Cities as engines of economic growth

The case for providing basic infrastructure and services in urban areas

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The Human Settlements Group works to reduce poverty and improve health and housing conditions in the urban centres of Africa, Asia and Latin America. It seeks to combine this with promoting good governance and more ecologically sustainable patterns of urban development and rural-urban linkages

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Urbanisation offers substantial opportunities to reduce poverty, in part because it is more cost-effective to meet many basic needs in cities than in rural areas. This paper demonstrates that providing electricity to the 200 million urban residents who currently lack access would require only $1.37 billion per year to 2045. Generating this electricity from low-carbon options (consistent with avoiding a 2°C temperature rise) would cost only 1% more. This demonstrates that relatively small amounts of resources need to be mobilised to deliver basic services and infrastructure to the urban poor – an essential precursor to inclusive and sustained economic growth.

Contents

Summary

Cities have often been described as engines of economic growth, but neither all cities, nor all residents within a given city, necessarily benefit from the potential dividends of urbanisation. This is evident by the fact that one in seven of the world's people live in poverty in urban areas. The urban poor often lack access to basic infrastructure and services, which substantially reduces their wellbeing, resilience and productivity. Yet urbanisation offers substantial opportunities to reduce poverty, not least because it is more cost-effective to meet many basic needs in urban areas than it is in rural ones.

Focusing on the electricity sector, this paper demonstrates that the investment needs associated with providing basic infrastructure and services to un-served urban populations are small relative to their benefits. Nearly 200 million urban residents, primarily in sub-Saharan Africa, currently lack access to electricity. Providing them all with a basic level of electricity access – enough to power two light bulbs, two mobile phones and a couple of small appliances – would cost $1.37 billion per year to 2045. Generating this electricity from low-carbon options (consistent with avoiding a global average temperature rise of more than 2°C) would cost $1.38 billion per year – less than 1 per cent more than using conventional technologies. These estimates include the capital, operating, maintenance and financing costs of the generation, transmission and distribution infrastructure. This equates to less than 0.03 per cent of the world's annual fossil fuel subsidies (as estimated by the International Monetary Fund in 2015).

This global analysis illustrates that relatively small amounts of finance are needed to provide basic services and infrastructure to the urban poor. However, mobilising these resources depends on the political will to introduce enabling policies and local capacities to make the infrastructure investments. In the absence of the necessary commitment and capacities, rising inequality in urban areas is likely to constrain economic growth by limiting the productivity of low-income groups. This suggests that cities can only achieve their potential to be engines of economic growth in the long-term if they prioritise poverty reduction in the near-term.

1

Introduction

Cities are engines of economic growth. This idea has captured the imagination of decision-makers for decades, from the seminal report *Urban Policy and Economic Development: An Agenda for the 1990s* (World Bank, 1991) to more recent work by the Commission on Growth and Development (Duranton, 2008; Spence, *et al.*, 2009) and the Global Commission for the Economy and Climate (Floater, *et al.*, 2014; Gouldson, *et al.*, 2015). The rapid economic growth usually associated with urbanisation can be partially attributed to structural transformation, as labour moves from the agricultural sector to industry and services. It can also be attributed to agglomeration and scale economies, as proximity and density reduce the per capita costs of providing infrastructure and services, as well as creating knowledge spillovers and specialisation that hugely enhance the productivity of urban residents.

However, neither all cities, nor all residents within a given city, necessarily benefit from the potential economic dividends of urbanisation. This is evident by the fact that one in seven of the world's population live in poverty in urban areas. Even in cities with a high per capita GDP, many urban residents lack access to basic services and infrastructure, such as safe and accessible drinking water, sanitation, waste collection, all-weather roads, education, health care, emergency services and electricity.

Official statistics typically under-estimate the scale of urban poverty, particularly where they depend on income-based poverty lines that do not reflect the costs and realities of living in urban areas. The dollar-a-day poverty line used in the Millennium Development Goals is perhaps the most egregious example. Such simplistic measurements have resulted in a lack of attention to urban poverty reduction by many governments and development agencies (Mitlin & Satterthwaite, 2013). Defining poverty in terms of unmet basic needs, such as lack of basic services, tenure or safe housing, rather than in terms of income reveals that the number of people living in urban poverty has dramatically increased over recent decades (UN-Habitat , 2016; Satterthwaite, *et al.*, 2016). Indeed, between 1990 and 2015, many countries experienced a decline in the proportion of their urban populations that had with water piped to premises or improved sanitation (Satterthwaite, 2016).

Yet governments can meet many basic needs at a lower cost in cities than is typically possible in rural areas. This is because higher population density reduces unit distribution costs and permits economies of scale. In other words, the more people who can connect to or use a system, the lower the average costs of that system (Wenban-Smith, 2006; Duranton, 2008; Turok & McGranahan, 2013). Therefore, although urbanisation is often associated with poverty, it in fact offers substantial opportunities to enhance wellbeing. Achieving these development objectives, and maximising agglomeration and scale economies, depends on the presence of enabling policies and infrastructure investments (Turok & McGranahan, 2013). The persistent scale and depth of urban poverty therefore represents a chronic failure of governance.

This failure is in part because governments and utilities "struggle to generate the resources needed for providing the trunk infrastructure (for water, waste water, roads, paths, electricity) to underpin universal provision" (Satterthwaite & Mitlin, 2014, p. 8). The investment needs far exceed municipal budgets: local governments in Bangladesh, Kenya and Nepal, for instance, all have less than $20 to spend per person per year (UCLG, 2010), most or all of which is needed for recurrent expenditure such as salaries. Local governments consequently need to secure large transfers from national government, attract development assistance or access capital markets to redress infrastructure deficits. The challenge of planning, financing and delivering urban infrastructure is made more complex by the scale and pace of urbanisation: 1.3 million people move to urban areas every week (Seto, *et al.*, 2014), with 90 per cent of this growth taking place in Africa and Asia (UN DESA, 2014).

The combination of rapid population growth and underinvestment in infrastructure and services has led to an increasing number of urban dwellers living in informal settlements. Standard planning processes compound this problem, because the regulatory and legal instruments typically used to implement urban plans exclude those who cannot participate in formal land and labour markets (Watson, 2009). Although the resulting informality can create environmental and social risks (Dodman, et al., 2016a), it also offers space for urban residents to develop livelihoods, build or find homes and access services in the absence of formal provision. In many cities, a large part of the informal economy serves formal sector enterprises. Indeed, the informal sector can be more dynamic and resilient than the formal sector, for example, in situations where government regulation inhibits innovation, or where informal providers of goods and services are able to move rapidly to serve new areas (Benjamin, *et al.*, 2012; Brown, *et al.*, 2014). Organised groups of the urban poor have an impressive record of building community-level systems, such as piped water systems, community toilets or sewer and drain networks, to serve informal settlements (Burra, et al., 2003; Hasan, 2006; Dobson, et al., 2015; Boonyabancha, et al., 2012). But they lack the authority, capacity and resources to build citywide trunk infrastructure, and therefore depend on partnerships with government (d'Cruz & Mudimu, 2013; Satterthwaite, 2013).

Yet governments frequently lack the political will to invest in these parts of the city. This may be because residents of informal settlements are not seen as legitimate citizens with rights and entitlements (Bhan, 2009; Patel, *et al.*, 2012); because governments want to discourage rural-urban migration to levels consistent with the availability of jobs and services (Tacoli, *et al.*, 2008; McGranahan, *et al.*, 2013); or because the concentration of people in urban areas enables more effective organisation and participation in political processes (Satterthwaite, 2008; Dodman & Mitlin, 2013), therefore posing a perceived threat to governments. These views mean that even governments that embrace cities as prospective drivers of economic development can also see large proportions of the urban population as threats to the functioning of the city, and therefore allocate resources in ways that perpetuate poverty and compound exclusion (McGranahan, *et al.*, 2016).

This paper offers new quantitative research that demonstrates the low cost of constructing and operating such urban infrastructure and services, focusing on the economics of generating and distributing electricity. There is case study evidence that sanitation, water, housing and other basic needs can be met in an affordable way through individual, collective or public investments (see Chaplin, 2011; Sutherland, et al., 2014; Banana, et al., 2015), but the economic data, technological options and delivery models are often not transferable to other contexts. By comparison, data for the electricity sector are relatively robust and solutions can be reproduced across different urban areas. It is also widely recognised that access to modern energy is essential for both social and economic development (Modi, *et al.*, 2006). Access to legal, reliable electricity in urban areas has been associated with improvements in household incomes, due to reduced expenditure on energy and improved productivity; better public health, due to reduced indoor air pollution and incidence of burns; and improved security and reduced levels of domestic violence, due to street and household lighting (Crousillat, *et al.*, 2010). Ensuring "access to affordable, reliable, sustainable and modern energy for all" is accordingly the seventh Sustainable Development Goal (United Nations Development Programme, 2015).

The paper is structured as follows. Section 2 details the methods used to calculate the size of the un-served urban population and the costs of constructing and operating the necessary infrastructure. The results are presented in Section 3, both at a global level and in case studies from South Africa and India. The implications of this work are considered in Section 4, which also offers recommendations to policymakers and practitioners.

2

Methods

Two data sets were used to estimate the number of urban dwellers without access to electricity. The Electricity Access Database in *The World Energy Outlook 2015* (IEA, 2015a) provided the percentage of the urban population without access to electricity by country in 2013. These data were multiplied by the urban population in each country in 2015, projected in *World Urbanization Prospects 2014* (UN DESA, 2014).

The economics of generating and distributing electricity were calculated assuming that each urban resident would require 100kWh a year, the definition for 'modern energy access' used by the International Energy Agency (IEA) (Moss & Gleave, 2014). This level of electricity access could support two compact fluorescent light bulbs, two mobile phones and up to three small appliances (for example, a fan, small refrigerator, radio, sewing machine, welding appliance or small television in each household) – enough to significantly enhance basic quality of life and economic productivity (Yeager, 2001; cited in Pereira, *et al.*, 2010).

The economic needs were calculated from the perspective of a public utility or government agency, assuming that additional generation, transmission and distribution infrastructure would need to be constructed to meet new demand from previously un-served urban residents. In practice, there is scope to redistribute the existing electricity supply in most of these countries to ensure that all urban residents have sufficient electricity access. In the short-term, this would provide a just means to resolve lack of electricity access. In the long-term, however, all the countries included in this analysis need to invest in new supply infrastructure to meet demand. This analysis, therefore, estimates the cost of meeting the proportion of that demand that would come from achieving universal electricity access in urban areas.

Two metrics were used in the economic analysis: the levelised cost of electricity (LCOE) and the overnight capital costs in each country or region. These measures offer different information relevant to prospective policymakers and planners. LCOE is the cost per unit of energy ($/MWh) of building and operating a generating plant over its lifetime. It includes capital, financing, operating, fuel and maintenance costs. Calculating the LCOE requires assumptions about the lifespan, discount rates, interest rates, capacity factors and utilisation rate of different generation technologies. The LCOE offers a useful summary of the competitiveness of different generation technologies (or a particular package of technologies) over their lifetime. By comparison, the overnight capital costs reflect the resources that an investor would need to mobilise if the power plant were to be constructed overnight. It does not include the interest incurred during the construction period, the labour required to construct the plant or the subsequent costs of operating the plant. The overnight capital costs are an important indicator of the economic competitiveness of different generation technologies because they reflects the fact that many prospective investors (including governments and utilities) face limited resource envelopes and significant opportunity costs, and that their investment options are accordingly constrained.

