# DATA

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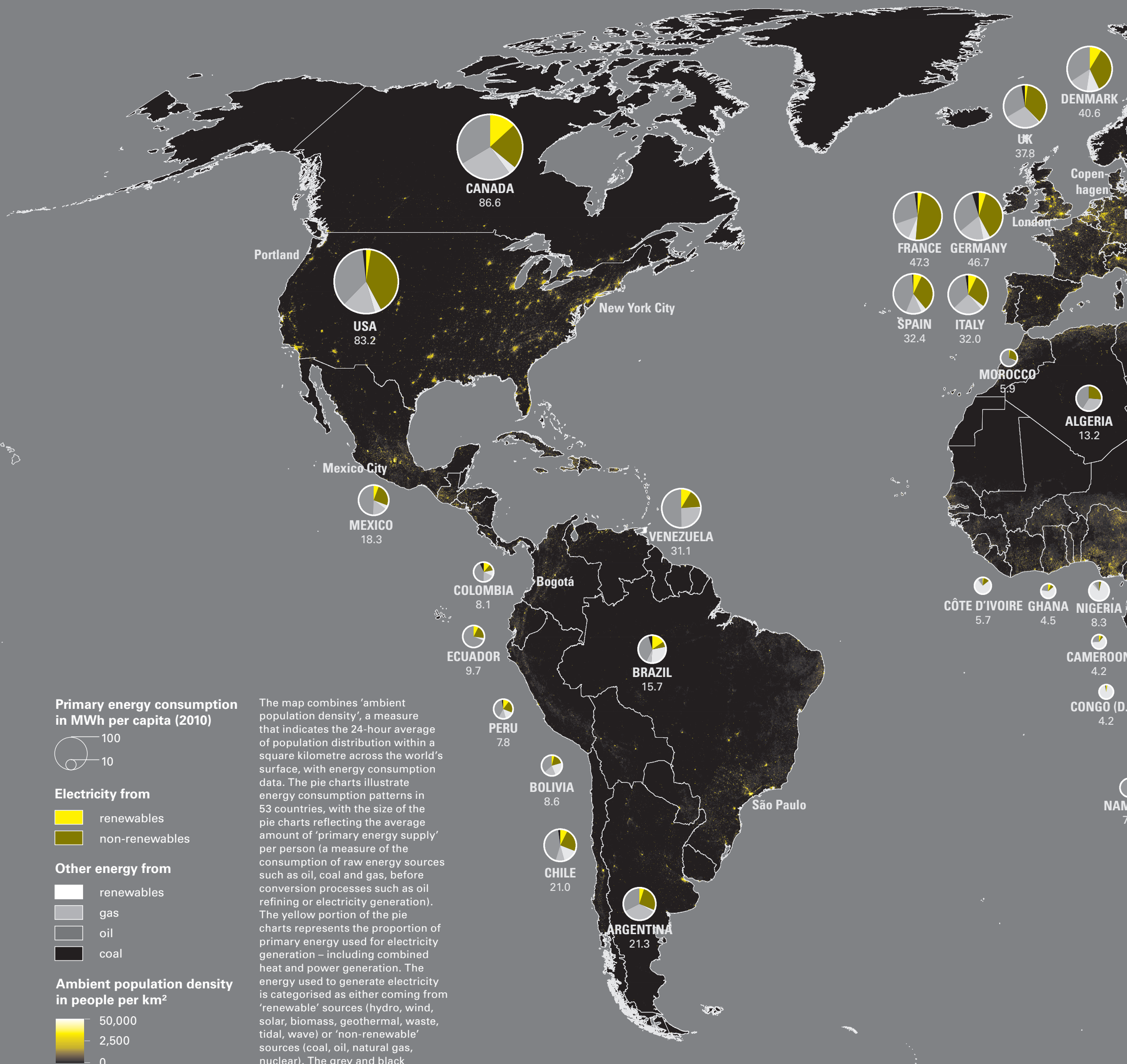Guido Robazza, James Schofield, Michael Delfs

LSE Cities investigates the links between social and physical dimensions of cities. Over the last year, our research has focused on the environment and climate change in a series of projects that investigate how cities are becoming more innovative in promoting the green agenda. Some of this research is summarised in the following pages of the Urban Age Electric City newspaper, providing a global overview of energy consumption and pollution patterns and detailed comparisons of density, transport and governance between established Urban Age cities – London, New York, Berlin, Istanbul, Mumbai and São Paulo – and a selection of 'green pioneer' cities – Hong Kong, Stockholm, Copenhagen, Portland, Singapore and Bogotá.

Human Development, Ecological Footprint and Urbanisation Level
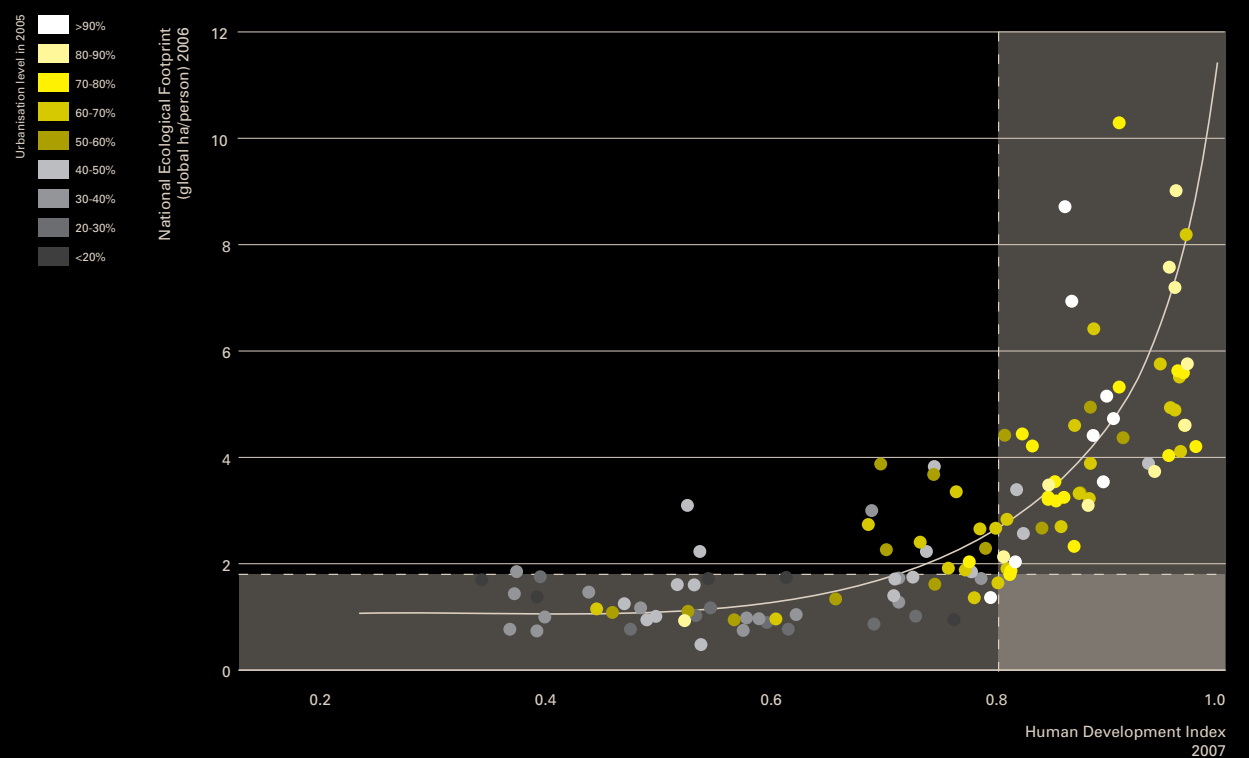
This graph captures the key relationships that drive much of LSE Cities' research on cities, by mapping social and environmental dimensions of cities against each other. In countries across the world urbanisation has been accompanied by an increase in well-being – but also by unsustainable environmental impacts. Only a few highly urbanised countries have low environmental impact, but almost all countries with high levels of human development are urbanised. Achieving sustainability – a human footprint that fits within the earth's bio-capacity while allowing for social wellbeing – has proved elusive. Nevertheless, considerable variation in the environmental footprint of urbanised societies provides evidence that certain forms of urban living are more sustainable than others. The challenge for future cities lies in learning from the world's green leaders to ensure cities provide for human flourishing by using innovation, design and technologies to live within the earth's ecological limits.
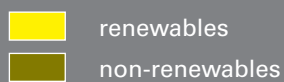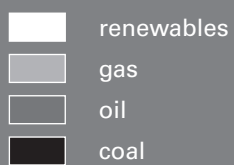
GEOGRAPHY OF ENERGY CONSUMPTION

DENMARK 40.6

UK 37.8

Copen-hagen

London

FRANCE 47.3

GERMANY 46.7

SPAIN 32.4

ITALY 32.0

MOROCCO 5.9

ALGERIA 13.2

CANADA 86.6

Portland

USA 83.2

New York City

Mexico City

MEXICO 18.3

VENEZUELA 31.1

COLOMBIA 8.1

Bogotá

CÔTE D'IVOIRE 5.7

GHANA 4.5

NIGERIA 8.3

CAMEROON 4.2

ECUADOR 9.7

BRAZIL 15.7

CONGO (D. 4.2

PERU 7.8

BOLIVIA 8.6

São Paulo

NAM 7

CHILE 21.0

ARGENTINA 21.3

Primary energy consumption in MWh per capita (2010)

— 100
— 10

Electricity from

renewables
non-renewables

Other energy from

renewables
gas
oil
coal

Ambient population density in people per km²

— 50,000
— 2,500
— 0
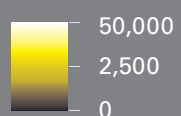
The map combines 'ambient population density', a measure that indicates the 24-hour average of population distribution within a square kilometre across the world's surface, with energy consumption data. The pie charts illustrate energy consumption patterns in 53 countries, with the size of the pie charts reflecting the average amount of 'primary energy supply' per person (a measure of the consumption of raw energy sources such as oil, coal and gas, before conversion processes such as oil refining or electricity generation). The yellow portion of the pie charts represents the proportion of primary energy used for electricity generation – including combined heat and power generation. The energy used to generate electricity is categorised as either coming from 'renewable' sources (hydro, wind, solar, biomass, geothermal, waste, tidal, wave) or 'non-renewable' sources (coal, oil, natural gas, nuclear). The grey and black portions represent energy used for purposes other than electricity generation, including transport, heating and industry.
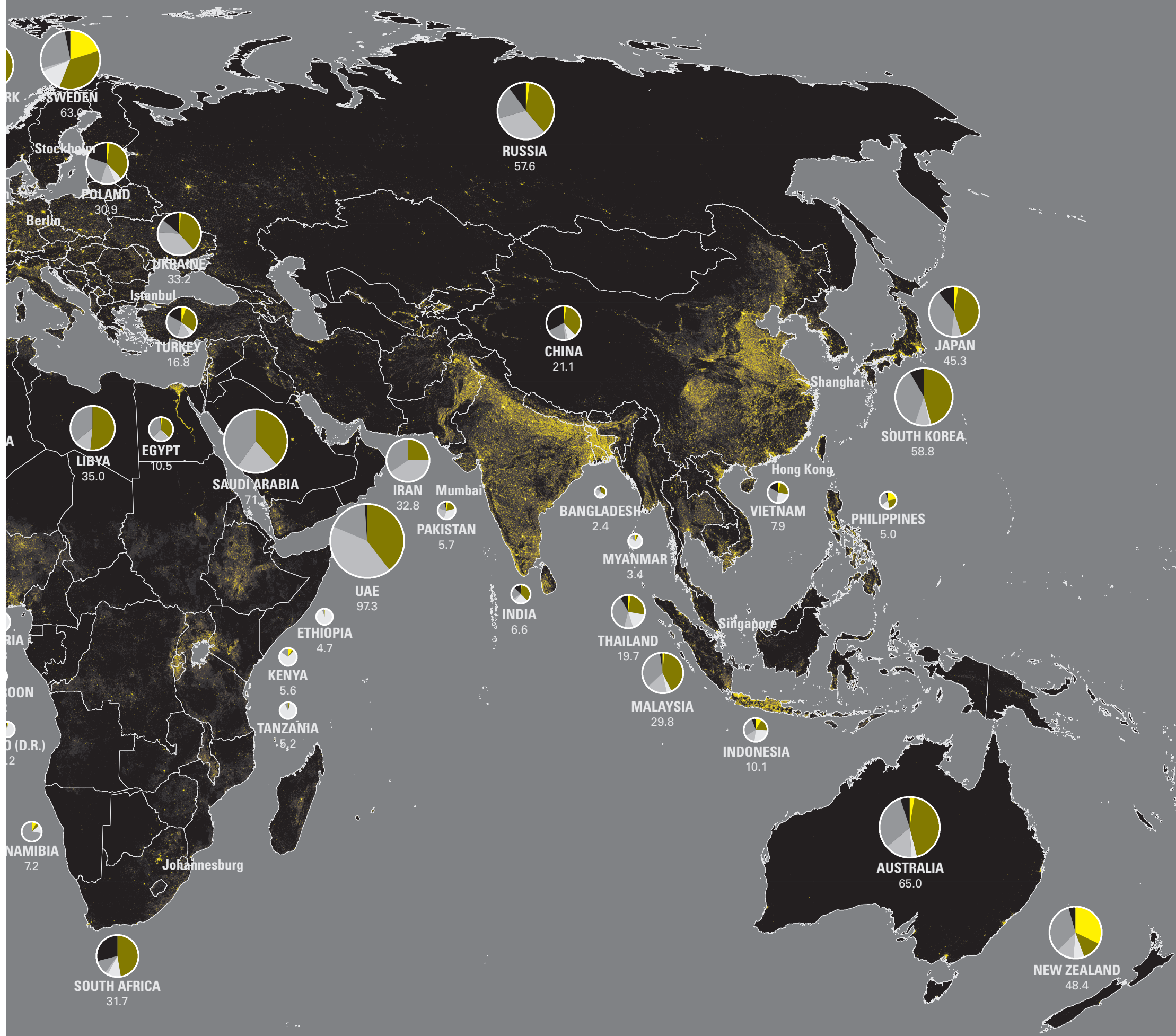
Where people live and how much they consume are inextricably linked. Yet, their patterns of distribution do not match up. People living in the highly concentrated urbanised regions of eastern China and the Ganges Valley in India have modest consumption patterns compared to the oil and petrol-guzzling habits of those in the more sparsely populated regions of North America and the Middle East. There are equally varied patterns between the established urban areas of Europe and the US and the more widely scattered, but dense cities of Latin America and Africa. Reflecting global disparities in wealth, lifestyles and consumption, these data show that a person living in the United Arab Emirates is likely to use 40 times more energy than a Bangladeshi, while a UK citizen consumes less than half of his US counterpart, but twice as much as a Mexican, and slightly less than a Dane.
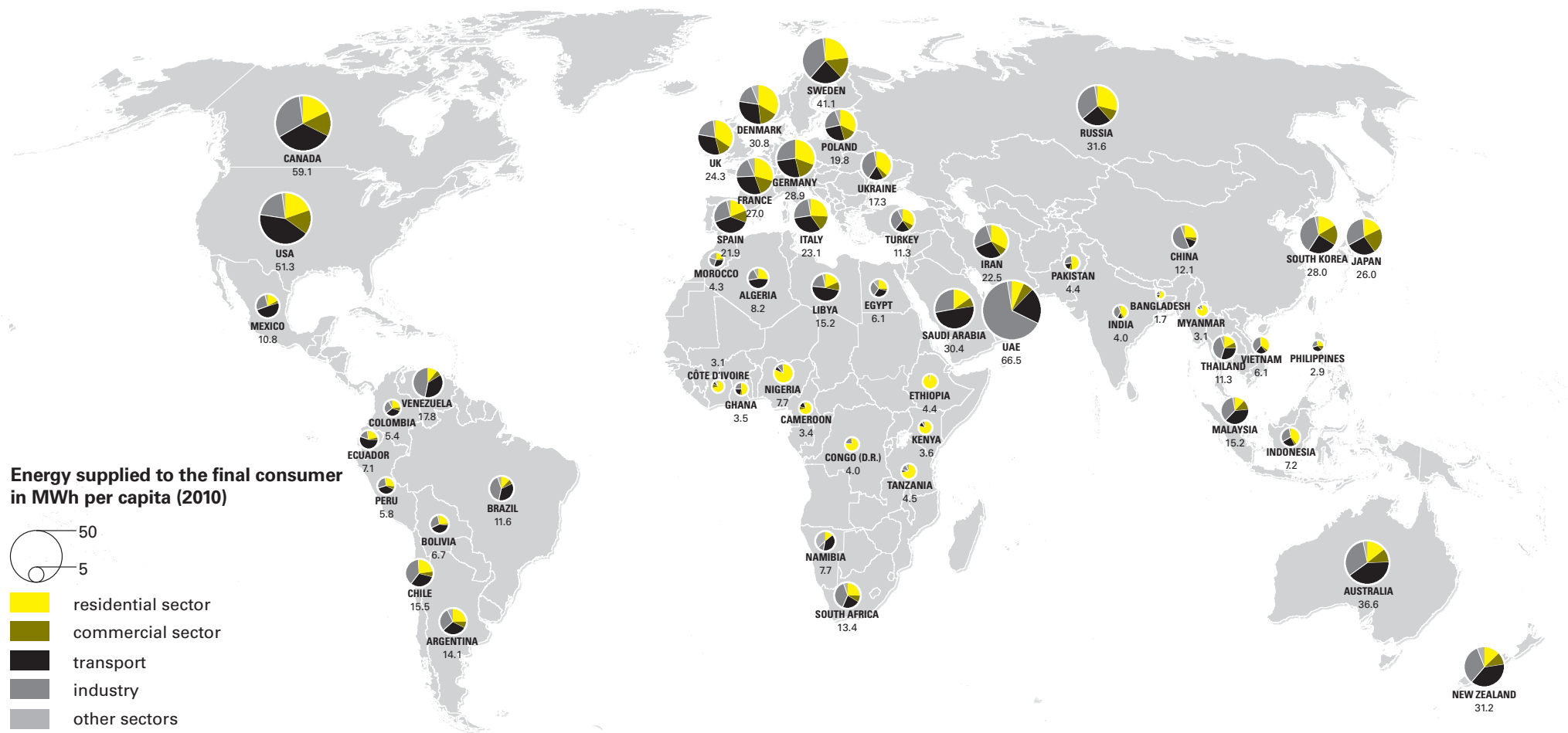
Electricity is a major component of the world's energy mix. Yet, despite living in the 'electric age', electrification differs substantially between countries, swinging from less than 5 per cent of total energy in Nigeria and Nepal, to more than 50 per cent in Sweden and France. But a high share of electricity does not necessarily deliver environmental benefits. Generation is still dominated by carbon emitting fossil fuels, and electricity is not always the most efficient energy choice for uses such as heating and cooling in buildings.

Aside from electricity, most of the world's energy consumption involves directly burning fossil fuels, such as oil for transport, coal for making steel and cement industries and gas for heating. Despite recent improvements in some countries in procuring energy from renewables, they make up only 13 per cent of the world's total consumption – mostly hydro-electricity in high-income countries and biomass for cooking and heating in low-income countries.

SWEDEN
63.0

Stockholm

POLAND
30.9

Berlin

UKRAINE
33.2

Istanbul

TURKEY
16.8

RUSSIA
57.6

CHINA
21.1

JAPAN
45.3

Shanghai

SOUTH KOREA
58.8

LIBYA
35.0

EGYPT
10.5

SAUDI ARABIA
71.

IRAN
32.8

Mumbai

BANGLADESH
2.4

Hong Kong

VIETNAM
7.9

PHILIPPINES
5.0

PAKISTAN
5.7

UAE
97.3

ETHIOPIA
4.7

INDIA
6.6

MYANMAR
3.4

THAILAND
19.7

Singapore

KENYA
5.6

TANZANIA
5.2

MALAYSIA
29.8

INDONESIA
10.1

NAMIBIA
7.2

Johannesburg

AUSTRALIA
65.0

SOUTH AFRICA
31.7

NEW ZEALAND
48.4

ENERGY, ELECTRICITY AND EMISSIONS

ENERGY CONSUMPTION BY SECTOR

CANADA 59.1
USA 51.3
MEXICO 10.8

SWEDEN 41.1
DENMARK 30.8
POLAND 19.8
UK 24.3
GERMANY 28.9
UKRAINE 17.3
FRANCE 27.0
SPAIN 21.9
ITALY 23.1
TURKEY 11.3
MOROCCO 4.3
ALGERIA 8.2
LIBYA 15.2
EGYPT 6.1
IRAN 22.5
PAKISTAN 4.4
CHINA 12.1
SOUTH KOREA 28.0
JAPAN 26.0
RUSSIA 31.6
SAUDI ARABIA 30.4
UAE 66.5
BANGLADESH 1.7
INDIA 4.0
MYANMAR 3.1
THAILAND 11.3
VIETNAM 6.1
PHILIPPINES 2.9
MALAYSIA 15.2
INDONESIA 7.2

3.1
CÔTE D'IVOIRE
NIGERIA 7.7
GHANA 3.5
CAMEROON 3.4
ETHIOPIA 4.4
KENYA 3.6
CONGO (D.R.) 4.0
TANZANIA 4.5

VENEZUELA 17.8
COLOMBIA 5.4
ECUADOR 7.1
PERU 5.8
BRAZIL 11.6
BOLIVIA 6.7
CHILE 15.5
ARGENTINA 14.1

NAMIBIA 7.7
SOUTH AFRICA 13.4

AUSTRALIA 36.6
NEW ZEALAND 31.2

Energy supplied to the final consumer in MWh per capita (2010)

- 50
- 5

- residential sector
- commercial sector
- transport
- industry
- other sectors

Source: International Energy Agency (2010). World Energy Balances Database (2012 Edition)

ELECTRICITY SHARE AT HOME

CANADA 10.6
USA 10.1
MEXICO 1.8

SWEDEN 9.4
DENMARK 10.3
POLAND 6.4
UK 8.3
GERMANY 8.8
UKRAINE 6.4
FRANCE 7.9
SPAIN 4.1
ITALY 6.0
TURKEY 3.6
MOROCCO 1.0
ALGERIA 2.1
LIBYA 2.8
EGYPT 1.6
IRAN 7.3
PAKISTAN 2.3
CHINA 3.1
SOUTH KOREA 4.7
JAPAN 4.5
RUSSIA 9.1
SAUDI ARABIA 4.6
UAE 4.4
BANGLADESH 1.0
INDIA 1.6
MYANMAR 2.5
THAILAND 1.9
VIETNAM 2.1
PHILIPPINES 0.8
MALAYSIA 1.8
INDONESIA 2.8

