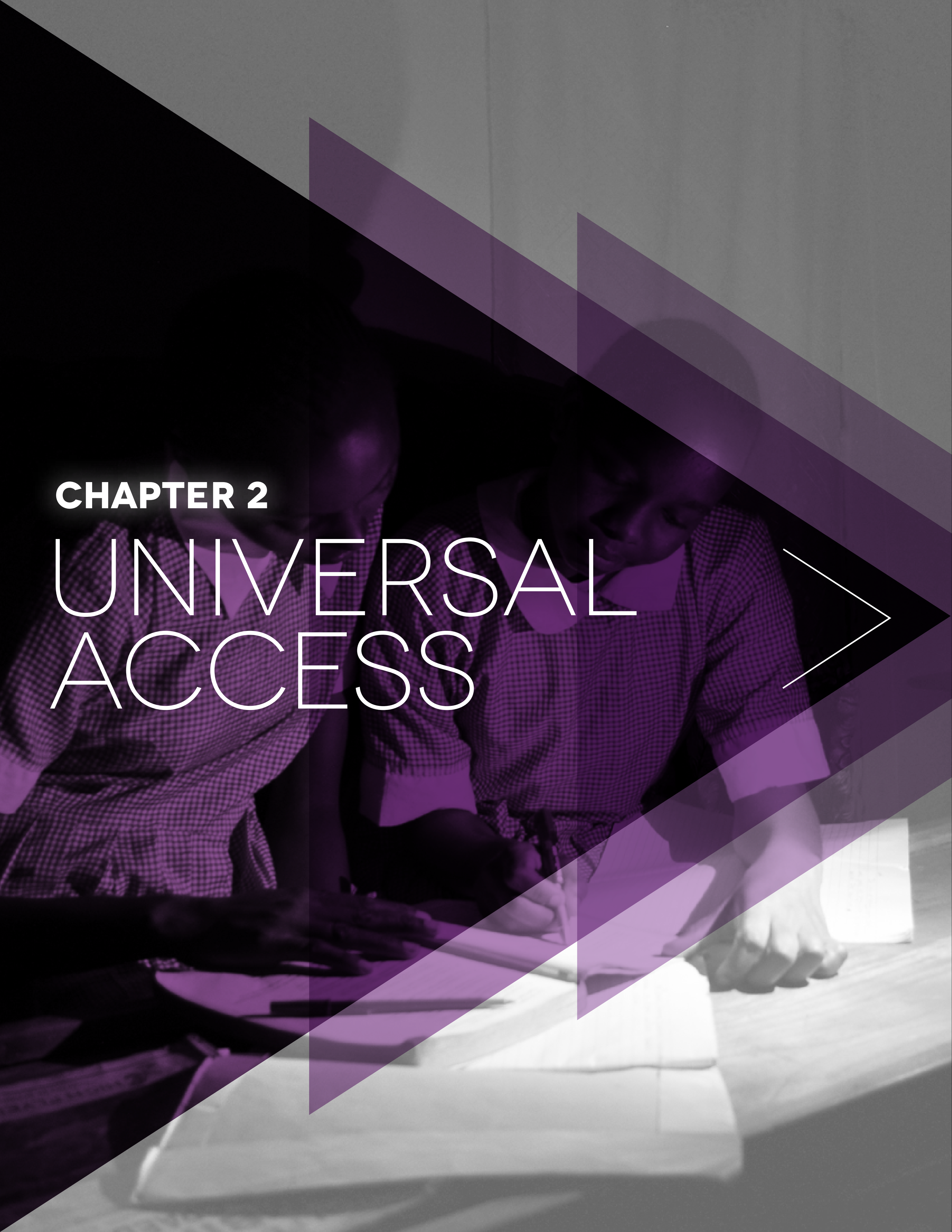
CHAPTER 2

UNIVERSAL ACCESS



CHAPTER 2: UNIVERSAL ACCESS TO MODERN ENERGY SERVICES

One of the three objectives of the Sustainable Energy for All (SE4ALL) initiative is to ensure universal access to modern energy services by 2030. The first section of this chapter examines the methodological challenges of measuring progress toward that goal and suggests approaches to address them. It also explains the methodology used to establish a starting point for the initiative. Succeeding sections describe global trends in access, opportunities to expand it, and the scale of the challenge ahead.

SECTION 1: METHODOLOGICAL CHALLENGES IN MEASURING ACCESS TO ENERGY

There are two initial challenges in measuring access to energy: (i) the absence of a universally accepted definition of "access" and (ii) the difficulty of measuring any definition in a precise manner. Access to electricity is usually equated with the availability of an electricity connection at home or the use of electricity for lighting. Similarly, access to energy for cooking is usually equated with the use of non-solid fuels[1] as the primary energy source for cooking. These binary metrics, however, fail to capture the multifaceted, multi-tier nature of energy access and do not go beyond a household focus to include productive and community applications of energy.

There is a growing consensus that access to energy should be measured not by binary metrics but along a continuum of improvement. Over the past decade, there have been several attempts to develop a more comprehensive measure—using single and multiple indicators, composite indicators, and multi-tier frameworks (annex 1). However, all these approaches have been underpinned by available databases, which are typically derived from household surveys, household connection data obtained from utilities, or residential consumption information at the country level.

Taking advantage of the unique opportunity for international collaboration that SE4ALL presents, the data needed to measure access can be improved over time, making it possible within five years to track access on the basis of multi-tier metrics supported by appropriate refinements in data-collection instruments. The rigorous piloting of questionnaires, technology certification, and consensus building in participating countries can substantially improve future measures of access.

The following subsection begins by identifying the databases currently available for measuring access and the main challenges of defining and measuring it. Proposals for multi-tier metrics of electrification and cooking solutions are laid out, and elements of those proposals are integrated into the proposed global and country-level tracking frameworks.

Compiling global databases to measure access at the starting point

A variety of data sources, including primarily household surveys and utility data, are used to measure access today. The most common indicators are (i) the rate of household connection to electricity, (ii) the proportion of households relying primarily on non-solid fuels for cooking, and (iii) average residential electricity consumption.[2] These indicators are assembled from the following databases.

[1] *Non-solid fuels* include (i) liquid fuels (for example, kerosene, ethanol, or other biofuels), (ii) gaseous fuels (such as natural gas, liquefied petroleum gas [LPG], and biogas), and (iii) electricity. *Solid fuels* include (i) traditional biomass (for example, wood, charcoal, agricultural residues, and dung), (ii) processed biomass (such as pellets, and briquettes); and (iii) other solid fuels (such as coal and lignite).

[2] Some household surveys also track certain electrical appliances (for example, radios, televisions, refrigerators), but data are not sufficient to build a global data base.

The World Bank's Global Electrification Database and the World Health Organization's Global Household Energy Database

To estimate access at the initiative's starting point, set as 2010, the partner agencies used two global databases: the World Bank's Global Electrification Database and the World Health Organization's (WHO's) Global Household Energy Database.[3] Various household data sources were leveraged in compiling these two databases to establish a historical series of data on electrification and primary fuel use between 1990 and 2010. Among the different sources, data from nationally representative household surveys (including national censuses) were given preference wherever possible[4], as these provide the most promising basis for future global tracking (table 2.1). Sources include the United States Agency for International Development's (USAID's) demographic and health surveys (DHS) and living standards measurement surveys (LSMS), the United Nations Children's Fund's (UNICEF's) multi-indicator cluster surveys (MICS), the WHO's World Health Survey, other nationally developed and implemented surveys, and various government agencies (for example, ministries of energy and utilities). While utility data are a valuable complement to household survey data, they provide a different perspective on access and cannot be expected to yield the same results. In particular, utility data may fail to capture (i) highly decentralized forms of electrification in rural areas and (ii) illegal access to electricity in urban areas.[5] Given the importance of these phenomena in the developing world, global tracking will be grounded in a household survey perspective.

The development of the two global databases used in the Global Tracking Framework followed an iterative process. As a first step, data on low- and middle-income countries were compiled from nationally representative household surveys. For electrification, this included 126 countries and encompassed 96 percent of the world's population; for cooking, the coverage was 142 countries and 97 percent of the world's population. Countries classified as developed countries according to the regional aggregation of the United Nations[6] are assumed to have achieved a 100 percent rate of access to electricity and non-solid fuel (that is, they are assumed to have made a complete transition to using primarily non-solid fuels or modern cooking devices with solid fuels) (Rehfuess, Mehta, and Prüss-Üstün 2006).[7]

Household surveys, though a consistent and standardized source of information, also present a number of challenges. Surveys such as the DHS or the LSMS/income-expenditure surveys are typically conducted every 3–4 years, while most censuses are held every 10 years. Thus, a number of countries have gaps in available data in any given year. Further, different surveys may provide different types of data because of differences in questions posed to respondents. For example, the question "Does your household have an electricity connection?" may elicit a different perspective on the household's electrification status than would another question, such as "What is the primary source of lighting?" This is especially the case for people who do not use electrical lighting despite having a connection—owing, for example, to a lack of supply during evening hours or the need to use what little electricity is available for other activities. Similarly, different results are observed when "expenditure on electricity" data are triangulated with "having an electricity connection." Further, most nationally representative surveys on household energy use fail to capture "fuel/cookstove stacking," or the parallel use of various kinds of stoves and fuels. Data collected are typically limited to primary cooking fuel. In some cases, inconsistencies may arise purely from sampling error or from the different sampling methodologies of the underlying surveys.

3 World Health Organization (WHO), http://www.who.int/indoorair/health_impacts/he_database/en/index.html.

4 For cooking solutions, only nationally-representative surveys are included in the WHO Global Household Energy Database and used to derive modeled estimates.

5 The distinction between household survey data and utility data is clearly highlighted in the case of Indonesia. The utility (PLN) reports an electrification rate of 74 percent, while the national statistical agency (BPS) puts forth a figure of 94 percent based on household surveys. http://www.pln.co.id/eng/?p=55 and http://sp2010.bps.go.id/index.php/site/tabel?tid=301&wid=0

6 High-income countries with a gross national income (GNI) of more than $12,276 per capita (World Bank, http://data.worldbank.org/about/country-classifications) and countries in the developed country group according to the UN aggregation (see table at front of this report).

7 The International Energy Agency (IEA) also publishes energy access databases, with broad country coverage (on electricity access and on the traditional use of bio mass for cooking) and collates these in its annual World Energy Outlook (WEO). The World Bank and IEA electricity access databases are consistent for most countries but, in some cases, differences in methodology mean that they rely on differing sources.

