

TOWARDS A MORE EQUAL CITY

Powering Cities in the Global South: How Energy Access for All Benefits the Economy and the Environment

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EXECUTIVE SUMMARY

Highlights

- ▶ Energy is fundamental to economic productivity and livelihoods, and cities have a major role to play in how it is provided and consumed.
- ▶ Cities in the global South face three fundamental energy challenges: the urgent need to increase access to clean, affordable, and reliable energy; how to meet increasing electricity demand while addressing inadequate supply and system inefficiencies; and the imperative to chart a new model of development that slows the growth of carbon emissions and is not fossil fuel-intensive.
- ▶ Solutions exist that can both address the needs of the urban under-served and provide economic and environmental benefits to the whole city.
- ▶ We highlight three solutions in which the city itself can play a key implementing role: accelerating the shift to cleaner cooking; scaling up distributed renewable energy within cities; and increasing energy efficiency of buildings and appliances.
- ▶ These solutions require enabling institutions and governance, finance, and policy, as well as decisions by diverse actors in cities.



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Background

The world is entering a new epoch of urbanization. By 2050 it is projected that two-thirds of the world's population will live in urban areas, with a net urban population increase of 2.4 billion people from 2015, mostly in Africa and Asia.¹ Cities that are already struggling to provide clean, affordable, and reliable energy for their residents will likely find it challenging to keep up with the pace and scale of growth. Without much-needed changes in approach, the urban “under-served” population—those who lack access to core services—will expand in cities in rapidly growing parts of the global South. This challenge presents an unprecedented opportunity to create a different kind of city: one that is more equal, where everyone has access to core services, and where all residents can live, work, and thrive.

This paper is concerned with the challenge of expanding access to energy in the growing cities of the global South. More specifically, it asks, *How can cities in the global South provide cleaner, more affordable, and more reliable energy services to the under-served while achieving economic prosperity and safeguarding environmental quality?*

About This Paper

This working paper is part of the larger World Resources Report *Towards a More Equal City*, which views sustainability as composed of three interrelated issues: the economy, the environment, and equity. We use the equitable provision of urban services as the premise for examining whether meeting the needs of the under-served can improve the other two dimensions of sustainability.

To address the question of how to power the city for all, we have conducted extensive literature reviews and consulted with international organizations such as the Global Alliance for Clean Cookstoves, the Collaborative Labeling and Appliance Standards Program, the Global Buildings Performance Network, the Energy Sector Management Assistance Program, and the World LPG Association.

Our goal is to draw attention to the under-appreciated problem of urban energy access. This paper takes a unique approach in that it looks not only at how to improve energy services for the under-served, but also at how various solutions to the access challenge could impact the city's overall economic and environmental well-being. We believe that expanding access to modern

energy sources and systems to include the poor and marginalized is not in conflict with action to mitigate climate change. While energy is often considered outside the purview of cities, our paper argues that energy is a fundamental urban issue and that cities have a large and essential role to play in providing clean, affordable, and reliable energy to all their residents.

An equally important goal is to inform urban change agents—a broad suite of actors that include national and regional governments, international financial institutions, civil society, and the private sector—on priority urban energy action areas.

Urban Energy Challenges

We identify three key energy challenges facing cities in the global South (see Figure ES-1). The first is the urgent need to increase energy access, where access comprises not only the basic ability to obtain energy but also the reliability, affordability, and quality of the energy source. The second is that rapidly growing regions in the global South face potentially unsustainable growth in demand for energy that could overwhelm their supply systems and leave millions more people without access. The third challenge is that rapidly growing regions cannot continue to replicate past models of development if they are to avoid locking in dependency on fossil fuels and the associated volatile prices, air pollution, and expensive infrastructure.

Energy access, reliability, and affordability remain vexing and overlooked urban problems in much of the global South

In some countries, particularly those in East Asia and the Pacific, Latin America and the Caribbean, and South Asia, urban electricity access is high, averaging more than 97 percent in 2012.² However, in low-income countries, average levels of urban energy access were only 58 percent that same year.³ In addition, national-level data on access can sometimes mask much worse conditions in individual cities. Even where populations have access to electricity, unreliability and inefficiency can be acute problems. Aging and inefficient infrastructure strains the ability of utilities to supply adequate power, which subjects customers to frequent power outages.

Access to modern, non-solid fuels is also lacking in many urban areas in the global South. Nearly half a billion urban residents worldwide still use solid cooking fuels.⁴ Cooking with such fuels on traditional stoves and open fires is highly polluting and linked to premature mortality and morbidity.

The cost of electricity and fuels can represent a major burden. Poor households in the global South often spend as much as 14 percent to 22 percent of their income on energy, although households are typically considered energy poor if they spend 10 percent or more of their income on fuel and electricity.⁵ Moreover, even if the poorest residents can meet the cost of monthly bills, they may not be able to afford high connection charges and are thus denied access altogether.

Rapidly growing regions in the global South face potentially unsustainable growth in energy demand

Increasing electricity access in the global South is a development imperative, but emerging cities face the dual challenge of rising demand and inadequate supply, made worse by system inefficiencies and line losses. More than 15 percent of electricity in much of the global South is lost during transmission and distribution; in some cities the percentage is higher.⁶ In many cities in the global South, growth rates of electricity consumption are

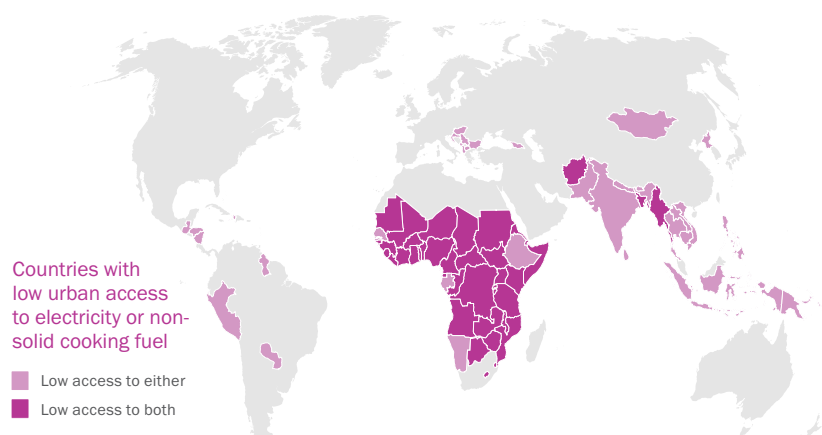
much greater than rates of population growth. Going forward, cities in the global South will need to expand their sources of energy supply and provide better-quality services per unit of energy.

Rapidly growing regions cannot continue to replicate past models of development

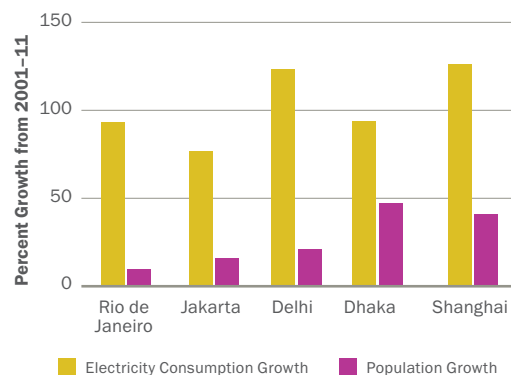
The old fossil fuel-intensive model of development that was undertaken in the global North is not tenable, given a greater awareness of the health impacts of air pollution in cities. The majority of cities in Africa and Southeast Asia monitored by the World Health Organization have experienced increases in particulate matter (PM₁₀) concentrations in recent years. Among the megacities, those in South Asia, for example, have at least double the PM_{2.5} concentrations of cities in the global North, such as New York, Paris, or London.⁷ Furthermore, fossil fuel-intensive electricity generation entails energy security risks and import dependence for a number of countries in the global South. For example, in 2014, the Philippines, Senegal, and Sri

Figure ES-1 | **Urban energy challenges in the global South**

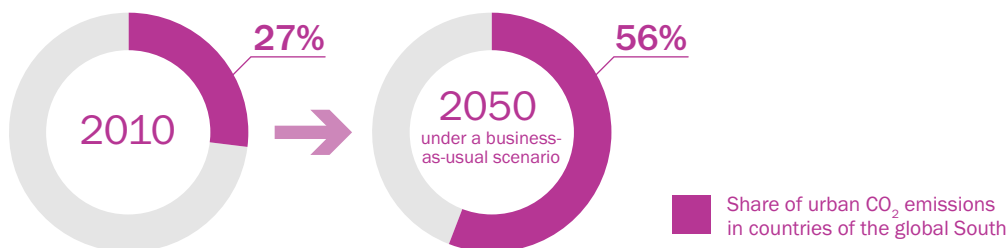
1. Existing problems with poor energy access, reliability, and affordability



2. Unprecedented growth in energy demand from rapid urbanization



3. Continued carbon-intensive development driving pollution, energy insecurity, and climate risks



Source: World Bank, 2016b; IEA, 2015; Kennedy et al., 2015; Erickson and Tempest, 2014.

Lanka all imported about 50 percent of their energy.⁸ Urban areas globally are responsible for the majority of global final energy use and the associated greenhouse gas (GHG) emissions. On average, per capita GHG emissions in urban areas in the global South are still far lower than in the global North, but in terms of absolute emissions, the picture is changing rapidly. In 2010, China, developing Asia, India, Africa, and Latin America⁹ comprised about one-quarter of total urban GHG emissions from the core sectors of buildings, transport, and waste disposal.¹⁰ In a business-as-usual scenario, those regions are projected to be responsible for about 56 percent of total urban emissions in 2050.¹¹ With future electricity demand projected to increase, national and local governments must make decisions now about their future energy infrastructure.

Solutions to the Urban Energy Challenges

This paper focuses on three urban energy solutions in which the city itself can play a major role in implementation (see Figure ES-2). Despite the breadth of the challenge, our solutions are deliberately focused more narrowly, to make them easier to implement. The focus of the World Resources Report *Towards a More Equal City* is on the urban under-served, so our first concern is to ask how a solution enhances services for the under-served in terms of access, reliability, cost, health impacts, and livelihoods, and whether a solution is practical and scalable. Our second concern is how these solutions improve life in the city as a whole, by enhancing economic productivity, improving air quality, and avoiding the long-term lock-in of inefficient energy consumption and rising GHG emissions.

Based on our framing, we argue that urban change agents should focus on the following solutions:

- ▶ Accelerate the shift to cleaner cooking
- ▶ Scale up distributed renewable energy within cities, especially using solar photovoltaic (PV) systems
- ▶ Increase energy efficiency via measures that include building codes for new construction and energy-efficient appliance standards

This paper focuses on three urban energy solutions in which the city itself can play a major role in implementation.

While these solutions may not be new, we hope to provide a new perspective by evaluating their benefits across the three dimensions of equitable access for the under-served, the economy, and the environment of the overall city.

Accelerating the shift to cleaner cooking

The use of modern cooking fuels—such as liquefied petroleum gas (LPG), electricity, biogas, and ethanol—would result in dramatic reductions in indoor air pollution and improved health benefits for the urban poor. Because of the premature mortality associated with solid cooking fuels, no urban energy intervention would have a greater public health impact. Globally, indoor air pollution from household cooking with solid fuels accounted for 3.5 million deaths and 4.5 percent of disability adjusted-life years in 2010.¹² If we assume exposure is the same for rural and urban populations, and given the fact that about 16 percent of all people using solid cooking fuels in 2010 were in urban areas, then close to 550,000 premature deaths might have occurred in urban areas in that year due to indoor air pollution from solid cooking fuel.¹³ In many cases, modern fuels can also result in significant cost and time savings to households, compared to biomass or kerosene.

Scaling up distributed renewable energy

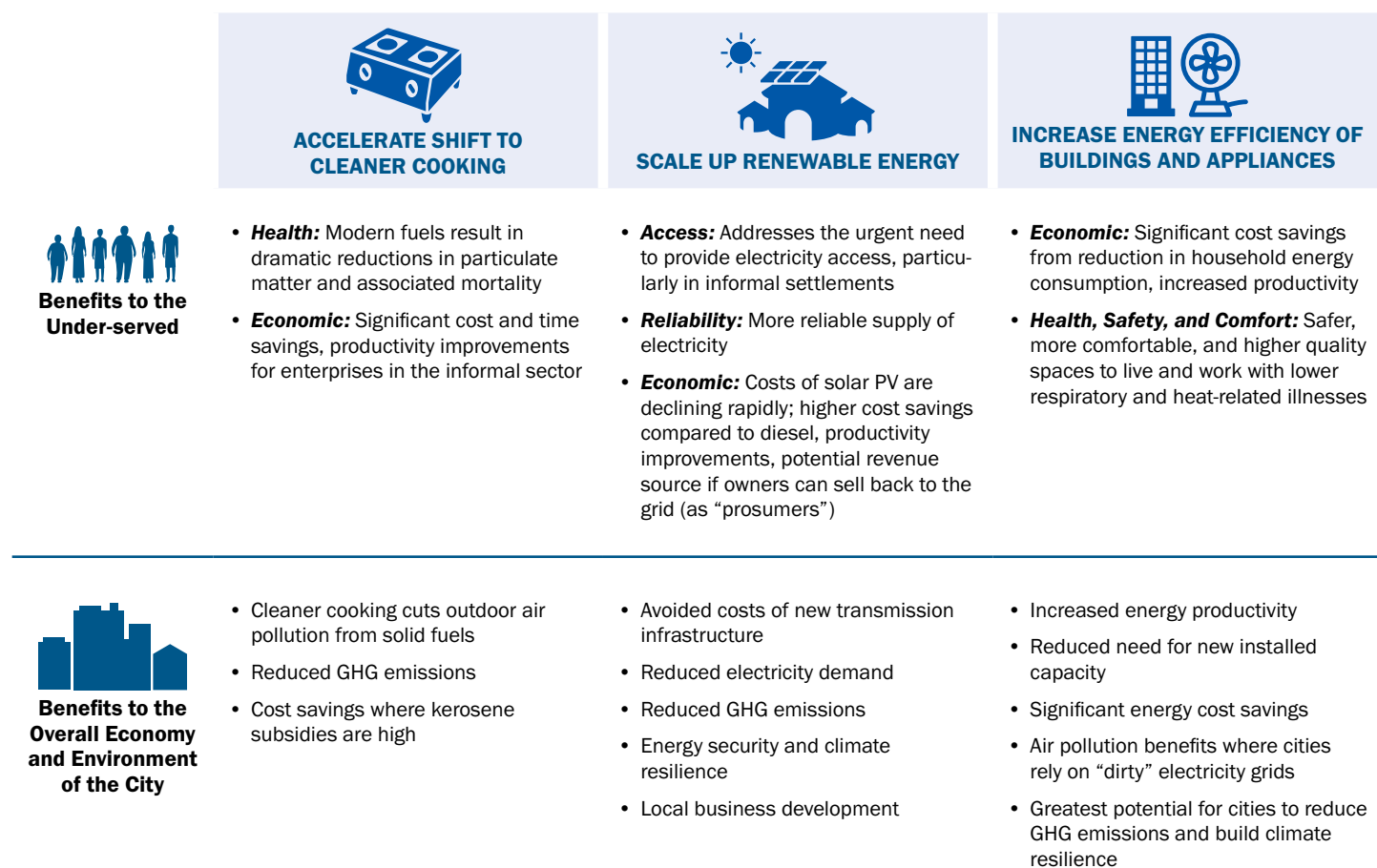
Distributed renewable energy (such as solar PV) addresses the urgent need to provide electricity access and offers additional benefits when compared to traditional grid connection. While we recognize that other distributed renewable energy solutions exist, solar PV systems have greater overall potential in urban areas than technologies such as wind power. Solar PV is still an option even where individuals do not have adequate rooftop space, and community-owned, community-shared solar systems are a promising model in such cases. Solar PV (both on-grid and off-grid) can offer affordability, reliability, and productivity benefits to the under-served. Grid electricity can be expensive, and the cost of solar PV systems and storage batteries is declining.

The average levelized cost of electricity (LCOE) for residential rooftop solar PV in India and China is now within the cost range for natural gas-fired generation in both countries. With greater access to more reliable and affordable supplies, the urban under-served will rely less on dirty diesel and kerosene, which are used extensively in the global South and are often expensive. In addition, home-based enterprises undertaken by the under-served are often energy-intensive and require a reliable supply of power. In some cases rooftop solar PV systems may allow owners to sell power back to the grid, although such arrangements are in nascent stages in the global South.

Increasing energy efficiency of buildings and appliances

Over time, the development and enforcement of energy-efficiency building codes and energy-efficient appliance standards can bring both direct and indirect benefits to the under-served. More energy-efficient structures and appliances will provide benefits in terms of reduced energy bills, improved economic productivity, comfort, health (reduced illnesses), and climate-change resilience (e.g., to heat waves). Potential savings in energy consumption (and hence cost) realized by switching to the best available household appliances and equipment are on the order of 40 percent to 50 percent.¹⁴

Figure ES-2 | Recommended approaches to the urban energy challenges in the global South



Environmental and economic benefits for the whole city

In addition to benefiting the urban under-served, the solutions described above will enhance wider environmental quality and economic productivity. Household heating and cooking is a significant source of ambient (outdoor) air pollution, in addition to indoor pollution. In 2010, outdoor air pollution from the use of solid fuels for household cooking was estimated to have resulted in 370,000 deaths and 9.9 million disability-adjusted life years, globally.¹⁵ Given that in 2010 about 16 percent of the total population using solid fuels for cooking resided in urban areas, then at least 58,000 premature deaths and 1.5 million disability-adjusted life years were likely attributable to outdoor air pollution from solid fuels for cooking in urban areas.¹⁶ The decrease in premature mortality among all urban residents—not only those using solid cooking fuel—from air pollution reductions (both household and ambient) would result in increased economic productivity for cities in the global South. In countries where kerosene subsidies are high, shifting to modern fuels can result in cost savings, given the increases in energy efficiency.

Switching to modern fuels and the cleanest-burning biomass stoves would also result in lower GHG emissions compared to traditional biomass stoves. While this benefit transcends the city's environmental quality, climate change action is an important entry point for local and national leaders who have made climate change commitments, and is an important consideration for programs led by international development finance institutions. Increased use of distributed renewables can help reduce pressures on grid electricity. At scale, rooftop solar PV can offer savings due to the avoided costs of new

transmission infrastructure, which translate into savings for electricity customers. That being said, the impact of rooftop solar PV on utilities' overall financial viability needs to be carefully examined, particularly in terms of technical concerns (e.g., intermittency), load forecasting and balancing, and planning. Rooftop solar PV can also contribute to energy security, climate change resilience, and economic development opportunities for cities through the creation of local businesses and employment opportunities.

Scaling up distributed renewable energy could result in GHG emissions reductions and decreased associated air pollution. This is especially the case where countries' electricity grids are carbon-intensive, as they are in South Africa, China, India, and Indonesia. We calculate that the power generated by tripling the current installed capacity of solar PV across 60 countries (assuming constant demand) would reduce GHG emissions by 108 MtCO₂e, an amount equivalent to the total annual emissions of Belgium in 2012.¹⁷

On average, residential and commercial buildings are the largest energy consumers in urban areas globally. Because they can exist for decades, buildings represent the biggest lock-in for cities in terms of energy use. The economic case for energy efficiency is well understood. Building energy-efficiency measures can generally reduce energy use by up to 50 percent to 90 percent in new buildings and 50 percent to 75 percent in existing buildings.¹⁸ Energy cost savings in municipal buildings translate into more money for other public services. Furthermore, every kilowatt-hour (kWh) saved where cities depend on “dirty” electricity grids also means reduced air pollution associated with fossil fuel-fired electricity generation.

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Moving Forward: Barriers to and Enablers of Change

The three solution areas we recommend in this paper—accelerating the shift to cleaner cooking, scaling up distributed renewable energy within cities, and increasing energy efficiency of buildings and appliances—all require the critical enablers of institutions and governance, finance, and policy.

Institutions and governance

Government leadership at all levels, effective and well-coordinated institutions, modern regulatory frameworks, and engagement with the under-served are fundamental to success. Issues related to property tenure need to be addressed. Institutions must be adequately staffed to set standards; promote energy efficiency and renewable energy targets; develop local plans; enforce and monitor compliance with regulations on modern fuels, building codes, and appliance standards; provide training to project developers, regulators, and utilities; and raise awareness. Often, national- and subnational-level agencies or specialized departments need to be developed to coordinate efforts. Participatory process and civil society organization (CSO) engagement are vital to make sure equity concerns are incorporated in planning processes and implementation.