The LCOE and upfront investment needs of universal electricity access were calculated under two scenarios:

1. CONVENTIONAL: Additional demand from previously un-served urban residents will be met by electricity generated from sources consistent with the national or regional average in 2020. In other words, the LCOE and the upfront investment needs are calculated based on new capacity projected to be installed between 2013 and 2020 under business-as-usual conditions. The conventional

scenario for each country or region is based on the New Policies Scenario developed by the IEA, taking account of broad policy commitments and plans that have been announced by countries.

2. LOW-CARBON: Additional demand from previously un-served urban residents will be met with a greater proportion of electricity generated from low-carbon technologies. The low-carbon scenario for each country or region is based on the 450 Scenario developed by the IEA, which sets out an energy pathway consistent with limiting the concentration of greenhouse gases in the atmosphere to 450 parts per million (which should ensure that the global average temperature change does not exceed 2°C).

The choice of discount rate is central to calculating the LCOE, because it determines the rate at which future costs and benefits are converted into costs and benefits today. The discount rate is determined by the opportunity cost of an investment and the time preference of the investor. Investors using lower discount rates can be understood to have a longer-term investment horizon, with greater value placed on future costs and benefits compared with investors using higher discount rates, who place a higher value on costs and benefits in the near-term. Public actors would typically be expected to use lower discount rates and to factor wider social returns (such as emission reductions) into investment decisions than private actors. We therefore additionally conducted a sensitivity analysis using four different discount rates (1 per cent, 3 per cent, 5 per cent and 7 per cent). For reference, *The Stern Review on the Economics of Climate Change* used an average discount rate of 1.4 per cent (Stern, 2006), while Nordhaus used an average discount rate of 5.5 per cent in his critique of *The Stern Review* (Nordhaus, 2007). The former can be considered a social-welfare-equivalent discount rate, while the latter can be understood as a finance-equivalent discount rate (Goulder & Williams, 2012).

The analysis assumes that the electricity provided to the un-served urban population would be part of a larger bundle of investments in electricity generation and distribution infrastructure, as specified in the two IEA scenarios. The calculations below reflect the proportion of total costs required to provide 100kWh per person per year to the un-served urban population. The calculations take into account the additional cost of electricity due to transmission and distribution losses, which mean that significantly more electricity has to be generated than will be consumed. Country-level data on transmission and distribution losses were obtained from the World Bank (World Bank, 2014).

The data sources and assumptions for each country/region are specified in Appendix 1.

Limitations

City-scale data on population and access to services are inadequate in most low- and middle-income countries. Dependence on outdated data, collected according to inappropriate criteria, has long been a challenge for designing meaningful poverty reduction strategies in urban areas (Satterthwaite, 2003; Satterthwaite, 2016). In particular, estimates of the urban population in many countries are not reliable, because they are based on projections from censuses completed 10 or more years ago. Similarly, data on the share of the population with access to basic levels of electricity are not robust, due to the variations in the reliability, legality and affordability of the connection. In light of these uncertainties, this paper does not project the future size of the un-served urban population, but focuses solely on the cost of providing electricity to those who currently lack access.

This study does not take into account policy frameworks that may influence the economics of different technologies. Fossil fuel subsidies, carbon taxes, feed-in tariffs and other interventions significantly change the attractiveness of individual generation options. Current global policy frameworks heavily favour fossil fuels, with the International Monetary Fund estimating that post-tax subsidies reached $5.3 trillion of 6.5 per cent of global GDP in 2015 (Coady, *et al*., 2015). It is also worth highlighting that the use of LCOE and overnight capital cost metrics do not capture technology or price risks, which may further affect the feasibility of different policies and investments (Grossa, *et al*., 2010).

Even in the 450 Scenario (the low-carbon pathway presented here), the IEA projects that a significant proportion of new electricity infrastructure will be in the form of coal and gas power plants, particularly in low- and lower middle-income countries. There are compelling arguments to be made against this approach, particularly with regard to the negative health costs associated with fossil fuel technologies (Wilkinson, *et al*., 2007) and the increased likelihood of carbon lock-in leading to a global temperature rise exceeding 2°C (Unruh & Carrillo-Hermosilla, 2006; Bertram, *et al*., 2015). While recognising these criticisms, the 450 Scenario was used because it is technologically viable, unlike some more ambitious scenarios that depend heavily on technologies which are not yet commercially or technically feasible, such as energy storage, carbon capture or tidal/marine energy. This is particularly important in the context of low- and lower-middle income countries.

3

Results

Current levels of electricity access

Based on data from the International Energy Agency and United Nations (IEA, 2015a; UN DESA, 2014), 199.2 million urban dwellers currently lack access to a basic level of electricity. Nearly 140 million of them live in sub-Saharan Africa (20 per cent in Nigeria alone), with most of the remainder living in urban centres in South Asia. The distribution of un-served urban residents is presented in Figure 1, and the countries with the most significant un-served populations in Table 1.

If these nearly 200 million urban dwellers were to each consume 100kWh per year, they would consume 19.9TWh of electricity. For reference, this is roughly equivalent to the current energy consumption of Kolkata (population 16.3 million) or 2.5 per cent of the current energy consumption of Metropolitan New York (population 22.2 million) (Kennedy, *et al.*, 2015).

Table 1. Countries with the largest number and proportion of urban residents without access to electricity (IEA, 2015a; UN DESA, 2014).

COUNTRIES WITH LARGEST NUMBER OF UN-SERVED URBAN RESIDENTS		COUNTRIES WITH LARGEST PROPORTION OF UN-SERVED URBAN RESIDENTS	
Nigeria	39,456,225	South Sudan	96%
India	16,797,555	Central African Republic	95%
Democratic Republic of Congo	12,419,095	Sierra Leone	90%
Indonesia	7,970,476	Chad	86%
Myanmar	7,479,950	Liberia	83%
Pakistan	6,854,541	Democratic Republic of Congo	81%
Côte d'Ivoire	6,645,817	Burundi	73%
Angola	5,438,279	Malawi	68%
Bangladesh	5,388,424	Somalia	68%
DPR Korea	5,384,353	Togo	65%

Figure 1. Global distribution of urban dwellers who do not have any access to grid electricity. Millions more have an unreliable electricity supply or obtain their electricity illegally.


Urban population without electricity access

Economics of urban electricity access

The levelised cost of electricity generated from conventional technologies would be $38.22/MWh.[1] When the costs of transmission and distribution infrastructure are factored in, it would cost $1.37 billion per year to 2045 to provide a basic level of electricity for the 200 million urban residents who currently lack access (Figure 2).

The LCOE is lowest in Latin America, at $32.97/MWh (Table 2). This is because there is a large share of hydropower in that part of the world, which is a very cost-effective option. By comparison, the LCOE in the Middle East is $44.51/MWh, which is 35 per cent more than in Latin America.

Under business-as-usual conditions, this new infrastructure would produce a quantity of greenhouse gas emissions not compatible with avoiding a 2°C temperature rise. We therefore evaluated the economics of pursuing a low-carbon pathway consistent with limiting the concentration of greenhouse gas emissions in the atmosphere to 450 parts per million. The LCOE in this scenario would be $38.82/MWh. Combined with constructing transmission and distribution infrastructure, it would cost $1.38 billion per year to generate electricity from renewable energy sources to meet the demand of un-served urban populations – in other words, less than 1 per cent more than in the conventional scenario.

The economic implications of pursuing a low-carbon energy pathway vary among regions. In Asia, Latin America and South Africa, the cost of providing low-carbon electricity is on average 3.9 per cent higher than providing electricity under a business-as-usual scenario. However, the two scenarios are almost equivalent across the rest of Africa, while the levelised cost of low-carbon electricity is lower than that of conventional options in the Middle East.

The composition of electricity in the different scenarios is shown in Figure 3. This shows that even in the low-carbon scenario, the IEA still anticipates a substantial expansion of coal and natural gas power plants to generate baseload electricity in low- and lower middle-income countries. In this scenario, renewable technologies are expected to play a more significant role in upper middle- and high-income countries that have the financial and technical capacities necessary to cover the high upfront costs and to integrate a greater share of intermittent energy sources into the grid.

Estimates of the LCOE are heavily influenced by assumptions about the discount rate, or the rate at which future costs and benefits are converted into costs and benefits today. The LCOE of electricity

Table 2. The levelised cost of electricity (USD/MWh) under business-as-usual conditions (conventional scenario) and pursuing an energy pathway consistent with limiting the concentration of greenhouse gas emissions in the atmosphere to 450 parts per million (low-carbon scenario). The LCOE includes the capital, financing, operating, maintenance and fuel costs of new generation infrastructure. These estimates are based on a discount rate of 3 per cent and an interest rate of 5 per cent.

	CONVENTIONAL SCENARIO	LOW-CARBON SCENARIO	INCREMENTAL COST OF LOW-CARBON SCENARIO
Africa (excluding South Africa)	$37.46	$37.66	0.53%
Asia (excluding India)	$41.82	$42.38	1.34%
India	$36.90	$39.92	8.18%
Latin America	$32.97	$34.81	5.58%
Middle East	$44.51	$42.37	–4.81%
South Africa	$38.95	$43.40	11.17%
Weighted average	$38.22	$38.82	1.57%

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[1] The LCOE of electricity is typically expressed in cents per kilowatt-hour. In this paper we have used dollars per megawatt-hour to more clearly show the difference among regions and scenarios.

Figure 2. Annual costs (USD) of electricity infrastructure to meet the needs of un-served urban populations, comparing business-as-usual and low-carbon options by region. These estimates include the capital, financing, operating, maintenance and fuel costs of the generation, transmission and distribution infrastructure.