NAME	DESCRIPTION	COVERAGE (NO. OF COUNTRIES)	NUMBER OF SURVEYS (1990–2010)	QUESTION: ELECTRICITY	QUESTION: COOKING FUEL
Census	National statistical agencies	214	346	Is the household connected to an electricity supply or does the household have electricity?	What is the main source of cooking fuel in your household?
Demographic and health surveys (DHS)	MACRO International, supported by USAID	90	195	Does your household have electricity?	What type of fuel does your household mainly use for cooking?
Living standards measurement surveys (LSMS) or income expenditure (IE) surveys	National statistical agencies, supported by the World Bank	29 LSMS 116 IE	15 453	Is the house connected to an electricity supply? **or** What is your primary source of lighting?	Which is the main source of energy for cooking?
Multi-indicator cluster surveys (MICS)	UNICEF	65	144	Does your household have electricity?	What type of fuel does your household mainly use for cooking?
World Health Survey	WHO	71	71		What type of fuel does your household mainly use for cooking?

TABLE 2.1 **DESCRIPTION OF HOUSEHOLD SURVEYS**

SOURCE: AUTHORS.

As a second step to develop the historical evolution and starting point of electrification rates, a simple modeling approach was adopted to fill in the missing datapoints – around 1990, around 2000, and around 2010. Therefore, a country can have a continuum of zero to three datapoints. There are 42 countries with zero data point and the weighted regional average was used as an estimate for access to electricity in each of the data periods. 170 countries have between one and three data points and missing data are estimated by using a model with region, country, and time variables. The model keeps the original observation if data is available for any of the time periods. This modeling approach allowed the estimation of access rates for 212 countries over these three time periods.

For the WHO Global Household Energy Database a mixed model[8] was used to obtain a set of annual access rates to non-solid fuel for each country between 1990 and 2010 (see annex 2) (Bonjour and others 2012). This model derived solid fuel use estimates for 193 countries. Generating time-series curves for countries based on available actual data points has several advantages. It can derive point estimates for those countries for which there are no data by using regional trends. It also incorporates all the available data to derive point estimates and is not unduly influenced by large fluctuations in survey estimates from one year to the next.

Comparing the survey data from the latest available year and the modeled estimates suggests that differences are driven by inconsistent intervals between successive household surveys and by the absence of survey data for some countries at the starting point in 2010. Even so, the global and regional access rates from the modeled estimates and data on the latest survey year are remarkably aligned, at 83 percent (table 2.2). Oceania is the only region with a substantial divergence, but that region includes the largest group of countries with the least number of survey data points.

ACCESS RATE (% OF POPULATION)		
CCA	99	100
DEV	100	100
EA	100	98
LAC	95	95
NA	99	99
Oceania	18	25
SA	75	75
SEA	88	88
SSA	32	32
WA	90	91
WORLD	83	83

TABLE 2.2 **COMPARING SURVEY DATA AND MODELED ESTIMATES IN THE GLOBAL ELECTRIFICATION DATABASE**

SOURCE: AUTHORS.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

IEA World Energy Statistics and Balances

The International Energy Agency's (IEA's) World Energy Statistics and Balances database includes time series information on total annual energy consumption in households at the aggregate level.[9] The database draws from a variety of sources—including meter readings made by utility companies and surveys of household energy consumption—and represents 132 countries (but none in Oceania and only 21 in Sub-Saharan Africa), covering 96 percent of the world's population. The global information on residential electricity consumption presented in this chapter is taken from this database. When plotted together, data on the electrification rate and average annual household electricity consumption can suggest a country's electricity access profile. However, as figure 2.1a shows, the correlation between the two variables is minimal. The spread of average consumption levels is extremely wide, not only among countries that achieved universal access but also among countries with lower electrification rates. The most dramatic increase in residential consumption between 2000 and 2010 occurred in Eastern Asia, where it rose by more than twice (figure 2.1b).

9 Statistics on energy consumption in households include those on gas, electricity, and stockable fuel consumption (IEA 2012).

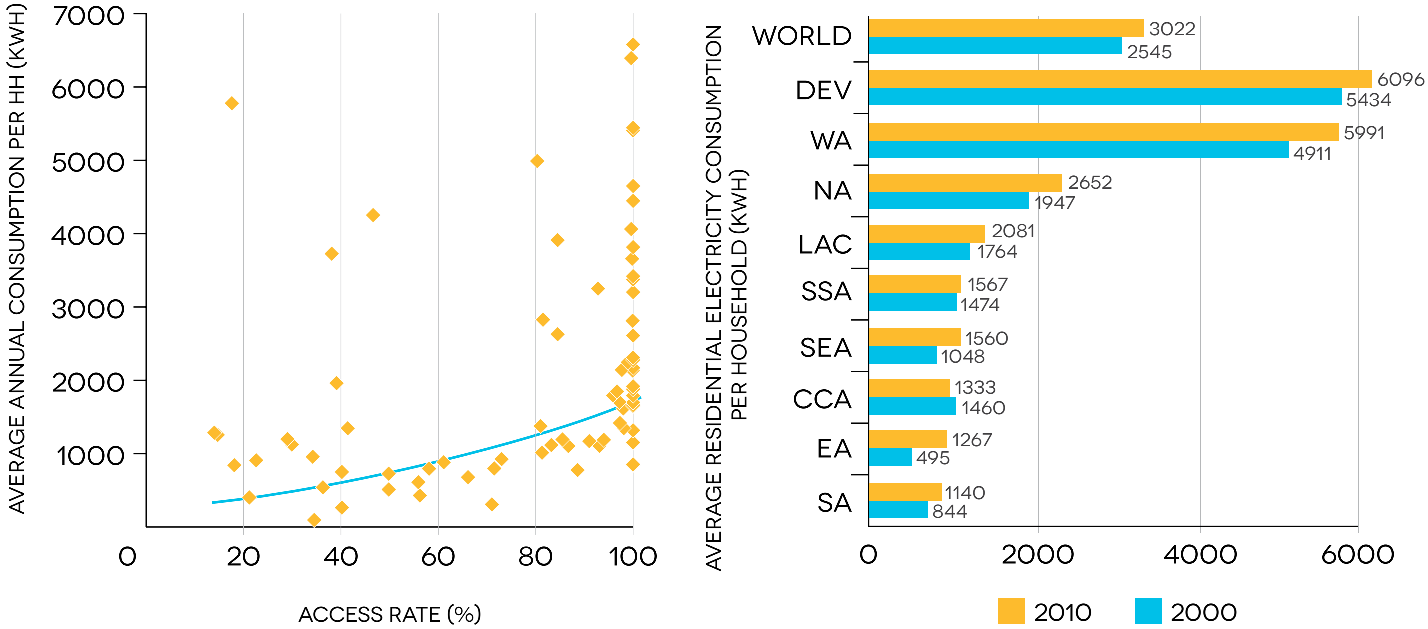


FIGURE 2.1 **AVERAGE ANNUAL HOUSEHOLD ELECTRICITY CONSUMPTION**

SOURCE: BASED ON THE WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE AND IEA (2012).
NOTE: IEA = INTERNATIONAL ENERGY AGENCY.

Challenges to defining and measuring access at the starting point

Access to electricity

The existing definitions and measurements of access to electricity, although convenient, fail to capture several important aspects of the problem.

Multiple access solutions. Off-grid options (for example, solar lanterns or stand-alone home systems) and isolated mini-grids are required in many countries as transitional alternatives to grid-based electricity. In geographically remote areas, these options could potentially serve as long-term solutions as well.[10] Therefore, expansion of access through off-grid and mini-grid solutions needs to be tracked in addition to main grid connections, though it is important to recognize that such solutions may vary in the quantity and quality of electricity they can provide—and the measurement of electricity access should reflect those differences. Using current data and measures, access to electricity cannot be differentiated based on the supply characteristics of the electricity source.

Supply problems. In many developing countries, grid electricity, typically provided by utility companies, suffers from irregular supply, frequent breakdowns, and problems of quality (such as low or fluctuating voltage). Power is often supplied only at odd hours (such as midnight or midday), when the need for electricity is minimal. Low wattage also significantly reduces the usefulness of access under such conditions. Connection costs and electricity charges constrain energy use among households that cannot afford them. Illegal and secondary connections serve a significant proportion of the population in many countries, representing lost revenues for the utility and posing a safety hazard. None of these attributes of the availability, quality, affordability, and legality of supply are reflected in existing data on access.

Electricity supply and electricity services. Finally, electricity is useful only if it allows desired energy services to be run

[10] The International Energy Agency (IEA) has projected that about 60 percent of households not connected to the main grid at present are likely to obtain electricity through such systems by 2030 (IEA 2012).

adequately. Access to electricity supply is therefore different from use of electricity services, which implies the ownership of the appropriate electrical appliance and the actual use of electricity.[11] It is nonetheless important to measure both of these in order to inform policies and project design. Meanwhile, measuring access to electricity services through consumption of kilowatt-hours (kWh) fails to capture several important factors. First, such a measure does not reflect which energy services are actually operated within the household. Second, it tends to emphasize higher consumption, clashing with energy-efficiency goals. Poor households often have no choice other than to operate old and inefficient applications to meet their needs, despite high unit costs. Finally, electricity consumption depends on several external factors, such as household income, household size, household spending priorities, and so on. Therefore, ownership of appliances rather than electricity consumption provides a preferable measure of access to electricity services.

Access to cooking solutions

Current measures of access to modern cooking solutions are confined to fuels and therefore omit the role of the cookstove. Understanding the cooking solutions of households entails knowing not only the fuels but also the type of cookstoves used. It is the combination of the two that will determine levels of efficiency, pollution, and safety outcomes. Meanwhile, individual behaviors, cooking practices, and housing characteristics also affect the actual performance of a household's cooking solutions.

Technical standards and certification systems related to cookstoves. Ongoing development of improved or advanced cookstoves shows that high performance in terms of efficiency, pollution, and safety can be achieved even with solid fuels. This is important, since it is projected that a large part of the developing world will continue to rely on solid fuels (biomass and coal) for cooking despite increasing use of non-solid fuels (IEA 2012). Therefore, advanced biomass cookstoves that offer significant improvements over traditional self-made cookstoves may serve as a transitional alternative to the most modern cooking solutions. Nonetheless, it is not possible to evaluate the technical performance of a cookstove through simple observation. A certification system is therefore needed, whereby cookstoves carry a stamp that indicates their performance level.[12] This presents an additional challenge to reach universal consensus on the technical standards used for certification.

Convenience of cooking solutions. For the poorest households cooking often involves lengthy and exhausting fuel collection, particularly for women.[13] Several studies analyze the impacts of this burden on women's health, income-generating opportunities, and time for other tasks, not to mention leisure and repose (Clancy, Skutsch, and Batchelor 2003). Time and effort invested in cookstove preparation and cleaning, as well as in cooking itself, are also important dimensions to consider. It is therefore important to measure the "convenience factor" along with the technical performance of a cooking solution to obtain a comprehensive measure of access.

The variability of performance outcomes. The performance of cooking solutions, as evaluated under standard testing conditions, may not be achieved in practice owing to individual behavior, cooking practices, and site conditions. Maintenance requirements may have been disregarded and accessories such as chimneys, hoods, or pot skirts not used, deteriorating the performance of the cookstove.