Policy

There are numerous complementary policies that can help catalyze these solutions. Pretax fossil-fuel consumption subsidies totaled about US\$330 billion in 2015, and subsidy reforms, such as replacement of these subsidies with targeted cash transfers for the poor, could remove some “headwinds” for clean cooking, energy efficiency, and renewable energy.¹⁹ Import policies on modern fuels and cookstoves can be made less restrictive so as

to foster uptake. Renewable energy policies adopted at either the national or city level—such as feed-in tariffs, net or gross metering, and reverse auctions, or special tariffs for renewable energy customers such as green tariffs, quotas, and renewable portfolio standards—can help accelerate distributed renewable energy.

Finance

The proliferation of new finance models, such as pay-as-you-go consumer payment schemes, bode well for distributed solar energy, energy-efficient appliances, and clean cooking. It is likely that affordability will continue to increase for distributed renewables. The costs of solar PV technology have declined in a steep, nonlinear fashion, and the cost of battery storage is projected to decline significantly in the future. Other financing models include innovative blended finance, social impact and green bonds, and revolving funds. However, more needs to be done to address up-front costs and willingness-to-pay issues. One important role for international public finance is to address externalities, such as the climate change and local air pollution costs of energy, through carbon finance and results-based payments. When combined with consumer finance models, these have the potential to make the economics of clean cooking, energy efficiency, and distributed solar even more favorable.

The solutions we have identified necessitate involvement by diverse change agents in the urban space—municipal leaders, utilities, national and state leaders, international aid organizations and development agencies, the private sector, and CSOs. It is only through the coordinated actions of these actors that the energy needs of the urban under-served and the long-term environmental and economic interests of the city as a whole will be met.

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INTRODUCTION

For the first time in human history, a majority of the world's population is now urbanized. By 2050, it is estimated that two-thirds of humanity will live in urban areas.²⁰ The urban population will have grown by 2.4 billion people compared with 2015, and most of these people will be living in Africa and Asia.²¹ Many cities lack the capacity to effectively manage this growth. The population increase will make it even more challenging for already struggling cities to provide clean, affordable, and reliable energy for their residents.

At the same time, the rate of urban poverty is increasing and, without much-needed changes, the “under-served” population—those who lack access to core services—in cities in rapidly growing parts of the global South is likely to expand.²² This shift demands that we create a different kind of city: one that is more equal, where everyone has access to core services, and where all residents can live, work, and thrive.

This paper asks: *How can cities in the global South provide cleaner, more affordable, and more reliable energy services to the under-served while achieving economic prosperity and safeguarding environmental quality?* Our goal in this paper is to draw attention to the under-appreciated problem of access to energy services in the city and show that addressing access can actually promote the economy and the urban environment. While energy is often considered to be outside the purview of cities, energy is a fundamental urban issue, and cities have a large and essential role to play in providing clean, affordable, and reliable energy to all their residents.

Addressing energy services is critical to a city in a number of respects. In many parts of the global South, especially in low-income countries and sub-Saharan Africa, populations lack access to electricity and modern cooking fuels. As these countries develop, there is a risk that decisions regarding infrastructure, on both the energy supply and demand side, will lock in conventional energy-use patterns, together with their associated impacts on human health and high greenhouse gas (GHG) emissions, over the long term. There is currently an opportunity for cities in the global South that have yet to build tomorrow's infrastructure to embark on a sustainable development pathway.

Box 1 | Who Are the Urban Under-served?

Urban populations rely on a range of goods and services for their survival, health, and livelihoods, including access to water, toilets, household waste removal, health care, fuels/electricity, schools, and public transport. Provision of these services can be assessed in terms of who is under-served in the quality and reliability of the good or service. As this paper describes, a household that has an electricity connection may still be under-served if the supply is unreliable, unaffordable, or dangerous. Definitions of service quality matter because they influence who is considered to be under-served. In urban centers in high-income nations, all households have regular and safe electricity connections—although low-income households may face serious difficulties in affording electricity bills. By contrast, in many cities in the global South, large sections of the population lack electricity connections, including many that have incomes above the poverty line. The under-served also includes those households that cannot afford to shift up the “energy ladder” to cleaner fuels.

Scope and Definitions

We consider the following energy services: lighting, cooking, heating and cooling, productive uses (e.g., running small machines), and appliance use. While other service sectors—such as housing, transport, and water provision and treatment—rely on the production and consumption of energy,²³ these issues are not addressed in this paper. Our definition of the under-served includes, but is not limited to, those who lack access to core urban services (see Box 1). The under-served includes the poor and lower-middle income residents who, in an *absolute* sense, do not have access to clean, affordable, and reliable energy. The term also includes, for example, those residents in higher income brackets whose electricity access may be a *quality* issue, where supply is plagued by intermittency and unreliability, forcing households to purchase diesel generators as a backup source of power. Our geographic focus is on cities in the global South, especially the rapidly growing parts of sub-Saharan Africa and Asia.

Our Approach and Purpose

In this paper, we first emphasize the importance of energy for the city, then examine current energy challenges for cities in the global South, and finally make recommendations in three solution areas that we argue can have the greatest impact on the urban under-served. We analyze each solution in terms of benefits to the under-served and impact on the city's overall economic productivity and environmental quality. We also describe barriers to implementing each of these solutions and possible enabling factors, in terms of institutions and governance, finance, and policy. Many of the solutions are also relevant to the developed world, but we are concerned solely with cities in the global South. In the World Resources Report *Towards a More Equal City: Framing the Challenges and Opportunities*, we develop a city typology based on cities' current income and projected ratio of economic growth to population growth and categorize cities as *struggling*, *emerging*, *thriving*, or *stabilizing*.²⁴ Our implicit focus in this paper is on the first two categories, but we do not disaggregate the solution areas further and map them to each city category. Wherever possible, we make our arguments using urban-level data; that being said, the general paucity of urban data is well documented.

Our methodology for examining the current energy challenges facing cities in the global South and determining the solution area is based largely on extensive literature reviews as well as syntheses and consultations with international organizations such as the Global Alliance for Clean Cookstoves, the Collaborative Labeling and Appliance Standards Program, the Global Buildings Performance Network, the Energy Sector Management Assistance Program, and the World LPG Association. We analyzed publicly available data sets (e.g., the World Bank's World Development Indicators) and conducted in-depth interviews on the urban energy issues of households and small businesses in the global South.

We hope this paper will inform *urban change agents*—a broad suite of actors from national and regional governments, international financial institutions, civil society, and the private sector—on priority urban energy action areas, barriers, and enablers in the solution areas that we identify.

THE IMPORTANCE OF ENERGY FOR THE CITY

Energy is a fundamental urban issue. The amount and type of energy available has profound implications for a city's economic productivity and environment.

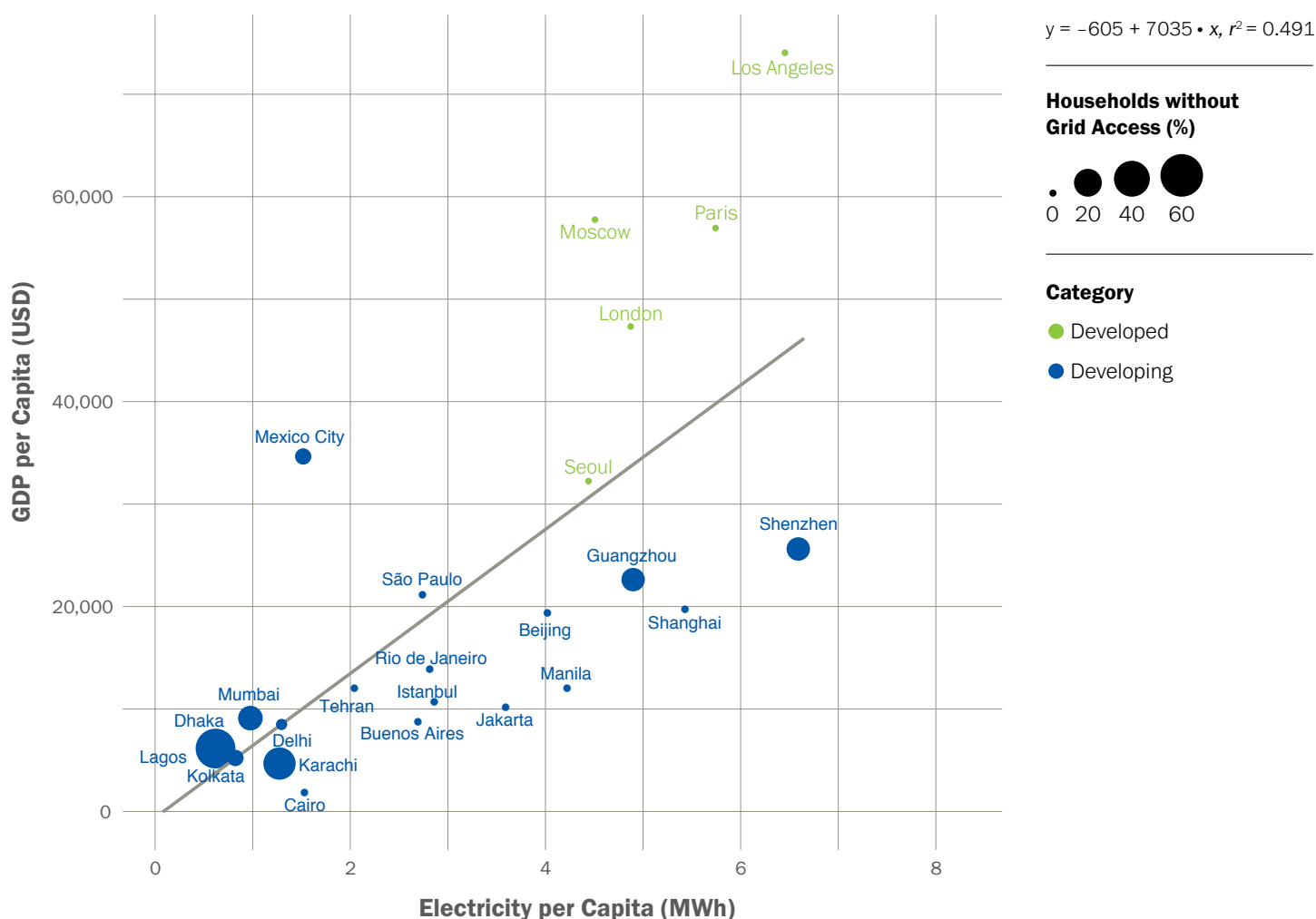
Energy Is a Prerequisite for Economic Productivity

Cities are economic engines, responsible for 85 percent of global gross domestic product (GDP) in 2015.²⁵ Energy fuels the city, providing the services necessary to homes and livelihoods, such as lighting, cooking, heating, cooling, small machines, transport, and water. It is essential for economic productivity, including the operations of small and micro-enterprises. Electricity consumption per capita is correlated with a city's per capita GDP (see Figure 1). In addition, while electricity access in and of itself may not cause economic growth, a city that cannot provide widespread access to electricity may struggle to support healthy GDP growth.

At the household level, the amount of energy available is one determinant of the economic productivity within the home. In many low- and middle-income countries, it is common for low-income households to operate businesses out of their homes.²⁶ In Salvador, Brazil, for example, a survey of two neighborhoods found that 58 percent of enterprises in one neighborhood and 96 percent in the other were located in the owners' houses.²⁷ In Lagos, Nigeria, nearly half of surveyed residents relied solely on their home-based enterprises for their income.²⁸

The contribution of informal settlements to the city's GDP is often overlooked, and these settlements are where many of the under-served reside. Dharavi, in Mumbai, India, spreads across some 525 acres; it is one of the world's 30 megaslums and is among the largest in Asia.²⁹ Dharavi is home to an estimated 1,700 manufacturing units of all kinds, from small-scale manufacturers employing 5 to 10 people to medium-scale industries.³⁰ Businesses based in Dharavi include food manufacturers, restaurants, printing presses, scrap and recycling units, and manufacturers producing goods entirely for export. Most of the businesses are in the informal sector, so data are scarce, but total income in Dharavi may be INR 1,500 to INR 2,000 crore (x 10⁷ INR) per year (about US\$220 million to \$294 million in 2016 dollars).³¹ Improving energy services to households in informal settlements in the global South will likely enhance the city's productivity.

Figure 1 | **There is a strong relationship between per capita electricity consumption, per capita GDP, and electricity access in the world's megacities**



Notes: Data from 2011. RSE = 14170, DF = 22, p value = 0.0001. Megacities = cities with population ≥ 10 million. While comprehensive data are available only for megacities, this relationship is robust across city sizes. There were no data on GDP per capita for three megacities—New York, Osaka, and Tokyo—and no data on electricity access for Lagos.

Source: Data from Kennedy et al., 2015.

Current Energy Consumption Patterns and Air Pollution in Cities

Emissions from fuel combustion—for heating, cooking, transport, industrial production, and electricity generation, among other activities—are the major cause of outdoor and indoor air pollution in cities. The sources of local air pollution depend on the development context. For example, globally, the major sources of urban $PM_{2.5}$ concentrations (particulates less

than 2.5 micrograms in size) are traffic, domestic fuel burning, and industrial activities (including power generation). However, there is much regional variation; in India, traffic is the major contributor, while in Africa, domestic fuel burning dominates.³² In 2012, just over 7 million premature deaths worldwide can be attributed to the joint effects of household and ambient (outdoor) air pollution.³³ More than 94 percent of those deaths were located in Africa, Southeast Asia, and low- and middle-income countries in other regions of the world.³⁴

URBAN ENERGY CHALLENGES

Energy Access, Reliability, and Affordability Remain Vexing and Overlooked Urban Problems in Much of the Global South

Access

Energy access is often overlooked as an urban issue, but cities in the global South face challenges in availability (access to a connection) and in quality (a connection that is legal, safe, affordable, and reliable). In some countries, particularly those in East Asia and the Pacific, Latin America and the Caribbean, and South Asia, urban electricity access is high: on average, more than 97 percent of the urban populations in these countries had connections in 2012.³⁵ However, in low-income and sub-Saharan Africa, average levels of urban energy access were only 58 percent and 72 percent, respectively.³⁶ Globally, about 131 million people in urban areas lacked access to electricity; 95 million of them lived in sub-Saharan Africa.³⁷

Data on urban access at the national level sometimes mask worse conditions in individual cities. In Bangladesh, Dhaka had an access rate of just 33 percent at the metropolitan scale in 2011, compared to a reported 82 percent access rate for the urban population nationally in 2012.³⁸ In Kibera, Nairobi's largest informal settlement, 42 percent of the population used electricity for lighting in 2007, and only about 30 percent of small to medium enterprises in the settlement used electricity.³⁹ This contrasts with an access rate of 74 percent for Kenya's entire urban population at that time.⁴⁰ These data inconsistencies cloud the picture of who actually has access and can lead to the misperception that energy access is not an urban problem. The scale of illegal connections in many cities can also mask the problem of low access to energy. In Dakar, Senegal, the high electrification rate of almost 90 percent obscures the fact that an estimated 25 percent of peri-urban households are illegally connected to the grid.⁴¹

In the context of informal settlements, most barriers to electricity access are institutional or political in nature, but a number of upgrading programs have successfully addressed some of the issues around lack of tenure and community engagement (see Box 2).

Box 2 | Informal Settlements and Lessons Learned on Electrification

In many urban contexts, the main barriers to electrification for low-income groups are political. Governments are often hesitant to provide infrastructure investments in informal areas for fear of legitimizing informal settlements.^a Many electric utilities are reluctant to service informal areas because of real or perceived costs due to lack of tenure, illegal tapping of electricity lines, narrow streets and alleys, and challenges in obtaining right-of-way documents.^b Secure tenure is often necessary to provide residents with a full range of infrastructure and service improvements. Thailand's Baan Mankong program overcame this obstacle through quasi-household IDs that allow residents of informal settlements to apply for electricity connections without having legal land ownership. This program, implemented by the Community Organization Development

Institute, has reached over 80,000 households in 249 urban settlements. Other challenges include recent increases in tariffs and high connection costs, the lack of a coordinated energy strategy for the urban poor, and limited community awareness of quasi-household registration processes.^c

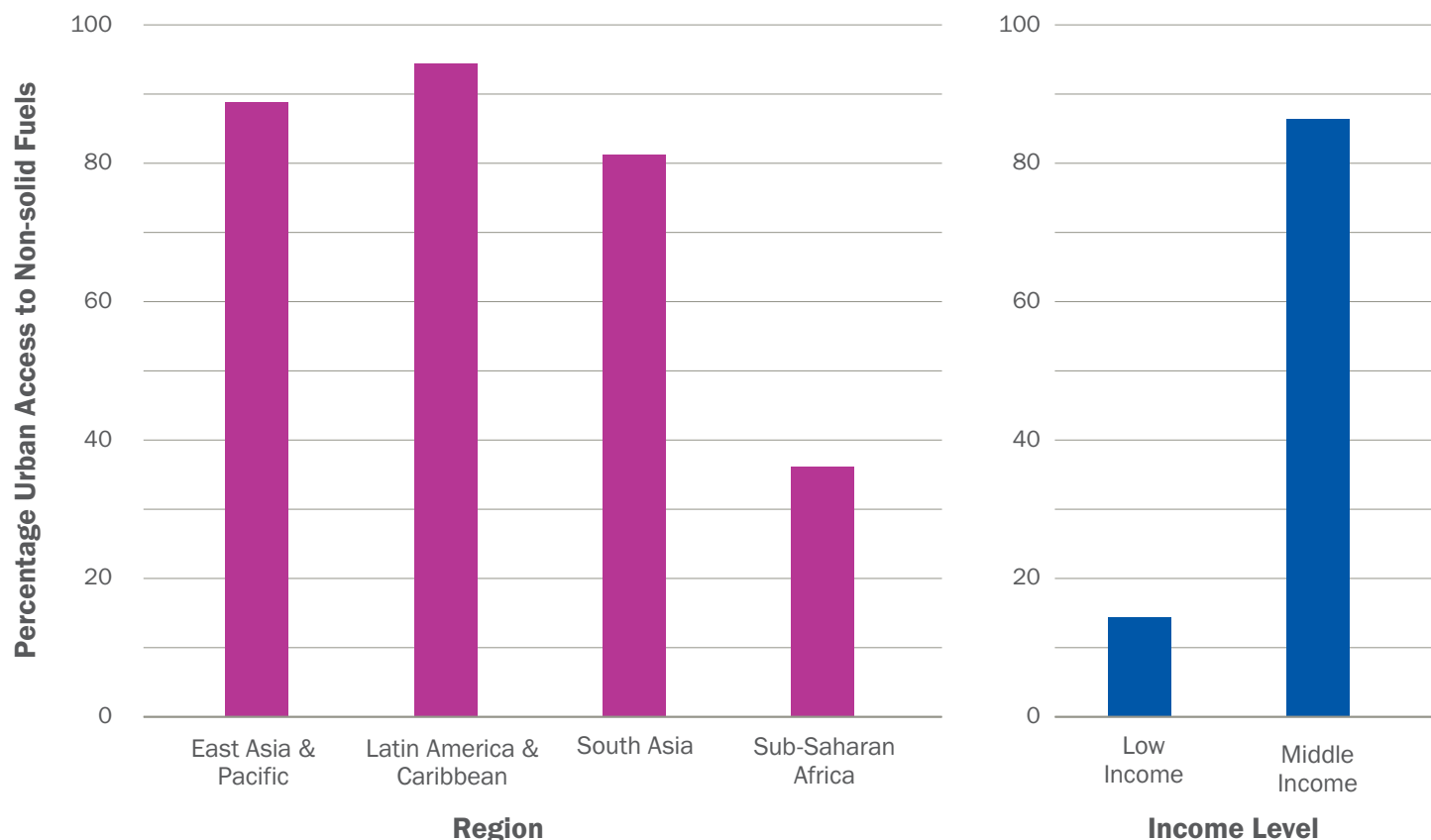
Large-scale electrification partnerships with NGOs have been successful in India. Ahmedabad's informal settlements have been electrified via a partnership between the Ahmedabad Electricity Company (a commercialized public utility) and the Self Employed Women's Association (SEWA) and its housing micro-finance agency, Mahila Housing Trust.^d The project created a supportive legal framework for electrification while avoiding onerous tenure regularization processes. After the pilot project proved that subsidizing connection costs was financially

viable, it went on to electrify 100,000 households between 2001 and 2008.^e The program is now under way in smaller cities in Gujarat and Rajasthan. NGOs played important roles in social mobilization and as intermediaries with the utility, which initially did not want to electrify informal settlements in the absence of a policy framework. SEWA and Mahila Housing Trust helped mobilize residents, negotiated with the utility for monthly bills (more affordable than billing every two months), and facilitated learning workshops and communication more generally.^f

Notes:

- a. Singh et al., 2015.
- b. Baruah, 2015; USAID, 2009.
- c. Singh et al., 2015.
- d. Baruah, 2015.
- e. Baruah, 2015.
- f. Baruah, 2015.