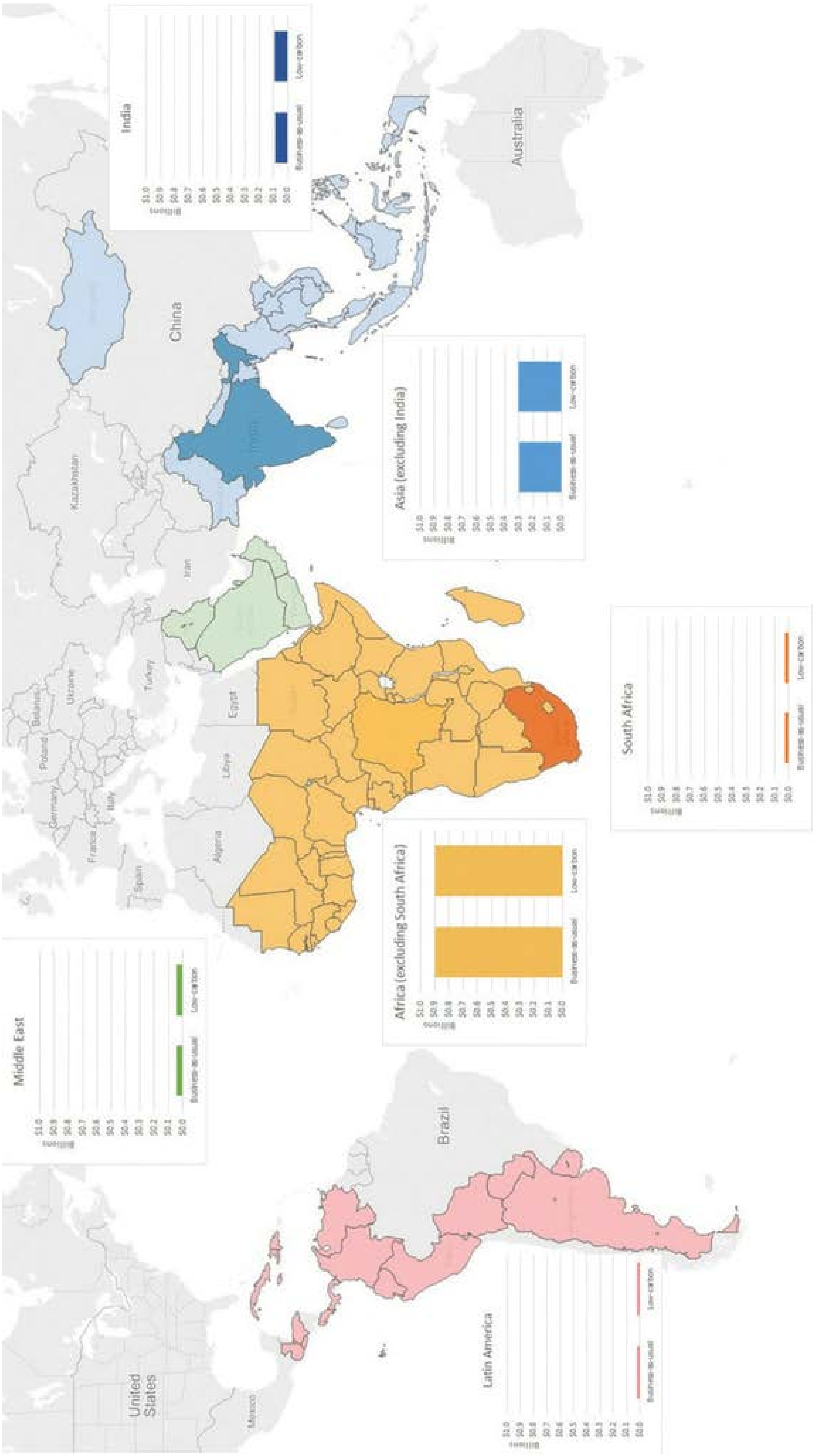
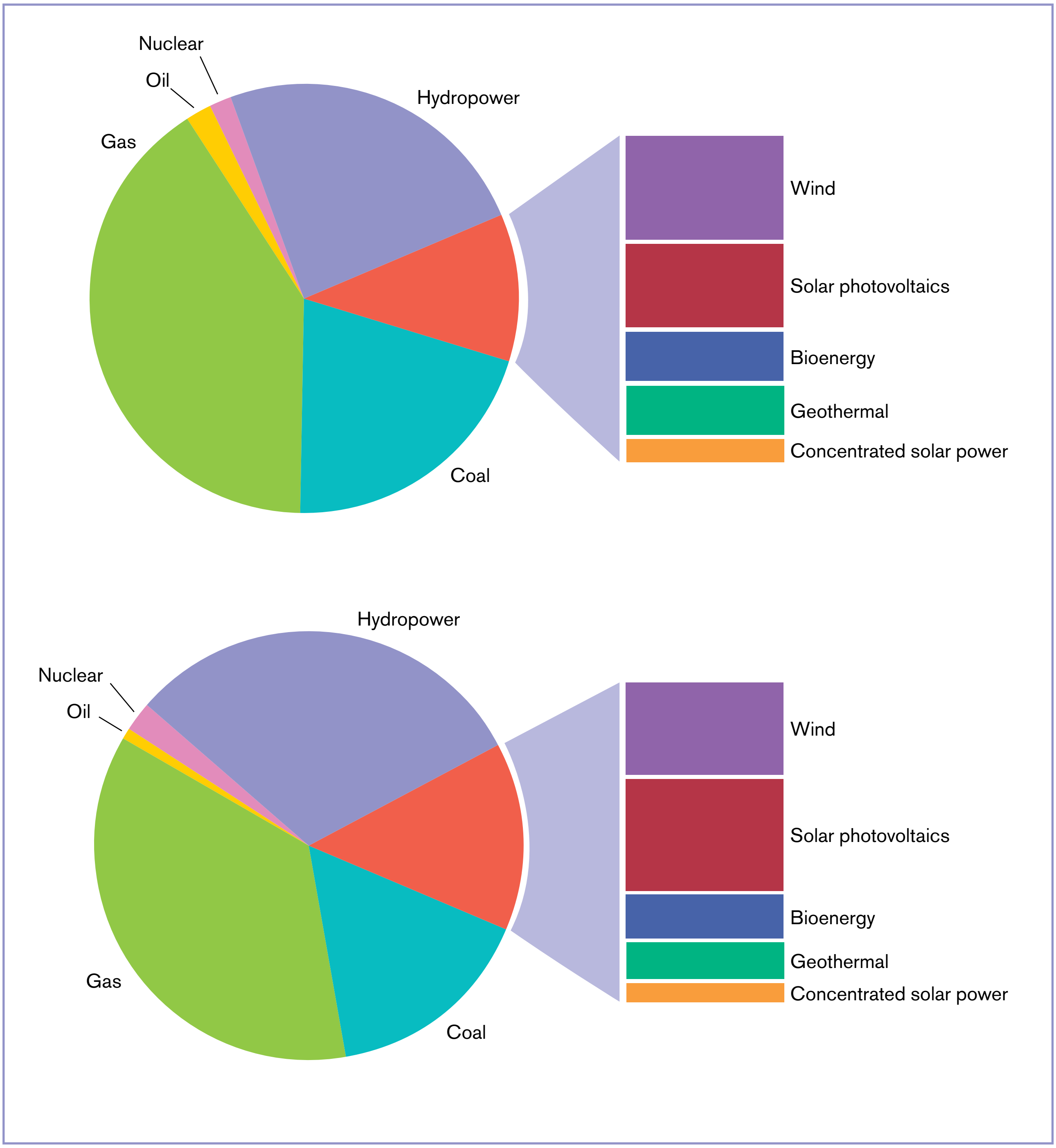


Figure 3. Electricity generation (%) by fuel type in the conventional scenario (above) and low-carbon scenario (below).



is also influenced by the interest rate, because this determines the cost of borrowing money to finance new infrastructure investment. The higher the proportion of upfront costs, the more significant the impact of the discount rate and interest rate will be on the LCOE.

The LCOE above (Table 2, Figure 2) is based on a discount rate of 3 per cent and interest rate of 5 per cent. Figure 4 shows the global LCOE under a range of different discount and interest rates. This sensitivity analysis demonstrates that conventional generation options prove increasingly attractive with higher discount rates. This reflects the different cost profiles of the two scenarios. Conventional options typically have low overnight capital costs compared with low-carbon technologies, but require significant expenditure on fuel throughout their lifetime: for instance, fuel costs represent 35 per cent of the LCOE for coal-fired power plants, and 73 per cent for gas-fired power plants

(IEA, 2015d). By comparison, the greater capital costs of renewable energy systems mean that prospective investors have to borrow more and therefore face higher financing costs. This means that a higher interest rate increases the cost of low-carbon technologies more than conventional options. Therefore, the transition to a low-carbon energy pathway would be substantially enabled by low interest rates and large-scale investment by actors with low discount rates, such as government agencies. Under the most favourable conditions (discount rate of 1 per cent and interest rate of 2.5 per cent), the LCOE of low-carbon electricity is 0.3 per cent cheaper than that generated from conventional technologies.

The upfront costs are also an important consideration for prospective investors (whether public or private). New infrastructure in the low-carbon scenario has higher investment needs than that in the conventional scenario, because renewable energy technologies are capital-intensive but do not incur fuel costs, so expenditure is 'front-loaded'. By comparison, coal- and gas-fired power plants tend to have lower investment needs than renewables, but the LCOE is comparable due to the ongoing cost of fuel inputs.

Under business-as-usual conditions, it would cost $8.5 billion to build enough new infrastructure to generate electricity for the 200 million un-served urban residents. It would cost an additional $509.8 million if this new generation capacity was consistent with maintaining global carbon dioxide levels at or below 450ppm, 6 per cent more than it would cost using conventional options. However, as the LCOE analysis above indicates, much of this would be recovered from the lower operating costs associated with renewable energy technologies.

The additional capital costs of the low-carbon scenario vary greatly by region. In Asia (excluding India), the capital costs of low-carbon options are less than those of conventional options. By comparison, the low-carbon investment needs are substantially higher than those

Figure 4. Sensitivity analysis: the weighted average of the levelised cost of electricity (USD/MWh) under a range of different discount rates and interest rates. The LCOE includes the capital, operating, maintenance and financing costs of generation infrastructure.