2.2
CÔTE D'IVOIRE
NIGERIA 6.2
GHANA 1.8
CAMEROON 2.4
ETHIOPIA 4.1
KENYA 2.8
CONGO (D.R.) 3.0
TANZANIA 3.3

VENEZUELA 1.9
COLOMBIA 1.2
ECUADOR 1.5
PERU 1.6
BRAZIL 1.4
BOLIVIA 1.6
CHILE 3.6
ARGENTINA 3.5

NAMIBIA 1.1
SOUTH AFRICA 3.4

AUSTRALIA 5.3
NEW ZEALAND 4.0

Residential energy consumption in MWh per capita (2010)
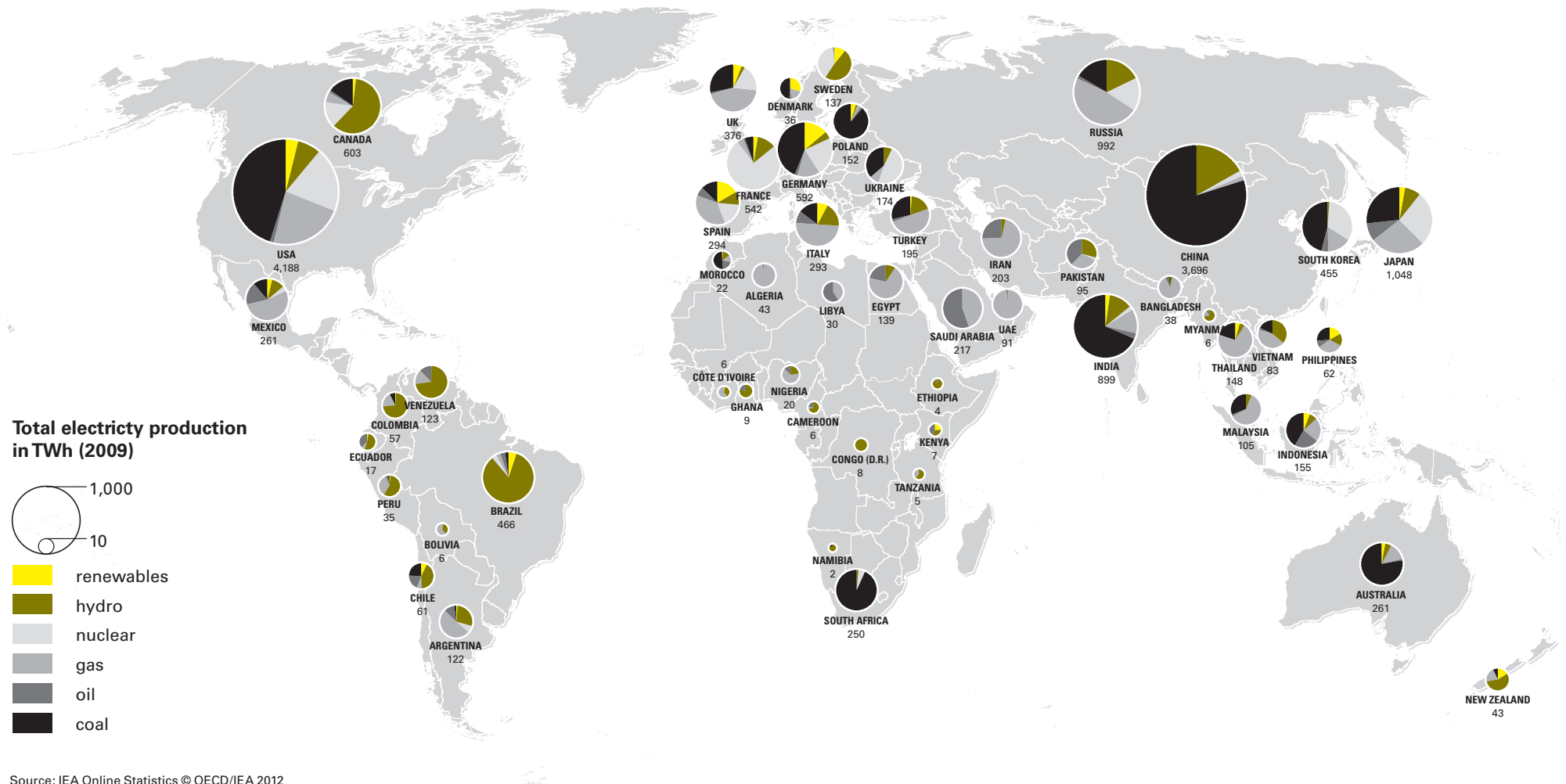
- 10
- 1

- electric
- non-electric

Source: International Energy Agency (2010). World Energy Balances Database (2012 Edition)

Energy consumption by sector shows variations in levels of average consumption per person and differences in the mix of activities for which energy is used. Energy is used at higher proportions in Sub-Saharan Africa for domestic use, especially for cooking and lighting, and by the transport sector in North Africa and in the Middle East, reflecting high levels of motorisation combined with inexpensive local oil supply. Energy for the commercial sector – offices, shops and public services – accounts for less than 10% of total consumption, although the proportion is higher in advanced economies. Industrial energy use dominates Asian manufacturing hubs in China, South Korea and Thailand. **Electricity share at home** reveals wide variations in household use and the degree of electrification. In Saudi Arabia, Australia, New Zealand and Japan, most household energy is electric but in other high-income countries other sources, such as gas for heating, make up a greater proportion of total consumption. Average consumption per person is highest in wealthy parts of Europe and North America, but is also high in Sub-Saharan Africa where dependence on biomass sources (such as wood for cooking) explains the reasonably high levels of domestic energy use in the absence of electricity infrastructure.

Electricity generation by source shows variations in the total amount of electricity generation (rather than per capita values as in the other maps). Coal is a major source of power in the US, China, India and Germany – some of the world's biggest economies. The oil-rich Middle East and North Africa burn oil and gas, while in South America cleaner hydro-sources dominate. Despite recent policy shifts, renewable sources other than hydro-electric power – energy generated from wind, solar and geo-thermal sources – contribute to only 3 per cent of the world's electricity generation – with the highest proportion in Denmark, where they fuel around a quarter of electricity generation. **Carbon emissions by sector** confirms that fossil-fuel based electricity is an important contributor to global climate change. Emissions from electricity generation vary depending on fuel source, with coal-dependent countries such as Australia, China and South Africa showing high proportions. In contrast, Denmark has lower emissions fom electricity due to its high level of renewable generation. Varying levels of emissions from transport echo motorisation rates. Global carbon emissions are concentrated in a few nations with China and the US alone producing 39% of global emissions.

ELECTRICITY GENERATION BY SOURCE

Total electricty production in TWh (2009)

1,000
10

- renewables
- hydro
- nuclear
- gas
- oil
- coal

Source: IEA Online Statistics © OECD/IEA 2012

CARBON EMISSIONS BY SECTOR

Carbon emissions in tonnes per capita (2008)

10
1

- electricity and heat production
- residential buildings and commercial and public services
- transport
- manufacturing industries and construction
- other sectors

Source: World Bank (2008). World Development Indicators – CO_2 Emissions

CITIES AND THE GREEN TRANSITION

Between January and September 2012 LSE Cities surveyed close to 100 city governments from around the world to better understand the leading role cities are playing in adopting environmental policies and transitioning to a green economy. The survey was completed in partnership with ICLEI (Local Governments for Sustainability) and the Global Green Growth Institute, with results published for the Rio+20 Summit in June and the Global Green Growth Forum in Copenhagen in October 2012.

The survey included a diverse range of cities representing variations in population size, regional location and income level. The findings reveal insights on cities' motivations for adopting green policies, their progress in integrating complementary economic and environmental objectives and their experiences in coordinating governance for green policy. While a range of environmental challenges and green aspirations were found to be widely shared across the world, the results also find important distinctions in green policy experiences, particularly associated with the substantial differences in wealth across the surveyed cities.

The results featured on this page summarise key findings from the survey, with a more comprehensive set of results available at: http://lsecities.net/publications/reports/going-green/.

ENVIRONMENTAL CHALLENGES

The survey responses confirm that environmental problems are some of the most pressing challenges facing cities today. Many of the most widely experienced problems are associated with transport and urban planning and include air pollution, road congestion and urban sprawl – all significant challenges for more than 60 per cent of the surveyed cities. Storms and flooding, solid waste management, water pollution and lack of green space are also problems for the majority of them.

Cities in middle- and low-income countries face additional environmental challenges compared to those experienced in high-income countries. Commonly reported problems are often associated with inadequate infrastructures and include clean water supply, sewage treatment and dumped household waste.
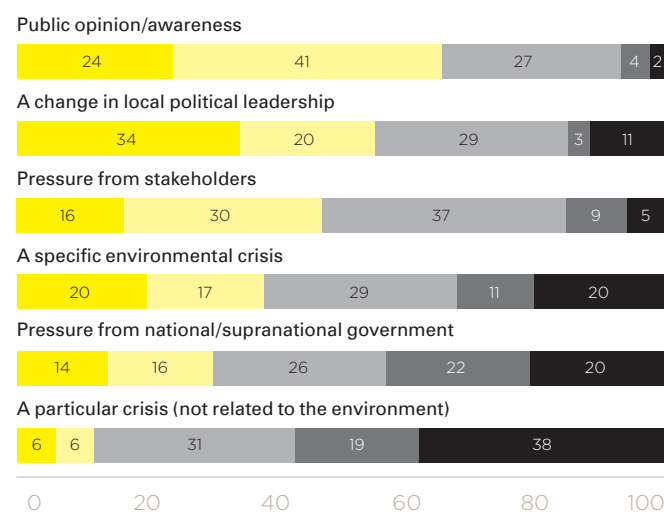
GREEN TRANSITION: PROGRESS TO DATE

In a context where many urban environmental problems continue to be unresolved, virtually all city governments regard green objectives as important components of their political agendas. This priority for green issues is a relatively recent shift, with 65 per cent of cities reporting that green objectives have only become politically important since the 1992 Rio Earth Summit.
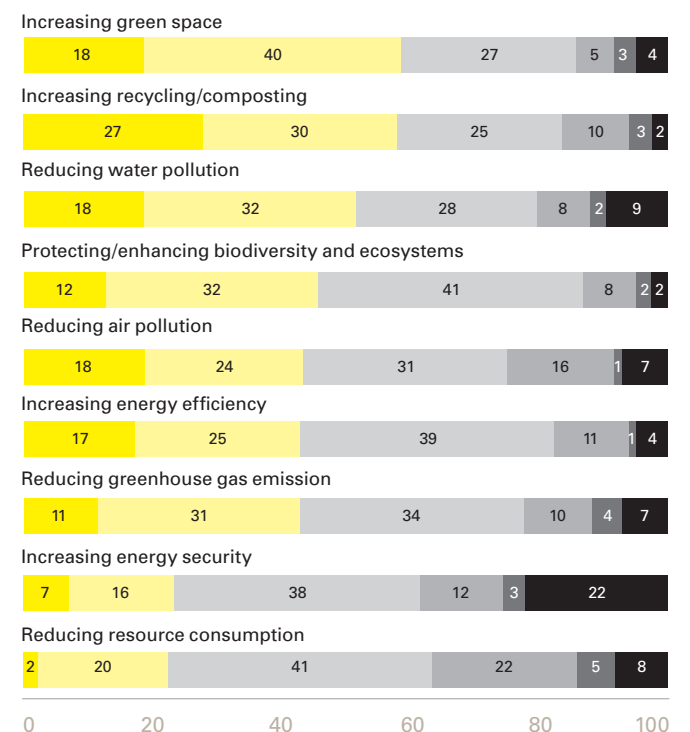
Although urban environmental problems are significant, local environmental crises or tipping points have not been the primary drivers of the green transition. Rather, public awareness and changing political leadership have been more important triggers prompting the adoption of green objectives. In middle- and low-income countries, pressure from national governments and international agencies has also been important in prompting green policy development.

Green objectives are widely shared, but progress in developing policies varies across sectors. More than half of cities report their policies as well-developed in the waste (65 per cent), land-use (60 per cent) and water sectors (60 per cent), while only one in five cities report having well-developed policies for the food sector. For the waste and water sectors, comprehensive policies have translated into successful outcomes on the ground, with most cities increasing waste recycling and reducing water pollution – particularly those in high-income countries. Reducing resource use and establishing energy security have proved more challenging, with less than a quarter of cities reporting success in achieving these objectives.

How important were/are the following triggers in making green objectives as important part of your city's political agenda?

Public opinion/awareness
24 | 41 | 27 | 4 | 2

A change in local political leadership
34 | 20 | 29 | 3 | 11

Pressure from stakeholders
16 | 30 | 37 | 9 | 5

A specific environmental crisis
20 | 17 | 29 | 11 | 20

Pressure from national/supranational government
14 | 16 | 26 | 22 | 20

A particular crisis (not related to the environment)
6 | 6 | 31 | 19 | 38

0   20   40   60   80   100

To what extent have the following green policy objectives achieved successful outcomes in your city?

Increasing green space
18 | 40 | 27 | 5 | 3 | 4

Increasing recycling/composting
27 | 30 | 25 | 10 | 3 | 2

Reducing water pollution
18 | 32 | 28 | 8 | 2 | 9

Protecting/enhancing biodiversity and ecosystems
12 | 32 | 41 | 8 | 2 | 2

Reducing air pollution
18 | 24 | 31 | 16 | 1 | 7

Increasing energy efficiency
17 | 25 | 39 | 11 | 1 | 4

Reducing greenhouse gas emission
11 | 31 | 34 | 10 | 4 | 7

Increasing energy security
7 | 16 | 38 | 12 | 3 | 22

Reducing resource consumption
2 | 20 | 41 | 22 | 5 | 8

0   20   40   60   80   100

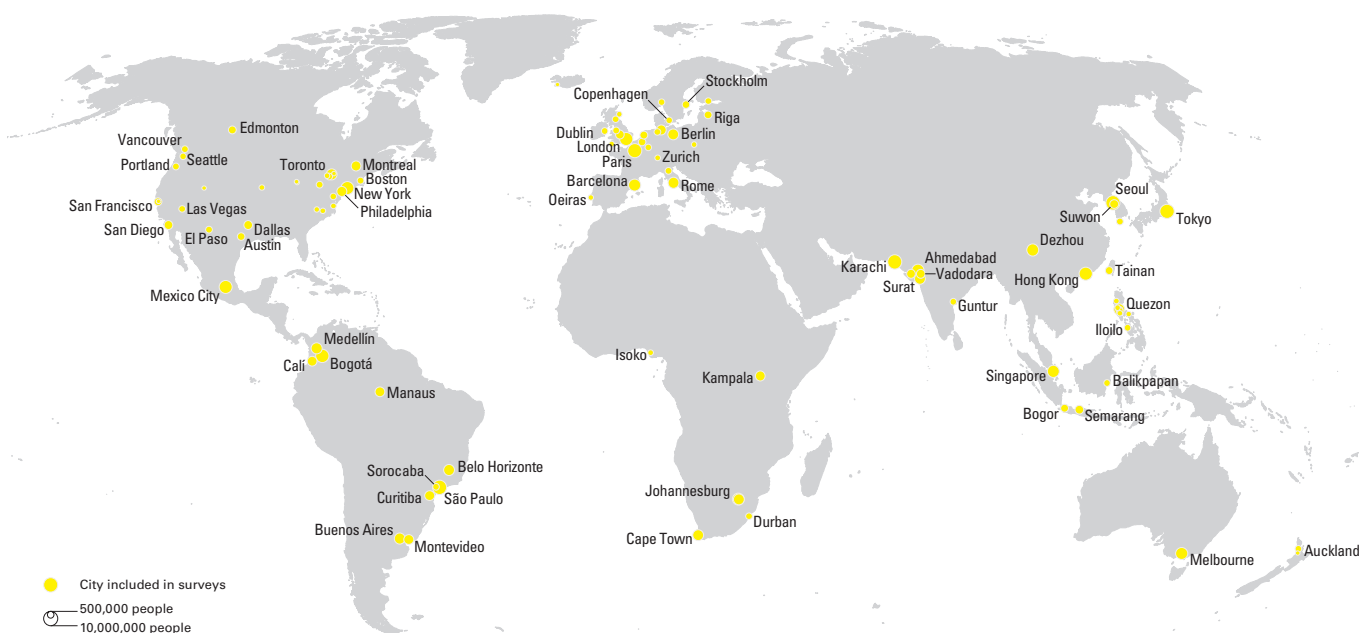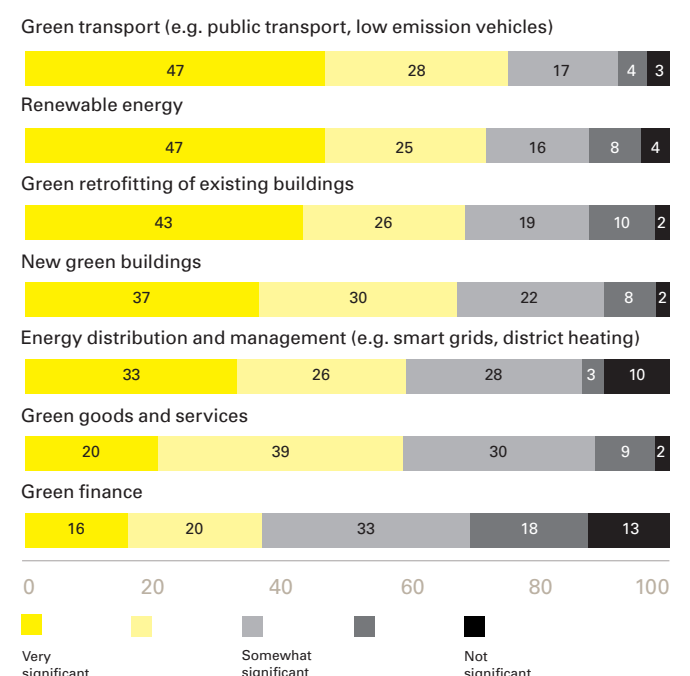## BUILDING THE GREEN ECONOMY

In tackling environmental problems, cities are realising the opportunity for considerable economic co-benefits. An overwhelming majority of city governments (93 per cent) expect their green policies to have a positive economic impact. Most cities view economic growth and improved environmental outcomes as complementary, with 65 per cent describing economic growth as a primary goal of their green policies, and a further 31 per cent regarding growth as a secondary goal.

Alongside economic growth, cities expect a broad range of economic benefits arising from their green policy agendas, including attracting investment (78 per cent of cities), increasing innovation (76 per cent), creating jobs (72 per cent), and increasing economic resilience (69 per cent).

Cities identify urban transport, buildings and energy as the key sectors for green economic growth. Both new green buildings and retrofits of existing buildings are seen as making important contributions to green growth, while renewable energy generation and energy distribution networks, such as smart grids, are identified as particularly promising areas within the energy sector.

While city authorities are confident that green policies can lead to economic gains as well as environmental benefits, economic impact assessments of these policies are rare. This presents a major gap. City governments could strengthen their case for more effective and efficient green economic policies by building a rigorous evidence base for the economic impacts delivered.

How significant are the following sectors of the green economy for your city's economic growth?

Green transport (e.g. public transport, low emission vehicles)
47 | 28 | 17 | 4 | 3

Renewable energy
47 | 25 | 16 | 8 | 4

Green retrofitting of existing buildings
43 | 26 | 19 | 10 | 2

New green buildings
37 | 30 | 22 | 8 | 2

Energy distribution and management (e.g. smart grids, district heating)
33 | 26 | 28 | 3 | 10

Green goods and services
20 | 39 | 30 | 9 | 2

Green finance
16 | 20 | 33 | 18 | 13

0   20   40   60   80   100

Very significant | Somewhat significant | Not significant

Map

Stockholm, Copenhagen, Riga, Berlin, Dublin, London, Paris, Zurich, Barcelona, Oeiras, Rome

Edmonton, Vancouver, Portland, Seattle, Toronto, Montreal, Boston, New York, Philadelphia, San Francisco, Las Vegas, Dallas, Austin, San Diego, El Paso, Mexico City

Seoul, Suwon, Tokyo, Dezhou, Tainan, Karachi, Ahmedabad–Vadodara, Hong Kong, Surat, Guntur, Quezon, Iloilo, Singapore, Balikpapan, Bogor, Semarang, Isoko, Kampala

Medellin, Cali, Bogotá, Manaus, Sorocaba, Belo Horizonte, Curitiba, São Paulo, Buenos Aires, Montevideo, Johannesburg, Durban, Cape Town, Melbourne, Auckland

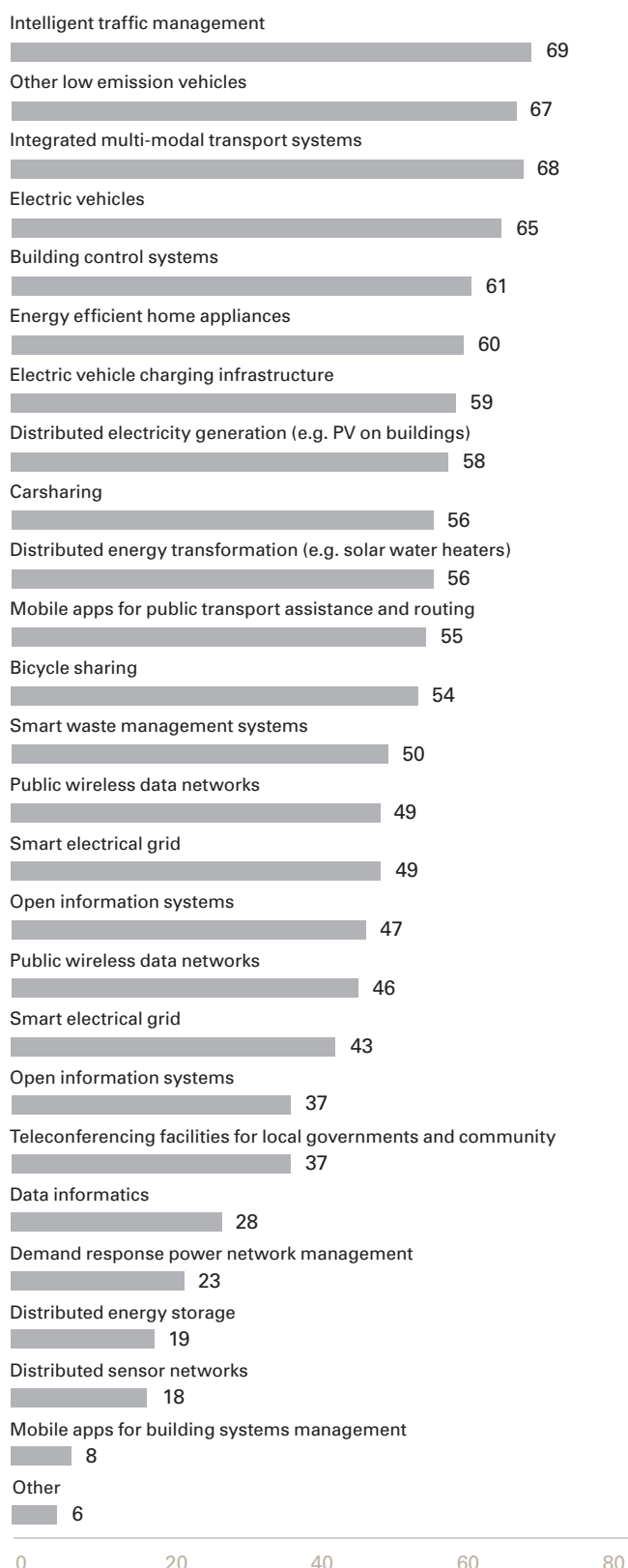- City included in surveys
- 500,000 people
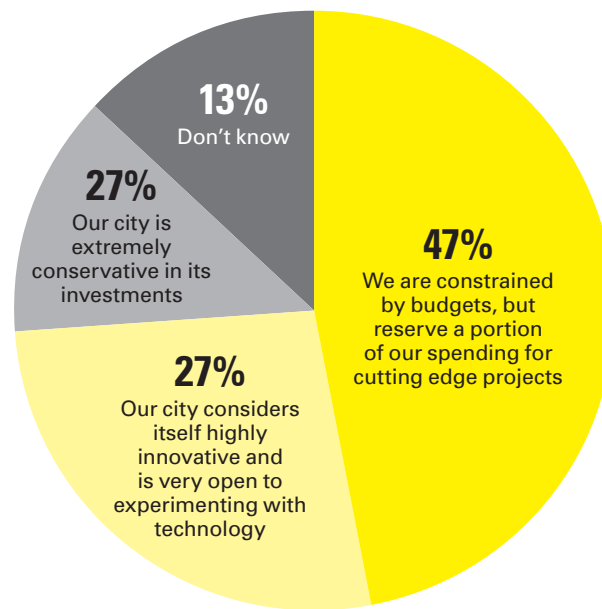- 10,000,000 people

TECHNOLOGY AND INNOVATION

Cities see technology as playing a key role in the transformation to a green economy. New technologies are identified as being particularly important for green transport, energy generation and green buildings – with more than three quarters of surveyed cities agreeing that new technology is important in these sectors. A number of specific technologies are seen as most relevant for green economy strategies including transport technologies, such as intelligent traffic management and low-emission vehicles, and energy-saving technologies, such as efficient home appliances and building control systems.

