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SUSTAINABLE CITIES

Beacons of light against the shadows of unplanned urbanization

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SUSTAINABLE CITIES
Beacons of Light Against the Shadow of Unplanned Urbanization

As Theodore Parker once said, “Cities have always been the fireplaces of civilization, whence light and heat radiated out into the dark.” While great cities have shaped our civilizations over the millennia, sucking in resources both natural and human before radiating them out to the world through commerce and culture, this received wisdom that ‘cities are the engines of growth’ is, we believe, failing.

Cities may generate 80% of global GDP currently, but while they have historically pulled in resources as they grew via industrialization, this phase of urbanization is being driven as much by populations being pushed into cities by rural poverty and depravation. This switch to ‘growth being the engine of cities’ has profound implications: it is the people that need the city, not the city that needs the people.

Some 4 billion people, representing 54% of the global population currently live in cities; the UN expects this to grow by 1 billion by 2030, and 2 billion by 2050, by which time 66% of us will be living in cities. To put that in context, that is one and a half extra ‘China’s’ or ‘India’s’, or six extra ‘USA’s’ all living in cities over the next 30 years. Cities may only occupy 2% of our global landmass, but they already consume 75% of all global resources and generate 70% of direct CO$_2$ emissions. These new urban populations will require basic services such as water, energy, sanitation, food, and housing, as well as the 'luxuries' of employment, education, culture, and recreation. What impact will an extra 2 billion people add?

The challenge though is even greater than this. Of our 2 billion new urbanites, 1.2 billion will come from Asia, and 800 million from Africa. These cities already have chronically limited revenue bases and offer meager services even to those already living there. With the lack of accompanying economic growth and financial contribution from this new populous, how can cities finance the vast investment needed to accommodate them? If these rapidly growing cities cannot finance themselves through income, and if central governments will not contribute more, then the capital must come externally.

And so with challenge comes opportunity. The good news is that trillions of dollars in capital is looking to invest in long-dated, income-generating assets, especially if they are sustainability focused. And what an opportunity! In our Citi GPS report Infrastructure for Growth from October 2016, we estimated that global infrastructure spend to 2040 was $58.6 trillion, with the bulk of that urban — but cities are not just about physical infrastructure, they are about people, and hence there is a similarly vast ‘social’ spending opportunity.

So how do we make it happen? In this report we contrast the vicious and virtuous circles of urban investment, and set out our 'Seven Steps for Sustainable Cities', which examine how cities can make the most of the money which they have, and gain access to greater funding via innovative new financial structures.

Those seven steps will require central governments, industry, the financial community, and cities to all do their part to tackle what is one of the greatest challenges of the coming decades. With much of the infrastructure yet to be built, and with a typical life span of 30 -100 years, our choices now may resonate over centuries; we have the opportunity to reshape our future, by creating new and sustainable cities which can once again operate as 'beacons of light' radiating out into the world, or we can let the darkness of unplanned urban squalor continue to sprawl. As Aristotle once said, "A great city is not to be confounded with a populous one" — let us seize the opportunity to ensure that our cities of the future are once again truly great cities and beacons of light, and not just populous ones.
Sustainable Cities: Bringing Cities into the Light

Where do cities get their funding from?

Central government financing

Local taxation
- Personal
- Business
- Land registry

Usage fees
- Rail
- Parks
- Museums
- Education
- Roads
- Electricity
- Health
- Galleries
- Water
- Waste
- Parking
- Sport facilities

Borrowing
- Bank loans
- Green bonds
- Development finance
- Municipal bonds
- Social bonds

Private investment / PPP
- Concessions
- Insurance companies
- Infrastructure funds
- Pension funds
- Listed equity vehicles
- Corporate investment

Urban wealth funds

Seven Steps to Sustainable Cities

1. Political and Regulatory Stability and Rule of Law
   Key is to eliminate corruption

2. Information and Data
   Having a comprehensive, consistent, and audited full set of data for cities around the world

3. Long-term Infrastructure Plans
   To facilitate the commitment of external parties to capital intensive projects

4. Urban Wealth Funds
   Determining the real value of assets and managing them to generate a yield

5. Innovative Forms of Finance
   Using a combination of Green and Social Bonds

6. Innovation Zones
   Incentivizing innovative enterprises and start-ups

7. Economies of Scale
   Used in both revenue collection and purchasing

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The amount of people living in cities is expected to increase by 2 billion people...

2015  4 billion
2030E  5 billion
2050E  6 billion

...with the largest increase expected in emerging markets

1.2 billion increase in Asia
800 million increase in Africa

Although cities only occupy 2% of global land mass, they generate 80% of global GDP but consume 75% of resources and generate 70% of direct CO₂ emissions.

The Significance of Cities

- 88% Proportion of urban populations exposed to unacceptable pollution
- 40% share of transport related emissions from cities
- 70% share of direct CO₂ emissions from cities
- 72% share of urban energy use from fossil fuels
- 74% share of electricity demand from cities
- 12% share of global landmass providing water to 100 biggest cities
- 2% Global landmass occupied by cities
- 54% share of global population living in cities
- 70% Amount of land used in cities for housing
- 13% share of global population living in slums
- 75% share of all resources consumed by cities
- 64% share of primary energy demand from cities

Source: UN Population Division

Source: UN, OECD, Citi Research
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What is a Sustainable City?

People often assume that building a sustainable city simply means building a 'green' city – but a truly sustainable city encompasses so much more than that. A sustainable city might be defined as an urban environment that works on an economic, social, and environmental level for its existing population, without compromising the ability of future generations to experience the same.¹

Figure 1. The 11th UN Sustainable Development Goal is 'Sustainable Cities and Communities'

Goal 11 of the United Nation’s Sustainable Development Goals (UN SDGs), “Sustainable Cities and Communities”, aims to ‘make cities and human settlements inclusive, safe, resilient and sustainable’.² It includes a number of ambitious targets to be achieved by 2030 that aim amongst others to

- Enhance inclusive and sustainable urbanization overall;
- Reduce the environmental impact of cities;
- Ensure sustainable and affordable housing;
- Provide sustainable transport systems;
- Protect and safeguard cultural and world heritage;
- Provide universal access to safe and inclusive green spaces; and
- Significantly reduce the number of people affected by disasters with a focus on protecting the poor and people in vulnerable situations.

Achieving this goal and the ambitious sub-targets set by the UN requires cities to invest not only in physical, economic assets (renewable energy sources, efficient use of water, fast and reliable public transport systems, improved waste and recycling systems, etc.) but also in social (sustainable housing, education, cultural) and human assets (the development of people). The challenge is immense given the rapid rate of urbanization around the world — however the opportunity, as we highlight in this report, is equally tremendous.

2 The UN has developed 17 sustainable development goals (SDG’s) and 169 targets that seek to build on the prior Millennium Development Goals and complete what those goals did not achieve.
Two billion additional people are expected to be in urban regions by 2050

Why is Making Cities Sustainable so Important?

The world is experiencing unprecedented urban growth. In 2015, 54% of the population (approximately 4 billion people) lived in cities and this number is expected to grow to about 5 billion by 2030 and 6 billion by 2050\(^3\) (refer to Figure 2 below). Currently most of the urbanized regions are found in North America (in 2014, 82% of people lived in urban areas), Latin America (80%), and Europe (73%). In contrast Africa and Asia remain mostly rural with 40% and 48% of their population, respectively, living in urban areas. However, over the coming years Africa and Asia are expected to urbanize faster than any other regions.\(^4\) By 2050 it is estimated that over 800 million and 1.2 billion more people are expected to live in urban areas in Africa and Asia, respectively (Figure 4). To put that into context, it equates to almost another one and a half 'India's' or 'China's', or more than six 'extra USA's' living in cities by 2050 — a challenge indeed.

Cities in Africa and Asia are expected to be the fastest growers

The rate at which cities grow will be influenced by a number of factors such as the types of industries that characterize the city's economy, geographical location, climate, availability of natural resources, and proximity to other cities in the region. The UN estimates that mega-cities (defined as cities with a population of more than 10 million people) will increase from 29 cities in 2015 to 41 cities in 2030. Figure 5 shows how this rapid urbanization has occurred in the past and is expected to continue in the largest cities of 2015. Some of these figures are staggering — in 1990 the population of Delhi for example was estimated at an already enormous 9.7 million people, a figure which increased to 15.7 million by the year 2000 and has now reached over 25 million people. By 2030 the UN estimates that the population of Delhi will grow by over 10 million people, reaching a total population of 36 million. By 2030 we could potentially see new cities with populations of over 20 million such as Dhaka, Karachi, Lagos, and Kinshasha. Cities such as Lunda in Angola, Ho Chi Min City in Vietnam, Dar es Salaam in Tanzania, and Lima in Peru are all expected to increase their population to over 10 million by 2030.

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\(^3\) https://sustainabledevelopment.un.org/sdg11

Although large and mega-cities stand out as being the face of urbanization on account of their economic importance and influence, they are not the fastest growing. According to the World Bank\(^4\), medium and small cities with less than one million people currently account for 59% of the world’s urban population and 63% of urban populations in Africa. However, most urban planning especially in developing countries seems to be focused disproportionately on large cities; if small and medium cities are to grow effectively and sustainably, then investment is also needed in these areas.

There is no doubt that past urbanization has lifted many people out of poverty as we will see later, but uncontrolled and unplanned urbanization has a darker side and can lead to numerous social and human issues. Given the problems of equity, the provision of basic services both physical and social, air quality, traffic congestion, and a lack of affordable housing in many urban areas, rapid urbanization could exacerbate these already serious problems unless better and sustainable planning occurs in many of these regions.

**Urbanization and Economic Growth**

The majority of cities are centers of economic activity, and already play an important role in the global economy; in fact 80% of global GDP is generated by cities. Their contribution to national income is often greater than their share of the national population — for example cities contribute 55% of national GDP in low-income countries, 73% in middle-income countries and 85% in high-income countries.\(^4\) Most successful high-income countries have economically dynamic cities at the heart of their regional and national economies, such as Paris which has 16% of the population of France but accounts for 30% of GDP, while New York City has 2.6% of the U.S. population but accounts for 8% of U.S.’s GDP.

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Uncontrolled and unplanned urbanization can lead to numerous social and human issues

Cities are historically the centers of economic activity
Urbanization has historically been closely linked with an increase in income per capita — in fact the correlation between urbanization and growth is sometimes used as proxy for income per capita in comparisons to development over time. Historically as countries develop, people move out of rural areas and agricultural activities into urban centers, where they engage primarily in manufacturing and service activities, a process known as industrialization. However Vollrath et al. (2016) argue that patterns of urbanization observed especially in emerging economies are changing; the expected relationship between urbanization and industrialization is now markedly absent in large parts of the developing world.

**Urbanization and Emerging Markets**

There has always been a compelling link between urbanization and GDP growth in emerging economies. It is well-established that no country has reached middle-income status without a rise in urbanization, the canonical example of this being China. In 1980, China’s urbanization ratio was close to 20 percent, at a level of per capita GDP (in purchasing power parity (PPP) terms) that was a mere 2.5 percent that of the U.S. By 2011, China’s urbanization ratio had reached 50 percent, while its per capita GDP had risen to a level that was 21 percent that of the U.S. In 1990, the world’s three biggest cities were in advanced economies, and only five of the biggest ten cities were in developing countries. By 2015, two of the three biggest cities — Delhi and Shanghai — were located in the developing world, as were for seven of the biggest ten cities globally. This is not simply a consequence of overall population growth; the population of these seven cities almost doubled between 1990 and 2015, while the population of the countries they are located in increased by about a third.

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5 Trujilla J.L, Parilla J (2016), Redefining Global Cities, Global Cities Initiative, The Brookings Institute, Metropolitan Policy Program
https://www.brookings.edu/research/redefining-global-cities/.

Cities facilitate organizational efficiency by giving firms access to workers and suppliers of inputs such that they can match skills with demand.

The link between urbanization and growth is best explained by a concept known as ‘agglomeration economies’, which is something akin to economies of scale. Cities facilitate organizational efficiency by giving firms access to workers and suppliers of inputs in a way that makes it easier for firms to match their varying demands for these inputs to a large pool of available supply. Cities also allow firms to share resources like infrastructure, and to benefit from the enhancement of a country’s workforce that is created by the supply of education, health, and adequate housing. There is also a political-economy argument at work here: cities offer proximity to political power, and this enhances a firms’ access to patronage and decision-making.

Cities can be seen as networks whose linkages generate efficiency.

Another way of thinking about cities is as a form of network, a tool of analysis recently popularized by Niall Ferguson. Social networks facilitate the transfer of information to the extent that the network components — governments, workers, and firms, in this case — are connected to each other. Cities offer a way of increasing the number of linkages between those components, and this generates efficiency. This way of thinking about cities is useful because it helps to capture one important aspect of the rise of emerging market cities during the past thirty years: namely, that this rise has coincided with an era of globalization. Globalization increases the value of cities-as-networks, because globalization has the effect of creating networks out of networks: the connection between countries that globalization relies on is facilitated by the series of connections between cities which are the result of urbanization.

In today’s world, rural deprivation can increase urban growth.

However, globalization has not necessarily improved the process of urbanization with economic growth. Glaeser (2015) states that prior to globalization, closed economies experienced an increase in urban growth in conjunction with agricultural productivity or transportation improvements, whereas in the more open economies of today, these statistics have “reversed themselves” and rural deprivation can increase urban growth.

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In other words, while traditionally a closed economy’s agricultural prosperity increased its urbanization, in today’s open and globalized economies, it is agricultural desperation causing urbanization. This means that poor mega-cities in developing countries not only have to grapple with normal city issues (congestion, crime, contagious diseases, etc.), but they have to do so without the economic wealth or a necessarily capable government traditionally associated with large cities.

The link between urbanization and growth is determined by the extent to which urbanization enhances productivity. Some research suggests that a 25 percent increase in a city’s size can increase output per worker by 1-2 percent. In the best case, that increase in productivity will happen because of the positive externalities above.

Whether urbanization contributes to productivity will depend partly on whether the urbanization is motivated by ‘pull’ factors or ‘push’ factors. In the case of the latter, the move to cities can be driven by drought, conflict, falling agricultural prices, mechanization of agriculture, and below-subsistence income levels. In these circumstances it is not clear that urbanization and growth will reinforce each other at all. The World Bank’s World Development Report for 2000 made it clear that African urbanization had failed to serve as a driver of growth, and at least one study has suggested that there had been a negative correlation between urbanization and growth in Africa between 1985 and 2000.

Following this trend, many cities in emerging markets are urbanizing without becoming traditional factory cities. Due to their large supplies of natural resources, Gollin et al. (2016) refer to such areas as ‘resource-exporters’ or ‘consumption cities’ (such as Kuwait City and Luanda in Angola). However, the authors note that these ‘resource-exporters’ tend to have higher poverty rates and a higher share of population living in slum areas. According to the authors, even though the income boost from resource exports makes cities richer, the income generated from exporting resources is not as high as the income from other ‘production cities’. Thus, this does not translate into improved quality of life to the same degree as cities that have been boosted through industrialization — as the literature suggests, ‘convergence is faster in industry than in services’. These cases should be referred to as examples of ‘premature urbanization’ as opposed to ‘premature deindustrialization’.

Even within our urbanizing ‘production cities’, mechanization is transforming the process. In our Citi GPS report on Technology at Work v2, we argued that technological development, such as automation in manufacturing, is likely to yield substantially less manufacturing employment in the next generation of emerging economies.

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10 Ibid.
As cities grow, it will be important to manage the negative externalities that urbanization creates.

The consideration of different city types shows us that the link between urbanization and growth is not a necessary one. And as urbanization continues, it will be increasingly important to manage some of the negative externalities that the process can create: congestion, over-crowding, excess demand for infrastructure, and rising inequality. In addition to this, there are three broad factors that might constrain urbanization in the future. The first is the future of globalization itself. If urbanization has been fostered by globalization during the past 30 years, then it follows that rising protectionism might decelerate the process. The second is technology. If cities can be thought of as social networks, then it is conceivable that the growth of technologies that allows us to network virtually could undermine the need for us to network physically in the form of cities. And the third is domestic politics. As Ferguson argues, ‘networks are profoundly inegalitarian’ which may help to explain why China now has more income inequality than the United States.

It could be that cities are no longer the engines of growth but that growth is the engine of cities.

All of this is simply to make the point that our thinking about urbanization should be shaped by two concerns. The first is that it is not so much the case that ‘cities are the engines of growth’ but rather that ‘growth is the engine of cities’. And the second is that one’s optimism about the future of urbanization in emerging markets can only be as strong as one’s optimism about the future of globalization.
The Sustainability Challenges of Urbanization

The growth model of unmanaged, unstructured urban expansion is starting to break down. Poorly managed urban growth can incur not only substantial economic costs, but also carries potentially enormous social and human costs. The scale of the challenge is vast, and the overview below, while far from comprehensive, tries to put some of the challenges examined later in this report, into context.

- **Resources and Waste:** Cities currently occupy only 2% of the world’s landmass, but are responsible for 75% of all of the natural resources consumed globally, and produce 50% of waste volumes globally. According to the World Bank, in 2012 the world's cities had a footprint of 1.2 kilograms of waste per person per day, which generated 1.3 billion tonnes of solid waste, a figure which is set to grow to 2.2 billion tonnes of waste by 2025. Generally, the higher the income level and rate of urbanization, the greater the amount of solid waste produced (i.e., packaging), while lower income countries have a far higher share of organic waste; however, low-income countries only collect 43% of the municipal solid waste that is generated, while in high-income countries the figure stands at 98%. Solid waste management dominates municipal annual budgets in low middle-income countries with shares as high as 30-50%, and total global solid waste management currently costing $205.4 billion, a figure expected to increase to approximately $375.5 billion in 2025.

- **Energy:** Cities are currently responsible for 64% of the world’s total primary energy demand, consume 74% of gross global electricity generation, and produce 70% of direct CO₂ emissions, a figure which rises to around 80% if we include indirect emissions. Twenty-two percent of global urban populations still lack access to clean cooking fuels, a significant health risk factor due to pollution as examined below. Cities meet approximately 72% of their total energy demand from coal, oil and natural gas. Emerging markets have the largest overall urban populations, are seeing the fastest rates of urban population growth, the fastest rates of growth in energy usage per capita, and most worryingly, take almost half of their total primary energy demand from coal. In our Citi GPS report **Energy Darwinism II**, we estimated the total global spend on energy (capital expenditure and fuel) to be some $190 trillion over the next 25 years, with the International Energy Agency’s (IEA’s) estimate of capital expenditure alone at around $50 trillion for the next 20 years, and the majority of that spend will be in meeting the increasing demand from cities.

- **Water:** The global demand for water for domestic purposes is expected to increase from 400 km³ to 660-900 km³ by 2030, the majority of this demand increase coming from cities; a number of cities around the world are already facing acute water shortages.

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12 Arab Hoballah, UNEP, Resource Efficient Cities, Drivers of Change and Engine of Sustainability.
13 The World Bank (2017), Solid Waste Management Brief, November 7, 2017
16 UN Habitat estimates.
17 World Bank data.
18 Citi, Solutions for a Global Water Crisis, The End of Free and Cheap Water.
It is estimated that 100 of the largest cities in the world currently occupy less than 1% of the world’s land area, but their source watersheds cover over 12% of the world’s land area, equating to approximately 1.7 billion hectares, transferring a total of 3.2 million cubic meters of water an average distance of 5,700 km every day in artificial channels. The World Health Organization (WHO) estimates total global economic losses from inadequate water supply and sanitation to be in the region of $260 billion annually. In our Citi GPS report Solutions for the Global Water Crisis we estimated that an infrastructure investment of $7.5 to $9.7 trillion is needed globally to upgrade, maintain, and build new water infrastructure, with again, the majority of that investment needed in cities.

**Transport:** Around 10 billion trips are made every day in urban areas around the world, with congestion costing the global economy a staggering amount. It is estimated that commuters in the United States waste 4.8 billion hours in traffic each year, translating to $101 billion in lost economic productivity; in Buenos Aires it is estimated to cost 3.4% of GDP, while in Mexico City it is estimated at 2.6% of GDP. Moreover, around 40% of total global transport-related emissions emanate from cities, with an estimated 90% of the increase in transport related carbon emissions expected to come from developing cities. Cars of course are the problem; we estimate that around 94% of all urban passenger energy consumption comes from light road vehicles (i.e. cars), and are responsible for a similar 93% of all urban passenger transport-related emissions.

**Pollution:** The WHO estimates that 88% of urban populations, where data is available, live with pollution levels which exceed their air quality guidelines, with over half experiencing particulate matter >2.5x recommended acceptable levels. Furthermore, they estimate that ambient air pollution was responsible for 3.7 million deaths in 2012, the vast majority of those in emerging markets, with the Organisation for Economic Co-operation and Development (OECD) estimating that outdoor pollution costs OECD countries plus China and India an estimated $3.5 trillion dollars a year in terms of the value of lives lost and ill health.

**Housing:** Housing accounts for more than 70% of land use in most cities, and accommodating the rapid growth in urban populations in a healthy, safe, and acceptable manner will represent an enormous challenge. Already, housing shortages in southern Asia are estimated at a staggering 38 million dwellings, while worldwide the UN estimates that one billion new homes will be needed worldwide by 2025, costing an estimated $650 billion per year or $9-11 trillion overall. Quality of housing is an equally huge issue; the UN estimates that one in eight people live in slums today, representing around 1 billion people, with the largest proportion (over 880 million) of those in developing regions.

**Social Needs:** Educating the populations of these growing cities is of paramount importance, as this is a key determinant of future prosperity, and has been shown to have a major impact on reducing the future costs of welfare and crime, as well as boosting urban GDP and tax take. One study estimates that every dollar invested in early education can yield future savings of between $7 and $12.

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19 IEA.
20 Citi Research analysis based on IEA data.
21 OECD (2014), The Cost of Air Pollution, Health Impacts of Road Transport.
22 World Cities Report, 2016.
23 According to the UN the word ‘slum’ refers to inhabitants suffer one or more of the following household deprivations - lack of access to improved water, sanitation, lack of sufficient living area, lack of housing durability and lack of security of tenure.
■ Health: Providing adequate healthcare such as hospitals and doctor’s offices, for the rapidly growing urban populations, will also require enormous investment, and a failure to do so could see associated costs rise dramatically. Furthermore, a population doesn’t just live to work — a successful sustainable city will need recreational facilities such as sports centers, cultural sites such as theatres and museums, as well as parks and green spaces. As we examine later, investing in these can improve the quality of urban life considerably, and lead to significant savings in both physical and mental health.

■ Infrastructure: All of the above (as well as telecoms and civic buildings) will require vast amounts of infrastructure. In our Citi GPS report Infrastructure for Growth we estimated that there is a global need for infrastructure spending of $58.6 trillion over the next 15 years — with an average annual global spend of $3.5 trillion between 2016-2020 and $4 trillion between 2020-2030 — the majority of this being needed in cities.

And so the challenge before us is truly enormous. Yet it also offers a huge opportunity for cities to reshape the future, by creating new clean cities which are attractive, healthy, rewarding, and safe places to live. We can invest now to build sustainable cities which work for all for the longer term, or we can allow urban squalor to continue to sprawl, and ultimately be faced with the even greater costs of fixing the numerous problems which will result — and then have to build sustainable cities anyway. The life span of urban infrastructure typically ranges from 30 -100 years, so the choices that we make now in how to build these sustainable cities (or not) will resonate over centuries. Future-proofing of cities is equally important, ensuring that new infrastructure is built to be resilient to changes in technology, emission standards, and potential climate change risks such as sea-level rises and changes in weather patterns. The challenges around the world are different, but each offers its own opportunities; emerging cities have the opportunity to become global leaders in driving forward the sustainable city concept, given that much of their infrastructure has yet to be built, while developed cities have the opportunity to improve connectivity, introduce modern and smart energy and water systems, transform mobility, and retrofit existing development.
Financing Sustainable Cities

With a huge challenge before us, how do we ensure that we follow a path which is successful and sustainable for the future? Clearly with an unlimited amount of money and the will to do so, we could fix most of the urban ills of the world, and build shiny new cities where everything worked properly, and everyone was well educated, gainfully employed, and living a happy and fulfilled life — the problem is, we do not.

So, given that money is limited, what should urban governments do? The following section examines where cities get their money from, and then moves into our so-called 'Seven Steps for Sustainable Cities', which examines how cities could change their governance structures and boost their finances, as well as utilize what they already have more effectively. Section II of this report then goes on to look at what cities actually spend their money on now, with a comparison between different types of cities around the world, and the marked differences therein. Section III examines the main areas of spend and investment for cities, and how cities could invest and allocate their capital in a more sustainable manner.

Where Do Cities Get Their Money From?

To illustrate the different urban revenue mixes around the world, we have chosen five different global cities, from both developed and developing markets, each of which exemplifies a different 'type' of city around the world — from technology and innovation hubs, through global financial centers, to manufacturing and industrial heartlands — at differing stages of their development. While no one city is a 'pure play' on these types, the cities we have chosen are as follows:

- San Francisco is the fourth largest city in the state of California and geographically the smallest county. In 2016 the population was estimated at 870,887 people, a 1% increase from the previous year. The city is an innovation and technology center attracting many high-skilled people — in fact it is estimated that over 30% of adults in the city have at least a bachelor degree and over 20% of adults have a graduate or professional degree. San Francisco has a rich portfolio of well-established industries and is an economic center for knowledge-based services such as financial services, IT, digital media, and health care. As of March 2017, San Francisco had the second lowest unemployment rate, at just 3%, among California’s 58 counties.  