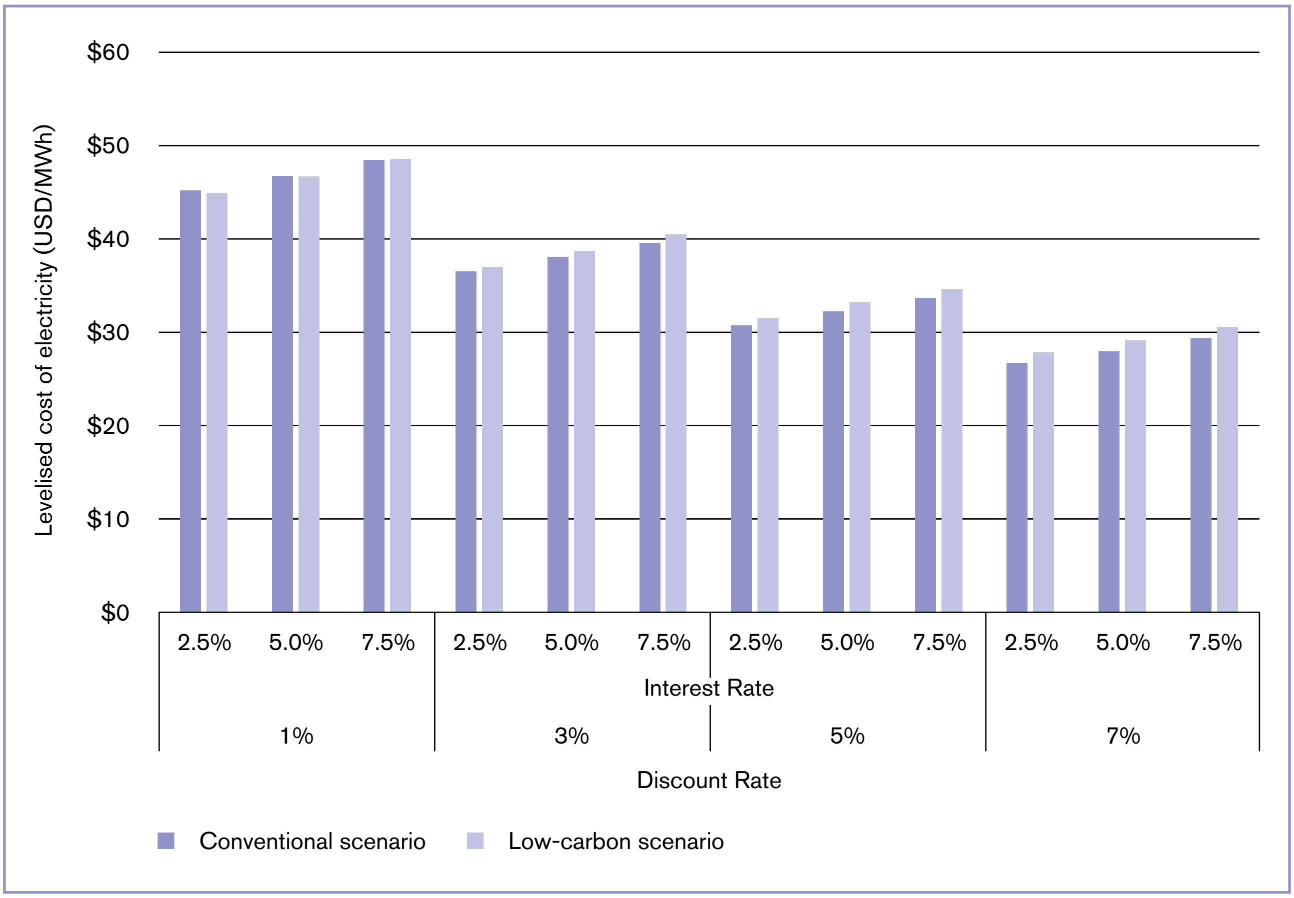


Table 3. Overnight capital costs of the electricity generation infrastructure required to provide 100kWh per year to currently un-served urban residents, under business-as-usual and low-carbon scenarios.

	CONVENTIONAL SCENARIO	LOW-CARBON SCENARIO	INCREMENTAL COST OF LOW-CARBON SCENARIO
Africa (excluding South Africa)	$5,695,010,919	$6,086,046,274	6.9%
Asia (excluding India)	$1,500,584,274	$1,488,987,375	–0.8%
India	$689,324,227	$740,259,134	7.4%
Latin America	$404,310,783	$451,500,970	11.7%
Middle East	$78,968,156	$86,451,300	9.5%
South Africa	$132,372,600	$157,132,797	18.7%
TOTAL	$8,500,570,958	$9,010,377,851	6.0%

required in the conventional scenario in Latin America and South Africa (Table 3 and Figure 5).

This analysis clearly shows that the levels of investment needed to provide electricity to un-served populations are not significant. When the operating (including fuel), maintenance and financing costs are added to the overnight capital costs, governments would need to mobilise $761.2 million per year to 2045, or $773.1 million in the low-carbon scenario. Transmission and distribution would require a further $607.7 million per year in both scenarios.

With 135.9 million un-served urban residents in Africa, it is unsurprising that most of this investment (67.3 per cent) would be required in this region, with nearly 40 per cent of this in Nigeria and the Democratic Republic of the Congo alone. Critically, the costs of pursuing a low-carbon scenario on the African continent are not significantly different over the lifetime of the infrastructure, although the overnight capital costs are 6.9 per cent higher. Most of the remaining investment would be required in Asia, overwhelmingly South Asia.

Although mobilising resources at this scale is a challenge for municipal authorities, utilities and even national governments, this is not a significant sum in the context of current flows of development assistance and infrastructure investment. For instance, under the Paris Agreement[2], developed countries have committed to mobilise $100 billion annually by 2020 for mitigation and adaptation (UNFCCC, 2015). Moreover, prospective investors could expect to recover most of their costs through electricity bills: in both scenarios the annual costs equate to less than $7 per person per year, which most urban residents would be able to pay.

Two case studies are presented below, which serve to illustrate both the opportunities and challenges facing cities.

Case study: South Africa

South Africa's deep inequalities manifest in its uneven patterns of energy access and use. High-income households and industry consume substantial amounts of electricity, which contributes to the country's high per capita emissions of 9.3 tonnes of carbon dioxide equivalent (World Bank, 2016b). Yet 3.5 million South African urban dwellers do not have access to electricity. This is a legacy of the apartheid era: just 36 per cent of South African households had access to electricity in 1994 (Pegels, 2010).

The generation infrastructure necessary to provide 100kWh of electricity annually to all un-served urban residents would cost $16.9 million per year to 2045 (including capital, financing, operating, maintenance and fuel costs). The low LCOE ($38.95/MWh) is mostly due to the substantial and easily accessible coal reserves in the country (Pegels, 2010). By comparison, generating this electricity from low-carbon technologies would cost $18.2 million per year, 8 per cent more than that generated under business-as-usual conditions, even though coal and gas would still make a significant contribution to electricity generation (Figure 6). Over the same period, South Africa would need to invest a further $11.6 million each year to finance connection and distribution infrastructure.

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[2] The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), negotiated at the 21st Conference of Parties of the UNFCCC in December 2015. The agreement sets out a global action plan to avoid dangerous levels of climate change by limiting global warming to well below 2°C above pre-industrial levels, and to seek to limit the temperature increase to 1.5°C.

Figure 5. Overnight capital costs (US$2012) of constructing electricity supply infrastructure to meet the needs of un-served urban populations, comparing business-as-usual and low-carbon options by region.

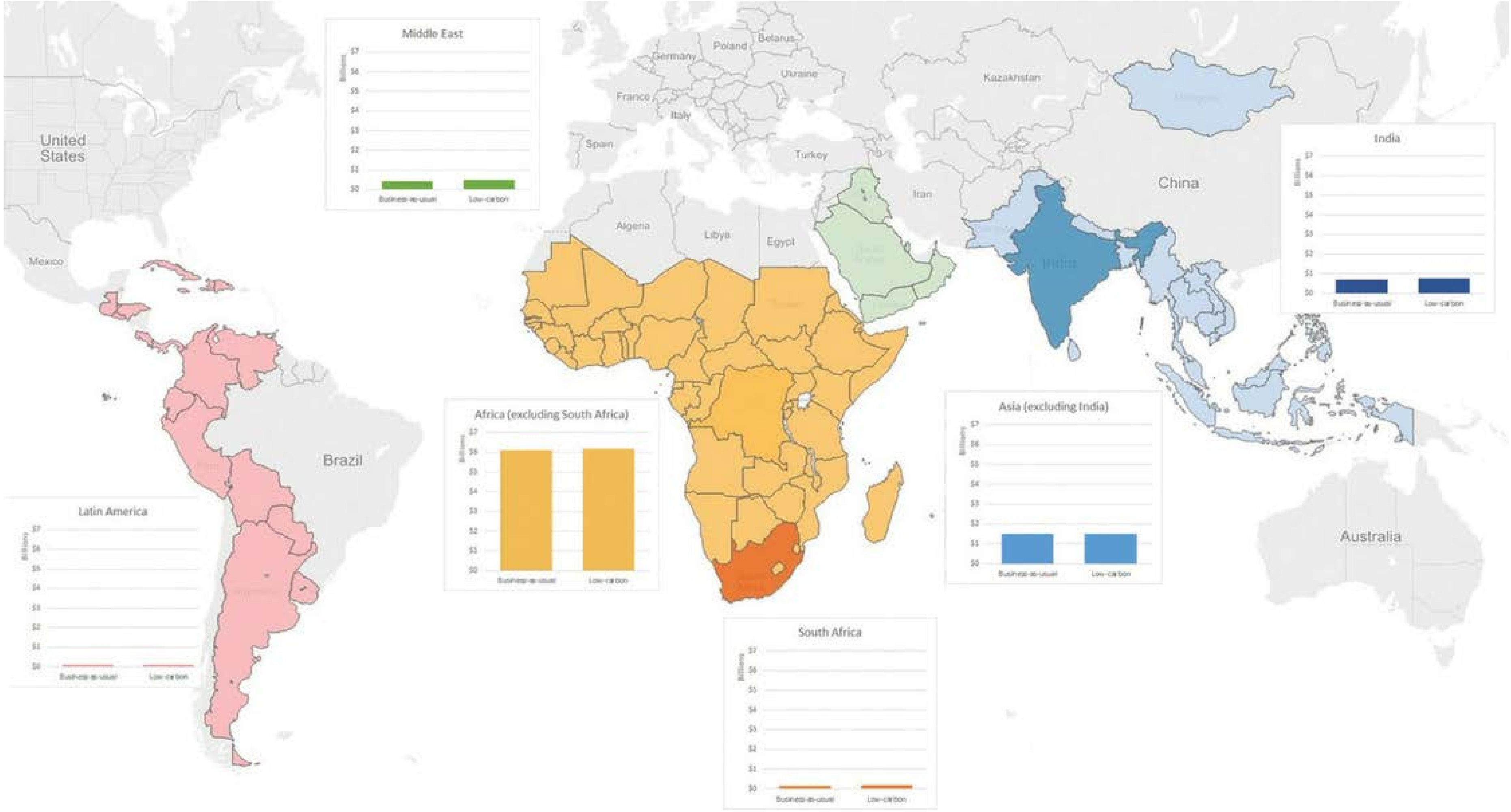
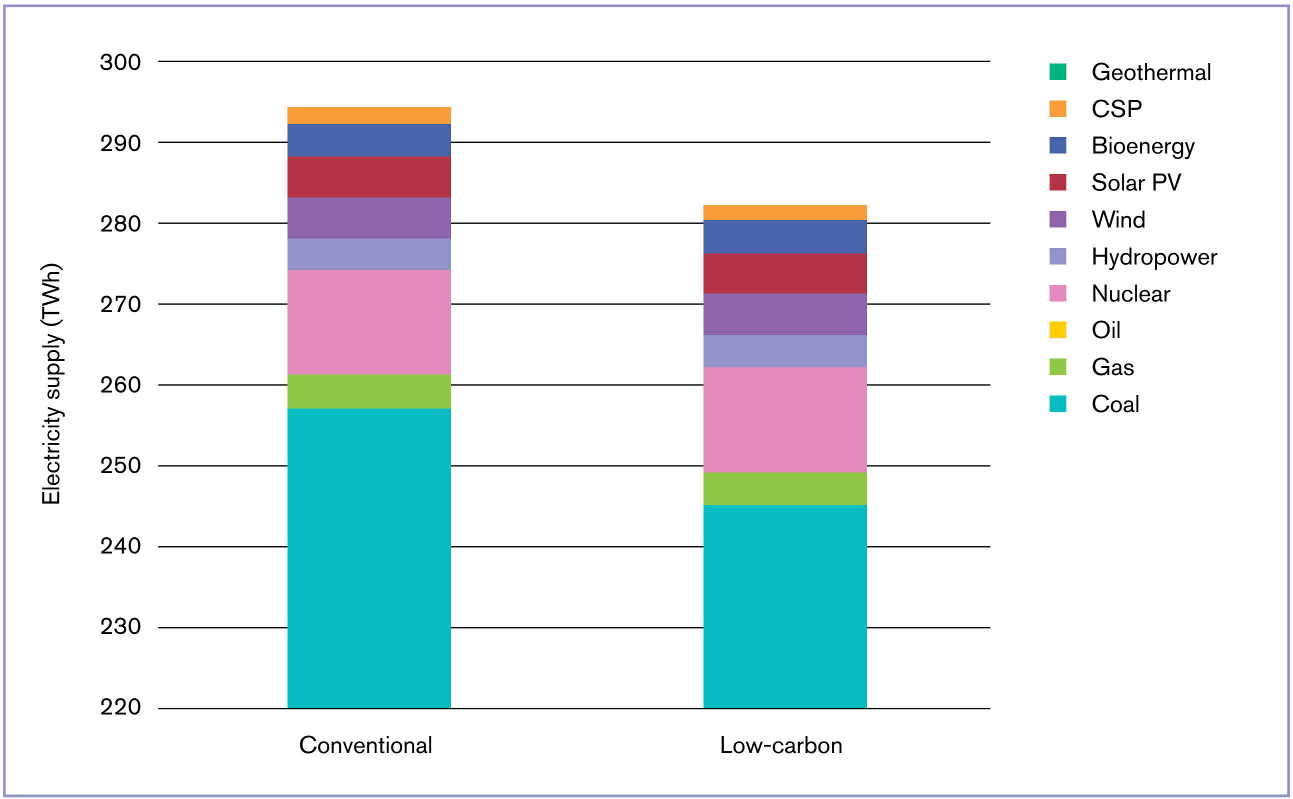