Fuel stacking. Any measure of access solely based on the primary cooking solution will fail to capture the complex phenomenon of fuel stacking, which refers to the parallel use of multiple fuels and cookstoves (box 2.1). The transition to more modern energy solutions in the home is a dynamic process, and many factors contribute to the choice of fuels and cookstoves.[14] Even households that have adopted a modern fuel or an advanced cookstove may continue to use—in parallel—secondary and tertiary fuels and cookstoves on a regular basis. The underlying causes of this practice need to be identified to inform policy and project design.

[11] Measurement of access to electricity supply reflects the performance of utilities, markets, and policies in ensuring that electricity supply is fully usable, while measurement of access to electricity services reflects the combination of electricity supply and consumer behavior. Greater use of modern energy affects socioeconomic development.

[12] A stamp or label could indicate the stove's performance as measured during laboratory tests and field-tests where available.

[13] Gender roles and inequalities impose differential burdens on family members with regard to cooking energy systems. Women and children bear the main negative impacts of fuel collection and transport, indoor air pollution, and time-consuming and unsafe cooking technologies.

[14] Modern cooking solutions include those that involve electricity or liquid/gaseous fuels (including liquefied petroleum gas), or the use of solid/liquid fuels paired with stoves that have overall emissions rates at or near those of LPG.

BOX 2.1 Capturing home energy needs: Fuel stacking and multiple end uses

Regular use of multiple fuels and cookstoves, also called "fuel stacking," is a common practice throughout the developing world. Households in both urban and rural areas routinely use two or more fuels for cooking alone. Different studies in Latin America find that even households that have switched to liquefied petroleum gas (LPG) as a primary cooking fuel still rely on simpler, less-efficient cookstoves or open fires to prepare some types of foods (for example, tortillas—a daily staple), or to meet their space or water heating needs (Masera, Díaz, and Berrueta 2005; Davis 1998). Similar patterns of multiple fuel use have been documented in Vietnam, Brazil, Nepal, Ghana, India, and South Africa (Heltberg 2004). Fuel and cookstove stacking have been attributed to a combination of factors, including household income, multiple end uses (cooking, re-heating, boiling, etc.), cooking practices (types of food prepared, cooking time, taste, etc.), fuel availability and fuel consumption, as well as available infrastructure (access to electricity and gas pipelines) (Heltberg 2005; Davis 1998; Link, Axinn, and Ghimire 2012).

Access to heating

Heating is a major energy requirement in many countries, and its measurement presents several challenges. Heating needs can be met through a range of solutions: heat from a cookstove, fuel-based heating devices, a district heating system provided by a public utility based on combined generation of heat and power, or electric heating. Heating needs depend not only on the geographical location and weather patterns of a country, but also on the housing situation (poor insulation can substantially increase heating needs). As yet, there are no available data on energy for heating that would allow the compilation of a global database. In the medium term, SE4ALL envisions development of a framework to adequately measure access to heating.

Community and productive uses of energy

A household-based definition of access to energy excludes access to energy for community services and productive uses.[15]

Energy is crucial for enterprises. It drives economic and social development by increasing productivity, incomes, and employment[16]; reducing workloads and freeing up time for other activities; and facilitating the availability of higher-quality or lower-priced products through local production. In addition, providing energy to businesses secures the higher economic sustainability of electrification projects, as productive activities often translate into higher energy demand density and more reliable capacity to pay (EUEI 2011).

Energy for community services (e.g., health and education) is fundamental for socioeconomic development, because it can lead to the substantial improvement of human capital. Healthier, more-educated people with access to basic community infrastructure (such as clean water, street lighting, and so on) have better chances of escaping the poverty trap (Cabraal, Barnes, and Agarwal 2005). Models that deliver energy and energy services to poor households in a financially sustainable manner by leveraging productive and community energy users as anchor loads have been demonstrated across many countries—albeit still on a small scale.

Data paucity is again a major constraint in measuring access to energy for community services and productive uses. Only recently, the IEA attempted to measure access to energy for public services and productive uses (IEA 2012). Similarly, the nongovernmental organization (NGO) Practical Action has identified households, community institutions, and productive enterprises as three dimensions of energy access (PPEO 2012; 2013). In the health sector, a recent joint WHO and USAID collaboration to harmonize indicators for health-facility assessments resulted in a

15 Productive uses of energy are defined as those that increase income or productivity and refer to the activities that add value, which could be taxable if part of the formal economy (EUEI 2011).

16 It is understood that energy access is a necessary but rarely sufficient condition for driving economic growth. Access to finance, markets, raw materials, technology, and a qualified workforce are also determinant factors.

comprehensive and cross-cutting facility-assessment tool called the Service Availability and Readiness Assessment (SARA), which includes an energy component. Created to fill critical gaps in measuring and tracking progress in the strengthening of health systems based on minimum service standards, SARA provides a consistent methodology for annual country-led monitoring of health service delivery in the country, including energy access (that is, the availability, source, and reliability of electricity). Currently, additional efforts by the WHO are under way to develop an energy module for health-care facilities that can be used as a stand-alone assessment tool or in conjunction with SARA. In the education sector, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has been tracking access to electricity, teaching aids, and computers in schools as a part of its survey of school infrastructure quality. These available data, based on connection rates, indicate that many schools and health clinics are not electrified (figure 2.2).

Relying on such efforts and methodologies, the SE4ALL initiative will begin to develop comprehensive frameworks for measuring energy access across community services and productive uses. Those frameworks will be implemented over the medium term.

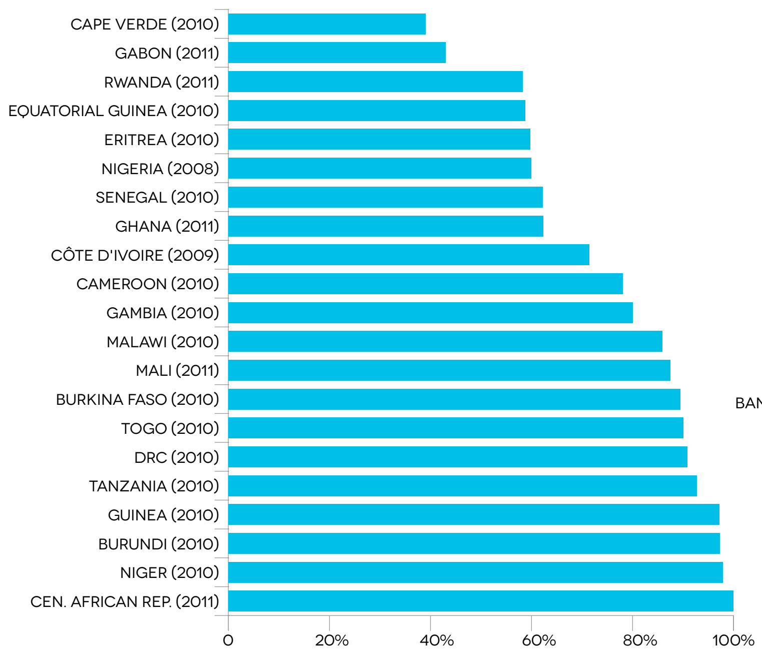


FIGURE 2.2A **PUBLIC PRIMARY SCHOOLS WITHOUT ELECTRICITY**

SOURCE: : UNESCO INSTITUTE OF STATISTICS (UIS) DATABASE.

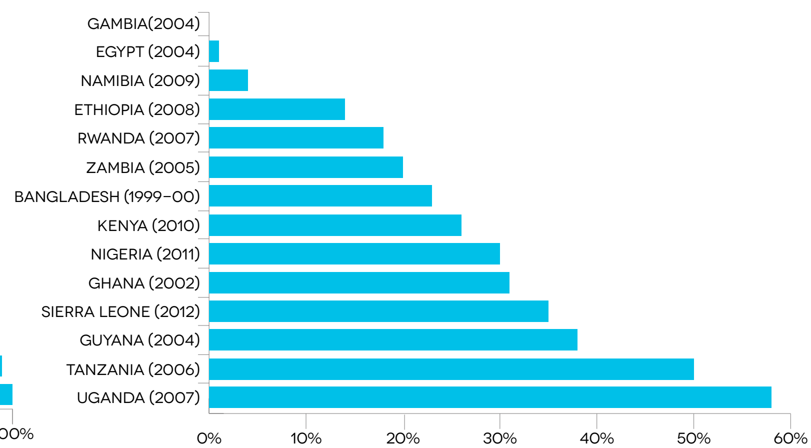


FIGURE 2.2B **HEALTH CLINICS WITHOUT ELECTRICITY**

SOURCE: : SOURCE: WHO ENERGY IN HEALTH CARE FACILITIES DATABASE

A candidate proposal for tracking access

The multi-tier metric described below may be considered as a candidate proposal to address the challenges in current definition and measurement techniques, drawing on numerous recent efforts. The metric is flexible and allows for country-specific targets to be set. Because the challenge of energy access varies across and within countries, setting minimum standards of energy access without due regard to the stage of evolution of energy systems would understate the challenges faced around the world. A bar set too high (for example, universal access to uninterrupted grid-based electricity or to gaseous fuels for cooking by 2030) would be unachievable for many countries. A bar set too low (for example, universal access to lighting) risks making the SE4ALL initiative less relevant for countries with high rates of grid electrification but suffering from poor supply. A multi-tier approach would embrace the appropriate interventions to adequately track progress toward universal energy access across countries.

Access to electricity

The candidate proposal consists of a multi-tier measurement encompassing the following considerations (figure 2.3).

Electricity supply and electricity services. The multi-tier proposal consists of two distinct yet intertwined electricity measurements that can be compiled into two indices. On the one hand, it measures access to electricity supply[17] using multiple tiers, defined by increasing levels of supply attributes, including quantity (peak available capacity), duration, evening supply, affordability, legality, and quality, whereby more and more electricity services become feasible (annex 3). Different energy services (such as lighting, television, air circulation, refrigeration, ironing, and food processing) require different levels of electricity supply in terms of quantity, time of day, supply duration, quality, and affordability.[18] On the other hand, it measures use of electricity services using multiple tiers, based on ownership of appliances categorized by tier, each corresponding to the equivalent tier of electricity supply needed for their adequate operation. For instance, in tier 1, access to basic applications such as task lighting, radio, and phone charging is possible. From tier 2 onwards, access becomes increasingly advanced, allowing a higher number of electricity applications to be used.

Diversity of supply options. The structure of this proposal is technology-neutral and encompasses off-grid, mini-grid, and grid solutions, while reflecting the large spectrum of electricity access levels. Each technology is evaluated based on its capacity to provide for a certain tier of electricity supply, which subsequently affects the provision of energy services.