- New York City is the leading job hub for banking, finance, and communications in the U.S. The city has an estimated population of over 8.5 million people and the New York City metropolitan area is the largest metro area by GDP, generating over $1.4 trillion in 2016.

- London is often ranked as the most economically competitive city in the world. It currently has a population of over 8.7 million people and is expected to grow to 11.4 million people by 2030. It is also estimated that London receives over 15 million international visitors every year.

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24 Mayor’s Office of Public Policy and Finance, Proposed Budget
25 UN population predictions
26 Mayor of London, London Infrastructure Plan 2050, A Consultation
Lagos is situated in Lagos State, which is the smallest state in Nigeria but accounts for over 60% of the country’s industrial and commercial activities. It contains the metropolitan area called Lagos city which is the most populous city in Nigeria with a population of well over 16 million (figures are disputed and range between 16 million to 21 million) and houses around 85% of the state’s population. According to UN population projections, the population of the metropolitan area is expected to increase to over 24 million by 2030.

The National Capital territory of Delhi is a city and union territory of India that covers over 550 square miles, with a population of over 18 million residents as of 2016, second only to Mumbai. If one includes Delhi’s extended urban area, the population increases to just under 28 million (2018), making it the world’s second largest urban area, and as of 2016 the most productive metro area in India. The city has struggled to keep up with its growth, which has resulted in inadequate commercial and residential infrastructure. Consequently, nearly 50% of Delhi’s population currently reside in slums, resulting in the territory being four times lower than the national average poverty line.

Current Sources of Urban Finance

As Figure 12 shows, urban funding traditionally comes from 2 broad buckets: income and financing. Simplistically, income comes from a mixture of grants and finance from the central government, local taxation, and local revenue from the use of services or facilities. Funding refers to external financing, and can come from traditional bank borrowing (including development banks) and other forms of borrowing such as municipal bonds or innovative new forms of credit such as green or social bonds. It can also come on an asset/service-specific basis from private investment in the form of concessions, or indeed on a hybrid basis via public-private partnerships (PPP). Lastly it can come via the creation of an urban wealth fund, one of the innovative forms of financing on that we focus on later, which we believe offers real scope to transform the financing of cities and their ability to invest, and is a highly important element which could boost the prevalence and growth of sustainable cities around the world.

References


Operational Income

Turning to our example cities, San Francisco is supported by a number of different revenue sources that are used to finance their yearly operational expenses. Most of its revenue stream is internally generated from a mixture of different sources such as business (7% of revenue) and property taxes (19% of revenue), charges for services (29% of revenue), local taxes (10% of revenue), and others. Only 16% of its operational budget comes from state and federal funding.

Similar to San Francisco, New York uses different revenue tools such as property tax (29% of total revenue in 2017), income tax (14%), corporation tax (4%), and others to raise revenue for its operational expenses. Seventy-four percent of New York City’s operational revenue is internally generated and only 26% comes from state and federal funds.
London has very limited fiscal autonomy; it relies heavily on funds from the central government for most of its operational and some of its capital expenditure. It has a two-tiered government system which includes the Greater London Authority and 33 London boroughs (including the City of London). The Greater London Authority (GLA) is run by an elected mayor who is responsible for setting the strategic framework for all London boroughs. It has some executive powers over city-wide areas such as transport, policing, fire and emergency services, and regeneration and housing. The London boroughs are responsible for education, housing, social services, street cleaning and maintenance, urban planning, and culture and related services in the capital city. Other areas such as national rail operations are managed by Network Rail (a public company that is answerable to the Department of Transport and Transport Scotland), while airport policy is a national government responsibility, although Transport for London (TfL) provides some of the access to the airports. Energy, water, and telecom services are provided by private companies and private companies collect and dispose of waste under contracts to local authorities.

The majority of the funding for London’s operational expenses comes from central government (over 60% for London boroughs and 45% for the GLA). Central government currently maintains a high degree of control over London’s tax base, while London’s local government control is limited to a number of negotiated fiscal schemes such as council tax and business retention schemes.

30 LSE Cities, Governance structures.
Lagos is one of the only local governments in Africa that has the ability to generate its own revenue. As shown from the Figure 19 below only 21% of its revenue comes from the federal government, with 55% being internally generated. However Nwagwu and Oni (2015)\(^31\) state that even though the city’s internally generated revenue is high compared to other Nigerian states, it is still not sufficient to meet the increasing social welfare, infrastructure, and environmental needs in the city. Lagos’ economy is diversified when contrasted with the larger Nigerian economy which is heavily reliant on the oil and gas industry. However, the State of Lagos is facing an increasing pressure — as oil prices have fallen in recent years more citizens from other Nigerian states have moved to Lagos in search for employment in the metropolitan area.


\(^{32}\) Lagos State Government, Y2017 Abridged Annual Budget.
Delhi is supported through several revenue streams. Most of its revenue is generated internally from its tax revenue (80%), with the remaining 20% split between non-tax revenue and the repayment of loans, with state and federal funding contributing only 6% of Delhi’s 2017/18 budget. However, it is not entirely clear whether the central government directly funds other capital projects in the region.

### Figure 20. Revenue for Operational and Capital Expenditure, Delhi

Amongst developed market cities, levels of financial independence can vary widely…

…and surprisingly emerging market cities rely little on the central government for budget

### Figure 22. Percentages of operating budget financed by central government

Intuitively, one might expect there to be a significant distinction between developed and emerging markets, with large, well-established markets having their own long-standing revenue bases and tax collection systems, and hence having a greater level of financial autonomy. Conversely, the rapid unplanned urban expansion in developing market cities is likely to be associated with much smaller revenue bases and less efficient collection mechanisms from their rapidly expanding populations, many of whom may be living in slums or shanty towns, and are much less likely to be contributing either economically or to taxation, due to a lack of (formal) employment. Hence one might have reasonably expected them to be much more dependent on central government funding, but once again this is not borne out by our example cities. For Lagos, only 21% of its entire budget (both operational and capital) comes from central government, while for Delhi, state and federal funding appear to represent only 6% of its budget.

### Taxation and Income — Centralized or Locally Controlled?

The first thing that strikes us about the city examples above is the different levels of financing from central government, i.e., the extent to which a city is self-financing. While New York and San Francisco take just 26% and 16%, respectively from state and federal funding, London is wildly different, with on a weighted basis, 56% of operating expenses coming from central government. The picture is in fact even more extreme than that, given the numerous other activities and expenses which are managed at a central level. So, even amongst developed market cities, levels of financial independence can vary widely.
There is a continuing debate over the merits of local versus national taxation to fund city operational expenditures. Much has been written about the relative merits of local versus national taxation to fund city operational expenditures, (e.g., Martinez-Vazquez\(^\text{33}\)) and we do not intend to reproduce that debate in full here. While cities are clearly enormously important to national economies, there is a strong argument for taxation and spending to be controlled on a devolved basis — i.e., the city is (simplistically) likely to be best placed to judge its issues and areas of needed spend. The rise of the modern mayor has also been a positive catalyst for change, championing local issues and (theoretically) directing investment to those areas most in need, or most in keeping with local opinion. From a political perspective, there is often a greater linkage in taxpayer minds between the local taxes they pay and the services which they receive; if you pay the local council for waste collection, and physically see someone arrive once a week to take your refuse away, you may be more inclined to pay. This is likely to lead to greater accountability for local government and politicians, but hence the flip side is also true; local politicians might prefer to keep revenue collection for certain things at a national level, thereby being able to distance themselves from taxation increases, or corresponding poor service. Health, education, and potentially policing could be prime examples here.

The downside of financial devolution is the potential for friction with centralized ministries and departments who have historically overseen elements of infrastructure or social provision, such as transport, especially as they may be losing control of their ‘flagship’ and highest-revenue-generating assets. As Paul Smoke of NYU points out, 'The core paradox of decentralization is that it involves the voluntary sacrifice of power and resources by central government actors'.\(^\text{34}\)

Clearly though, there is no hard and fast rule as to which is better, as the comparisons of New York and London admirably demonstrate. New York has far greater control over its $80 billion+ budget for its 8.5 million inhabitants, while London’s budget is far more centralized, only being responsible for an operating budget of ~£19 billion ($26m) for a similar number of citizens. But is one better than the other? Despite this lower level of local control, many people would argue that London's infrastructure is 'streets ahead' of New York's. However, is the same true for policing, or the fire service, or for schools? These offer far less obvious comparisons than for something that can be seen and experienced every day. Is this because large scale infrastructure projects are better sourced and managed centrally where there is more experience and purchasing power for large-scale and hugely capital-intensive infrastructure? Would a local authority construction manager have the experience to award, manage, and deliver a £14.5 billion ($20bn) London Crossrail project? Maybe, especially if recruited specifically for that role, but the strength of the argument for central government management in certain areas is equally clear as that for devolution.

The reality is that there are a huge number of variables which can affect which model is more appropriate, from levels of local corruption, to the efficiency of operation/lack of bureaucracy in central government, and how much national governments respect and value the importance of their cities. One thing that is likely to be true in both developed and emerging markets is that major cities are likely to contribute far more to the national budget than they take in funding. In London, there is currently a campaign to gain more power from the central government and secure fiscal and service devolution. If successful, this will enable London to retain some of its income tax paid by its residents, re-engineer outdated council tax rates in many boroughs, retain some of the business rates which are currently paid to


\(^{34}\) Ibid.
central government and distributed per capita to local authorities, and retain stamp
duty paid on London properties.\textsuperscript{35} The London Finance Commission estimates that
in 2013/2014 the city of London raised £34 billion ($47m)\textsuperscript{more} in taxes than was
spent in London from public expenditure.

The comprehensive UN Habitat report, 'The Challenge of Local Government
Financing in Developing Countries' and the enlightening sub-papers contained a
wealth of information and opinion on the topics of structure and governance models
raised in this section, and should be considered as further reading.

Usage Fees

Another potentially enormous source of revenue for a city comes from usage fees
for assets or services such as rail, roads (e.g. congestion charging, tolls), water,
electricity, waste, parking, recreational facilities such as parks and sports facilities,
and artistic institutions such as galleries and museums, some of which may or may
not be privatized. It could even extend to health and education services, though this
has potentially huge implications for levels of inequality and/or lower levels of
integration, with all the associated issues.

To charge for something, you need to have the asset first. Investing in new
infrastructure, as well as potentially facilitating and boosting economic activity can
generate significant usage revenues which can then be used to fund the financing
costs on the borrowing which was raised to finance the construction of the asset.
However, as highlight ahead, stable regulatory and political regimes, alongside the
clear rule of law will be necessary to enforce the payment/collection of these usage
fees, as well as ensuring adequate interest cover and creditworthiness (to raise the
capital in the first place). Moreover, in developing markets, close attention must be
paid to the ability of the intended users to pay for that service, i.e. affordability.

There is little point having a shiny new metro system if no one can afford to use it.
These aspects are covered in greater detail under 'Urban Wealth Funds', but many
obvious examples and solutions exist, such as TfL in London providing financing for
infrastructure investment, or most famously the Hong Kong MTR, where an
innovative structure not only facilitated the finance for investment, but usage fares
were made highly affordable by granting the return to developers through
land/development rights around metro stations, rather than via income from fares.

Financing for Investment

While some cities are prohibited by their central governments from borrowing, debt
can be an important source of financing for cities, so long as they adhere to one of
the most basic rules in fiscal policy, the so called 'Golden Rule', which states that
borrowing should only be used to finance investment, and not to fund current
expenditure (i.e. you can borrow to fund capital expenditures, but not operating
expenditure). Simplistically, this works, as capital investment (if conducted
efficiently) should entail a multiplier effect which provides an economic benefit (or a
reduced cost) greater than the cost of financing the investment. Conversely,
borrowing to fund operating costs simply adds an extra interest burden to those
operating costs, which presumably will still be there in following years, without the
benefit of the 'income'. In economic terms, greater levels of borrowing without
correspondingly greater levels of income will reduce creditworthiness and increase
the cost of debt, thereby raising the required rate of return and crowding out other
investment in lower return projects which no longer beat the return hurdle.
Moreover, the extent to which a city borrows is crucial; cities do go bankrupt.

However, in the absence of large scale central government funding, borrowing is critical in terms of facilitating the construction of large-scale, capital-intensive infrastructure projects. IMF Government Finance Statistics suggest that of the (often limited) money which central governments do give to cities, only around 20% is flagged to fund capital investment. Martinez-Vazquez & Timofeev estimate that despite that, nearly two-thirds of public infrastructure investment is conducted by sub-national governments.\(^{36}\)

Borrowing effectively spreads the cost of construction over the life of the asset, matching up the costs of the infrastructure against all of its users — rather than the current population spending all of the money — for the benefit of future users.

Borrowing for cities can come via traditional banking routes, including via development banks or supra-national organizations in emerging markets. For more developed markets the bond market offers further opportunity in the form of municipal bonds (so-called muni’s), as well as newer, more innovative forms of finance such as green bonds and social bonds. Clearly the ability to borrow, in particular via the bond market, is linked to the creditworthiness of the city and whether or not there are guarantees in place (from central government) or if there is collateral against the bonds.

Assuming a city is 'allowed' to borrow, and given the fundamental importance of creditworthiness, the issue identified earlier that emerging market cities are not experiencing economic growth in line with their growth in scale is, as much as anything, an issue for central government. The tone of political, regulatory, and financial stability will be largely set at a national level, and is a pre-requisite for business investment (and for borrowing, unless at exorbitant rates). If central governments cannot provide that backdrop, local governments are unlikely to be able to borrow (even if allowed), and hence the central government must allocate scarce capital to facilitate capital investment — which as we have seen, they largely don’t.

Generally speaking, large cities in developed markets will be well-established, stable entities, with long-standing revenue bases and tax collection systems, and their more gradual population growth means there are less acute challenges related to extreme growth and burgeoning demands on services. They (again generally) are likely to have more stable legal, regulatory, and political backdrops, and hence are more likely to be able to raise external finance for investment (or can do so at a lower cost).

Conversely, extending services such as water, sewerage, power, waste collection, not to mention policing, health, fire services, education, etc. to areas of rapid expansion in emerging market cities may be disproportionately expensive given inverse economies of scale.\(^{37}\) Moreover, the population which is going to use this service may not be able to afford it, or alternatively, extending some form of revenue collection system (i.e., rates/taxes) may not be practical or enforceable across the population given the lack of formal employment/economy. These emerging market cities will also typically have a less stable political, regulatory, and legal backdrop, alongside less well-developed and liquid local financial markets, which will also make raising external capital more difficult, or at least more expensive.

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Debt is not a panacea for everything — cities can and do go bankrupt. Moreover, while central government backing might help with creditworthiness, it is also worth noting that it can be counterproductive in terms of local financial prudence and moral hazard given the national backstop.

Nevertheless, the simple fact remains that these emerging market cities are growing at a phenomenal pace, and we have a simple choice — we either invest alongside (and preferably even ahead of) that growth, so that they grow in a sustainable fashion, or we face the unpalatable and unacceptable alternative of letting them sprawl uncontrollably into endless slums with all of the terrible social, economic, and human ills with which they are associated. If we must therefore invest, we have to recognize that urban ‘income’ in emerging market cities is never going to finance that investment, struggling as it does to keep up with operational demands, and hence debt, especially the new types of debt instruments described later, is critical to achieving a world of sustainable cities.

Types of Urban Debt Instruments

As above, the key to being able to raise financing on the bond market is the perception of creditworthiness, i.e., the ability to repay, which will be, amongst other things, a factor of the scale of the revenue stream in the city (and the level of interest cover), and the stability of that revenue, as well potentially the existence of collateral. As discussed in more detail in the ‘Urban Wealth Funds’ section, the lack of a complete asset schedule and hence balance sheet potentially hinders a city’s ability to borrow.

The most common form of urban borrowing is in the form of a municipal bond, or ‘muni’ for short. Innovative types of bonds, such as green and social bonds, are gathering pace rapidly and offer further opportunities for cities to use financing to fund investment in sustainable development.

Municipal Bonds

Municipal bonds make up one of the largest fixed income markets in the United States. At over $3.8 trillion of outstanding debt obligations, it is a major source of funding for state and local governments. Municipalities in countries across the world issue bonds of their own, but the U.S. municipal market is the largest, most liquid, and most sophisticated.

The municipal market is split into two major categories: general obligation (GO) bonds and revenue bonds. The most common and usually most secure form of GO debt is the unlimited GO. Unlimited GO debt is backed by the “full faith and credit” of its issuer. It is usually issued by a government or school district to fund the general operations of the state, county, district, or locality. Revenue bonds which make up two-thirds of the municipal market are backed by a dedicated revenue stream. Unlike with “full faith and credit” security, if the revenues generated by the issuer are insufficient to pay debt service, the issuer is not compelled to use other means to raise revenue and bondholders may face losses.

Since 2012 the U.S. green municipal bond market has seen significant growth with retail investors driving demand. Municipal green bonds are similar to traditional municipal bonds with the exception that issuers label the bonds green, proceeds are earmarked for green investments, and issuers track and report on the use of proceeds to ensure compliance. However, states and municipalities can potentially incur extra issuance costs through this process, i.e., having to obtain an independent review to ensure the green label.
The Brookings Institute estimates independent reviews could cost issuers between $10,000 and $50,000, which could disincentive some cash-strapped issuers from issuing green bonds; however the market continues to grow. The Climate Bonds Initiative projects $20 billion in green municipal issuance for 2018 as states and local governments look to ramp up climate-resilient infrastructure investments.

San Francisco

So how do our example cities raise finance for investment? San Francisco has a diverse variety of funding sources at its disposal that it can use to raise capital for its planned infrastructure projects. These include the San Francisco General Fund (Pay-as-You-Go Program), publically issued debt, federal and state grants (such as funds from the Federal Aviation Administration and the California Department of Transport), and other local funding sources (such as Marina Yacht Harbor Fund and Road Fund). The Pay-as-You-Go program consists of various taxes collected by the city including property, sale, business, and hotel taxes. Improvements paid through this mechanism are smaller in scale than those projects financed by debt mechanisms ($1.8 billion over a 10 year period).

San Francisco uses three types of municipal debt to finance its long-term capital projects; these include general obligation bonds (rated Aa1/AA+/AA+ by Moody’s, Standard and Charter, and Fitch Ratings respectively), lease revenue bonds (rated Aa2, AA/AA), and certificates of participation. It uses general obligation bonds to leverage property tax receipts for the acquisition or improvement of property such as libraries, hospitals, parks, and educational facilities. Lease revenue bonds and certificates of participation are used to leverage General Fund receipts (such as local taxes, fees, and charges) to finance capital projects which provide a direct revenue benefit or cost savings to the city. Debt service payments for these types of debt are usually paid from the revenue of the related project such as fees, taxes, or usage fees from the project in question. The city also sometimes uses Commercial Paper Certificates of Participation Program to pay for approved project costs and Tax and Revenue Anticipation Notes to meet ongoing General Fund expenditures.

In total, the city has $3.7 billion in projected outstanding debt, and the operational budget of fiscal year 2017-18 provides $438.7 million for the payment of debt service. The City has a set limit of $6.3 billion on the amount of G.O. bonds it can issue; therefore the remaining legal capacity for G.O bond debt is at $4.3 billion based on fiscal year 2016 to 2017. A number of public enterprise departments such as the Airport Commission and the Municipal Transport Agency issue their own revenue bonds to leverage operating revenues to finance their capital projects and, therefore do not rely on the traditional debt instruments that are used by the city.

<table>
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<th>FY-23-27</th>
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Source: ONESF, Citi Research

San Francisco can raise capital for planned infrastructure projects from a diverse variety of funding sources.

39 CSF Budget Book.
New York generally finances its capital program through the issuance of bonds. New York's capital program is generally financed by borrowing, usually through the issuance of bonds, with financing costs (i.e., interest/coupons) covered in the operational budget. A number of different bonds are used to finance the capital commitments of New York City, including general obligation bonds which is debt backed by general revenues, in particular property tax revenues which are pledged to G.O. debt services before they are available for other city spending. The Transitional Finance Authority (TFA) issues debt backed by personal income tax, while Water Authority Bonds which include commercial paper and revenue bonds are issued for the water and sewer's capital program. Total city debt is estimated at $46 billion (not including TFA debt which is not subject to constitutional debt limits), with the total debt limit is estimated at $98 billion.

Pay-As-You-Go capital is sometimes used as an alternative to debt financing for smaller capital projects, thereby avoiding adding unnecessarily to the city's total outstanding debt.

London uses a number of tools to fund its capital investment plan. London plans to use a number of tools to fund its capital investment plan. These include capital receipts (11% in 2017-2018), capital grants (16%), debt issuance (22%), and in some cases (such as TfL) revenue contributions (20%). The largest capital investment funds have been allocated to transport projects under the management of TfL.

Figure 25. Planned Bond Issuance 2018-2022

London

London plans to use a number of tools to fund its capital investment plan. These include capital receipts (11% in 2017-2018), capital grants (16%), debt issuance (22%), and in some cases (such as TfL) revenue contributions (20%). The largest capital investment funds have been allocated to transport projects under the management of TfL.

40 New York City Independent Budget Office, Understanding New York City's Budget, A Guide to the Capital Budget
TfL is funded from four main sources which include fares, income (advertising, property rental, and income from congestion charges), grant funding from local and government sources from the Department of Transport (DoT)\(^{42}\) and the Greater London Authority,\(^{43}\) and Crossrail funding. Private investment is also sought for some transport projects. For example Crossrail which is a new east-west railway for London and the South East, has received funding from the central government (£4.7 billion), the Mayor of London and TfL (£7.1 billion direct contributions and loans), and London businesses through a variety of different mechanisms. Other financial contributions include funding from the City of London Corporation, Heathrow Airport Holdings, Canary Wharf Group, and Berkeley Homes. Usage charges from the rail system will be contributed towards the debt raised during the construction phase.

TfL also borrows from a variety of sources including bonds, commercial paper, loans for specific projects from the European Investment Bank and the Public Works loan.\(^{44}\) They currently have over £9.8 billion ($13.7bn) of debt raised and a further £2.5 billion ($3.5bn) borrowing requirement up to 2021. In 2015, TfL also issued a green bond for £0.4 billion ($0.6bn) which has a tenor of 10 years and a coupon of 2.125%.\(^{45}\) The eligible green projects included low carbon transport for overground rail, low emission hybrid buses, cycling improvements, and others. TfL is required to adopt prudential indicators to support their decision-making on planned capital expenditure and borrowing and they must stay within the authorized limits for external debt.\(^{46}\)

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\(^{42}\) There are two grants given by the Department for Transport (DfT) — the DfT general grant which covers some of TfL’s operational costs (this will come to an end in 2017/2018) and the DfT investment grant which is used for capital improvements.

\(^{43}\) The Northern line extension is funded from a grant from the Greater London Authority and is financed from incremental business rates generated and retained.

\(^{44}\) https://tfl.gov.uk/corporate/about-tfl/how-we-work/how-we-are-funded.


The capital investment plan in Figure 26 only includes projects run by the Greater London Authority. Capital projects that are managed by central government/central government bodies (for example Network Rail) or private firms that manage private assets such as energy, water, and telecoms are not included in the above estimates.

Lagos

To cover the costs of various infrastructure projects, the government plans to raise N170 billion ($0.4 billion) through internal loans, external loans, and through bonds. N85 billion ($0.24 billion) was raised in 2017 via bond issuances with maturities of seven and ten years, representing the third tranche of an overall N500 billion ($1.4bn) debt program approved by the State parliament. The net proceeds will be used to fund infrastructure projects, which include the construction and upgrade of roads and bridges, tourism sites, the upgrade of health systems, and the development of waterways and transportation. While it is encouraging to see cities such as Lagos issuing bonds, the coupon of 17.25% (admittedly against inflation of 16.5%) shows the extraordinarily high costs of finance in emerging market cities. 

Delhi, as highlighted earlier, does not separate its income figures, and hence financing for investment is included in the previous ‘income’ charts.

\[47\] https://af.reuters.com/article/africaTec/idAFL8N1L02TF.
The 'Seven Steps to Sustainable Cities'

So how can cities get more money — or more out of what they've got — and change their structures to be more effective? While the following suggestions are far from exhaustive, our 'Seven Steps to Sustainable Cities' highlight key factors to maximizing a city's access to funding, and to make the most of existing funding and assets. While building a sustainable city isn't just about money, our focus on finance reflects our belief that the will to address these issues is already there, but that governance and access to capital remains one of the most important challenges to overcome.

1. Political and Regulatory Stability and the Rule of Law

A stable political, legal, and regulatory backdrop and the rule of law is perhaps the first and most important element of building a successful and sustainable city. The elimination of corruption is key as it not only ensures effective spending of the budgets which do exist (as opposed to nepotism, cronyism and at the extreme, embezzlement), but that stable backdrop maximizes a city's ability to raise external revenue to fund investment (borrowing), and also serves as a major factor in the decision of businesses to set-up, relocate, invest, and grow, with the knock-on effects of an increased taxation revenue base, greater employment, lower social costs, etc.