Figure 6. Levels and composition of electricity supply in South Africa in 2020 in the conventional and low-carbon scenarios (IEA, 2014c). The low-carbon scenario is heavily dependent on energy efficiency measures, so requires less electricity to be generated.



Despite the higher upfront costs, the South African government is unlocking significant private finance for renewable energy technologies: nearly 780MW of solar photovoltaics and 560MW of wind power were added in 2014 alone. The government has facilitated this investment through enabling policies such as net metering, utility quota obligations, auctions, capital subsidies or rebates and tax exemptions (IRENA, 2015).

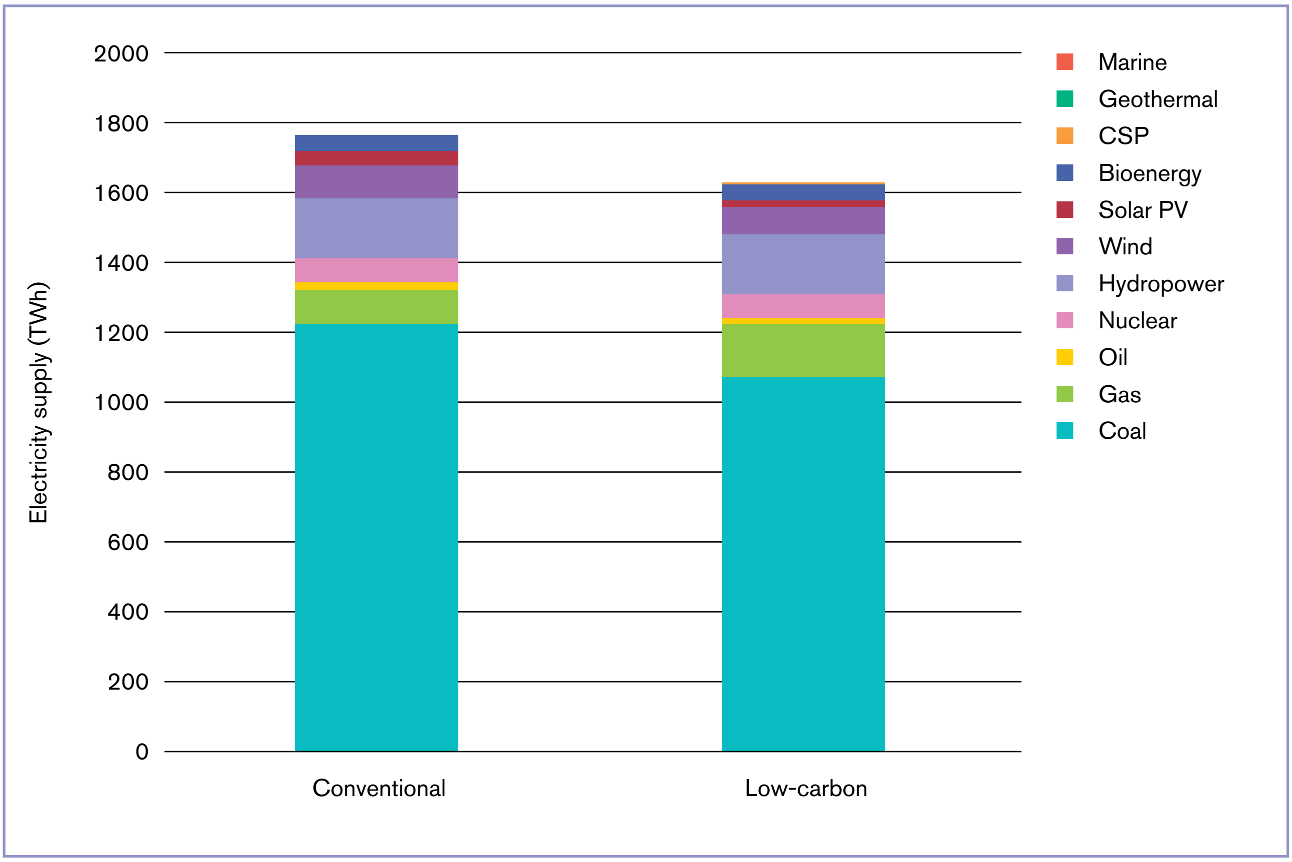
Case study: India

Nearly 17 million Indian urbanites do not have access to electricity. Nearly a third of these people live in the urban centres of Uttar Pradesh, although there are also more than two million urban residents without access to electricity in Bihar and West Bengal (IEA, 2015b).

The cost of providing these people with a basic level of electricity is equal to $94.1 million per year to 2045, including capital, operating, maintenance and financing costs. This equates to a LCOE of $36.90/MWh. Electricity generated in the low-carbon scenario would have a levelised cost of $39.92/MWh, which means that India would need to spend $101.9 million per year to provide electricity to the un-served urban population. This is 8.2 per cent higher than electricity generated under business-as-usual conditions, even though low-cost coal is still a significant source of energy in the low-carbon scenario (Figure 7). India's coal has low calorie and high ash content (Garg, 2012), and the resulting air pollution has the most severe impacts on low-income and other marginalised groups (Foster & Kumar, 2011; Garg, 2011). These health considerations create an additional incentive for decision-makers to choose clean energy technologies.

Although most urban residents in India have access to electricity, many depend on illegal connections to the grid. This is often because electricity utilities do not have policies and practices in place to work with informal settlements: for instance, residents may lack the documented proof of address needed to register for new connections to the grid or live on land owned by national agencies that prevent any infrastructure or service provision. Community-based organisations and non-government organisations are playing an important role in engaging with utilities to adopt more flexible and inclusive systems. The Mahila Housing SEWA Trust in Ahmedabad, for example, has worked with local utilities to change their policies, so that residents can legally connect to the grid under a new category of electricity bills that cannot be used as proof of address,

Figure 7. Levels and composition of electricity supply in India in 2020 in the conventional and low-carbon scenarios (IEA, 2014c). The low-carbon scenario is heavily dependent on energy efficiency measures, so requires less electricity to be generated.



therefore creating space for informality within formal systems. Such initiatives demonstrate the important role that organised communities can play in securing basic infrastructure and services through advocacy to, and partnership with, government. This example also shows that, although the analysis above suggests that India needs to invest $56 million per year on distribution infrastructure to connect un-served households, most cities would benefit from additional policy interventions and investment in the grid to ensure that informal settlements have a legal, reliable electricity supply.

4

Discussion

This analysis demonstrates that generating and distributing electricity to un-served urban populations does not require significant resources: using conventional generation technologies, only $1.37 billion per year would be needed to generate and distribute 100kWh to each urban resident who currently lacks access. This equates to less than 0.03 per cent of annual fossil fuel subsidies (Coady, *et al.*, 2015). Two-thirds of these resources would be required in Africa, where most un-served urban residents reside. With rapid urban population growth across the continent and continuing underinvestment in infrastructure, the investment needs are likely to increase significantly over coming decades.

Such an investment could have a multiplier effect on health (for example, by reducing the incidence of burns or accidental fires), education (for example, by generating light to study) and telecommunications (for example, providing the power to charge mobile phones). Access to electricity also facilitates income-generating activities, such as fabrication of textile goods and food processing (Modi, *et al.*, 2006; Chen, 2016).

Investment in other basic services and infrastructure are likely to have similarly low per capita costs, and would offer different socio-economic benefits. Provision of affordable, reliable and accessible drinking water, for instance, reduces the incidence of disease for urban residents, thereby reducing costs, reducing income lost to being off work and enhancing productivity (Mitlin & Walnycki, 2016). Tenure can increase the security of low-income groups and thereby facilitate investment in housing and land (Budds, *et al.*, 2005; Payne, *et al.*, 2009).

Yet planning and investment that benefits the poor is only likely to take place in cities where the voices of low-income and other marginalised groups are heard and organised (Watson, 2009). Too often, formal policy frameworks and markets exclude these groups. For instance, in many countries, the scale of electricity theft is viewed as a major problem because it means that utilities cannot finance future investments in new generating capacity – yet residents of informal settlements are not permitted to legally connect to the grid to pay for the electricity they consume (Smith, 2004; Depuru, *et al.*, 2011). Urban planning and governance systems need to find ways to bridge the gap between formal and informal systems if they are to deliver basic infrastructure and services to un-served urban residents.

This research also shows how cities can pursue climate-compatible development without having to unlock significant additional investment. In the case of the electricity sector, the cost of providing electricity from low-carbon rather than conventional generation options would be less than 1 per cent higher over the lifetime of the technologies. This is consistent with other literature on the economics of low-carbon cities, which reveal large opportunities to reduce emissions through cost-effective investments in cities in low- and middle-income countries (Colenbrander, *et al.*, 2015; Colenbrander, *et al.*, forthcoming). With favourable interest rates or rapid technological learning, renewable energy technologies could prove even more competitive (Sudmant, *et al.*, 2016).