Figure 2 | **Urban access to non-solid fuels varies by world region and income level**



Note: Data from 2012. There is overlap between the region and income-level categories.

Source: World Bank, 2016b.

Access to modern fuels⁴² is also lacking in many urban areas in the global South. On average, only 14 percent and 36 percent of the urban populations in low-income and sub-Saharan African countries, respectively, had access to modern, non-solid cooking fuels in 2012 (see Figure 2).⁴³ This translates into about 482 million urban residents worldwide who use solid cooking fuels, more than 40 percent of whom live in sub-Saharan Africa.⁴⁴ Cooking with solid, unprocessed fuels on traditional stoves and open fires is highly polluting in terms of particulate matter, CO₂, and other pollutants. On average, a traditional woodstove or an unvented coal stove produces about 17 times more PM_{2.5} on a per-unit basis than a modern fuel stove.⁴⁵ Moreover, there are large associated fire risks from kerosene stoves and lamps (much more so than other liquid or gaseous fuels), as well as health risks, including poisoning and respiratory impacts.

Reliability

Providing electricity access is not simply about connections. Even where populations have access to electricity, unreliability and inefficiency can be acute problems. In 2012, more than 15 percent of electricity in South Asia, Latin America and the Caribbean, and low-income countries overall was lost during transmission and distribution, including through pilferage.⁴⁶ These losses strain utility companies' ability to supply adequate power to meet demand, resulting in power outages. On average, the number of power outages experienced by firms in South Asia exceeded 25 per month in 2013.⁴⁷ That year, firms in Pakistan and Bangladesh experienced an average of 75 and 65 outages per month, respectively.⁴⁸ In Africa, most countries experience power outages every day.⁴⁹

Affordability

The cost of electricity and fuels can be a major burden on the under-served. If a household spends more than 10 percent of its income on fuel and electricity, it is commonly classified as energy poor.⁵⁰ Poor urban households in cities in the global South often spend as much as 14 percent to 22 percent of their incomes on energy (see Box 3).⁵¹ In Cajú, an informal settlement in Rio de Janeiro, residents were estimated to spend more than 15 percent of their total income on energy, while in Kibera, Nairobi, energy expenditures reached 20 percent to 40 percent of monthly incomes.⁵² Moreover, the 10 percent threshold of energy poverty does not always apply in urban areas in low- and middle-income nations, where energy poverty manifests itself more as the use of poor quality fuels and/or the cutting of fuel expenditures. For example, households might cook only one meal per day and shift to foodstuffs that require less cooking, to have more money to meet their basic needs.

In urban and peri-urban areas in the global South, including informal settlements, the most challenging issue related to adequate electricity access is not necessarily the cost of ongoing service but rather the affordability of an electricity connection. In some areas of sub-Saharan Africa, where connection charges can be more than \$100 per household, poor consumers are often unable to afford this initial up-front cost, even when they are able to afford subsequent monthly charges.⁵³

The cost of irregular supply often hits small-scale firms the hardest, including those in informal settlements. Unreliable electricity supplies force firms with grid connections to use dirty and expensive diesel generators to supplement their power.⁵⁴ Electricity produced by diesel generators has a levelized cost of \$0.35 to \$0.60/kWh, which is in most cases greater than the costs of renewable generation in non-OECD countries.⁵⁵ In South Asia and sub-Saharan Africa, approximately 50 percent of firms own or share backup generators.⁵⁶ In Nigeria the need to

Box 3 | The Challenge of Affordable and Reliable Electricity in Accra

Adelaida is a banker and mother, born and raised in Accra, Ghana. She represents a middle-income family earning roughly \$250/month.^a Adelaida explains that although most homes in Accra are connected to the national grid, households often cannot access electricity because they cannot afford it. Even when they can afford access, the supply is unreliable. Adelaida spends a quarter of her income on electricity but is dissatisfied with her level of service, which is frequently interrupted by unannounced power outages. She is frequently unable to tend to her household chores in the evenings after work because there is no light. To overcome these challenges, Adelaida makes sure she irons her clothing in bulk when she has access to light, and she always has her three rechargeable lamps on standby at home. Power outages also affect her ability to store food, which has limited her ability to cook larger meals in preparation for the week.^b

Notes:

- a. Ephirim, 2016.
- b. Ephirim, 2016.

purchase a generator or provide other means to ensure a regular electricity supply accounts for as much as 20 to 30 percent of the initial investment in setting up a new enterprise.⁵⁷

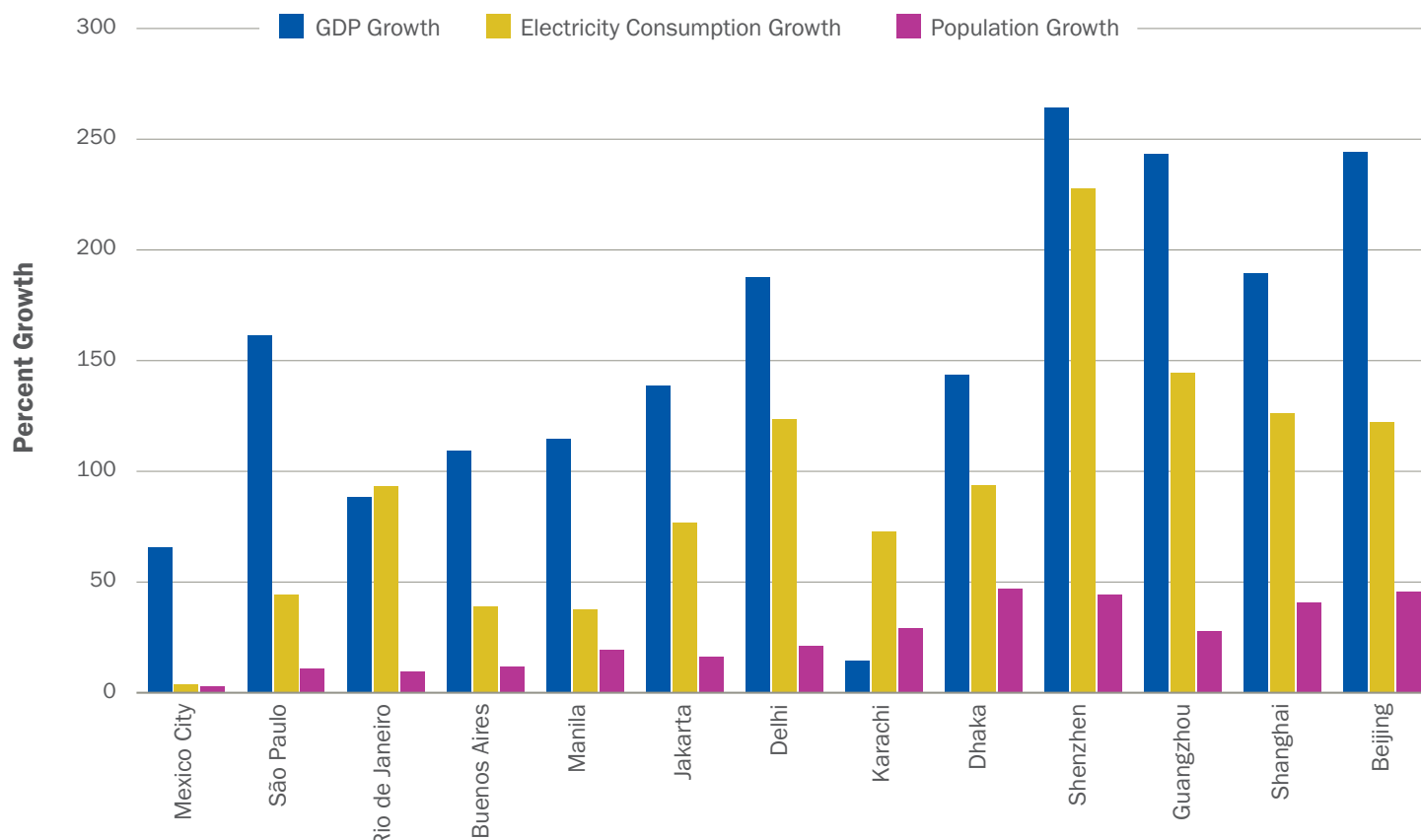
In 2010 the national economic costs of power outages (e.g., fuel for backup diesel generators and lost production) in sub-Saharan Africa typically ranged from 1 percent to 4 percent of GDP, with costs exceeding 5 percent of GDP in Malawi, Uganda, and South Africa.⁵⁸

Rapidly Growing Regions in the Global South Face Potentially Unsustainable Growth in Energy Demand

Considering those megacities for which we have comprehensive data, five megacities in the global South had 10-year growth rates (2001–11) in electricity consumption greater than 100 percent, and 12 had rates at least double the rates of population growth (see Figure 3).⁵⁹ Even though most cities in the global South consume energy (and electricity) at much lower levels than cities in the developed world, these growth rates may not be sustainable as the wave of urbanization continues.⁶⁰ Increasing electricity access in the global South is a development imperative, but emerging cities face the dual challenge of rising demand and inadequate supply, made worse by system inefficiencies and line losses.

While grid connections continue to expand, there is a recognition that grid connection alone will not be sufficient to provide universal access in urban areas.⁶¹ The International Energy Agency (IEA) has projected that more than 100 million people will lack access to electricity in urban areas in 2030 under business-as-usual.⁶² Furthermore, as we have described, there are many problems with the traditional electricity grid model in the global South, particularly regarding inefficiency and line losses. In Lagos line losses are estimated to be 40 percent of total electricity consumption, compared to less than 10 percent in London or Los Angeles.⁶³ The very nature of centralized grid systems makes them less resilient to disruptions, including natural disasters, but in the global South this is exacerbated by a lack of resources to maintain infrastructure.⁶⁴ Under the traditional electric utility business model, it is quite a challenge to permanently assure a reliable service at a lower cost.⁶⁵ In many countries in the global South, state utilities are

Figure 3 | **Growth in electricity consumption is outstripping population and GDP growth in much of the global South**



Note: Data from 2001–11.

Source: Kennedy et al., 2015.

mandated to operate regardless of financial viability, and they receive public subsidies to make up revenue shortfalls.⁶⁶ Tariffs for grid electricity for low-income customers are typically cross-subsidized by higher-paying customers, a system whose effectiveness and viability requires payment enforcement.⁶⁷ Without such enforcement, grid systems are handicapped by several factors, including a lack of incentives to meet the needs of the under-served, especially in informal areas; high connection costs; intermittency; and theft. In India 20 percent of the electricity generated is lost to theft alone.⁶⁸ We do not discuss solutions to these common operational, financial, and enforcement challenges in this paper. Going forward, cities in the global South will need to explore new ways to expand their energy supply and improve efficiency to provide better-quality services per unit of energy.

Rapidly Growing Regions Cannot Continue to Replicate Past Models of Development

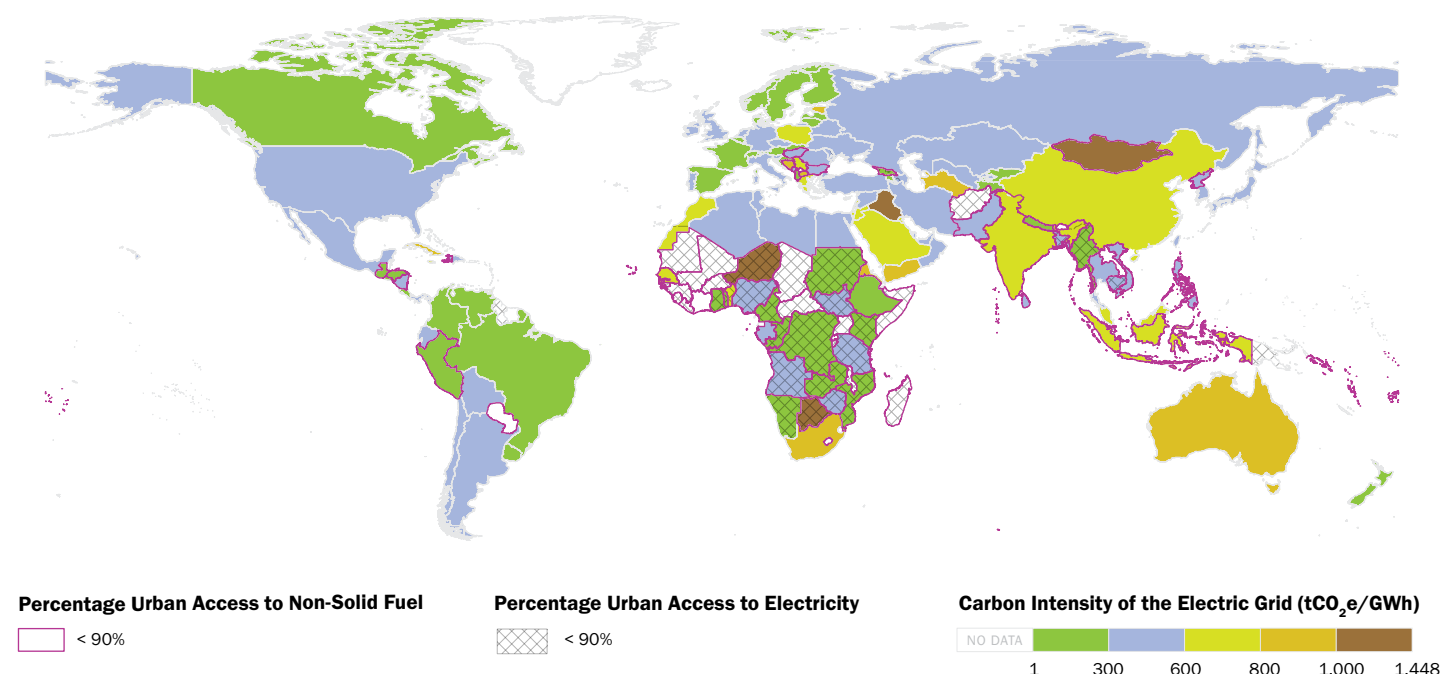
Going forward, it will be difficult for cities to continue to replicate the fossil fuel-intensive model of development that was undertaken in the global North. As discussed, local air quality from fossil-fuel combustion is a major public health concern, particularly in the global South, and a greater reliance on fossil fuels will only exacerbate air pollution problems in cities. Of 414 cities in low- and middle-income countries in Latin America, Africa, and Asia included in a World Health Organization (WHO) database on PM_{10} and $PM_{2.5}$ concentrations, only 10 had mean annual $PM_{2.5}$ concentrations equal to or below WHO guidelines during the most recent reporting.⁶⁹ The majority of cities in the database located in Africa and Southeast Asia have experienced increases in PM_{10} concentrations in recent years. Among the megacities, those in South Asia, for example, have at least double the $PM_{2.5}$ concentrations of cities in the global North, such as New York, Paris, or London; Karachi and Delhi have concentrations more than seven times greater.⁷⁰ Furthermore, fossil fuel-intensive electricity generation entails energy security risks and import dependence for a number of countries in the global South. For example, in 2014, the Philippines, Senegal, and Sri Lanka all imported about 50 percent of their energy.⁷¹

Going forward, it will be difficult for cities to continue to replicate the fossil fuel-intensive model of development that was undertaken in the global North. As discussed, local air quality from fossil-fuel combustion is a major public health concern, particularly in the global South, and a greater reliance on fossil fuels will only exacerbate air pollution problems in cities.

In addition to these local and regional issues, urban energy use has major implications for climate change. Cities dominate the world's consumption of energy and are responsible for about 70 percent of associated CO_2 emissions.⁷² Urban areas in the global South, on average, still have dramatically lower estimated per capita GHG emissions than urban areas in the developed world. However, in terms of absolute emissions, the picture is changing rapidly. China, developing Asia, India, Africa, and Latin America are projected to be responsible for about 56 percent of total urban CO_2 emissions by 2050 (under a business-as-usual scenario).⁷³ Cities in some of the fastest-growing parts of the global South still rely on carbon-intensive national electricity grids. With future electricity demand projected to increase, national and local governments must make decisions now about their future energy infrastructure. Choices regarding energy sources and distribution systems will lock in future emissions for decades to come.

Figure 4 shows where the challenges of electricity access, the use of solid cooking fuels, and carbon intensity of the electricity grids are most pronounced. The lack of access to electricity and the use of solid cooking fuels are most profound in sub-Saharan Africa, although solid cooking fuels are also a concern in parts of South and Southeast Asia and Latin America. The electricity grids in much of the global South are fairly low-carbon, except for countries such as South Africa, India, China, and Indonesia.

Figure 4 | **The urban energy access challenge and electric grid carbon intensity**



Note: The urban access to electricity and non-solid fuel data are for 2012. The carbon intensity of the national electric grid data are the average from 2011 to 2013. Carbon intensity is expressed as the amount (in metric tons) of carbon dioxide equivalent emitted per gigawatt-hour of electricity generated (tCO₂e/GWh). Sources: Data from World Bank, 2016b; IEA, 2015.

SOLUTIONS TO THE URBAN ENERGY CHALLENGES

This paper focuses on three urban energy solutions that the city itself can play a major role in implementing. Energy policy is typically formulated at the national or regional level, and much of the energy supply, transmission, and distribution infrastructure transcends the municipal boundaries of the city. A survey of 59 C40 cities in both the global North and global South found that only 42 percent had direct control over their municipal energy supply, with half of those owning and operating utilities.⁷⁴ This fact should not discourage action at the city level or encourage a focus on small-scale, granular technology fixes. We focus on more ambitious and generally applicable solutions, where success can be achieved by deploying appropriate technology, finance, institutional capacity, policy, and other governance enablers.

Although we focus on three distinct solution areas, we recognize that, in the long run, it will be important for cities to adopt an “energy system” approach, a planning perspective that looks at all functional components of the urban system, regardless of whether they are located within the city.⁷⁵

Our Choice of Solution Areas Was Guided by Our Focus on the Under-served

The World Resources Report *Towards a More Equal City* focuses on the urban under-served, so our first concern is to ask how the solution areas enhance services for this group in terms of access, reliability, cost, health impacts, and livelihoods and whether the solutions are practical and scalable. Our second concern is how these solutions improve the overall city—for example, by enhancing economic productivity, improving air quality, and avoiding the long-term lock-in of inefficient energy consumption and rising GHG emissions.

Based on our framing, we argue that urban change agents should focus on the following approaches:

- ▶ Accelerate the shift to cleaner cooking
- ▶ Scale up distributed renewable energy within cities, especially using solar PV systems
- ▶ Increase energy efficiency via measures that include building codes for new construction and energy-efficiency standards for appliances

The following sections explore each of these solutions in more detail.

Accelerate the Shift to Cleaner Cooking in Urban Areas

There is no more urgent urban energy challenge than transitioning urban residents away from solid cooking fuels, especially in low-income and sub-Saharan countries. Because of the premature mortality associated with solid cooking fuels, this urban energy intervention would have by far the greatest impact on public health. This could be accomplished by:

- ▶ Expanding the use of modern cooking fuels, such as liquefied petroleum gas (LPG), ethanol, biogas, and electricity
- ▶ Promoting the use of low-emission and efficient cookstoves for solid fuels⁷⁶

Unlike rural areas, cities are likely to have many of the physical features and agglomeration benefits that allow for the development of a distribution network for modern fuels and accelerated access—dense population, better maintained roads, proximity to ports (for fuel importation), and major transport corridors. Several countries in the global South have undergone major shifts to modern fuels, especially LPG, through national programs that have especially benefited their urban populations. Examples include Brazil, India, Indonesia, Senegal, and Thailand (see Table 1). In Brazil, for example, 100 percent of urban households now have access to LPG (see Box 4).⁷⁷ As we discuss later, cities can also play a role in the shift to cleaner cooking.

Multiple factors can influence the decision to pursue cleaner fuels or cookstoves. This is illustrated by the case of Ecuador, which has embarked on a campaign that urges citizens to switch from gas to electric induction stoves. The campaign's goal is to get 3.5 million homes to adopt electric induction stoves by the end of 2017 (see Box 5).⁷⁸

Box 4 | Achieving 100 Percent Access to LPG in Urban Areas of Brazil

In the 1960s, only 18 percent of Brazilian households had access to LPG or natural gas. Today, 98 percent of all households—and 100 percent of urban households—have access to LPG.^a The Brazilian government was motivated by the view that energy should be provided to all citizens. Three main factors explain Brazil's success:

- creation of a national infrastructure for LPG production and distribution;
- creation of a retail market that featured the participation of private entrepreneurs; and
- provision of subsidies to ensure affordable prices to consumers.