Incidence and intensity of access. The proposed approach evaluates both the extent of access (how many households have access) and the intensity of that access (the level of access that households have). This structure allows for an aggregated analysis of access to electricity supply as well as use of electricity services using two separate indices that can be calculated for any geographical area.[19] It is possible that the same household would not reach the same tier across the two measurements. Indeed, a higher level of electricity supply does not automatically result in additional electricity services. Electricity services typically lag behind improvements in supply, as consumers gradually acquire electrical appliances. Increased use of electricity is also constrained by limited household income and telescopic electricity tariffs.[20] Some households may also benefit from higher tiers of electricity services despite having poor electricity supply because they can afford stand-alone solutions (for example, diesel generators and inverters) as backups. Thus, gaps between access to electricity supply and access to electricity services are to be expected, revealing important information on the types of interventions needed to improve access.

Data collected in the course of calculating the two indices can also be used to conduct a disaggregated analysis of the incidence of various aspects of supply constraint,[21] by type of supply technology or by level of access to electricity services.

[17] Access to electricity supply can be achieved through a combination of central grid, mini-grid, and stand-alone solutions.

[18] For example, a grid-based electricity connection where supply is not available during the evening hours is not suitable even for basic lighting.

[19] A village, a district, a province, a country, a continent, or the whole world.

[20] The unit price of electricity increases at higher consumption levels.

[21] Share of households receiving less than four hours of electricity per day, share of households facing affordability issues or poor quality of supply, and so on.

ACCESS TO ELECTRICITY SUPPLY

ATTRIBUTES	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Peak available capacity (W)	-	>1	>500	>200	>2,000	>2,000
Duration (hours)	-	≥4	≥4	≥8	≥16	≥22
Evening supply (hrs)	-	≥2	≥2	≥2	≥4	≥4
Affordability	-	-	√	√	√	√
Legality	-	-	-	√	√	√
Quality (voltage)	-	-	-	√	√	√

- Five-tier framework.
- Based on six attributes of electricity supply.
- As electricity supply improves, an increasing number of electricity services become possible.

Index of access to electricity supply $= \sum(P_T \times T)$

with P_T = Proportion of households at tier T

T = tier number {0,1,2,3,4,5}

USE OF ELECTRICITY SERVICES

TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
–	Task lighting AND phone charging (OR radio)	General lighting AND television AND fan (if needed)	Tier 2 AND any low-power appliances	Tier 3 AND any medium-power appliances	Tier 4 AND any high-power appliances

- Five-tier framework.
- Based on of appliances.

Index of access to electricity supply $= \sum(P_T \times T)$

with P_T = Proportion of households at tier T

T = tier number {0,1,2,3,4,5}

FIGURE 2.3 **CANDIDATE FRAMEWORK FOR MULTI–TIER MEASUREMENT OF HOUSEHOLD ELECTRICITY ACCESS**

SOURCE: AUTHORS

Cooking

The candidate proposal measures access to cooking by evaluating, on the one hand, the technical performance of the primary[22] cooking solution (including the fuel and the cookstove), and, on the other hand, assessing how those solutions meet the needs of households. The combination of the two metrics offers a comprehensive measurement of access to cooking. Similar to electricity, the methodology is based on multiple tiers and is fuel-neutral (figure 2.4).

[22] The primary cookstove is defined as the one that is the most used for cooking meals.

STEP 1: TECHNICAL PERFORMANCE

- Multi-tier technical measurement of the primary cooking solution in two steps:
  1. Three-level measurement based on the direct observation of the cookstove and fuel.
  2. Manufactured non-BLEN cookstoves (medium grade) are further categorized into four grades based on technical attributes. This grade categorization would only be possible for cookstoves that have undergone third-party testing. Non-BLEN manufactured cookstoves that have not been tested are assumed to be Grade D.

LOW GRADE	MEDIUM GRADE	HIGH GRADE
Self-made[1] cookstove	Manufactured[2] non-BLEN cookstove	BLEN[3] cookstove

	LOW GRADE	MEDIUM GRADE			HIGH GRADE
Attributes	Grade-E	Grade-D	Grade-C	Grade-B	Grade-A
Efficiency			Certified Non-BLEN manufactured Cookstoves		
Indoor pollution					
Overall pollution	Self-made cookstoves or equivalent	Uncertified Non-BLEN manufactured cookstoves			BLEN cookstoves or equivalentt
Safety					

1 A self-made cookstove refers to a three-stone fire or equivalent, typically made by an untrained person without the use of premanufactured parts.

2 A manufactured cookstove refers to any cookstove available in the market (including cookstoves from artisans and small local producers trained under a cookstove program)

3 BLEN cookstove refers to stove-independent fuels (such as biogas, LPG, electricity, natural gas). BLEN equivalence of more fuels (such as ethanol) would be examined going forward. Non-BLEN cookstoves include most solid and liquid fuels for which performance is stove dependent.

STEP 2: ACTUAL USE

- Measurement of additional aspects of access beyond technical performance.
- Three types of attributes, as listed below:

Conformity	• Chimney/hood/pot skirt used (as required). • Stove regularly cleaned and maintained (as required).
Convenience	• Household spends less than 12 hrs/week on fuel collection/preparation. • Household spends less than 15 min/meal for stove preparation. • Ease of cooking is satisfactory.
Adequacy	• Primary stove fulfills most cooking needs of the household, and it is not constrained by availability or affordability of fuel, cultural fit, or number of burners. • If multiple cooking solutions are used (stacking), other stoves are not of a lower technical grade.

- Multi-tier measurement is based on technical performance adjusted for the above attributes.

LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
				Grade-A w/o CCA	Grade-A w/ CCA
			Grade-B w/o CCA	Grade-B w/ CCA	
		Grade-C w/o CCA	Grade-C w/ CCA		
	Grade-D w/o CCA	Grade-D w/ CCA			
Grade-E w/o CCA	Grade-E w/ CCA				

FIGURE 2.4 **CANDIDATE FRAMEWORK FOR MULTI–TIER MEASUREMENT OF HOUSEHOLD COOKING SOLUTIONS***

SOURCE: AUTHORS.

$$\text{Index of access to electricity supply} = \sum(P_T \times T)$$

with P_T = Proportion of households at tier T

T = tier number {0,1,2,3,4,5}

SOURCE: WORLD BANK /ESMAP.

NOTE: BLEN = BIOGAS–LPG–ELECTRICITY–NATURAL GAS; CCA = CONFORMITY, CONVENIENCE, AND ADEQUACY.

* The proposed multi-tier framework (above) is complementary to the multi-tiered technical standards for cookstove performance proposed by the Alliance led International Workshop Agreement (IWA). The IWA multi-tier standards provide the basis for measurement of cookstove performance on the four technical attributes—efficiency, indoor pollution, overall pollution, and safety (annex 4). Laboratory measurements based on the IWA standards would be used by the multi-tier framework (above) to determine the overall technical performance of the primary cookstove in step-1. The objective of the multi-tier framework (above) is to measure the level of household access to cooking solutions. It builds upon the technical performance of each of the multiple cooking solutions being used in the household (including the use of non-solid fuels), while also taking into account CCA attributes.

The technical performance of the primary cooking solution is evaluated in two steps. First, the cooking solution is categorized as low, medium, or high grade, based on direct observation of stove and fuel type, and on whether it is (i) a self-made cookstove,[23] (ii) a biogas-LPG-electricity–natural gas (BLEN) cookstove,[24] or (iii) a manufactured non-BLEN cookstove (including kerosene cookstoves—see box 2.2).[25] A self-made cookstove is assigned a Grade E, while the BLEN cookstove is assigned a Grade A. Second, the manufactured non-BLEN cookstove is assessed based on whether it has been tested or not. If it is not tested, its performance is unknown and it is assigned a Grade D. If results are available from third-party testing that meet the requirements of the International Standards Organization's (ISO's) International Workshop Agreement (IWA),[26] the technical grades can be refined further.

Non-BLEN manufactured cookstoves are differentiated across Grades A, B, C, D, and E based on their performance across four technical attributes that correspond to the four performance indicators in the IWA: (i) fuel efficiency, (ii) overall emissions, (iii) indoor emissions, and (iv) safety. The IWA tiers of performance have been directly mapped to Grades A to E for this measurement system. The cookstove performance on these attributes may be measured using the IWA developed by the Global Alliance for Clean Cookstoves (hereafter, the Alliance)[27] (annex 4).

Results from the third-party testing of cookstoves should be reported publicly through the Stove Performance Inventory, which is maintained by the Alliance. Certified cookstoves may also carry an easily identifiable stamp or label (or brand name) that provides easy indication of their technical performance based on laboratory testing, through a certification system developed at the country level. A network of designated certification agencies and laboratories could be established for this purpose, possibly assisted by the Alliance and WHO.[28]

It is acknowledged that the evaluation of tested or certified cookstoves adds complexity to the framework. Yet it is desirable to base the evaluation of technical performance on empirical data and capture the efforts of the Alliance, testing centers, donors, and manufacturers in promoting advanced cookstoves. The five-grade technical measurement is therefore essential for capturing the wide spectrum of manufactured cookstoves, and for incentivizing testing and certification.[29]

[23] Including open fires and all types of self-made cooking arrangements.

[24] BLEN fuels are stove independent, that is, their technical performance does not depend on the type of stove used.

[25] Including locally made or imported traditional stoves, clay stoves, improved stoves, advanced stoves, or any type of stove on the market. It is assumed for practical reasons that manufactured cookstoves perform better than self-made cookstoves, although this may not always be true.

[26] The standards have been developed in collaboration with the WHO and International Standards Organization (ISO), and the latest version was agreed on at the International Workshop Agreement (IWA) meeting in February 2012. Protocols are under development for additional types of cookstoves (for example, plancha and charcoal) and multiple end-use stoves and will be incorporated into the IWA framework.

[27] The Global Alliance is a public-private partnership aiming to achieve universal access to modern cooking by promoting a global market for clean and efficient household cooking solutions.

[28] The Global Alliance has started the process of establishing regional testing sites and aims to encompass a wide range of cookstoves and fuels.

[29] A manufactured cookstove without certification is automatically categorized into the lowest level of manufactured stoves (Grade D), since its performance is unknown.

Beyond the technical performance of the cooking solution, the framework attempts to evaluate its impact on the daily lives of users. First, it determines whether the household uses the cooking solution in conformity with instructions (that is, a chimney, hood, or pot skirt is used if required and regular cleaning and maintenance are performed). It also evaluates convenience, by considering how long it takes the household to collect the fuel and how long it takes to prepare the cookstove. Finally, it examines the issue of fuel stacking by considering whether the household regularly uses a secondary cooking solution and for what reason (for example, the primary fuel is too expensive or is not always available; or the solution does not satisfy cultural preferences or does not have the desired number of burners). If the use of the primary cooking solution is constrained by such factors, it is inadequate.

Conformity, convenience, and adequacy (CCA) are the three attributes considered, in addition to technical performance, to obtain an integral measurement of access to a modern cooking solution. The methodology proposes to adjust the technical grade of a cooking solution to account for these attributes to obtain the household tier (level) of access. If all three attributes are satisfied, the technical grade is raised to a higher tier (level). If the household's solution does not comply with all three attributes, the technical grade remains unchanged at the lower tier (level).