Even if allowed by the central government to borrow in principle, a rapidly growing city in an emerging market with a fragile political, economic, regulatory, and legal backdrop may have questionable creditworthiness, and hence may not be able to raise finance, or at the least may only be able to borrow at exorbitant rates, the cost of which could negate any potential benefits.

2. Information and Data

One of the first things that strikes you when you start writing a report such as this, is the extraordinary lack of precise and comparable data which exists on cities around the world. While there is much data around, it is often incomplete, out of date, and in most cases totally incomparable between cities. While initiatives do exist — such as the C40 initiative, the Compact of Mayors, or UN-Habitat Urban Data — which are trying to fix this, having a comprehensive, consistent and audited full set of data for cities around the world (even on something as basic as financing, let alone crime, education, health, transport, and emissions) would be an enormous help in identifying areas of lowest hanging fruit and of spreading best practice, as well as encouraging cities to work collaboratively to achieve best outcomes.

3. Long-term Infrastructure Plans

If external parties are to commit to capital-intensive projects with long asset lives, they need to understand how a particular asset or project fits into an overall, long-term infrastructure plan. For example, building an airport might be necessary and make perfect economic sense, but if it doesn’t go hand-in-hand with transport solutions such as a metro and serviceable enough roads to reach it, it becomes a 'white elephant', i.e., an under-utilized asset which has an economic multiplier effect of potentially <1. Industry is interested to partner with cities to formulate those longer-term investment plans, providing the benefit of their decades of large-scale infrastructure investment around the world in return for being involved in potentially lucrative construction and concession management consortia.
Moreover, their extensive experience of financing these types of projects, and their ability to do so as part of a portfolio of projects can be crucial in terms of spreading risk, and removing financing liabilities from resting purely with municipalities.

The opportunities offered by private investment, or the hybrid version of PPP (Public Private Partnerships), can negate the need for a city to raise financing for investment itself, by allowing private capital to Build, Own and Operate (BOO) an asset for a defined concession life, before potentially Transferring the asset back to local authority ownership and control (BOOT).

As we highlighted in Infrastructure for Growth, in this era of ultra-low income from all asset classes, pension and insurance funds, not to mention infrastructure funds, are crying out for long-dated, income-generating assets to match against their liabilities. Moreover, the many large global infrastructure concession operating companies are keen to invest in numerous types of infrastructure concessions — from toll roads, through metros, airports and water projects, to power plants and networks — essentially any of the physical infrastructure which rapidly expanding cities need. Hence the right project, with the right structure and returns can be provided to a municipality at minimal cost. As before though, regulatory, political, and legal stability and trust are likely to be of paramount importance, or the project returns (and hence the cost to the populous of using the asset) may be prohibitively high, if the project is indeed do-able or financeable.

Those returns do not have to come purely in the form of operating revenues, which may prove too expensive for some local populations in emerging markets. The classic example of this is the Hong Kong Mass Transit Railway (MTR) Corporation. Established in 1975, the developer was granted property rights around the stations; clearly as the stations were developed, the real estate in close proximity appreciated in value. Combining the metro operation and real estate aspects has allowed the business to be profitable despite ‘low’ fares, while facilitating private investment and infrastructure development.

Hong Kong is not alone in using this so-called ‘land value capture’ (LVC) approach, with various projects in Queensland, Atlanta, San Francisco, and Kansas City having adopted a similar approach. London is also examining similar approaches: in a technical report by TfL and the Greater London Authority, it was estimated (by KPMG and Savills) that a sample of eight prospective TfL projects with a cost of around £36 billion ($50bn) could produce land value uplifts of about £87 billion ($121bn), and appropriate land value capture mechanisms could help to fund the investment.

4. Urban Wealth Funds

Cities are normally well aware of what their annual cashflows are (both in and out) and should be aware of their liabilities (including their pension liabilities), but are often woefully blind as to the real value of their assets. In simple terms, they have an operating budget of revenue received and expenditure incurred each year, and this will extend to short-term debtors and creditors where sums due have rolled over period ends. It may also extend to longer-term liabilities where there are municipal borrowings/bonds. However, in almost no cases does the asset schedule extend to current values of long-term (i.e. fixed) assets.

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48 Land Value Capture, Transport for London, 2017
In accounting terms, what it means is that while cities generally have cashflow statements, it is not possible to build a full balance sheet, as shown in Figure 28, and therefore it is not possible to build a complete profit and loss account. It is also not possible for an investor to get a sense of the net assets of a city, and moreover, without an accurate assessment of long-term assets, it is hard to ascertain:

1. Whether an appropriate return is being made on those assets, and
2. To determine an accurate 'depreciation/amortization' charge related to the assets, which therefore precludes the formation of a meaningful P&L account for the city.

Another way to look at this is that while there may be a maintenance charge for an asset or infrastructure class, we have no way of knowing whether this is in any way related to a sensible depreciation charge based on both the value of the asset and an implied asset life. This is highly significant given the widely-held view that cities underinvest in maintenance of existing assets — which we suspect is basically because you get much more political 'bang' for a shiny new asset or program than you do for simply keeping something running, although clearly one does not avoid the negative political implications when a civic asset stops working through neglect and underinvestment.

Most importantly though, if you have no idea of the value of your assets, it is not possible to generate an implied yield, and therefore to make informed decisions about whether to develop a waterfront from a partially used port or airport into a booming new residential district, building a new airport elsewhere or a smaller, newer, more efficient port somewhere else.
We don’t intend to labor the point in this report, as it is the key message from our sister Citi GPS report, *The Wealth of Cities*, by Dag Detter and Willem Buiter. In the book of the same name which predates the GPS report, Dag Detter and Stefan Fölster observe that “Achieving a reasonable yield on luckily owned commercial assets could free more resources than most cities’ current investment in infrastructure, including roads, railroads, bridges, water, electricity, and broadband. Most cities could more than double their investments with smarter use of their commercial assets.”

The authors estimate that “governments around the world have an estimated $75 trillion of public commercial assets”. This figure equates closely to one year of global GDP, and contains everything from real estate to government-owned enterprises. Their calculation highlights that a higher return of just 1 percent on these assets would add $750 billion to revenues. In the context of global annual infrastructure investment of ~$2.5 trillion as discussed in *Infrastructure for Growth*, this could facilitate a 30% increase in global levels of infrastructure investments — and clearly the impact in terms of urban infrastructure investment would be proportionally much greater. Moreover, the impact of this spending on global economic growth, if conducted efficiently, could be considerable.

So what does ‘managing assets better’ mean in practice? Cities own vast amounts of assets, from enormous real estate portfolios such as civic buildings, schools, social housing, to utility networks, waste treatment assets, and transport assets such as roads, rail, trams, buses, airports and harbors, as well as parking. It can also encompass ‘intangible’ assets such as mobile telephony/data spectrums, and derivative assets such as development rights, to name but a few.

Often these assets may be poorly run and not earning nearly enough of a commercial return compared to their potential market value, and at the extreme may be vacant, given the impact which technology and automation has had on physical provision of civic services (e.g., telephone exchanges).

This is not just using an existing asset to its fullest effect — it is looking at the location of for example civic offices which may occupy prime real estate, which could be sold (or leased) with more modern and appropriate facilities developed at cheaper locations resulting in significant savings for the city. Detter and Fölster cite the example of Boston’s Logan airport which occupies prime waterfront real estate, which if moved could free up extremely valuable land for development, while the airport could be moved to less valuable real estate inland. Transport assets can generate a return if managed properly via usage fees which can then be reinvested in networks, much as in the example of Transport for London which has dramatically improved services. London’s congestion charge provides another example of leveraging a city’s assets, namely the roads, to generate an income which can be reinvested in mass transport solutions, as well as the promotion of sustainable forms of transport such as London’s Cycle Superhighways.

Assets can also be monetized beyond a simple return — time-of-day tariffs for example can be used to effect changes in habits which can materially reduce productivity losses from congestion, and hence emissions. Anyone who has walked out of London’s Bank station in the middle of a weekday and been shocked at the empty streets will understand what a difference these schemes can make to a city center. If this location ultimately ends up being pedestrianized as a result, it has facilitated the development of the center of one of the world’s greatest financial centers into a much more ‘human’ place to work. Time-of-day pricing can work just as well for trains — in the same way congestion charges can discourage usage, reduced fares can be used as incentives to change travel behaviors.

The assets of a city can also be financial, in the form of its pension funds. These represent just another element of the vast assets of a city which could in many cases be managed much more effectively than currently, potentially by pooling them with other urban centers to achieve economies of scale, which could then be outsourced to be managed professionally.

So how do you create an Urban Wealth Fund? The first step must be to form a proper schedule of assets, both long and short term, as well as liabilities, to build a fully-inclusive balance sheet based on current rather than historic values. The next step, while not imperative, but probably desirable, is to outsource the management of these assets to a well-qualified external third party (with the correct governance and oversight) which can manage the assets efficiently. Their task will be to compare the revenue generation (or cost saving) from these assets against their current market value to examine implied returns, to consider what alternative solutions are possible, and identify the biggest gaps between current returns and potential returns, thereby identifying the greatest opportunities.

Examples of Urban Wealth Funds already exist, including the City of London Corporation, and a particularly good example, Temasek in Singapore. The latter, established in 1974, has proved so successful in its management of assets that it has since moved internationally, with a fund value which stood in March 2017 at some $275 billion.

These greater returns (essentially more money either through income, or reduced costs) can afford a city much greater opportunity to either invest in further physical infrastructure, which if handled efficiently can produce a significant economic multiplier effect, thereby boosting employment and the economy, as well as potentially social benefits by the increased/improved provision of services to the populous, such as transport, telecoms, water, energy, or waste services.
However it could also be invested in a social investment fund which could be used to invest in social assets such as parks or leisure facilities, and/or invested in social schemes such as education, re-training, health, housing, or rehabilitation. All of these could potentially reduce the future costs of crime, health, and so on, as well as improve the overall quality of life for all the residents of a city, as examined in the later section on 'social infrastructure'.

Another potential benefit is that a group with independent oversight of assets may be more at liberty to do what is 'right' for a city from a longer-term perspective, being removed from the political pressures of taking to shorter-term vote-winning actions. Moreover, the correct independent structure can, with the right governance and oversight, reduce the risk of corruption, nepotism, and institutional inefficiency.

Conversely, an Urban Wealth Fund may be criticized by some as 'selling off the family silver' to what are perceived to be purely financially-orientated private interests — this does not have to be the case, since the assets (or the benefit of selling/moving/replacing or restructuring them) will still be 'owned' by the city. However, the right structure and oversight, and explaining the concept and benefits fully to voters, should help to alleviate (if not totally eliminate) these concerns. We believe Urban Wealth Funds to be certainly one of, if not the single biggest opportunity to facilitate investment and further the development of sustainable cities around the globe.

5. Innovative forms of finance

Green bonds

Recent years have seen the emergence of the so-called 'green bond'. Green bonds are a fixed income instrument, the proceeds of which will be used exclusively to finance 'green projects', defined as any activity or project which promotes progress on environmentally sustainable activities, and is in accordance with the recently launched 'green bond principles' outlined below:

1. **Use of Proceeds**: The finance raised by the green bond must be used for environmentally friendly and sustainable projects such as renewable energy, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, clean transportation, sustainable water management, and climate change adaptation.

2. **Project Evaluation and Selection**: The green bond issuer must outline the decision-making process it intends to adopt in determining the eligibility of projects to receive proceeds, in terms of the specific category of project, the criteria which makes the project eligible, and the environmental sustainability objectives.

3. **Management of Proceeds**: The proceeds should be credited to a sub account and tracked as they are invested with a high level of transparency. The use of an auditor or other third party to verify allocation of funds and tracking is encouraged.

4. **Reporting**: Issuers should report at least annually on the use of proceeds, in terms of which projects have been financed. The principles also recommend the use and disclosure of qualitative and quantitative performance indicators of the expected environmental sustainability impact of the investments.
Types of Green Bonds

There are four main types of green bonds: The most popular and mainstream is a regular fixed income bond which has a full guarantee by the Issuer, however the “use of proceeds” of the bond can only be used for “climate friendly” projects, as mentioned above.

1. **Green Use of Proceeds Bond**: the most common type, a normal fixed income bond with recourse to the issuer, the proceeds of which must be used for environmentally friendly/sustainable projects.

2. **Green Use of Proceeds Revenue Bond**: non-recourse to issuer, linked instead to income streams.

3. **Green Project Bond**: Linked to a single/multiple qualifying green project, with no recourse to the issuer.

4. **Green Securitized Bond**: A bond with collateral and cashflows provided by multiple projects.

While the first green bonds were issued by supranationals, the market has evolved into sovereign green bonds and corporate green bonds, before progressing to the first cities issuance of a green bond in 2013.

As Figure 31 shows, green bond issuance grew 78% in 2017 to $155.5 billion, with more than 1,500 issues from 37 different countries, taking the cumulative green bonds issuance to around $350 billion. France issued the largest single green bond ever for $10.7 billion, being one of three sovereign green bond issues in 2017 from around the world (Fiji and Nigeria being the other two). 2018 has started well, with notable features being Indonesia’s issuance of a $1.25 billion green sukuk, the first sovereign green bond issued in Asia; however, Bloomberg reports that Hong Kong is planning an even bigger sovereign green bond plan of up to $12.8 billion, in which use of proceeds would be for green public works projects.
At a city level, green bond issuance started with around $90 million of issuance from the City of Gothenburg in Sweden in 2013, with Stockholm, Orebro, and Johannesburg following suit in 2014. In the years following, the cities became bigger as did the issuances, with cities such as LA, Paris, Mexico City, and Cape Town to mention but a few. This ignores listings by city institutions or departments such as city housing, educational, or utility organizations, and transport entities such as Transport for London which issued a £400 million sterling green bond in April 2015. So, while the ‘pure’ city green bond issuance is around $5 billion, the actual figure if we take municipal entities is actually higher — but still tiny when compared to the overall green bond market and the scale of credit markets overall.

The Climate Bonds initiative forecasts $250-$300 billion of green bond issuance for 2018, implying another year of spectacular growth. The market for green bonds is still evolving, but the emergence of accrediting organizations and industry guidelines/best practices such as the green bond principles is helping to develop the market. Given the potential focus of green bonds in terms of what they are used to finance, their applicability to cities is key, and we believe they will be an important factor in building the sustainable cities which will be needed to tackle issues associated with rapid global urbanization.

Social Bonds

Social bonds are very similar in concept to green bonds, differing only in terms of their use of proceeds, and offer further potential for cities in financing sustainable investment. Social bonds are defined in ICMA’s Social Bond Principles (SBP) as ‘any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance in part or in full new and/or existing eligible Social Projects and which are aligned with the four core components of the SBP.’

The four components of the social bond principles are essentially the same as those for the green bond principles, the main difference being in terms of the eligible social projects. These are defined in the social bond principles as projects which ‘directly aim to help address or mitigate a specific social issue and/or seek to achieve positive social outcomes especially, but not exclusively, for target populations’. It goes on to list potential projects such as affordable basic infrastructure such as water, sanitation, transport, basic services such as health and education, as well as access to finance, availability of affordable housing, employment, and food security, plus socioeconomic advancement and empowerment. Without listing all of the many possible groups here, targeted populations are clearly those which are economically and/or socially disadvantaged in some manner.

Clearly there is much potential overlap between green and social bonds, and those which intentionally blend both elements are known as sustainability bonds.

Another key element of social bonds can be the conditions which may be attached to payment of the coupon. While not necessarily the case, the coupon is often performance based, in terms of the performance against a specific social goal. For example, private finance is generated by a social bond, which is then provided to a not-for-profit contractor, tasked with reducing or eradicating a specific social issue (e.g. the number of prisoners reoffending within a certain timeframe). The ‘coupon’ can then be paid by the issuer (e.g. a government or local authority) to the bondholders based on the performance against certain pre-agreed metrics.

The four main types of social bonds are almost identical to the four types of green bonds highlighted earlier, but substituting ‘social’ for ‘green’.

As Figure 33 shows, with close to $9 billion of social bonds issued in 2017 and about $12.5 billion issued cumulatively, social bonds are much smaller than the ~$350 billion green bond market, but are growing very quickly. As Figure 34 demonstrates, social bonds have been a much more public sector-centric product, with private issuance at a relatively small level. As awareness of this interesting new bond class comes through, we would expect growth to be significant, just as it has been in the green bond market. With the potential benefits of sustainable projects in cities, be they ‘environmental’ in energy, water, waste, transport, or more ‘social’ in nature, relating to education, health or law and order, the applicability of green and social bonds is very clear, and we would expect to see urban issuance (i.e. the ‘sustainable muni’ market) accelerate accordingly. Closely allied with the emergence of green and social bonds is the emergence of green sukuk’s, essentially an Islamic green bond, which complies with Islamic (sharia) law via the absence of interest (riba), the ‘return’ being achieved via other methods, most typically via partial ownership of the underlying assets and hence a share of the revenue which those assets generate. Given that our entire discussion here relates to financing investment, with many of the fastest growing cities in the world having large Muslim populations, the potential for green or social sukuk’s is very apparent.

A key driver of the growth in both green and social bonds is institutional demand, and it is here that the good news starts: demand for sustainability-related investments is growing dramatically. While much of the asset management industry is suffering from the so-called rise of passive investment (essentially low-cost trackers and exchange-traded funds (ETF’s)), Environmental, Social & Governance (ESG)-related assets have grown at a 12% compound annual growth rate (CAGR) in recent years. About 1,200 asset managers with $62 trillion of assets under management (AUM), which will include fixed income and alternatives, have signed the UN-backed Principles for Responsible Investment. While credit markets may be some way behind equity markets in terms of Sustainable and Responsible Investing (SRI) and ESG integration, it is picking up pace in what is a much larger market.

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52 Global Sustainable Investment Review (2016), GSIA.
Twenty fixed income asset managers with over $19 trillion of fixed income AUM, as well as 14 credit rating agencies have signed the "ESG in Credit Ratings Statement", the purpose of which is self-explanatory. With the global bond market approaching $100 trillion in value, and being much larger than the equity market's $70 trillion, the scope for growth in sustainability-focused investments, especially given their shared longer-term investment horizon is clear.

While subject to the same hurdles and considerations affecting a city's ability to issue municipal bonds, green and social bonds offer scope for cities to attract directly sustainability-focused capital, from potentially more ‘motivated’ lenders which may (though not necessarily) lead to cheaper rates of financing — a debate which we are sure will continue to rage for some time.

6. Innovation Zones

As well as the above initiatives and the many financing routes highlighted in both our Infrastructure for Growth and Energy Darwinism II Citi GPS reports, there are other options available to cities to boost finances and investment, such as innovation zones, essentially areas for development where tax breaks or other incentives are offered to promote investment. These encourage corporates to invest, which in turn boosts employment with all the associated benefits of higher (income) tax revenues, boosted output, lower social costs, etc. This can be particularly important when trying to rejuvenate older industrial areas of towns.

7. Economies of scale

It is also reasonable to assume that there is an optimum scale for revenue collection — to put a tax assessment and collection system in place for a small town is likely to be ineffective and prohibitively expensive. Conversely, as cities become too big there are likely to be bureaucratic diseconomies of scale. While large cities will have to tackle their own bureaucratic complexities, groups of smaller cities clubbing together to achieve scale can provide welcome economies of scale to taxation or income collection.

The same can also be said of purchasing, and not just due to the simple effect of buying in bulk likely to lead to a lower price — scale can also be instrumental in effecting change. Perhaps the best example of this comes in the form of electric buses. Early mover cities which wanted to adopt electric buses were in a minority hence potential order volumes were small, with manufacturers reluctant to devote R&D to developing electric buses, leaving products limited and prohibitively expensive on a piecemeal basis. However, by cities clubbing together, and committing collectively to buy in bulk, manufacturers could see the potential size of the market, and were willing to invest, leading to the development of the product and the potential market size leading to lower pricing.

Accordingly, if cities report, discuss, and compare what they need, and act collectively via networks such as the C40 initiative, they can not only reduce costs, but actually change the options available to them and create new ones. The 26 cities which signed the C40 ‘Clean Bus Declaration’ represented a collective population of 165 million spread over 20 countries, having between them more than 175,000 buses — a sizeable market. This initiative should see around 45,000 zero emission buses in these cities by 2020, resulting in a saving of almost 1m tonnes of emissions.53

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53 C40 Cities Clean Bus Declaration of Intent.
Cities can also group together many thousands of smaller projects, for example via domestic loft/attic insulation or boiler replacement programs, thereby making financing available more widely, yet still utilizing some of the larger and more liquid financial instruments highlighted earlier.
Summary and Conclusions

So, cities are different. While Lagos, New York, and San Francisco generate much of their revenue internally, the U.S. cities have a vast array of fiscal tools at their disposal to generate revenue, such as personal, property, and business taxes, usage charges, fines, etc., while Lagos is reliant on generating 79% of its limited revenue from income taxes. The City of London receives the majority of its income from central government and only has access to revenue from council tax and a percentage of business rates. Many argue that local fiscal autonomy for a metropolitan area is important as it allows local governments to raise additional revenues if needed to provide important services to its residents and develop a city which is internationally competitive. It also provides a platform for the city to leverage some of its revenue streams to borrow money more easily. However, as we have seen it is not clear cut whether fiscal autonomy delivers a ‘better’ and more sustainable city. London, with its more limited fiscal autonomy, still ranks highly in many different global indexes; for example the study done by IESE Business School on ‘Cities in Motion’ ranks cities based on a number of indicators including human capital, social cohesion, the economy, governance, mobility, and transport and international outreach, and it ranks London second after New York City. In the Global City Index developed by A.T. Keaney, London also ranks second after New York City and ranks fourth in its Global Cities Outlook Index which takes into consideration personal well-being, economics, innovation, and government.

IESE Cities in Motion Index

The Cities in Motion Index created by IESE Business School assesses 180 cities representing 80 countries in relation to 10 key dimensions: the economy, human capital, technology, the environment, international outreach, social cohesion, mobility and transportation, governance, urban planning, and public management. The goal of the assessment is to enable the measurement of the future sustainability of the world’s cities together with the quality of life of their inhabitants. The index allows cities to help identify effective solutions since the index identifies both the strength and weaknesses of each city. It uses a number of indicators to help quantify the 10 key dimensions listed above. For example to assess human capital the analysis measures the proportion of population with secondary higher education, movement of students, number of universities, expenditure on leisure and recreation, and others. The index ranks cities according to their total value and according to each key dimension. Fifty-three percent of the cities included in the study have a performance rated high or relatively high, headed by New York City and London. Thirty-two percent of the cities have an average performance while 16% of the cities are classified as low. The index also ranks cities according to each dimension — New York is the first overall ranked place driven by its performance in the economy (first place), technology (second place), and human capital and public management (fourth place). However it continues to score rather low in the dimensions of social cohesion and the environment. London is ranked second and, similar to New York, it ranks high in several dimensions including the economy, human capital, and international outreach but rather low in social cohesion. San Francisco is ranked fifth while Delhi and Lagos are ranked 168 and 179 respectively and need improvements in many of the key dimensions studied — see Figure 35.

There are several other indexes available that compare the performance of cities over time. However they all agree that a city is more powerful, prosperous, and competitive if it manages to develop its various dimensions — from the economy, to the quality of life of its citizens, the use of technology, and to its cultural importance.

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But to do so, we must invest in sustainable cities anyway. As we will see in Section II of this report, which looks at the differences in how cities spend their money, while spend does differ between cities and regions, there are significant areas of commonality, such as education on the operating expenses side and transportation on the capital investment side.

Emerging market cities, with the lowest per capital budgets, are experiencing the most rapid growth in populations. But while much is similar, the most dramatic difference comes in spend per capita between developed and developing markets. While this might seem obvious, it is worth elaborating — not only is the per capita spend in San Francisco a staggering 100 times higher than that of Lagos, developed market cities are much more stable, both in terms of their revenue bases, collection systems, and most importantly the rate of change of needed investment. Conversely, emerging market cities with those lowest per capita budgets already, are the cities experiencing the most rapid growth in populations, with the most dramatic needs for basic service provision, for populations which are often unlikely to have formal employment and are unlikely therefore to be contributing to urban revenues via taxation or usage charges. Moreover, as those populations sprawl outwards in unplanned urbanizations, the cost of providing those basic services becomes disproportionately large as the areas and distances involved become disproportionately larger (think concentric circles).

Building sustainable cities can tackle the challenge of urbanization and reshape the future. As discussed, we can tackle the challenge of urbanization and reshape the future by building sustainable cities which are attractive, healthy, rewarding, and safe places to live, by harnessing the virtuous circle of urban investment which we describe in Section II. The alternative is that we stand idly by while rapid, unplanned urbanization continues to grow in both scale and pace, allowing urban squalor to continue to sprawl, ultimately being faced with the even greater costs of fixing the numerous physical and social problems which will result — and then have to build sustainable cities anyway.

But to do so, we must invest, and if these cities are incapable of raising operating revenues themselves, and if central governments won’t provide finance, then the capital must come from external sources. While development banks may be maxed-out and many other institutions may be constrained by Solvency II and Basel III, there is still room for significant optimism.
New instruments such as green and social bonds offer enormous potential, especially if rather than investing directly development finance institutions or supranationals can provide some form of credit enhancement, thereby effectively leveraging their funds. Numerous examples currently exist in the energy space.

This could help to bring emerging market financial instruments up to investment grade, thereby opening up these markets to the vast pools of international finance which is crying out in this era of historically low returns, for long-dated asset-backed returns such as those offered by infrastructure assets and concessions.