The surveyed city governments generally believe that they should play a leading role in driving green innovation – with 81 per cent agreeing that they should lead by example and introduce innovations within their own operations. Furthermore, 74 per cent of city governments report that they are willing to invest in experimental cutting-edge projects to stimulate change – while only 15 per cent report taking a conservative approach to technological innovation and investment. Municipal governments see themselves as playing an important role in facilitating innovation, with only 6 per cent of respondents agreeing that responsibility for driving green innovation should be left solely to the private sector. The responses indicate that many cities are willing to be first movers and accept some degree of risk in fostering green innovation.

Which of the following technologies is your city intending to use as part of its green strategy?

Intelligent traffic management
69

Other low emission vehicles
67

Integrated multi-modal transport systems
68

Electric vehicles
65

Building control systems
61

Energy efficient home appliances
60

Electric vehicle charging infrastructure
59

Distributed electricity generation (e.g. PV on buildings)
58

Carsharing
56

Distributed energy transformation (e.g. solar water heaters)
56

Mobile apps for public transport assistance and routing
55

Bicycle sharing
54

Smart waste management systems
50

Public wireless data networks
49

Smart electrical grid
49

Open information systems
47

Public wireless data networks
46

Smart electrical grid
43

Open information systems
37

Teleconferencing facilities for local governments and community
37

Data informatics
28

Demand response power network management
23

Distributed energy storage
19

Distributed sensor networks
18

Mobile apps for building systems management
8

Other
6

0   20   40   60   80

Which of the following statements best describes the way your city approaches green technology innovations and investments?

13% Don't know

27% Our city is extremely conservative in its investments

47% We are constrained by budgets, but reserve a portion of our spending for cutting edge projects

27% Our city considers itself highly innovative and is very open to experimenting with technology
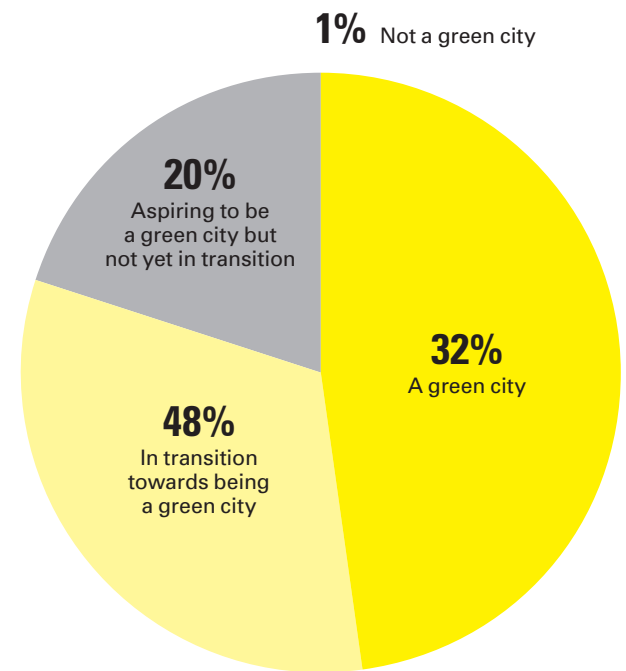
CHALLENGES TO GOING GREEN

City governments have bold green aspirations, yet the successful implementation of environmental and green economy policies is not without challenges. Insufficient public funding and lack of support from national-level governments emerge as the most important barriers thwarting achievement of green objectives – and were reported as significant by more than half of the cities involved.

Coordinating government objectives across scales – particularly between city and national governments – is seen as particularly important for accelerating green initiatives. For 60 per cent of cities, national policy frameworks currently fall short of supporting cities' green agendas – a problem particularly noted by North American and European cities. Policies in the transport and energy sectors are most frequently noted as undermining cities' green goals.

While lack of policy expertise or public support for green policies do not emerge as a particular challenges across the overall sample of surveyed cities, these problems do often exist for cities in middle- and low-income cities. Cities in these contexts report more challenges to going green and commonly identified lack of public support, lack of private-sector support, and lack of government and workforce expertise and skills as important barriers preventing progress towards their green agendas.

How significant are the following barriers to achieving your city's objectives?

Lack of public funding
33 | 22 | 27 | 13 | 4

Lack of national government support
30 | 19 | 26 | 11 | 14

Lack of private investment
16 | 22 | 38 | 21 | 3

Lack of state government support
24 | 13 | 25 | 18 | 20

Lack of private sector support
18 | 10 | 36 | 26 | 11

Lack of skills in the local workforce
12 | 14 | 19 | 34 | 21

Fragmented local governance
15 | 11 | 36 | 16 | 21

Lack of skills in local government
17 | 7 | 24 | 34 | 18

Lack of public support
12 | 9 | 36 | 21 | 22

0   20   40   60   80   100

How would you define your city in relation to the green agenda?

1% Not a green city

20% Aspiring to be a green city but not yet in transition

32% A green city

48% In transition towards being a green city

CAN CITIES DRIVE THE GREEN TRANSITION?

The survey highlights a number of common experiences for cities around the world as they develop environmental policies and build green economies. For instance, problems associated with unsustainable transport systems, including air pollution and urban sprawl, are widely reported. Cities from diverse contexts also report common challenges working against their green objectives – with coordination and alignment of policy between local- and national-level governments emerging as a particular problem.

Important differences in city governments' experiences also exist, with cities in middle- and low-income problems facing a broader range of local environmental problems, often associated with poor basic infrastructure, such as clean water supply and solid waste management. In working to resolve these challenges, poorer cities also unsurprisingly report more barriers to developing green policy with lack of public- and private-sector support and inadequate skills and expertise all being barriers that exist to a far lesser degree in high-income cities.
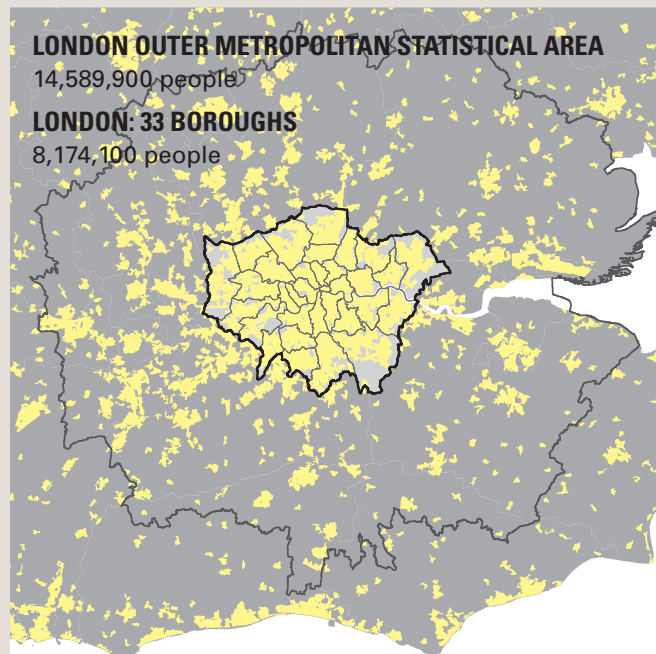
The survey reveals a promising opportunity for transitioning to a greener economy, with cities around the world embracing green aspirations. Most cities report good local capabilities and a willingness to take risks and innovate to achieve green objectives. Green policies are widely developed and success has been achieved in areas such as cleaning up waterways and increasing waste recycling. Cities have the opportunity to build on this momentum and take a leading position in driving the green transition.

URBAN AGE CITIES

Since 2005, Urban Age has investigated cities experiencing significant growth and change across the globe. As approximately 75 per cent of the world's energy use and 80 per cent of the world's carbon emissions result from urban activities, cities have an essential role in achieving environmental and economic sustainability. These goals need to be achieved in tandem with improving quality of life for the world's 3.5 billion urban residents. This analysis explores the overall form, population and administrative boundaries of six established Urban Age cities and introduces a further six 'green pioneer' cities, noted for their innovation in environmental policy and practice.

Strong civic leadership is a critical component in managing urban change and directing cities towards a more sustainable future. Governing cities is more challenging where the powers of city administrations are limited, and where dynamic urban regions extend beyond administrative boundaries. This is especially true in rapidly growing cities. In São Paulo, for instance, less than two thirds of the city's built-up core falls within its administrative boundary, and consequently this increases the importance of the State of São Paulo, its regional governance body. Metropolitan governance is strong in Berlin and Istanbul, enabling better coordination of growth, in contrast to New York and Mumbai, where functional regions extend far beyond administrative areas. The devolution of power to the Greater London Authority in 2000 has ensured alignment between population distribution and political authority, enabling more integrated and strategic planning in the UK capital.

LONDON OUTER METROPOLITAN STATISTICAL AREA
14,589,900 people
LONDON: 33 BOROUGHS
8,174,100 people

NEW YORK METROPOLITAN STATISTICAL AREA
19,015,900 people
NEW YORK CITY: 5 BOROUGHS
8,175,133 people

BERLIN METROPOLITAN REGION
4,971,331 people
BERLIN: 12 BEZIRKE
3,501,900 people

LONDON

London's population has grown by 900,000 in the last decade and reached 8.2 million in 2011. This is close to the city's historic peak of 8.6 million, recorded in 1939, and 400,000 more than anticipated by the Office of National Statistics. The establishment of an elected mayor has seen improved land use and transport coordination – reinforcement of the Green Belt and introduction of Congestion Charging – and a range of environmental initiatives aimed at reducing carbon emissions and improving air quality.
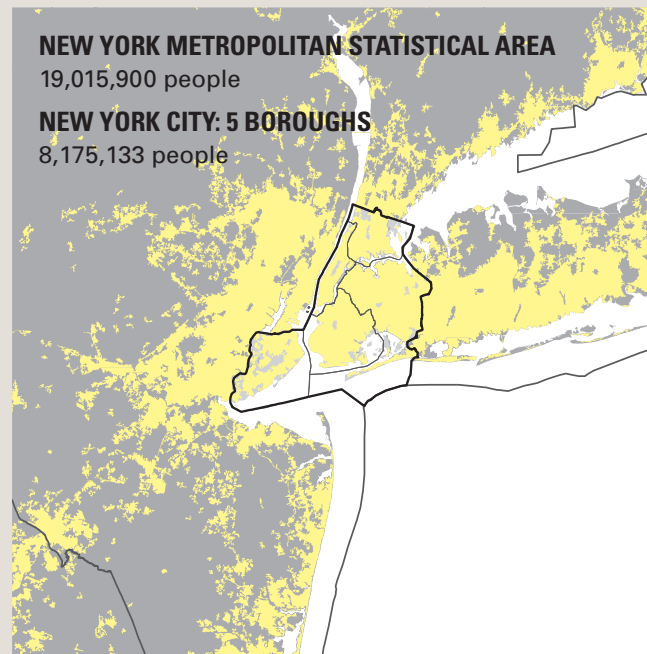
NEW YORK

New York City's population reached a record high of 8.2 million in 2010. The city is the core of an extensive metropolitan region of over 19 million people. Recent planning policy has focused on improving the quality of green spaces and upgrading building energy efficiency, but transport improvements have been frustrated by control of the Mass Transit Authority by the State of New York. On the economic front, digital sectors have been a key component of recent growth, including new media start ups concentrated in the high-profile 'Silicon Alley' cluster.
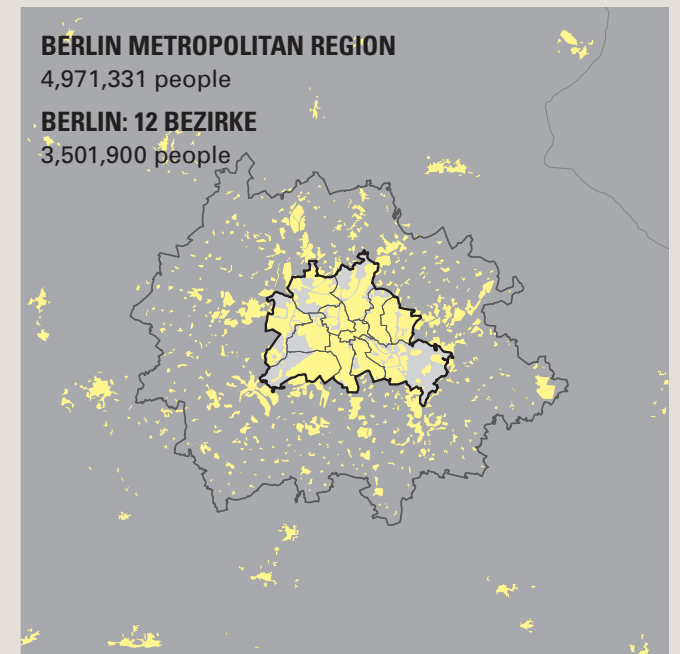
BERLIN

Berlin has undergone modest growth in the last decade and now has over 3.5 million residents. Despite its fragmentation, the city has an effective municipal and regional planning system, which has made the most of its dense inner city core and highly integrated multi-modal public transport network. Although the city has underperformed economically compared to Germany as a whole, it has fostered a significant cluster of digital economy and creative industry firms, and remains highly attractive to young families and artists due to affordable house prices and good quality of life.

ISTANBUL PROVINCE
13,624,240 people
ISTANBUL: 39 İLÇE
13,624,240 people

MUMBAI METROPOLITAN REGION
20,998,395 people
MUMBAI: 24 WARDS
12,478,447 people

SÃO PAULO METROPOLITAN REGION
19,889,559 people
SÃO PAULO: 31 SUBPREFEITURAS
11,253,503 people
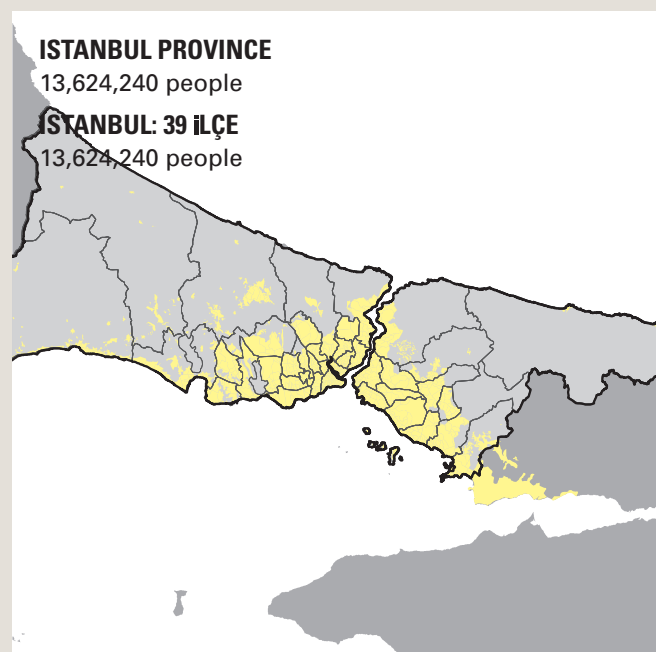
ISTANBUL

Istanbul's population has expanded rapidly in the last decade, from 10 million in 2000 to 13.6 million in 2011. Strongly committed to achieving global city status, the ancient 'hinge city' has a large, unified provincial and city government, which ensures greater regional coordination in transport and economic planning. The city is accommodating large numbers of new government-funded housing (TOKI) and has a complex public transport network of rail, metro, ferries and trams. The city introduced a Bus Rapid Transit system and is completing the first rail link across the Bosporus through the Marmaray tunnel.
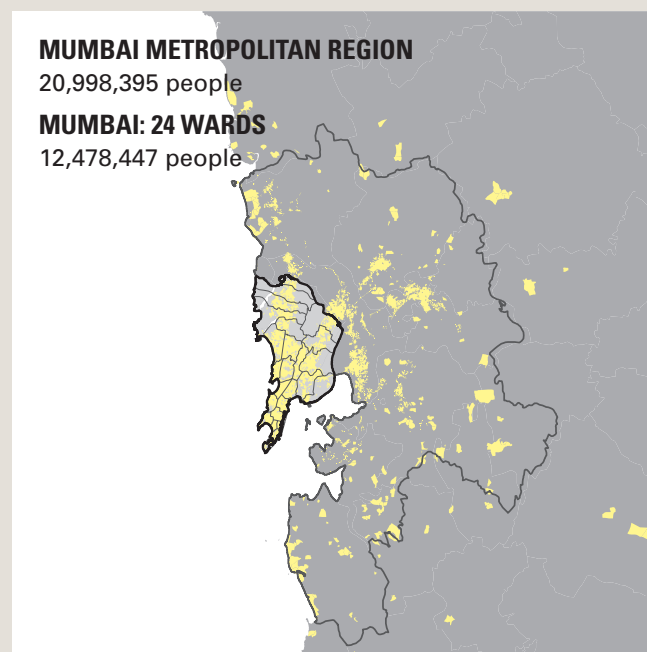
MUMBAI

Mumbai's population has more than doubled in the last 40 years to reach 12.5 million within the city boundary, and over 20 million in the wider metropolitan region. This extreme growth has placed pressure on the city's infrastructure, with large sections of the population living and working in the informal sector. Significant investment is taking place in the regional rail network and a new metro, and in a controversial road building programme. The regional development authority coordinates planning between the seven municipal corporations in the wider metropolitan area, but many key policy decisions are taken by the more extensive and remote State of Maharashtra.
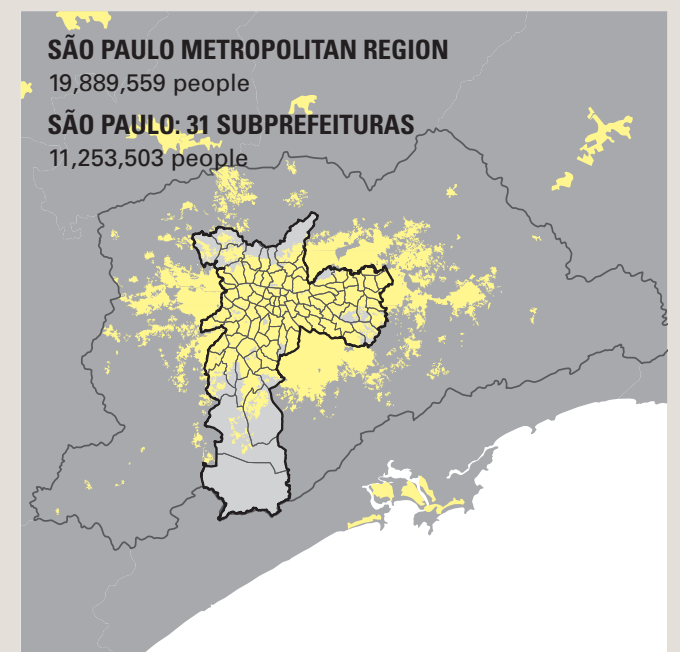
SÃO PAULO

Brazil's economic engine extends horizontally across a vast area that cuts across the city and state boundaries of São Paulo, with areas of poor infrastructure and informal housing pushed out to the periphery. Security and health care are prime concerns of Paulistanos, in a city with high crime and inequality rates. São Paulo's notorious traffic congestion can require four hours of daily commuting times for its residents, even though there have been recent attempts at both state and city level to improve public transport and make the most of Brazil's leadership in sustainable energy initiatives in biofuels and hydro-power.
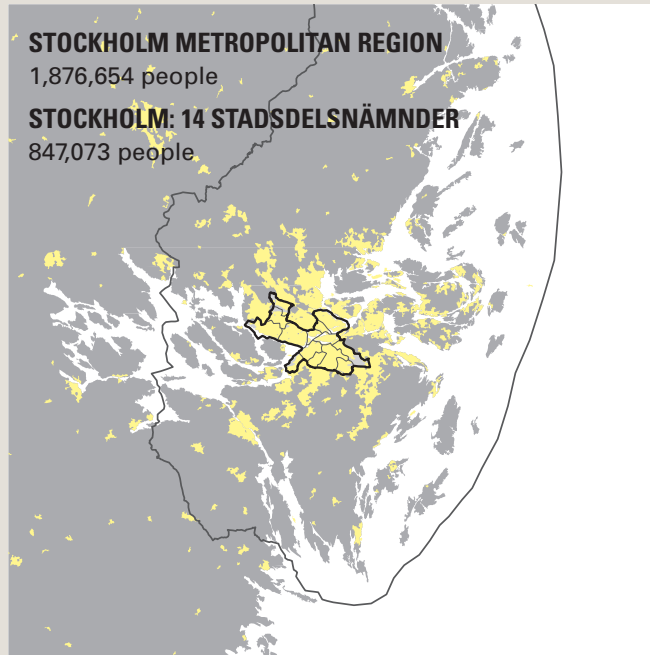
40 km   80 km

As national governments struggle to agree to environmental targets and objectives, greater innovation in sustainable urbanism is becoming more established in cities around the globe, regardless of size or geographical location. Here LSE Cities focuses on six cities that have provided leadership as 'green pioneers'. Environmental initiatives can result from long-standing policy traditions, as well as through new city programmes that cut across different sectors. In this respect, the Scandinavian capitals of Copenhagen and Stockholm stand out as having made a big impact in the fields of decentralised energy, building efficiency and promoting walking and cycling.

Other cities have made progress in more specific sectors. Portland is an interesting example from the US, where cohesive regional governance has implemented effective mechanisms to control sprawl, increase public transport use, and encourage walking and cycling. Implementing the policies of strong city mayors, Bogotá is an early developer of

green transport and cycleway systems, which have transformed travel patterns and road safety in the South American city, confirming that innovation from the developing world can have major impacts in areas of rapid urban change.

Hyper-dense and affluent cities, like Hong Kong and Singapore, offer a very different context for urban sustainability. Both cities have taken advantage of their limited land resources and centralised planning structures, promoting compact and well-connected urban form to render their cities more efficient and competitive. The highly controlled city-state Singapore has pioneered congestion charging, and radically improved efficiency in water use and in waste production. Hong Kong continues to invest in strong economic and social connectivity across the region, creating and sustaining one of the world's most efficient public transport and pedestrian networks.

STOCKHOLM METROPOLITAN REGION
1,876,654 people

STOCKHOLM: 14 STADSDELSNÄMNDER
847,073 people

COPENHAGEN METROPOLITAN REGION
1,822,000 people

COPENHAGEN CITY: 10 BYDELE
549,000 people

HONG KONG SPECIAL ADMINISTRATIVE REGION
7,072,000 people

HONG KONG: 18 DISTRICTS
7,072,000 people

Note urban areas in the wider Pearl River Delta region are not shown.