BOX 2.2 Kerosene use in the home for cooking, heating, and lighting

Kerosene makes a significant contribution to the basket of fuels that households use to meet their energy needs. In several Sub-Saharan countries, national surveys show that more than 80 percent of households rely on kerosene as their primary energy source for lighting. Similarly in some Middle Eastern and Sub-Saharan countries, national surveys indicate that more than 25 percent of households rely mainly on kerosene to meet their space-heating needs.

The results of national surveys from 122 low- and middle-income countries show that, on average, approximately 4 percent of households use kerosene as their primary cooking fuel. These households are concentrated in two regions, Sub-Saharan Africa and South Asia, with some countries exhibiting much higher levels of reliance on kerosene for cooking—such as Nigeria and Eritrea at about 20 percent, and Maldives and Indonesia closer to 40 percent of households.

Kerosene: A risk for health

In the past, kerosene stoves and lamps were considered a cleaner-burning alternative to traditional solid fuel for cooking, heating and lighting. But recent scientific studies have shown that, depending on the design of the device (cookstove, lamp), household use of kerosene can emit troubling amounts of health-damaging pollutants (particulate matter, carbon monoxide, and formaldehyde) that have been shown to impair lung function, increase infectious illnesses (for example, tuberculosis), and cancer risk (Lam and others 2012). Kerosene use also poses a number of health and safety risks in and around the home, including poisoning and burns (Mills 2012).

Accordingly, use of kerosene lamps for lighting is classified as tier 0 in the multi-tier framework for access to electricity supply. For the purpose of tracking access to modern cooking solutions, kerosene is classified as a non-BLEN fuel (see figure 2.4). Because emissions from kerosene-based cooking depend on the design of the cookstove (whether wick-type or pressurized-type), technical performance can vary substantially.

SOURCE: WHO GLOBAL HOUSEHOLD ENERGY DATABASE.

Global and country tracking of access

SE4ALL's goal of universal access to modern energy services by 2030 will be achieved only if every person has access to modern cooking and heating solutions, as well as productive uses and community services (SE4ALL 2012). This report proposes tracking arrangements for access to electricity and modern cooking solutions. It is expected that similar frameworks for heating, productive uses, and community services will be developed and implemented over the medium term.

Given that access to modern energy is a continuum of improvement and will be measured using the proposed multi-tier methodology, countries are encouraged to set their own targets (choosing any tier above tier 0). Such targets will depend on the current access situation in the country, the evolution of the energy needs of users, the availability of energy supply for income-generating activities, and the affordability of different energy solutions in the country. For example, countries in which most people are without electricity in any meaningful form might set a target of achieving universal access to electric lighting. Other countries may choose to set the target of universal grid connectivity. Countries that have recently achieved near-universal electricity connections but face problems of adequacy, quality, and reliability of supply may choose to set a target that emphasizes improved supply. Similarly, for household cooking solutions, countries with very low penetration of modern fuels or electricity may choose to set a target of certified advanced biomass cookstoves. Other countries may aim to achieve universal access to BLEN fuels. Countries have the flexibility of choosing whether they will improve access tier by tier or jump across tiers. Large countries may set different targets for different provinces or subregions.

To address limitations in data availability, a phased (immediate versus medium term) and differentiated (global versus country-level) approach is proposed (table 2.3).

	IMMEDIATE	MEDIUM TERM
Global tracking	Binary measurement of access to electricity and cooking solutions.	• Modification of global omnibus surveys to obtain information for simplified three-tier measurement. • Simplified three-tier measurement of access to electricity and cooking solutions. • Piloting and possible regular implementation of customized energy surveys to obtain five-tier access information globally.
Country-level tracking		• Piloting of multi-tier framework for electricity and cooking solutions in select countries. • Development and piloting of approaches to track access to energy for heating, community, and productive uses. • Regular multi-tier measurement of access to electricity and cooking solutions through

TABLE 2.3 **IMMEDIATE AND MEDIUM-TERM TRACKING ACROSS GLOBAL AND COUNTRY LEVELS**

SOURCE: AUTHORS.

Tracking access to energy in the immediate term

In the immediate term, the nature of existing databases constrains measurement possibilities. The World Bank's Global Electrification Database and the WHO's Global Household Energy Database will continue to support the tracking process. For estimating the starting point of electricity access and tracking in the immediate future, household connection to electricity constitutes the threshold, regardless of the type of supply or services. Similarly, for cooking, the use of non-solid fuel as the primary cooking fuel is deemed to constitute access. In the absence of data on cookstove type, the primary use of solid fuels is treated as lack of access. Apart from the World Bank and WHO databases, the IEA's energy access databases are a valuable additional source of information to support the tracking process.

Tracking access to energy in the medium term

The adoption of a multi-tier metric, either in its entirety or in part, would require enhancements to existing data-collection instruments, moving away from a binary definition and measurement of access.

Household surveys remain the instruments best suited to obtaining the data required, but additional energy-focused questions should be designed. For electricity, surveys could facilitate the reporting of households served by off-grid technologies (for example, solar lanterns or stand-alone home systems), as well as households connected to decentralized mini-grids. Such technologies are most likely to reach underserved peri-urban and rural populations—where substantial progress is likely to be made in coming decades. Household surveys are also able to capture the level of electricity supply (in terms of duration, quality, affordability, and so on) availed by end-users and to identify the electricity applications used within the household. On the cooking side, in the absence of any centralized utility, household surveys are the only sources of data available to comprehensively capture all the fuels and types of cookstoves used by households and to assess questions of convenience and fuel stacking.

Country-level tracking. Countries that opt into a program to expand access to energy under the SE4ALL initiative will likely be able to implement a more elaborate system of monitoring access. A multi-tiered, comprehensive measurement of access, as in the candidate proposal, is possible only if a country's government has developed the requisite methodologies, extensively revised household surveys, established testing laboratories, and carried out detailed consultations with the parties involved. Such efforts need to ensure that high-quality data are consistently generated.

Global tracking. It is acknowledged that a major effort to improve data is a long and intensive process and that not all countries will be able to collect all the new data required. A simplified three-level measurement system that condenses the six tiers of the multi-tier candidate proposal would require only marginal improvement in data collection (figure 2.5). The few additional questions needed to capture this information could be added to the household survey instruments of the various international survey networks (such as DHS, LSMS, and MICs).

TRACKING ACCESS TO ELECTRICITY	GLOBAL TRACKING	NO ACCESS	NO ACCESS	ADVANCED ACCESS			
		NO ELECTRICITY	SOLAR LANTERN OR RECHARGEABLE BATTERY LANTERN	HOME SYSTEM OR GRID CONNECTION			
	COUNTRY-LEVEL TRACKING	TIER-0	TIER-1	TIER-2	TIER-3	TIER-4	TIER-5
TRACKING ACCESS TO COOKING	GLOBAL TRACKING	NO ACCESS	BASIC ACCESS			ADVANCED ACCESS	
		SELF-MADE COOKSTOVE	MANUFACTURED NON-BLEN COOKSTOVE			BLEN COOKSTOVE	
	COUNTRY-LEVEL TRACKING	TIER-0	TIER-1	TIER-2	TIER-3	TIER-4	TIER-5

FIGURE 2.5 **TRACKING ACCESS IN THE MEDIUM TERM**

SOURCE: AUTHORS.
NOTE: BLEN = BIOGAS-LPG-ELECTRICITY-NATURAL GAS.

For electricity, access is graded as "no access," "basic access," and "advanced access." No access is aligned with tier 0 of the multi-tier measurement, reflecting a complete lack of electricity. Basic access, aligned with tier 1, corresponds to the level of supply and the level of electricity services that a solar lantern can provide. Advanced access corresponds to tiers 2 and above, which are likely obtained by off-grid and grid solutions. Using this simplified measurement system, advances under programs such as Lighting Africa and Lighting Asia would be counted as basic access. Stand-alone off-grid and mini-grid solutions would be counted as advanced access. To facilitate the data-collection process, this simplified version is technology-based. It does not capture the nuances of advanced access or the different attributes of electricity supply.

For cooking, access is graded as for electricity. No access is aligned with tier 0 of the multi-tier measurement, and corresponds mainly to self-made cookstoves. Basic access, aligned with tiers 1–3, reflects the use of manufactured non-BLEN cookstoves. Advanced access, aligned with tiers 4 and 5, corresponds to BLEN cookstoves or the equivalent. Under this simplified measurement system, the use of manufactured non-BLEN cookstoves is captured as basic access, while the use of BLEN fuels would be considered advanced access. To facilitate the data-collection process, this measurement system is based on the simple observation of fuels and cookstoves. It does not capture the technical grade of the cooking solution or additional details about the convenience or adequacy of the cooking solution.

Such a simplified three-level measurement system follows the same methodology of weighted aggregation as the full multi-tier system. It is therefore possible to construct an index to capture both the incidence of access (how many households have access) and its intensity (the level of access the households have—basic or advanced).

To sum up this section, binary metrics that rely on available data have been used to set the starting point for the SE4ALL initiative and will continue to be used for global and country-level tracking in the immediate future. Meanwhile, multi-tier approaches that address many of the shortcomings of the binary metric will be refined and piloted in select participating countries in order to validate them for wider application. The feasibility of rolling out global customized energy surveys will also be explored. Methodologies for measuring access to energy for productive and commercial uses, as well as for heating applications, will also be developed. For country tracking in the medium term, the refined version of the multi-tier metric for electricity and modern cooking solutions will be implemented across all participating countries. Selected implementation of measurements of heating, productive, and community uses will also be carried out over this period. For global tracking in the medium term, a simplified version of the multi-tier metric comprising two thresholds will be adopted. Nationally representative household surveys will need to be modified to capture the necessary household information for an effective implementation of this tiered metric (table 2.4).

CHALLENGE	PROPOSED APPROACH TO GLOBAL TRACKING	PROPOSED APPROACH TO COUNTRY TRACKING
Off-grid, mini-grid, and grid solutions	Two-threshold measurement to reflect access to electricity for lighting and for more advanced applications on a technology-neutral basis.	Technology-neutral multi-tier measurement based on attributes of supply and covering grid and off-grid solutions.
Quality of supply	Not reflected. Quality of supply cannot be measured without detailed household surveys or reliable utility data.	Quality of supply aspects are reflected through detailed household surveys using the multi-tier framework.
Access to electricity supply versus electricity services	Electricity supply and services overlap across the two-threshold measurement.	Both electricity services and electricity supply are measured through separate multi-tier frameworks.
Productive and community uses	New methodologies to be developed.	New methodologies to be developed.
Heating	New methodologies to be developed.	New methodologies to be developed.
Improved solid fuel cookstoves	Two-threshold measurement to reflect the use of manufactured non-BLEN cookstoves and BLEN cookstoves (based on direct observation).	Technology-neutral multi-tier framework reflects the wide range of technical performance of non-BLEN cookstoves, along with the associated CCA attributes.
Stacking of stoves and fuels	Only the primary cooking solution is reflected.	Multi-tier framework reflects fuel stacking through the adequacy attribute.
Convenience and conformity	Not reflected. BLEN cookstoves may be assumed to be convenient and conforming.	Multi-tier framework reflects all actual use attributes.