As we have also seen, while national governments may not be willing to stump up the money directly, they can at least do their part by providing the political, regulatory, and legal stability which is so fundamental to facilitating foreign direct investment. Cities can help themselves by collecting and analyzing data, by being transparent with that data, and by cooperating with other cities to share that data, to cross-fertilize best practice, and by acting in concert on areas such as planning and purchasing. Cities should develop longer term investment plans which are insulated from short-term political considerations, and terms of political tenure should be adjusted as appropriate. These should be formulated in conjunction with industry, bringing its long-standing expertise of equipment, infrastructure investment, and operation to the table, and if these plans can be managed by independent bodies such as Urban Wealth Funds, then potentially so much the better.

So, simplistic as it may seem when laid out like this, our 'Seven Steps for Sustainable Cities' are as follows:

1. Political and regulatory stability and the rule of law — at both a national and a local level;
2. Rigorous and consistent data collection from cities, sharing and cross fertilization of best practice;
3. Longer term infrastructure/capital investment programs which are published and developed hand-in-hand with industry and the financial community to mobilize private and corporate investment as well as partnership in concessions;
4. External management of urban assets and capex programs via independent Urban Wealth Funds, which are insulated from short-term political tenure and interference;
5. Innovative financial instruments such as green and social bonds, alongside credit enhancement mechanisms such as pain/gain sharing mechanisms potentially from development finance institutions or supranational organizations;
6. Innovation and industrial zones with associated incentives to encourage corporate investment; and
7. Pooled projects and programs to improve liquidity and purchasing power and mitigate the risk of funding instruments.

The money is there, as is the will to tackle this burgeoning issue which is only going to get bigger, but everyone from central governments, through local urban governing bodies, to financial markets, and industry will have to come together and do their part to make sure that we proactively invest to build cities which work both now and in the future on economic, environmental, and a human level.
Section II
How Cities Spend Their Money
How Do Cities Spend Their Money?

Given our earlier reasoning that cities are not necessarily engines of growth, but that growth is the engine of cities, cities have crucially important choices to make about what type of city they would like to be when they grow up. Do they want to be manufacturing centers, tech and innovation hubs, cultural and tourism centers, centers of trade and finance, or a combination of all of the above? How they choose to allocate and invest their scarce financial resources is crucial to their achievement of both short and longer-term goals.

The Virtuous and Vicious Circles of Urban Spending

Just as cities can be the engines of growth and progress, they can also be endlessly sprawling and expanding centers of decay, disease, and poverty, which can suck the lifeblood out of a nation. So what determines which of these wildly diverging routes a city takes?

Figure 36 and Figure 37 show a highly simplified schematic of both 'the virtuous and vicious circles of urban investment'. Clearly there are thousands of factors which go into determining a city's success, from the personality, drive, and desire of a mayor to eliminate corruption through cultural and historic factors, to physical, geological, demographic, and geographic factors, as well as the tone set at a national level. The majority of these are going to be beyond a city's control, so we are by no means trying to say that this is easy — indeed it is anything but. However, there are steps which cities can take to give themselves a better chance of creating the virtuous rather than vicious circle.

The two cycles are fairly self-evident; an infrastructure deficit, both physical and social, can lead to a decline in economic activity, greater unemployment, and hence lower tax and asset usage revenues and increasing social costs from unemployment, crime, etc. as less is invested in social development and training. This negative spiral often means taxes are raised to fund an ever more indebted city, with less money to invest in infrastructure, both of which then make a city less attractive to business and to skilled workers, and so on. Conversely, cities which are able to invest efficiently in the right infrastructure can benefit from the fiscal multiplier effect, which can lead to greater economic activity, greater employment and potentially lower social costs, as well as greater usage fees and tax receipts, all of which free up more capital for investment.
Put simply, it is the difference between a growing city which is investing for the future, versus a declining city which is spending an ever greater proportion of dwindling receipts on 'operating costs'. At its most simple, it is the contrast between capital expenditure on which a return is being earned, versus operating expenditure which is essentially a sunk cost. To be clear, this isn’t just investment in physical infrastructure — it applies equally well to investment in education (especially if directed towards historically lower achieving areas) which can reduce crime rates, unemployment, and costs/social liabilities in the future.

Clearly how money is invested, on what, and how efficiently makes a massive difference, as we examined in detail our Infrastructure for Growth Citi GPS report. In summary, the key factors we identified for effective investment were as follows:

1. **Bottlenecks and Output Gaps**: Identifying the correct assets to build, and in what order, is critical; the right asset which reduces costs and boosts output (e.g. a bridge which dramatically reduces commuting and transport times and costs, and opens up an area for industrial development and hence job creation) will have a much larger multiplier effect, rather than the famed 'white elephant' projects or bridges to nowhere.

2. **Financial Efficiency**: Infrastructure investments are notorious for overspend and delays, and clearly if a project costs too much it can more than negate any potential benefits. The correct rigor and project management are critical to achieving a large positive multiplier effect. All too often the announcement of huge infrastructure investment program is associated with a 'bottomless pit of money' mentality on the parts of local governments gold-plating assets, while contractors see the associated gold mine and bid in accordingly.

Successful investment can however have negative social consequences — it can lead to increasing house prices, which can lead to greater levels of inequality and can see less financially mobile individuals pushed out to other cities, which may be cheaper as they are in a negative decline spiral. Hence the overall effect on a national economy needs to be considered — a successful city does not necessarily improve the overall national effects by the same amount as it does locally, and it may reduce overall GDP growth and wealth creation.

**Investment Choices**

So what to spend the money on? The easiest place to start is to think about where you would like to live. Most people would opt for a safe city with good employment prospects and a vibrant economy, good schools, attractive leisure, sporting and cultural opportunities and facilities, reliable services, good transport links, and a good balance of civic amenities and parks. While the social and cultural aspects are attractive in their own right, if the employment opportunities are not there, it is unlikely that people will want to live there as, quite simply, they won’t be able to afford it. Hence what attracts businesses to a city is of paramount importance. For a business to commit, it needs basic services, (power, water, waste), and crucially, good IT and communications in the form of fiber/broadband. They need accessibility (local, national, and international transport), potentially local sourcing and end markets depending on the product or service, and crucially a supply of appropriate labor. Of paramount importance is political, legal, and regulatory stability to reduce risk on investment and to enable longer term strategic planning, as well as potentially tax incentives or subsidies on investment. These are also likely to be associated with a ‘safer’ city where the rule of law is paramount and appropriately enforced, with less crime and corruption.
So a successful city needs to develop both from a business perspective and on a personal/social level to allow this symbiotic relationship to develop fruitfully — to focus too much on one might boost short-term results, but is doomed to ultimate failure. To achieve their full economic potential, cities need to be able to provide a multitude of public services — these include investing not only in ‘hard’ infrastructure such as transport networks, clean water, power, and effective waste management but also in other public services such as health, education, cultural facilities, parks, and libraries.

**Who is Responsible for What?**

The nature of expenditure responsibilities, just as the types of revenue tools that a city has available to finance public services varies, depends on the governance of that city. Some cities such as London form part of a unitary country in which administration divisions such as cities and/or provinces exercise only powers that central government chooses to delegate. Other cities such as New York or San Francisco from part of a federal country where there is a federal government plus state/provincial and local governments. The state governments and in some cases local governments have powers to legislate, raise taxes, and other revenue sources and ultimately decide how to spend their budgets.

Some cities are single-tier cities, while others are multi-tier cities where responsibility is divided amongst different government bodies. For example the mayor of London has some executive powers over a number of areas such as transport and policing, while 33 local boroughs in London are responsible for other areas such as waste collection, education, and social care.

As with income, it is very difficult to compare operational and capital expenditure across many cities, given that the level of reporting and the way each city treats its expenditure is very different. The data that is used in this analysis is taken from local budgets and from national statistics offices, and while not always directly comparable, it is still interesting to understand the different spending priorities of different cities.

**San Francisco**

The city has two separate budgets — one for recurrent operational expenses and the other for capital projects. It operates on a two-year budget for its operational expenses and revenue and also engages in long-term planning (a 10-year capital plan) for the city’s infrastructure and information technology needs. The responsibility of the execution of the budget lies largely with the different departments however the Mayor’s Office and the Controller’s Office monitor department spending throughout the year.

**Operating Expenditure**

The recurrent expenditure for the fiscal year 2017-2018 is estimated at $10.2 billion. Thirty-two percent of this amount (gross $3.57 billion) is earmarked for public works, transportation, and commerce which include funds for the municipal transport agency ($1.2 billion), Airport Commission ($0.98 billion) and water and wastewater enterprises ($0.8 billion). Eighteen percent of the budget is expected to be used for public health which includes among other things funding for disease prevention programs, long-term care, and mental health.

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57. [https://lsecities.net/media/objects/articles/governance-structures/en-gb/](https://lsecities.net/media/objects/articles/governance-structures/en-gb/)
The rest of the operational funds are divided between public protection (13%), human welfare (12%), general city (11%), and general administration (10%). The city has also set aside $0.44 billion for culture and recreation which includes museums, parks, and libraries.  

![Figure 38. Operational Expenses, Estimated at $10.2 Billion (gross)](image)

![Figure 39. Public Works, Transportation, and Commerce Operational Expenses, Estimated at $3.57 Billion (gross)](image)

Source: SF Open Book, Citi Research

**Capital Investment**

The city of San Francisco is required by law to prepare a multi-year capital plan. While departments receive money on an annual basis, the city produces a strategic planning document for capital expenditures over a 10-year timeframe. As shown below, the capital plan recommends spending over $35 billion between the fiscal years (FY) 2017-18 to 2026-27 for seven service areas including transportation, recreation, culture and education, infrastructure and streets, etc. The largest proportions of funds are expected to be allocated to transportation projects (43% of funds in FY 2018-22), followed by infrastructure and streets (25% of funds in FY 2018-2022). Examples of transportation projects include a 1.7 mile extension of the existing Third Street light rail line to Chinatown ($1.6 billion) and the redevelopment of Terminal 1 and the renovation of the western side of Terminal 3 ($2.5 billion over the next 10 years) at San Francisco International Airport. The infrastructure and streets program includes investment in streets, water, power, and sewer systems ($6.1 billion FY 2018-22). For the year 2018, it is estimated that over $7 billion will be invested into infrastructure projects.

New York

Operating expenditure

For 2017, the adopted expense budget for New York City was estimated at $82 billion. Twenty-eight percent of this total was earmarked for education, 18% for general welfare, 11% for pension contributions, and 7% for public safety. Four percent of the budget was set aside to pay for debt.

Source: New York City Council, Citi Research

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OND, The City and County of San Francisco Capital Plan, Fiscal Years 2018-2027
New York has a five-year capital commitment plan. New York City’s Capital Commitment Plan for the FY 2018-2022 commits $79.6 billion, of which $71.9 billion will be city-funded.\(^{61}\) This is divided into six main sectors which include environmental protection, transportation, education, housing and economic development, administration and justice, and city operations and facilities (see Figure 43 below). The largest proportion of the capital plan is allocated to city operations and facilities (28% of total plan FY 2018-2022) which include parks, public buildings, sanitation, health, fire, and cultural institutions (see Figure 44 below).

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London Operating Expenditure

Similar to San Francisco and New York, the city of London has both revenue and capital expenditure budgets. The revenue expenditure budget for the year 2017-2018 is estimated at over £18 billion ($25bn). Thirty-five percent of the spending is earmarked for education, 16% for policing, 13% for adult care, 8% for transport, and 8% for children’s social care.

Figure 45. Total Operational Expenditure for the City of London — £18.3 Billion

The £18.3 billion expenditure budget is split between London’s 33 boroughs and the Greater London Authority (GLA) (see Figure 46 and Figure 47 below). The boroughs spend the majority of revenue on education (48%), adult care (17%), and children’s social care (11%). The GLA on the other hand, spends the majority of its operational revenue on police services (61%), followed by highway and transport (27%). In transport, the Mayor of London is responsible for Transport for London (TfL) which manages the underground, overground, light railway (DLR), buses, river services, trams, and taxi services. The governance of the road network in London is divided between TfL and London boroughs.
The majority of capital expenditure funds are earmarked for Transport for London

Capital Expenditure

A total of £21.6 billion ($30.2bn) has been estimated for capital expenditure on different projects in London from 2016-2021. The majority of this has been earmarked for Transport for London as shown in the figure below (71% of funds in 2017-2018). These includes funds for the completion of Crossrail, the modernization of a number of tube lines, the Northern line extension, major station upgrades, and improvements in infrastructure for pedestrians and cyclists as part of the health streets initiative.

Figure 48. Capital Plan for London 2016-2021

Source: Greater London Authority, The Mayor of London’s Capital Spending plan 2017-2018

62 Greater London Authority, The Mayor of London’s Capital Spending plan 2017-2018
Lagos

The State of Lagos prepares one budget document which includes both its operational and capital expenditure plans. In 2017, the State government committed to spending a total of N812.98 billion ($2.3bn) on all projects (operating and capital expenditures), a remarkably small number versus New York or London, given that the city has between two and three times the population, respectively. Recurrent expenditure was estimated at just N300.535 billion ($0.84bn) while capital expenditure was N512.464 billion ($1.43bn). The majority of the revenue expenditure was earmarked for general public service which includes amongst others governance, economic planning and budget, finance, science and technology, and loans repayment.

Over 50% of the capital budget is earmarked for economic affairs which includes works and infrastructure and transportation. According to the State’s budget document a total of N542 billion ($1.5bn) is set aside for critical infrastructure projects which include road infrastructure (N141 billion) and education (N92 billion) — see Figure 50 below. The budget document also states that the State government intends to improve water supply and ensure efficient waste management systems through Private Public Partnerships.

Delhi

India’s capital, New Delhi (one of eleven districts within Delhi), is jointly administered by the federal government of India and the local government of Delhi. Delhi’s 2017-18 budget report saw two interesting changes — the shift from its traditional framework of budgeting into “plan” and “non-plan” towards dividing the budget between “Revenue” and “Capital”, and the introduction of its “Outcome Budget”, which aims to shed transparency and accountability on public spending.⁶⁴,⁶⁵

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⁶³ Lagos State Government, Y2017 Abridged Annual Budget
⁶⁴ Delhi 2017/18 Budget
⁶⁵ Delhi 2017/18 Budget Speech
Operating expenditure

The 2017-18 operational budget is estimated at $6 billion. Fifty-eight percent of this amount (~$3.5 billion) is reserved for Social and Community Services that encompass funds primarily for General Education ($1.5 billion), Medical & Public Health ($780 million), Urban Development ($375 million), and Social Security and Welfare ($360 million). Nine percent of the budget is expected to be used for Transport which will be predominantly used for Road Transport, in addition to Roads & Bridges, and Other Transport Services. The remainder of the operational funds are split between Interest Payments & Servicing of Debt Interest Payments (8%), Fiscal Services (6%), Administrative Services (5%), Irrigation and Floor Control & Energy (5%), Economic Services (4%), with the remaining 9% largely going towards Loans to Government Servants, and Grants-in-Aid and Contributions.

![Figure 51. Planned Operational Expenditure 2017-2018](image1)

![Figure 52. Social and Community Services Expenditure](image2)

Source: Government of National Capital Territory of Delhi; Citi Research

Source: Government of National Capital Territory of Delhi; Citi Research

Capital Expenditure

Unlike other cities that periodically produce multi-year capital plans, Delhi’s capital expenditure plans are disclosed on an annual basis vs. producing multi-year capital plans. Delhi’s capital expenditure plans are disclosed on an annual basis in each of its budget reports. The remaining $1.5 billion of Delhi’s budget is aligned to capital expenditure, representing 20% of the total budget, again a staggeringly small figure given the population of 18-28 million. Of this, only ~$0.8 billion (54%) is expended on capital, with the remaining 46% exhausted on repaying debt on previous capital investments, titled Loans & Advances. Other cities include repayment of loans and payments in their operational budget. The majority of the loans were used for water supply & sanitation, power projects, and road transport purposes. Delhi disseminates the $0.8 billion between three categories, namely General Services (7%), Social Services (45%), and Economic Services (48%). Of this amount, Roads & Bridges (23%), Education, Sports Art and Culture (21%), Medical & Public Health (13%), and Other Rural Developments (11%) are most heavily invested.
Comparing City’s Spend

The above sections highlight the different operating and capital expenditures of a number of cities for a particular year. Each city is governed differently, some are more autonomous than others and have a number of fiscal tools that are available to raise revenue (i.e., New York and San Francisco), while others depend mostly on the central government for their finances and only have limited fiscal tools that they can use to raise revenue (i.e., London). Most cities mentioned above have different priorities and different responsibilities. For example the government of London (GLA and local boroughs) is responsible for London transport which includes underground, overground, buses, taxies, and light rail, but doesn’t include national rail or national airports which are run either privately or by central government.

Some cities have similar priorities. For example New York, London, Lagos, and Delhi spend a large amount of their operational budget on education — 35%, 28% 19%, and 25% in London (GLA and borough’s budget), New York, Lagos, and Delhi, respectively. Where education is not listed in municipal expenses (e.g., San Francisco) it could be delivered by a separate authority or by the state government or grouped up within a sector. Transportation is a significant operational expenditure in London (8% of operational budget of both local boroughs and GLA) and Delhi (9% of operational budget) but it does not account for a very large percentage in other cities budget. San Francisco allocates 32% of its operational budget to public works, transportation, and commerce of which 26% is allocated to the airport commission and 31% to municipal transport. In New York City only 4% is allocated to transport — this is because transportation is delivered by the Metropolitan Transit Authority which is under the responsibility of the State of New York. It is not quite clear from Lagos’ budget documents how much of its recurrent expenditure is used for transportation. In Delhi 58% of its operational budget is allocated to social and community services which include public welfare and urban development.

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While not strictly ‘urban’ in definition, the IMF data on ‘local government spend’ (which as we have seen, the vast bulk of which will be urban) demonstrates some not so surprising results — that developed markets generally spend far more at a local level on social protection, health, recreation, and the environment, while emerging markets spend more on social housing and general public services.

With regards to capital expenditure, the largest proportion of funds in London and San Francisco are allocated to transportation — 71% of total 2017-2018 capital plan in London and 45% of the 2018 capital plan in San Francisco. In New York City over 30% of its capital budget is allocated to city operations which includes parks, public buildings, health, fire, cultural institutions, sanitation, and others, while in Lagos 50% of its capital budget for 2017 is earmarked for economic affairs. This includes agriculture, commerce and industry, tourism, transport, and works and infrastructure. In Delhi (besides loan repayments which are included in the capital budget) the majority of its capital investment is allocated to roads and bridges, education, and health.

So while we see large brackets of common spend starting to emerge, such as education on the operating side and transport on the capital side, as highlighted previously the lack of complete data or indeed comparable data proves a real stumbling block for cities to benchmark themselves against others and exchange best practice.

It is not only the percentage of operational and capital expenditure allocated to different sectors and entities that is interesting. The absolute spend and spend per capita is perhaps the biggest and most shocking takeaway. Figure 57 compares the capital and operating expenditures and the population size in the different cities. New York City seems to be a complete outlier with both operational and capital expenditure exceeding other cities for the size of its population, though this is as much as anything an effect of the amount of its budget which is devolved from central and state governments. The emerging cities of Lagos and Delhi spend far less, despite having dramatically larger populations than other cities studied. This is best demonstrated by looking at per capita spend as shown in Figure 58.

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**Figure 56. Local Government Spend Differentials Between Developed and Emerging Countries**

Source: IMF, Citi Research
The per capita spend (both operational and capital) in Lagos and Delhi are particularly small when compared to more developed cities, despite populations increasing at a rapid pace in these emerging cities, with an urgent need for infrastructure investment. San Francisco spends the most per capita followed by New York City, while London is a unique case as it only includes operating and capital expenditure by GLA and boroughs, and not any operating or capital expenditure undertaken by central government or other bodies. With Delhi it is not entirely clear (again due to a lack of data and transparency) whether central government funds other bodies that are in charge of capital projects in the region.

Population in Delhi is estimated at 27.9 million; in Lagos it is estimated at 17.5 million

Source: Citi Research

Source: Citi Research
Section III – How Can Cities Invest More Sustainably
Energy in Sustainable Cities

When we think about energy usage in cities, it is not the energy per se which interests us, rather it is two different impacts, firstly in terms of the impact on the environment — both holistically in terms of their impact on global warming, and locally in terms of air quality and pollution — and secondly in terms of the provision, resilience, and affordability of energy, given its potential to transform the lives of a city's inhabitants.

Energy usage in cities is of enormous significance; according to UN Habitat, cities are responsible for 78% of primary energy usage globally, and also emit between 50-60% of total global greenhouse emissions, rising to around 80% if we include indirect emissions generated by urban populations. Accordingly, how much energy we use in cities, and how we generate that energy has an enormous impact not just within cities, but on the planet overall.

Just over a billion people around the world still lack access to electricity, (with half of those living in sub-Saharan Africa). However, lack of access to electricity is a predominantly rural issue, with 96.3% of the world’s urban populations having access to electricity in 2014, versus only 73% for rural populations.

![Figure 59. Access to Electricity — Urban vs. Rural by Region](image)

Source: Sustainable energy for all global tracking framework, 2017. Citi Research

Of the 1.06 billion people around the world who lacked access to electricity in 2014, only around 130 million of them were in urban centers, the rest being rural, and of those urban figures, 105 million were in Africa, the remainder being in Asia-Pacific cities.

The rate of electrification in urban areas throughout the world is generally outpacing the growth in population, with 81 million new urban connections between 2012 and 2014, versus an increase in global urban population of 78 million. Unfortunately the corollary of that is that rural access is increasing more slowly than population increase.
Access to electricity is not the only energy issue for cities though; globally, 53% of the population in low-and middle-income countries still lack access to clean fuels and technologies for cooking in 2014, equating to more than 3 billion people, the bulk of that figure being in Asia and, once again, sub-Saharan Africa. Once again, this is more of a rural issue than an urban one, with 78% of the world’s urban population having access to clean cooking fuel, versus only about 22% for rural populations (in emerging markets only). However, this data belies the fact that it will be the poorest urban populations living in slum areas which are most likely to be using polluting cooking fuels such as wood, charcoal, or coal, which can lead to significant levels of indoor pollution with all the associated health effects (source WHO 2016). The IEA’s base case scenarios suggests that by 2030, while more than 780 million people will still lack access to electricity — a predominantly rural effect — there will still be around 2.3 billion people who lack access to clean cooking fuels. While once again more of a rural issue, the significantly greater proportion of those in cities (vs. lacking access to electricity) means that providing access to gas networks could have a significant impact on urban levels of pollution.

Affordability appears to be less of an issue though. According to a recent World Bank report ‘Regulatory Indicators for Sustainable Energy’ (RISE), electricity is deemed to be unaffordable if a usage level of 30kWh per month per home costs more than 10% of the gross national income per household, for the bottom 20% of households. The report demonstrates that for countries with an access to electricity figure of less than 90% (with populations of >1 million people), basic consumption costs less than 5% of the indicator in 73% of those countries. Given that urban incomes are likely to be greater than rural incomes, we see affordability, while important for those that cannot, as a limited issue in terms of its scale regarding urbanization.

So, if access to energy is not the biggest issue, it is how that electricity is generated which is the largest potential issue?
As Figure 60 and Figure 61 show, while the global population is set to rise from 7.4 billion in 2015 to 9.8 billion in 2050, the rate of growth in urban populations is set to rise from 4 billion to 6.3 billion over the same time frame. In terms of growth rates, what this means is that while the global population is set to rise at a CAGR of 0.8%, urban populations are set to rise at a rate of 1.4%, or to look at it another way, a 70% faster growth rate.

Figure 62 and Figure 63 highlight this in further granularity, showing that urban population growth rates in Africa and Asia far outstrip global population growth, and indeed population growth rates overall in those regions due to rapid urbanization, as shown in Figure 64 below.
Energy usage will rise significantly more quickly than the global average per capita consumption in those areas seeing the most rapid rise in urbanization.

So much for population growth, but what has this got to do with energy? Put simply, energy usage per capita is far lower in those areas seeing the most rapid rise in urbanization, but will rise significantly more quickly than the global average per capita consumption as GDP per capita rises, creating a disproportionately large demand for energy. Moreover, emerging markets tend to have a significantly more ‘dirty’ energy mix than developed markets, understandably so as they are often going for the fastest and cheapest form of energy, which often tends to be coal.

Figure 65. Energy Usage Per Capita vs GDP Per Capita in Cities Around the World

While the correlation is not great, there is clearly a corresponding increase in cities in energy demand per capita as GDP per capita increases.

This is particularly important if we look at GDP per capita in the regions where we are forecasting the largest growth in urban populations, as this GDP per capita is starting from a low base, and will grow rapidly, leading to disproportionately large energy demand increases.

Combining all of these effects produces the worrying, yet intuitively correct picture in Figure 66, which shows that those regions with the largest urban populations, are seeing fastest rates of growth in urban populations, and on top of that, the fastest rates of growth in energy usage per capita.
Figure 66. The Most Populous Areas of the World are Exhibiting the Fastest Rates of Urbanization and the Fastest Growth in Energy Usage Per Capita

![Chart showing the most populous areas of the world with the fastest rates of urbanization and energy growth.]