STOCKHOLM

Stockholm's population expanded to nearly 850,000 inhabitants (1.9 million at metro level) by 2010, and its administration has prioritised environmental sustainability for decades. The development of the city's district heating network started over 50 years ago, and now accounts for nearly 80 per cent of the city's demand, with its strict building regulations, which exceed Swedish national standards, set by the city government. Stockholm has a comprehensive public transport system and high quality pedestrian environment, and has been effective at promoting high-density development on redundant industrial land.
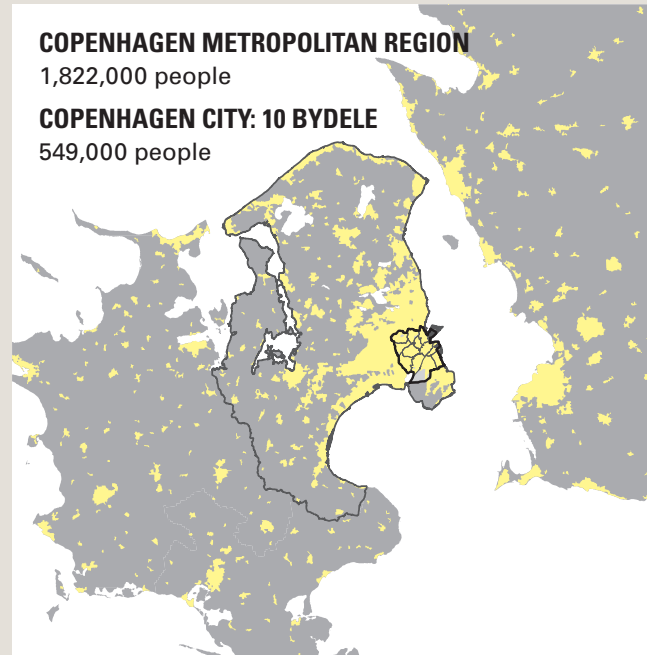
COPENHAGEN

Recognised as a world leader in green policies, Copenhagen's population has grown 18 per cent since 1990 to reach 550,000 (1.8 million at metro level). In addition to district heating and regional land use planning initiatives, Copenhagen is best known for its investment in a wide and well-used cycling infrastructure with 370 km (224 miles) of bike lanes across the municipality. The city has invested in public transport by expanding the new metro system and improving links in the cross-border Øresund region, and is promoting a new generation of green buildings and housing typologies.

HONG KONG

Constrained by mountains and the sea, Hong Kong's population reached nearly 7.1 million in 2011, building on its connections to mainland China and its international port activities. The city has achieved a high level of integration between land use planning and transport, developing one of the world's most efficient rail networks in one of the world's densest cities. The unitary government structure gives the city extensive powers in planning and fiscal policy, maintaining control over land freehold and development rights.

PORTLAND METROPOLITAN STATISTICAL AREA
2,265,600 people

PORTLAND: 7 DISTRICT COALITIONS
583,776 people

BOGOTÁ METROPOLITAN REGION
7,881,156 people

BOGOTÁ: 20 LOCALIDADES
6,776,009 people

SINGAPORE CITY STATE
5,312,400 people

SINGAPORE: 5 COMMUNITY DEVELOPMENT COUNCILS
5,312,400 people

Note urban areas in Malaysia and Indonesia are not shown.
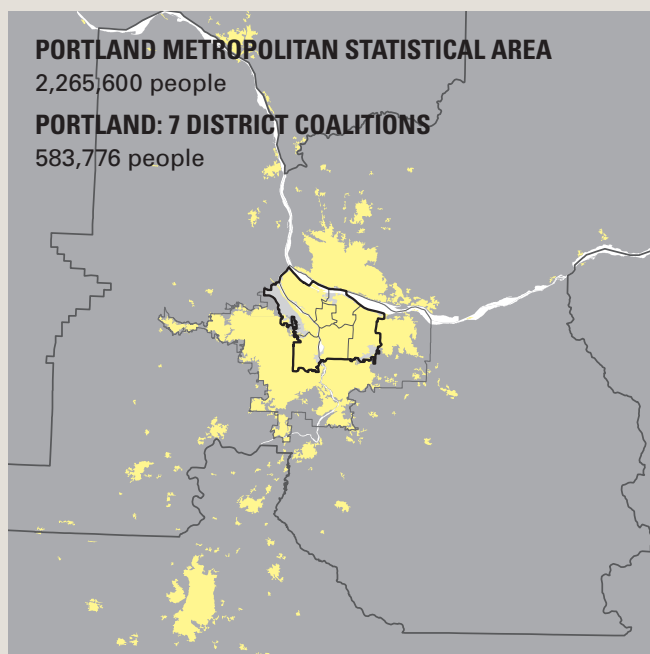
PORTLAND

The city of Portland in the US north-western state of Oregon forms part of a wider urban region integrating several municipalities in a continuous built-up area. Grouped in a regional metropolitan authority that controls land use planning, these authorities have led the field in environmental policy innovation, making the city and its region a radical pioneer within the North American context. The implementations of an Urban Growth Boundary and allied initiatives have boosted public transport demand, with the city developing a light rail network and significant cycling provision. Portland is also an innovator in green buildings and developing digital tools for civic participation.
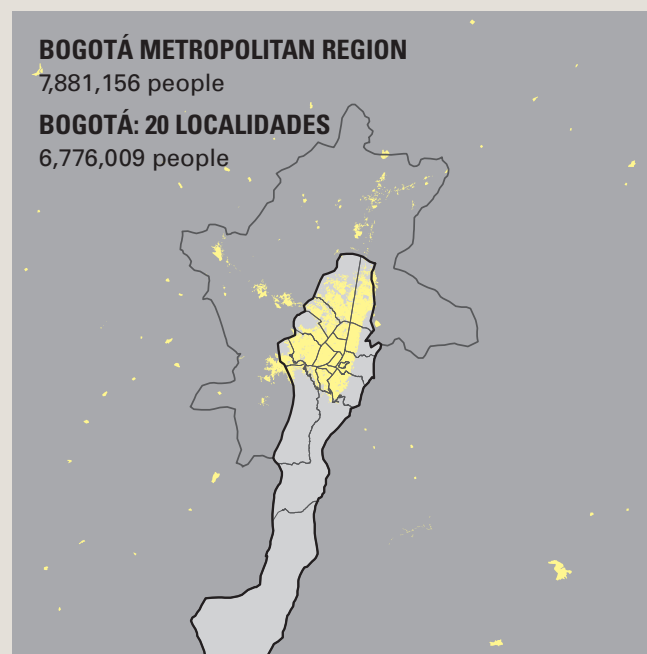
BOGOTÁ

Bogotá's population increase has mirrored South American trends, expanding nearly seven-fold, from less than 1 million in 1950 to 6.8 million in 2010. The population lives in a dense urban environment, constrained by the city's mountainous hinterland, with a large and growing informal sector. For over a decade, subsequent city mayors have invested in innovative transport policies, creating the successful and affordable TransMilenio Bus Rapid Transit and Ciclovia cycle network. Like many South American countries, over two-thirds of electricity production in Colombia is based on hydropower, which significantly reduces greenhouse gas emissions for the city.
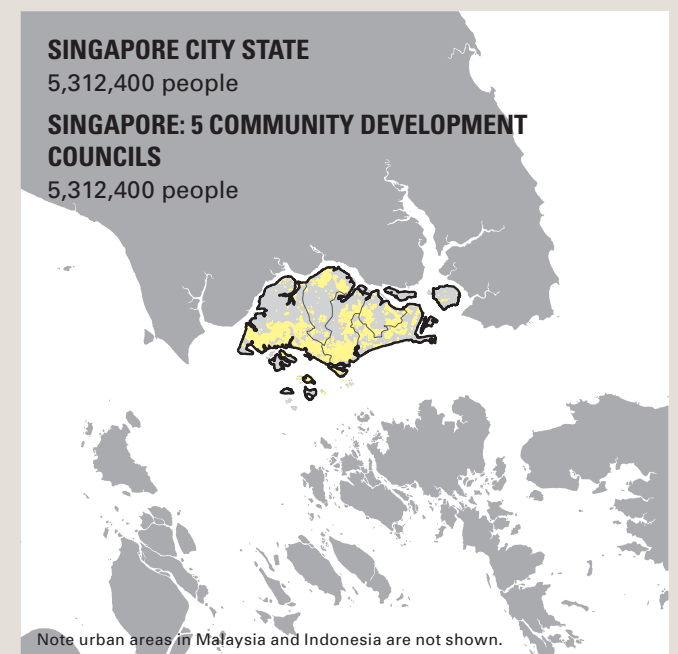
SINGAPORE

As the leading global port city, Singapore's population increased by over a million between 2000 and 2011, and now totals 5.3 million. With a highly integrated and efficient form of city governance, it has implemented significant initiatives across all sectors of land use and transport planning, housing and public space, and more recently has focused on the need to reduce civic waste and improve water use efficiency. In addition, Singapore is investing heavily in the digital economy, with many smart city initiatives and innovation in green ICT tools.

PATTERNS OF CHANGE

The challenges cities confront in becoming more sustainable places to live and work vary depending on the distinct socio-economic, environmental and spatial constraints of each of them. Yet all cities are broadly united in their efforts to improve the well-being of their residents, ideally by raising their income while improving their quality of life through accessible social services and environmental amenities. While there are no universal approaches, the main objective of sustainable cities is to ensure that continued economic and population growth can occur without a commensurate increase in a city's environmental footprint. This so-called 'decoupling' of economic prosperity from increasing levels of resource consumption impact is increasingly seen as a fundamental component of a sustainable future. The graphs below show the diverse patterns of change taking place in cities over the past 20 years. Comparing economic and population growth to selected environmental indicators provides a sense of the drastic transformations these cities have experienced over a relatively short time span.

Several of the cities profiled below have achieved a remarkable level of positive decoupling. This is particularly visible in leading green cities of the industrialised world (Portland, Copenhagen, Stockholm), demonstrating a rapid decrease in energy use and per capita CO_2 emissions, and the proliferation of more sustainable modes of transport. On the whole, cities in the emerging economies do not seem to be leapfrogging to a post-fossil fuel future, appearing at least in part to be following in the developmental footsteps of the industrialised world. Rising electricity consumption and per capita CO_2 emissions,

All variables are indexed: 1997=100
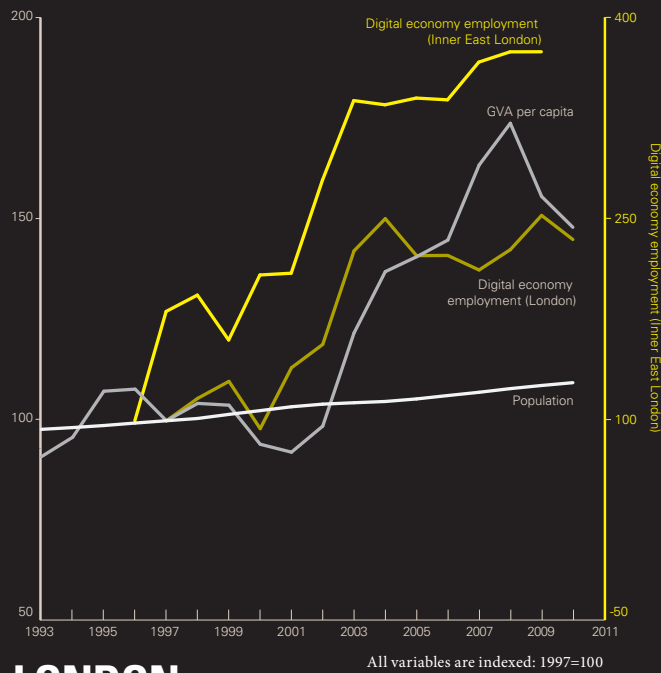
LONDON
London's metropolitan economy has grown strongly over the past 20 years. Despite the recent global downturn, the economy grew by 47 per cent between 1997 and 2011 (measured by Gross Value Added (GVA) per capita), accompanied by a 10 per cent increase in the metropolitan population. Some sectors of the economy have experienced particularly rapid growth: employment in the digital economy has grown by 44 per cent since the late 1990s. The majority of recent job growth in the sector has been concentrated in Inner East London, where an emerging tech cluster now employs nearly 50,000 people – a 400 per cent increase since 1997.

All variables are indexed: 1993=100
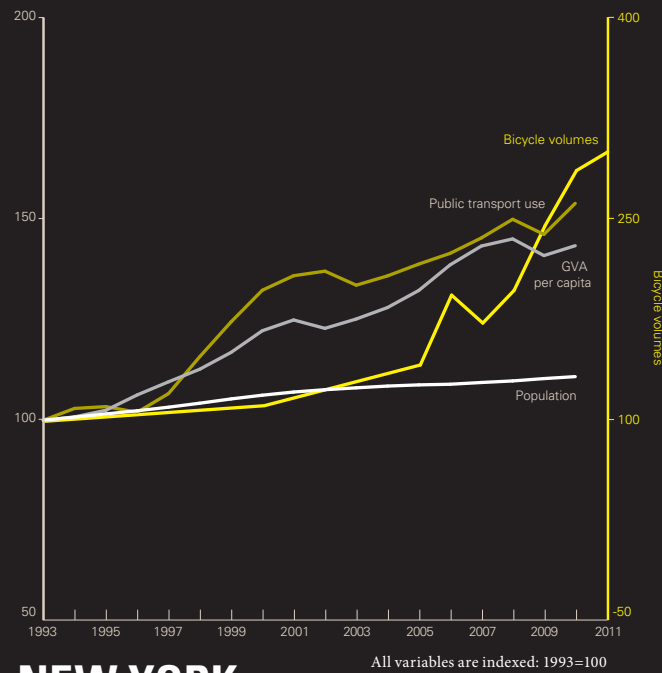
NEW YORK
New York City's metropolitan economy has grown by 43 per cent since 1993 and the region's population by more than 10 per cent to 19 million people in 2010. A top global city, New York City's dense concentrations of firms and jobs has long been supported by an extensive public transport system. Recent upgrades to the subway and bus systems have contributed to a 43 per cent increase in public transport use between 1993 and 2010. Cycling still only accounts for 0.7 per cent of all trips, but is growing rapidly, with the number of people entering and leaving Manhattan by bicycle more than tripling since 1993.

All variables are indexed: 1993=100
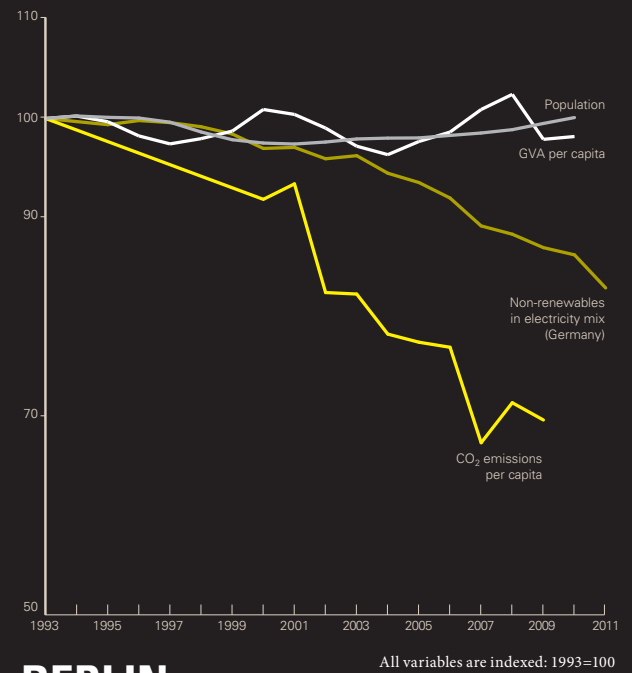
BERLIN
Berlin's regional economy contracted slightly, by 2 per cent, between 1993 and 2010, while the population remained relatively stable at 4.9 million. During the 1990s, rapid de-industrialisation resulted in the loss of more than 150,000 manufacturing jobs, which initially helped reduce greenhouse gas emissions. Today Berlin is re-inventing itself as a clean technology hub, having cut per capita carbon emissions by more than 30 per cent since 1993. This trend is in line with Germany's national-level policy ambition for a sweeping energy transformation. Between 1993 and 2011, the share of renewable energy in Germany's electricity mix increased from 3.9 per cent to 20.3 per cent.

All variables are indexed: 1994=100
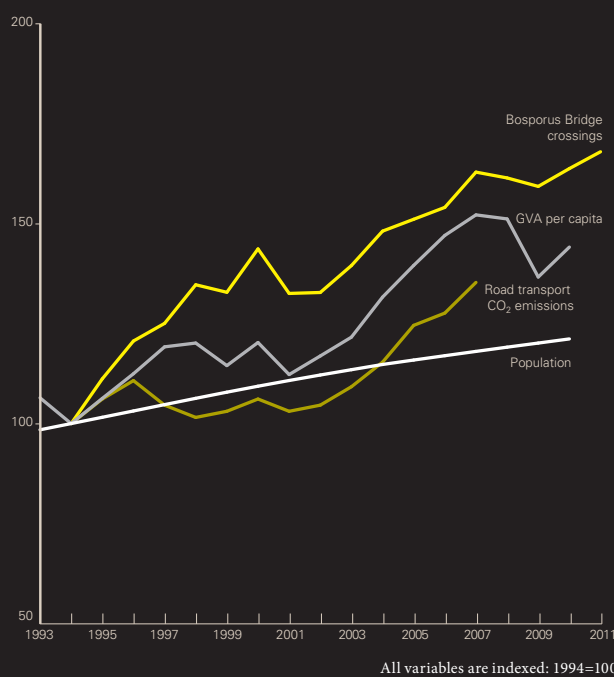
ISTANBUL
Istanbul's continuous growth over the past two decades has been accompanied by rapid motorisation. The population reached 13.6 million in 2011, while GVA per capita increased by 44 per cent between 1994 and 2010. The city's expanding suburbs and higher car ownership rates have led to a 68 per cent increase in Bosporus Bridge crossings and a 37 per cent rise in carbon emissions from road transport, despite considerable investments in public transport. These developments raise questions about the environmental impact of a planned third Bosporus Bridge and a new motorway North of the city.

All variables are indexed: 2001=100
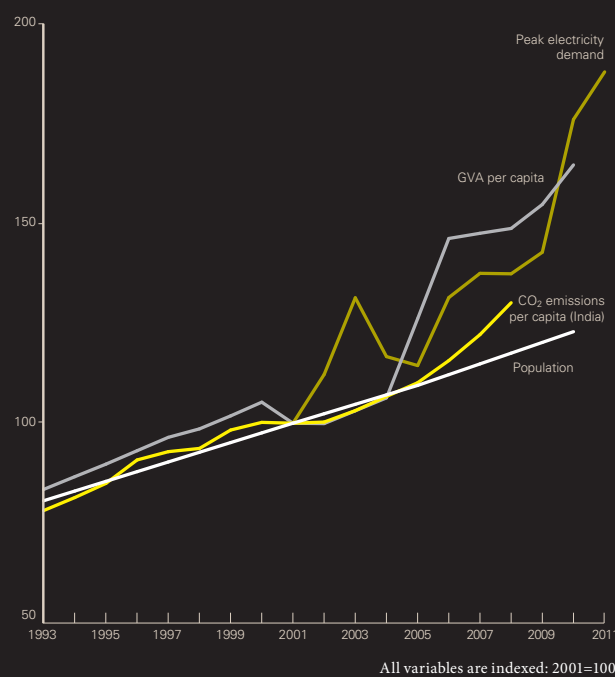
MUMBAI
Mumbai's metropolitan economy has grown at a strong pace, with GVA per capita increasing by 65 per cent over the last 10 years, and the population by 23 per cent to reach 20 million. Growth has been accompanied by drastically changing consumption habits: peak electricity demand in the city increased by more than 90 per cent since 2001 straining the system beyond its limits. Carbon emissions for India as a whole have increased by 30 per cent since 2001, but remain at very low levels on a per person basis. Shifting Indian cities' reliance on coal-fired electricity and investing in renewables will become increasingly vital as electricity demand continues to rise.

All variables are indexed: 1993=100
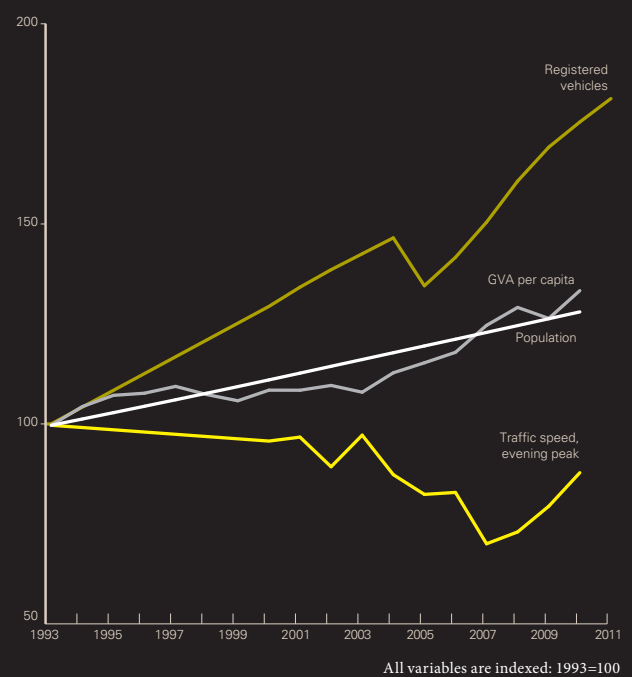
SÃO PAULO
São Paulo's GVA per capita has grown by 33 per cent and the population by 28 per cent between 1993 and 2010. In this city of nearly 20 million people, the number of registered vehicles increased by 82 per cent between 1993 and 2010, and the city currently has a motorisation rate of 368 cars/1,000 people. Unsurprisingly, traffic congestion is a perpetual problem: average evening rush hour traffic speeds decreased by 30 per cent between 1993 and 2007, although recent efforts to restrict private vehicle use and improve Metro and Bus Rapid Transit (BRT) infrastructure have shown promising success.

as well as increased car ownership rates and traffic congestion, together with increase in population and wealth highlight the worrying trends that underlie growth in Mumbai, São Paulo and Istanbul. Yet the data also indicate some positive trends in cities that have decided to buck the 'business-as-usual' trajectory, investing in new policies and initiatives that have changed things for the better, and often at a remarkable pace. The success of Bogotá's TransMilenio bus system and corresponding improvements to road safety are evidence that innovative thinking and the targeted application of new technologies can drastically change the urban experience of millions of people. Such changes in public transport provision are not confined to developing world cities. Increasing numbers of cyclists on the streets of London and New York, and a rise in public transport use in

Singapore and Hong Kong demonstrate a growing awareness of the need to move away from private vehicle use, with people embracing more efficient and environmentally sustainable ways of getting around the city.

The selected statistics illustrate that all cities, irrespective of their level of development, are experiencing profound and far-reaching changes across a variety of sectors. How a city changes and at what pace this change takes place is often dependent on targeted policies put in place by city, regional or national governments, highlighting the importance of a comprehensive and integrated approach to urban planning.