Unlike other countries, Brazil did not first embark on an effort to improve biomass cookstoves. The state oil company, PETROBRAS, was charged with producing (and importing, if necessary) LPG and distributing it to private companies and retailers. Initially, the government created franchises for LPG distribution with exclusive regional concessions. Later, commercialization quotas were given, opening up competition. With greater competition came improved service and an emphasis on branding and quality certificates.^b

The government administered and controlled prices by subsidizing production

costs. LPG was subsidized by a cross-subsidy scheme, with funds collected from various petroleum fuels. In 2001 end-user prices for LPG were liberalized. The previous subsidy for all LPG users was replaced by a subsidy only for families with a monthly per capita income of no more than half the minimum wage (part of the Bolsa Família program). An estimated 8.5 million households receive the monthly LPG voucher, allowing them to purchase a 13-kilogram (kg) LPG bottle, sufficient to meet cooking needs for one month.^c

Notes:

- a. Jannuzzi and Goldemberg, 2014.
- b. Jannuzzi and Goldemberg, 2014.
- c. Jannuzzi and Goldemberg, 2014.

Box 5 | Encouraging Electric Induction Cookstoves in Ecuador

In large part, Ecuador's campaign responds to the country's reliance on imported LPG for 80 percent of its consumption and very high LPG subsidies that total \$700 million a year.^a The government is offering long-term, low-interest loans for purchasing electric stoves and installation kits, and 80 free KWh of electricity per month until 2018.^b Induction stoves are efficient; they use up to 90 percent of the energy emitted, compared to 40 percent for gas.^c Another factor encouraging the switch to induction stoves is the country's use of clean hydropower for electricity. There is a strong climate change mitigation argument for electrifying devices (e.g., household appliances, transport) when the carbon intensity of electricity generation is low.^d Also, electric stoves do not require additional infrastructure, which is necessary for liquid or gaseous fuels. Finally, electric cooking requires reliable access to electricity, and on average, just three power outages per month were experienced by firms in Latin America and the Caribbean in 2013.^e This also works in favor of Ecuador's shift to electric stoves.

Notes:

- a. International Partnership on Mitigation and MRV, 2015.
- b. International Partnership on Mitigation and MRV, 2015.
- c. Sweeney et al., 2014.
- d. Kennedy, 2015.
- e. World Bank, 2016b.

There is no “one-stove” approach to clean cooking, and the choice of modern fuels depends on national circumstances. Moreover, households typically do not make a complete fuel switch; rather, they use a combination of fuels depending on availability, prices, and cooking needs—a practice known as “fuel stacking.”

In cities that have access to agricultural feedstocks, biogas and ethanol remain options. While ethanol stoves have made inroads in some countries (e.g., Nigeria, Ethiopia, and Haiti), in general, they are less commonly used. Stoves that run on renewable fuels are used in fewer than 1 percent of all households in sub-Saharan Africa.⁷⁹ Biogas and biofuel stoves have the highest sales growth of any modern fuel in the region, but their numbers remain very small.⁸⁰ Solar stoves have also had a limited uptake, with a distribution of 80,000 across the region.⁸¹ While solar cookers have low operating costs, quality models are expensive, and they entail long cooking times.⁸²

Some of the modern fuels described above can be considered intermediate fuels in the transition to natural gas, but piped natural gas infrastructure is expensive and likely not a viable solution in the near term for much of the global South. In 2010 only about 1.6 million urban residents in all of sub-Saharan Africa had access to natural gas.⁸³ Furthermore, piped natural gas requires high housing density. In Brazil an old piped natural gas network serves about 2 million customers.⁸⁴ The network is expanding, but the high costs of installing gas pipelines means that the reach is small, confined to areas where the number of customers per kilometer of pipeline is large.⁸⁵ Nevertheless, natural gas may sometimes be an option as part of the construction of dense, new housing settlements.

There is no “one-stove” approach to clean cooking, and the choice of modern fuels depends on national circumstances. Moreover, households typically do not make a complete fuel switch; rather, they use a combination of fuels depending on availability, prices, and cooking needs—a practice known as “fuel stacking.”

People shift to modern fuels in low- and middle-income countries for many different reasons that concern efficiency, economy, cleanliness, safety, or convenience. However, as we discuss below, a wide range of factors may limit the adoption of modern fuels. These range from fuel and technology characteristics; to household characteristics; knowledge and perception; personal taste, finance, and cost; market development, regulation, legislation, and standards; and program and policy mechanisms.

Table 1 | **Scale-Up of LPG Use in Urban Households**

COUNTRY	DESCRIPTION	ENABLING FACTORS
Brazil	<ul style="list-style-type: none"> ▶ 100% of urban households have access to LPG in Brazil.^a 	<ul style="list-style-type: none"> ▶ Development of LPG infrastructure in all regions. ▶ The government introduced an Auxilio-Gas (“gas assistance”) program to allow low-income households (with incomes less than half the minimum wage) to purchase LPG. The program is now part of Bolsa Família.^b ▶ High LPG prices in recent years have resulted in an increase in residential biomass consumption.^c
India	<ul style="list-style-type: none"> ▶ LPG consumption grew 10% in 2014.^d ▶ 65% of urban residents used LPG in 2011.^e 	<ul style="list-style-type: none"> ▶ Cylinders are subsidized both directly and through under-recoveries by public-sector oil-marketing companies.
Senegal	<ul style="list-style-type: none"> ▶ LPG consumption increased from less than 3,000 metric tons in 1974 to 15,000 metric tons in 1987 and to 100,000 metric tons in 2011.^f In Dakar nearly 85% of households own LPG stoves, while 66% of households in other urban areas own them.^g 	<ul style="list-style-type: none"> ▶ Subsidies to support the distribution of small LPG cylinders (3 kg and 6 kg) and support for pots, pans, and burners that attach to the cylinders (the subsidy was withdrawn in 2008).^h
Thailand	<ul style="list-style-type: none"> ▶ 79% of urban households used LPG in 2011.ⁱ ▶ Over the past 25 years, the amount of LPG for cooking has increased by an annual average of 10%.^j 	<ul style="list-style-type: none"> ▶ In the 1980s the price of LPG was set at the cost of production, not at world market prices.^k ▶ Thailand's Oil Stabilization Fund subsidized the costs to transport LPG from storage facilities to regional storage facilities.^l ▶ The state-owned oil company permitted LPG suppliers/distributors and traders to use its storage facilities without charge.^m
Indonesia	<ul style="list-style-type: none"> ▶ By the end of the LPG conversion program in 2009, the percentage of urban households using LPG increased from 7% to 93%.ⁿ 	<ul style="list-style-type: none"> ▶ The program was initiated in 2007, with the goal of providing LPG to 50 million households.^o The main motivation was the large petroleum fuels subsidy, ranging from 9% to 18% of total state expenditures from 2001 to 2008.^p ▶ People were given a free starter kit of a 3 kg LPG cylinder, a first gas fill, a one-burner stove, a hose, and a regulator.^q ▶ Kerosene agents and retailers were converted to become LPG agents and retailers. Kerosene was withdrawn from areas where the starter packages were distributed completely. There is a refill subsidy for LPG (far lower than the kerosene subsidy).^r

Notes:

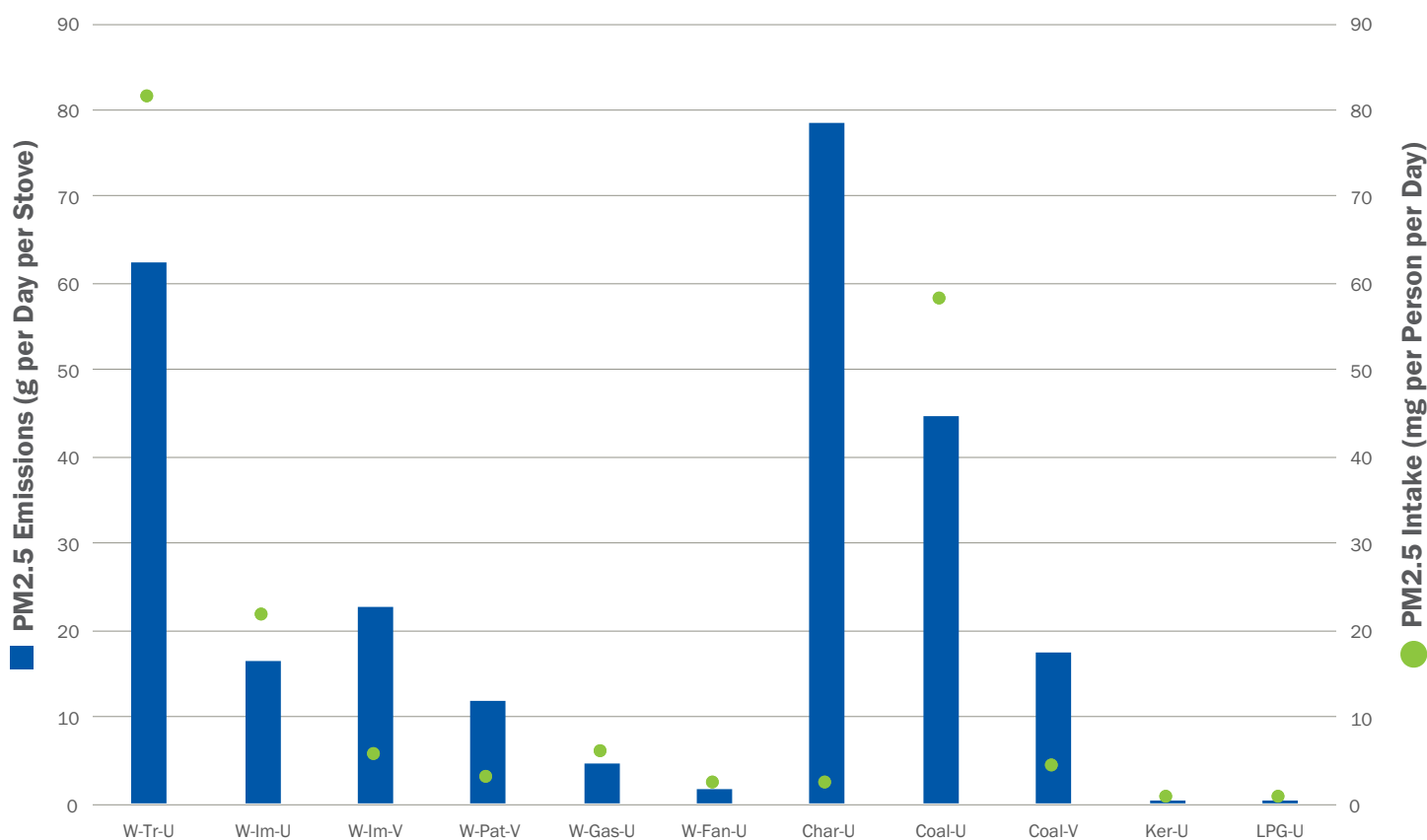
a. Jannuzzi and Sangab, 2004; Lucon et al., 2004; Jannuzzi and Goldemberg, 2014; b. Jannuzzi and Sangab, 2004; Lucon et al., 2004; Jannuzzi and Goldemberg, 2014; c. Jannuzzi and Sangab, 2004; Lucon et al., 2004; Jannuzzi and Goldemberg, 2014; d. Argus Media and WLPGA, 2014; e. IISD, 2014; f. Ekouevi and Tuntivate, 2011; g. Ekouevi and Tuntivate, 2011; h. Ekouevi and Tuntivate, 2011; i. ESMAP, 2015; j. Ekouevi and Tuntivate, 2011; k. Ekouevi and Tuntivate, 2011; l. Ekouevi and Tuntivate, 2011; m. Ekouevi and Tuntivate, 2011; n. Andadari et al., 2014; o. Budya and Arofah, 2011; p. Budya and Arofah, 2011; q. Budya and Arofah, 2011; r. Budya and Arofah, 2011.

How does clean cooking help the under-served?

Shifting to modern fuels would benefit the under-served by significantly reducing their exposure to indoor air pollution. People using traditional, unvented woodstoves and unvented coal stoves are estimated to inhale up to 150 and 110 times, respectively, more particulate matter (PM_{2.5}) per stove per day than people using LPG stoves (see Figure 5).⁸⁶ Ethanol stoves can reduce indoor air pollution levels by 84 percent compared to traditional stoves using wood, charcoal, kerosene, or open fire.⁸⁷ Electric stoves are the cleanest cooking solution, producing indoor PM_{2.5} concentrations that are similar to ambient levels.⁸⁸

Globally, household air pollution from solid fuels accounted for 3.5 million deaths and 4.5 percent of disability-adjusted life years in 2010.⁸⁹ In South Asia, household air pollution is responsible for the greatest share of overall disease burden.⁹⁰ If we assume exposure is the same for rural and urban populations, and given the fact that about 16 percent of all people using solid cooking fuels in 2010 were in urban areas, then close to 550,000 premature deaths might have occurred in urban areas in 2010 due to household use of solid cooking fuels.⁹¹ While the differences are not as stark for improved solid fuel stoves, their use would bring marked improvements in indoor air quality. The public health gains, however, are contingent on stoves being used appropriately and regularly.⁹²

Figure 5 | People inhale more particulate matter when they cook with solid fuels



Notes: W-Tr-U: Woodstove (traditional)—unvented; W-Im-U: Indian woodstove (improved)—unvented; W-Im-V: Chinese woodstove (improved)—vented; W-Pat-V: Mexican wood Patsari stove—vented; W-Gas-U: Indian wood Karve gasifier stove—unvented; W-Fan-U: Wood Phillips Fan stove—unvented; Char-U: Indian charcoal stove—unvented; Coal-U: Chinese coal stove—unvented; Coal-V: Chinese coal stove—vented; Ker-U: Indian kerosene wick stove—unvented; LPG-U: Indian LPG stove—unvented. These are central estimates. Intake is how much a person inhales, while emissions for charcoal stoves include both production and use, which is why the value for intake is so low compared to the daily emissions. The calculation assumes half the biomass is from non-renewable sources.

Source: Based on raw data from Grieshop et al., 2011, modified by WRI.

In many cases, switching to modern fuels can offer households significant savings in cost and time. Modern fuels are much more efficient in terms of heat per unit of fuel, which translates into a reduction in cooking time of approximately 50 percent when switching from traditional biomass cooking to LPG.⁹³ Women benefit disproportionately from the reductions in time spent on both fuel collection and cooking.

Despite these efficiency gains, the annual costs of different modern fuels vary considerably when one takes both fuel consumption and the amortized price of the stove into account. For example, in sub-Saharan Africa, the most expensive form of cooking in 2012 was an electric stove, with an average annual cost of \$310 per year.⁹⁴ Biogas digesters had the lowest costs on average (\$80/year), and while both LPG (\$230/year) and ethanol (\$191/year) were more expensive than purchased wood, they were less expensive than charcoal stoves on average.⁹⁵ Modern fuels score particularly well when compared to kerosene. In Ghana, the lifetime costs of biogas, electricity, and LPG were all less than 75 percent of the cost of kerosene.⁹⁶ In Indonesia, surveys indicate that the average monthly savings from using LPG instead of kerosene led to a significant reduction in the share of fuel in average household expenditure; the amount spent on fuel fell from 84 percent to 58 percent of total spending.⁹⁷ The use of more-efficient solid fuel cookstoves would result in fuel savings as well, with payback periods of a few months.⁹⁸

The use of LPG over biomass would have productivity benefits for many enterprises in the informal sector, which can be highly energy intensive, such as textile and paper processing, brick drying and curing, and shea butter processing. In Indonesia, LPG is being promoted for processing soybeans for the tofu and tempeh industry.⁹⁹

Given that in 2010 about 16 percent of the total population using solid fuels for cooking resided in urban areas, at least 58,000 premature deaths and 1.5 million disability-adjusted life years can likely be attributed to outdoor air pollution from solid fuels for cooking in urban areas.

How does clean cooking enhance the city's economic productivity and environmental quality?

The economic and environmental benefits that would result from shifting to cleaner cooking are deeply intertwined. Direct economic benefits can result from scaling back expensive subsidies for fuels like kerosene. Indirect economic benefits would flow from the reduction in morbidity and mortality, and associated productivity losses, that result from high levels of cooking-related air pollution. Cleaner cooking fuels and stoves can also contribute to climate change mitigation, with substantial economic and environmental benefits over the longer term.

In countries where kerosene subsidies are high, shifting to modern fuels can result in real cost savings, given the increase in energy efficiency. In Indonesia the massive shift to LPG from kerosene resulted in a gross subsidy savings of \$3 billion by 2010; factoring in the LPG conversion costs of \$1.2 billion, the program resulted in net savings of \$1.8 billion.¹⁰⁰

Household cooking is a significant source of ambient (outdoor) and indoor pollution. Globally, cooking with solid fuels was responsible for 12 percent of ambient PM_{2.5} pollution in 2010, but in southern sub-Saharan Africa and South Asia, the figures were much higher, at 37 percent and 26 percent, respectively.¹⁰¹ For the Global Burden of Disease project, Chafe et al. (2014) further evaluated the impact of household cooking with solid fuels on regional population-weighted ambient PM_{2.5} and estimated the burden of disease associated with this exposure due to household cooking.¹⁰² Outdoor air pollution caused by the use of solid fuels for household cooking is estimated to have resulted in 370,000 deaths and 9.9 million disability-adjusted life years globally in 2010.¹⁰³ Given that in 2010 about 16 percent of the total population using solid fuels for cooking resided in urban areas, at least 58,000 premature deaths and 1.5 million disability-adjusted life years can likely be attributed to outdoor air pollution from solid fuels for cooking in urban areas.¹⁰⁴ This is a conservative estimate because the exposure (intake fractions) would be higher in densely populated urban areas than in rural areas.¹⁰⁵

The decrease in premature mortality and morbidity among all urban residents—not just users of solid cooking fuel—that would result from air pollution reductions (both household and ambient) would thus raise the economic productivity of cities in the global South.

Shifting to clean cooking: barriers and enablers

Clean biomass cookstove programs have had a checkered history over the past 30 years, due in no small part to such obstacles as poor stove quality, inadequate research on consumer needs, and lack of producer technical capacity and finance. From 1980 until about 2002, most artisan-produced models were of poor quality and easily degraded.¹⁰⁶ The second wave of cookstoves, produced from the late 1990s to the early 2000s, involved more expensive models that were constructed from more durable materials.¹⁰⁷ While there were notable successes—especially in China, where more than 100 million cookstoves are still in use—many programs were plagued by implementation problems and lack of monitoring.¹⁰⁸ A new generation of factory-made biomass cookstoves is benefiting from market studies and more rigorous testing of materials and quality control.¹⁰⁹ Lack of production at scale remains a big hurdle, but the potential to aggregate demand in urban areas can help. Table 2 identifies a number of barriers that stand in the way of achieving the shift to clean cooking.

At the consumer level, important barriers include lack of awareness and access, taste preferences, inappropriate stove design, and product quality and safety. Affordability, particularly the up-front cost of a stove, can be a major deterrent. For example, in sub-Saharan Africa, the cost of a basic kerosene

stove in 2012 was between \$5 and \$20, whereas the cost of a single-burner LPG stove ranged from \$10 to \$50.¹¹⁰ However, in some cases the annual costs of modern fuels in urban areas are competitive with those of solid fuels. Consumers' willingness to adopt LPG as a cooking fuel also depends on adequate supply and delivery infrastructure and on concerns about safety (compared to biomass), inadequate cylinder size, and price volatility.¹¹¹

INSTITUTIONS AND GOVERNANCE

Accelerating the shift to cleaner cooking in urban areas requires effective institutions. However, governments have often not provided leadership on clean cooking. Few countries have established national institutions or agencies that support an enabling policy environment for clean cooking (e.g., conducting research and development and setting quality and safety standards for stoves), although the number of countries with agencies or institutions that focus on clean cooking has been growing in recent years. Strong government leadership has been a significant driver where countries have undergone major transitions to LPG, for example, in Brazil, Ghana, India, Indonesia, Peru, and Senegal.¹¹² A dedicated government body can set quality and safety standards for stoves, support their technical development, engage with consumers, and monitor implementation.¹¹³

Table 2 | **Barriers to Clean and Improved Cooking**

GOVERNMENT	EQUIPMENT/SERVICE PROVIDER	END USER	FINANCIERS
<ul style="list-style-type: none"> ▶ Insufficient attention to clean cooking in urban areas ▶ Lack of national institutions or agencies that support an enabling policy for clean cooking ▶ Absence of standards, testing, and research and development 	<ul style="list-style-type: none"> ▶ Lack of high-quality durable models ▶ Dearth of research on consumer needs ▶ Lack of cost-effective distribution ▶ Absence of producer/distributor finance ▶ Lack of producer technical capacity ▶ Inadequate after-sales support/warranties 	<ul style="list-style-type: none"> ▶ Affordability (stove and fuel) ▶ Consumer awareness (e.g., lack of knowledge on the harmful effects of traditional solid fuels and alternatives) ▶ Taste preferences ▶ Access and fuel supply ▶ Appropriate design ▶ Product quality/safety 	<ul style="list-style-type: none"> ▶ Lack of finance for clean cooking ▶ Insufficient attention to clean cooking in urban areas ▶ Dearth of research on consumer needs ▶ Inadequate monitoring of programs

Source: Based on material drawn from Kammila et al., 2014, modified by WRI.