While the low-carbon scenario is only marginally more expensive than the conventional scenario in the long-term, the difference in the near-term is significant: the overnight capital costs are 6 per cent higher. In the context of widespread urban poverty, decision-makers must consider the opportunity costs of this incremental investment. There is an equally compelling economic and social case to be made that these resources should be spent on other infrastructure or services, rather than on lower-carbon electricity infrastructure (Colenbrander, *et al.*, forthcoming). Urban populations' current vulnerability to climate change is largely due to deficits and deficiencies of basic infrastructure, such as drainage and sanitation (Satterthwaite, *et al.*, 2009). There is therefore a clear complementarity between poverty reduction and adaptation in urban areas (Ayers & Dodman, 2010). To further enhance the adaptive capacity of low-income urban residents, it is important that governments and other decision-makers create opportunities for meaningful community participation in planning and delivering this infrastructure. This helps to integrate the informal sector into formal urban planning and governance systems, and to challenge the power relations that perpetuate and compound poverty and vulnerability (Archer, et al., 2014; Dodman, *et al.*, 2016b).

It is essential not to downplay the challenges of financing these kinds of public goods. Trunk infrastructure is expensive and the costs are front-loaded, while the returns are often uncertain and diffuse. However, there is a clear revenue stream from these investments via electricity bills. Per capita costs are equivalent to less than $7 a year, which even low-income urban residents would almost always be able to pay. The challenge is in meeting the high upfront costs, particularly in the low-carbon scenario.

Discrete, technically straightforward infrastructure projects of this nature should be able to secure private finance, with the possible exception of those in fragile and conflict-affected states where the risks are higher. The scale of the opportunity should be particularly attractive to institutional investors such as pension funds, sovereign wealth funds and insurance companies, which have substantial financial resources and long investment horizons. But public finance needs to play an anchoring role in improving risk-adjusted returns to private investors. National governments have an important role to play in establishing enabling policy frameworks. To illustrate, Indonesia has immense geothermal resources, but is struggling to attract private investment because its tender processes currently favour coal-fired power plants (Smith, 2012). National governments can also offer incentives, such as tax rebates, tax exemptions, capital grants/subsidies and feed-in tariffs, which help infrastructure projects to attract private finance by improving the rate of return. South Africa has successfully deployed many of these policies, and is seeing a commensurate increase in wind and solar generation capacity (IRENA, 2015). Electricity utilities can reduce the risk to prospective investors by offering power purchase agreements, while development banks and climate funds play a similar role by offering credit guarantees, first-loss capital or insurance to prospective infrastructure investments. Finally, municipal authorities can work with community-based organisations to map informal settlements and ensure that the new infrastructure serves all residents. In sectors such as water, sanitation and solid waste collection, municipal authorities and community-based organisations can play a larger role in constructing and financing new infrastructure.

In an ideal world, poverty reduction would be incentive enough to build the political will and strengthen the institutional capacities required to make these investments. In the absence of such commitment, it is necessary to highlight the economic case for the universal provision of basic infrastructure and services. This case would be strengthened from greater quantitative analysis of the impacts, such as the value of public health improvements in informal settlements or productivity gains in the informal economy.

A growing body of evidence suggests that extreme inequality constrains economic growth. Recent research from the International Monetary Fund shows that increasing the income share of the poor leads to higher GDP growth, while increasing the income share of the rich is associated with a decline in GDP growth (Dabla-Norris, *et al.*, 2015). This is because inequality limits the scope for low-income groups to accumulate human and physical capital, thereby reducing net productivity (Stiglitz, 2012). Income stagnation for the poor can also fuel political crises (through the breakdown of social cohesion) and financial crises (through the adoption of populist policies) (Milanovic, 2016).

As governments come together at Habitat III to agree on a New Urban Agenda[3], it is imperative that they recognise that sustained economic growth is likely to depend on reducing inequality within and among cities. In particular, national and local governments need to prioritise poverty reduction through the provision of basic infrastructure and services, such as safe drinking water piped to homes, improved sanitation, household waste collection, durable housing, health care, education and electricity. By improving livelihoods, public health and resilience to shocks and stressors, these measures increase the capacity of low-income and other marginalised groups to contribute to the city economy. Such measures are also likely to enhance political stability and social capital by reducing poverty and facilitating wider participation in urban economies and societies. Although the costs of constructing and operating these systems may seem significant compared to municipal budgets, decision makers need to recognise that they are essential investments if cities are to achieve their potential as engines of economic growth. As Barbara Ward (1976) wrote for Habitat I:

> *"Cities must not be built for economics alone – to build up the property market – not for politics alone – to glorify the Prince (in whatever form of government). They must be built for people and for the poorest first."*

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[3] Habitat III is shorthand for the United Nations Conference on Housing and Sustainable Development, which is held every twenty years. The purpose is to renew political commitment to sustainable urban development and identify global priorities and pathways to deliver it in the New Urban Agenda. A draft of the New Urban Agenda was agreed in Surabaya in September 2016, and will be adopted in Quito in October 2016.

Appendix 1: Data sources and assumptions

The *World Energy Investment Outlook 2014* (IEA, 2014b) provided the data on different power generation technologies, including capital costs, operating and maintenance costs, efficiency, capacity factors, construction times and learning rates. We use the figures projected for 2020 in this analysis.

The net present value (NPV), integral to calculating the LCOE, is evaluated for each technology and region over a 30-year period, including construction times obtained from the IEA (IEA, 2014b). As illustrated above, the LCOE of each bundle of technologies was tested using a range of different discount rates and financing costs.

In all scenarios, photovoltaic solar panels, wind turbines and concentrated solar power have average lifespans of 25 years, while nuclear, geothermal and some fossil fuel plants may last twice as long. Including returns beyond this horizon may drive down estimates of the LCOE for conventional technologies. However, this would have only a small impact due to the front-ended nature of the costs and the impact of discounting – and in practice, few investors evaluate returns over such a long period.

We assume that new oil-based generation capacity using oil is in the form of combined-cycle gas turbines. This is in part due to lack of data on the capital costs of oil-fired power plants, and the improbability of construction of dedicated oil-fired power plants in the future. Data on global grid-connected biomass capacity by feedstock and country/region were obtained from the International Renewable Energy Agency (IRENA, 2012, p. 21). We assumed transmission and distribution costs of $500 per household (World Bank, 2012), with average household sizes calculated using data from the *World Economic Factbook* (Euromonitor International, 2013).

Some energy prices were drawn from the World Bank Commodities Price Forecast: coal produced in Australia is projected to cost US$54.8/mt in 2020, crude oil to cost US$65.6/bbl and natural gas produced in Europe to cost US$5.8/mmbtu (World Bank, 2016a). We use the current, long-term cost of uranium: $1,880/kg (including the costs of processing, enrichment and fabrication) (World Nuclear Association, 2016).

Africa (excluding South Africa)

The African analysis covers the following countries with un-served urban populations: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

The *conventional* scenario in Africa is based on the New Policies Scenario developed by the IEA (IEA, 2014a, p. 192), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 669). We subsequently subtracted data for South Africa, which we considered independently (IEA, 2014c, pp. 676, 677). It is important to note that the low-carbon scenario put forward for Africa by the IEA has nearly the same level of renewable energy capacity as the conventional scenario. The reduced carbon intensity of electricity is primarily due to lower levels of investment in fossil fuel power plants (particularly coal and gas) and assumptions about improved energy efficiency (see Table 4). This might reduce continent-wide expenditure on electricity supply infrastructure, but does not significantly change total investment needs to address the unmet demand of urban residents. In other words, the economic case for the conventional and low-carbon scenarios are very similar in this region.

Table 4. Key data points used to estimate investment needs and levelised cost of electricity in Africa (IEA, 2014a; IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	26	17	303	282
Gas	117	77	383	343
Oil	4	1	93	90
Nuclear	0	0	13	13
Hydropower	68	74	182	188
Wind	7	8	14	15
Solar PV	6	6	11	11
Bioenergy	5	5	11	11
CSP	3	3	5	5
Geothermal	7	7	9	9
Marine	0	0	0	0

We assume that new wind-based generation capacity in Africa is from offshore turbines. We assume that all coal-fired power plants in the region are sub-critical rather than supercritical. We assume that all hydroelectricity serving urban grids is generated from large hydropower plants, as these generate the vast proportion of hydroelectricity and the small hydropower plants in the region are a major source of energy for micro- or off-grid systems in rural areas (IEA, 2014a). We assume transmission and distribution losses of 17.9 per cent. This figure is calculated using a weighted average according to the number of un-served urban residents in each country, with countries in sub-Saharan Africa (excluding South Africa) have average transmission and distribution losses of 18 per cent and those in North Africa of 14 per cent (IEA, 2014a).

Asia (excluding India)

The Asian analysis covers the following countries with un-served urban populations: Bangladesh, Cambodia, Indonesia, the Democratic People's Republic of Korea, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand and Vietnam.

The *conventional* scenario is based on the New Policies Scenario developed for non-OECD Asia by the IEA (IEA, 2015a, p. 630), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 653).

We subsequently subtracted data for India, which we considered independently, and China, which has no un-served urban population and has a large enough grid to distort the findings. The *conventional* scenarios for India and China are based on the New Policies Scenario developed for the countries by the IEA (IEA, 2015b, pp. 634, 636), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, pp. 657, 661).

Capital, operating and maintenance costs for different energy technologies are assumed to be equal to those of India, provided in the *World Energy Investment Outlook 2014* (IEA, 2014b). We assume that 10 per cent of new hydropower capacity is from small hydro, and 90 per cent from large hydro, which is consistent with projected global averages to 2040 (IEA, 2015a, p. 353). We assume transmission and distribution losses of 15.5 per cent, an average generated from country-level data (World Bank, 2014) and weighted according to the number of un-served urban residents in each country. The high rate of transmission and distribution losses is largely due to Myanmar and Pakistan, which have 2 million and 1.2 million un-served urban residents respectively, as well as transmission and distribution losses of 27 per cent and 13 per cent.

Table 5. Key data points used to estimate investment needs and levelised cost of electricity in non-OECD Asia, excluding China and India (IEA, 2015a; IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS- USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS- USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	49	34	652	540
Gas	28	23	557	550
Oil	0	0	83	86
Nuclear	3	3	72	72
Hydropower	23	19	238	232
Wind	4	4	10	12
Solar PV	8	5	13	10
Bioenergy	4	3	32	36
CSP	0	0	2	0
Geothermal	2	2	29	30
Marine	0	0	0	0

India

The *conventional* scenario in India is based on the New Policies Scenario developed by the IEA (IEA, 2015b, p. 176), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 661).

We assume transmission and distribution losses of 17.7 per cent in 2020 (IEA, 2014c), and that new wind-based generation capacity in India is from onshore turbines. We use a price of US$13/tonne for bagasse and US$26/tonne for rice husks (IRENA, 2012, p. 31), and assume that utilities can use biogas at no extra cost.

Table 6. Key data points used to estimate investment needs and levelised cost of electricity in India (IEA, 2015b; IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	90	61	1,224	1,072
Gas	22	30	96	154
Oil	1	2	26	18
Nuclear	5	4	66	64
Hydropower	16	15	174	174
Wind	21	22	93	77
Solar PV	15	13	40	22
Bioenergy	4	3	48	46
CSP	1	1	0	2
Geothermal	0	0	0	0
Marine	0	0	0	0

Latin America

The Latin American analysis covers the following countries with un-served urban populations: Argentina, Bolivia, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay and Venezuela.