HONG KONG

All variables are indexed: 1998=100
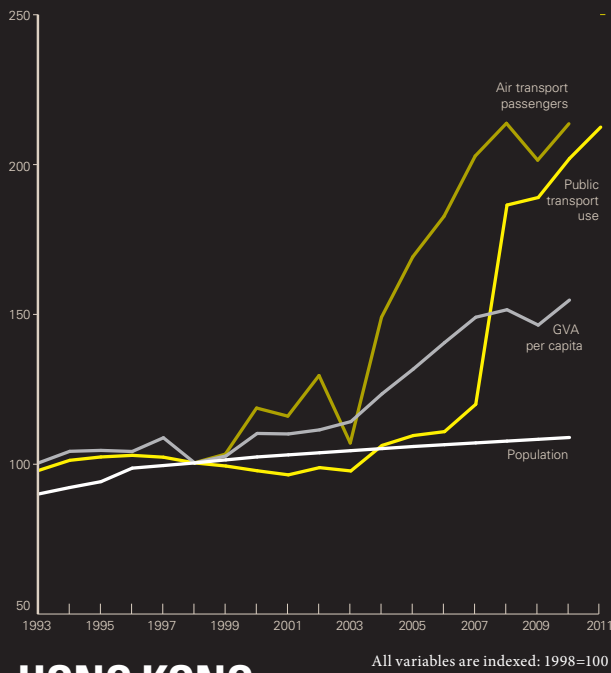
Hong Kong has cemented its position as a global hub for trade and finance since the 1997 handover from the UK to Chinese control. Since 1998, the city's per capita GVA experienced rapid growth, increasing by 51%. The city's strong international connections are reflected by continued air passenger growth, with numbers more than doubling since 1998. Hong Kong is one of the most densely populated cities in the world and a sophisticated public transport system efficiently provides mobility for the city's 7 million residents. Expansion of the Mass Rapid Transit system has contributed to a doubling in passenger numbers since 1998 and only 6 %of trips are made by car.

STOCKHOLM

All variables are indexed: 1993=100
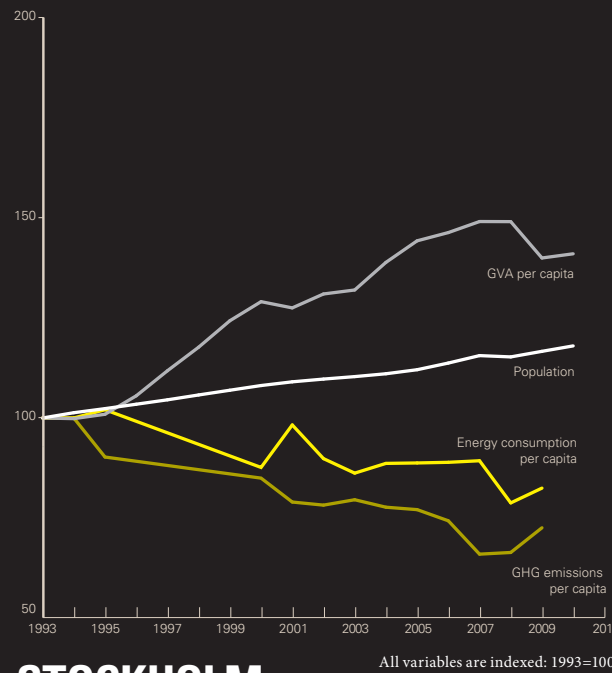
Stockholm's metropolitan economy grew by 41% between 1993 and 2010, while the population increased by 18 % to nearly 1.9 million. Stockholm's is successfully 'de-coupling' growth from negative environmental impacts, and GHG emissions in the city have declined by 31 %since 1993 to 3.7 tCO$_2$e per capita, while energy consumption per person has fallen by 18 %. Much of this success can be attributed to energy efficiency improvements in buildings prompted by strict green building policies at the national level. Today, 80% of the energy used for Stockholm's district heating comes from renewable fuels, energy from waste, or residual heat from combined heat and power plants.

COPENHAGEN

All variables are indexed: 1993=100
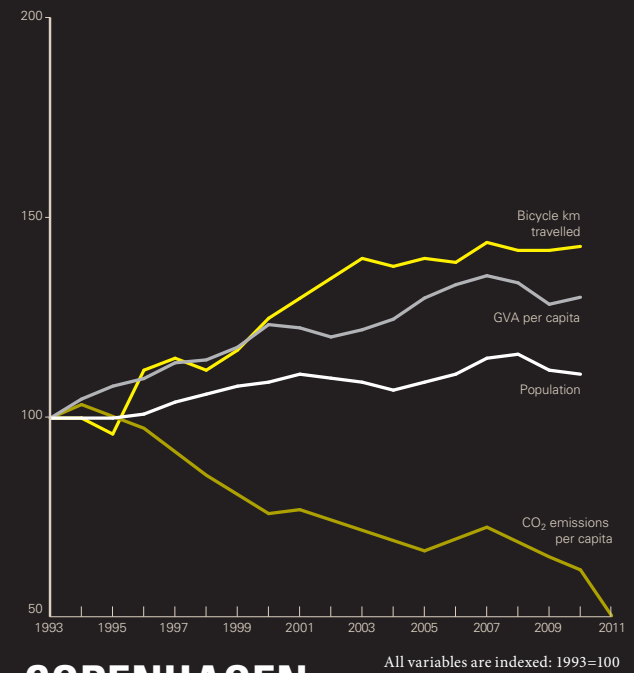
Copenhagen's GVA per capita grew by 30 per cent between 1993 and 2010, while the metropolitan population grew by 11 per cent to 1.8 million. The city has been successful in its pursuit of 'green growth': in the Municipality of Copenhagen carbon emissions halved since 1993 to 3.5 tCO$_2$ per capita, moving the city closer to its goal of becoming carbon neutral by 2025. Replacing coal with biomass for heating and power generation, and increasing the use of wind energy have contributed substantially to emission reductions. The city's progress has been further accelerated by the increased use of non-motorised transport, with bicycle kilometres travelled growing by 43 per cent since 1993.

SINGAPORE

All variables are indexed: 1993=100
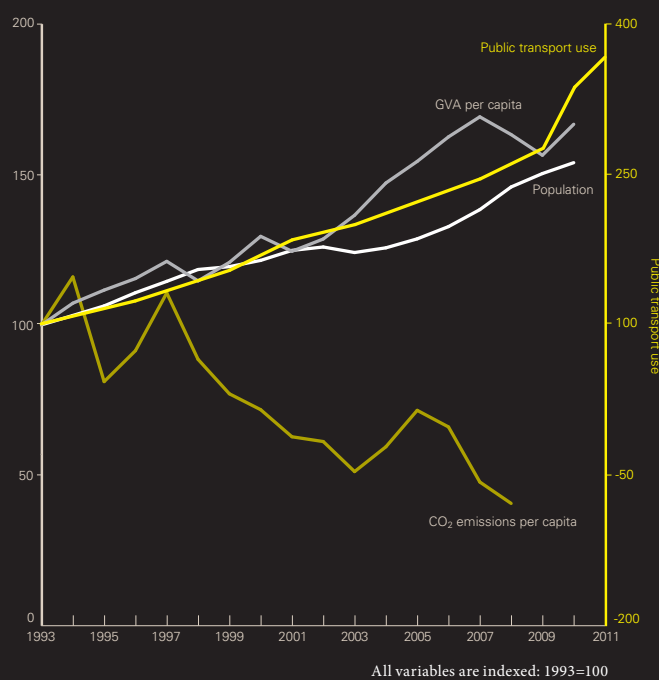
Singapore's GVA per capita grew by 67 per cent and the population by 54 per cent between 1993 and 2010. Public transport use has seen a substantial increase at a rate of 270 per cent in passenger trips on the rapid transit network since the early 1990s, helping to lower carbon emissions. The city-state has managed to dramatically cut emissions by 60 per cent: from 16.4 tCO$_2$ in 1993 to 6.7 tCO$_2$ per capita in 2008, by switching from coal to gas and improving energy efficiency of its urban distribution systems. However, Singapore remains almost exclusively reliant on imported fossil fuels for its energy needs.

PORTLAND

All variables are indexed: 1993=100
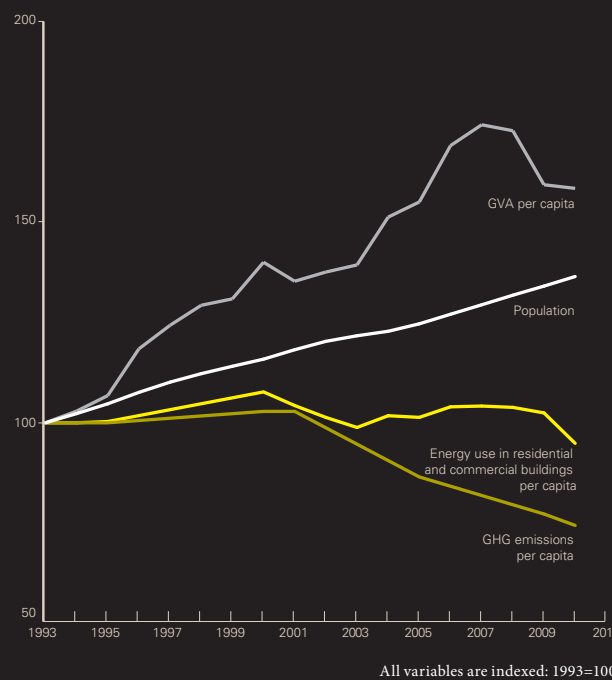
Portland's metropolitan region has experienced rapid economic growth, amounting to a 59 per cent increase in GVA per capita between 1993 and 2010. The region's population has also grown strongly – by 37 per cent over the same time period to reach almost 2.3 million in 2010. A comprehensive green policy programme has led to notable achievements, with greenhouse gas emissions decreasing by 26 per cent to 10.4 tCO$_2$e per capita in Multnomah County. Building energy use has fallen by 5 per cent per capita since 1993. Despite this, Portland's energy and resource use is still very high by global standards. .

BOGOTÁ

All variables are indexed: 2001=100
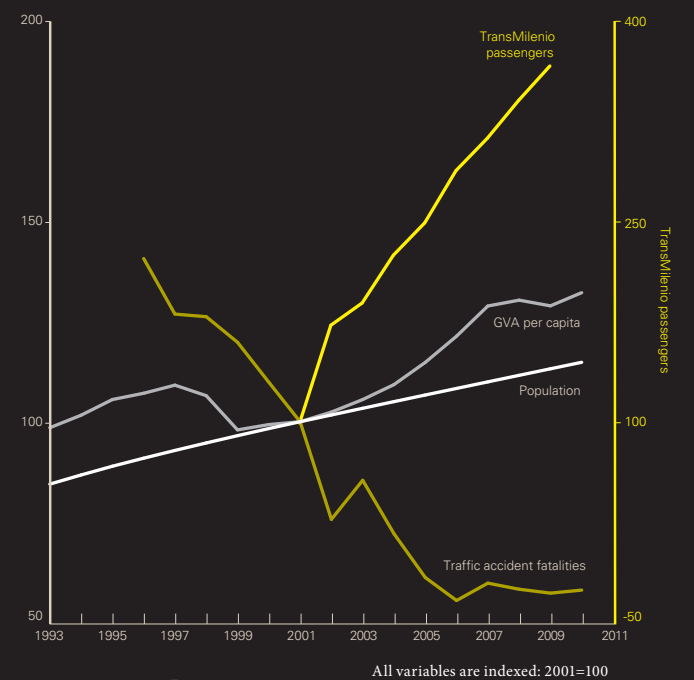
Bogotá's economy grew by 32 per cent between 2001 and 2010, following a severe recession in the late 1990s, while the metropolitan population increased by 14 per cent to nearly 8 million. Together with Curitiba, the city is regarded as pioneering the establishment of Bus Rapid Transit (BRT) systems, a cost-effective form of public transport. Bogotá's TransMilenio system has been gradually expanded since opening in 2001 and now carries 0.5 billion passengers a year. The 40 per cent decrease in road fatalities since the introduction of the TransMilenio can partly be attributed to improved road safety as a result of fixed bus lanes and enclosed stations.

COMPARING CITIES

Behind the statistics of global city growth lie very different patterns of urbanisation, with diverse spatial, social and economic characteristics that dramatically affect the urban experience. In addition to standard measures of population growth and the economy, LSE Cities has assembled socio-economic and environmental data from a range of official sources, allowing for a preliminary assessment of how these twelve cities compare to each other on a set of key performance indicators.

The graphic overview of these results highlights some striking differences, especially when it comes to these cities' speed of growth. While São Paulo has grown nearly 8,000 % since 1900, and London only 16 % (having experienced its major growth spurt in the previous century), it is Mumbai that is changing the fastest of the twelve, adding 54 additional residents every hour. In comparison, Copenhagen and Berlin will only gain 1 person per hour, Hong Kong 8 and London 10. These trends are also reflected in different patterns of age distribution: around a third of the residents of Mumbai, São Paulo, Bogotá and Istanbul are under the age of 20, while in Hong Kong and Berlin the younger generations shrink to 20 % or less. Mumbai also leads on economic growth, having experienced an average annual increase in GVA of 6.7 % between 1993 and 2010. Over the same period, the economies of São Paulo and Bogotá grew at about half that speed – nevertheless impressive when compared to Berlin's nearly stagnant economy. Another factor that differs drastically between cities is the proportion of the country's population residing in the metropolitan region and the corresponding contribution to national economic growth. Mumbai, with the largest metropolitan population of all twelve cities, only makes up 1.3 % of India's total population, and produces a mere 3.8 % of the national GVA. In contrast, 30 % of Denmark's total population reside in Copenhagen, and the capital region accounts for a staggering 38 % of national GVA. However, national level economic patterns tell us very little about the differences in wealth between cities. Looking at total GVA per capita, Stockholm and New York top the list (US$52,267 and US$51,337 respectively), closely followed by Copenhagen (US$48,294) and London (US$47,313). People living in these four cities are many times wealthier, on average, than in other world cities such as Istanbul and Bogotá (less than US$10,000), which in turn are significantly wealthier than the average resident of Mumbai (US$1,550). Despite its low per capita GVA, Mumbai's level of income inequality indicated by the Gini coefficient – a measure of income distribution with a higher number representing greater inequality – is nearly half that of São Paulo, which is the most unequal of the twelve cities, while Copenhagen and Berlin are the most equitable.

London, Hong Kong and Berlin contribute similar levels of CO_2 emissions per person, but the number doubles in Portland, where annual per capita carbon emissions exceed 10 tonnes, mainly owing to emissions related to high car use. Istanbul, with close to 38 % of its workforce in the manufacturing sector, produces just 2.7 tonnes of CO_2 per person, while Mumbai's residents contribute only 0.4 tonnes – less than 10 % of that of residents in most other global cities. Car ownership varies drastically between all
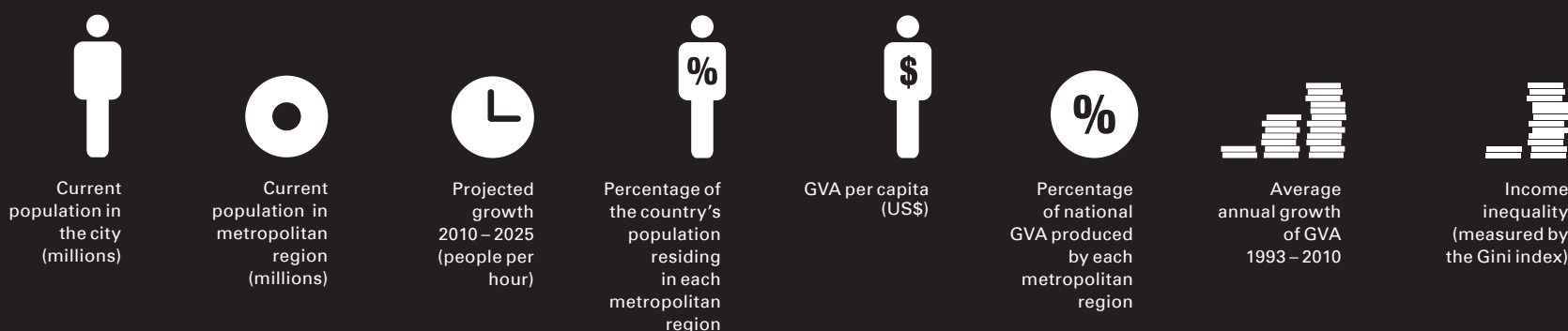
	Current population in the city (millions)	Current population in metropolitan region (millions)	Projected growth 2010 – 2025 (people per hour)	Percentage of the country's population residing in each metropolitan region	GVA per capita (US$)	Percentage of national GVA produced by each metropolitan region	Average annual growth of GVA 1993 – 2010	Income inequality (measured by the Gini index)
LONDON	**8.2** 2011	**14.6** 2011	**10** 2011	**23.9** 2010	**47,313** 2010	**32.8** 2010	**2.9** 2010	**31.7** 1995
NEW YORK	8.2 2010	19.0 2011	26 2011	6.3 2010	51,337 2010	8.5 2010	2.8 2010	53.5 2011
BERLIN	**3.5** 2011	**5.0** 2010	**1** 2011	**4.3** 2010	**26,909** 2010	**3.5** 2010	**-0.1** 2010	**29** 2010
ISTANBUL	13.6 2011	13.6 2011	30 2011	18.2 2010	9,368 2010	27.2 2010	3.1 2010	43 2003
MUMBAI	**12.5** 2011	**21.0** 2011	**54** 2011	**1.8** 2010	**1,550** 2010	**3.8** 2010	**6.7** 2010	**35** 2004
SÃO PAULO	11.3 2010	19.9 2010	27 2011	10.5 2010	18,116 2010	33.6 2010	3.2 2010	61 2005
STOCKHOLM	**0.8** 2010	**1.9** 2010	**3** 2011	**21.2** 2010	**52,267** 2010	**28.9** 2010	**3.5** 2010	**34** 2009
COPENHAGEN	0.5 2012	1.8 2012	1 2012	30.0 2010	48,294 2010	38 2010	2.0 2010	24.8 2012-DENMARK
HONG KONG	**7.0** 2010	**7.0** 2010	**8** 2011	–	**31,340** 2010	–	**3.6** 2010	**53** 2007
SINGAPORE	5.3 2012	5.3 2012	5 2011	–	38,307 2010	–	5.7 2010	47.3 2011
PORTLAND	**0.6** 2010	**2.3** 2010	**4** 2011	**0.7** 2010	**42,454** 2010	**0.9** 2010	**4.7** 2010	**49.4** 2011
BOGOTÁ	6.8 2005	7.9 2005	22 2011	15.9 2010	5,430 2010	26.2 2010	3.6 2010	58 2001

twelve cities, highlighting their diverse economic and spatial characteristics and varying transport infrastructure. Paralleling the trend in CO_2 emissions, Portland has the highest car ownership rate: 690 cars per 1,000 inhabitants, five times higher than the rate for New York. São Paulo has more than ten times as many cars per 1,000 people as Mumbai, the second highest figure, although improvements in public transport over the past few years are slowing the trend towards private motorised transport. Mumbai is catching up fast, with an increase of 35 % in vehicles on the city's roads in the past 5 years alone. Yet the majority of Mumbaikars still get around the city on foot or by bicycle, making it the city with the highest non-motorised modal share of the twelve. In contrast, only 11 % of all trips in New York are made by walking and cycling, with most people relying on the city's nearly 600 km long rail network. Looking at rail network systems for other cities provides an indication of their public transport infrastructure. London and Berlin have by far the most extensive network (1,393 km and 984 km respectively), with the average rail network length for all cities just below 500 km. This is in stark contrast to Bogotá, famous for its TransMilenio bus system, but lacking a rail network, although the Bogotá metro is currently under construction with a planned opening date of 2016.

Looking at water and electricity use highlights the divergent consumption patterns of residents in these twelve cities. Mumbai has the smallest consumption footprint, using just 90 litres of water per person per day, compared to 572 in New York, 229 in Stockholm and 185 in Istanbul. Although electricity consumption is rapidly increasing, the average resident of Mumbai or Bogotá still uses less than 1 MWh of electricity per year, compared to 12.1 in Portland and 7.8 in Singapore. Stockholm, Copenhagen and Berlin have managed to lower their electricity use over the past twenty years and all consume less than 2 MWh per capita, largely owing to the widespread use of district heating in these cities. How the electricity is generated also differs widely between cities. While decentralised power generation is becoming increasingly common, the vast majority of energy is still distributed to individual cities via a national grid, which is why energy use and renewable energy performance are shown at the country level. Unsurprisingly, the United States is by far the biggest energy user, with the average person consuming more than ten times as much as someone in India or Colombia. Due to their cold climate, Denmark and Sweden also have higher than average per capita energy consumption levels. Renewable energy sources make up nearly 90 % of the total national electricity generation in Brazil and more than 70 % in Colombia, owing to the predominance of hydro-power in these countries. In contrast, Hong Kong and Singapore still rely almost exclusively on fossil fuels for their electricity generation. With the exception of Sweden (57.7 %) all other countries currently generate less than a quarter of their electricity from renewable sources (see the World Maps at the beginning of this section for a more detailed discussion of global energy patterns).

Measurement years and methodologies used to calculate indicator values may differ between cities and data are not always comparable. For full references to data sources, please see: http://ec2012.lsecities.net/references/

| Percentage of the population under 20	Life expectancy (years)	Percentage of daily trips made by walking and cycling	Rail network system length (km)	Car ownership rate (per 1,000 inhabitants)	Daily water consumption (litres per capita)	Annual CO₂ emissions (tonnes per capita)	Annual electricity use (MWh per capita)	Annual energy use (MWh per capita, national)	Renewable energy as percentage of total electricity
23.8 (2009)	79.2 (2004)	32 (2011)	1,393 (GIS-BASED)	331 (2009)	167 (2005)	5.6 (2010)	5.2 (2011)	24.3 (2009)	7.3 (2009)
25.7 (2008)	77.6 (2001)	11.2 (2008)	579 (GIS-BASED)	209 (2008)	572 (2005)	6.5 (2010, CO₂E)	6.0 (2011)	51.3 (2009)	10.6 (2009)
16.6 (2007)	78.5 (2010)	42 (2010)	984 (2012)	324 (2011)	112 (2010)	5.2 (2009)	1.7 (2011)	28.9 (2009)	16.2 (2009)
31.3 (2011)	72.4 (2000)	45 (2008)	163 (GIS-BASED)	140 (2011)	195 (2010)	2.7 (2005)	2.3 (2010)	11.3 (2009)	19.6 (2009)
36.3 (2001)	68.1 (2001)	56.3 (2007)	477 (GIS-BASED)	36 (2006)	90 (2008)	0.4 (2008 MAHARASHTRA STATE)	0.8 (2008 MAHARASHTRA STATE)	4 (2009)	14.1 (2009)
31 (2010)	70.8 (2000)	33.8 (2007)	275 (GIS-BASED)	368 (2007)	185 (2003)	1.1 (2003)	2.0 (2006)	11.6 (2009)	89 (2009)
21.3 (2010)	80.3 (2005)	38 (2006)	405 (2010)	359 (2006)	229 (2011)	3.7 (2010, CO₂E)	1.5 (2009 - SWEDEN)	41.1 (2009)	57.7 (2009)
21.8 (2012)	76.6 (2011)	43 (2010)	600 (2008)	184 (2009)	110 (2010)	3.4 (2012)	1.3 (2010)	30.8 (2009)	24.8 (2009)
20.1 (2010)	82.5 (2010)	44.7 (2002)	247 (GIS-BASED)	56 (2009)	220 (2009)	5.5 (2011)	5.9 (2011)	13.3 (2009)	0 (2009)
23.1 (2012)	81.1 (2011)	23 (2011)	176 (2011)	121 (2009)	157 (2009)	6.7 (2008)	7.8 (2011)	29.1 (2009)	0 (2009)
21.5 (2011)	77.9 (2005)	14 (2012)	115 (2012)	690 (2011)	440 (2010)	10.4 (2010, CO₂E)	12.1 (2008)	51.3 (2009)	10.6 (2009)
35.1 (2005)	72 (2000)	17 (2008)	0 (2012)	148 (2006)	114 (2009)	2.2 (2011, CO₂E)	0.1 (2011)	5.4 (2009)	72.8 (2009)

RESIDENTIAL DENSITY

This section looks in more detail at the density and transport systems of six of the twelve case study cities. These six cities are innovators in land-use and transport policies across highly varied social and geographical contexts, and insights can be gleaned through their comparison.