In the case of modern fuels, especially LPG, governments need to modernize regulatory frameworks by adopting international standards and protocols, for example, regarding transportation, storage, and safety and fuel specifications. Governments also need to enforce such regulations, promote fair competition among suppliers, provide training to small-scale distributors to prevent accidents, and—in conjunction with industry associations—widely communicate information to the public on safety and storage. For many countries, these are not easy tasks. The regulatory framework in Turkey provides some guidance. It imposes a small fee on marketing companies to finance monitoring and enforcement, requires training of all personnel involved in supplying LPG, and sets strict rules under which cylinders can be refilled.¹¹⁴

Clear household addresses and secure property tenure may need to be obtained as part of any attempt to shift to modern fuels. In Indian cities, for example, LPG is delivered directly to households (as opposed to being purchased or collected off-site, as is usually the case with solid fuels), which requires addresses and tenure documents. In urban India, 89 percent of households surveyed reported using LPG, but 41 percent of them obtain the fuel from illegal sources.¹¹⁵ In Thailand, by contrast, grocery stores distribute canisters without permission procedures, obviating the need for official addresses.¹¹⁶

Vested political and economic interests may also impede the transition to modern cooking. For example, charcoal production in Tanzania, which is valued at \$650 million per year and provides jobs for 300,000 households, is monopolized by a small group of politically connected entrepreneurs in the informal sector.¹¹⁷

POLICY

A number of policy conditions are relevant to the acceleration of clean cooking. Among the most important are import policies, fossil fuel subsidies, and direct subsidies for cookstoves and cooking fuels.

Supportive import policies are necessary for modern fuels in countries that do not have domestic sources. For example, Cambodia and the Lao People's Democratic Republic restrict the importation of petroleum-based fuels, which contributes to the majority of their populations being dependent on solid cooking fuels.¹¹⁸ Until the early 1990s, China restricted the import of LPG in order to maintain foreign exchange reserves.¹¹⁹ This led to informal rationing, making LPG unavailable even to those who could afford it.¹²⁰ Across a dozen markets in Africa,

Fossil fuel-subsidy reform is also necessary to catalyze clean cooking. In many countries kerosene is subsidized, which can impede the market penetration of cleaner fuels such as LPG.

the combination of value-added tax and tariffs tops 30 percent, resulting in 50 percent to 100 percent increases in the end-user cost of cookstoves, when all distribution value-chain margins are taken into consideration.¹²¹ However, a consequence of changing import policies may be negative impacts on domestic artisans who currently make cookstoves.

Fossil fuel-subsidy reform is also necessary to catalyze clean cooking. In many countries kerosene is subsidized, which can impede the market penetration of cleaner fuels such as LPG. In Indonesia, prior to the shift to LPG, kerosene production cost about Rp 6,700/liter, whereas the subsidized price was Rp 2,500/liter.¹²²

Government subsidies for fuels and cookers may be required but should be targeted and set at the lowest possible level. This is the case, for example, with subsidies for poor families in the Bolsa Família program in Brazil.¹²³ In Senegal subsidies of small cylinders enabled poorer households to use LPG.¹²⁴ However, in Thailand, the initial deposit for LPG cylinders is not subsidized, and the cylinders have high unit costs that impose regressive burdens on low-income customers.¹²⁵

Government subsidies can create fiscal pressures that become counterproductive. In Senegal, subsidies were removed in 2008, and there has since been a reversion in LPG usage and an increase in charcoal usage in Dakar; annual per capita LPG consumption dropped from 11.7 kg per person in 2005 to 8.6 kg in 2008.¹²⁶ India's subsidies for LPG incurred budgetary and nonbudgetary expenditures of about \$7.6 billion in 2012–13, while the bottom half of the population received only about 8 percent of the total subsidy transfer.¹²⁷ However, the Indian government has sought to address this situation, including through a campaign to encourage wealthier consumers to voluntarily give up the subsidy, launched in 2015 (“GiveItUp”).¹²⁸

It has also introduced a direct benefit transfer program that links an LPG consumer number and the consumer's bank account details, allowing subsidy funds to be transferred to those most in need.¹²⁹ In Ecuador the government is using a combination of long-term and low-interest loans, plus preferential electricity rates, to incentivize the shift to induction stoves.¹³⁰

Subsidies for stoves and fuel cylinders can reduce up-front costs, but in the long run, programs that rely on market-based approaches are likely to be more successful.¹³¹

FINANCE

Several innovative financial approaches can encourage a shift to clean cooking. The case of solar home systems in Bangladesh is one possible model. There, a combination of subsidies, micro-finance, and concession loans resulted in an exponential increase in the number of solar home systems. Launched in 2003, the program had installed 3 million systems by early 2014, mostly in rural areas.¹³² The program includes a fixed \$25 subsidy directed at poorer households and a refinancing facility allowing micro-finance institutions to refinance 70 percent to 80 percent of the loans made to consumers with a Ministry of Finance-owned company at favorable rates, providing long-term access to finance and liquidity to lenders while reducing consumers' monthly payments.¹³³ The various financial elements of this program, such as micro-finance, deserve exploration in urban areas.

Pay-as-you-go (PAYG) installment finance, which has been successfully used to pay for solar lighting, is also a promising model for clean cooking, and has been piloted by Toyola in Ghana.¹³⁴ BURN Manufacturing has partnered with M-Kopa in Kenya, which has deployed a PAYG model for solar home systems.

To address the co-benefits of clean cooking, particularly the health benefits, social impact bonds or other forms of results-based payments could be used to pay for implementation.

When customers finish paying for their solar system, M-Kopa offers them an improved charcoal stove; customers can continue to pay 40 cents a day to buy the stove.¹³⁵ In Zambia, Emerging Cooking Solutions sells stoves and pellet systems through large employers, with customers paying for stoves through payroll deductions.¹³⁶ More sophisticated PAYG models use mobile payment. For example, Wana Energy Solutions in Uganda has developed a kitchen-sharing model for LPG that customers use on a PAYG basis with mobile phones.¹³⁷ (The kitchen-sharing model also reflects the fact that many people in informal settlements may not have space for a kitchen.) Another financial model integrates the stove and fuel such that the up-front costs of the stove are later built into the fuel price.¹³⁸

Development finance institutions have not focused significantly on clean cooking, and when they have funded projects, they have tended to underestimate the importance of clean cooking in urban areas.¹³⁹ But international sources of finance could be scaled up to cover the up-front and operational costs of improved and advanced cookstoves. For example, carbon finance has been used to reduce end-user costs. In sub-Saharan Africa, Clean Development Mechanism and Gold Standard verified emission reduction (VER) projects covering 19 countries have used carbon revenues to allow manufacturers to reduce end-user prices by 20 percent to 50 percent.¹⁴⁰ The donor community should continue to ensure that carbon finance is dedicated to clean cooking. Using an average social cost of carbon value of \$36/tCO₂e,¹⁴¹ the value of shifting one traditional wood or unvented coal or charcoal stove to an LPG stove could be worth between \$100 to \$300 per year,¹⁴² which would be in the range of the annual operating costs of LPG in sub-Saharan Africa in 2012.¹⁴³

To address the co-benefits of clean cooking, particularly the health benefits, social impact bonds or other forms of results-based payments could be used to pay for implementation. With social impact bonds, private investors pay the up-front costs of providing services, while the public sector repays the investors with a return if the goals are met.¹⁴⁴

Figure 6 summarizes the roles of different actors in accelerating the transition to clean cooking.

Figure 6 | **Roles of different actors in accelerating the transition to clean cooking in urban areas****DEVELOPMENT FINANCE INSTITUTIONS**

- ▶ Put urban clean cooking on the development agenda (Sustainable Development Goal #7).
- ▶ Expand finance for urban clean cooking, including the creation of dedicated funds and use of innovative financing, including consumer finance, carbon finance, and results-based payments. Address the externalities, such as the social costs of climate change and local air pollution.
- ▶ Support R&D into stove design, standards, and testing. Utilize standards and facilitate harmonized testing to improve clarity in decision making.
- ▶ Invest in port infrastructure, customs, hospitality arrangements for LPG storage (where companies trade off storage between different areas), and clean fuel distribution infrastructure.
- ▶ Conduct public awareness campaigns on the benefits of clean cooking, proper use, and safety.
- ▶ Promote locally appropriate cookstove designs and supply chains for clean fuels.
- ▶ Collect data on stove use.

PRIVATE SECTOR

- ▶ Address up-front costs and willingness-to-pay issues by developing and applying new consumer finance models for stoves/fuel cylinders, especially small fuel cylinders.
- ▶ Utilize multiple stove distribution channels. Local stove manufacturers and financiers should work together on stove distribution.
- ▶ Create public-private partnerships for developing clean fuel distribution infrastructure (e.g., LPG storage).
- ▶ Focus on cooking fuel, not just cookstoves. Invest in downstream fuel ecosystem (e.g., cylinder suppliers/fillers/after-sales support).
- ▶ Pay attention to stove quality, end-use experience, and durability.
- ▶ Conduct public awareness campaigns on the benefits of clean cooking, proper use, and safety.

NATIONAL GOVERNMENTS

- ▶ Recognize the importance of clean cooking to national climate change mitigation plans and goals.
- ▶ Provide direct, targeted subsidies for clean stoves and fuel cylinders.
- ▶ Support R&D into stove design, standards, and testing. Implement standards policies.
- ▶ Promote locally appropriate cookstove designs and supply chains for clean fuels.
- ▶ Improve safety/regulations to boost consumer confidence in technology.
- ▶ Promote consumer access to finance.
- ▶ Reduce/eliminate tariffs on imported stoves/fuel.
- ▶ Reduce/eliminate subsidies for kerosene.
- ▶ Invest in port infrastructure, customs, hospitality arrangements for LPG storage, and clean fuel distribution infrastructure.
- ▶ Adopt and enforce clear regulations on safety.
- ▶ Promote competition for firms.
- ▶ Conduct public awareness campaigns on the benefits of clean cooking, proper use, and safety.
- ▶ Collect data on stove use.

CITY GOVERNMENTS

- ▶ Enforce regulations (e.g., safety).
- ▶ Conduct public awareness campaigns on the benefits of clean cooking, proper use, and safety.
- ▶ Collect data on stove use.

CIVIL SOCIETY

- ▶ Conduct public awareness campaigns on the benefits of clean cooking, proper use, and safety.
- ▶ Develop new consumer finance models.
- ▶ Monitor and evaluate clean cooking projects.
- ▶ Disseminate research, analysis, and lessons learned on clean cooking initiatives to decision makers.

Sources: WRI, partially based on Kojima, 2011; and Kammila et al., 2014.

Scale Up Distributed Renewable Energy within Cities

In this section, we argue that urban change agents should promote the scaling up of distributed renewable energy—in particular, solar photovoltaic (PV) systems. This solution aims to address the challenges regarding lack of access and the unreliability of grid electricity, and to foster greater city ownership over energy services. While we recognize that other distributed renewable energy solutions exist, solar PV systems have a greater overall potential in urban areas than technologies such as wind power. In addition, solar PV is the most commonly found example of distributed renewable energy in cities in the global South (see Box 6). Solar PV is a viable option even where individuals do not have adequate rooftop space; community-owned, community-shared solar systems are a promising model in such cases. Such systems can be constructed on community- or municipality-owned land or buildings. Individuals are either

connected to the grid or connected together via a microgrid. This is analogous to a community standpipe for water.

Given the enormity of the electricity access problem, both distributed renewables (whether off-grid or on-grid) and traditional grid connection must be viewed as complementary. While scaling up distributed renewable energy, improvements must be made to the grid infrastructure to increase reliability, reduce line losses, and manage more variable sources, while also making grid connection more affordable through measures such as cross-subsidies.

Solar PV includes systems installed on the rooftops of residential, commercial, or industrial buildings, or on other surface areas located near demand centers. These systems generate power during the day, while feeding surplus power either into a backup battery or back into the power grid.¹⁴⁵ The discussion in this section includes both off-grid and grid-connected solar PV systems.

Box 6 | Distributed Renewable Energy and Its Advantages

Distributed renewable energy refers to on-site generation or district/decentralized energy that is generated or stored by a variety of small, grid-connected or off-grid devices, such as solar PV systems. Odarno et al. (2015) distinguish between systems that are above the 100-watt range (that is, systems that can support services such as refrigeration) versus very small capacity devices, such as those for task lighting. While these smaller devices are important in providing household lighting and other basic needs, they do not provide enough energy for productive uses, and the markets for these products often exist in more rural areas. Therefore, in this paper, we focus on systems larger than 100 watts, which are more relevant to the policy, regulatory, and financing requirements in urban areas.

Distributed renewable energy resources, whether grid connected or not, offer benefits to rapidly growing areas by increasing the

use of clean sources of energy, improving grid reliability, and making the grid more affordable by reducing system costs. Crucially, they also allow customers to actively engage in city energy management. For example, rooftop solar PV systems offer consumers the option to use the power they generate for their own needs without having to rely on grid connections or, in cases where they are connected to the grid and where enabling policies exist, to sell electricity they do not use.^a However, this practice can also create technical and financial problems for utilities.

While there are other examples of distributed generation systems based on renewable energy in urban settings—such as biomass heating and cooling, micro-grids (which can be partially or fully run by renewable energy), district energy systems, and wind turbines^b—rooftop solar PV systems are the most common

example of distributed renewable energy found in cities in the global South. Solar PV has a power density (W/m^2) that matches the demand densities of 10 to 30 W/m^2 observed in cities; thus, it has a greater potential in urban areas than other sources, such as wind.^c Solar water heaters are another important distributed renewable energy option in cities because heating accounts for 75 percent of the energy demand globally within the buildings sector.^d According to REN21 (2015), domestic hot water heating is the most energy-intensive activity for households in the global South, and solar water heaters can typically meet 40 percent to 80 percent of total demand.^e

Notes:

- a. Kammen and Sunter, 2016.
- b. IEA, 2016a.
- c. Kammen and Sunter, 2016; IEA, 2016a.
- d. Kammen and Sunter, 2016.
- e. Kammen and Sunter, 2016.

Scaling up the deployment of distributed solar PV could be accelerated by reforming the energy sector, introducing distributed renewable energy policy mechanisms, and offering financing options to promote adoption of distributed systems.

The emergence of alternative, smaller-scale, and distributed generation systems in the global South has been made possible in large part by energy-sector reform, particularly via utility restructuring (unbundling generation, transmission, and distribution), deregulation, and liberalizing wholesale and retail markets. These reforms allow for increased competition in the market, the introduction of targeted distributed renewable energy policy mechanisms, and the entrance of new players, such as independent power producers and independent energy regulatory agencies, which are more open to distributed energy programs. In turn, power market reform presents opportunities for cities to be involved in energy systems and planning, whereas traditionally, energy planning and decision making has been fairly centralized at the state or national level.¹⁴⁶ Cities and towns worldwide are increasingly using their unique purchasing and regulatory authority to promote deployment of renewable-based systems.¹⁴⁷ However, energy-sector reform can also lead to a more market-oriented sector in which social needs may be overlooked. Deregulation must pay particular attention to the needs of those who may be excluded.

How does distributed renewable energy help the under-served?

Distributed renewable energy, and specifically solar PV, can have several direct and indirect benefits for the under-served, including affordability, reliability, and productivity.¹⁴⁸

AFFORDABILITY

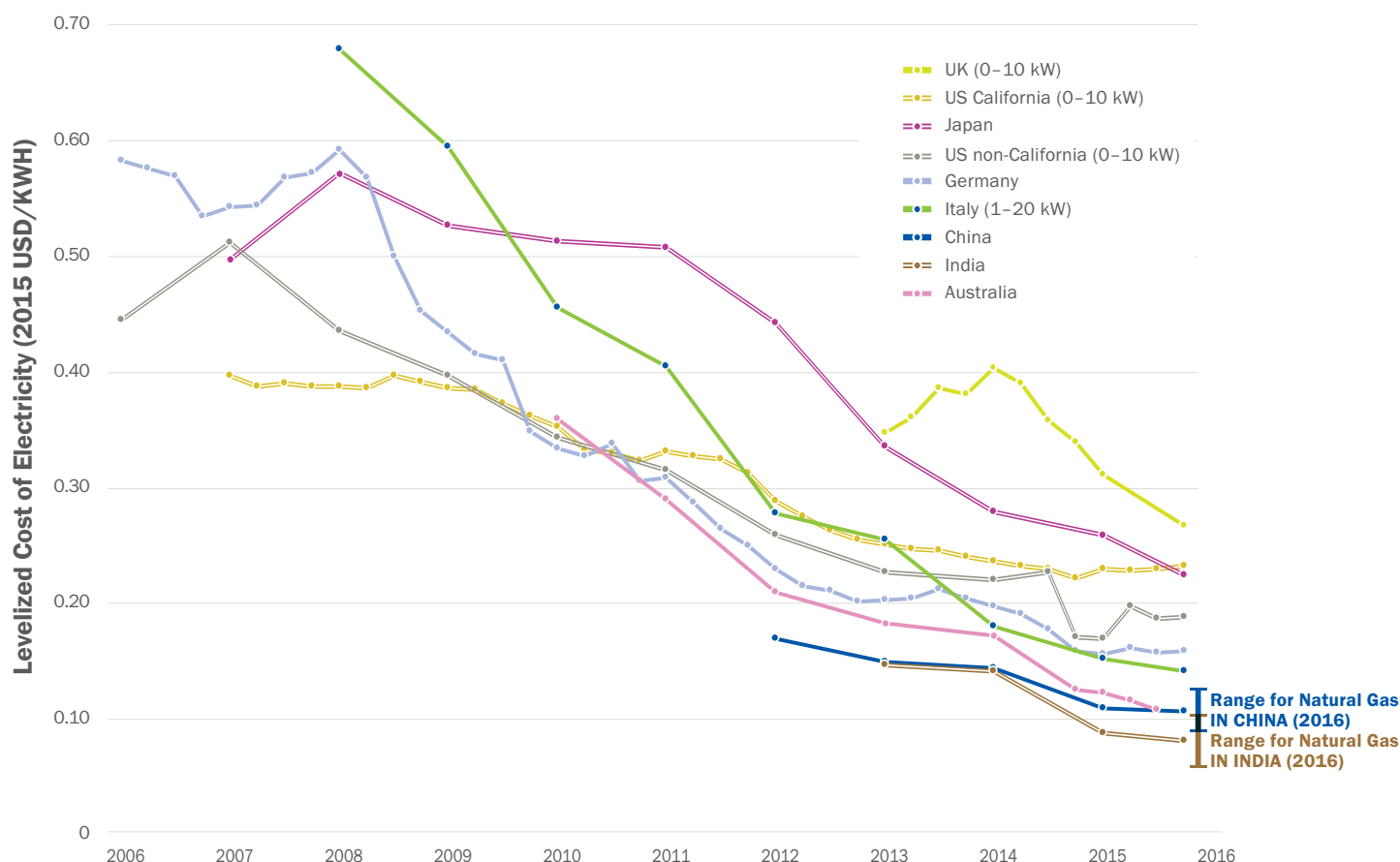
Solar PV that is not connected to the grid may reduce the high cost burden of grid connection. In urban areas, where most people are within range of grid connection, cost is the main barrier for the under-served. In many cities in the global South, the electricity connection charge itself can be onerous. For example, in 2013 the cost was at least 100 percent of monthly income in Burkina Faso, Central African Republic, Kenya, Tanzania, and Rwanda.¹⁴⁹ A survey in Kibera found that the total up-front cost for electricity connection was about three to five months' estimated household income.¹⁵⁰

The cost of residential solar PV has declined significantly in recent years. Utility-scale solar electricity has already reached “grid parity” and is competitive with retail electricity in a number of markets globally.

Moreover, the cost of grid electricity continues to rise in many places. In India, for example, electricity tariffs vary widely from state to state, but on average, from FY2009 to FY2013, residential tariffs increased by 15 percent and commercial tariffs rose by 16 percent—an annual increase of roughly 6 percent.¹⁵¹ As the cost for grid electricity rises for customers and the cost for solar PV falls, solar PV will become an increasingly appealing option for residential and commercial consumers, as solar PV need not be connected to the grid.

