is missing or not available for the desired city definition we have scaled down (from national or regional level) or scaled up (from narrower city definitions) using the closest matching GDP/GVA data and population data. Generally, this has been done by first deriving employment estimates (by industry) for the required city definition (see Section 3.4). City productivity was then estimated from national/regional/city productivity estimates, adjusted to reflect likely productivity differentials between the country/region and the city. These adjusted productivity estimates are then applied to city employment to arrive at city GVA by industry. The city productivity adjustments are based on empirical analysis of available data across panels of different country types (e.g. advanced, emerging and developing economies), and the difference between city and region and country sector productivity.

The rationale for adjusting city productivity relative to regional or national level is that some industries (such as financial and business services) are likely to be more productive in cities due to factors such as better infrastructure, firm clusters and more highly skilled workers. To determine the magnitude of these productivity adjustments, we analysed city versus regional/national productivity data for different groups of countries according to level of economic development. This enabled us to estimate productivity adjustment factors by industry. Although one key check in doing this was to ensure the city sector GVA estimate was never higher than the national sector GVA figure.

In many developing countries no sub-national (regional or city) GDP/GVA data existed. The method of scaling down from national estimates outlined above would tend to produce city series with limited variance in growth rates relative to the national level. However one would expect, for example, the consumer service industry to have grown faster in cities as it is where much of the increase in population is concentrated. We therefore refined the above approach in a number of developing countries such that estimated historical GVA growth in certain industries is also influenced by population growth and GVA growth in other industries (i.e. as a proxy for intermediate demand).

Data for other urban areas in countries included in Oxford Economics Global Cities 2030 database

1. Global 750 cities total GVA is subtracted from national total GVA for each sector to obtain the residual amount of GVA in each sector in each country
2. For each sector, the residual GVA obtained from step 1 is allocated between other urban and rural areas based on a productivity factor estimated from Eurostat data for GVA by sector in 13 European countries for which the Eurostat urban/rural classification is broadly consistent with that used by the UN.
3. Total GVA in other urban and rural areas is the sum of the six sectors.

Data for other urban areas in countries not included in the Oxford Economics Global Cities 2030 database

National GVA by sector taken from OE database for Afghanistan, Bahamas, Bahrain, Barbados, Cyprus, Djibouti, Eritrea, Fiji, Guinea-Bissau, Guyana, Iceland, Liberia, Libya, Maldives, Malta, Mauritania, Montenegro, Papua New Guinea, Suriname, Turkmenistan.

For these countries, GVA is allocated between other urban and rural areas using the methodology described above. Total GVA in other urban and rural areas is the sum of the six sectors.

For other countries, total GVA is estimated using the average ratio of GVA to population for the respective region of the world. GVA by sector is estimated using the average share of that sector for the respective world region. The total for the sector is allocated between urban and rural areas using the average split for the respective world region.

Total GVA for other urban and rural areas is the sum of the six sectors.

GDP

750 cities taken directly from the Oxford Economics Global Cities 2030 database

Data for other urban and rural areas

The total GVA estimates described above are uplifted using the ratio of GVA to GDP for the respective country. Where this ratio is not available for a country, the average ratio for the respective world region is applied.

Car ownership (750 cities only)

National data and forecasts in the Oxford Economics Global Cities 2030 database

The starting point is the World Bank's passenger cars per capita dataset, which uses a definition of 'passenger car' from the International Road Federation:

"Road motor vehicle, other than a motor cycle, intended for the carriage of passengers and designed to seat no more than nine persons (including the driver). The term 'passenger car' therefore covers microcars (need no permit to be driven), taxis and hired passenger cars, provided that they have fewer than ten seats."

Five country panels were constructed: Advanced (all of Europe, USA, Canada, New Zealand, Australia, Japan and South Korea), Africa, Asia, Latin America and Middle East. Based on the relationships observed in these panels, Oxford Economics has forecast car ownership in each country out to 2030 using GDP per capita and the working age share of population in each country. For the Middle East only GDP per capita was included in the regression.

City data and forecasts for countries where historical data are available in the Oxford Economics Global Cities 2030 database

City level car ownership data have been collected from national sources where available. In total, a least one year of data were available for at least one city in 49 countries in Table 3 below. The ratio of car ownership in each city has been estimated relative to its respective national average. This series is then forecast to 2030 using city level income growth relative to national income growth. The ratio is applied to the forecast of car ownership at national level to determine the level of car ownership in each city in each year.