TABLE 2.4 **ADDRESSING METHODOLOGICAL CHALLENGES THROUGH THE MEDIUM TERM**

SOURCE: AUTHORS.
NOTE: BLEN = BIOGAS–LPG–ELECTRICITY–NATURAL GAS; CCA = CONFORMITY, CONVENIENCE, AND ADEQUACY.

SECTION 2. ACCESS TO ELECTRICITY

This section presents a global and regional snapshot of electricity access in 2010 and access trends since 1990. It delves into country trends, identifying high-impact and fast-moving countries. The analysis makes use of binary access metrics and rests on modeled estimates from the World Bank's Global Electrification Database, as elaborated in section 1.

Global snapshot in 2010

The starting point for global electrification, against which future improvement will be measured, is established as 83 percent in 2010, with the SE4ALL global objective being 100 percent by 2030. Due to the lim itations of the binary metric in capturing inadequate service quality, this can be considered an upper bound for electrification.

1.2 BILLION
PEOPLE LIVED
WITHOUT ELECTRICITY IN 2010

The electricity access deficit affects 17 percent of the global population, or 1.2 billion people, about 85 percent of whom live in rural areas and 87 percent in Sub-Saharan Africa and Southern Asia. The rest of the unelectrified are scattered around the world, with a sizeable number in Southeastern Asia (figure 2.6). The primary sources of energy for the unelectrified population are kerosene, candles, and batteries. Ensuring sustainable delivery of modern energy services to this unserved population is vital to global prosperity and development.

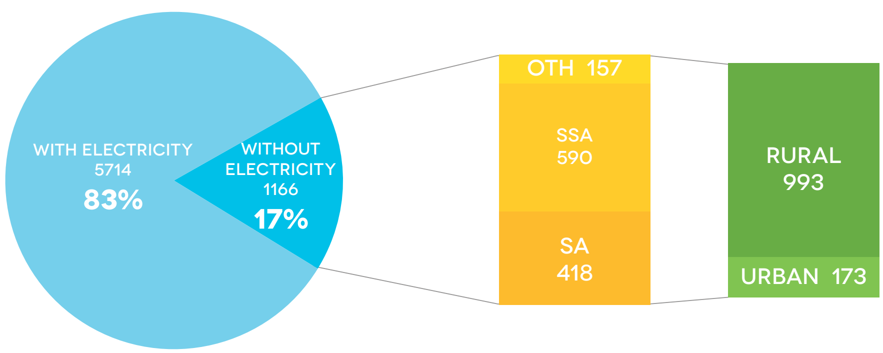


FIGURE 2.6 **THE ELECTRICITY ACCESS DEFICIT IN 2010 (% AND ABSOLUTE NUMBER OF UNELECTRIFIED PEOPLE IN MILLIONS)**

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: AUSTRALIA AND NEW ZEALAND ARE INCLUDED IN THE DEVELOPED COUNTRIES GROUP (AND NOT IN OCEANIA). CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND THE CARIBBEAN; NA = NORTHERN AFRICA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA; OTH = OTHERS.

The regional electrification rate varies from 25 percent in Oceania to 32 percent in Sub-Saharan Africa to near-universal access (greater than 95 percent) in the Caucasus and Central Asia, Eastern Asia, Northern Africa, and the developed countries. More-urbanized and higher-income regions typically exhibit higher electrification rates. Northern Africa, Eastern Asia, Southeastern Asia, and the Caucasus and Central Asia are clustered together and demonstrate a distinctly higher electrification rate than the other developing regions. Western Asia and Latin America are to some extent outliers which report by far the highest income and urbanization rate, yet report lower electrification rates than Eastern Asia and Northern Africa (figure 2.7). Southern Asia also stands out as having an electrification rate of around double that observed in Sub-Saharan Africa and Oceania both with comparable income levels and rates of urbanization.

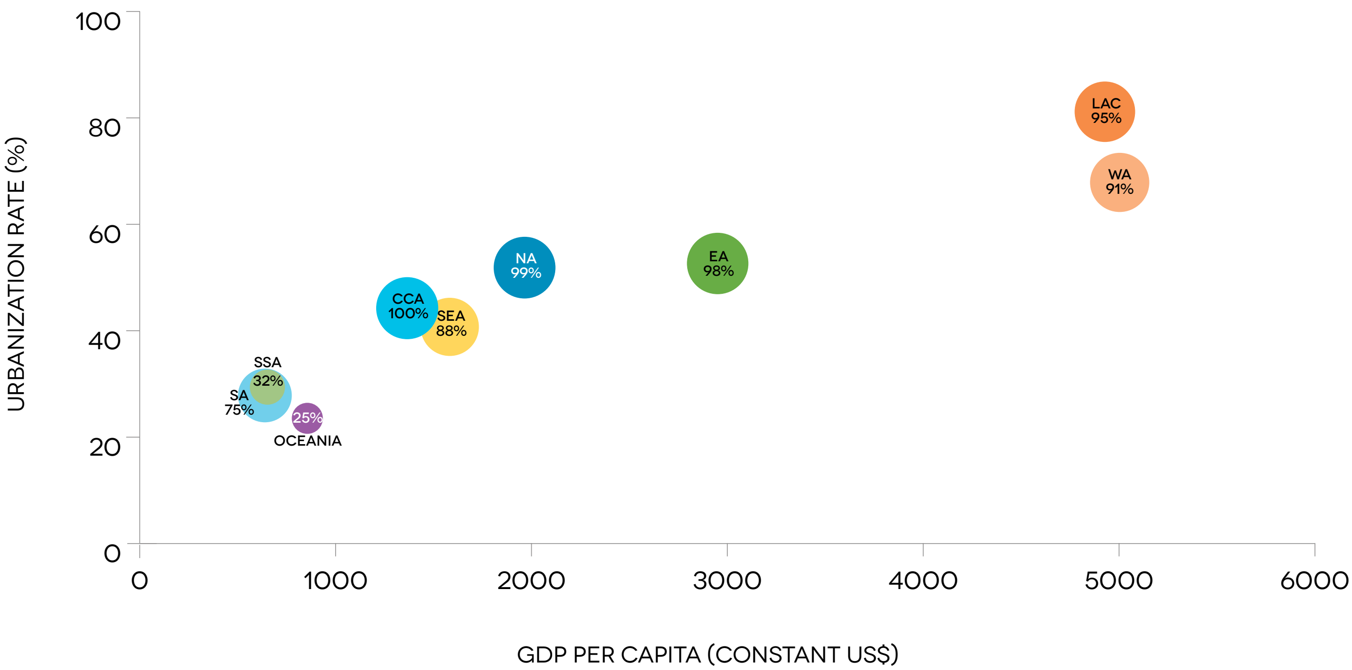


FIGURE 2.7 **REGIONAL ELECTRIFICATION RATE IN 2010, BY LEVEL OF URBANIZATION AND INCOME**

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: SIZE OF BUBBLE INDICATES ELECTRIFICATION RATE BY REGION. CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Sub-Saharan Africa and Oceania are the only regions where the majority of the population remains unelectrified. In fact, Sub-Saharan Africa accounts for 48 percent of the unelectrified rural population in the world. Rural areas have achieved more than 63 percent electrification in every region except Sub-Saharan Africa and Oceania (where only 14 percent of the rural population is electrified in bot region). Similarly, urban areas have achieved more than a 90 percent electrification rate in every region except Sub-Saharan Africa (63 percent of urban population) and Oceania (65 percent of urban population). It is evident that rural areas the world over remain far from universal access, while in urban areas the challenge is largely concentrated in Sub-Saharan Africa and Oceania (figure 2.8).

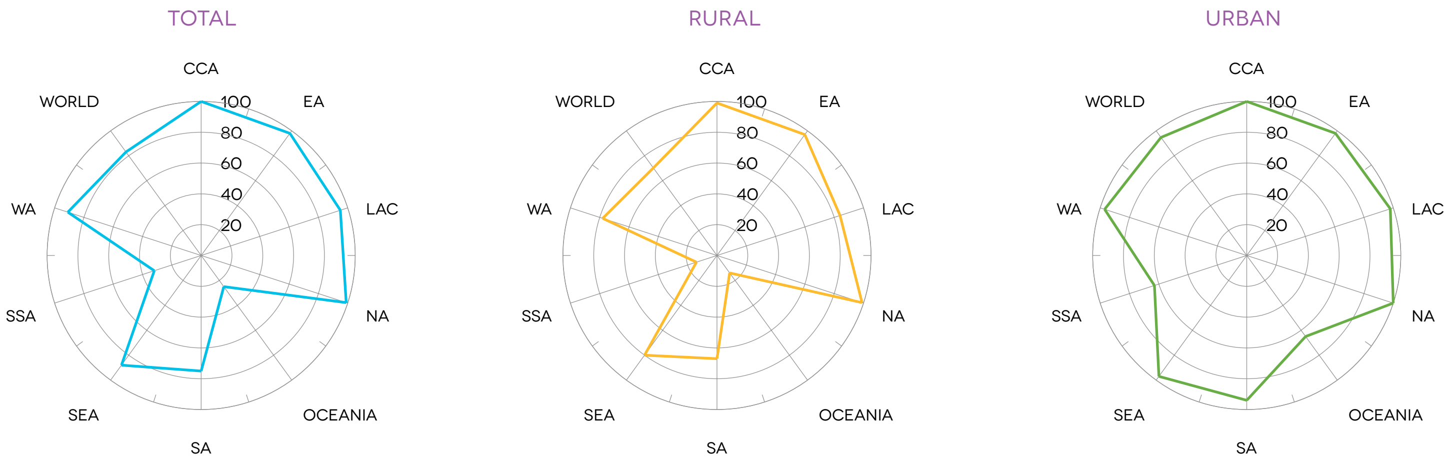


FIGURE 2.8 **REGIONAL ELECTRIFICATION RATES IN 2010: BY REGION**

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Global trends

In the 1990s and 2000s, the global electrification rate rose from 76 percent to 83 percent within 20 years, driven by expansion in rural areas, where the access rate grew from 61 percent to 70 percent. The urban electrification rate remained relatively stable, growing from 94 to 95 percent across the period. Southeastern Asia and Southern Asia witnessed dramatic progress, both displaying a 24 and 17 percentage point increase respectively. Sub-Saharan Africa followed far behind, with gains of 9 percentage points and Oceania with 4 percentage increased in 20 years. Eastern Asia, Northern Africa, Latin America and the Caribbean, and the Caucasus and Central Asia had already accomplished near-universal access by 2000. The remaining regions registered modest or negligible changes in the two decades and remained in the 80–95 percent electrification range (figure 2.9).