The cost of residential solar PV has declined significantly in recent years. Utility-scale solar electricity has already reached “grid parity”¹⁵² and is competitive with retail electricity in a number of markets globally.¹⁵³ Under certain policy conditions, retail costs for rooftop solar PV have already reached grid parity for industrial and commercial electricity customers in 12 Indian states.¹⁵⁴ While there is a paucity of data for countries in the global South, the average levelized cost of electricity (LCOE) for residential rooftop solar PV in 2016 in India and China was within the range of the LCOE for natural gas-fired generation in both countries (see Figure 7), although this does not include the cost of battery storage.¹⁵⁵ Given that about half of the cost of rooftop solar PV is for hardware, rooftop solar PV would likely be competitive in many other parts of the global South.¹⁵⁶

Figure 7 | **The cost of residential solar PV is declining**



Notes: The data for coal and gas for China and India are from the first half of 2016 and represent the LCOE benchmark value. The natural gas LCOE is for combined cycle gas turbines. The solar PV numbers assume a 7.5 percent weighted average cost of capital (WACC) for OECD countries and China and a 10 percent WACC for India. This does not include the cost of battery storage.

Sources: Data for rooftop solar PV are from IRENA, 2016; data for China and India coal and gas are from Bloomberg New Energy Finance, 2016.

While the cost of solar PV systems is declining, the cost of batteries—the most commonly used storage solution for small, distributed solar applications—remains a major barrier for lower-income households that might wish to adopt integrated battery/PV systems.¹⁵⁷ According to several studies from countries in the global South, the battery cost varies from 19 percent to 40 percent of the total equipment cost of a solar home system.¹⁵⁸ However, battery prices have also declined sharply in recent years and are projected to decrease further in the future.¹⁵⁹

Even though the costs of solar PV and batteries are dropping, these systems may not be so appealing to consumers whose electricity is subsidized and for whom tariffs have not risen to the same extent. In India low-income customers are protected through cross-subsidies.¹⁶⁰ This means that higher-income customers are charged higher tariffs to subsidize lower-income customers. As high-income customers choose to leave utilities for off-grid options, utility revenues are negatively affected. Those customers who continue to purchase electricity from the

grid may be proportionately affected because utilities will be less able to provide low-cost electricity to low-income households. For this reason, as distributed generation becomes a more viable option, it will become increasingly important for decision makers and regulators to properly value costs, ensure increased access, and maintain affordable prices.¹⁶¹

RELIABILITY AND PRODUCTIVITY

Grid extension has traditionally been the solution of choice to the access challenge; however, the grid does not always provide reliable or consistent service. With rising demand in growing urban centers, already overburdened grids are subject to increasing power cuts and shortages. Electricity outages are not limited to rural areas; in many African and Asian countries, supply interruptions occur frequently in cities. Data on outages are often unavailable or nonexistent, meaning that these types of supply interruptions are not represented in official electrification statistics and the electrification challenge in urban centers is underestimated. In Kinshasa, in the Democratic Republic of Congo, for example, traditional access indicators report 90 percent access to electricity, but extensive restrictions in service hours, unscheduled blackouts, and voltage fluctuations effectively mean that in reality, access does not surpass 30 percent.¹⁶²

Solar PV systems offer the option of providing backup power or powering loads. Grid-connected solar PV systems have become an option in India for backup power, where the supply/demand gap remains high.¹⁶³ Similarly, in Uganda, the commercial market for solar home systems is growing due to increased demand in households for backup power in the urban centers of Kampala and Entebbe, which suffer from unreliable grid supply.¹⁶⁴

Daily activities undertaken by the under-served can be energy-intensive and depend on a reliable supply of power. In the global South many households operate small and medium enterprises within their residences and require electricity to operate small machinery, provide lighting, and run appliances. Although solar PV may not be sufficient to provide all the necessary electricity to run a small business, it can enhance welfare by increasing security, extending the hours children can study, increasing income by providing more reliable or backup power electricity for productive uses, boosting social status, and reducing the expense of alternative fuels.¹⁶⁵

How does distributed renewable energy enhance the city's economic productivity and environmental quality?

Increased use of distributed renewables can help reduce the pressure created by the rising electricity demand that confronts many growing cities in the global South, where cash-strapped utilities struggle to provide base-load capacity. Solar PV can offer savings by avoiding the costs associated with network losses and transmission infrastructure, which could translate into savings for electricity customers. In India rooftop solar PV can result in potential savings from reduced transmission and distribution losses from INR 1.24 (\$0.02) per kWh to INR 1.87 (\$0.03) per kWh, which represents 30 percent to 45 percent of average residential costs in that country.¹⁶⁶ That being said, the impact of rooftop solar PV on utilities' overall financial viability needs to be carefully examined (see Box 7). Solar PV can also offer cities climate change resilience and energy security benefits. In contrast to utility-scale electricity generation, which is often located outside a city's boundaries, solar PV is an in situ solution to electricity generation needs.

Moreover, under-utilized rooftops in cities represent potential sites for value creation. For example, where third-party developers lease roof spaces from building owners, long-term rental income can be provided to those owners. This is the case in Gujarat, where the government has implemented a "rent a roof program," in which residents rent their rooftops to private solar energy companies that in turn pay them INR 3 (\$0.05) for every unit of energy produced.¹⁶⁷

Rooftop solar can provide economic development opportunities for cities, such as the creation of local businesses and jobs. The PROSOL solar home system program in Tunisia directly created more than 3,500 jobs between 2002 and 2010.¹⁶⁸ Because parts of the value chain (e.g., assembly, distribution, after-sales service) can be localized within the city, rooftop solar PV can increase the number of direct jobs in the city.¹⁶⁹ Renewable energy generates more jobs per unit of energy delivered than the fossil fuel-based sector, with solar PV creating the most jobs per unit of electricity output.¹⁷⁰ However, countries in the global South generally lack data on the net employment impacts, including expenditure-induced impacts on employment in the general economy.¹⁷¹

Box 7 | The Impact of Solar PV on Utilities and Electricity Tariffs

Policymakers need to consider how an increase in solar PV projects would impact utility tariffs. The introduction of new technologies and required infrastructure will raise new cost concerns, and the advent of self-generation could threaten utilities with the loss of consumers. In South Africa, for example, the government is reluctant to encourage residential households to generate their own power because electricity tariffs represent a large revenue source for municipalities. If customers left the grid, it would reduce income for the utility and cash-strapped municipalities.^a Similarly, in India utilities are starting to come under financial pressure as they lose their higher-paying customers to distributed renewable energy. Such was the case in the southern state of Tamil Nadu, where utility revenue loss attributed to consumers' purchasing renewables outside their utility accounted for 35 percent of the utility's total revenue gap.^b Regulators and policymakers will therefore need to rethink how electricity costs and tariffs are determined. Properly valuing and distributing system costs and benefits among customers will become increasingly important. The valuation of these costs and benefits is also important to ensure increased electricity access and maintain affordable prices.^c

Notes:

- a. Engerati, 2016.
- b. Jairaj et al., 2016.
- c. Jairaj et al., 2016.

Scaling up distributed renewable energy: barriers and enablers

In many urban contexts, the main barriers to improving electricity access for low-income groups—whether through grid connections or by providing alternatives—are political, institutional, and governance related. We highlight some of the main challenges in Table 3.

INSTITUTIONS AND GOVERNANCE

Lack of coordination among government institutions and information and implementation asymmetry between national, state, and local governments are in large part responsible for the absence of integrated electricity policies for the urban under-served.

Traditionally, energy planning and decision making have been fairly centralized. However, this approach is being challenged by the emergence of alternative, smaller, and decentralized energy systems and closer involvement of local decision makers. Cities and local governments are realizing the important roles they can play in addressing local development issues, providing energy services, and confronting challenges related to climate change and, most importantly creating change. Renewable energy targets and policies introduced at the local level are often the most ambitious and most rapidly implemented. Numerous municipalities worldwide are aspiring to or have already become fully dependent on renewables, setting good examples of what can be achieved at the municipal level.¹⁷⁶

This is not to say that national governments no longer have a role in promoting distributed renewable energy. The participation and vision of local, regional, and national stakeholders is important to achieving planned outcomes.¹⁷⁷ National actions need to be coordinated with local priorities, and likewise, local actions need to be coordinated with national priorities. As a consequence, energy policy design is handled by multiple levels of government.¹⁷⁹ For policies to be designed and implemented successfully, the roles of these various levels of government need to be clearly defined and understood by all.

Management and technical capacity building will be necessary to administer distributed renewable systems, which involve very different challenges than centralized grid systems. Regulators are not accustomed to the new types of generation and ownership models and are still grappling with questions, such as: Who will pay for improvements and innovations in the grid to enable benefits from emerging renewable technologies? Who will pay for added infrastructure? How will costs be

Compared to a business-as-usual baseline, scaling up distributed renewable energy would lower the trajectory of GHG emissions and decrease associated air pollution. This is especially the case where countries' electricity grids are carbon-intensive ($\text{tCO}_2\text{e}/\text{GWh}$), as they are in, for example, South Africa, China, India, and Indonesia.¹⁷² Using the data on carbon intensity of electricity grids¹⁷³ and the current installed capacity of solar PV (utility scale and residential) across 60 countries of the world,¹⁷⁴ we calculate that the power generated by tripling the current installed capacity of solar PV (assuming constant demand) would reduce GHG emissions by 108.3 MtCO_2e , which is on par with the total GHG emissions of Belgium in 2012.¹⁷⁵ This is just an indicative number based on current demand. While demand is unlikely to remain constant in the global South, we may assume that significantly scaling up the region's solar PV installed capacity would help slow the rate of increase in GHG emissions.

Table 3 | **Barriers to Scaling Up Distributed Renewables in the Global South**

GOVERNMENT	SERVICE PROVIDERS	END USERS	FINANCIERS
<ul style="list-style-type: none"> ▶ Misperception of the urban energy access challenge ▶ Low energy pricing and distorting fossil fuel prices ▶ Lack of capacity for distributed renewable planning ▶ Lack of institutional framework or coordination across and between governments (national and city) ▶ Lack of technical capacity to develop new energy regulation that accommodates distributed renewables ▶ Limited or poor data on energy needs and consumption 	<ul style="list-style-type: none"> ▶ Poor recognition of informal settlements and their service requirements ▶ High project-development costs ▶ Limited financial and technical capacity for infrastructure development ▶ Perceived risk of late/non-payment by consumers ▶ Limited technical capacity ▶ Lack of trust between utility and customers 	<ul style="list-style-type: none"> ▶ Lack of awareness ▶ Lack of participatory processes (e.g., communicating energy needs) ▶ Affordability—high up-front costs and ability/willingness to pay incremental cost ▶ Perceived risks of new technologies ▶ Limited ability to borrow ▶ Lack of trust between utility and customers 	<ul style="list-style-type: none"> ▶ High up-front costs ▶ High perceived risks ▶ Lack of knowledge or capacity

Source: WRI authors.

distributed?¹⁷⁹ The variability of generation and load, energy storage, and on-site generation are expected to make grid operation and planning more complex.¹⁸⁰ Currently, cities often lack standards for PV installation and accredited installation courses, which creates further implementation challenges for the solar market.¹⁸¹ A number of measures can help bridge the institutional capacity gaps in providing electricity access to the urban under-served:

- ▶ Local-level planning can be critical in helping determine which electrification solutions are appropriate. Planning for distributed generation, even if initiated at the national level, will benefit immensely from local-level demand and supply analysis to ensure that energy needs, as well as the range of available local options for meeting those needs, are well understood.
- ▶ National- and subnational-level agencies or specialized departments dedicated to promoting clean energy (renewable energy and energy efficiency) are emerging as a mechanism to coordinate efforts in the sector.

- ▶ Training will be required for project developers, regulators, utilities, financiers, and in some cases, consumers, because distributed renewable technologies present new technical, regulatory, and institutional challenges. Relevant agencies should prepare themselves to enhance institutional capacities to manage a more decentralized system involving these new technologies and generating entities.

Lack of awareness and trust among stakeholders often inhibits the distribution and adoption of innovative distributed renewable solutions. As long as this lack of trust persists, service providers will be reluctant to work in under-served areas, and the under-served will continue to rely on illegal intermediaries for their electricity needs.¹⁸² Improved communication between electricity service providers and the urban under-served is necessary—consumer engagement (collective or individual) in both the planning and implementation of distributed generation is important not only to build support for projects but also to promote their financial sustainability. In Buenos Aires, Argentina, for example, surveys and workshops were carried out to identify specific consumption patterns to highlight unmet energy needs by usage. Surveys resulted in enhanced social inclusion and facilitated the development of creative solutions.¹⁸³

Utilities can also make a significant difference if they engage and invest in access improvements for poor neighborhoods. In addition, project developers can make informed decisions about tariff levels and payment and collection methods that are well suited to the nature of target consumers' income flows and livelihood patterns.¹⁸⁴ Consumer engagement can help inform decisions regarding which is the best distributed-generation option for a given community.

POLICY

Targeted policy initiatives and mechanisms are necessary to promote local distributed energy systems. These can include target setting, government support mechanisms, regulations, operation of municipal infrastructure, voluntary actions, and information and awareness building. Economic instruments are becoming more commonly used; examples include feed-in tariffs (FiTs), net or gross metering, reverse auctions, special tariffs for renewable energy customers (e.g., green tariffs), quotas, and renewable portfolio standards. FiTs and net-metering schemes are among the most popular mechanisms to support distributed renewable power by enabling generators to receive credit or payments for on-site generation.¹⁸⁵ In 2015 about one-third of the jurisdictions that adopted FiTs were at the provincial or state level, not the national level.¹⁸⁶ Moreover, the adoption of local-level policies to promote clean energy is

Targeted policy initiatives and mechanisms are necessary to promote local distributed energy systems. These can include target setting, government support mechanisms, regulations, operation of municipal infrastructure, voluntary actions, and information and awareness building.

becoming more prevalent in the global South.¹⁸⁷ In India almost all states have announced net and/or gross metering policies that allow generators, including residential generators, to receive credit or payments for excess on-site generation.¹⁸⁸

Green tariffs, or renewable energy purchasing programs offered by utilities, allow customers to buy energy from renewable energy projects. Green tariff mechanisms have proven popular in U.S. states where there is no functional retail electricity choice to access fixed-price renewable energy.¹⁸⁹ New policies to support battery storage, such as special tariffs, could also support distributed renewable energy.

At the city and municipal level, FiT and net-metering policies have proven to be important tools for promoting the deployment of distributed renewable energy. In 2015 the city of Cape Town in South Africa introduced a net-metering scheme that allows for the sale of surplus energy from renewable energy installations into the municipal grid system.¹⁹⁰ Since November 2014, the city of Bengaluru in the state of Karnataka, India, has been encouraging the growth of rooftop solar PV systems through the implementation of a net-metering policy.¹⁹¹ The city provides some useful lessons on scaling up rooftop solar PV, although it still needs to expand the program to low-income residents (see Box 8).

FINANCE

Affordability remains a concern despite the continuing fall in solar PV costs. High up-front costs still pose a barrier to purchase in the absence of subsidies or support schemes, especially for lower-income consumers who may lack the ability to borrow. End-user consumer finance can play an important role in addressing these up-front costs and has been crucial to scaling up solar home systems in rural areas.¹⁹² Approaches include finance provided to customers by municipalities, utilities, banks, or micro-finance institutions to purchase a system; third-party finance, such as leasing options or PAYG programs; or free use of a system by a customer.¹⁹³

Box 8 | Prosumers in Bengaluru: Lessons for Scaling Up Rooftop Solar PV

Like many cities in the global South with rapidly growing urban centers, Bengaluru, in the Indian state of Karnataka, is struggling to meet electricity demand. Rooftop PV provides the potential for residents to be not only consumers but also prosumers of electricity, selling power back to the grid. Indeed, scaling prosumer adoption of rooftop solar PV through net metering is one attempt to minimize the pressure on electricity supply. Bengaluru's rooftop solar PV market has steadily gained traction since the introduction of BESCO's net-metering program in November 2014.^a Under the program, owners of rooftop solar PV systems are paid a promotional rate for net excess generation provided to the grid on a monthly basis. By March 2016, over 5.6 MW of grid-connected rooftop solar PV systems on 262 rooftops were connected.^b

While Bengaluru is making progress in capacity addition, the pace of rooftop solar PV system adoption will need to accelerate if Karnataka is to meet its 400 MW grid-connected solar PV goal by 2018.^c In Bengaluru a number of specific barriers prevent further scale-up of rooftop solar PV, but they also offer useful lessons:

- **Lack of uptake by the poor and limited appeal of the net-metering program.** Because local banks are generally hesitant to give out loans for solar PV, lower-income residents have not been participating in the program. Some national subsidies are available to implement rooftop solar, but many people stay away because the application process is burdensome; those who do obtain the subsidy also get a lower net-metering rate. To expand the limited reach and appeal of the net-metering program, program administrators can undertake market research to understand why the program appeals to some population segments more than others, and to identify how the program can be redesigned to reach a larger share of the population.
- **Poor understanding of PV performance, cost, and payback.** To address limited understanding among prosumers, program administrators can increase newspaper advertisement campaigns and provide more detail on rooftop solar PV technology through more articles or television reports.
- **Confusion on net-metering specifications.** To address a lack of clarity about program specifications and processes, program administrators can develop concise program guidelines that specify each process in a step-by-step, easy-to-follow format, as well as expected timelines.
- **Uncertainty in project developer selection and interaction.** To improve prosumer trust in project developers, program administrators can offer an open certification process for developers. Furthermore, program administrators can offer training and education programs for project developers, specifically about BESCO's net-metering program specifications.
- **Limited institutional capacity of the program administrator.** To strengthen institutional capacity, program administrators can introduce short-term solutions, such as streamlining approval procedures, as well as longer-term solutions, such as creating a "one window" unit that manages the entire net-metering process and provides specialized training sessions for employees.

Notes:

- Government of Karnataka, 2014.
- Government of Karnataka, 2014.
- Government of Karnataka, 2014.

Pay-as-you-go (PAYG) is a successful model for providing solar home systems in a rural context, and it has experienced staggering growth. In less than one year, the number of households using PAYG systems in sub-Saharan Africa doubled to 450,000–500,000 households in 2015.

Many municipalities have created programs to increase the affordability of solar projects through loans, subsidies, and rebates. In these cases finance is usually raised through bonds, and costs are passed on either directly to customers or to developers to install systems on customers' roofs. Utilities have also started giving their customers the option of owning solar systems, with finance being used either to help customers install systems or as a direct loan.¹⁹⁴

In a third-party financing or ownership option, a third-party provider installs, owns, and operates the system on a customer's site and either leases the PV system to the customer or sells the electricity to the building or back to the grid.¹⁹⁵ Third-party financing models represent an important option for customers who want to install a rooftop solar system but may not have the up-front capital to do so. Some Indian states have introduced net-metering policies in an attempt to expand rooftop solar. Many of these policies allow third-party solar leasing.

An alternative to third-party leasing models is the roof rental model. Under this model, developer companies rent roofs, install their own systems, and sell electricity to the grid. In Delhi, where net-metering exists, home owners can either own a solar power system or lease their roof space to project developers.¹⁹⁶ In this model, project developers lease out a solar PV system to an interested roof owner, who in turn pays developers a monthly lease rent. The electricity generated from such a system is used to meet the household's or rooftop owner's energy needs, with the excess fed back to the grid.¹⁹⁷ In Brazil the government is looking to change legislation around renewable energy to enable this type of arrangement.¹⁹⁸

Another less traditional leasing model is the PAYG model. PAYG is a successful model for providing solar home systems in a rural context, and it has experienced staggering growth. In less than one year, the number of households using PAYG systems in sub-Saharan Africa doubled to 450,000–500,000 households in 2015.¹⁹⁹ It is likely the model could be applied in the urban context to address up-front cost issues as well. M-KOPA, headquartered in Nairobi, Kenya, is one of the most popular companies offering PAYG systems in Africa. From its commercial launch in October 2012, M-KOPA has connected more than 280,000 homes in Kenya, Tanzania, and Uganda to solar power and is continuing to connect 500 new homes each day. Customers acquire solar systems for a small deposit and then buy daily usage "credits" for \$0.50, which is less than the price of traditional kerosene lighting.²⁰⁰ Customers own their solar systems outright after one year and can then upgrade to more power.²⁰¹

Community-shared solar is relatively new in cities in the global South. Community-shared solar is a business model that allows multiple individuals—many of whom may lack financial capacity or available on-site resources—to pool their resources to purchase PV systems.²⁰² Under community ownership models, projects are often operated and maintained by local communities with some degree of external help, especially with the project's financing, design, and installation. There are many different types of community-shared solar, including utility-sponsored models, in which the utility owns and operates a project; the special-purpose entity model, in which an individual investor joins an enterprise or cooperative to develop a community project; and a nonprofit "buy a brick" model, where donors contribute to a community solar installation owned by a nonprofit organization.²⁰³

The energy sector involves multiple levels of government, decision makers, and stakeholders that all play a role in promoting distributed renewable energy. At the local level alone, numerous actors can play roles in providing access to clean, affordable, and reliable energy. Figure 8 summarizes the varying roles these actors can play in promoting distributed renewable energy.