Table 3
Car ownership data: countries with at least one year of data for at least one city

Car ownership data: countries which had at least one year of data for at least one city			
Argentina [ARG]	Germany [DE]	Norway [NO]	Venezuela [VEN]
Australia [AUS]	Greece [GR]	Paraguay [PRY]	
Austria [AT]	Hungary [HU]	Peru [PER]	
Bangladesh [BGD]	India [IND]	Poland [PL]	
Belgium [BE]	Indonesia [IDN]	Romania [RO]	
Bolivia [BOL]	Ireland [IE]	Serbia [RS]	
Brazil [BRA]	Italy [IT]	Slovakia [SK]	
Bulgaria [BG]	Japan [JPN]	Slovenia [SI]	
Chile [CHL]	Kazakhstan [KAZ]	Spain [ES]	
China	Latvia [LV]	Sweden [SE]	
Czech Republic [CZ]	Lithuania [LT]	Switzerland [CH]	
Denmark [DK]	Malaysia [MYS]	Thailand [THA]	
Egypt [EGR]	Mexico	Turkey [TR]	
Estonia [EE]	Morocco [MAR]	United Kingdom [UK]	
Finland [FI]	Netherlands [NL]	United States [US]	
France [FR]	Nicaragua [NIC]	Uruguay [URY]	

City data and forecasts for countries where historical data are not available

For all non-Chinese cities a relative per capita car series was estimated using relative sub-national/national GDP per capita, and the coefficient from the national regression panels.

For sub-national China provincial level data were sourced from the China statistical database. Except for the provincial cities (Beijing, Shanghai, Chongqing and Tianjin), the provinces are much larger than the prefectures, province numbers were adjusted to better represent their respective prefectures. This was undertaken by forecasting provincial level relative cars per capita using a fixed-effects panel regression using relative provincial/China household income per head as the explanatory variable. The prefecture level forecasts were created by applying the prefecture/provincial relative household income per head to the respective provincial per capita cars.

Adjustment to US data implemented for this project

Within the US, and following the advice of LSE Cities, it was determined that metro area data from the American Community Survey (ACS) provide a closer fit with the metro area emissions data estimated by Brown et al. 2008[3], than the data derived from state car registrations and the US National Household Travel Survey that is incorporated in the Global Cities 2030 database as

standard. This is an important consideration since the equation used to estimate city emissions in all countries is estimated using the Brown et al. results for US cities, as per LSE Cities' guidance. Our approach to estimating US cars per capita for this project has therefore been adjusted to:

1. Estimate cars per capita in metro areas, relative to the US average, using the ACS data
2. Apply this ratio to our existing national series for passenger cars per 1,000 people from the World Bank
3. Grow the 2010 base year figure forward using the growth rates estimated in the standard Global Cities 2030 dataset.

This approach enables the analysis to benefit from the improved fit with emissions data that we get from the ACS data, whilst also retaining the international consistency needed to apply the equation to other countries.

National carbon emissions for countries in the Oxford Economics Global Cities 2030 database

Data sources

Historical data from the IEA have been used for most countries. EIA used for countries not included within the IEA database.

Approach to forecasting total CO_2 emissions

Emissions by country are estimated using the Kaya identity:

[3] *Brown, M.A., Southworth, F. and Sarzynski, A (2008). Shrinking the carbon footprint of metropolitan America, Metropolitan Policy Program at Brookings*

$$CO_2 = (CO_2/E) \times (E/GDP) \times (GDP/POP) \times POP$$

Where:
CO_2: Carbon emissions
CO_2/E: Carbon intensity of energy
E/GDP: Energy intensity of GDP
POP: Population
GDP/POP: Real GDP per head

GDP and population data and forecasts have been taken from the Oxford Economics database

Energy forecasts have been taken from Oxford Economics Global Macroeconomic model. Oxford Economics' energy forecasts reflect demand for energy by industry, transport, electrical power and cooking. As standard they take into account the IEA's 'new policy scenario' forecasts, which assume existing policies plus the anticipated impact of the cautious implementation of declared policy changes. For the purposes of this project, these forecasts have been adjusted to reflect the IEA's 'no new policies scenario'.

Carbon intensity has been projected based on recent trends in each country.

The resulting forecasts have been constrained to be consistent with IEA world and regional totals.

Approach to forecasting CO_2 emissions by sector

Manufacturing

Based on the historic share of manufacturing emissions in total emissions and the expected change in the share of manufacturing in total GVA.

Transport

Based on the historic share of transport emissions in total emissions and the expected change in the share of transport in total GVA.