70%
OF THOSE GAINING ACCES
TO ELECTRICITY BETWEEN 1990 AND 2010 WERE FROM URBAN AREAS

Between 1990 and 2010, the global population expanded by around 1.6 billion, while the global electrified population rose by around 1.7 billion people. Globally, therefore, access to electricity outpaced population growth by about 128 million people during the period. While growth in the electrified population in Southern Asia, Eastern Asia, Southeastern Asia, Latin America and the Caribbean, Northern Africa, the Caucasus and Central Asia, and Asia Oceania kept pace with growth in population, the growth in the electrified population of Sub-Saharan Africa fell behind growth in population.

1.7 BILLION
PEOPLE GAINED ACCESS TO ELECTRICITY;
JUST SLIGHTLY AHEAD OF GLOBAL POPULATION GROWTH

The increment in electrification was comparable across both decades, but the geographical growth centers varied. Southeastern Asia, Western Asia, and Northern Africa added an almost equivalent number of people in both decades. Southern Asia and Sub-Saharan Africa added a comparatively higher number of people in the second half of the period (figure 2.10).

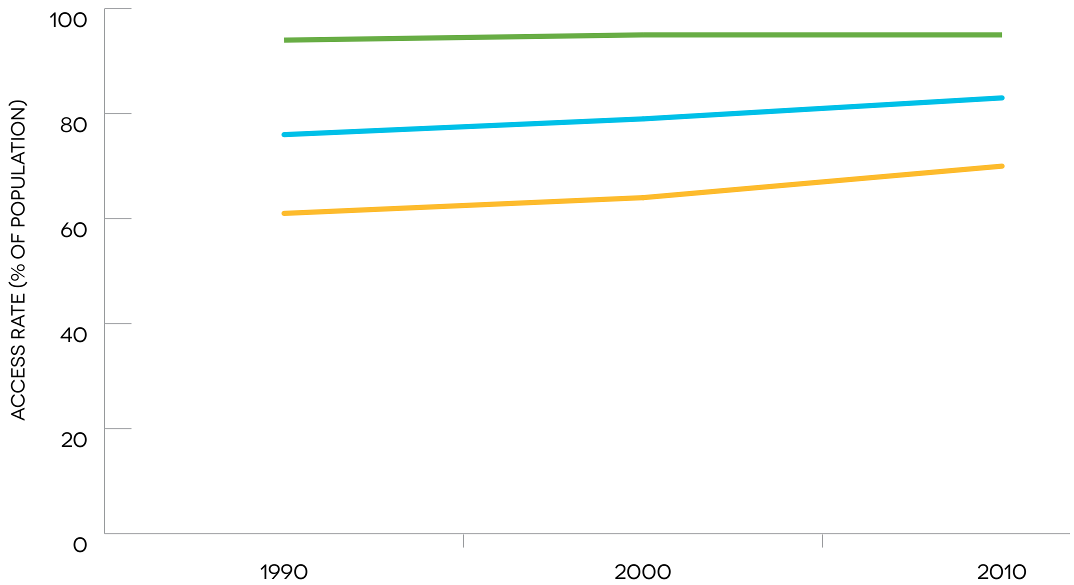


FIGURE 2.9A **GLOBAL TRENDS IN THE ELECTRIFICATION RATE, 1990–2010**

TOTAL RURAL URBAN

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.

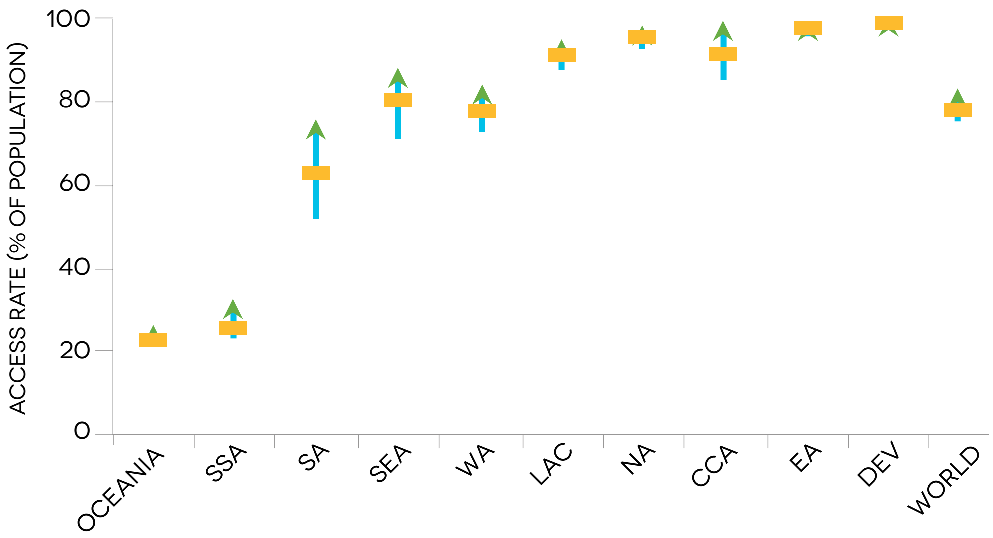


FIGURE 2.9B **REGIONAL TRENDS IN THE ELECTRIFICATION RATE, 1990–2010**

1990 2000 2010

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

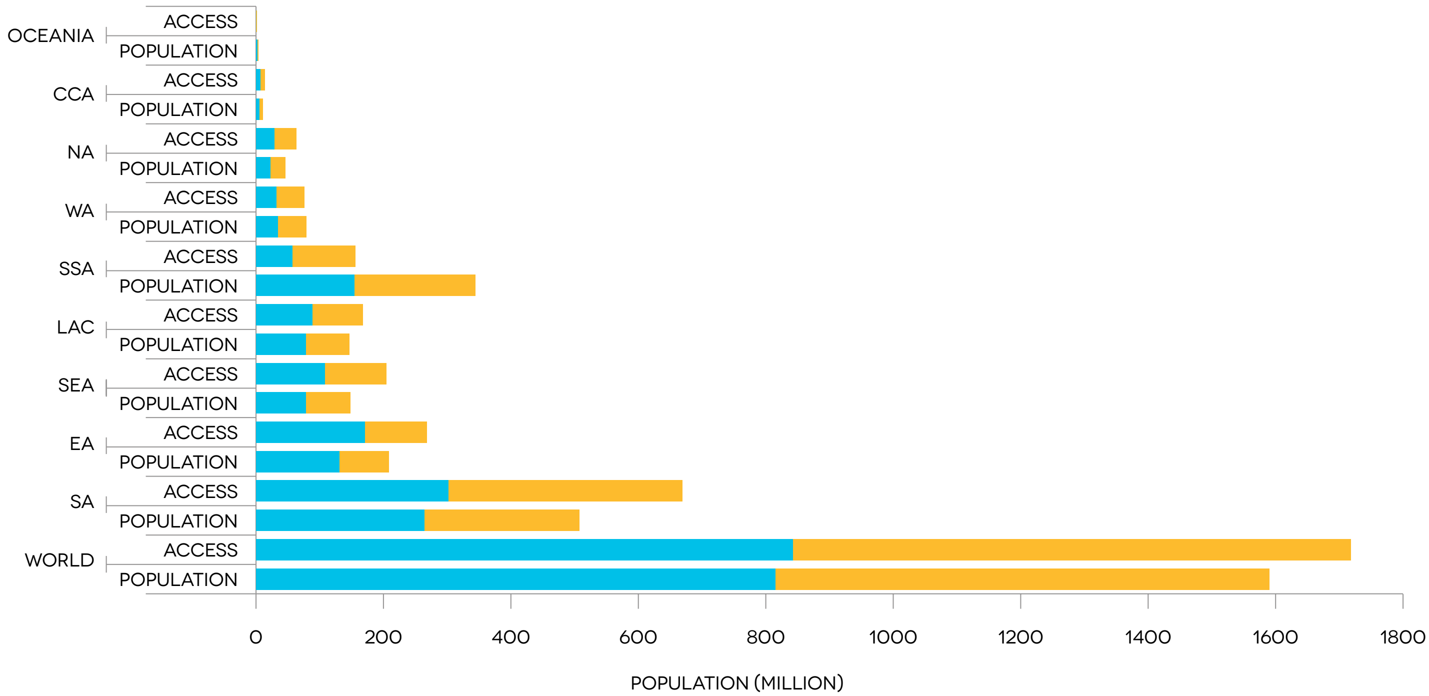


FIGURE 2.10 **POPULATION GROWTH AND PROGRESS IN ACCESS TO ELECTRICITY, 1990-2010**

SOURCE: WORLD BANK GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Dramatic urbanization has altered the profile of electrification during 1990–2010. Population growth in urban areas was explosive (about 1.3 billion people, compared to 315 million in rural areas). As a result, the global population is now roughly equally divided between urban and rural areas. The evolution of electrification, meanwhile, differed in its pattern. Starting in 1990, the electrified population was 2.1 billion in urban areas and 1.8 billion in rural areas, respectively (figure 2.11). Expansion of electrification in urban areas, at 1.7 percent annually, far outstripped the 0.8 percent growth rate found in rural areas. However, due to more rapid demographic growth in cities, electrification in urban areas falls behind population growth by 56 million people. On the other hand, the relatively modest population growth in rural populations made it possible for rural electrification to outstrip population growth by 195 million. Consequently, rural electrification rates jumped by 9 percentage points in 1990–2010.

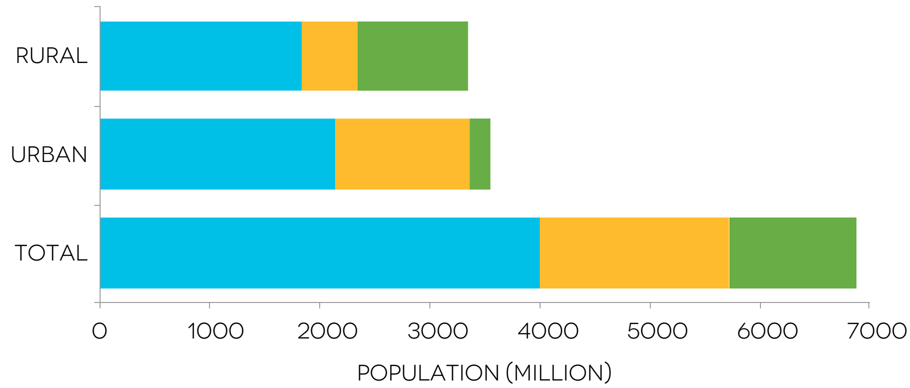


FIGURE 2.11A **GLOBAL PROGRESS IN ACCESS, BY URBANIZATION STATUS, 1990–2010**

POPULATION WITH ACCESS IN 1990 INCREMENTAL ACCESS IN 1990–2010 POPULATION WITHOUT ACCESS IN 2010

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.