The *conventional* scenario is based on the New Policies Scenario developed for Latin America by the IEA (IEA, 2015a, p. 654), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 681). We subsequently subtracted Brazil's installed capacity (GW) and electricity supply (TW) because the size of its grid distorted the regional results, and there are no un-served urban populations in Brazil. The *conventional* scenario for Brazil is based on the New Policies Scenario developed for the country by the IEA, while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 685).

We assume that all existing coal-fired power plants in Latin America are subcritical, and that coal-fired power plants constructed from 2016 will be supercritical. Although there is substantial potential for offshore wind around Chile, Colombia and Peru, this requires substantial technical capacities so we assume all new wind infrastructure will be from onshore turbines. Capital, operating and maintenance costs for different energy technologies are assumed to equal those of Brazil, provided in the *World Energy Investment Outlook 2014* (IEA, 2014b). We use a price of US$12/tonne for bagasse and US$71/tonne for charcoal, based on prices in Brazil (IRENA, 2012, p. 31), and assume that utilities can use sewage gas at no extra cost.

We assume transmission and distribution losses of 37.9 per cent, an average generated from country-level data (World Bank, 2014) and weighted based on the number of un-served urban residents in each. The high rate of transmission and distribution losses is largely due to Haiti, which has 3.45 million unserved urban residents, accounting for 74.2 per cent of the un-served urban population in Latin America, and has transmission and distribution losses of 54 per cent.

Table 7. Key data points used to estimate investment needs and levelised cost of electricity in Latin America, excluding Brazil (IEA, 2015a; IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	2	1	21	17
Gas	13	7	167	168
Oil	0	0	122	96
Nuclear	1	1	9	14
Hydropower	14	17	359	377
Wind	2	3	7	6
Solar PV	2	1	3	2
Bioenergy	1	3	14	14
CSP	0	0	0	0
Geothermal	0	1	5	5
Marine	0	0	0	0

Middle East

The Middle East analysis covers the following countries with un-served urban populations: Iraq, Oman, Qatar, Saudi Arabia and Yemen.

The *conventional* scenario for the Middle East is based on the New Policies Scenario developed by the IEA (IEA, 2015a, p. 640), while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, p. 665).

We assume that the 1GW of coal-fired power capacity to be constructed between 2013 and 2020 will be supercritical and that new wind power capacity comes from on-shore sources. We find that more than 99 per cent of new hydropower is in the form of 'large' plants, i.e. 10MW or more. We assume transmission and distribution losses of 9.8 per cent, an average generated from country-level data (World Bank, 2014) and weighted according to the number of un-served urban residents in each of the five countries.

South Africa

The *conventional* scenario for South Africa is based on the New Policies Scenario developed by the IEA, while the *low-carbon* scenario is based on its 450 Scenario (IEA, 2014c, pp. 676, 677).

We assume that new wind-based generation capacity in Africa is from offshore turbines. We assume that the only supercritical coal-fired power plants in the country are the Kusile and Medupi plants, with a combined size of 4,800MW. We assume that all hydroelectricity that serves urban grids is generated from large hydropower plants, because these generate the vast proportion of hydroelectricity, and the small hydropower plants in the region are a major source of energy for micro- or off-grid systems in rural areas (IEA, 2014a). We assume transmission and distribution losses of 10 per cent (IEA, 2014a).

Table 8. Key data points used to estimate investment needs and levelised cost of electricity in the Middle East (IEA, 2015a; IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	1	1	3	3
Gas	68	50	826	725
Oil	16	6	330	291
Nuclear	4	2	37	20
Hydropower	4	2	30	28
Wind	1	2	2	4
Solar PV	3	3	4	5
Bioenergy	0	0	2	3
CSP	1	1	1	3
Geothermal	0	0	0	0
Marine	0	0	0	0

Table 9. Key data points used to estimate investment needs and levelised cost of electricity in South Africa (IEA, 2014c).

	NEW POWER GENERATION CAPACITY (2013–2020) (GW)		COMPOSITION OF ELECTRICITY SUPPLY IN 2020 (TWH)	
	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO	BUSINESS-AS-USUAL SCENARIO	LOW-CARBON SCENARIO
Coal	9	6	257	245
Gas	3	2	4	4
Oil	0	0	0	0
Nuclear	0	0	13	13
Hydropower	1	1	4	4
Wind	2	2	5	5
Solar PV	3	3	5	5
Bioenergy	1	1	4	4
CSP	1	1	2	2
Geothermal	0	0	0	0
Marine	0	0	0	0

References

Archer, D., Alamansi, F., DiGregorio, M., Roberts, D., Sharma, D., Syam, D. 2014. Moving towards inclusive urban adaptation: approaches to integrating community-based adaptation to climate change at city and national scale. *Climate and Development*, 6(4), pp. 345–356.

Ayers, J. & Dodman, D., 2010. Climate change adaptation and development I: the state of the debate. *Progress in Development Studies*, 10(2), pp. 161–168.

Banana, E. et al., 2015. Sharing reflections on inclusive sanitation. *Environment and Urbanization*, 27(1), pp. 19–34.

Benjamin, N. et al., 2012. *The Informal Sector in Francophone Africa Firm Size, Productivity, and Institutions.* Washington DC, USA: World Bank.

Bertram, C. et al., 2015. Carbon lock-in through capital stock inertia associated with weak near-term climate policies. *Technological Forecasting and Social Change*, 90(A), pp. 62–72.

Bhan, G., 2009. "This is no longer the city I once knew". Evictions, the urban poor and the right to the city in millennial Delhi. *Environment and Urbanization*, 21(1), pp. 127–142.

Boonyabancha, S., Carcellar, F. & Kerr, T., 2012. How poor communities are paving their own pathways to freedom. *Environment and Urbanization*, 24(2), pp. 441–462.

Brown, D., McGranahan, G. & Dodman, D., 2014. *Urban informality and building a more inclusive, resilient and green economy.* London, UK: International Institute for Environment and Development.

Budds, J., Teixeira, P. & SEHAB, 2005. Ensuring the right to the city: pro-poor housing, urban development and tenure legalization in São Paulo, Brazil. *Environment and Urbanization*, 17(1), p. 89–114.

Burra, S., Patel, S. & Kerr, T., 2003. Community-designed, built and managed toilet blocks in Indian cities. *Environment and Urbanization*, 15(2), pp. 11–32.

Chaplin, S., 2011. Indian cities, sanitation and the state: the politics of the failure to provide. *Environment and Urbanization*, 23(1), pp. 57–70.

Chen, M., 2016. Technology, informal workers and cities: insights from Ahmedabad (India), Durban (South Africa) and Lima (Peru). *Environment and Urbanization.*

Coady, D., Parry, I., Sears, L. & Shang, B., 2015. *How Large Are Global Energy Subsidies?* Paris, France: International Monetary Foundation.

Colenbrander, S., Gouldson, A., Roy, J., Kerr, N., Sarkar, S., Hall, S., Sudmant, A., Ghatak, A., Chakravarty, D., Ganguly, D., McAnulla, F. Forthcoming. Can low-carbon urban development be pro-poor? *Environment and Urbanization.*

Colenbrander, S., Gouldson, A., Sudmant, A. & Papargryopoulou, E., 2015. The economic case for low-carbon development in rapidly growing developing world cities: A case study of Palembang, Indonesia. *Energy Policy*, Volume 80, pp. 24–35.

Crousillat, E., Hamilton, R. & Antmann, P., 2010. *Addressing the Electricity Access Gap.* Washington DC, USA: World Bank.

Dabla-Norris, E. et al., 2015. *Causes and Consequences of Income Inequality: A Global Perspective*. Washington DC, USA: International Monetary Foundation.

d'Cruz, C. & Mudimu, P., 2013. Community savings that mobilize federations, build women's leadership and support slum upgrading. *Environment and Urbanization*, 25(1), pp. 31–45.

Depuru, S., Wang, L. & Devabhaktuni, V., 2011. Electricity theft: Overview, issues, prevention and a smart meter based approach to control theft. *Energy Policy [Special Section on Offshore wind power planning, economics and environment]*, 39(2), p. 1007–1015.

Dobson, S., Nyamweru, H. & Dodman, D., 2015. Local and participatory approaches to building resilience in informal settlements in Uganda. *Environment and Urbanization*, 27(2), pp. 605–620.

Dodman, D., Colenbrander, S. & Archer, D., 2016b. Towards adaptive urban governance. In: D. Archer, S. Colenbrander & D. Dodman, eds. *Responding to Climage Change in Asian Cities: Governance for a More Resilient Urban Future.* London, UK: Routledge.

Dodman, D., Leck, H., Rusca, M. & Colenbrander, S., 2016a. African Urbanisation and Urbanism: Implications for risk accumulation and reduction. *Urban Africa Risk Knowledge (UrbanARK): Working Paper 10.*

Dodman, D. & Mitlin, D., 2013. Challenges for community-based adaptation: Discovering the potential for transformation. *Journal of International Development*, 25(5), pp. 640–659.

Duranton, G., 2008. *Cities: Engines of Growth and Prosperity for Developing Countries?* Washington DC, USA: World Bank.

Euromonitor International, 2013. *The World Economic Factbook*. London, UK: Euromonitor International.

Floater, G. et al., 2014. *Cities and the New Climate Economy: the transformative role of global urban growth*. London, UK: Global Commission on the Economy and Climate.

Foster, A. & Kumar, N., 2011. Health effects of air quality regulations in Delhi, India. *Atmospheric Environment*, 45(9), pp. 1675–1683.

Garg, A., 2011. Pro-equity effects of ancillary benefits of climate change policies: A case study of human health impacts of outdoor air pollution in New Delhi. *World Development*, 39(6), pp. 1002–1025.

Garg, P., 2012. Energy Scenario and Vision 2020 in India. *Journal of Sustainable Energy & Environment*, Volume 3, pp. 7–17.

Goulder, L. & Williams, R. I., 2012. The choice of discount rate for climate change policy evaluation. *Climate Change Economics*, 30(4), p. 1250024 (18 pages) .

Gouldson, A., Colenbrander, S., Sudmant, A., Godfrey, N., Millward-Hopkins, J., Fang, W., Zhao, X. 2015. *Accelerating Low-Carbon Development in the World's Cities*. London, UK: Global Commission for the Economy and Climate.

Grossa, R., Blyth, W. & Heptonstall, P., 2010. Risks, revenues and investment in electricity generation: Why policy needs to look beyond costs. *Energy Economics [Policymaking Benefits and Limitations from Using Financial Methods and Modelling in Electricity Markets]*, 32(4), pp. 796–804.

Hasan, A., 2006. Orangi Pilot Project; the expansion of work beyond Orangi and the mapping of informal settlements and infrastructure. *Environment and Urbanization*, 18(2), pp. 451–480.