Residential

Forecast by extrapolating historic trends in residential emissions per capita and multiplying by Oxford Economics population projections.

Other

The 'Other' category includes emissions from commercial/institutional activities, and agriculture, forestry, fishing. For the purposes of this project we assume that the main driver of emissions in this sector is office-based employment.

Forecasts are based on a combination of the historic share of other emissions in total emissions, and the expected change in financial and business services, and public sector employment from the Oxford Economics database. These sectors have been selected as a proxy for office-based employment.

City level emissions forecasts

City level emissions have been estimated by allocating a proportion of national emissions for each sector to cities as described below.

Cities in the Global 750

Manufacturing emission

Estimated based on each city's share of national industry GVA.

Transport emissions

Based on econometric estimation using car ownership data from the Oxford Economics database and net population densities from www.demograhphia.com and LSE Cities' database of urban net population densities.

An equation was established using the Brown et al. data for US city emissions[4] to estimate how transport emissions per head in each city change over time, relative to the respective national average. Rates of growth in city transport emissions over time can be derived using the results from this equation. A time series for the level of city transport emissions is obtained by applying these growth rates to the level in the base year. The latter was also estimated using data on a city's net population density and level of car ownership.

Residential emissions

Based on econometric estimation using the following variables:

• GDP per capita from the Oxford Economics Global 750 Cites database;
• Household size from the Oxford Economics Global 750 Cites database;
• Net population densities from www.demographia.com and LSE Cities;
• Climate information on heating and cooling degree days from www.degreedays.net. Heating degree days are a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than the selected base temperature of 18 degrees. Cooling degree days are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than the selected base temperature of 18 degrees. There are caveats to using this approach due to the fact that heating and cooling systems in buildings do not observe a rigid parameter of outside air temperature. The need for further future research in this area is strongly suggested.

Once again, an equation was established for US cities using emissions data from Brown et al. to estimate how residential emissions per head in each city change over time, relative to the respective national average. Rates of growth in city residential emissions over time can be derived using the results from this equation. A time series for the level of city residential emissions is obtained by

[4] *Brown, M.A., Southworth, F. and Sarzynski, A (2008). Shrinking the carbon footprint of metropolitan America, Metropolitan Policy Program at Brookings*

applying these growth rates to the level in the base year. The latter was estimated using the same variables as the growth equation.

Other emissions

Estimated based on each city's share of national employment in the financial, business and public services sectors. Total emissions for each city have been calculated as the sum of the four sectors.

Note on land areas

The land area component of the net population density estimates mentioned above has been projected to increase in response to city population growth. Per LSE Cities' suggestion, data from Seto et al. 2012[5] were used to estimate the expected percentage increase in land area for each percentage point increase in population for regions of the world. These factors are shown below in Table 4.

Table 4
Projected change in land area by region

	Projected % change in urban land area 2000-2030 (75–100% probability estimates)	Projected % change in urban population 2000–2030	% change in urban land / % change in population
Central America	304	58	5.3
China	273	109	2.5
Eastern Asia	106	19	5.7
Eastern Europe	6	0.3	21.1
India	353	108	3.3
Mid-Asia	147	59	2.5
Mid-Latitudinal Africa	916	209	4.4
Northern Africa	351	81	4.3
Northern America	91	39	2.3
Oceania	93	53	1.7
South America	168	45	3.7
Southern Africa	207	55	3.8
Southern Asia	446	104	4.3
Southeastern Asia	255	96	2.6
Western Asia	234	101	2.3
Western Europe	91	21	4.4
Sources:	*Seto et al. 2012*	*UN World Urbanization Prospects 2011*	*Calculation*

Sources: Seto et al. 2012; UN DESA World Urbanization Prospects 2011

The coefficients in the final column of Table 4 were combined with population forecasts to estimate the percentage change in land area for each city.

[5] *Seto, K., Guneralp, B. and Hutyra, L.R. (2012) Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools,*

available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3479537/

Other urban areas in countries included in the Oxford Economics Global Cities 2030 database

Manufacturing emissions

Estimated based on other urban areas' share of national industry GVA.

Transport emissions

For the US, Europe and Oceania these were estimated using the value for average transport emissions per capita in the cities in the Global 750 database, in that country. This average value was increased by 13%, based on the difference between Global 750 cities and non-Global 750 cities in the study of US cities by Brown and Logan 2008 .