Density is a fundamental measure of urban structure, and here we map the number of residents in each square kilometre of a 100 by 100 kilometres region – the taller the bar on the diagram, the higher the density of people living in a particular area of the city. Lower urban densities apply to suburban-like neighbourhoods, often characterised by houses and garden, or mid- to high-rise buildings surrounded by large areas of open space. Higher urban densities – where tall, medium- or even low-rise buildings are clustered together in a tighter urban grid – can facilitate more sustainable public transport, walking and cycling, improve service delivery efficiency, and promote urban vitality. These advantages depend, however, on high-quality urban design and effective city management to minimise the negative impacts of overcrowding, stress and pollution.

Urban density is driven by topographical constraints, the provision of infrastructure, and by inherited traditions of urban development. The city that stands out in the mapping is Hong Kong, with its extremely high residential densities exceeding 110,000 people per km². Here planners have responded to scarce land availability with very tall (over 30 storeys), high-density development. Topography and history have also influenced the development of New York City, where Manhattan densities peak at 59,000 people per km². London is, in contrast, more spread out, with a heritage of much lower-density urban living, with peak levels less than a quarter of Hong Kong's. Roughly 8 million Londoners occupy twice the footprint of the same number of New Yorkers.

Bogotá's development has been contained by its mountainous hinterland, and parts of the city reach peak densities at similar levels to New York, although with lower and different building forms. Copenhagen and Stockholm are smaller cities with lower densities and significant areas of open space. The Scandinavian capitals are, however, leaders in integrated regional planning, as shown by the distinct corridors of development radiating along rail lines from their urban centres.
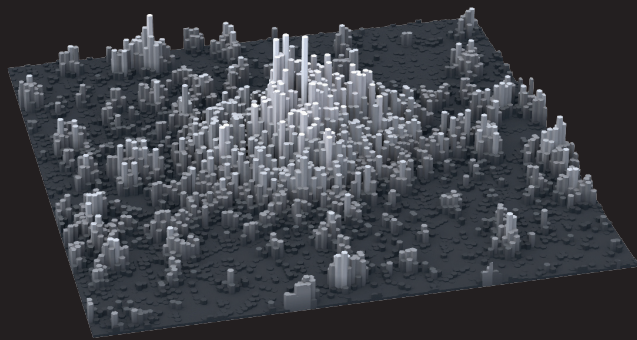
LONDON PEAK 27,100 pp/km²

London has lower residential densities than other world cities, although current policy focusing on the intensification of available urban land is affecting this pattern. While the most significant changes are occurring in East London (where the 2012 Olympics were held), densities remain highest in the West, in areas like Notting Hill and Earl's Court, but peaking at 27,100 people per km² in Pimlico.
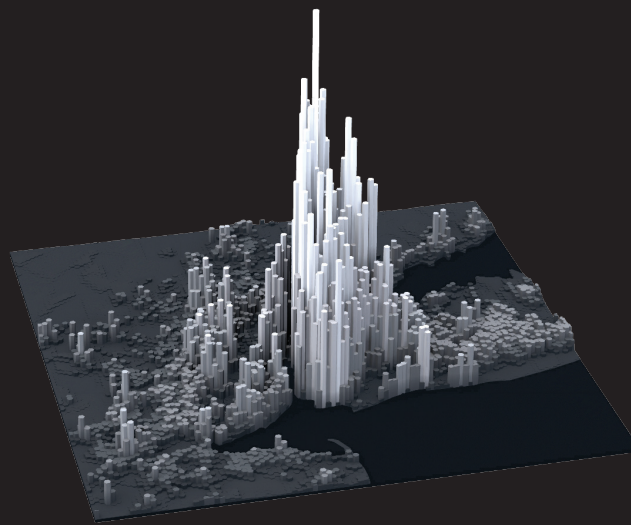
NEW YORK PEAK 59,150 pp/km²

New York's highest residential densities are in Manhattan, peaking at 59,150 people per km² in the Upper East Side. High-density living is prevalent across New York City, with hotspots in the Bronx, Brooklyn and Queens. Outside of the urban core, lower-density suburban patterns dominate in the outer boroughs, New Jersey and Long Island.
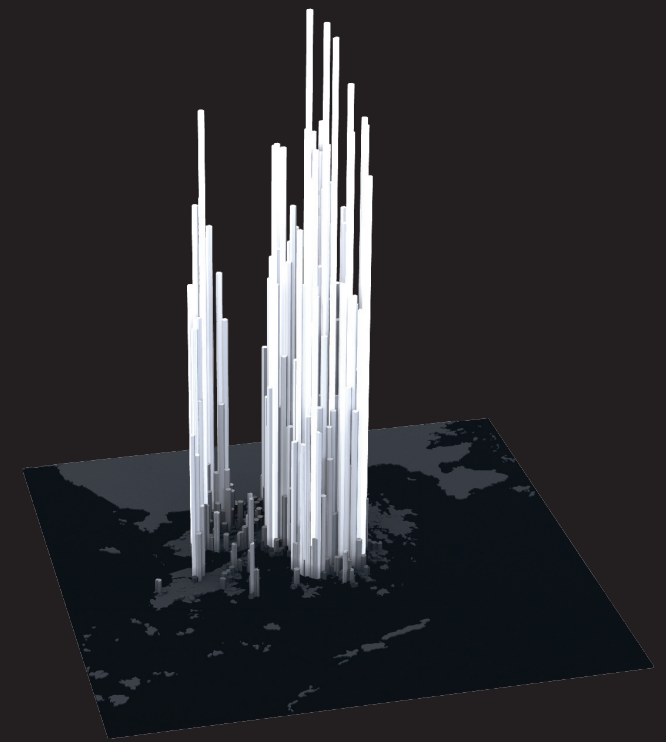
HONG KONG PEAK 111,100 pp/km²

Hong Kong's hyper-dense tall building typology, which reaches peaks of over 100,000 people per km² (double New York City's), is not restricted to Hong Kong Island, but can also be found in West Kowloon, Kwun Tong and the New Territories. Planning authorities have pursued a 'Rail plus Property' development model, with extremely high-density development clustered around public transport nodes.
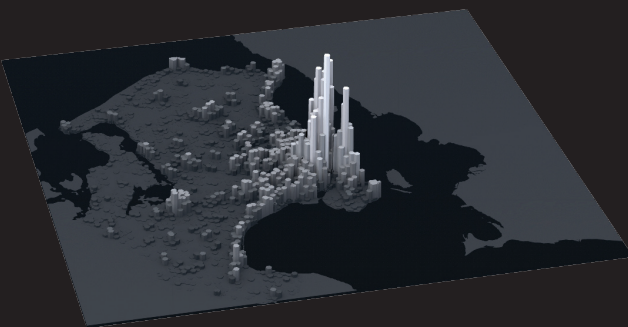
COPENHAGEN PEAK 24,050 pp/km²

For the last fifty years Copenhagen's regional planning has been based around the 'Finger Plan' of development corridors along rail lines that radiate out from the dense city centre, which are clearly visible in the above map. Peak residential densities reach 24,050 people per km², closer to London levels, which are typical of the European compact city model.
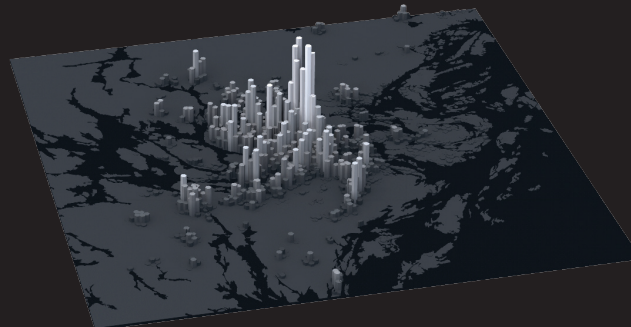
STOCKHOLM PEAK 24,900 pp/km²

Stockholm's form has many similarities to Copenhagen's, with tightly controlled regional development along public transport corridors and generous open areas. Stockholm's peak density is just short of 25,000 people per km². Recent population growth has been accommodated in the inner city with the regeneration of dock areas, such as Hammarby Sjöstad.
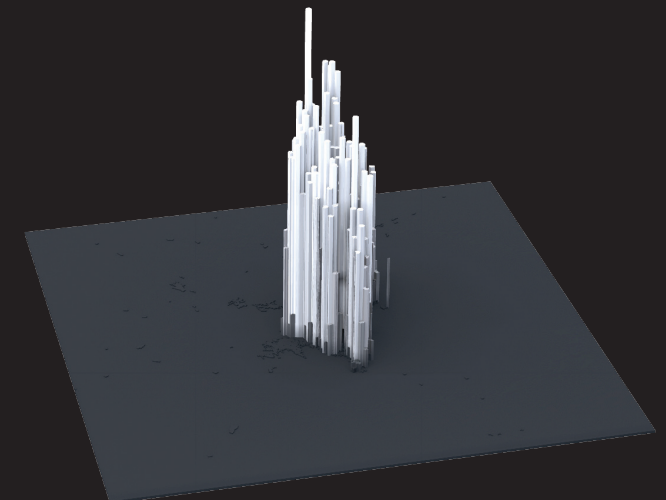
BOGOTÁ PEAK 55,800 pp/km²

Some of the highest residential densities in Bogotá occur at the city outskirts, to the South, West and North-West of the city centre, with the peak density occurring at Patio Bonito to the West. At the fringe of the city the geography quickly alters into a steep mountainous landscape, constraining horizontal expansion. Data beyond the city boundary are not illustrated.
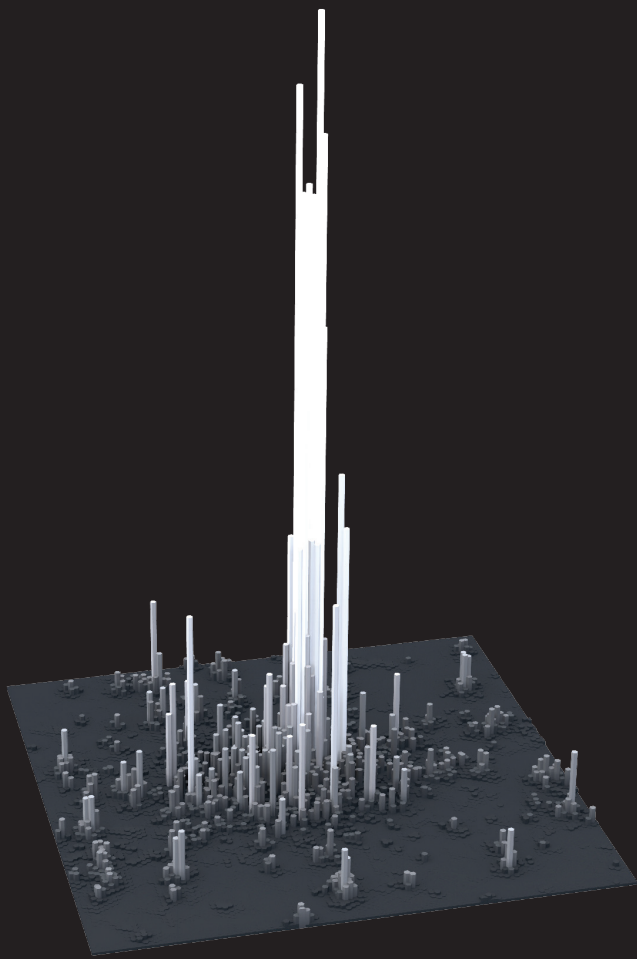
EMPLOYMENT DENSITY

The mapping of employment densities provides a very different perspective on urban form and dynamics, providing a novel point of comparison with the residential densities illustrated on the facing page. These diagrams capture a dimension of urban economic life by describing how many people work in different parts of the city on typical working days. As with residential densities, the taller spikes in the diagrams represent higher numbers of people concentrated in particular locations (CBDs, shopping high streets, business districts, etc.), while flatter zones suggest more residential neighbourhoods.

The diagrams reveal that despite the digital revolution, proximity and face-to-face contact remains essential for urban businesses to access labour markets, connect to fast-changing information and engage in direct interaction with clients, customers and partners. Knowledge economy sectors such as financial and business services and creative industries still seek out commercial space in inner city cores, taking advantage of good public transport provision (where they exist) and co-location of shops, food, bars, entertainment and other facilities.

London, New York and Hong Kong graphically illustrate that office workers are drawn to well-connected central locations, with peaks of over 150,000 jobs per km² in tightly clustered areas in Midtown Manhattan in New York City. London follows closely behind at over 140,000 jobs per km², concentrated in the City of London and the West End. But while in both these cases office workers do not coincide with residential densities – fuelling the need for intense commuting patterns – Hong Kong has a close integration between residential and employment peak densities. This pattern is associated with a strong mix of uses and shorter travel distances. Bogotá, Copenhagen and Stockholm also share integrated forms, in contrast to London where residential and employment densities are highly divergent.

LONDON PEAK 141,600 pp/km²
Peak employment densities in London occur at the core of the financial district in the City of London around Bank, reaching 141,600 jobs per km² and in the West End around Oxford Circus. There are also important employment sub-centres in Canary Wharf, Croydon and Heathrow, all well served by public transport, but not at the same levels of central locations.
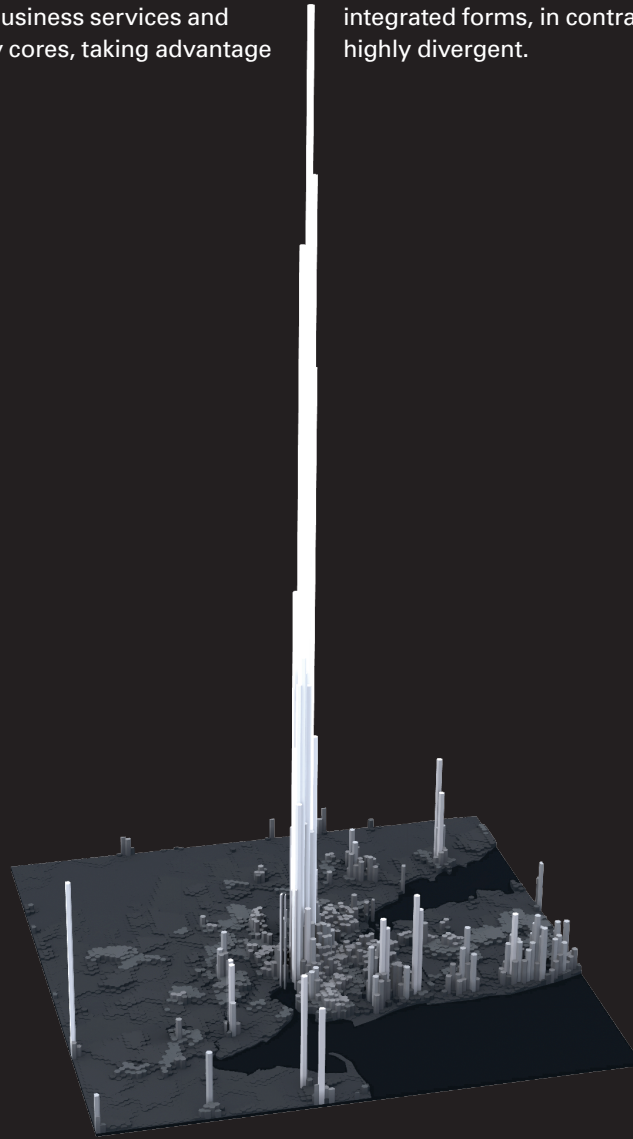
NEW YORK PEAK 151,600 pp/km²
New York's employment peak of over 150,000 jobs per km² is found in Midtown Manhattan above West 42nd Street, close to Times Square. Downtown, the Lower Manhattan business district around Wall Street is returning to pre-9/11 density levels. Outside Manhattan, employment activities are relatively low, with few high-density sub-centres.
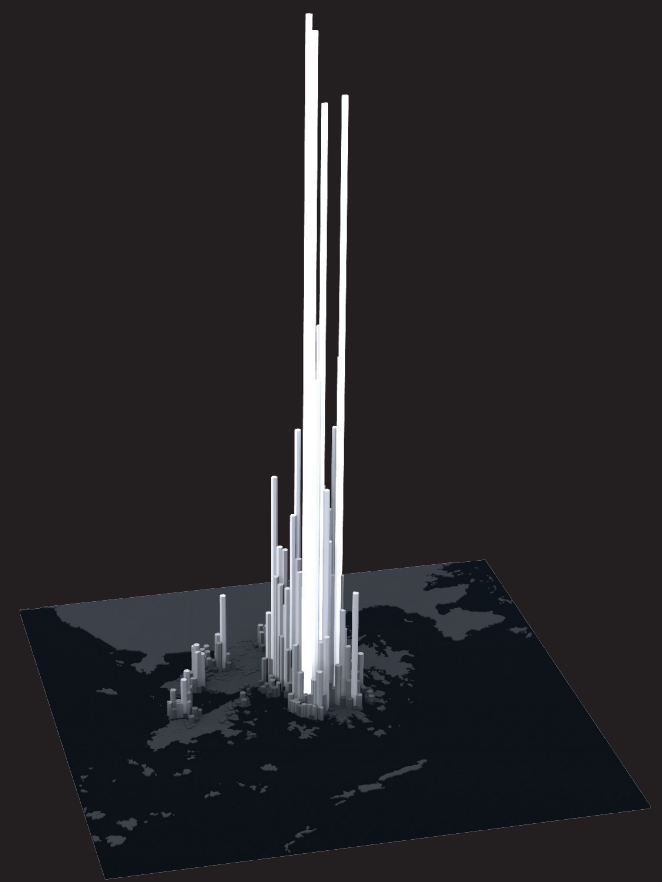
HONG KONG PEAK 120,200 pp/km²
Peak employment districts in Hong Kong occur at Central and Wan Chai on Hong Kong Island, and Tsim Sha Tsui and Kwun Tong in Kowloon, making the most of a new generation of super skyscrapers occupied by companies and corporations. Hong Kong employment survey data do not include government jobs and the actual peak densities are likely to be higher than shown.
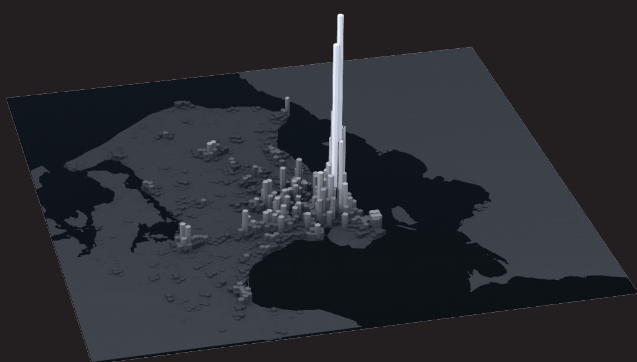
COPENHAGEN PEAK 40,100 pp/km²
Relatively high levels of employment clustering are also evident in Copenhagen where densities reach 40,100 jobs per km², with many office areas easily accessible by rail, underground or bicycle. As well as financial and business services, Copenhagen retains an industrial base, particularly in shipping, which is characterised by lower employment levels than the tertiary sector.
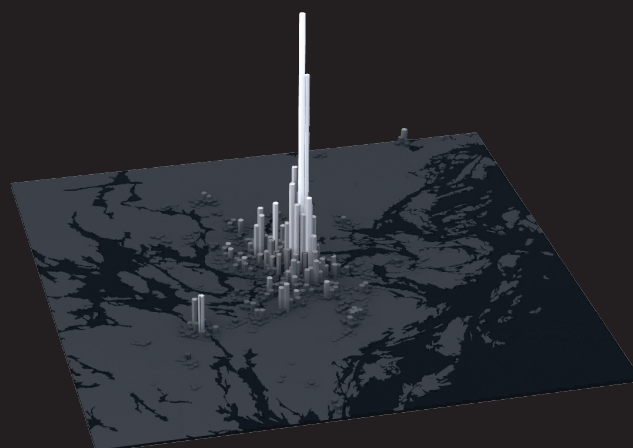
STOCKHOLM PEAK 51,950 pp/km²
Stockholm's peak employment density exceeds 50,000 jobs per km², with the city specialising in financial and business services and IT. With space restricted in the city centre, planners have promoted a degree of decentralisation to well-connected peripheral hubs in regional centres, such as Kista Science City to the North of Central Stockholm.
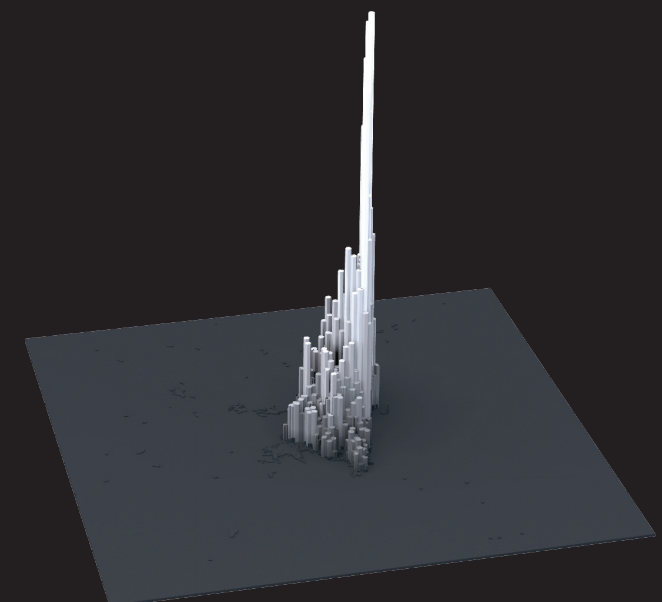
BOGOTÁ PEAK 61,550 pp/km²
Bogotá's employment activities are strongly clustered in the city centre, along the main North-South link of Avenue Caracas. While financial and business services and retail are located in central districts with densities exceeding 60,000 jobs per km², industrial and manufacturing activities remain significant on the city outskirts.

MAPPING ACCESSIBILITY

Connectivity is the lifeblood of cities and urban evolution is intrinsically linked to transport infrastructure. These maps display the multi-modal public transport networks in six case study cities, revealing stark differences in distribution of transport routes with commensurate effects on urban form and accessibility both within cities and to their regional hinterlands.

Given that these cities have been selected as exemplars of sustainability, they do not display the dominance of roads and motorways that characterise so many of the world's emerging megacities, as illustrated by São Paulo in earlier pages. Instead they demonstrate close connections between land use and public transport, summarised by the accessibility indicator graph to the right.

Hong Kong and Stockholm have uniquely high accessibility, with over 40 per cent of their respective populations living within 500 metres' distance from a rail or underground station. London, New York and Copenhagen also perform well, exceeding 20 per cent of their populations within 500 metres from a rail or underground station. Bogotá's results are lower, at around 12 per cent, yet it substantially outperforms car-dependent cities such as São Paulo and Los Angeles.