Source: Citi Research, World Bank, IMF Data

The primary focus of our worrying picture of the interplay between urbanization and climate change is provided by looking at the energy mix by region.

Figure 67. OECD Primary Energy Demand by Fuel, Base Case

![Chart showing OECD primary energy demand by fuel from 2013 to 2050.]

Source: International Energy Agency, Energy Technology Perspectives 2016 - www.iea.org/etp2016, 4 degree scenario; Citi Research

Figure 68. Non-OECD Primary Energy Demand by Fuel, Base Case

![Chart showing non-OECD primary energy demand by fuel from 2013 to 2050.]

Source: International Energy Agency, Energy Technology Perspectives 2016 - www.iea.org/etp2016, 4 degree scenario; Citi Research

Emerging markets tend to use ‘dirtier’ fuels and have greater capita intensity per unit of GDP. Those mix differentials can best be seen in two charts from our Energy Darwinism II GPS, which highlight the greater carbon intensity per unit of GDP in less developed countries, and that emerging markets typically tend to use ‘dirtier’ fuels, as we have seen in the previous charts.
So, in summary, the outpaced energy demand from rapidly urbanizing emerging markets creates pressure to provide cheap energy quickly, which can promote the use of dirty and carbon intensive fuels.

Urban emissions from emerging cities are already reaching the rates of large developed cities. For example Beijing, Shanghai, and Tianjin have per capita emissions similar to those of large European and some Northern American cities.  

According to the World Bank, cities meet approximately 72% of their total energy demand from coal, oil, and natural gas, and while they also use about 70% of the energy generated from renewable resources around the world, those sources still only represent a very small proportion of the total energy consumed. The reality for most cities is that they are under severe space constraints (especially the rapidly expanding ones) which means that large scale renewable sources such as wind turbines are often impractical, not least from a sound, light reflection, and safety issues. While solar is easily deployable in cities, the density of humans means that roof space per capita is likely to be significantly lower (think tower blocks), and hence the ability to meet the needs of consumers from solar is more limited than it is rurally. Hence the majority of cities obtain their electricity from large-scale power plants transmitted over a distance, and given this, the reality is that while cities can make a difference to their energy use and their carbon footprints as we shall see later, the issue from an electricity perspective at least, is largely a central government one in terms of the national generation mix. As we shall also see though, electricity is actually a relatively small part of the overall energy issue in cities.

Having examined the issue of national energy mixes around the world, their impact on climate change and the potential solutions in our Energy Darwinism II report we do not intend to regurgitate the debate here. However, there are measures that cities can take, and to understand what those are, we first need to understand what cities use energy for.

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67 Better Climate, Better Growth, Chapter 2 cities.
68 World Bank, Cities contribution to climate change.
Energy Use in Cities

Where Do Cities Get Their Energy From?

While commenting that electricity mixes may be more of an issue for central governments, what this misses is that electricity only represents one element of the energy usage of a city. As Figure 71 and Figure 72 show, electricity only represents about a quarter of final urban energy demand in developed economies, and around a fifth in emerging markets. Gas represents a much bigger share in developed economies being used for heating and for industry, while oil takes such a big share due to its use in road transport. For emerging markets, the much larger share of coal reflects its greater use in what is a much higher share of industrial activity in emerging markets. The scale of the charts is also different and worth bearing in mind, with final urban energy demand in emerging markets being 24% higher than in developed markets.

Figure 71. Final Urban Energy Demand, OECD

![Energy Demand Diagram](energy-demand-oecd.png)


Figure 72. Final Urban Energy Demand, Non-OECD

![Energy Demand Diagram](energy-demand-nonoeconom.png)


It is also important to understand where that electricity comes from, and how it differs between markets. Figure 73 and Figure 74 show the generation type which provides the electricity for urban consumption around the world, clearly highlighting the much greater proportion of coal which is used in emerging markets. As we highlighted in our Energy Darwinism II report looking at the economics of climate change and potential solutions, how we meet the huge demand which, as discussed, will come from urban centers in emerging markets, is one of the most critical questions as to whether we are successful in limiting climate change to less than 2 degrees Celsius.

In emerging markets, coal makes up a much larger share of urban energy demand

How we meet the huge electricity demand coming from urban centers in emerging markets is critical to climate change policy
The shocking reality is that almost half of all primary energy demand in emerging markets comes from coal.

Pulling the previous charts together in terms of primary energy demand, i.e., as far up the value chain as we can go, produces the charts shown in Figure 75 and Figure 76. They highlight the rather shocking picture that almost half of all primary energy demand in emerging markets comes from coal. Conversely, the higher urban oil usage in developed markets reflects our historically insatiable appetite for the internal combustion engine. The silver lining though is that Electric Vehicle penetration increases, and as more developed markets move away from coal due to legislation, carbon taxes, or potentially a lack of financing, urban energy mixes in developed markets should improve, though clearly there is no room for complacency. As discussed, the real challenge comes in emerging markets given the growth prospects and the predominance of coal in the primary energy mix.
How Do Cities Use Energy?

Understanding what cities use energy for is critical to working out how we can ultimately reduce energy use, and reduce emissions. Figure 77 and Figure 78 highlight the differences in final urban energy demand between developed and emerging markets.

The first thing which leaps out is the huge significance of industry in emerging markets. This is perhaps unsurprising given the focus of manufacturing in emerging markets versus (simplistically) more service led-economies in developed markets. While residential use is similar (in fact almost identical in absolute terms, though clearly across a much larger population in emerging markets), transport takes a much larger share in developed markets, again not least due to levels of car ownership.

These charts start to give us an idea about where we should begin in terms of trying to reduce energy usage in cities, by focusing on buildings (both residential and office) and transportation, as well as trying to improve energy efficiency and choice of primary energy source for industry in emerging markets. Reducing energy usage is only one half of the picture though — we also need to look at where emissions come from, which are clearly a mixture of the levels of energy demand, but also which sources are used to provide that energy.

Emissions in Cities — Where Do They Come From?

Figure 79 shows us that the previous pie charts may have lulled us into a false sense of security about how to fix the problem. While final energy demand may only be in total around 24% higher in emerging market cities than in developed markets, the emissions picture looks very different, once again because of the dominance of industry in emerging markets, and its', as well as power generation's, dependence on coal.
So, simplistically, in developed markets, where electricity is a greater share of energy use, we should focus on energy efficiency and greening the generation mix, while continuing to look at transport, buildings, and industry in almost equal measure (though some sectors have more low hanging fruit, as we shall see). In emerging markets however, the focus needs to be on greening the energy mix for both industry and power generation, and in terms of the huge growth that is forecast in populations, building energy and resource efficient buildings which are fit for the future and do not lock in emissions for decades to come, as well as focusing on urban design to promote low carbon forms of transport, be they cycling, or low emission per passenger kilometer forms of mass transit.

**Sustainable Urban Energy Solutions**

To look at potential solutions it is easiest to look in turn at the sectors of energy use and emissions. We have not focused on ‘industry’ in this report or indeed the electricity generation mix overall, given that as discussed these are more macro issues in terms of energy mix, and have been covered in great detail within our Energy Darwinism II report, and are not, as we see it, a peculiarly urban issue. That is not to say that energy efficiency will not play a hugely significant part in reducing that demand, but again this is not a specifically ‘urban’ issue. Instead, we have chosen to focus on buildings (both residential and commercial) and transport.

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**Figure 79. Direct Urban CO₂ Emissions by Sector, OECD and Non-OECD**

As Figure 80 and Figure 81 show, both energy usage and emissions from residential buildings are around twice those of commercial buildings, not least due to the fact that cooking is a largely domestic activity (unless of course you're a chef). Cooking is important, not least as we discussed earlier in terms of the huge proportions of people in cities around the world who still lack access to clean cooking fuels, and residential pollution caused by this is a major contributor to deaths and health problems in emerging markets.

Energy efficiency standards in appliances in homes clearly have a major part to play, and again are more of a national/regulatory issue, though clearly cities can apply minimum standards, or indeed provide subsidies for energy efficiency in appliances. Lighting is also important, though more so for commercial buildings and relatively easy solutions such as phasing out of incandescent bulbs in favor of energy efficiency alternatives such as LED's with smart lighting sensors can make a major difference.

The elephant in the room though is clearly heating, primarily of space, but also of water. Water heating again has some fairly obvious solutions, in terms of efficient boilers, such as combi boilers which negate the need for hot water tanks, heating water on demand, as well as providing hot water for central heating. Where appropriate in the world, solar thermal water heaters on roofs are a very energy efficient alternative with effectively zero running costs, though as with solar PV, limited roof space per capita in urban centers may make this hard to apply.

Incentive schemes for boiler replacement, such as subsidies, have been around for a long time in developed markets and offer obvious potential savings in terms of money, energy usage and emissions.

The real issue though is space heating, being responsible for almost half of urban residential building CO₂ emissions, and over 70% of urban commercial building emissions. With a focus on the future, and the huge expansion in both population and economic activity from cities, especially in emerging markets, urban authorities insisting on minimum building energy usage standards (insulation etc.) will make a huge difference to the energy footprint of urban buildings going forward. If done properly, savings can be material and payback periods very short, but as always,
Residential planning in emerging markets offers huge potential but given the age of buildings in developed markets, it becomes more of an issue.

Regulation is needed to kickstart the process back up the design, building materials, and construction stage.

Residential also offers huge potential in emerging markets for the same reasons, especially if urban planning is approached in a holistic fashion, with greater population densities (which lead to lower overall energy use and emissions, via lower transportation requirements, etc.). Housing more people in larger (but attractive) buildings offers scope for energy efficiency on a much greater scale and at much lower cost per capita than individual residences.

Strangely enough, this is more of an issue for developed markets than for emerging market cities though, given the generally much greater age of buildings in developed markets. Retrofitting is typically more expensive than incorporating energy efficiency in new designs using new materials, and is often hampered by attempting to preserve (quite rightly) the heritage of buildings. The fact is that older buildings were not built with energy efficiency in mind, and moreover, the materials which were available at the time were significantly more limited than is now the case. London offers a case on point here, as shown in Figure 82.

Figure 82. Age of Buildings in London

Source: https://data.london.gov.uk/dataset/property-build-period-1soa

While completely draught-proofing a Georgian house may not be easy, or even advisable given the porous bricks used in their construction, there are options available for older buildings, in terms of synthetic window replacement/refurbishment, partial reduction of air flow in chimneys, heating system updates, and perhaps most of all, insulation of roof spaces, as well as the previously mentioned options on boilers and water heaters.
Transport

With a chapter of this report devoted entirely to transport and potential solutions therein for sustainable cities, we do not intend to revisit that analysis here; however, it is extremely important, as with buildings, to understand exactly where those emissions come from if we are to attempt to tackle the biggest or easiest wins first.

Figure 83 shows that, unsurprisingly, our energy use for transport in cities is very much based around oil-based products. What may be less obvious is just how much bigger, as shown in Figure 84, light road transportation is in terms of its energy usage, especially when compared to rail, which on that scale barely measures.

Oil-based products dominate energy use for transport in cities but mostly in light road transportation vs. heavy or rail

Figure 85 shows that, unsurprisingly, our energy use for transport in cities is very much based around oil-based products. What may be less obvious is just how much bigger, as shown in Figure 84, light road transportation is in terms of its energy usage, especially when compared to rail, which on that scale barely measures.

Oil-based products dominate energy use for transport in cities but mostly in light road transportation vs. heavy or rail

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Figure 85 shows that, unsurprisingly, our energy use for transport in cities is very much based around oil-based products. What may be less obvious is just how much bigger, as shown in Figure 84, light road transportation is in terms of its energy usage, especially when compared to rail, which on that scale barely measures.
A similar picture emerges in terms of overall urban transport emissions (passenger and freight), as demonstrated in Figure 85, where light road (i.e. car) emissions dramatically outweigh heavy road emissions, with rail again appearing negligible.

What this captures as much as anything though, is just how much we like travelling in cars; what we really need to look at to decide what to focus on in terms of reductions, is the emissions intensity of each mode of transport, in terms of the amount of emissions per kilometer traveled. This is shown in Figure 86, and the results are striking, if perhaps intuitively unsurprising. What this demonstrates is that light road vehicles, i.e. cars, produce significantly more emissions per passenger kilometer traveled, and most worrying is that we use these for by far the greatest number of kilometers traveled. It is striking that heavy road (i.e. buses) are similar to rail in emerging markets (where occupancy is high) and in particular, how small rail’s emissions are (and sadly, the number of kilometers traveled). To put it in perspective – our calculations imply that traveling a car in an OECD city produces almost six and a half times the amount of CO₂ emissions that travelling by rail would over the same distance.

As above, we do not intend to revisit the transportation section here, but suffice to say, getting cars off the road (or swapping internal combustion engines for electric vehicles as an interim measure) via car scrappage schemes, (time of day) congestion charges or higher parking costs. Moving people onto bicycles and mass transit systems, be they buses (electric) or rail, would have an enormous effect on energy usage and emissions in cities, as well as free up huge amounts of space from roads and parking lots, and potentially lead to a dramatic improvement in quality of life in terms of air quality, and open (pedestrianized?) urban spaces.
Water and Sanitation

It is estimated that over 800 million people do not have access to clean water and 2.4 billion people lack access to basic sanitation services. Every day nearly 1,000 children die due to preventable water and sanitation-related diseases. It is also estimated that 80% of wastewater resulting from human activities is discharged into rivers or into the sea without any sort of treatment. Clean water is at the core of sustainable development and is critical for socio-economic development, health ecosystems, and for human survival.

Rapid population growth, coupled with an increase in wealth and dietary changes is expected to increase the global demand for water. The demand for water for domestic purposes (cleaning, sanitation and drinking) is expected to increase from 400 km$^3$ to 660-900 km$^3$ by 2030. The majority of this demand will occur in cities, however as we have highlighted in our Citi GPS report Solutions for a Global Water Crisis, a number of cities are already facing acute water problems (see Figure 87). They are particularly vulnerable because they depend on the water resources from outside their city boundaries. They face twin challenges; water that is both scarce and water that is polluted. According to McDonald et al. (2014), 100 of the largest cities in the world currently occupy less than 1% of land area, however their source watersheds (i.e. rivers, forest, ecosystems) cover over 12% of land area. This is equal to approximately 1.7 billion hectares of land that collects filters and transports water to nearly 100 billion people before reaching man-made infrastructure. Cities play a significant role in the management of water, as they impact both the quantity and quality of water resources due to land use change, over exploitation of water resources and contamination. Therefore it is not only adequate infrastructure that cities need to provide, but sustainable solutions outside their city boundaries. However, infrastructure does play at important part, and in many areas, city infrastructure has not kept pace with the massive urban growth, leaving people without adequate access to clean drinking water and sanitation. The concentration of millions of people into small areas increases the stress on finite water supplies available in or near city centers.

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69 Sustainable Development Goals- Goal 6: Ensure access to water and sanitation for all.
70 Citi, Solutions for a Global Water Crisis, The End of Free and Cheap Water.
72 Ibid.
### Figure 87. Largest Cities Under Water Stress

<table>
<thead>
<tr>
<th>Urban agglomeration</th>
<th>Country</th>
<th>Population in 2014 (Million)</th>
<th>Population 2030 (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyo</td>
<td>Japan</td>
<td>37.8</td>
<td>37.2</td>
</tr>
<tr>
<td>Delhi</td>
<td>India</td>
<td>24.9</td>
<td>36.0</td>
</tr>
<tr>
<td>Shanghai</td>
<td>China</td>
<td>22.9</td>
<td>30.0</td>
</tr>
<tr>
<td>Mexico City</td>
<td>Mexico</td>
<td>20.9</td>
<td>23.8</td>
</tr>
<tr>
<td>Beijing</td>
<td>China</td>
<td>19.5</td>
<td>27.7</td>
</tr>
<tr>
<td>Karachi</td>
<td>Pakistan</td>
<td>16.9</td>
<td>27.4</td>
</tr>
<tr>
<td>Kolkata</td>
<td>India</td>
<td>14.7</td>
<td>19.0</td>
</tr>
<tr>
<td>Istanbul</td>
<td>Turkey</td>
<td>13.9</td>
<td>16.7</td>
</tr>
<tr>
<td>Chongqing</td>
<td>China</td>
<td>12.9</td>
<td>17.4</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>Brazil</td>
<td>12.8</td>
<td>14.1</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>U.S.</td>
<td>12.3</td>
<td>13.3</td>
</tr>
<tr>
<td>Moscow</td>
<td>Russia</td>
<td>12</td>
<td>12.2</td>
</tr>
<tr>
<td>Tianjin</td>
<td>China</td>
<td>10.8</td>
<td>14.7</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>China</td>
<td>10.6</td>
<td>12.0</td>
</tr>
<tr>
<td>London</td>
<td>U.K.</td>
<td>10.1</td>
<td>11.4</td>
</tr>
<tr>
<td>Lima</td>
<td>Peru</td>
<td>9.7</td>
<td>12.2</td>
</tr>
<tr>
<td>Bengaluru</td>
<td>India</td>
<td>9.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Chennai</td>
<td>India</td>
<td>9.6</td>
<td>13.9</td>
</tr>
<tr>
<td>Hyderabad</td>
<td>India</td>
<td>8.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Wuhan</td>
<td>China</td>
<td>7.8</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Source: McDonald et al. (2014)\(^{73}\), UN (2014)\(^{74}\), Citi Research

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\(^{76}\) Ibid.
The 100 largest cities currently transfer a total of 3.2 million cubic meters of water at an average distance of 5,700 km every day in artificial channels. For example the city of Los Angeles obtains on average nearly 9,000 million liters of water per from the Owens River via the Los Angeles Aqueduct and the Colorado River Aqueduct, thousands of miles from the city. Interbasin transfers secure over 180 million people from scarcity which is excellent however the infrastructure needed for long distance transport of water is not cheap. Not all cities can afford to build complex transbasin infrastructure systems. This creates a divide with rich cities able to buy their way out of scarcity and poor cities relying on local water resources for their needs. Developed and developing cities have different problems — developed cities need to continue to maintain their infrastructure while developing cities need to build new infrastructure that enables their residents to have access to clean water and sanitation. It is also not only the quantity of water that is important, but the quality of water received by the city.

**Figure 90. Cross-basin Transfers in Different Cities**

<table>
<thead>
<tr>
<th>City</th>
<th>Country</th>
<th>Population in 2014 (Million)</th>
<th>Cross-basin transfer (Million litres per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>USA</td>
<td>12.3</td>
<td>8895</td>
</tr>
<tr>
<td>Boston</td>
<td>USA</td>
<td>4.7*</td>
<td>3307</td>
</tr>
<tr>
<td>Mumbai</td>
<td>India</td>
<td>20.7</td>
<td>3220</td>
</tr>
<tr>
<td>Karachi</td>
<td>Pakistan</td>
<td>16.1</td>
<td>2529</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>China</td>
<td>7.2</td>
<td>2447</td>
</tr>
<tr>
<td>Alexandria</td>
<td>Egypt</td>
<td>4.4*</td>
<td>2300</td>
</tr>
<tr>
<td>Tianjin</td>
<td>China</td>
<td>10.8</td>
<td>2179</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Japan</td>
<td>37.8</td>
<td>2170</td>
</tr>
<tr>
<td>San Francisco</td>
<td>USA</td>
<td>3.6*</td>
<td>2014</td>
</tr>
<tr>
<td>San Diego</td>
<td>USA</td>
<td>3.2*</td>
<td>1442</td>
</tr>
<tr>
<td>Ahmedabad</td>
<td>India</td>
<td>7.1</td>
<td>1363</td>
</tr>
<tr>
<td>New York</td>
<td>USA</td>
<td>18.6</td>
<td>1348</td>
</tr>
<tr>
<td>Tel Aviv</td>
<td>Israel</td>
<td>3.3*</td>
<td>1225</td>
</tr>
<tr>
<td>Pretoria</td>
<td>South Africa</td>
<td>1.5*</td>
<td>1217</td>
</tr>
<tr>
<td>Sydney</td>
<td>Australia</td>
<td>4.5*</td>
<td>1210</td>
</tr>
<tr>
<td>Chennai</td>
<td>India</td>
<td>9.6</td>
<td>1130</td>
</tr>
<tr>
<td>Algiers</td>
<td>Algeria</td>
<td>2.8*</td>
<td>1070</td>
</tr>
<tr>
<td>Aleppo</td>
<td>Syria</td>
<td>3.0*</td>
<td>1062</td>
</tr>
<tr>
<td>Athens</td>
<td>Greece</td>
<td>3.3*</td>
<td>1036</td>
</tr>
<tr>
<td>Cape Town</td>
<td>South Africa</td>
<td>3.4*</td>
<td>994</td>
</tr>
</tbody>
</table>

Source: McDonald et al. (2014), Citi Research

The inadequate supply of water can cause damage to an economy. One has to just read about the water crisis in Cape Town and the effect that a shortage of water is having on the agriculture sector, on industry, tourism, and on the city’s inhabitants. The World Health Organization estimates that the total global economic losses related to inadequate water supply and sanitation to be in the region of $260 billion annually. Climate change could also have a severe impact on water supply in many cities, in fact the World Bank ranks water supply and flood protection as one of the three adaptation costs to climate change estimated between $14.4 and $19.7 billion per year.77 In our Citi GPS report *Solutions for the Global Water Crisis* we estimated that an infrastructure investment of $7.5 to $9.7 trillion is needed globally to upgrade, maintain, and build new infrastructure.

Traditionally much of the investment in water in cities has focused on grey infrastructure such as building wastewater treatment and desalination plants. Even though grey infrastructure plays an important part in solving a city’s water problem, it is essential that detailed studies are undertaken to ensure that these large capital investments are sustainable, especially in a changing dynamic environment. For example following a 12-year drought the Australian authorities invested in four big desalination plants in Sydney, Adelaide, Melbourne and Brisbane. The Melbourne plant alone cost $4 billion. Soon after this investment, the water levels returned to normal — since then none of the four plants are in operation, however ongoing maintenance cost reaches approximately $1 billion per year.\textsuperscript{79} Even though desalination plants provide resilience to low water supply issues in these cities, they have ultimately become stranded assets. However there are many examples where desalination has provided an essential water resource for a city — for example desalination is Dubai’s only water source. Desalination and wastewater treatment plants are also energy intensive, carbon intensive, and expensive to build and operate. There are other solutions that can either complement or replace such intensive capital investment projects — these include amongst others investment in green infrastructure projects, restoration of watersheds away from the city, and smart urban water systems. Below are some examples.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Green Infrastructure: A Case Study of Portland} & \\
\hline
Soft engineering also known as green infrastructure is a potential solution that could save city money and provide solutions similar to grey infrastructure. In Portland, Oregon water quality in the River Willamette had deteriorated dramatically due to frequent spills from the overloaded sewerage network. In 2002, Portland experienced 50 overflow events, discharging around 13 million m\textsuperscript{3} into local waterways. The choice faced by the city was clear: it could invest in expanding the below ground pipe network by building more grey infrastructure, or it could look upstream and attempt to take water out of the system at the source. This was the basis for the city’s successful Grey to Green initiative. The city budgeted $50 million in stormwater management fees to invest in green infrastructure over 5 years, adding over 100 hectares of eco-roofs, installing 920 green street components, planting over 80,000 trees in yards and along streets and buying over a 1000 hectares of high priority natural areas. Its downspout disconnection program disconnected more than 56,000 downspouts from over 26,000 properties within the Combined Sewer Overflow area, allowing more than a million cubic meters of stormwater to infiltrate into the ground annually. The city has installed street gardens in curb extensions and flow tests have shown these can reduce peak flow from a 25 year storm event by 88 % — enough to protect local basements from flooding and reduce total runoff to the combined sewer system by 85%. The city estimates that resolving flooding and other problems caused by runoff in the region using only conventional infrastructure and pipe solutions would have cost an estimated $144 million, compared with an estimated $86 million using largely green infrastructure. Such measures also provide benefits in terms of enhancing water quality, providing amenity and recreational spaces, adding to urban biodiversity and providing other functions such as carbon sequestration and pollutant trapping on leaf surfaces.\textsuperscript{80}
\hline
\end{tabular}
\end{table}

\textsuperscript{79} Schneider (2016), In Water-Scare Regions Desalination Plants are Risky Investments, Circle of Blue
\textsuperscript{80} US EPA Portland Oregon, A case study of how green infrastructure is helping manage urban stormwater challenges in Green Infrastructure Case Studies: Municipal Policies for
Investing in source watersheds can help cities improve the quality and quantity of water resources. It is estimated that a reduction in sediment and nutrients by 10% could lead to a 5% reduction in wastewater treatment plants. McDonald and Shemie (2014) state that if all possible conservation strategies were applied, global water savings on treatment plants operation and maintenance would be at $890 million per year.