Figure 8 | **The roles of different actors in scaling up distributed renewables****DEVELOPMENT FINANCE INSTITUTIONS**

- ▶ Emphasize the importance of distributed renewables in addressing SDGs 7 and 11.
- ▶ Create dedicated funds that target distributed renewable energy in cities, especially for the under-served.
- ▶ Conduct public awareness campaigns for renewable energy.

NATIONAL GOVERNMENTS

- ▶ Emphasize the importance of distributed renewables in addressing SDGs 7 and 11.
- ▶ Ensure enabling policies, plans, and targets are in place, clearly defining long-, medium-, and short-term goals and implementation strategies.
- ▶ Ensure financing mechanisms are in place to incentivize the uptake of clean and distributed energy solutions. These can include subsidies, loan programs, and tax incentives.
- ▶ Enable local governments to take leadership by providing a national vision around distributed generation, but also coordinating national initiatives with local priorities.
- ▶ Facilitate grid connections.
- ▶ Reform fossil fuel subsidies.

REGULATORS

- ▶ Implement tariffs that incentivize the use of distributed renewable energy.

UTILITIES

- ▶ Implement and administer innovative distributed renewable energy financing programs.
- ▶ Work with communities to develop innovative solutions to electricity access.

CITY GOVERNMENTS

- ▶ Emphasize vision setting and targets, including renewable energy targets, establish urban planning processes to promote renewables, integrate renewables into urban development strategies, promote institutional strengthening, and coordinate with stakeholders.
- ▶ Develop and invest in city-owned projects, facilitate direct purchasing of renewables, and make municipal land available for projects.
- ▶ Establish regulations that promote renewables (e.g., building codes, permitting procedures, solar ordinances, grid connection regulations, technical standards, and obligations on energy suppliers).
- ▶ Finance renewable energy projects, including facilitating low-interest and long-term loans for property owners, project developers, and small-scale purchasers.
- ▶ Conduct advocacy and engagement, including raising awareness, promoting knowledge sharing among stakeholders and dissemination to individuals and CSOs.

PRIVATE SECTOR

- ▶ Develop innovative finance and business models for distributed renewable energy in cities.
- ▶ Work with communities to develop and implement finance and business models.

CIVIL SOCIETY ORGANIZATIONS

- ▶ Work with local government and utilities on solutions for improved access and distributed renewable energy.
- ▶ Work with local communities to understand and communicate their energy needs.
- ▶ Work with local decision makers and utilities to promote distributed renewable energy.
- ▶ Disseminate research, analysis, and lessons learned about distributed renewable energy to decision makers.

Source: WRI authors, based on IEA, 2016a.

Increasing Energy Efficiency of Buildings and Appliances

Two important policy instruments for driving more efficient energy use are building energy-efficiency codes (BEECs) and energy-efficiency standards and labels for appliances and equipment, such as heating/cooling systems and lighting. Strong BEECs and appliance standards that are well enforced, strengthened over time, and adapted to the local climate and other conditions are among the most cost-effective and environmentally powerful policy instruments available to government.²⁰⁴ The IEA has identified both BEECs and appliance standards as priorities across areas of the global South, including Southeast Asia, Brazil, China, Mexico, and South Africa.²⁰⁵

The dilemma facing many growing cities in the global South is that, in the short term, both policy approaches can seem far removed from the hard realities of proliferating informal settlements, high demand for affordable formal housing, and low interest in or awareness of energy efficiency among either developers or consumers. And yet, in the absence of even minimal efficiency codes and standards, such cities will lock in grossly inefficient buildings, services, and products that will drive high energy costs and negative impacts on human health and productivity for decades to come. Despite the difficulties, a number of countries in the global South have made significant progress. China, India, Mexico, Indonesia, and Brazil have successfully introduced energy-efficient building codes, while China, India, Ghana, and Thailand have established energy-efficient standards and labeling (S&L) schemes for appliances.

No single set of codes or standards will be appropriate for every city or country, and no single timetable for implementation can be adopted. The answer may lie in an incremental approach by which each city strives over time to ratchet up the energy performance required of buildings—commercial, public, and residential—and the minimum efficiency levels required of appliances and other products. Policymakers can implement and publicize a cycle of regular code and standard revisions, beginning with low standards that can be met by most developers and manufacturers, while indicating that the standards will be raised over time. Building codes in struggling and emerging cities need to be sensitive to the fact that these

cities are transitioning up the housing and energy ladders, from informal to formal settlements. Given this reality, codes should evolve and initially target segments where economic benefits are the greatest and enforcement is most likely to succeed. Indeed, regarding BEECs, India first focused on large commercial buildings rather than residential ones, as the barriers to adoption were much higher for residential buildings.

While building codes, efficiency standards, and labeling schemes are usually set at the national level, cities are usually responsible for overseeing their implementation and enforcement.²⁰⁶ This is one area where local authorities have significant power to act. According to a C40 survey, at least 70 percent of cities reported strong ownership or operational control, authority over policy setting and enforcement, and budgetary control over new or existing municipal buildings.²⁰⁷

Building energy-efficiency codes

This section focuses on the use of building codes for new commercial and municipal buildings (e.g., schools, hospitals, public housing), and private housing development. We recognize that this may appear to have little immediate relevance those living in informal settlements. However, it is our contention that direct benefits to the under-served can accrue in the form of more comfortable, safer buildings, where they may work or educate their children. Building codes that apply to commercial and municipal buildings, such as schools and hospitals, and to social housing can benefit the urban under-served. And, indirectly, the wider benefits of lower costs per unit of energy delivered, reduced air pollution, improved respiratory health, and reduced risk of heat-related illness or death will have significant benefits for the urban under-served and the residents of the city as a whole. By 2015, some 40 countries had developed BEECs and most industrialized countries have already mainstreamed them.²⁰⁸ However, there is a dearth of codes in Latin America, Southeast Asia, and especially Africa, where only two countries have codes for new residential buildings (Tunisia and South Africa, and the latter is voluntary).²⁰⁹ Countries in the global South where BEECs have been adopted provide useful insights and highlight some of the challenges, particularly in countries with low financial, technical, and engineering capacity (see Table 4).

China, India, and Mexico have, to different degrees, made progress with implementing BEECs. China has been successful in mainstreaming BEECs, largely because of strengthened capacity and willingness of local governments to enforce the codes, widely available quality building materials and components for compliance, and the capability of the construction industry to meet technical requirements, as well as its ability to afford the incremental costs of BEEC compliance.²¹⁰ These conditions are often lacking in the global South, which underscores the need for BEECs to evolve gradually with incremental efficiency improvements.

In Mexico, the National Housing Agency requires developers who participate in its subsidized low-income housing program to satisfy sustainability requirements.²¹¹ In Shenzhen, China, the municipal government has promulgated rules requiring specific green building standards for affordable housing projects in the city.²¹² These standards could potentially serve as models in other countries on how to link low-income housing development with energy efficiency. While countries should first address BEECs for new construction, especially commercial buildings, it is important to eventually expand them to retrofits of existing buildings.

Table 4 | **Examples of BEECs in the Global South**

COUNTRY	DESCRIPTION
Brazil	<ul style="list-style-type: none"> ▶ Brazil does not have energy-performance requirements for buildings but instead has energy-efficiency labeling schemes—RTQ-R and RTQ-C for residential and commercial buildings, respectively. ▶ Measures covered include building envelope, HVAC, and lighting.^a
China	<ul style="list-style-type: none"> ▶ China has three separate mandatory urban residential codes for four climatic zones and one mandatory national BEEC. ▶ Measures covered include building envelope and HVACs, as well as district heating in cold and severe cold zones. ▶ Code is mainstreamed in large markets.^b
India	<ul style="list-style-type: none"> ▶ The national Energy Conservation Building Code (ECBC) sets minimum energy-efficiency requirements for commercial buildings' envelope, HVAC, electrical system, lighting, water heating, and pumping systems.^c The code is voluntary, and 22 states are at various stages of mandating the ECBC.^d
Indonesia	<ul style="list-style-type: none"> ▶ Indonesia has four energy standards for buildings, which cover the building envelope, air-conditioning, lighting, and building energy auditing. ▶ A 2005 law mandated that buildings must consider energy-conservation measures, but enforcement is lacking. ▶ The country is currently finalizing the National Guidelines on Green Buildings, with energy efficiency as one of the main criteria.^e
Mexico	<ul style="list-style-type: none"> ▶ No building energy codes now exist, but Mexico has national standards on minimum energy performance of building elements and materials. Measures covered include building envelope and residential lighting.^f Standards are mandatory at the national level, and in order to achieve compliance, these standards have to be included in state and municipal building regulations. Few states have done so, mainly due to a lack of interest by local governments in incorporating the requirements into their local building regulations. The federal government has proposed Mexico's first national energy code for commercial buildings.^g ▶ Energy-efficiency design requirements are mandated in low-income housing that receives federal funding.^h

Notes:

a. Global Buildings Performance Network, 2016; b. Liu et al., 2010; c. Global Buildings Performance Network, 2016; d. Bureau of Energy Efficiency 2017;

e. Global Buildings Performance Network, 2016; f. Global Buildings Performance Network, 2016; g. Global Buildings Performance Network, 2016;

h. Liu et al., 2010.

Appliance standards and labeling

In recent years there has been considerable progress globally in the development of standards and labeling (S&L) for equipment and appliances such as lighting, air-conditioning, and refrigerators. Between 2004 and 2013, the number of measures almost tripled, and 81 countries have adopted standards and labels.²¹³ The most common type of appliance standards are minimum energy-performance standards, which set a minimum level of efficiency or a maximum level of energy consumption but do not specify a product's technology or design.²¹⁴ However, there is real scope to scale up energy-performance standards in the global South,

especially in Africa, where the majority of standards are in the planning stages and only eight mandatory measures exist.²¹⁵

Appliance S&L programs have brought large estimated energy savings to some countries in the global South, including China, India, Thailand, and Ghana (see Table 5). Ghana enacted the first appliance standard in sub-Saharan Africa in 2000 for room air-conditioner units in response to an energy crisis in the 1990s.²¹⁶ Economic growth was outstripping electricity supply, and rolling blackouts from 1998 to 2000 suppressed economic output in the industrial and service sectors.²¹⁷ Air-

Table 5 | Examples of Energy-Efficient Appliance S&L Programs in the Global South

COUNTRY	DESCRIPTION	IMPACT
China	<p>The program in China has three components:</p> <ul style="list-style-type: none"> ▶ Mandatory minimum efficiency standards—there are now more than 40 minimum energy-performance standards for residential and commercial appliances, lighting, and heating and cooling equipment.^a ▶ Voluntary energy-efficiency labeling for more than 75 products; analogous to the U.S. Energy Star program.^b ▶ Mandatory energy information labeling for over 30 product categories.^c 	<ul style="list-style-type: none"> ▶ Residential and commercial appliance standards (excluding motors, transformers, and air compressors) are projected to save a cumulative 6,947 TWh by 2030, or 14% of the cumulative consumption of building electricity by 2030.^d
Ghana	<ul style="list-style-type: none"> ▶ S&L was first developed for room air conditioners (gazetted in 2001), then CFLs and residential refrigerators.^e 	<ul style="list-style-type: none"> ▶ It is estimated that the standard for air-conditioning will save Ghana \$775 million by 2020, and the standard for refrigerators \$72 million per year.^f As a result of the CFL standard, households have received income savings of 2.5% in larger cities, on average.^g
India	<ul style="list-style-type: none"> ▶ S&Ls have been developed for 20 categories of products. Appliances are rated on a scale of 1 to 5, with the most efficient carrying a five-star label.^h ▶ Program participation is mandatory for seven categories of products and voluntary for the rest.ⁱ 	<ul style="list-style-type: none"> ▶ Estimated savings in 2012 of 4,847 MW of avoided capacity, or 5,954 GWh, equivalent to GHG reductions of 5.6 MtCO₂.^j
Thailand	<ul style="list-style-type: none"> ▶ Label No. 5 program is a comparative label that rates products from 1 (least efficient) to 5 (most efficient). The program covers room air conditioners, CFLs, ballasts, electric fans, rice cookers, lighting fixtures, T5 fluorescent lamps, standby power for televisions, and computer monitors.^k 	<ul style="list-style-type: none"> ▶ Cumulative savings from 1994 to 2013 include installed capacity (2.8 GW), power generation (17 TWh), and avoided CO₂ emissions (10.3 GtCO₂).^l

Notes:

a. CLASP, 2016; b. CLASP, 2016; c. CLASP, 2016; d. Zhou et al., 2011; e. CLASP, 2002; CLASP, 2013; f. CLASP, 2013; g. CLASP, 2013; h. Jairaj et al., 2013; i. Jairaj et al., 2013; j. Dhingra et al., 2016; k. Jairaj et al., 2013; l. Jairaj et al., 2013.

conditioning was prioritized, given that air-conditioning use is highly synchronous with peak electricity demand. Standards for lighting and refrigerators followed. Prior to the standard for refrigerators, more than half the refrigerators sold were secondhand, many shipped from Europe.²¹⁸ Overall, the standards for air-conditioning, compact fluorescent lighting (CFL), and refrigerators have resulted in an estimated cumulative savings of \$840 million that would otherwise have been invested in new power plant acquisition and thermal energy generation.²¹⁹

It is important to develop minimum energy-performance standards for devices and appliances that most impact the under-served, including lighting, refrigerators, and fans, but also for space air-conditioning (AC). AC penetration is low in the global South (e.g., just 5 percent of households in India in 2011), but in countries like Brazil, India, and Indonesia, sales are growing at 10 percent to 15 percent per year, and AC use will inexorably increase, regardless of sustainability concerns.²²⁰ In Delhi the AC load is already 40 percent to 60 percent of peak electricity load.²²¹ The ratcheting up and harmonization of effective and stringent standards is critical to stop the “leakage” of inefficient appliances to countries with low or nonexistent standards.

In addition to building codes and appliance standards, other urban energy measures can yield significant efficiency gains. These include energy-systems integration (e.g., cogeneration, waste-to-energy, waste-heat recycling), district heating and cooling services, and combined heat and power systems. China has the world’s largest network of district heating and has scaled up waste-to-energy, but these approaches are not yet common in other parts of the global South.²²² Currently, such measures may have less immediate benefit for the under-served than those we have identified; moreover, they are capital-intensive and economical only where urban density is sufficiently high. However, in the longer term, they may become viable solutions for many cities in the global South.²²³

How does increasing the energy efficiency of buildings and appliances help the under-served?

More energy-efficient buildings (both homes and places of work) provide direct and indirect benefits to the under-served—who often spend a greater percentage of their income on energy than higher-income urban residents—in terms of cost savings, comfort, health, and resilience. The under-served may not consume much energy in an absolute sense, but the relative improvement in energy efficiency and associated cost savings may be important: Every dollar saved can translate into more

money for food, health, and education. Benefits also accrue beyond the household level. As incomes increase, energy consumption will increase. If energy-efficiency measures are implemented at a large scale, they will yield huge savings to cities in the global South that will allow those cities to invest more in providing access to the under-served.

Potential savings in unit energy consumption that can be achieved by switching to the best available individual household appliance and equipment are on the order of 40 percent to 50 percent.²²⁴ As many case studies attest, there can be considerable cost savings from reduced energy consumption (see Table 5). In Ghana it was estimated that standards for refrigerators save Ghanaians \$35 per year, one-third the total cost of a refrigerator.²²⁵ In Mexico, the national energy-efficiency S&L programs (e.g., for refrigerators/freezers, air conditioners) resulted in estimated savings to consumers of \$3 billion between 2002 and 2014.²²⁶ It is important, however, to robustly evaluate the actual impact of more energy-efficient appliances. In Mexico, a large-scale appliance replacement program resulted in reduced electricity consumption by more energy-efficient replacement refrigerators, but increased the use of, and hence the electricity consumed by, replacement ACs.²²⁷

Structural building efficiency improvements will result in improved indoor air quality and more comfortable buildings, especially given the impacts of climate change. Building codes have often been overlooked as disaster reduction strategies in the global South.²²⁸ Extreme weather events such as heat waves are expected to occur more frequently and with longer duration over most land regions of the world.²²⁹ The impact of extreme heat events on mortality is well documented in studies of the United States, Europe, and China.²³⁰ Those who live or work in dense urban concentrations face higher risks from heat waves due to the exacerbating heat island effect. The poor are often especially at risk from high temperatures because of their living conditions, the poor quality of their housing, the location of their housing in areas without green space, and a lack of ventilation and access to air-conditioning.²³¹ While most urban warming impact assessment studies have focused on external conditions (e.g., the heat island effect), some studies indicate that building characteristics are important for indoor temperatures and, consequently, overheating risk.²³² Based on an assessment of vulnerability (population density, percent of population over age 65, per capita GDP, and education level) and projected changes in heat wave days, Dong et al. (2015) conclude that sub-Saharan Africa, South Asia, and Southeast Asia have the highest heat health risk over the course of the century.

Building efficiency measures can also enhance climate resilience by not only making buildings more tolerable during heat waves but also by reducing peak demand and the likelihood of power outages.²³³

How does increasing the energy efficiency of buildings and appliances enhance the city's economic productivity and environmental quality?

On average, residential and commercial buildings consume the most energy in urban areas, globally.²³⁴ In 2010 residential and commercial buildings were responsible for one-third of global final energy consumption and 19 percent of energy-related CO₂ emissions.²³⁵ Currently, the highest rates of growth in energy consumption and the least energy-efficient buildings are found mostly in the global South. This means that energy-efficient buildings offer huge potential for cities in terms of slowing the growth of energy consumption and related economic, social, and environmental costs.