For other countries, non-750 transport emissions were allocated based on the share of urban areas in non-750 population. Residential emissions

Estimated using the value for average residential emissions per capita of the cities in the Global 750 database, in that country. This average value was increased by 3%, based on the difference between Global 750 cities and non-Global 750 cities in the study of US cities by Brown and Logan (2008)[6].

Other emissions

Estimated based on other urban areas' share of national financial, business and public services employment.

Emissions in rural areas were also estimated as national emissions minus Global 750 emissions minus other urban areas emissions.

Urban areas in countries not included in the Oxford Economics Global Cities 2030 database

Manufacturing emissions

Based on the regional manufacturing emissions per capita, multiplied by the country's population. The urban and rural split was estimated using the share of industry GVA in each type of area.

Transport emissions

Based on average transport emissions per capita for that region of the world. The split between urban and rural areas was estimated using population shares.

[6] *Brown, M.A. and Logan, E. (2008) The Residential Energy and Carbon Footprints of the 100 Largest U.S. Metropolitan Areas*

Residential emissions

Based on average residential emissions per capita for that region of the world. The split between urban and rural areas was estimated using population shares.

Other emissions

National emissions based on the regional average for other emissions per capita multiplied by population. The urban and rural split was estimated using the urban and rural share of employment in financial, business and public services.

A final stage in the estimation process for these countries adjusted the totals to ensure they sum to the residual after the total

for Global Cities 2030 countries has been subtracted from the world total.

Alternative scenario city level emissions forecasts

The alternative scenario aims to explore the potential impact on city emissions as a result of a more efficient use of urban land (indicated by reducing the rate of urban expansion) and a shift towards more energy efficient transport modes (indicated by lower car ownership levels). No other policy changes are assumed in this scenario. Thus, the alternative scenario includes improvements related to motorisation and density but uses the same baseline figures for the national context as the baseline scenario. For instance, national total emissions in each scenario are simply calculated as baseline national emissions less the reduction in the scenario from changes in the metro areas. Therefore, each city's share of national emissions would not vary if the national total emissions figure changes (but it does vary if population density and car ownership change).

Car ownership was capped so that by 2030 the number of cars per 1,000 people cannot exceed that of a benchmark city in the same world region. Benchmark cities were identified by LSE Cities based on having low car ownership levels, but above average income levels in their respective region. The benchmark cities are shown in Table 5 below and used as the 'ceiling' motorisation rate for cities in the rest of the region. In case a city's original forecast value is less than this cap for its region, the original forecast was retained in order not to artificially inflate the motorisation rate in some cities, which will cancel out savings elsewhere.

Table 5
Cities with lowest car ownership but above average incomes in their respective region

Cities with lowest car ownership (but above average incomes) in their respective regions				
Metro areas	GDP per head (US$ 2012 prices and exchange rates)	Region	cars per 1000 2012	cars per 1000 2030
Central America				
Santo Domingo	12,931	Central America & Caribbean	129.28	188.98
China and Eastern Asia				
Hong Kong	36,789	North East Asia	61.05	73.11
Eastern Europe				
Kazan - Metro	14,021	Eastern Europe	232.97	308.65
India				
Nagpur	4,244	South Asia	22.96	64.87
Mid-Asia				
Astana	22,781	Eastern Europe	291.81	387.57
Mid-Latitudinal Africa / Sub-Saharan Africa				
Dar Es Salaam	2,915	East Africa	23.80	47.70
Northern Africa				
Suez	6,213	North Africa	60.82	122.86
North America				
New York	69,556	North America	319.75	380.94
Oceania				
Sydney	70,729	Oceania	511.45	555.15
South America				
Guayaquil	12,873	South America	60.77	94.15
Southern Africa				
Windhoek	9,774	Southern Africa	91.29	190.48
Southern Asia				
Rawalpindi	1,732	South Asia	22.89	45.14
South-Eastern Asia				
Manila	7,624	South East Asia	39.06	82.30
Western Asia / Middle East				
Istanbul - Metro	16,399	Middle East	147.62	297.61
Western Europe				
Paris - Metro	65,046	Western & Northern Europe	216.41	213.64

The notes for the baseline scenario explained how land area change was estimated based on data from Seto et al. 2012. For the alternative scenario, the population density estimates have been adjusted to incorporate the following assumptions: a coefficient of zero urban land area growth (no expansion) for developed countries (Western Europe, North America and Oceania) and a coefficient of one for developing countries (the rest of the world) were taken into account. This means that urban land area grows in proportion to population growth in cities in less developed countries. Zero urban land area growth is assumed for cities where population is forecast to decline between 2014 and 2030.