Manila water is often regarded as one of the success stories of how a private company helped avert a water crisis. Water privatisation began in Manila in 1997 and today it is one of the largest populations served by private operators in the developing world. Previous to this, the capital’s water supply and distribution were in disarray — characterized by under investment that led to poor water services and low coverage. Service delivery of water was beset by huge system losses due to leakage and low sanitation cover. This prompted the Philippine government to enact the National Water Crisis, which paved the way for the water system to be privatised. 81 Two 25-year concessions were bid out – the East Zone and the West Zone with private public partnership (PPP) arrangements administered by concessions agreements signed by the government and the winning bidders. Manila Water won the bid for the East Zone and is now the exclusive provider of water and wastewater services to more than six million people in the capital. 82 With a $1 billion investment, the company replaced kilometers of pipes, expanded service connections, and increased service availability. It has improved the potable water supply from 26% of the population living in the East Zone to 99% in 2014. It has invested in a combined wastewater treatment plant with a capacity of 142 million liters per day. 83

The population of Manila is expected to increase from 12.9 million in 2015 to 16.7 million in 2030. 84 The government agency responsible for the country’s water infrastructure is currently looking at new water sources to meet the increased projected demand due to population growth in the city. Currently Manila gets nearly half of their water from three watersheds — Angat, Ipo and La Mesa. New built infrastructure will be part of the solution; however the existing supply of water from its watersheds needs to be protected. Reforestation of Riperian areas has become an important strategy for Manila Water. For example in the Ipo Watershed, the city and the water concessionaries have reforested a total of 560 hectares — Manila Water has planted more than 88,000 trees in the watershed. This is a win-win for the city as not only are they improving the quality of water in these watersheds for future use, but they are also creating parks where city residents can enjoy. For example La Mesa Eco Park which is just ten miles from the city has become a popular destination for city residents who pay an entrance which helps pay for the costs of conservation. Manila Water together with the Metropolitan Waterworks and Sewerage System (MWSS) are working on an integrated watershed management system for all the watersheds that supply the city.

Managing Stormwater with Green Infrastructure EPA-841-F-10-004 August 2010
http://www.epa.gov
Smart Water

Smart technologies are revolutionizing the water utilities business. These technologies use Internet-of-Things (IoT)-enabled sensors to collect real time data — this enables optimization in the system and allows easy detection of leaks, allows easy monitoring of the water that is distributed across the network and allows people to make informed decisions about their usage of water.

Case Study: K-Water South Korea

Korean Water Resources (K-Water) has been embracing smart water technologies for a number of its projects. The company was established in 1967 to manage the country’s water resources. By the late 1980’s the demand for water in South Korea started to surge. Aside from the demand, the country also faced problems with frequency and intensity of both floods and droughts affecting supply. Besides investment in water supply and treatment projects, K-Water also developed a smart water management system composed of a core set of integrated smart technologies that included the whole process of the water cycle. Its K-Water Hydro Intelligent Toolkit is a smart water management system that operates 33 dams, 16 weirs, 25 hydropower plants, 350 gauging stations, and 184 warning stations. The tool kit collects real-time hydrological data on water levels; collects discharge and water quality data; predicts and forecasts weather and rainfall patterns; provides flood forecasts and early warning systems through satellite data; and monitors dams and weir operations remotely.

K-Water manages the Seoul Metropolitan Water Supply Operation Center, the world’s largest integrated multi-regional water supply operation centre with high-end information technology facilities and provides safe drinking water to over 10 million citizens. K-Water also works with several water utilities overseas — it has completed 67 water projects in 24 countries and is currently undertaking a further 13 projects in 10 countries. In 2015 it undertook a feasibility study in Indonesia to establish a water management center, to automate floodgate information, and to advance water management technologies in the country. The organization has also embraced the sustainable development goals (SDGs) — they have developed a number of targets to embrace the SDG’s related to water including spreading their expertise globally on various fields including integrated water resources management and water energy development and to globalize their values and promote and share them for future generations.

Building a Sustainable Water Future in Cities

Now more than ever, with urbanization increasing, cities are facing a number of challenges related to the sustainable use of water resources. These include an increase in demand for water due to population increase, and an increase in flooding and drought events due to climate change. The geographical location of a city also poses some challenges with many cities obtaining water resources from outside their borders or depending exclusively on desalination to provide their water. Cities in emerging economies have different challenges to cities in more developed economies — these include access to finance, building new water infrastructure, and rapid urbanization.

86 k-learn.adb.org.
Arcadis in their publication ‘Sustainable Cities Water Index’ highlight three elements to a sustainable water future — resilience, efficiency, and quality. These three elements are extremely important to improve and enhance the sustainability of water use in a city. Investment in aging infrastructure or in building new future-proof water infrastructure is essential to improving the sustainability of water used in a city. Innovative green infrastructure solutions as described above could provide cheaper solutions compared to traditional storm water defences, while investment in the management of watersheds can ensure a continuous supply of clean water. Smart water management solutions like those embraced by K-Water could increase the efficiency of urban water use over time. Demand side economic instruments such as efficient water pricing, regulation, and effective institutions also play an important role in the sustainable management of water in cities.

There isn’t one particular solution that a city should adopt — some of these solutions depend on the individual challenges that the city faces. However if it was possible to build a city from scratch, then the geographical location of the city taking into consideration the availability of water close to a city’s boundaries and minimal risks of future flooding and droughts would be a first priority. Second, building a ‘sponge city’ which includes natural and green infrastructure such as permeable pavements, green roofs, etc. will enable water to be successfully captured and re-used and is cheaper than building grey infrastructure. One then needs to distribute clean water to the end-users and this will require investment in treatment plants, pipes, and a water network with limited leakages. Obviously cities need to also provide efficient transport networks, energy, affordable housing, hospitals, jobs, and more as described in more detail below.
Transport

Around 10 billion trips are made every day in urban areas around the world. Of these a significant and increasing proportion are undertaken using private vehicles; 80% of the increase in global transport emissions since 1970 has been due to road vehicles. It is also estimated that 90% of the increase in carbon emissions from transport is expected to come from developing cities. Besides emissions, cars are also responsible for high air pollution levels which could contribute to an increase in public health problem. The World Health Organization estimates that more than 80% of people living in urban areas that monitor air pollution levels are exposed to air quality levels that exceed their limits. Ninety-eight percent of cities in low- and middle-income countries with more than 100,000 inhabitants do not meet their air quality standards — this decreases to 56% in high-income countries. Not all this pollution is attributed to motorized vehicles cars; however they are responsible for a large portion of this pollution.

By 2050, cities will add more than 2.5 billion people and global car ownership could reach 2 billion, nearly double today’s level. More people in cities could potentially mean more cars. This could lead to more congestion, less economic productivity, and a decrease in air quality levels. For example in the United States, it is estimated that commuters waste 4.8 billion hours in traffic each year, translating to $101 billion in lost economic productivity. INRIX conducted a study on global traffic in 1,360 cities in 38 countries and ranked the cities studied by the number of peak hours that drivers spent in congestion in 2017 (see Figure). Los Angeles tops the list with drivers spending on average 102 peak hours in congestion, costing drivers on average $2,830 and equalling more than $19.2 billion to the city as a whole. This includes direct (opportunity cost of time lost due in congestion, additional fuel cost and social cost of emissions released by vehicle) and indirect costs (borne by households through the increase in prices of goods and services due to congestion faced by businesses). In London drivers spent on average 71 hours in traffic costing London drivers £2,430 each and the city as a whole £9.5 billion from direct and indirect costs. INRIX’s study does not cover cities in China and India, however in Beijing the cost of congestion and air pollution are estimated at 7%-15% of GDP. Cars also require space for parking — an additional 45,000-70,000 km² would be required for car parking alone by 2050, which is a huge waste of land, given that cars are left idle for the majority of time. In the U.S., it is estimated that the average car is parked for 96% of the time.

The good news is that many cities are investing in different modes of transport with the aim to reduce the use of private cars in their conglomerate. Figure 92 below shows the capacity and infrastructure costs of a number of transport systems such as Bus Rapid Transit, metros, light rail and others. These types of transport are suitable for key corridors in cities and as part of a larger and more integrated public transport system. A shift away from private car infrastructure towards public transport, walking, and cycling could generate massive capital cost savings. In New York it is estimated that density-related cost savings through reduced expenditure on cars and gasoline translates to approximately $19 billion annually. Connected transport systems are also being deployed in cities — these systems connect housing, employment and commercial clusters in an organized and effective way and can include bus rapid systems, bicycle superhighways, smarter traffic information systems, and electric vehicles with charging points based on renewable energy. The use of big data is also being used to monitor and respond to traffic flows at a city scale to ease congestion and reduce air pollution. Below are some examples of some projects that are being deployed in a number of cities:

### Figure 92. Capacity and Infrastructure Costs of Different Transport Systems

<table>
<thead>
<tr>
<th>Transport Infrastructure</th>
<th>Capacity (pers/h/d)</th>
<th>Capital Costs ($/km)</th>
<th>Capital Costs/Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Lane Highway</td>
<td>2,000</td>
<td>10m-20m</td>
<td>5,000-10,000</td>
</tr>
<tr>
<td>Urban Street (car use only)</td>
<td>800</td>
<td>2m-5m</td>
<td>2,500-7,000</td>
</tr>
<tr>
<td>Bike Path (2m)</td>
<td>3,500</td>
<td>100,000</td>
<td>30</td>
</tr>
<tr>
<td>Pedestrian Walkway/pavement (2m)</td>
<td>4,500</td>
<td>100,000</td>
<td>20</td>
</tr>
<tr>
<td>Commuter Rail</td>
<td>20,000-40,000</td>
<td>40m-80m</td>
<td>2,000</td>
</tr>
<tr>
<td>Metro Rail</td>
<td>20,000-70,000</td>
<td>40m-350m</td>
<td>2,000-5,000</td>
</tr>
<tr>
<td>Light Rail</td>
<td>10,000-30,000</td>
<td>10m-25m</td>
<td>800-1,000</td>
</tr>
<tr>
<td>Bus Rapid Transit</td>
<td>5,000-40,000</td>
<td>1m-10m</td>
<td>200-250</td>
</tr>
<tr>
<td>Bus Lane</td>
<td>10,000</td>
<td>1m-5m</td>
<td>300-500</td>
</tr>
</tbody>
</table>

Source: Rode et al., Citi Research

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**Figure 91. Peak Hours of Congestion in Major Cities**

Source: INRIX, Citi Research

Deploying connected transport systems in cities could reduce the use of private cars.
Bus Rapid Transit

Bus rapid transit (BRT) is a bus-based mode of transport operating on exclusive right-of-way lanes at the surface level; in some cases underpasses or tunnels are used to provide grade separation at intersections in dense cities. 166 cities have adopted BRT systems, carrying a total of over 32 million passengers per day.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Passengers per Day</th>
<th>Number of Cities</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>468,178 (1.44%)</td>
<td>4 (2.4%)</td>
<td>117 (2.39%)</td>
</tr>
<tr>
<td>Asia</td>
<td>9,301,372 (28.8%)</td>
<td>43 (25.9%)</td>
<td>1,593 (32.48%)</td>
</tr>
<tr>
<td>Europe</td>
<td>1,613,580 (4.99%)</td>
<td>44 (26.5%)</td>
<td>875 (17.84%)</td>
</tr>
<tr>
<td>Latin America</td>
<td>19,643,856 (60.83%)</td>
<td>54 (32.53%)</td>
<td>1,757 (35.82%)</td>
</tr>
<tr>
<td>Northern America</td>
<td>827,288 (2.56%)</td>
<td>17 (10.24%)</td>
<td>466 (9.5%)</td>
</tr>
<tr>
<td>Oceania</td>
<td>436,200 (1.35%)</td>
<td>4 (2.4%)</td>
<td>96 (1.95%)</td>
</tr>
</tbody>
</table>

Source: BRT Centre of Excellence, Citi Research

Globally, the range of BRT systems varies from very high-capacity systems such as the BRT system in Bogota with a passenger demand of 2.2 million per day, to medium- and low-capacity BRT systems such Istanbul’s and Paris BRT systems which carry approximately 750,000 and 89,000 passengers per day, respectively. The largest adoption of BRT systems has been in Latin America with over 54 cities using this system — 21 cities in Brazil currently have BRT systems, totaling over 750km and carrying over 10.7 million passengers per day, with the largest corridors found in Rio de Janeiro and Sao Paulo. The capital costs for BRT systems include busway, infrastructure, stations, and technology such as passenger information and fare collection systems and cost from around $1 million per kilometer to $12 million per kilometer. The range of costs reflects the extent of road improvements needed and the cost of labor and materials in different countries. BRT systems allow cities to shift commuters to high-capacity buses saving travel time — they substitute older buses with more efficient technologies and reduce the amount of bus fleet needed—therefore reducing CO₂ emissions and air pollution in a city. Below is a case study on Metrobus BRT system in Mexico City.

Figure 94. Passenger Demand of BRT Systems in Different Cities (Thousands)

Source: BRT Centre for Excellence, Citi Research

Embarq, Social, Environmental and Economic Impacts of BRT systems.
Case Study: BRT Mexico City

Mexico City is home to over 8 million people however the metropolitan area is much larger with a population of over 21 million people with an average of 6 million cars, making it one of the most congested cities in the world. It is estimated that congestion costs the city 2.6% of GDP every year and deteriorating air quality in the city has become a major threat to public health.93 According to UN population statistics the population in the metropolitan area is expected to increase to approximately 24 million people by 2030.

Mexico City has a variety of public transport systems. It is served by one of the largest metro systems in Latin America — however this only covers half of the urban area. In 2005 it introduced its BRT system called Metrobus. The initial line served 220,000 people along a 19km route with 80 buses; it has now expanded to 6 corridors94 with a total length of 125km and serves on average 1.1 million people. It is estimated that this BRT system reduced travel time for passengers by 50% and resulted in a reduction of between 80,000-120,000 tons of CO₂ annually.95 96

EMBARQ calculated the costs and benefits of Metrobus Line 3 — see tables below. The majority of the costs for Line 3 were associated with infrastructure costs estimated at $122.5 million while reduced travel time was the largest benefit estimated at nearly $142 million. Net benefits totaled over $35 million when taking into consideration reduced road accidents, health benefits, and reduced climate change costs resulting from the BRT system.

<table>
<thead>
<tr>
<th>Present Value Costs (12% discount rate)</th>
<th>USD millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure construction</td>
<td>122.5</td>
</tr>
<tr>
<td>Infrastructure Maintenance</td>
<td>14.9</td>
</tr>
<tr>
<td>Bus fleet Acquisition</td>
<td>25.7</td>
</tr>
<tr>
<td>Bus renovation plus salvage value</td>
<td>-4.6</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td><strong>158.5</strong></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>PV of Benefits 12% Discount Rate</th>
<th>$US millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Travel Time in Public Transport</td>
<td>141.6</td>
</tr>
<tr>
<td>Time Lost During Construction</td>
<td>-13.6</td>
</tr>
<tr>
<td>Reduced Operating Cost of Public Transport</td>
<td>37.7</td>
</tr>
<tr>
<td>Negative saving operation cost during construction</td>
<td>-11.3</td>
</tr>
<tr>
<td>Reduced Road Accidents</td>
<td>23.1</td>
</tr>
<tr>
<td>Benefits from Physical Activity</td>
<td>6.9</td>
</tr>
<tr>
<td>Health Benefits from Reduced Emissions</td>
<td>4.5</td>
</tr>
<tr>
<td>Reduced Climate Change costs from emissions</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Total Benefits</strong></td>
<td><strong>194</strong></td>
</tr>
</tbody>
</table>

Source: EMBARQ, Citi Research

Key players involved in the BRT systems include both public and private institutions — SETRAVI (Federal District government transport and highway department) who is in charge of planning and regulation, Corredor Insurgentes SA de CV (private), Red de Transporte de Pasajeros del Distrito Federal (public) that manages the vehicle fleet, a Trust Fund that manages investment and distribution of fare collection, and ASK (a private company) that supplies contactless smart cards, readers etc.97

93 Adriana Lobo (2015), $150 million to transform sustainable transport in Mexico City, World Resources Institute.
94 A corridor is a section of road or contiguous roads served by one or multiple bus routes with a minimum length of 3km that has a segregated bus lane.
95 EMBARQ, Social, Environmental and Economic Impacts of BRT systems.
96 World Resources Institute, Ross Center, Mexico City’s Metrobus celebrates 10 years of service.
Mexico City is expanding its BRT system, with two new extensions — a new 15km BRT corridor (Line 7) along Paseo de la Reforma connecting Indios Verdes and Periférico. A fleet of 90 double decker buses will replace 180 older buses currently serving the route. This BRT system includes 29 passenger stations and two terminals. The project is near to completion and should be opening soon. Line 5 is also being extended to Glorieta de Vaqueritos and will include an additional 70 buses on this route.

**Metro**

Metro is an urban electric transport system using rail tracks with high capacity and high frequency of service. Metros use tunnels, viaducts, or can be at the surface level but with a physically separated infrastructure. The most renowned metro system is in London which first opened in 1863. Even though metro systems are capital intensive, their high capacity and speed makes them invaluable for a number of cities. In the 1970’s there were only 40 cities that had metro systems, currently there are over 187 cities that have a metro system which forms part of their public transport system.

**Case Study: Hong Kong**

Hong Kong with a land area of 1,105 km² has a population of more than 7 million people. The majority travel by public transport — in fact over 12.6 million passenger journeys are made on the public transport system every day which includes railways, trams, buses, minibuses, taxis, and ferries. The backbone of public transport in Hong Kong is the railways/metro system which accounts for 41% of all trips made on public transport each day. It is managed and run by MTR Corporation which was established in 1975 with a mission to construct and operate an urban metro system in Hong Kong. The metro system in Hong Kong first opened in 1979 and now operates over 217km of track as well as more than 155 stations including 87 railway stations and 68 light rail stops. The average trip costs between $0.50 to US$3 and the system makes back over 180% of its operational costs on fares alone. The network covers all 18 districts in Hong Kong, carrying an average of approximately 5.6 million passengers each day in 2016 with over 5 million passengers on domestic and cross-boundary services. The service is 99.9% on time, and in 2016 it had only six incidents that had a delay of more than 30 minutes.

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98 UN (2013), Planning and Design for Sustainability Urban Mobility
The success of the system can in part be attributed to the urban density of the city — in fact over 41% of the population live within half a mile of the station\textsuperscript{99}. There are no suburbs from which people can commute by car — car ownership is really low in the city — 6 out of every 100 vehicles in Hong Kong are for personal use, whereas in the U.S. the number is closer to 70.\textsuperscript{100} MTR is also notable for its innovative financing structure, whereby operating costs are covered by fees, but the development costs have effectively been borne by issuing development rights around transit stops, with developers thereby benefitting from increase in real estate values by virtue of their proximity to a transit stop.

**Cycling**

Cycling is probably the most sustainable urban transport mode. It causes no environmental damage, promotes physical activity, takes up little space, and is economical both in terms of direct costs for users and public infrastructure costs. Bike sharing has increased immensely over the years — there are approximately 1,560 cities that have bike sharing systems in place and over 18 million self-service public use bicycles and electric assisted bicycles that are in use\textsuperscript{101}

\textsuperscript{99} Jeff Fong (2014), *Why No one drives to work in Hong Kong.*

\textsuperscript{100} Padukone N (2013), *The Unique Genius of Hong Kong’s Public Transportation System,* The Atlantic.

\textsuperscript{101} The bike sharing world map.
There has also been a rapid rise in the use of E-bikes which increased from 290,000 in the year 2000 to 35.3 million in 2016. Other interesting developments include investments in cycle superhighways which are express routes for bicycles and allow an increase in speed and safety along major routes and real-time information technology which provides better guidance on optimal routes, parking locations, bike sharing locations, available bikes per station, etc.

**Case Study: London**

When one mentions transport in London, the first thing that comes to mind is the tube system which has become one of the most renowned metro systems in the world. London’s public transport network includes a mixture of buses, metro, light rail etc. it is still heavily congested. Even though the percent of journeys made by private car have reduced over the years, the figure in 2015 (37% of journeys) was still considered to be high (see Figure 99).

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Figure 99. Transport Mode in London (Comparison Between 2000 and 2015)


To combat congestion and related air pollution the mayor of London launched the ‘Healthy Streets’ initiative which is a system of policies and strategies to help Londoners use the car less and walk, cycle, and use public transport more. The main aim is to reduce congestion, promote cleaner air in the city and encourage a healthier lifestyle for Londoners. One of the targets set is to increase journeys made by walking, cycling, and public transport from 65% today to 80% in 2041. An investment of £2.2 billion ($3.1bn) has set aside this initiative in order to promote healthier, more efficient and sustainable transport options. Out of this, £770 million ($1.1bn) will be spent directly on infrastructure and initiatives to promote cycling in the capital including investment in super cycle highways and improvements in road networks.

Cycle travel grew 221% in central London from 2000-2015, however it was still only 2% of the total journeys in 2015. In 2016 there was an average of 649,000 cycle trips made per day, an increase of 8% over 2015. London has and is investing in improvements to its cycle network infrastructure. London’s combined Superhighway and Quietway network is now more than 100km long and 26.7% of Londoners live within 400m of at least one of these routes. The mayor of London aims to increase this figure to 35% by 2022 and 70% by 2041. Seven Cycle Superhighways are now in operation, and construction work on phase 2 of the North-South Cycle Superhighway (between Farringdon and King’s Cross) has started. This will be followed by the implementation of three more Cycle Superhighway routes from Tower Bridge to Greenwich, Kensington Olympia to Brentford and Swiss Cottage to the West End. The TfL uses innovative data analysis (called Strategic Cycling Analysis) to identify future cycling provision which take into consideration growth forecasts, population growth, safety data, and existing demand.

Figure 100. Daily Average Cycle Stages and Trips in London


*A cycle trip is defined as a one-way movement that is conducted entirely by bike. A cycle journey stage includes these trips, but also shorter cycle legs undertaken as part of a longer trip using another mode.

London also has a bicycle sharing and hiring scheme with more than 11,500 bikes and over 750 docking stations. There were a total of 10.5 million cycle hires in 2016/17 up from 9.9 million in the previous year. The cost is just $2 per day to rent a bicycle and an app can be downloaded which provides information on docking stations, live bike and space availability, interactive maps, etc.

Figure 101. Number of Bicycle Hires in London


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106 https://data.london.gov.uk/dataset/number-bicycle-hires.
New Vehicle Car Technologies — Electric Vehicles

Cumulative global electric vehicle sales since 2010 have reached one million at the end of 2015 and two million in January 2017. The 14 cities mentioned in Figure 102 accounted for 32% of new electric vehicles sales in 2015. Shanghai, Beijing, and Los Angeles had the largest electric vehicles sales of over 41,000, 23,000, and 18,000, respectively in 2015. Oslo had the largest electric vehicle share (27%) of new passenger vehicles followed by Utrecht (15%), Shanghai (10%), and Shenzhen (10%). Electric buses are also on the rise — a study from Bloomberg predicts the sale of electric buses will increase from 386,000 to 1.2 million by 2025 with the majority being used in Chinese cities.

Public charging infrastructure is an important component of growth in the electric vehicles in cities and several governments are investing in providing the necessary infrastructure to facilitate that growth. Shanghai, Beijing, and Shenzhen have expanded their charge points dramatically over the years. These cities are required to provide one charge point for every 8 electric vehicles and charging stations should be no further than 1km from any point within the center of the city.

Although public charging infrastructure is important for electric car vehicle uptake, it is also important for cities to invest in home, work place, and fast charging availability such as DC systems.

Figure 102. Electric Vehicle Share in a Number of Cities

Source: The International Council on Clean Transport, 2017, Citi Research

While electric vehicles do not reduce congestion in cities, they can be effective in reducing tail-end air pollution and reduce carbon emissions especially if their charging source comes from low carbon renewable sources. Several cities have created a number of financial incentives to encourage the uptake of electric vehicles. The U.S., for example offers an income tax credit of up to $7,500 for purchasing an electric vehicle, while other cities such as London have created low emission zones and exemptions from congestion fees.

**New Vehicle Share Mobility — Autonomous Driving**

Currently there is an enormous amount of research being done on the technology of driverless/autonomous cars. In our Citi GPS *Car of the Future* series we not only highlight these technologies, but also discuss the different business models in which driverless cars could operate. We estimate that on-demand driverless rideshare networks in urban environments — a so-called robotaxi model situated in highly dense cities where dedicated tax-fleets could be used 70% of the time — could charge $0.25-$0.50 per mile per person and still earn strong gross margins. This cost is less than for a personal car, which is estimated at $0.76 per mile in the 2020-25 timeframe. Driverless carpools working in the same capacity as public transport networks where multiple people are picked up and dropped off at their destination could create low-cost commuting alternatives with the luxury of being picked up at home.

Other models include car peer-to-peer timeshare models where people with comparable schedules could partially own a vehicle and automaker subscription models where buying a driverless car could become a subscription to a whole entire fleet. All these models could ultimately reduce the number of cars in a city — reducing the amount of space needed for parking lots and garages and improving congestion and air quality in a city. For example Spieser et al. (2014) estimate that shared vehicle mobility, in particular shared-driverless cars can meet the personal mobility of the entire population of Singapore with one-third of the total number of passenger vehicles in operation. A BCG study estimated that under there could be an 11% reduction in the number of vehicles on the road in Boston if there is a gradual shift from private to shared driverless cars in Boston reducing emissions to 42% from current and reducing parking space by 16%. A number of cities are already testing autonomous cars, The city of Singapore is testing autonomous bus and taxi trials in a part of its city; in Gothenburg, Volvo is testing 100 of its autonomous cars, while in Boston NuTonomy has tested a number of vehicles on the roads and is now testing with passengers — it is also now collaborating with Lyft to optimize the automated vehicle user experience.