It has been estimated that an area equal to roughly 60 percent of the world's current total building stock will be built or rebuilt in urban areas by 2030.²³⁶ Much of this future infrastructure will be constructed in the global South. For example, in India, 80 percent of all buildings that are projected to stand in 2030 were not yet built as of 2010.²³⁷ The country, like many others in the global South, is at high risk of locking in decades of future inefficiency, high costs, and high emissions, leading to costly renovations in the future.²³⁸

When complied with, building efficiency codes and appliance standards can greatly enhance a city's energy productivity and result in cost savings. A major benefit is that reduced rates of growth in electricity demand translate into less pressure on the electricity supply system and potentially reduce the need for additional installed generating capacity. Energy-efficiency measures in buildings are estimated to be capable of reducing energy use by up to 50 percent to 90 percent in new buildings and 50 percent to 75 percent in existing buildings.²³⁹ In China, continued increases in the strictness of the building codes for new urban residential and commercial buildings and an expansion of the code to include retrofits could result in energy use reductions of 18 percent relative to business-as-usual by the end of century.²⁴⁰

Cities also have enormous potential to contribute to global climate change mitigation. Measures undertaken in residential and commercial buildings (e.g., implementation of building

energy codes, standards, and retrofit programs, including lighting and appliances) account for an estimated 70 percent of the global urban-level GHG abatement potential in 2030.²⁴¹

India's appliance S&L program illustrates the types of energy savings that can result from such initiatives, reducing or even eliminating the need for more installed capacity. An impact analysis of the program shows that annual energy savings (in terms of avoided generation capacity) for 2007–8 were around 260 MW, increasing to 599 MW in 2008–9, and to 2,179 MW in 2009–10.²⁴² Globally, the potential savings are enormous, with most of the savings coming from outside the United States, Europe, China, and India.²⁴³

Increasing energy efficiency of buildings and appliances: barriers and enablers

Energy-efficiency measures in cities are impeded in many ways—by government institutions, policy and regulations, private-sector equipment and service providers, end users, and financiers (see Table 6).²⁴⁴ Many of these barriers are institutional. Appropriate policies and regulations are needed to realize the gains of energy-efficiency measures, and energy subsidies, for example, may diminish the returns from efficiency programs. The establishment of robust BEECs and energy-efficient appliance standards is hindered by the lack of strong institutions both at the national and city level, including technical capacity and enforcement capabilities, and by the lack of participatory processes and awareness and information campaigns. Financing energy-efficiency projects requires technical capacity on the part of financial institutions, which may not have the risk appetite or experience in lending for nontraditional financial projects.²⁴⁵

INSTITUTIONS AND GOVERNANCE

Monitoring, evaluation, and implementation of energy-efficiency S&L programs suffer when implementing agencies are not clearly identified and programs are inadequately staffed and funded. Institutional and financial capacity is needed for program development; responsibility for executing those programs is then often split between various agencies and different scales of government.²⁴⁶ This is especially the case with enforcement and compliance. Ensuring that there are systems in place to monitor and assess whether industry is complying with all the provisions—whether of building codes or S&L schemes—is an essential component of success. Compliance is often overlooked in order to attract more participants or simply because regulators do not understand the benefits associated with compliance programs.²⁴⁷

Table 6 | **Barriers to Improving Energy Efficiency in Cities**

GOVERNMENT	EQUIPMENT/SERVICE PROVIDERS	END USERS	FINANCIERS
<ul style="list-style-type: none"> ▶ Low energy pricing and distorting fossil fuel prices ▶ Lack of public procurement and budgeting policies ▶ Limitations on public financing and borrowing ▶ Lack of capacity for energy-efficiency planning ▶ Lack of institutional framework or coordination across and between governments (national and city) ▶ Lack of technical capacity to develop appliance standards and building codes or lack of enforcement ▶ Focus on energy supply ▶ Limited or poor data on energy consumption 	<ul style="list-style-type: none"> ▶ High project-development costs ▶ Perceived risk of late/nonpayment by the public sector ▶ Limited demand for energy-efficiency goods/services ▶ Lack of technical capacity to translate standards into specific plans, strategies, and actions ▶ Diffuse/diverse markets and small end users ▶ New contractual mechanisms (e.g., energy service companies) ▶ Limited technical, business, and risk management ▶ Limited access to financing/equity 	<ul style="list-style-type: none"> ▶ Lack of awareness ▶ Lack of participatory processes (e.g., in setting of energy-efficient appliance standards) ▶ Affordability—high up-front costs and ability/willingness to pay incremental costs ▶ Low perceived energy-efficiency benefits relative to costs of other priorities ▶ Perceived risks of new technologies ▶ Lack of incentives, or split incentives (e.g., tenants pay energy bills but owners invest in energy-efficiency measures) ▶ Behavioral biases against energy-efficiency products ▶ Limited ability to borrow 	<ul style="list-style-type: none"> ▶ Lack of awareness of technologies, contractual mechanism ▶ High transaction costs ▶ High perceived risks or lack of appreciation of returns ▶ Opportunity costs ▶ Overcollateralization ▶ Behavioral biases

Sources: Sarkar and Singh, 2010; Becqué et al., 2016, modified by WRI.

Building energy-efficiency codes

Enforcement is a critical barrier to the implementation of BEECs. While BEECs are typically set by national or state governments, their adaptation, implementation, and enforcement is undertaken by city governments, which may lack the political will or technical capacity. However, where cities can ensure compliance, they can choose to enact more stringent BEECs than those at national or state levels. For example, Tianjin, China, achieves high compliance. This city has reduced the residential heating loads of buildings built after 2005 by 30 percent compared to the national code, while residential buildings built between 2005 and 2009 have saved an amount of energy equivalent to investing in a new 300 MW district heating plant.²⁴⁸ Cities in the global South that have capacity challenges can use a third party to leverage limited government resources.

It has been argued that the main factors for successfully complying with BEECs are the following:²⁴⁹

- ▶ Strong political support and financial incentives for building owners to exceed BEECs (grants, subsidized loans, and tax incentives; see the Finance section on p. 43)
- ▶ Market demand for energy-efficient buildings, which necessitates stakeholder engagement and education
- ▶ Sufficient resources for enforcement, including extra funding early on for capacity development and training
- ▶ A strong energy-efficiency champion in the city government
- ▶ Robust compliance software
- ▶ Strict and universal plan reviews
- ▶ Training of code officials, designers, and building industry officials

Appliance standards and labeling

In the case of appliance and equipment standards, institutional capacity is necessary to set standards and promote energy efficiency. In India, for example, compliance and enforcement is very resource intensive. It requires not only adequate and skilled human resources but also sufficient testing facilities and budgets. Compliance is often limited by the availability of laboratories with the capacity or the equipment to conduct the required tests. The Bureau of Energy Efficiency, the agency tasked with overseeing the country's S&L program, has recently engaged in extensive workshops and exercises regarding expanding test laboratory capacity; the impact of these efforts is likely to result in an increase in compliance testing.²⁵⁰

Public awareness is crucial to the success of any energy-efficiency program. For example, appliance end users need to understand how their homes use energy, the energy savings opportunities that are available, and which products constitute energy-efficient and cost-effective choices.²⁵¹ Although the evidence is mixed, one study in Brazilian *favelas* found that persuasive communication significantly increased the uptake of an energy-efficient lightbulb (a light-emitting diode, or LED).²⁵² Participatory processes are vital for the success of energy-efficiency programs. Involving many CSOs, such as voluntary consumer organizations, and increasing participation in appliance S&L programs can have positive impacts on consumer awareness.²⁵³ Participatory decision making and transparency can lead to the development of robust and implementable standards that are well recognized and relied on by consumers and can improve a program's overall efficacy.²⁵⁴

CSO participation can also address inequity concerns in appliance S&L programs and help ensure that the poor do not disproportionately shoulder the burden of national energy-efficiency targets. In 2001, the Collaborative Labeling and Appliance Standards Program partnered with Ghana's Electrical Appliance and Standards Program (CLASP) to create an S&L scheme customized to Ghana's energy needs, culture, and economic reality.²⁵⁵ The program considered the potential effect of energy-efficiency standards on low-income groups, the imperative to make efficient appliances affordable, and the need to attract businesses to supply the technology and services before any regulation was drafted.²⁵⁶

A further consideration is the potential impact of trade, given that many countries rely on imports for many of their appliances and much of their building equipment. Codes and standards should be adopted and harmonized with those of

nearby countries and major trade partners in the interest of preventing "leakage," that is, the importation of appliances from neighboring countries with lower standards. Ghana created the Ghana Energy Foundation, a public-private partnership, to promote energy efficiency in the country. It has been successful in part because of its credibility with the private sector. The Energy Foundation has fostered private-sector capacity through the creation of the Ghana Association of Energy Services Companies and Consultants and by providing technical assistance to individual firms.²⁵⁷

POLICY

The most important complementary policy change to support the energy-efficiency measures we have described may be energy subsidy reform. The IEA has estimated that in 2013, fossil fuel-consumption subsidies amounted to \$548 billion across 40 developing countries and emerging economies, while the International Monetary Fund (IMF) has estimated that pretax energy subsidies (including electricity) totaled \$333 billion in 2015.²⁵⁸

Energy subsidies may target the poor, but they tend to be regressive. The IMF has concluded that, across 20 countries in Africa, Asia, the Middle East, and Latin America, in absolute terms, the top 20 percent of the income distribution receives six times more in subsidies than the bottom 20 percent.²⁵⁹ Cash transfers and other direct transfers that target the poor and are linked directly to consumption tend to be more effective measures for addressing energy poverty. Indonesia introduced cash transfers to complement subsidy reforms in 2005, 2008, and 2009, although the funds did not always reach the poorest households.²⁶⁰ Mexico introduced an energy stipend to the existing antipoverty, conditional cash transfer program, Oportunidades.²⁶¹ Thailand has undergone a gradual subsidy reform process and has used alternative policies, such as free public transportation and free electricity for those who consume small amounts, which cannot be captured by wealthier income groups.²⁶²

Energy subsidies make energy-efficiency measures less competitive by reducing the potential savings and lengthening the payback period. Countries with low energy prices tend to have higher energy consumption per capita: Venezuela has very high fossil fuel subsidies and its petroleum consumption per capita in 2012 was more than three times the regional average in Latin America and the Caribbean.²⁶³ Moreover, there is a statistically significant relationship between a country's fossil fuel subsidies (per unit GDP) and emissions intensity.²⁶⁴ Recent modeling by the Global Subsidies Initiative has concluded that subsidy reform in 20 countries could lead, on average, to GHG

reductions of 11 percent between 2015 and 2020.²⁶⁵

Import policies that inflate the costs of new, efficient appliances need to be reformed. In Ghana, the Energy Foundation successfully advocated for a reduction in import tariffs for energy-efficient products.²⁶⁶

FINANCE

If well enforced, regulations like BEECs and appliance standards can effectively scale up energy efficiency, but they need to be coupled with financing programs to address the additional up-front incremental investment costs that might be borne by end users, especially the under-served. A number of measures have been adopted for financing energy efficiency:

- ▶ Government tax incentives and/or rebates
- ▶ Public finance, including grants, concessional finance, credit or risk guarantees, carbon finance, and special funds (e.g., revolving funds)
- ▶ Demand-side management

Tax rebates and incentives can be used in conjunction with BEECs, energy-efficient appliances, and other energy-efficiency programs that target the under-served. PAYG models could be used to address the up-front costs of appliances. Rio de Janeiro, Brazil, has promoted energy-efficient residential and commercial buildings through the use of the Qualiverde certification. During the construction phase, buildings that get Qualiverde certified (70 percent compliance) receive a 50 percent discount on property tax; for buildings with Total Qualiverde certification (100 percent compliance), property tax is canceled, and service and property sale taxes are reduced as well.²⁶⁷

Public finance, including grants, subsidies, and risk guarantees, can be deployed by local and national governments and by international financial institutions to address market barriers and address up-front costs for energy-efficiency technologies. For example, the Mexico Efficient Lighting and Appliances Project combined a World Bank loan, a Global Environment Facility grant, and climate finance (a concessional loan from the Clean Technology Fund) to fund the replacement of incandescent bulbs and inefficient appliances. A Green Climate Fund project for Latin America involves the use of concessional loans and partial risk guarantees to securitize energy-efficiency projects developed by energy service companies (ESCOs)—companies that identify, package, finance, and implement energy-efficiency projects—into green bonds (see Box 9). Thailand has used

Box 9 | An Innovative Energy-Efficiency Green Bond Program in Latin America

The Green Climate Fund (GCF) approved an innovative energy-efficiency bond project on November 5, 2015, as part of its first approvals.^a In Latin America and elsewhere, local financial institutions have limited experience and expertise in marketing, assessing, and structuring energy-efficiency finance. Consequently, ESCOs lack financing with which to implement projects. The project includes a two-step financing mechanism. During an accumulation phase, senior loans from the Inter-American Development Bank (IDB) and the GCF to special purpose vehicles will serve to finance, standardize, and aggregate projects developed by ESCOs for securitization. The mobilization phase will include partial credit guarantees from the IDB and GCF to support securitized bonds to be issued on local or international capital markets. The GCF is providing up to \$217 million in finance.^b The program will fund small and medium projects (below 30 MW), and the aggregate emissions reductions of the total financing are expected to be around 13.2 million tCO₂e.^c

Notes:

- a. Green Climate Fund, 2015.
- b. Green Climate Fund, 2015.
- c. Green Climate Fund, 2015.

a petroleum tax to finance a revolving fund called the Energy Conservation Promotion Fund that finances energy-efficiency programs in factories and buildings.²⁶⁸ The fund provides capital to Thai banks at no cost, which then provide low-interest loans to ESCOs. The tax raises around \$50 million a year.²⁶⁹

Utility demand-side management (DSM) involves designs to change consumers' consumption patterns. They can include efforts to reduce peak loads or shift consumption to low load periods of the day. In the global South, it is common to have DSM programs within utilities, given their technical and operational capacity.²⁷⁰ The World Bank financed a DSM program called the Efficient Lighting Initiative of Bangladesh, which provided more than 10 million CFLs in its first phase (5 million in a single day), eliminating the need for an estimated 300 MW of installed generation capacity.²⁷¹

Figure 9 describes the roles of different actors in driving improvements in energy-efficient buildings.

Figure 9 | **The roles of different actors in driving improvements in energy-efficient buildings and appliances**

DEVELOPMENT FINANCE INSTITUTIONS

- ▶ Emphasize the importance of buildings in addressing SDG 11—inclusive, safe, resilient, and sustainable cities.
- ▶ Provide technical assistance for the establishment of BEECs and appliance standards.
- ▶ Create dedicated funds that target building energy efficiency in cities, especially for the under-served, including refurbishment of low-income housing and energy-efficient appliance upgrades.
- ▶ Create public awareness campaigns for energy efficiency.
- ▶ Conduct training on BEECs.

NATIONAL GOVERNMENTS

- ▶ Include BEECs and harmonized appliance standards in national climate change mitigation plans and strategies.
- ▶ Support the implementation of stringent national BEECs and harmonized appliance standards.
- ▶ Reduce/eliminate tariffs on efficient imported appliances.
- ▶ Promote policies that encourage energy efficiency (e.g., remove price subsidies and disincentives for utilities to invest in DSM).
- ▶ Institute fossil fuel-subsidy reform (replace existing subsidies with targeted transfers to the poor).
- ▶ Facilitate public financing of building energy-efficiency programs that target the under-served (leveraging private-sector investment).
- ▶ Conduct public awareness campaigns for energy efficiency.
- ▶ Revise public budgetary and procurement rules to encourage energy efficiency.
- ▶ Conduct training on BEECs.

CITY GOVERNMENTS

- ▶ Include BEECs and harmonized appliance standards in city climate change mitigation plans and strategies.
- ▶ Enforce national BEECs and appliance standards.
- ▶ Adopt city codes that are more stringent than national codes and consider climate resilience, especially for social housing and municipal buildings.
- ▶ Lead by example—implement energy-efficiency initiatives in public buildings (e.g., municipal offices, schools, and hospitals).
- ▶ Conduct public awareness campaigns for energy efficiency.
- ▶ Facilitate public financing of building energy-efficiency programs that target the under-served (e.g., leveraging private-sector investment).
- ▶ Monitor and disclose energy usage for municipal buildings.
- ▶ Revise public budgetary and procurement rules to encourage energy efficiency.
- ▶ Conduct training on BEECs.

PRIVATE SECTOR

- ▶ Engage with national and city governments on the establishment of BEECs and appliance standards.
- ▶ Comply with BEECs and appliance standards.
- ▶ Co-finance energy-efficiency projects.

CIVIL SOCIETY ORGANIZATIONS

- ▶ Work with government to set BEECs and appliance S&L. Help ensure that the poor do not disproportionately shoulder the burden of national energy-efficiency targets.
- ▶ Raise local communities' awareness of proposed BEECs and appliance labels and standards.
- ▶ Disseminate research, analysis, and lessons learned on energy efficiency.
- ▶ Conduct training on BEECs.

Source: WRI, partially based on Liu, 2014.

CONCLUSION

Energy access in the global South remains a vexing and overlooked urban problem. In 2012, 131 million people in urban areas around the world lacked access to electricity, and 482 million used solid cooking fuels.²⁷² Many more urban households might have access to a connection, but the quality of service they receive in terms of affordability, reliability, and safety can be very poor. Providing clean, affordable, and reliable energy in urban areas, particularly in regions that are rapidly growing, is indispensable to achieving the Sustainable Development Goals of ensuring modern energy access to all (SDG 7) and creating cities that are inclusive, safe, resilient, and sustainable (SDG 11). While energy is often considered to be outside the purview of cities, our paper shows that energy is a fundamental urban issue and that cities have a large and essential role to play in providing clean, affordable, and reliable energy to all their residents.

The three solutions we recommend in this paper—accelerating the shift to cleaner cooking, scaling up distributed renewable energy within cities, and increasing energy efficiency of buildings and appliances—all require the critical enablers of governance, policy, and finance. These enablers are characterized by government leadership; effective and well-coordinated institutions; well-enforced regulations; consumer engagement and participatory processes; complementary policies (such as fiscal and regulatory policy to support renewable energy, fossil fuel-subsidy reform, and import policy reform); viable business models and engagement by the private sector; and finance models that truly address consumer affordability. While these may seem like Herculean challenges for capacity-constrained cities, there are many examples in the global South of real, tangible progress in urban energy. In Brazil and Indonesia, 100 percent and 93 percent of urban households respectively now use LPG.²⁷³ Cities have begun to scale up rooftop solar PV. China is successfully mainstreaming BEECs, and Ghana has pioneered the use of energy-efficiency standards for appliances in sub-Saharan Africa.

It is likely that affordability will continue to improve. The costs of PV technology have declined in a steep, nonlinear fashion, and the cost of battery storage is projected to decline significantly in the future. The proliferation of new finance models, such as PAYG consumer payment schemes, bode well for distributed solar energy, energy-efficient appliances, and clean cooking. These developments—combined with the use of international public finance to address externalities, such as the climate change and local air pollution costs of energy, through carbon finance and results-based payments—have the potential to make

the economics of clean cooking, distributed solar, and energy efficiency even more favorable.

We have proposed three discrete action areas for addressing the urban energy needs of the under-served and benefiting the city as a whole. However, these action areas are, in part, complementary. For example, making appliances and building structures more energy-efficient will reduce the growth rate in electricity demand, and that demand could, in turn, be partly met through more distributed solar energy.

Ensuring clean, affordable, and reliable energy requires the involvement of all actors in the urban space—municipal leaders, utilities, national and state leaders, international aid organizations, development finance institutions, and CSOs. Municipal leaders can finance programs that target the under-served, conduct awareness raising and outreach with communities, enforce regulations and codes, develop their own energy-efficiency and renewable energy targets, and invest in city-owned renewable energy projects. National and state leaders can provide an enabling environment by developing policies that encourage clean cooking, distributed renewables, and energy efficiency; reforming fossil fuel subsidies; reducing and/or eliminating import tariffs; implementing national building codes and stringent appliance standards; embarking on awareness campaigns and delivering training; and providing public finance, including R&D and programs that target the under-served.

Development finance institutions can make sure that these urban energy solutions are emphasized in the global development agenda and provide expanded finance for clean cooking, distributed renewables, and energy efficiency. Utilities can work with communities to develop and implement innovative distributed renewable energy programs. The private sector has a critical role to play in addressing the up-front cost of technology and developing consumer finance models that target the under-served, investing in distribution systems for technologies, improving product quality, complying with regulations and standards, and awareness raising. CSOs play an important intermediary role between communities, government, and the private sector. They can conduct training and awareness-raising programs and can help with the development of new consumer finance models, project monitoring and evaluation, and dissemination of lessons learned. It is only through the coordinated actions of these actors that both the energy needs of the urban under-served and the long-term environmental and economic interests of the city as a whole will be met.

ENDNOTES

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3. World Bank, 2016b.
4. World Bank, 2016b.
5. Parikh et al., 2012.
6. World Bank, 2016b.
7. World Health Organization, 2014a.
8. World Bank, 2017.
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10. Authors' analysis of the data from Erickson and Tempest, 2014.
11. Authors' analysis of the data from Erickson and Tempest, 2014.
12. Lim et al., 2013.
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14. Sarkar and Singh, 2010; Lucon et al., 2014.
15. Chafe et al., 2014.
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37. World Bank, 2016b.
38. Kennedy et al., 2015; World Bank, 2016b.
39. Karekezi et al., 2008.
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41. Fall et al., 2008.
42. Modern cooking fuels are nonsolid fuels such as electricity, liquid fuels, and gaseous fuels. They include petroleum gas (LPG), natural gas, kerosene (including paraffin), ethanol, and biofuels but exclude traditional biomass (firewood, charcoal, dung, crop residues) and coal (Legros et al., 2009).
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56. World Bank, 2016a.
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66. Jairaj et al., 2016.
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69. World Health Organization, 2014a.
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71. World Bank, 2017.
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73. Authors' analysis of the data from Erickson and Tempest, 2014.

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75. Grübler et al., 2012; IEA, 2016a.
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149. Golumbeanu and Barnes, 2013.
150. Karekezi et al., 2008.
151. Planning Commission of India, 2014.

152. A renewable energy system is at “grid parity” when the cost of the system over its lifetime is equal to or lower than the price of electricity from the grid.
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154. These conditions include accelerated depreciation and the proposed interest rate subvention. The 12 states that have reached grid parity under these conditions for commercial customers are West Bengal, Delhi, Karnataka, Kerala, Maharashtra, Tamil Nadu, Odisha, Andhra Pradesh, Uttar Pradesh, Punjab, Rajasthan, and Telangana. Commercial and industrial electricity tariffs are higher in India than residential tariffs, making “grid parity” more attainable in these segments than in the residential segment (Bridge to India, 2015).
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This is the third working paper in a series of working papers that comprise the World Resources Report *Towards a More Equal City*. It will be followed by other working papers on energy, transportation, water, and urban expansion. To obtain an electronic copy of this paper, and/or other working papers, and to view supporting materials, please visit www.citiesforall.org.

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