IEA, 2014a. *Africa Energy Outlook: A Focus on Energy Prospects in sub-Saharan Africa*. Paris, France: International Energy Agency.

IEA, 2014b. *World Energy Investment Outlook 2014: "Power Generation Investment Assumptions"*. Paris, France: International Energy Agency.

IEA, 2014c. *World Energy Outlook 2014*. Paris, France: International Energy Agency.

IEA, 2015a. *World Energy Outlook 2015*. Paris, France: International Energy Agency.

IEA, 2015b. *India World Energy Outlook 2015*. Paris, France: International Energy Agency.

IEA, 2015c. *World Energy Outlook Special Report: Energy and Climate Change*. Paris, France: International Energy Agency.

IEA, 2015d. *Projected Costs of Generating Electricity*. Paris, France: International Energy Agency.

IRENA, 2012. *Renewable Energy Technologies: Cost Analysis Series: Volume 1: Power Sector: Biomass for Power Generation*. Paris, France.: International Renewable Energy Agency.

IRENA, 2015. *Africa 2030: Roadmap for a Renewable Energy Future*. Abu Dhabi, United Arab Emirates: International Renewable Energy Agency.

Kennedy, C. et al., 2015. Energy and material flows of megacities. *Proceedings of the National Academy of Sciences of the United States of America*, 112(19), pp. 5985–5990.

McGranahan, G., Balk, D., Martine, G. & Tacoli, C., 2013. Fair and Effective Responses to Urbanization and Climate Change: Tapping Synergies and Avoiding Exclusionary Policies. In: G. Martine & D. Schensul, eds. *The Demography of Adaptation to Climate Change.* New York, USA; London, UK; Mexico City, Mexico: UNFPA, IIED and El Colegio de México, pp. 24–40.

McGranahan, G., Schensul, D. & Singh, G., 2016. Inclusive urbanization: Can the 2030 Agenda be delivered without it?. *Environment and Urbanization*, 28(1), pp. 13–34.

Milanovic, B., 2016. *Global Inequality: A New Approach for the Age of Globalization.* Boston, USA: Harvard University Press.

Mitlin, D. & Satterthwaite, D., 2013. *Urban Poverty in the Global South: Scale and Nature.* New York, USA: Routledge.

Mitlin, D. & Walnycki, A., 2016. *Why is water still unaffordable for sub-Saharan Africa's urban poor?* London, UK: International Institute for Environment and Development.

Modi, V., McDade, S., Lallement, D. & Saghir, J., 2006. *Energy and the Millennium Development Goals*. New York, USA: United Nations Development Programme, UN Millennium Project, and World Bank.

Moss, T. & Gleave, M., 2014. *Benefits and Costs of the Energy Targets for the Post-2015 Development Agenda: Post-2015 Consensus*. Copenhagen, Denmark: Copenhagen Consensus Centre.

Nordhaus, W., 2007. A review of the Stern Review on the Economics of Climate Change. *Journal of Economic Literature*, 45(3), pp. 686–702.

Patel, S., Baptist, C. & d'Cruz, C., 2012. Knowledge is power – informal communities assert their right to the city through SDI and community-led enumerations. *Environment and Urbanization*, 24(1), pp. 13–26.

Payne, G., Durand-Lasserve, A. & Rakodi, C., 2009. The limits of land titling and home ownership. *Environment and Urbanization*, 21(2), pp. 443–462.

Pegels, A., 2010. Renewable energy in South Africa: Potentials, barriers and options for support. *Energy Policy [Carbon Emissions and Carbon Management in Cities]*, 38(9), pp. 4945–4954.

Pereira, M., Freitas, M. & da Silva, N., 2010. Rural electrification and energy poverty; empirical evidences from Brazil. *Renewable and Sustainable Energy Reviews*, 14(4), pp. 1229–1240.

Satterthwaite, D., 2003. The Millennium Development Goals and urban poverty reduction: great expectations and nonsense statistics. *Environment and Urbanization*, 15(2), pp. 179–190.

Satterthwaite, D., 2008. Editorial: The social and political basis for citizen action on urban poverty reduction. *Environment and Urbanization*, 20(2), pp. 307–318.

Satterthwaite, D., 2013. The political underpinnings of cities' accumulated resilience to climate change. *Environment and Urbanization*, 25(2), pp. 381–391.

Satterthwaite, D., 2016. Missing the Millennium Development Goal targets for water and sanitation in urban areas. *Environment and Urbanization*, 28(1), pp. 99–118.

Satterthwaite, D., Hardoy, J., Pandiella, G., Johnson, C., Colenbrander, S., Archer, D., Brown, D., Evangelina Filippi, M. 2016. *Why Resilience Matters to the Urban Poor*. Washington DC, USA: World Bank.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H., Romero Lankao, P. 2009. Adapting to climate change in urban areas: The possibilities and constraints in low- and middle-income nations. In: J. Bicknell, D. Dodman & D. Satterthwaite, eds. *Adapting Cities to Climate Change: Understanding and Addressing the Development Challenges.* London, UK: Earthscan, pp. 3–50.

Satterthwaite, D. & Mitlin, D., 2014. *Reducing Urban Poverty in the Global South.* Oxon, UK: Routledge.

Seto, K. et al., 2014. Human Settlements, Infrastructure and Spatial Planning. . In: O. Edenhofer, et al. eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom: Cambridge University Press.

Smith, P., 2012. The potential for investment in Indonesia's geothermal resource. *International Journal of Engineering Technology*, 2(2), pp. 300–307.

Smith, T., 2004. Electricity theft: a comparative analysis. *Energy Policy*, 32(18), p. 2067–2076.

Spence, M., Annez, P. & Buckley, R., 2009. *Urbanization and Growth*. Washington DC, USA: World Bank.

Stern, N., 2006. *The Economics of Climate Change: The Stern Review.* Cambridge, UK: Cambridge University Press.

Stiglitz, J., 2012. *The Price of Inequality: How Today's Divided Society Endangers Our Future.* New York, USA: W.W. Norton.

Sudmant, A., Millward-Hopkins, J., Colenbrander, S. & Gouldson, A., 2016. Low carbon cities: is ambitious action affordable? *Climatic Change*, pp. 1–8.

Sutherland, C. et al., 2014. Water and sanitation provision in eThekwini Municipality: a spatially differentiated approach. *Environment and Urbanization*, 26(2), pp. 469–488.

Tacoli, C., McGranahan, G. & Satterthwaite, D., 2008. Urbanization, Poverty and Inequity: Is Rural-Urban Migration a Poverty Problem, or Part of the Solution?. In: *The New Frontier: Urbanization, Poverty and Environment in the 21st Century.* London, UK: Earthscan, pp. 37–54.

Turok, I. & McGranahan, G., 2013. Urbanization and economic growth: the arguments and evidence for Africa and Asia. *Environment and Urbanization*, 25(2), pp. 465–482.

UCLG, 2010. *Local Governments in the World; Basic Facts on 96 Selected Countries*. Barcelona, Spain: United Cities and Local Governments.

UN DESA, 2014. *2014 Revision of World Urbanization Prospects*. New York, USA: United Nations Department of Economic and Social Affairs.

UNFCCC, 2015. *Adoption of the Paris Agreement.* Paris, France, United Nations Framework Convention on Climate Change.

UN-Habitat , 2016. *World Cities Report 2016: Urbanization and Development: Emerging Futures*. Nairobi, Kenya: United Nations Human Settlements Programme.

United Nations Development Programme, 2015. *Goal 7: Affordable and clean energy.* [Online] Available at: http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda/goal-7.html [Accessed 8 9 2016].

Unruh, G. & Carrillo-Hermosilla, J., 2006. Globalizing carbon lock-in. *Energy Policy*, 34(10), pp. 1185–1197.

Ward, B., 1976. *The Home of Man.* New York, USA: W W Norton.

Watson, V., 2009. 'The planned city sweeps the poor away…': Urban planning and 21st century urbanisation. *Progress in Planning*, 72(3), p. 151–193.

Wenban-Smith, H., 2006. Urban infrastructure: density matters, not just size. *Research Papers in Environmental & Spatial Analysis*, Volume Working Paper 104.

Wilkinson, P., Smith, K., Joffe, M. & Haines, A., 2007. A global perspective on energy: health effects and injustices. *The Lancet*, 370(9591), p. 965–978.

World Bank, 1991. *Urban Policy and Economic Development: An Agenda for the 1990s.* Washington DC, USA: World Bank.

World Bank, 2012. *Addressing the electricity access gap.* Washington, DC, USA.: World Bank.

World Bank, 2014. *Electric power transmission and distribution losses (% of output).* [Online] Available at: http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS [Accessed 19 08 2016].

World Bank, 2016a. http://pubdocs.worldbank.org/en/764161469470731154/CMO-2016-July-forecasts.pdf, Washington, D.C., USA: World Bank.

World Bank, 2016b. *CO2 emissions (metric tons per capita).* [Online] Available at: http://data.worldbank.org/indicator/EN.ATM.CO2E.PC [Accessed 8 9 2016].

World Bank, 2016b. *GDP per capita (current US$).* [Online] Available at: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD [Accessed 22 08 2016].

World Nuclear Association, 2016. *The Economics of Nuclear Power*, s.l.: World Nuclear Association.

Yeager, K., 2001. *Electricity development for a sustainable world: bridging the digital divide.* Buenos Aires, Argentina: World Energy Council 18th Congress.

Related reading

Brown, D., McGranahan, G., Dodman, D. 2014. *Urban informality and building a more inclusive, resilient and green economy.* International Institute for Environment and Development. London, UK. Available from: http://pubs.iied.org/10722IIED/

Colenbrander, S., Gouldson, A., Roy, J., Kerr, N., Sarkar, S., Hall, S., Sudmant, A., Ghatak, A., Chakravarty, D., Ganguly, D., McAnulla, F. Forthcoming. Can low-carbon urban development be pro-poor? *Environment and Urbanization.*

McGranahan, G., Schensul, D. & Singh, G., 2016. Inclusive urbanization: Can the 2030 Agenda be delivered without it?. *Environment and Urbanization*, 28(1), pp. 13–34.

Satterthwaite, D. & Mitlin, D., 2014. *Reducing Urban Poverty in the Global South.* Oxon, UK: Routledge.

Turok, I. & McGranahan, G., 2013. Urbanization and economic growth: the arguments and evidence for Africa and Asia. *Environment and Urbanization*, 25(2), pp. 465–482.

Wilson, E., Symons, L. 2013. *Stimulating quality investment in sustainable energy for all.* International Institute for Environment and Development. London, UK. Available from: http://pubs.iied.org/17156IIED/

Urbanisation offers substantial opportunities to reduce poverty, in part because it is more cost-effective to meet many basic needs in cities than in rural areas. This paper demonstrates that providing electricity to the 200 million urban residents who currently lack access would require only $1.37 billion per year to 2045. Generating this electricity from low-carbon options (consistent with avoiding a 2°C temperature rise) would cost only 1% more. This demonstrates that relatively small amounts of resources need to be mobilised to deliver basic services and infrastructure to the urban poor – an essential precursor to inclusive and sustained economic growth.

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