**Big Data and Urban Transport**

The increasingly availability of transport data and computing power is allowing many urban planners to understand in more detail the impacts of different transportation projects or plans. The World Bank has created an OpenTripPlannerAnalyst (OTPA) Accessibility tool that allows cities to combine the spatial distribution of a city (for example the location of jobs or schools), the transportation network, and an individual’s travel behavior. This will allow cities to design transportation networks that more accurately address the needs of citizens.

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111 Bianca Bianchi Alves, *When cities forget about pedestrians, big data and technology can serve as a friendly reminder*, The World Bank
Transport for London is already utilizing the vast amounts of real-time data that it collects to understand how people move across the transport network and to predict future transport needs in the capital city. Dutch Railways the principal passenger railway operator in the Netherlands has integrated all the information available from different train operators into one and are using this data to provide reliable real-time information about train services to its passengers. Commuters are also able to use a travel planner application to ensure a smooth and prompt commute.\(^\text{112}\)

There are a number of different uses this vast amount of information collected by transport networks could be used to improve transport services. This includes predictive maintenance in the network, communicating real-time traffic congestion to travelers, planning more efficient bus routes as well managing peak congestion, mapping out air quality hotspots and reducing traffic, or improving transport in the area. The volume and speed at which data is collected today opens up huge opportunities for urban planners to get it right and improve transport networks in many urban areas.

**What Makes a Sustainable Transport System in Cities — Bringing it All Together**

We have highlighted a number of examples where cities have invested in or are investing in a variety of transport measures to reduce the use of private cars, improve air quality and reduce congestion in the city. A reduction in travel intensity in cities through higher urban densities, greater physical proximity, and a co-location of urban functions would allow easier deployment of sustainable transport systems in cities. A good example is Hong Kong where over 41% of the population lives within half a mile of a metro station and public transportation is used by the majority of people. In comparison cities such as Atlanta and Houston have a higher per capita usage of cars due to their sprawling nature. Investments in capital intensive projects should also be future proof — this is important given that new technologies such as autonomous cars could change the very nature of a city requiring less space for parking and easier mobility for people, while the increase in electric cars would require investment in public charging stations. Ease of use of public transport networks is also a must. A good example is the Oyster card in London which is a smart card which commuters can use on all public transport networks including bus service, inter-rail, and the tube service. The system now also allows payment with contactless bank cards on all services. Cities should leverage big data to understand the transport network better, to design more efficient services, and to predict future travel in the city. Moving millions of people from one place to the next sustainably is not easy — strategic planning and good urban design is a must for all cities to ensure sustainable transportation systems.

\(^{112}\) Eric Gerber (2017), Harnessing Big Data to Build a Smarter Public Transport System.
Waste

Managing solid waste is one of the biggest challenges of urban areas of all sizes, from mega-cities to small towns and villages. According to the World Bank, in 2012 the world's cities generated 1.3 billion tonnes of solid waste, amounting to a footprint of 1.2 kilograms per person per day.\(^{113}\) This is estimated to increase to 2.2 billion tonnes of waste by 2025.

Waste is generally an urban issue, as the waste generated in rural areas tends to be much lower. Generally, the higher the income level and rate of urbanization, the greater the amount of solid waste produced (see figure below which maps GDP per capita against urban waste generated). Solid waste management is the one thing that every city government provides for its residents. While service levels, environmental impacts and costs vary dramatically, solid waste management is arguably the most important municipal service. Solid waste management and street sweeping is also often the city's single largest source of employment.

Figure 103. The Higher the GDP Per Capita the Higher the Urban Waste Generated - 2013

![Graph showing the relationship between urban GDP per capita and urban waste generated](image)

The United States generates a total of 2 kg/person per day of waste, while Japan generates a total of 0.96 kg of waste per person per day. Figure 105 below shows the municipal solid waste (MSW) generation per capita for 20 major cities in Asia and Africa. Per capita MSW generation in some Asian cities such as Kuala Lumpur and Bangkok has already reached the level of some OECD member states.

\(^{114}\) OECD/IEA, Energy Technology Perspectives, Annex I- Municipal solid waste potential in cities.
Waste is generated in all sorts of ways and its composition and volume is influenced by a number of factors such as the level of economic development, consumption patterns, cultural norms, geographical location, energy sources, climate, etc. Generally as a country urbanizes and its population becomes richer, the consumption of inorganic waste such as packaging increases, at the same time the relative fraction of organic waste decreases. Low- and middle-income countries have a higher proportion of organic waste ranging from 40-85% of the total — see Figure 106.

### Figure 104. Waste Generation in Different Countries (2014)

Source: OECD, Citi Research

### Figure 105. Waste Generation in Different Asian and African Cities

Source: Kawai and Tasaki (2016), Citi Research

Increased urbanization leads to higher inorganic waste and lower inorganic waste.

### Figure 106. Average Waste Composition by Income

Source: Hoornweg and Bhada-Tata (2012), Citi Research

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Clear differences exist between developing and developed regions in waste management. There are clear differences in waste management practices between developed and developing regions. Waste management practices in developed cities currently focus on optimization strategies for resource conservation, while the approach to waste management in developing cities are often underdeveloped, inefficient, and inadequately managed. It is estimated that low income countries only collect 43% of the municipal solid waste that is generated, while in high income countries the figure stands at 98% (Figure 107). As expected, high-income countries generate the majority of waste and they also divert more than half of their waste away from landfills by either composting their waste, recycling, or by incineration. The majority of waste in upper middle-income countries is sent to landfill or dumped, with small amounts being recycled or composted, while waste in lower to middle-income countries, waste is often disposed of in uncontrolled landfills or openly burned. Residents in developing countries, especially the urban poor, are more severely impacted by unsustainably managed waste. These practices create serious health, safety, and environmental consequences — poorly managed waste serves as a breeding ground for different diseases. It can also have an effect on the environment. In low- and middle-income countries, mixed MSW, which includes at times household solid waste and hazardous waste, is often dumped in land close to slums and could have an effect not only on waste pickers and inhabitants in the area but also on water sources as well as air pollution from the burning of such waste (116) (also a major contribution to global climate change through methane generation (117)).

Figure 107. Waste Collection (%)

![Waste Collection (%)](chart1)

Source: Hoornweg and Bhada-Tata (2012), Citi Research

Figure 108. Waste Generation and Disposal Methods

![Waste Generation and Disposal Methods](chart2)

Source: Hoornweg and Bhada-Tata (2012), Citi Research

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118 China is included in the lower-middle income countries- therefore the figure for open dumping is rather high for this income region.
Managing waste efficiently is essential for building a sustainable city; however in many developing regions and cities it remains a challenge, mainly because effective waste management is expensive. Currently solid waste management globally costs about $205.4 billion and is expected to increase to approximately $375.5 billion in 2025. Solid waste management dominates municipal annual budgets in low-middle income countries with shares as high as 30-50%. Figure 10 below shows the cost of different waste collection and disposal for countries of different income levels. A study done for Campania in Italy estimated that the present value of the benefit of reducing the number of waste-related deaths after adjusting for a cancer premium through the reclamation of hazardous waste dumps was on average €11.6 billion (€5.4 to €20 billion assuming a time frame for benefits of 10 and 50 years respectively). The region had a number of hazardous waste dumps in region and it was estimated that a total of 848 cases of premature mortality and 403 cases of fatal cancer per year were as a consequence of exposure to dumpsites with hazardous materials. Rafiq et al (2015) analyzed the health effects that the open dumpsite at Hazar Khawani in Pakistan had on residents. They estimated that the annual benefit of the adoption of a modern landfill to the local residents of the region totaled PKR187,000,000 to PKR193,000,000 ($1.6 to $1.7 million).

**Figure 10. Cost of Waste Collection and Disposal**

<table>
<thead>
<tr>
<th></th>
<th>Low-Income Countries</th>
<th>Lower Mid-Inc Countries</th>
<th>Upper Mid-Inc Countries</th>
<th>High-Income Countries</th>
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</thead>
<tbody>
<tr>
<td>Income GNI/capita</td>
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<td>$876-3,465</td>
<td>$3,466-10,725</td>
<td>&gt;$10,725</td>
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<tr>
<td>Waste Generation</td>
<td>0.22</td>
<td>0.29</td>
<td>0.42</td>
<td>0.78</td>
</tr>
<tr>
<td>(%) collected</td>
<td>43%</td>
<td>68%</td>
<td>85%</td>
<td>98%</td>
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<table>
<thead>
<tr>
<th></th>
<th>Cost of Collection and Disposal (US$/tonne)</th>
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<tr>
<td></td>
<td>Collection 20-50</td>
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<tr>
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<td>30-75</td>
</tr>
<tr>
<td></td>
<td>40-90</td>
</tr>
<tr>
<td></td>
<td>85-250</td>
</tr>
</tbody>
</table>

Source: Hoornweg and Bhada-Tata (2012), Citi Research

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120 Greyl L, Vegni S, Natalicchio M, Cure S, Ferretti J, (2010), The Waste Crisis in Campania, Italy, for A sud, Italy.
Rapid urbanization will increase the amount of waste generated in many cities. The problem of waste is already acute in a number of these cities and regions. For example, landfills in Laogang in Shanghai, Jardim Gramacho in Rio de Janeiro, and Bordo Poniente in Mexico City compete for the title of the world’s largest landfills. Solutions and opportunities do exist, including recycling, composting and sustainable landfills, incineration especially for hazardous and medical waste, transforming waste to energy, reducing waste, treating waste as a resource, etc. Below are a number of case-studies of cities that have been successful in implementing sustainable waste management practices.

Promotion of Micro-enterprises and Cooperatives for Waste Pickers

A major challenge in the solid waste sector in developing countries is the informal sector and waste picking, and finding ways to incorporate or regularize these activities into the private sector solution. One solution that creates livelihood for urban poor is through the incorporation of micro-enterprises and informal waste recycling cooperatives into the municipal solid waste management system. An example of this is the waste pickers union in Pune, India which formed India's first member-managed and owned waste picker cooperative called SWaCH (Solid Waste Collection and Handling). In 2000, the national government set out new municipal solid waste management rules requiring municipalities to ensure waste segregation, door-to-door collection, and the processing of recyclable materials. This prompted the municipality of Pune to engage the city’s informal waste workers. Through a contractual agreement signed with the municipality, SWaCH workers provide door-to-door collection services; the workers get paid through user fees, and are accountable to residents as well as to the municipality. As part of the integration, workers were given training, adequate equipment, and working space. By 2008, SWaCH already had a presence in 127 of the 144 units in Pune, involving 1,500 informal workers and servicing 200,000 residents. This waste management system has not only provided a better service for the residents but has also enabled significant improvements in the livelihoods for waste pickers.123

Composting

Composting is an ideal solution for food waste. Food can be composted to create a natural fertilizer to enhance the soil and produce healthier crops, reducing the reliance on synthetic alternatives. There are a growing number of cities in Europe and North America that have set up successful programs to divert organics away from conventional landfills or incinerators. The city of Portland banned all non-food items, even compostable ones, from its organic flow in order to produce better quality compost. In 2009, the city of San Francisco introduced a law requiring the separation of recyclable materials, compostable materials, and landfilled waste. As part of its waste reduction program (see section on zero waste cities below) the city implemented the largest urban food waste composting collection program in the U.S. covering both commercial and residential sectors. Through this initiative it has successfully diverted more than one million tonnes of food and garden waste from being disposed in its landfilled and has produced a high quality compost that is used by local farmers and wineries in Napa and Sonoma counties.124

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Developed cities are not the only ones doing this. In India, a private company called Waste Ventures recognized the need to provide waste collection services in India and to restore the surrounding farmland. The company collects and turns municipal’s organic waste into high quality compost that fetches high prices from farmers that are able to cover 45% of their operational costs.\(^\text{125}\)

Composting food waste is an ideal solution to reduce organic waste being dumped or disposed to landfills while at the same time proving a high quality product for farmers. It is considered a cheaper alternative to landfilling as shown in Figure 109 and has the added benefit, if done well, of avoiding greenhouse gas emissions primarily from keeping methane-generating organics out of landfills.

**Waste-to-Energy**

A waste-to-energy plant converts municipal and industrial solid waste into electricity and/or heat for industrial processing or for district heating systems. These energy plants work by burning waste at high temperature and using the heat to make steam which then drives a turbine creating electricity. The global waste-to-energy market was valued at an estimated $25.32 billion in 2013 and is estimated to be worth $40 billion in 2023.\(^\text{126}\) An increase in recycling efforts in the U.S., Europe, Japan, and China are expected to drive this market forward, however there is also investment happening in the Middle East with Oman, Kuwait, Jordan, and Dubai all building new waste-to-energy plants.

**Waste-to-Energy: Oman**

Oman is investing in a waste-to-energy plant that aims to not only reduce the amount of waste that is disposed to landfills (the plant is able to take 700,000 tonnes of waste per year) but will also supply enough energy to the proposed South Al Batinah desalination plant. Waste management in Oman is currently poor due to lack of investment. It has a total of 350 landfills and dumpsites which are very close to residential areas and has limited access to expand given its limited land availability. The project will enable the country to reduce CO\(_2\) emissions, provide alternatives to natural gas as a fuel source, and spend less on developing and maintaining their landfills. The capital investment is estimated at approximately $600 to $700 million.\(^\text{127}\)

**Other Technology- Renescience**

Renescience is a new technology developed by Orsted (previously Dong Energy) that uses enzymes, mechanical sorting, recycled water, and anaerobic digestion to separate household waste into recyclables. It then liquefies the organic part of the waste and turns it into green energy. The aim of the technology is to turn every part of household waste into something that one can use. The technology has been developed from laboratory-scale via a demonstration plant in Copenhagen and is now being used in a new plant in Northwich.\(^\text{128}\) The Northwich Renescience plant treats up to 120,000 tons of waste per year (equivalent to 110,000 U.K. homes) and generates 5MW of renewable electricity a year.

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\(^{126}\) World Energy Council (2016), Waste-to-Energy.

\(^{127}\) Waste to energy Middle East (2016), Top Waste-to-energy projects.

The plant creates clean recyclable material (plant and metals) that can be used to make new products, the by-product of the process can be used for land restoration from mining, while the non-recyclable materials such as wood, textiles, etc. will become fuel material for cement kilns or incineration plants.

Zero Waste Cities

The goal of zero waste cities is to ensure resource recovery and to progressively minimize the amount of waste that is disposed of in incinerators, cement plants, dumps, and landfills. Snaga, a waste management company in Ljubljana in Slovenia has not only managed to reduce the amount of waste going to landfill, but has also managed to change the behavior of the city’s residents. In just over 10 years the quantity of recovered materials in Ljubljana increased from 16kg per person in 2004 to 145 kg in 2014. By 2014, the average resident produced just 283 kg of waste, 61% of which was recycled or composted. This means that the total amount of waste going to landfill decreased by 59%, and the total waste generated also decreased by 15% in this time period. They key ingredient for this success was attributed to the introduction of door-to-door collection, especially for biodegradable waste. The city of Ljubljana is committed to the zero waste initiative and aims to increase separate collections to 78% by 2025, reduce total waste generated to 280 kg per inhabitant and reduce yearly residual waste to 60 kg by 2025. Ljubljana is not alone; the city of San Francisco is also working to achieve zero waste by 2020. It has successfully diverted 80% of its waste from landfills through a number of easy initiatives such as an easy-to-use three bin system for waste, economic incentives for households to recycle and compost more, policies that promote zero waste goals, and extensive education for its residents and businesses about recycling and composting. The costs for their zero waste program are funded solely from the revenue generated through collection rates charged to customers.

What Makes a Sustainable Waste Management System in Cities — Bringing It All Together

Effective and sustainable waste management is a huge challenge for many cities. Different cities have different challenges they need to overcome with regard to managing their waste effectively. Ultimately, waste should be viewed as an important resource rather than a problem that needs to be dealt with. Organic waste could be turned into high quality compost, while inorganic waste could either be recycled and reused, or used to create energy. Working with different communities, as shown in the example on SWaCH, can provide effective waste management practices at minimal cost while also providing additional benefits to residents in the form of work opportunities and a better livelihood. Developing a source of revenue from organic waste, as shown in the example above on Waste Ventures, can create revenue streams for a company, reduce costs for the disposal of waste for the city and at the same time create a very good product for farmers. Disposing of waste into landfills should be seen as a last resort as it is the least effective way of managing waste and is costly.

A rapid surge in population in many emerging and developed cities will undoubtedly increase the amount of solid waste that is generated. With the right approach and strategic planning many waste streams can become income streams.

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130 SF Environment.
Social Infrastructure

Social infrastructure is defined as long-term physical assets in social sectors such as education, health, long-term care, and housing, etc. which enable goods and services to be provided. In our Citi GPS report Public Wealth in Cities we state that a successful city not only invests in economic assets but also in social and human assets as these have a crucial impact on the finances of cities and well-being of its citizens. Social assets provide important services for people’s health, environment, and happiness, thus minimizing social afflictions that could have a strain on a city’s budget. Human assets on the other hand (which include the skills and/or knowledge attained by citizens) are important for individuals to achieve economic independence and for government/cities ultimately to increase tax revenue.

According to an analysis by Numbeo, Canberra has the highest quality of life of any city (ranked 1 out of 177 cities), followed closely by Raleigh in the U.S. Their analysis takes into consideration a number of indicators that affect people’s well-being including a pollution index, house price-to-income ratio, cost of living index, safety index, health care index, traffic commuter time index, and climate index. The cities with the least quality of life index include Kuala Lumpur (ranked 173), Ho Chi Minh City (ranked 174), and Caracas (ranked 177). New York, Tokyo, and London are ranked in the bottom half of the list at 105, 106, and 129, respectively.

Figure 110. The 20 Top Cities for Quality of Life in 2017

<table>
<thead>
<tr>
<th>Rank</th>
<th>City</th>
<th>Quality of Life Index</th>
<th>Purchasing Power Index</th>
<th>Safety Index</th>
<th>Healthcare Index</th>
<th>Living Cost Index</th>
<th>Property Price to Income Ratio</th>
<th>Commute Time Index</th>
<th>Traffic Time Index</th>
<th>Pollution Index</th>
<th>Climate Index</th>
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<tr>
<td>1</td>
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<td>30</td>
<td>22</td>
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</table>

Source: Numbeo, Citi Research

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131 Fransen L, del Bufalo G, Reviglio E, Boosting Investment in Social Infrastructure in Europe, European Association of Long-term Investors
Since the global economic recession, many governments have reduced their spending on social assets/infrastructure. Currently the view of most local and central governments is that spend on social assets is a form of consumption; however there are long-term benefits associated with these investments both to the city/country and to society as a whole. The present value of the expected stream of social costs should be used to calculate the long-term benefits of investment in social assets. However, this could be quite cumbersome and more pragmatic approaches could be used. For example the Public Health calculator developed by Uppsala University in cooperation with Skandia has helped public entities use the data they have, to tailor their social investments in public health to where investments are actually needed.\footnote{Citi GPS report Public Wealth of Cities.} New Zealand is a great example where a government is applying evidence-based investment practices to social services\footnote{The Treasury, Kaitohutohu Kau.} by using available data to identify where to invest in early, rather than deal with social problems after they emerge. Through the practices, they have identified a number of key indicators associated with children who could have a higher risk of poor outcomes later in life without additional support, and they map their location so services can be better targeted to meet their needs.\footnote{Insights.apps.treasury.govt.nz.} Below are some examples of different social assets/infrastructure and their benefits to cities and their inhabitants.

### Social Infrastructure — Housing

Housing accounts for more than 70% of land use in most cities and determines urban forms and densities. Housing shortages in many cities represent a major challenge. In South Asia, housing shortfalls are particularly acute amounting to a staggering 38 million dwellings. The UN estimates that one billion new homes are needed worldwide by 2025, costing an estimated $650 billion per year or 9-11 trillion overall\footnote{World Cities Report, 2016.}. On top of this, there are shortfalls in the quality of housing. Whilst housing for the middle and upper-class citizens in many cities maybe over provided, the poor are generally under-housed.

In many cities there is an extreme imbalance in the supply and demand of housing. The housing stock of many expensive cities has not expanded quickly enough to meet the surge in demand due to an increase in urbanization. Housing over the years has also attracted a lot of speculative investment driving up prices. This has also led to high vacancy rates in a number of cities including Shanghai, Beijing, and Bangkok as property is bought for investment rather than for shelter. Figure 111 below shows the cities with the highest price-to-income ratio which is a basic measure for apartment purchase affordability (lower is better). Four Chinese cities are ranked in the top twenty (Beijing, Shanghai, Hong Kong, and Shenzhen) and are considered amongst the world’s most expensive when you measure the ratio of median apartment prices to median family disposable income. Households with a disproportionate share of monthly income going towards rent or mortgage payments have less money to spend on other things, ultimately affecting other parts of the economy.
Quality of housing is also a huge challenge in many cities. According to the UN one in eight people live in slums today—around 1 billion people—and the largest proportion of this group (over 880 million) live in developing regions (see Figure 112). Over the next two decades the urban population in the world’s poorest regions including South Asia and Sub-Saharan Africa are expected to double. Unless investment and adequate measures are put in place, the population living in slums in these areas could increase even further.

**Figure 111. Cities With the Highest Price-to-Income Ratio**

Quality of housing is also a huge challenge in many cities. According to the UN one in eight people live in slums today—around 1 billion people—and the largest proportion of this group (over 880 million) live in developing regions (see Figure 112). Over the next two decades the urban population in the world’s poorest regions including South Asia and Sub-Saharan Africa are expected to double. Unless investment and adequate measures are put in place, the population living in slums in these areas could increase even further.

**Figure 112. Number of Urban Residents Living in Slums in Developing Regions (Millions)**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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<tr>
<td>Developing Regions</td>
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<td>752</td>
<td>830</td>
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<td>Sub-Saharan Africa</td>
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<td>128</td>
<td>152</td>
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<td>Latin America &amp; the Caribbean</td>
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<td>117</td>
<td>112</td>
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<td>Southern Asia</td>
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<td>Western Asia</td>
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<tr>
<td>Oceania</td>
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<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Source: UN Habitat

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136 Price to Income Ratio is the basic measure for apartment purchase affordability (lower is better). It is generally calculated as the ratio of median apartment prices to median familial disposable income, expressed as years of income (although variations are used also elsewhere).

137 According to the UN the word ‘slum’ refers to inhabitants suffer one or more of the following household deprivations: lack of access to improved water, sanitation, lack of sufficient living area, lack of housing durability and lack of security of tenure.

138 UN Habitat, World Cities Report (2016).
For the most part, issues associated with the quality of housing in developed countries are less severe than those associated with certain urban slum housing, these must also be addressed. For example, in England it is estimated that in 2014, 20% of housing (total number of homes in 2015 was estimated at 23.5 million)\(^ {139}\) was considered to be 'non-decent'.\(^ {140}\) It is estimated that a total of 1 in 20 city-dwellers in the EU-28 faced severe housing deprivation.\(^ {141,142}\)

**Sustainable Housing**

Sustainable housing is not only about economic facets of housing but includes other indicators such as social, cultural, and environmental. According to the UN, sustainable housing are those that are built and managed as healthy, durable, safe and secure; affordable; using low energy and affordable building materials; resilient to potential natural disasters; connected to safe and affordable water, energy, and sanitation; use resources efficiently; well connected to jobs and; properly integrated into social, cultural, and economic fabric of society.\(^ {143}\) It is rather difficult to find cities that have managed to capture the whole definition of sustainable housing. Sustainable green living usually comes at a price and is rarely offered as affordable; on the other hand, some cities have developed affordable housing, but these are in areas which are cut off from employment, and from the social, cultural, and economic fabric of the city. There are, however, a number of examples where cities have embraced certain aspects of sustainable housing as described below.

**Case Study: Affordable Housing and Green**

Green housing is usually offered as premium housing, and is rarely considered to be affordable housing. However, a new 150,000 square-foot 90 unit called ‘The Rose’ in Southern Minneapolis has just shown that this does not need to be the case. The building was opened in 2015 and is one of the most ecologically sustainable affordable buildings in the United States.\(^ {144}\) The developers set out to build a sustainable project and spent the time and effort understanding green building techniques and strategies. The Rose received funding from numerous people including city, county, regional and state governments, and philanthropic foundations. The building was built with a focus on better materials, conservation, and better energy performance — units are 75% more energy efficient than traditional buildings. The architects kept down the cost by setting strict budgets and consulting experts to find new ways to build. In fact, where many high-end sustainable buildings cost $300-$400 per square foot, this complex came in at $144\(^ {145}\). Market-rate and affordable units are indistinguishable with regards to appearance and are generally dispersed throughout the building.


\(^{140}\) A decent home is defined as a dwelling that meets the current statutory minimum standard for housing, it is in a reasonable state of repair, it has reasonably modern facilities and services and it provides a reasonable degree of thermal comfort.

\(^{141}\) The severe housing deprivation rate is defined as the percentage of the population living in a dwelling which is considered overcrowded, while also exhibiting at least one of the housing deprivation measures such as a leaking roof, no bath/shower and no indoor toilet, or dwelling considered to be too dark.

\(^{142}\) Urban Europe- statistics on cities, towns and suburbs- poverty and social exclusion in cities, Eurostat.

\(^{143}\) UN Habitat (2012), Sustainable Housing for Sustainable Cities.

\(^{144}\) The Rose, Urban Land Institute, ULI case studies.