City populations in walking distance of rail and metro stations
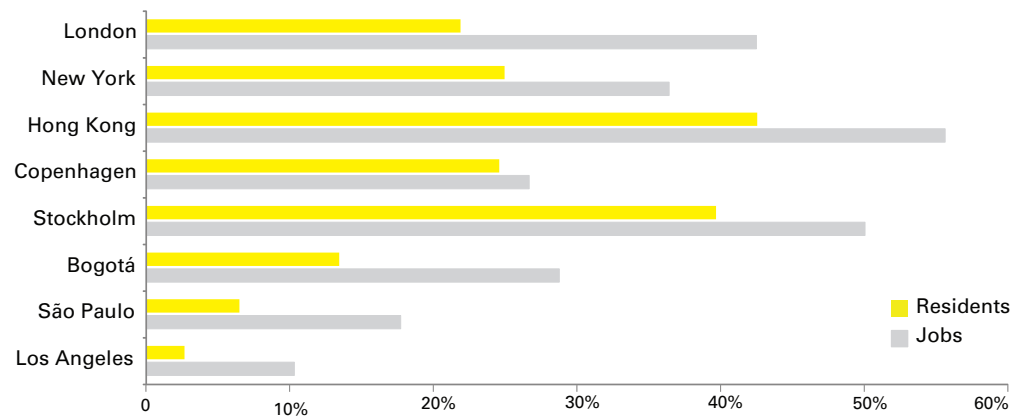
Residents
Jobs

This chart shows the proportion of metropolitan residents and jobs within 500 metres (5 to 10 minutes' walk) of rail, metro and bus rapid transit stations. Indicators produced by LSE Cities through GIS analyses of census and transport networks data.

LONDON
A nineteenth-century ban on railways entering central London led to a ring of rail terminals, prompting the development of the underground to link them and support London's outward expansion. London has an extensive, albeit ageing rail-based network. Effective lobbying from the Mayor has ensured investment into rail, underground and bus networks, with improved connections to Continental Europe via St. Pancras and Stratford.
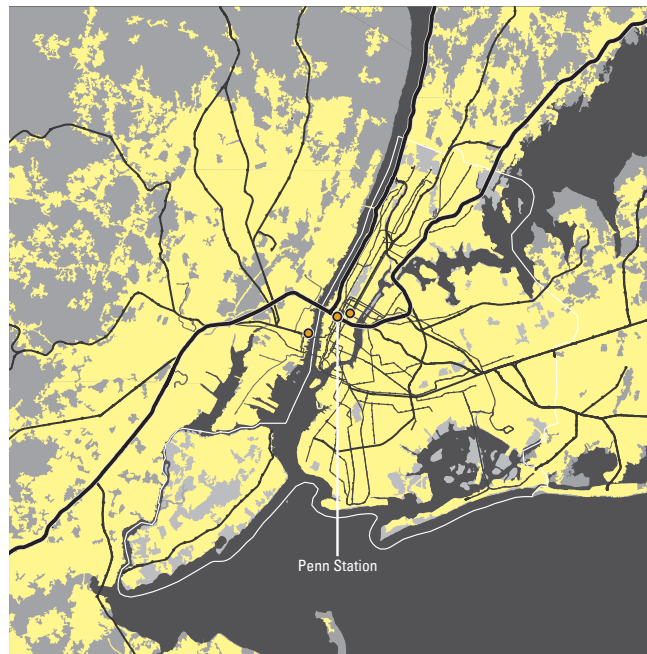
NEW YORK
New York City has long established and intricate public transport networks, connecting the city to its vast urban hinterland inhabited by 19 million people. Penn station is the busiest rail terminal in North America, serving 300,000 passengers a day. Current infrastructure developments include the new World Trade Centre Transportation Hub and further subway and rail upgrades for Manhattan.
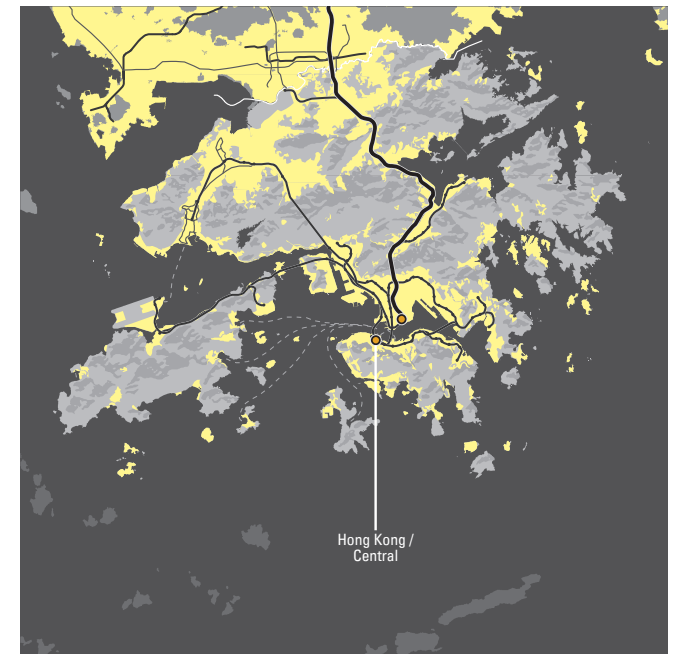

HONG KONG
Hong Kong's relatively young network has quickly developed into a highly efficient system that daily delivers millions of people to their destinations. The region achieves the closest integration between land use and transport of the six cities, as a result of the clustering of very high-density mixed-use development around stations. Future plans include new metro lines, and a high-speed link to Shenzhen and Guangzhou in mainland China.
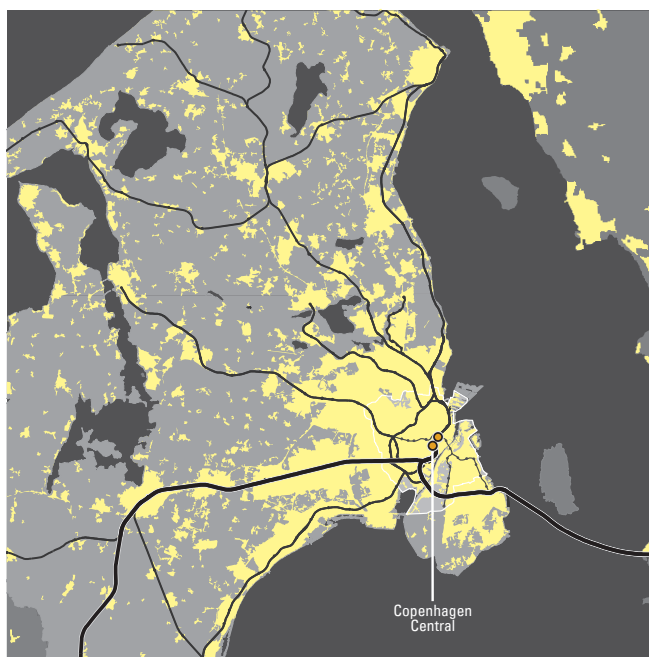

COPENHAGEN
Copenhagen has a well-established regional rail network, closely integrated with linear urban development patterns as well as its extensive cycle network. The city's central station provides high-speed services, including links to Sweden, with Copenhagen acting as a central node in the cross-border Øresund urban region. Copenhagen's recently developed metro system is currently limited to a single line, but new routes are planned.
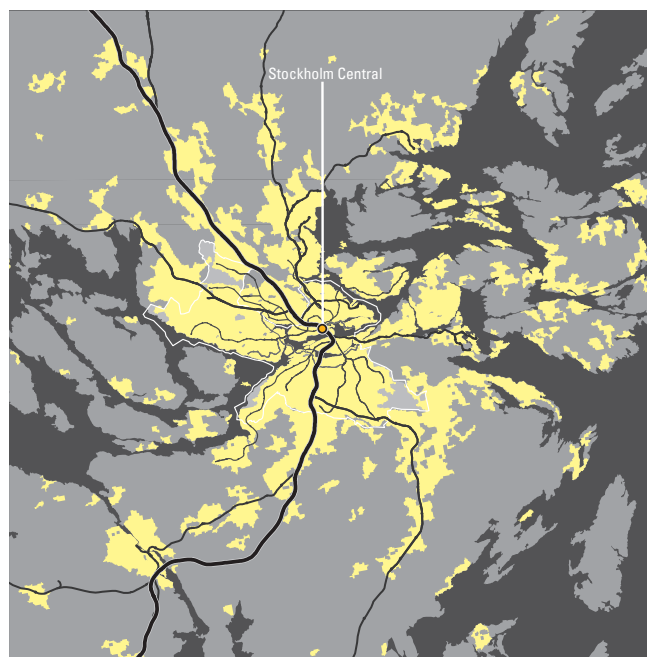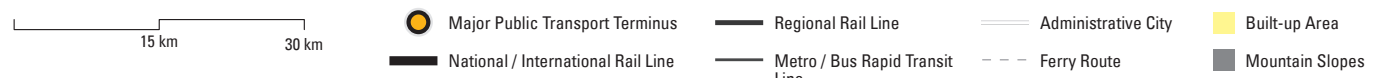

STOCKHOLM
Stockholm has excellent multi-modal public transport, with regional rail, subway, tram and international high-speed rail networks. The result of strong land-use planning and an extensive rail-based service is that 40 per cent of residents live within 500 metres from a metro station. Several subway and tram upgrades are in development, including better orbital access outside of the city centre.
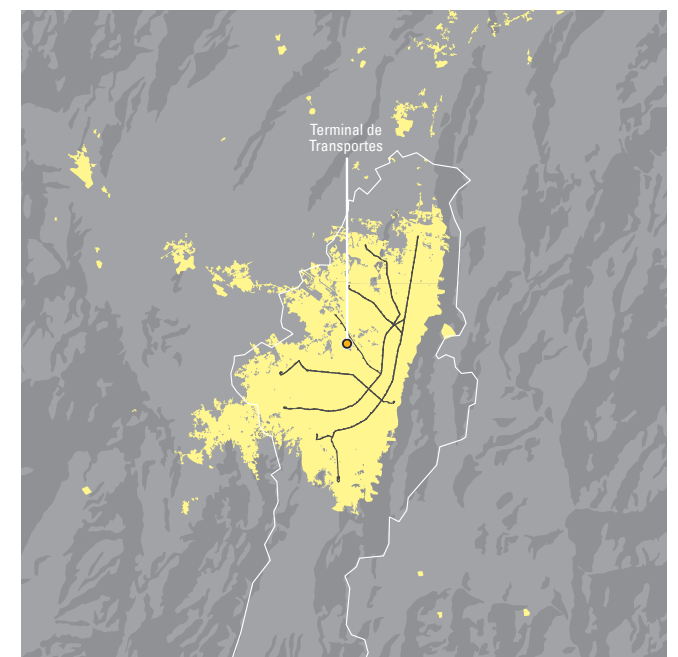
BOGOTÁ
Bogotá is a pioneering city in the development of a Bus Rapid Transit system, which has provided passengers with similar speed and capacity advantages to underground rail systems at a significantly lower cost. Ambitious plans to further expand the network have been slow to implement, though new lines are now under construction. A further challenge is to develop regional connections.

For full references to data sources, please see: http://ec2012.lsecities.net/references/

15 km   30 km

🟠 Major Public Transport Terminus   ▬ Regional Rail Line   Administrative City   ▨ Built-up Area
▬ National / International Rail Line   Metro / Bus Rapid Transit Line   – – – Ferry Route   ▨ Mountain Slopes

PATTERNS OF TRAVEL

This section explores the proportion of trips made by different transport modes in the six cities, enabling an understanding of how transport infrastructure and policies translate into real world behaviour for different user groups. The extensive transport networks found in all six cities ensure that public transport use is substantial though varied in the modes of public transport most frequently used. In addition, there are significant variations in walking and cycling patterns as well as car use, resulting from differing planning policies and inherited urban cultures.

After many decades of neglecting walking and cycling as serious transport modes, current planning policies view active travel as a key part of creating a vibrant city environment and promoting healthier lifestyles. Copenhagen and Stockholm have strong traditions of providing high quality infrastructure for walking and cycling, with Copenhagen in particular being a world leader in cycling infrastructure provision. London

and New York are attempting to repeat these achievements on a larger scale, though still have a long way to go to meet these standards. Hong Kong in fact has the highest proportion of pedestrian movements, with an impressive 45 per cent of trips. The city has developed a three-dimensional approach to urban mobility, with an extensive walking network on linked bridges above limited road space.

As cities improve from a low economic base, pressures for car use often increase. Bogotá is a low-income city, yet is developing quickly and car trips have increased by nearly 50 per cent in the last five years, despite investments in public transport. Cities seeking to limit car use can do so through a range of policies, including congestion charging and taxation (London and Stockholm), high fuel taxes (employed across Europe) and car ownership taxes (Hong Kong).
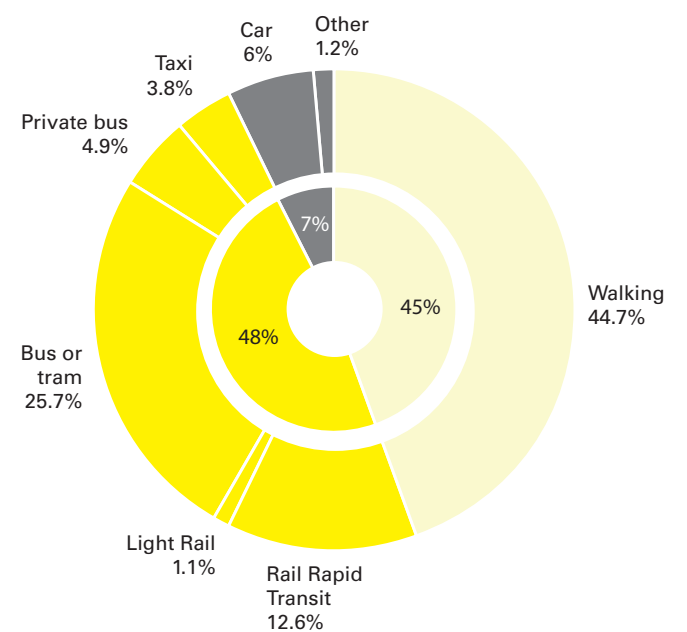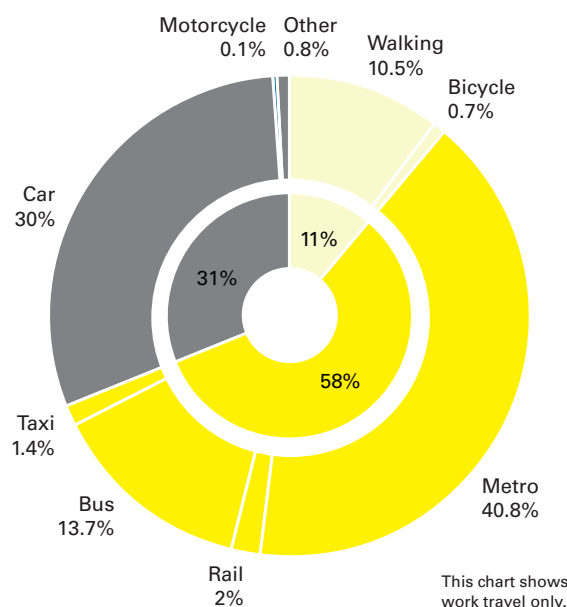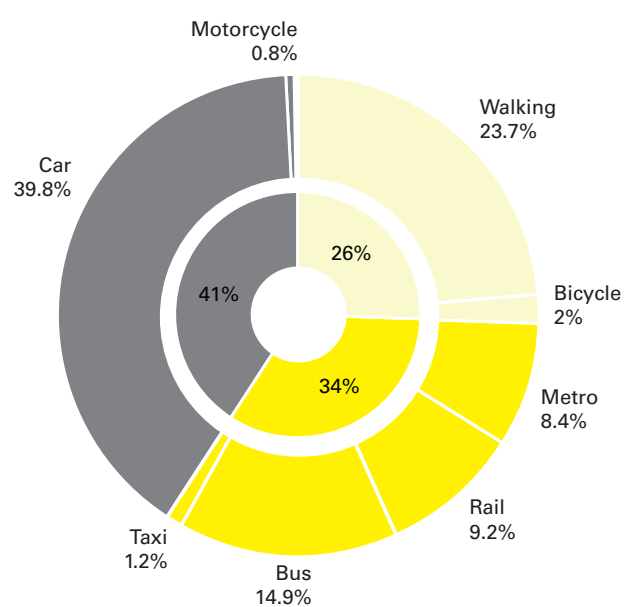
LONDON

In terms of total trips, buses provide the most important public transport mode in London, and the network has been substantially upgraded in the last ten years. While car use has fallen in the last decade, it remains substantial, especially in outer London. The success of congestion charging suggests it should be expanded further, though this issue has proved politically controversial. Bicycle travel is relatively low, but is increasing rapidly.

NEW YORK

The subway is the most important public transport mode in New York, carrying over 40 per cent of commuters. Detailed survey data on non-work travel for New York was not available, though we can assume that car and walking trips will be considerably more frequent for non-work travel. Like London, New York is investing in cycling infrastructure and this is having an impact, from a low historic base.

HONG KONG

Hong Kong has one of the lowest rates of car ownership in the world and consequently the proportion of car trips is incredibly small at 6 per cent. As in London, bus travel is an important means of linking public transport networks, and bus and tram trips account for 26 per cent of the total. The proportion of walking trips is very high at 45 per cent, making Hong Kong a leader in active travel.
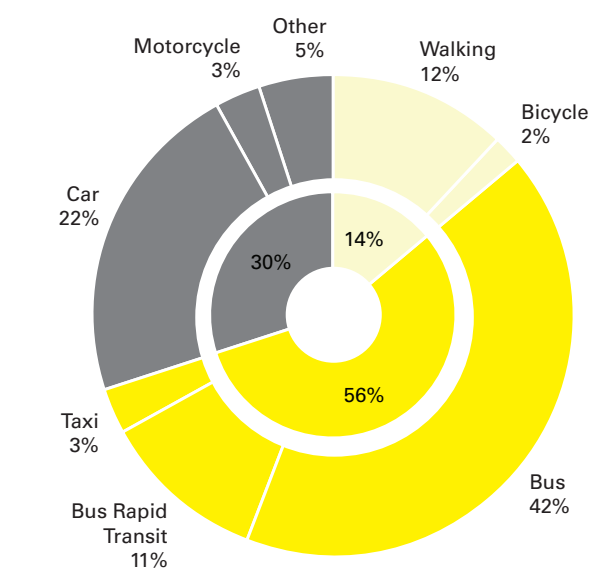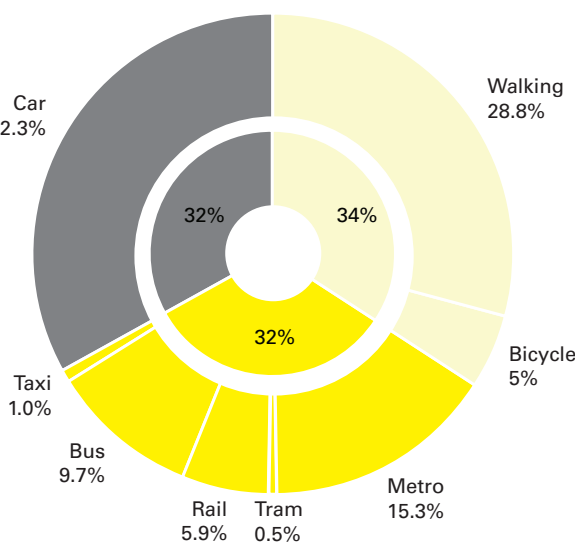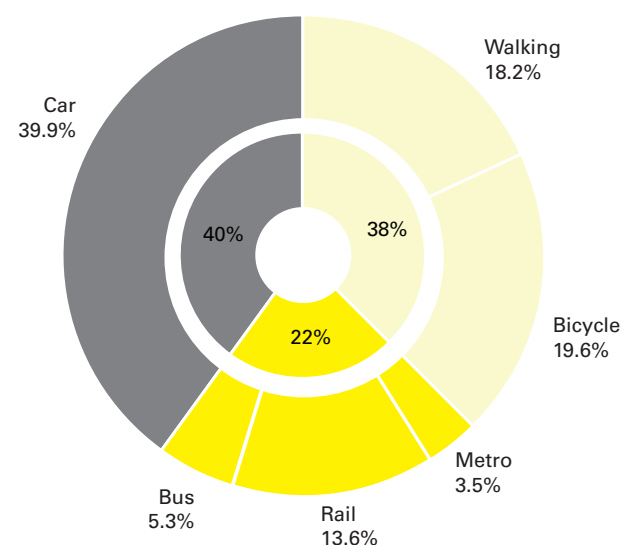
COPENHAGEN

Copenhagen is one of the world's leading cycling cities with 20 per cent of all trips by bike, including 36 per cent of work trips. The authorities are investing further in improving these figures. Public transport travel is proportionately lower than in the other example cities. The metro system is very new and will likely expand in the near future. Car use across the region is increasing and improved orbital public transport and demand management measures are being considered.

STOCKHOLM

Both walking and cycling trips are popular in Stockholm, with the city second out of our six case studies in both categories. The metro is the most frequently used public transport mode at 15 per cent of trips. Car use remains significant and Stockholm has severe congestion problems, even after the introduction of the city's congestion tax. Proposed remedies include improved public transport and a new bypass.

BOGOTÁ

Despite having a relatively modest infrastructure, Bogotá has the highest rate of public transport travel in all the example cities. The TransMilenio BRT network accounts for 11 per cent of trips, bolstered by 42 per cent of trips using the standard bus network. There have been significant reductions in road casualties through improved transport planning, although further progress is needed to improve Bogotá's pedestrian environment.

Legend: Walking and Cycling | Public Transport | Cars and Private Motorised Transport
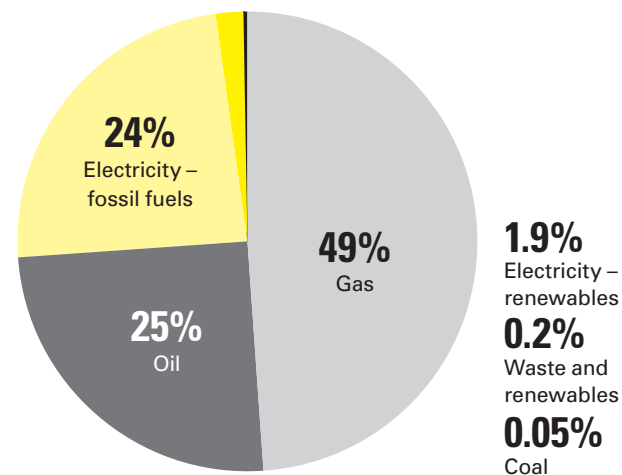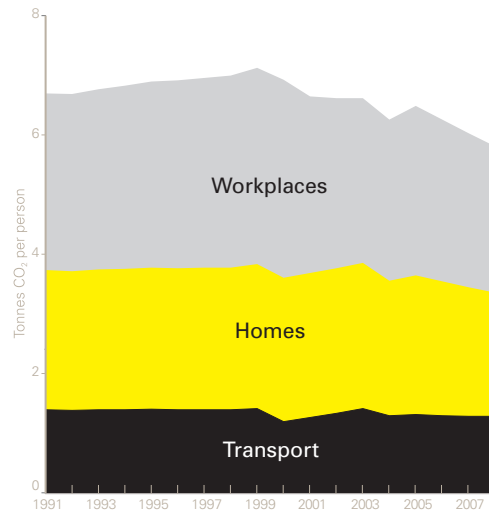
CHANGING LONDON

ENERGY

London has bold ambitions in the energy sector, with a goal of reducing emissions to 60% below 1990 levels by 2025. But London today relies heavily on fossil fuels and just 2% of total energy comes from renewable sources. London's residents produce significant carbon emissions – an annual average of 5.8 tonnes per capita. As in many cities across the developed world, carbon emissions have fallen in recent years thanks to de-industrialisation, efficiency improvements and shifts from coal to gas for heating and generating electricity.