Case Study: Energy Efficiency Retrofit Initiative in Low Income Households

The Kuyasa project is an energy efficiency retrofit initiative launched for over 2,300 low-income houses in the outskirts of Cape Town. The project consisted of installing solar heaters, ceiling insulation, and compact fluorescent lamps in these households. This project was able to save 6,440 tons of CO₂ emissions and enabled residents to reduce their costs on paraffin and electricity use. It took three years to complete (1999-2002) and was a collaborative project between the City of Cape Town, a Dutch non-governmental organization called SouthSouthNorth (SSN) and the residents of Kuyasa. The project also generated employment for residents within Kuyasa who were trained in a number of skills including carpentry, plumbing, and electrical and employed for the duration of the project. It was funded from financial gains and loans from multiple government entities; initially SSN together with the City of Cape Town decided to explore the Clean Development Mechanism for funding, however it became obvious that the sale of certified emission reduction credits would not provide upfront capital investment. Carbon credits together with a small monthly contribution of $4.24 from residents provided some revenue from the project that enabled to cover some loan repayments. Even though the project did not have a positive financial return (it was not meant to have one), the city believes that the economic returns far exceed the financial costs in terms of the environmental, social, health, and community improvements and benefits for the residents of Kuyasa. This project shows how energy efficiency interventions can also be implemented in low-income housing alleviating problems of poverty, unemployment, and environmental sustainability.

Sustainable housing encompasses many things, including affordability and green solutions, however the main takeaway is that people should be put at the core of such projects. The above examples show it is not inconceivable to develop projects which ultimately benefit residents. Although such projects might not have a positive financial return, as in the case of the Kuyasa project, the net benefits accruing from these projects such as environmental, health, and community improvements ultimately make them more than worthwhile.

Education

In our Citi GPS report called Education: Back to Basics we highlighted the direct benefits that education brings to governments and cities. In the U.K., it is estimated that the government’s net benefits of financing an undergraduate degree is approximately £108,000 for men and £63,000 for women, which corresponds to a rate of return of 11.4% and 9.6% for men and women respectively. The government makes money from such investments both on the interest charged on the loan and more importantly from taxes collected from higher future earnings. Even though some cities do not directly collect taxes from future earnings (as in the case of London), they still benefit from a more educated society. Social benefits from education include an increase in life expectancy, high life satisfaction, less crime in society and active involvement in society. Some of these social benefits are hard to measure. Figure 113 and Figure 114 below show that on average (and in OECD countries) a person with tertiary education is more likely to have better life satisfaction and less activity limitation due to health problems when compared to adults with upper or lower secondary education. The Perry Preschool study described below shows that education can also provide greater net benefits not only in the form of higher taxes but also in welfare and crime savings.

146 Energy Efficient Cities Initiative, Good Practices in City Energy Efficiency- Cape Town- Kuyasa Settlement, South Africa- Low Income Energy Efficiency Housing Project
Case Study: The Perry Preschool

Former President Barack Obama in his 2013 State of the Union address famously said that “Every dollar we invest in high-quality early childhood education can save more than seven dollars later on by boosting graduation rates, reducing teen pregnancy, even reducing violent crime.” Obama was making reference to the Perry Preschool program, led by James J. Heckman at the University of Chicago that concluded that each dollar invested returns in present value terms $7-$12 back to society. The High/Scope Perry PreSchool study is widely cited to support the economic argument for investing in early childhood programs. The study was undertaken from 1962 and 1967 and consisted of identifying a sample of 123 low-income African American children who were assessed to be at high risk of school failure. The study randomly assigned 58 children to a program preschool at ages 3 and 4, and 65 to another group that received no preschool program. Project staff then collected and analyzed data on both groups at different times of the children’s life. Figure 115 below shows the major findings of the study, while Figure 116 shows the costs and benefits (discounted at 3%) per participant. Even though this study should be criticized on a number of fronts including small sample size, the lack of statistical methods used, and the cruel nature of it all (with some children benefiting from preschool and others not), the data published seems to show that there is a benefit both to the individual and to society of good preschool education and that the returns to the public on its initial investment are substantial.
Moving Towards 21st Century Learning

Cities should also invest in education of their citizens because it is key to their economic development and growth. The UNESCO Global Network of Learning Cities was set up to provide the know-how and best practices for cities to help them develop lifelong learning for their citizens. It defines a learning city as one that “effectively mobilizes its resources in every sector to promote inclusive learning from basic to higher education; revitalizes learning in families and communities; facilitates learning for and in the workplace; extends the use of modern learning technologies; enhances quality and excellence in learning; and fosters a culture of learning throughout.”

Lifelong learning in cities lays the foundation for sustainable, economic, and environmental development and is particularly important for the marginalized or vulnerable who have not had the opportunity to acquire a good education or for those who need re-skilling.

Case Study: Life-long Learning in Hangzhou

Hangzhou in China has a population of over 9 million people with 21 million people living in its metropolitan area. It is situated in the Bay of Hangzhou between Shanghai and Ningbo. While the city already has an excellent, government-led formal education system, it also oversees a number of non-formal and informal learning activities in the city. The city has established free physical and digital learning platforms around the city for its residents and has provided access to more than 400 museums, galleries, and cultural centers in the urban area. To tackle the issue of a lack of education of migrant workers, which has become a problem in many Chinese cities, the city of Hangzhou has developed policies to ensure that migrant children enroll in standard education while adults can access a ‘Migrant College’ and follow training courses designed to meet the requirements of potential employers. Over the past five years, 128,500 people have received an adult vocational high school qualification and/or a professional certificate obtained from these training courses. The city collaborates not only with government bodies but also with the private sector to promote and encourage life-long learning.
In 2015, it spent $2.8 billion on culture and education which was used to fund its numerous high schools and vocational training colleges. It also placed 200 bookcases around the city encouraging people to borrow books for free. The city’s view of education and learning is that it should be comprehensive and inclusive and it understands that educating people brings numerous benefits to the city — in fact it estimates that the education and training industry generated an income of $8.7 billion in 2015 alone.

**Public Health**

Investment in public health is an essential priority for most societies. Mayors and local leaders have an important role to play in creating healthy urban environments. Policy initiatives and planning decisions in cities can negatively or positively affect things like air pollution, noise control, levels of physical activity (such as access to greenspaces), the availability of fresh food, social inclusion, etc., which all influence the physical and mental health of their citizens. Rapid urbanization will put cities under unprecedented strain to support their citizens in leading healthier lives, especially when set against the backdrop of health challenges in the 21st century such as the increase in diabetes, dementia, and other chronic illnesses. Cities are commonly designed with a generally young, healthy, and actively working population in mind. In these settings, older populations can become vulnerable. Therefore it is important that some cities cater for the needs of an aging population, which will require higher levels of care in the future while also remaining economically independent.

Cities in the past have tended to focus more on providing access to health care for their residents such as access to doctor practices, health clinics, hospitals, etc., which is important; however they should also invest in building healthier cities. This includes promoting active lifestyles (walking and cycling through better transport systems), better air quality, provision of better housing (efficient insulation and heating, better access to natural light, local community amenities), access to healthier foods, creating green urban spaces, and building a more resilient city.

Evidence shows that investing in a ‘healthy city’ could in the long-term save money. The cost of substandard housing (all homes with significant HHSRS hazards) in the U.K. to the National Health Service (NHS) is estimated to be £1.4-£2.5 billion ($1.95-3.5bn), while mental health costs the economy £110 billion ($153bn) per year and represents 10.8% of the health service budget. The Building Research Establishment (BRE) state that if the government could find £10 billion ($14bn) to improve poor quality homes, then this would save the NHS over £1.4 billion ($1.95bn) in the first year. They estimate that the payback period for this investment would be just over seven years. Air pollution is also a major cause of health costs in many cities. Global urban air pollution has increased by 8% among cities that actually monitor air quality. For example, air quality in Mumbai is 6.3 times the WHO safe levels. It is also estimated that over 620,000 people in India die of air pollution diseases every year.

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149 Myserson J, Cities and Health, Helen Hamlyn Centre for Design, Royal College of Art.

150 The World Health Organisation defines a healthy city as ‘one that is continuously creating and improving those physical and social environments and expanding those resources which enable people to mutually support each other in performing all the functions of life and developing to their maximum potential.’

151 BRE The cost of poor housing to the NHS.

In Europe, air pollution from road traffic costs EU countries an estimated $25 billion and physical inactivity costs up to €300 per European inhabitant.

The good news is that many cities are recognizing the importance of investing in healthy cities. The mayor of London launched a program called ‘Healthy Streets for London’ which aims to get Londoners to reduce their reliance on driving and increase walking and cycling. Their research states that if every Londoner walked or cycled for 20 minutes every day, it would save the NHS £1.7 billion ($2.42bn) in treatment costs over the next 25 years. Copenhagen has put the model of a healthy city at the core of its urban planning and has invested in CO₂ neutral transport and has implemented a policy mandating that all citizens should be able to reach parks and other green spaces within a 15 minute time frame. Urban parks and greenspaces provide a number of benefits for citizens as described in more detail in the next section.

**Case Study: Copenhagen — An Example of a Healthy City**

In February 2018, the Danish capital, Copenhagen, hosted the WHO European Healthy Cities Network Summit of Mayors, in which representatives adopted the Copenhagen Consensus; discussing how placing health and well-being at the heart of a city’s development can enable sustainable economic, social and political prosperity. But how does the host city fair itself?

Consistently ranked at the very top of the UN’s Happiness Index and one of the prominent success stories in the Healthy Cities initiative of the World Health Organisation, Copenhagen is presenting a model for healthy city implementation across the world in its quest to be crowned ‘healthiest city’. Focusing on its sustainable social infrastructure, the city aims to be smoke-free, serve 90% organic food in all daycares, schools, and homes for older people and to become the world’s first CO₂-neutral capital by 2025. By 2025, three quarters of all trips in the city are expected to be by foot, bicycle, or CO₂ neutral public transport (such as biofuel buses) and more people will use public transport instead of cars. It is a frontrunner in social cohesion, green mobility, and smart city solutions. Moreover, its policy is promoting health as a priority through its initiatives.

Voted one of the world’s most bike-friendly cities, over 62% of people living in the city are already cycling to work every day, regardless of weather. The city is designed for cyclists: when it snows, the city clears the bike lanes before car routes, there is a raised platform for cyclists to rest their foot without getting off the saddle at traffic lights, there are ‘drunken green bins’, tilted to make it easy for cyclists to throw their garbage when they are done. This also makes economic sense, as society gains a 23 cents profit for every kilometer ridden, compared to a net loss of 16 cents for the same distance made by car).¹⁵³

And to help reach carbon-neutrality, it has implemented green roof policies — mandating that every new building should have a green roof (i.e., partially or completely covered with vegetation). The city’s buses will switch from diesel to electric when current bus contracts expire in 2019 and its public transportation system is extremely punctual and reliable. As green mobility use rises, the city is encouraging the move through installing charging stations for electric vehicles.

¹⁵³ ‘Copenhagen’s getting healthier, thanks to everyone in the city’ The Guardian, Sep 2016.
Copenhagen, named ‘European Green Capital 2014’, already possesses a plethora of green spaces, to the extent that over 96% of Copenhageners are able to walk to parks or beaches in less than 15 minutes. This is in part due to effective municipal policy, which required that by 2015, all citizens should be able to reach these open spaces in this time frame. Such policy has also led to the creation and development of several new parks in areas of low vegetation, such as the innovative public park Superkilen, in the Nørrebro district of Copenhagen.

Although emphasis has previously been on physical health (regular exercise and healthy eating — over 88% of all public institutions already serve organic food), Copenhagen is also putting multiple initiatives in place to ensure its citizens’ mental health. It is offering free help for its citizens suffering from stress and anxiety through a series of classes and clinics and a 2016 evaluation of the program showed its positive effect on sleep patterns and signs of anxiety and depression on those whom had registered.

It is not simply public health officials implementing this policy, the city is relying upon continued private-public partnerships and the municipal administration’s cooperation.

The Net Benefits of Urban Green Spaces and Parks

Urbanization has brought about several undesirable environmental changes. As urbanization increases, this will inevitably change land cover, as natural surfaces are replaced by urban fabric. Urban green spaces have become an essential element in any sustainable city model and should be seen as a fundamental part of urban infrastructure. They play a crucial role in improving the quality of living in urban areas as they provide a number of different benefits for the inhabitants such as health and well-being, a sense of community, healthier patterns of children’s play, etc.\(^\text{154}\) However when it comes to investment, parks do not generally get the same consideration as other urban infrastructure — the main reason for this is that they are undervalued.

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\(^{154}\) Tempesta T (2015), Benefits and costs of urban parks: a review, AESTIMUM 67, December 2015: 127-143

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Calculating the net benefits of urban parks is particularly difficult but over the last decade a number of studies have started to emerge that calculate this. A study undertaken by the Trust for Public Land for the Philadelphia Parks Alliance has estimated that the park system in Philadelphia provides the city with a revenue of $23 million per year, municipal savings of $16 million per year, cost savings to citizens (direct use and health value) of $1.1 billion, and wealth increasing factors to citizens (property value increase from park proximity, and profit from tourism) of $729 million.\(^{155}\) The value far outweighs the cost of maintaining the parks with nearly $100 generated in economic value for $1 spent on maintenance.\(^{156}\) The City of Edinburgh has also measured and valued the benefits from parks in the city. They estimate that for every £1 invested around £12 of social, economic and environmental benefits are delivered by parks in the city. Vivid Economics in their study for Greater London Authority, National Trust, and Heritage Lottery Fund estimate that London public parks have a gross asset value in excess of £91 billion ($125bn) — this represents 30 years value at £5 billion ($7bn) per year appropriately discounted — see Figure 119.

### Figure 119. Economic Value Provided by London’s parks

<table>
<thead>
<tr>
<th>Variable</th>
<th>Public Services £bn</th>
<th>Residents £bn</th>
<th>Businesses £bn</th>
<th>Total £bn</th>
<th>Share %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td>17</td>
<td>17</td>
<td></td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Mental health</td>
<td>1.4</td>
<td>3.4</td>
<td>1.1</td>
<td>6.8</td>
<td>7</td>
</tr>
<tr>
<td>Physical health</td>
<td>2.1</td>
<td>5.5</td>
<td>3.1</td>
<td>10.7</td>
<td>12</td>
</tr>
<tr>
<td>Residential property</td>
<td>55.9</td>
<td></td>
<td></td>
<td>55.9</td>
<td>61</td>
</tr>
<tr>
<td>Carbon (soil)</td>
<td>0.2</td>
<td>0</td>
<td></td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Carbon (trees)</td>
<td>0.1</td>
<td>0</td>
<td></td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.6</td>
<td></td>
<td></td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>Gross asset value</td>
<td>91.3</td>
<td></td>
<td></td>
<td>91.3</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Vivid Economics Ltd\(^{157}\); Citi Research

Vivid Economics state that the total value of avoided healthcare costs due to London greenspace totals £950 million per year. This is made up of reduced disease risk due to higher levels of physical activity (savings of £580 million/year) and improved mental health (savings of £370 million/year) due to access to parks.\(^{158}\) Other benefits of London parks includes the increase in value of housing prices in close proximity to parks — it’s estimated that for each hectare of green space located within a 1km radius, the average house prices are 0.08% higher. They use this calculation to assess the total amenity value of parks in London. They also calculate the recreational value of parks estimated at £17 billion for London, which translates into an annual economic benefit of £930 million ($1.3bn) and £120/head/year. Environmental benefits are also included, i.e., the benefits of carbon storage and temperature regulation.

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\(^{155}\) The Trust for Public Land for the Philadelphia Parks Alliance (2008), How Much Value does the City of Philadelphia Receive from its Park and Recreation System?


\(^{158}\) Please refer to the report written by Vivid Economics for the methodology used.
The studies mentioned above are great examples that show the net benefits that parks provide to cities and their inhabitants. There are a number of uncertainties in quantifying some of these benefits, especially in understanding the exact relationship between health outcomes and park. However, there is no denying the fact that parks do provide benefits for cities and their residents. The World Health Organisation in their report on ‘Urban green spaces and health’ highlight the vast literature that has been written on the health benefits of urban parks. In their conclusions they state that the evidence shows ‘that urban green space has health benefits, particularly for economically deprived communities, children, pregnant women and senior citizens. It is therefore essential that all populations have adequate access to green space, with particular priority placed on the provision for disadvantaged communities….the need for green space and its value for health and well-being is universal.’

<table>
<thead>
<tr>
<th>Physical Health</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>£380m/yr</td>
</tr>
<tr>
<td>Estimated costs of physical inactivity</td>
<td>£8.5 bn/yr</td>
</tr>
<tr>
<td>Benefits from parks as a proportion of total cost</td>
<td>7%</td>
</tr>
<tr>
<td>Per person benefit</td>
<td>£67/head/yr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mental Health</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>£370m/yr</td>
</tr>
<tr>
<td>Estimated costs of mental ill health</td>
<td>£17 bn/yr</td>
</tr>
<tr>
<td>Per person benefit</td>
<td>£42/head/yr</td>
</tr>
</tbody>
</table>

Source: Vivid Economics\textsuperscript{157}, Citi Research
Smart Cities

Technology, sensors, the Internet-of-Things, the use of big data, and others, if properly applied can fundamentally alter the quality of life in an urban environment. The term ‘smart city’ is currently being used to depict a city that embraces technology to improve the efficiency of infrastructure and services provided to citizens. Even though this term has been around for decades, it particularly became popularized in 2010 when IBM launched its Smarter Cities Challenge. There are a number of definitions of smart cities: IBM defines a smart city ‘as one that makes optimal use of interconnected information available today to better understand and control its operations and optimize the use of limited resources and Cisco has a similar definition – a smart city is one that adopts ‘scalable solutions that take advantage of information and communications technology (ICT) to increase efficiencies, reduce costs, and enhance quality of life.’ Over the years the concept has changed from one that is focused on technologies and systems to one that is focused on citizens and the services that are provided for them.

Several applications of a smart environment have been introduced (or are in the process of being introduced) in many urban areas, including smart homes, smart grids, smart transportation, smart infrastructure, and smart healthcare. There are a number of cities (both developed and emerging) that have put smart technologies at the core of their strategic plans. For example the Indian government in 2015 announced its objective to build one hundred smart cities all over the countries. The first of these smart cities, Dholera is already under construction. Dubai has also been actively seeking to become the world’s smartest city and has launched their Smart Dubai Initiative which aims to ‘embrace technological innovation’ with the aim to make the city more efficient, safe, and a greater experience for their residents and visitors. Finland has invested a lot of thought and money in developing smarter platforms for their cities. In particular Kalasatama in Helsinki (which is currently being built) has incorporated a number of smart solutions such as smart houses with scalable technology related to heating and lighting, smart waste collection systems, smart grids, etc.

The market for smart solutions is definitely growing. In fact Markets and Markets estimates that the smart cities market would grow by a CAGR of 23.1% and reach $1.2 billion by 2022. Below are some examples of some smart applications that are being deployed in a number of cities.

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Smart Energy Systems

Smart energy grids have the potential to improve the efficient use of energy and ultimately improve the lives of citizens. The basic concept of a smart grid is to add monitoring, analysis, control, and communication capabilities to a national electricity delivery system to maximize efficiency while at the same time reducing energy consumption. It will allow utility companies to move electricity more efficiently to consumers and will allow consumers to have access to better information that could improve their energy usage. The analytics of smart grid data can also help predict the demand for power supply in the future.\(^{162}\)

Learning technologies such as Nest and Hive also enable consumers to manage and save on the energy usage in their homes. These systems learn the consumption pattern and temperatures that are used in a home and are able to turn the temperature down when there is no one in the house. It is estimated that since 2011 the Nest Thermostat system saved over 8 billion Kwh of energy in homes worldwide.\(^{163}\)

Other smart energy systems that are currently being marketed include Virtual Power Plants. These systems consist of a network of decentralized power generation units which could include combined heat and power (CHP units), solar energy, wind farms, as well as large-scale battery storage systems. They relieve the load on the grid by smartly distributing the power generated during periods of peak load.

Smart Water

Smart technologies are also revolutionizing the water sector. There are several Smart Water Management tools that are available on the market including smart metering, remote monitoring (SCADA), geographical information systems, and telecommunications systems which allow for the provision of real-time data and therefore real-time improvements to systems. Examples of such applications include WaterWiSe which has currently been deployed by the Singapore Public Utilities Board to monitor online hydraulic and water quality parameters, to detect leakage remotely, and to assimilate real time data into hydraulic models.\(^{164}\) K-Water- a company in South Korea has been embracing smart water technologies for a number of its projects (see section on water). K-Water has developed a smart water technology system that includes a core set of integrated smart technologies that are included in the whole process of the water cycle. The company is currently using its technology to help improve water usage in a number of different countries.

Smart Mobility

Digital innovation is also transforming the transport sector. Connected transport systems are already being deployed in a number of cities — these systems connect residential, employment, and innovation clusters in an organized way. Technology is also allowing public networks to become: (1) personal, based on user choices and data flows, (2) integrated and intelligent, (3) digitized (i.e., digitization of tickets and payless systems) and (4) automated and safer.\(^{165}\)

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\(^{163}\) https://nest.com/uk/thermostats/nest-learning-thermostat/overview/

\(^{164}\) www.visenti.com

\(^{165}\) Deloitte (2015), Transport in the Digital Age, Disruptive Trends for Smart Mobility
In the previous section on transport we highlight a number of initiatives that could revolutionize the transport sector, i.e. automated driverless rideshare networks, digitally enabled e-bikes, to the use of big data in transport networks that enable people to have real-time information about public transport networks. An example of such an application is Citymapper which uses open real-time data to help commuters navigate the fastest route/mode of transport to get them from one place to another. Other smart mobility solutions include integrated traffic control systems that can cut both peak-hour congestion and accident rates and on-street smart parking management that can enable better use of city parking assets.

**Smart Buildings**

A smart home is a home that incorporates advanced automation systems to provide inhabitants with sophisticated control over the building’s functions. The range of different smart home devices (Nest and Hive mentioned above are two examples) and technologies available is expanding rapidly with developments in sensors, computer controls, and the Internet-of-Things. In fact it is estimated that by 2022 500 smart devices will be present in a typical family home. IBM have created Watson IoT that enables residents to integrate rooms, devices, and services in a home, provides residents with the ability to analyze consumption of energy, improve the health and wellness of residents, and improve the safety and security of homes. Other IoT solutions have been designed to improve certain issues in the home. Stockrose, a Swedish property management company worked with Engia (a provider of intelligent cloud solutions) and the Azure IoT platform developed by Microsoft to track and improve the usage of hot water in their apartments. According to Microsoft this project enabled Stockrose property owners to save an estimated $42 million in hot water costs within 10 years.

**Smart Assets**

Sensors have enabled the creation of ‘smart assets’. For example infrastructure such as railway systems and sewer tunnels can be fitted with automatic, continuously transmitting networks of fiber-optic sensors. According to Lord Mair, President of the Institution of Civil Engineers these systems are able to tell us the condition of the assets as well as their behavior over time and warn the developers of the need for maintenance and repair before any failure occurs. The Crossrail project in London has been fitted with such sensors as part of their construction phase. Such technology would enable these assets to be managed efficiently over time, provide a more efficient service and ultimately save money and resources over time.

**Smart Citizen Engagement**

The above examples highlight technology developments that are occurring in a number of different sectors. Integrating all these systems into a smart city strategy is not easy. However it is also important to note that a city is not smart unless it ensures that its citizens are at the core of their urban strategies. As shown in our chapter on social infrastructure, big data can be used to improve social infrastructure in a city and ensure that the investments made by local or central governments are targeted correctly at projects that benefit citizens.

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167 www.smarthomeenergy.co.uk.
168 IBM.
The use of a public health calculator developed by Uppsala University has helped public entities tailor their investment in public health efficiently and where investments are actually needed while the government of New Zealand has used their data to help target services that meet the needs of their citizens.

Governments should also engage their citizens in the development of smart cities. Developing online portals or platforms for citizens to engage with government, developers, etc. can ensure that such projects are targeted for the needs of their citizens and not just for the sake of being smarter.

**Is a Sustainable City a Smart City?**

Building a sustainable city, does not need necessary mean that it needs to be ‘smart’, however being ‘smart’ enables better use of resources, more efficient transport networks, and more effective services for citizens. The opportunities for the development and deployment of innovative solutions offered by technology are tremendous. If this can be directed towards urban sustainability, and its investment can be justified by socio-economic and environmental concerns which ultimately benefit citizens, then unlocking this potential and exploiting these benefits could be the way forward.
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Key Insights regarding the future of Sustainable Cities

**SUSTAINABILITY**
Without proper planning, growing cities are apt to sprawl uncontrollably into endless slums with all of the terrible social, economic, and human ills with which they are associated. / If we choose to invest alongside or ahead of urban growth, we can create cities that work on an economic, social, and environmental level without compromising the ability of future generations to experience the same.

**INFRASTRUCTURE**
The challenges of creating sustainable cities is vast as a growing urban population requires greater services including housing, transport, energy, water, resources and waste management. / With much of the infrastructure yet to be built, and with a typical life span of 30 to 100 years, our choices now may resonate over centuries.

**TECHNOLOGY**
Future-proofing cities is important, to ensure new infrastructure is built to be resilient to changes in technology, emission standards, and potential climate change risks. / Smart cities will take advantage of new technology, sensors, IoT, and big data to improve the efficiency of infrastructure and services provided to citizens.