Declining emissions in wealthy cities hide carbon associated with growing consumption of imported goods. Counting imported emissions in food and manufactured goods, conventionally neglected, doubles Londoners' overall carbon footprint to 12.1 tonnes per person. A closer look at energy use across London shows that average per capita measures hide important variations. Mapping household energy use across the city reveals higher-income; suburban areas have the highest consumption, while the lowest use is in denser inner London areas.
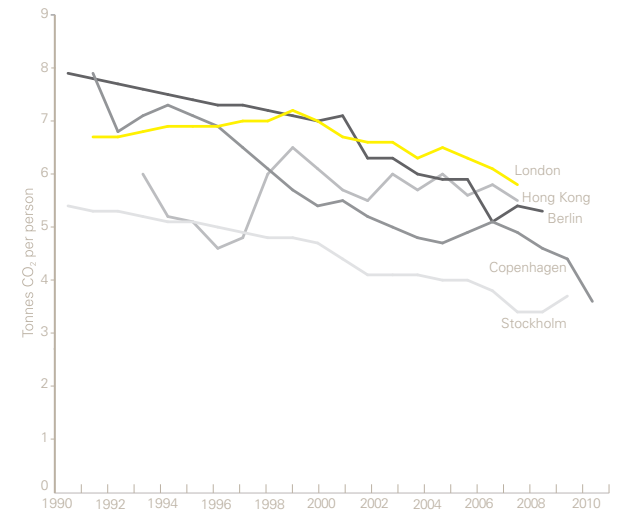
London's total energy use by fuel type
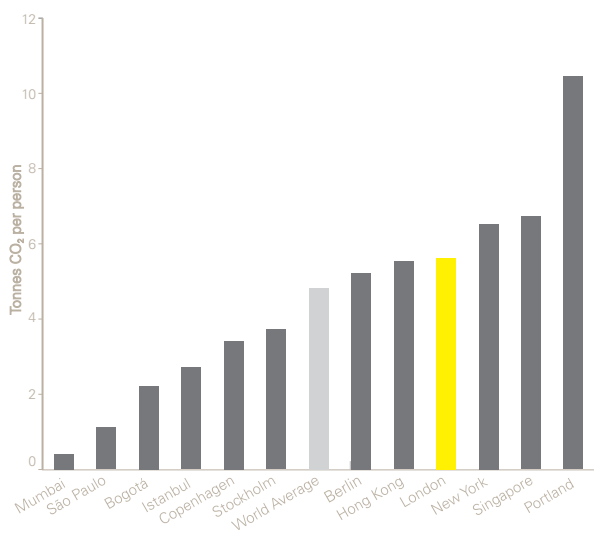Source: Greater London Authority

- 24% Electricity – fossil fuels
- 49% Gas
- 25% Oil
- 1.9% Electricity – renewables
- 0.2% Waste and renewables
- 0.05% Coal

London's carbon emissions by sector
Source: Greater London Authority

- Workplaces
- Homes
- Transport

Carbon emissions trends compared
Source: See http://ec2012.lsecities.net/references/

- London
- Hong Kong
- Berlin
- Copenhagen
- Stockholm

Cities' carbon emissions per person compared
Source: See http://ec2012.lsecities.net/references/

Mumbai, São Paulo, Bogotá, Istanbul, Copenhagen, Stockholm, World Average, Berlin, Hong Kong, London, New York, Singapore, Portland
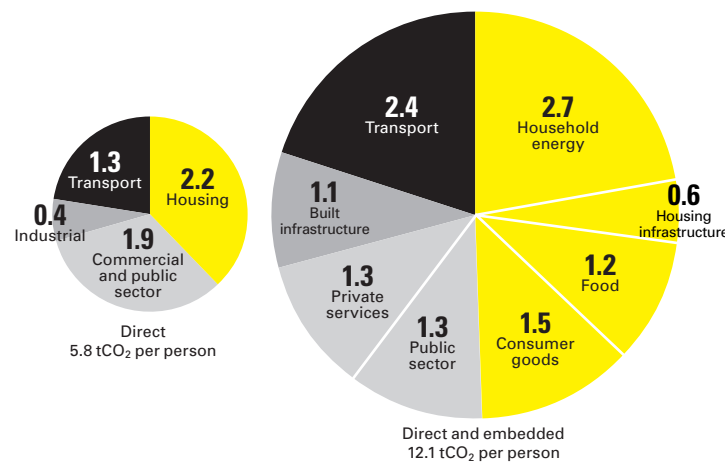
Direct and embedded emissions
Source: Greater London Authority

Direct 5.8 tCO_2 per person
- 1.3 Transport
- 2.2 Housing
- 0.4 Industrial
- 1.9 Commercial and public sector

Direct and embedded 12.1 tCO_2 per person
- 2.4 Transport
- 2.7 Household energy
- 1.1 Built infrastructure
- 0.6 Housing infrastructure
- 1.2 Food
- 1.3 Private services
- 1.3 Public sector
- 1.5 Consumer goods
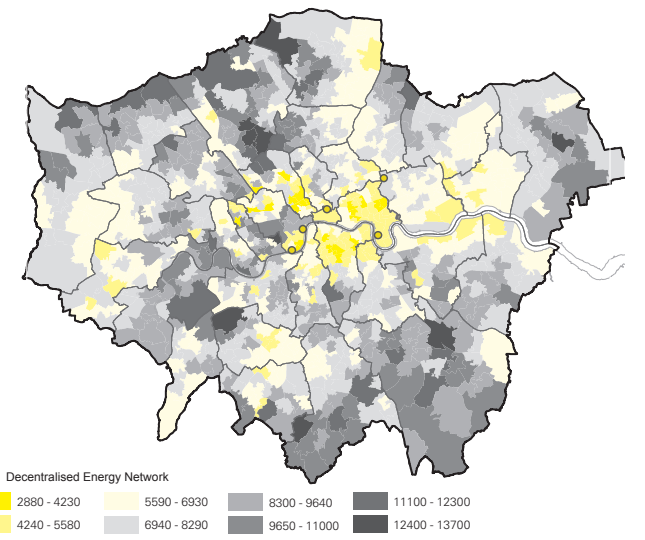
Domestic energy and gas use (2010 kWh per capita)
Source: Department of Energy and Climate Change Sub-National Energy Statistics 2010

- Decentralised Energy Network
- 2880 - 4230
- 4240 - 5580
- 5590 - 6930
- 6940 - 8290
- 8300 - 9640
- 9650 - 11000
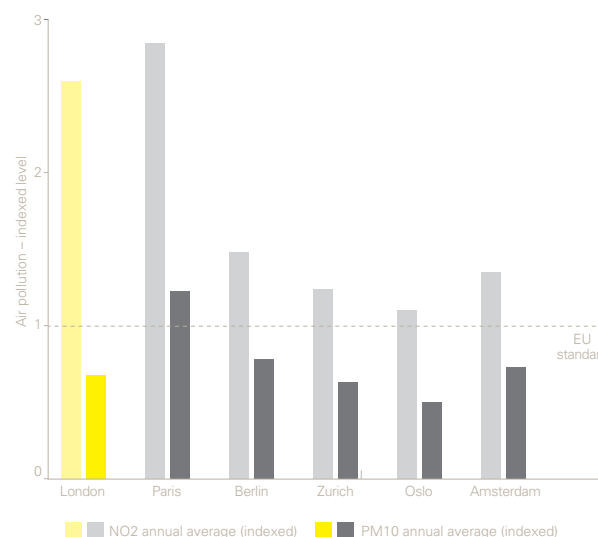- 11100 - 12300
- 12400 - 13700

ENVIRONMENT

Environmental policy programmes have led to some success. A comprehensive policy approach over the past decade saw average levels of household waste declining by 28% on a per capita basis, while recycling and composting rates increased over threefold. Today 34% of household waste is recycled or composted, although leaders in the field Austria and Germany have rates of over 60%. Air pollution remains a problem for Londoners, with only a modest improvement over a decade. It threatens health and quality of life, with the European Environment Agency suggesting

pollution may be responsible for 3,000 premature deaths each year in London. Mapping the location of air pollution shows that transport emissions are the major source, with concentrations evident around arterial roads and on Heathrow airport's runways. Average NO_2 levels exceed EU standards over most of inner London, and along all major roads. PM_{10} levels are a more localised problem, regularly exceeding standards along major roads, but background levels are generally within guidelines.
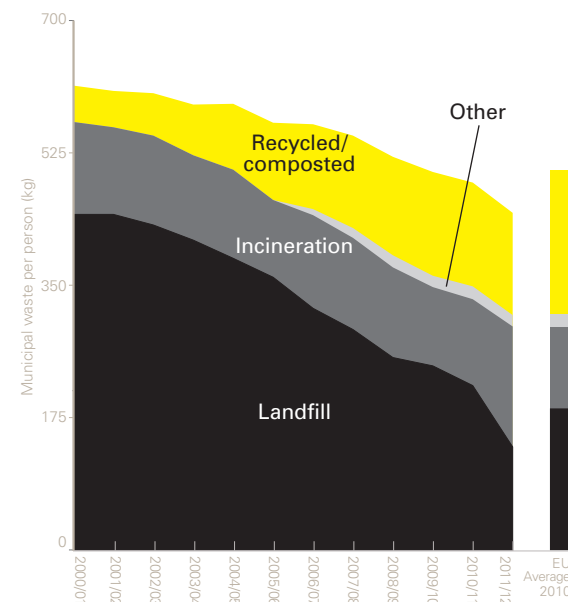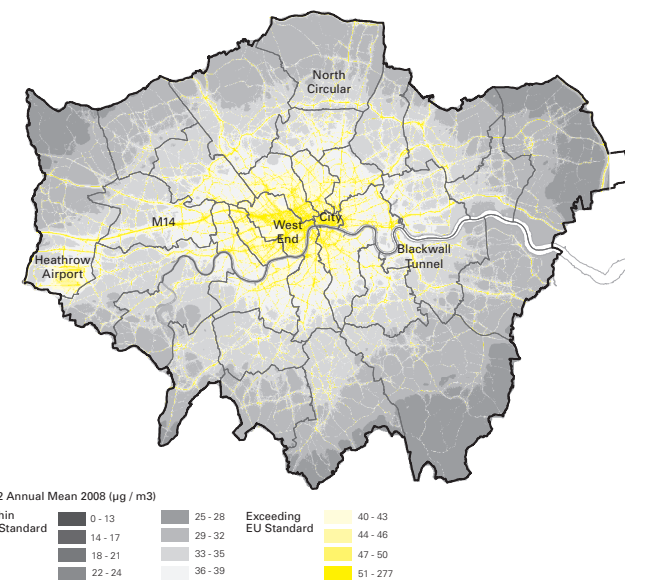
Trends in solid waste management
Source: DEFRA, EuroStat

- Recycled/composted
- Other
- Incineration
- Landfill

European cities' air pollution compared
Source: Citeair, www.airqualitynow.eu

EU standard

London, Paris, Berlin, Zurich, Oslo, Amsterdam

- NO2 annual average (indexed)
- PM10 annual average (indexed)

Air pollution: nitrogen dioxide
Source: London Atmospheric Emissions Inventory 2008

North Circular, M14, West End, City, Blackwall Tunnel, Heathrow Airport

NO2 Annual Mean 2008 (μg / m3)
Within EU Standard
- 0 - 13
- 14 - 17
- 18 - 21
- 22 - 24
- 25 - 28
- 29 - 32
- 33 - 35
- 36 - 39
Exceeding EU Standard
- 40 - 43
- 44 - 46
- 47 - 50
- 51 - 277

For full references to data sources, please see: http://ec2012.lsecities.net/references/

TRANSPORT AND PLANNING

London has seen a marked shift in the way people travel. Car kilometres travelled per person are now 25% lower than in 1999, while public transport passenger kilometres have grown by 40% over the same period on a per capita basis. London's shift towards more sustainable transport results from coordinated governance strategy and increased investment. Buses now offer 33% more service kilometres than in 2000, and tube and rail upgrades are making up for decades of under-investment.

Cycling has also experienced a renaissance with inner-city cyclist numbers tripling since the late 1990s. Cities in continental Europe still lead with much higher proportions of transport by bicycle – in London only 2% of all trips are by bicycle compared with 20% in Copenhagen. Reflecting the commitment to the compact city model, vast majority of new building development over the past decade has been located close to railway and underground stations, making the most of London's extensive public transport system and anticipating further improvements such as Crossrail.
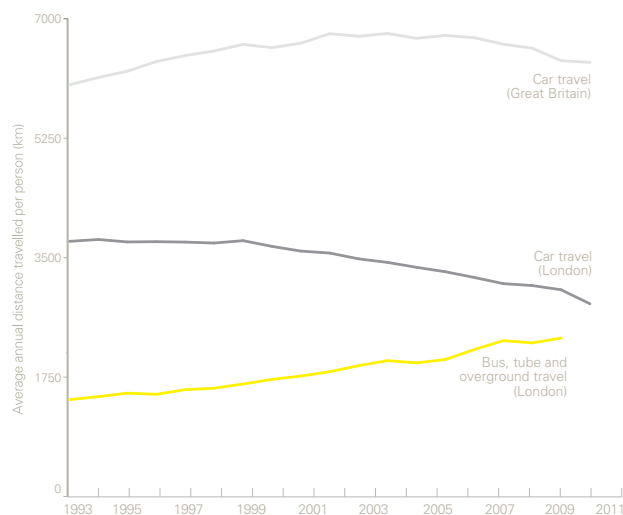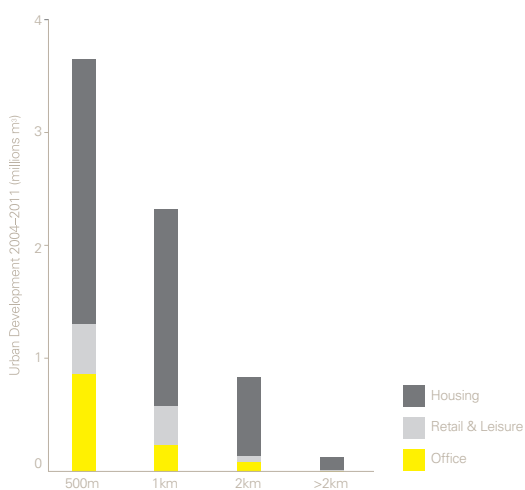

Car and public transport travel compared
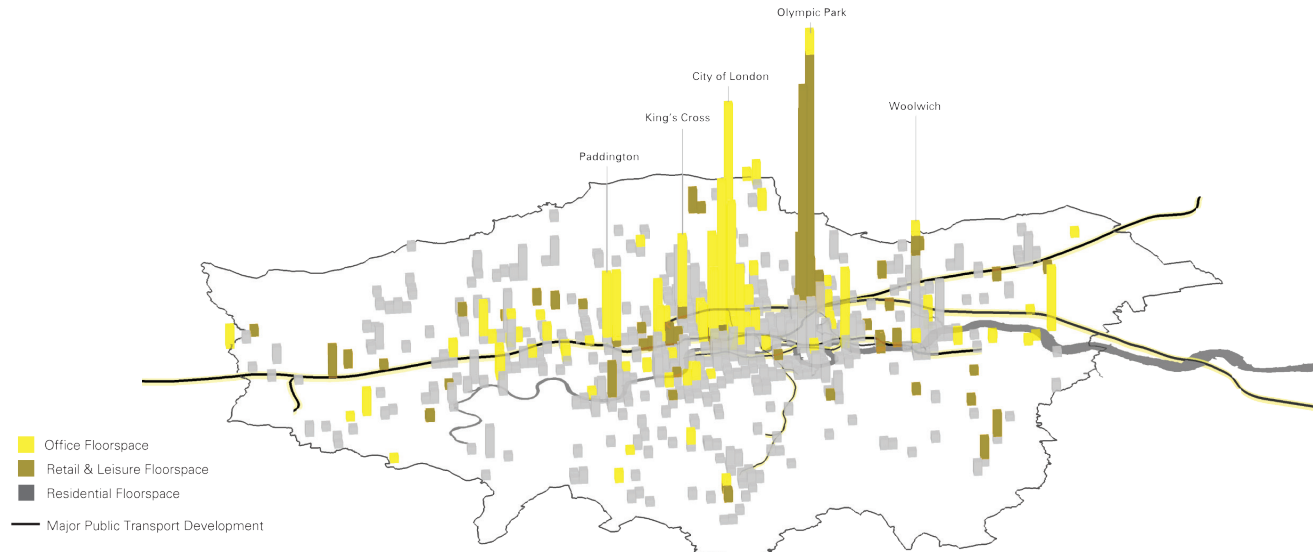Source: UK Department for Transport, Transport for London
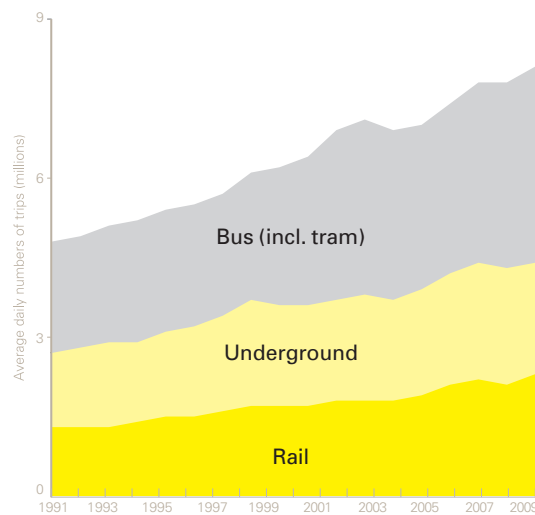
Public transport trip trends
Source: Transport for London
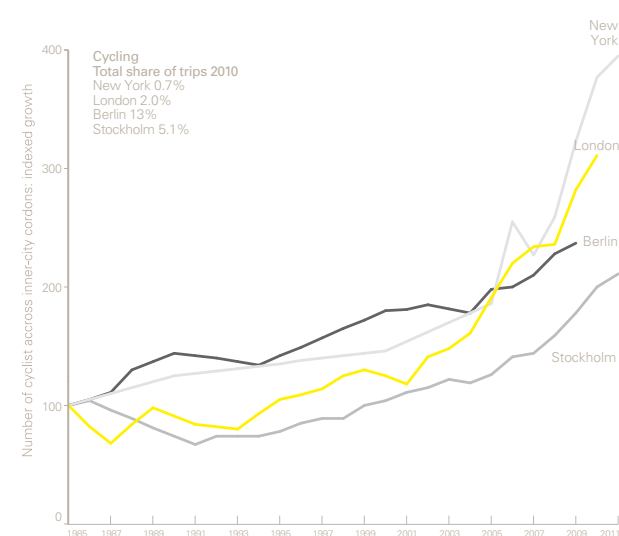
Cities' cycling trends compared
Source: See http://ec2012.lsecities.net/references/

Proximity of new development to public transport
Source: London Development Database (2012), Greater London Authority

London urban development 2004 – 2011
Source: London Development Database (2012), Greater London Authority

DIGITAL ECONOMY

London is home to the biggest concentration of digital firms in Europe. Over 23,000 firms, 390,000 employees, and an estimated GB£1.7 (US$2.73/€2.1) billion of exports can be attributed to software development and other tech industries. (See essay by Max Nathan, pp. 11-12)
Policy attention has recently focused on a cluster of digital firms centred on what is dubbed the Old Street 'Silicon Roundabout'. Both national and local level policymakers aim to build on the existing cluster to establish a technology centre to rival California's 'Silicon Valley' and New

York's 'Silicon Alley'. Despite these ambitions, growth in the digital economy's employment share appears to have stalled between 2005 and 2010. Recent studies of firms in the Inner East London cluster have identified various constraints to continued growth, including access to skilled staff and Internet connectivity issues. Indicators allowing for global comparisons of broadband quality are limited, however a 2010 study shows London's Internet infrastructure may slightly lag top European cities, and is of a lower standard than in some East Asian cities.
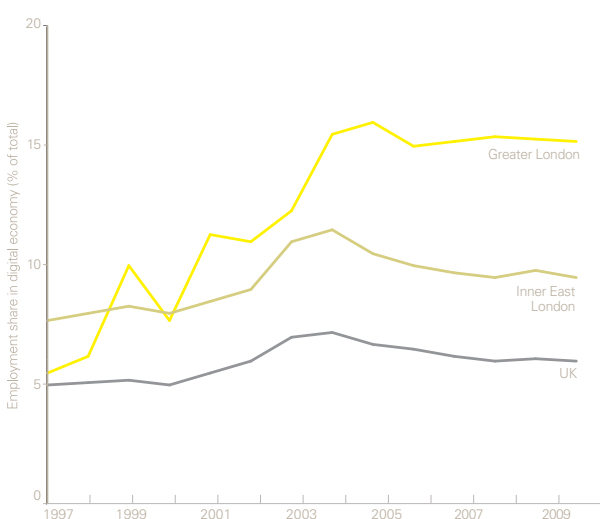
Digital economy employment share
Source: 'London's Digital Economy' (2012), Greater London Authority
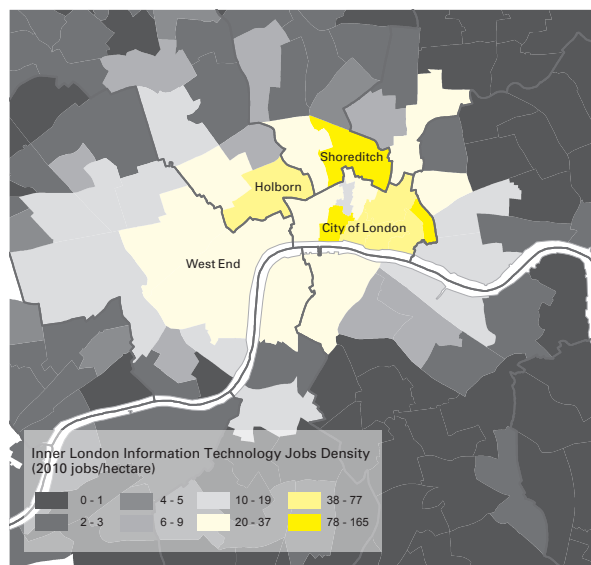
ICT jobs density
Source: Business Register and Employment Survey 2008 – 2011, NOMIS
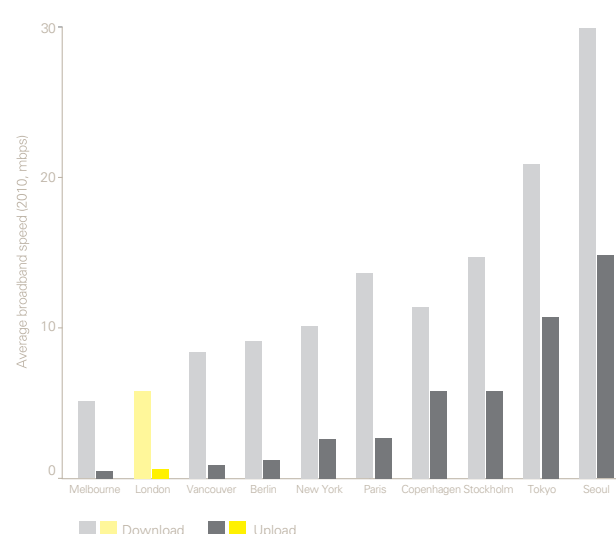
Cities' broadband speeds compared
Source: 'Broadband Quality Study 2010' in Greater London Authority 'London's Digital Economy' (2012)