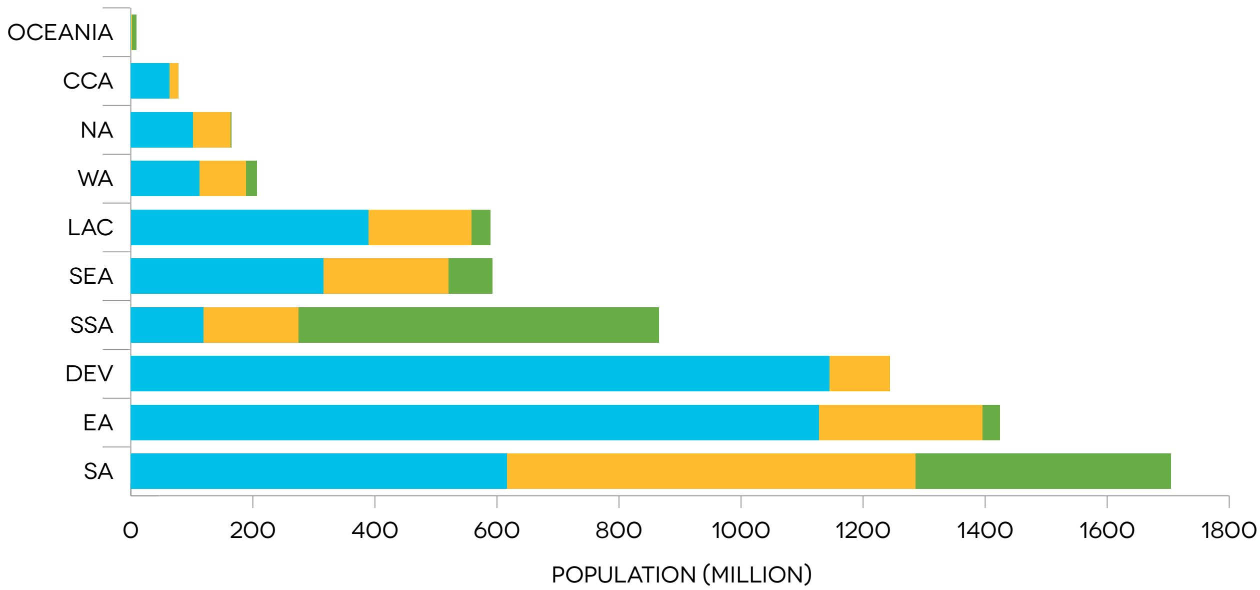


FIGURE 2.11B **GLOBAL PROGRESS IN ACCESS, BY REGION, 1990–2010**

POPULATION WITH ACCESS IN 1990 INCREMENTAL ACCESS IN 1990–2010 POPULATION WITHOUT ACCESS IN 2010

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

The most-remarkable urban growth stories occurred in the Asian regions and in particular in Eastern Asia, Southeastern Asia, Western Asia and Southern Asia. The four regions displayed close to a 2.5 percent annual urban growth rate and together managed to move 788 million people—39 million a year—into electricity use. The rural increment was highest in Southern Asia and Southeastern Asia, where 534 million, or 27 million people annually, were added to the rolls of rural electricity users.

In every region in the world, urban electrification expanded by around 1 percent a year. Rural electrification, on the other hand, witnessed minimal growth rates in Sub-Saharan Africa and Oceania and a negative growth rate in Eastern Asia and the developed countries. The growth performance of Southeastern Asia and in Southern Asia was impressive in both rural and urban areas.

Though the access deficit in 2010 is geographically concentrated in Sub-Saharan Africa and Southern Asia, the electrification trends in these two regions have moved in opposite directions. Sub-Saharan Africa is the only region where the unelectrified population increased in both urban and rural areas, owing to an inability to keep pace with a growing population. Southern Asia recorded the most remarkable progress in electrification, adding 669 million new users of electricity (about 33 million each year and 161 million more than population growth for the period). In Sub-Saharan Africa, by contrast, only 156 million people gained access to electricity in 1990–2010, trailing population growth by 189 million people. Rural electrification was particularly slow in Sub-Saharan Africa, where the electrified population grew only by 0.4 percent (figure 2.12). Eastern Asia experienced a decrease in rural population of about 163 million people over the two decades, with a consequent annual decline of 1 percent in the electrified rural population.

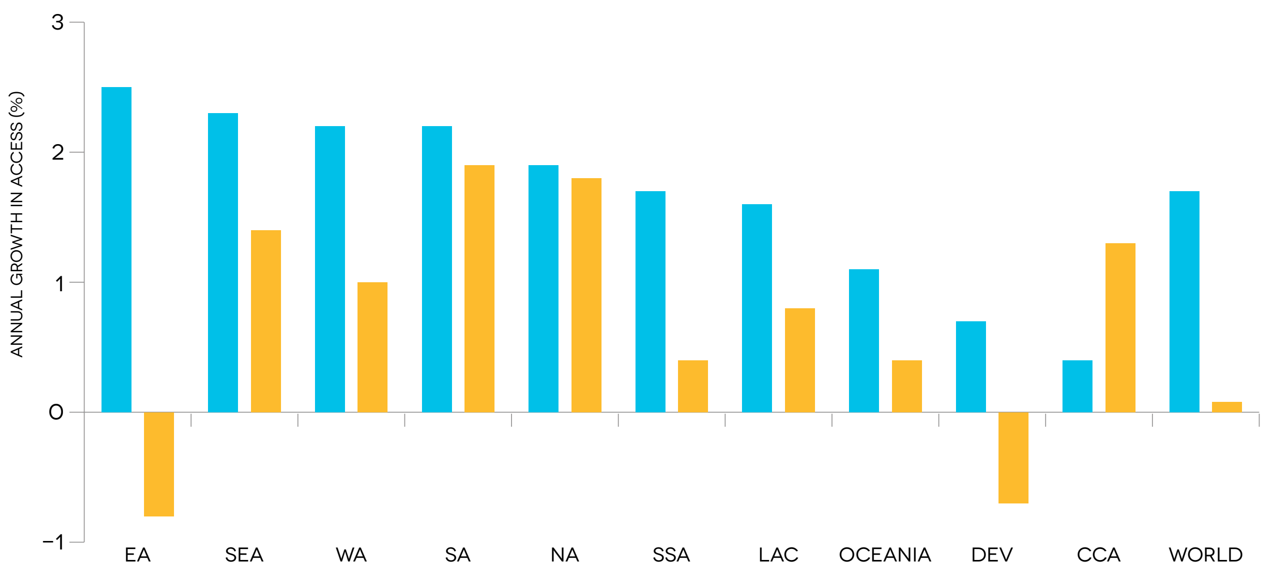


FIGURE 2.12 **ANNUAL GROWTH IN POPULATION WITH ACCESS: URBAN AND RURAL AREAS, 1990–2010**

RURAL URBAN

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Country snapshots in 2010

The electrification rate spans a wide range: from just 1.5 percent in South Sudan to near-universal access in 39 developing countries. (When the developed countries are added, the number of countries with near-universal access rises to 95.) Even within regions, there is heterogeneity in the electrification rate. For example, in Sub-Saharan Africa, Mauritius is the only country with access rates above 95 percent. In Southern Asia, the outliers are Bhutan and the Islamic Republic of Iran where access rates exceed 95 percent.

The world can be arbitrarily divided into three blocks of countries based on the electrification rate—those at the lower end (<30 percent), those in the middle (30–95 percent), and those at the high end (>95 percent). At the lower end are 32 countries—28 in Sub-Saharan Africa, 3 in Oceania, and 1 in Eastern Asia. Seven of these lower-end countries, all in Sub-Saharan Africa, have an access rate lower than 10 percent. At the higher end are 95 countries, only one of them in Sub-Saharan Africa (Mauritius). The Caucasus and Central Asia, Northern Africa, and the developed countries have homogenous universal access rates. In all other regions, the countries are spread across the three blocks, though in Sub-Saharan Africa countries at the lower end of the electrification rate outnumber the countries at the higher end (figure 2.13).

The heterogeneity stems primarily from disparities in rural areas. Four countries, all located in Sub-Saharan Africa, still have less than 1 percent of their rural population in the electrified category. The median rural access rate is at 9 percent in Sub-Saharan Africa, compared to a global median of 89 percent. The electrification rate is relatively uniform in urban areas, with 123 countries reporting near-universal access. In urban areas, the median is higher than 99.6 percent in all regions, except in Sub-Saharan Africa, where it is 53 percent.

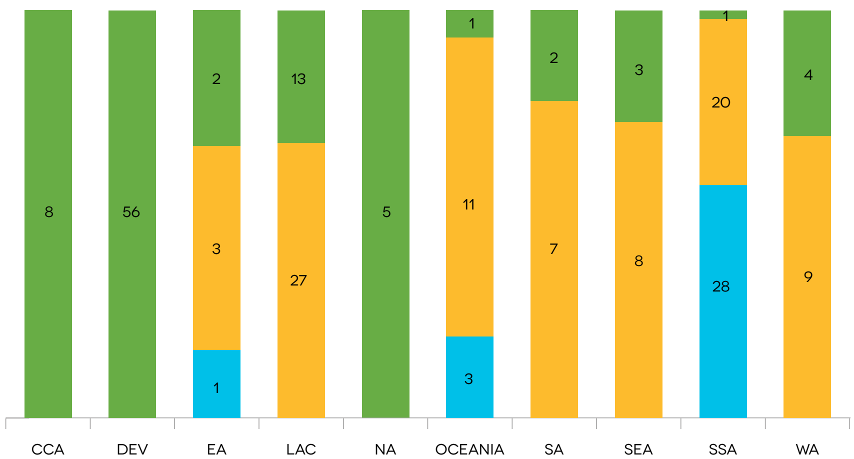


FIGURE 2.13 **DISTRIBUTION OF RATES OF ACCESS TO ELECTRICITY, BY NUMBER OF COUNTRIES PER REGION**

<30 30<>95 >95

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

High-impact countries

The 20 countries with the highest access deficits and the 20 with the lowest electrification rates—dubbed "high-impact countries" for purposes of achieving the SE4ALL target of universal access by 2030—illustrate the magnitude of the access challenge. The 20 countries with the greatest access deficits measured in absolute terms are home to 889 million people who lack access to electricity—more than two-thirds of the global total. Eight are in Asia and 12 in Africa. India's share is the largest—India's unelectrified population is equivalent to the total population of the United States. 19 of the top 20 countries with the lowest electrification rates are in Sub-Saharan Africa. All 20 countries together represent about 287 million unelectrified people, one-fourth of the global total (figure 2.14). The development impact of electrification in these countries is immense, even though their contribution to the SE4ALL universal access objective is projected to be substantially smaller than that of the group of countries with the largest access deficits.

19/20
COUNTRIES
WITH THE LOWEST ENERGY ACCESS RATES GLOBALLY ARE IN SUB-SAHARAN AFRICA

74%
OF THE GLOBAL ACCESS DEFICIT
FOR ELECTRICITY IS CONCENTRATED IN JUST 20 COUNTRIES

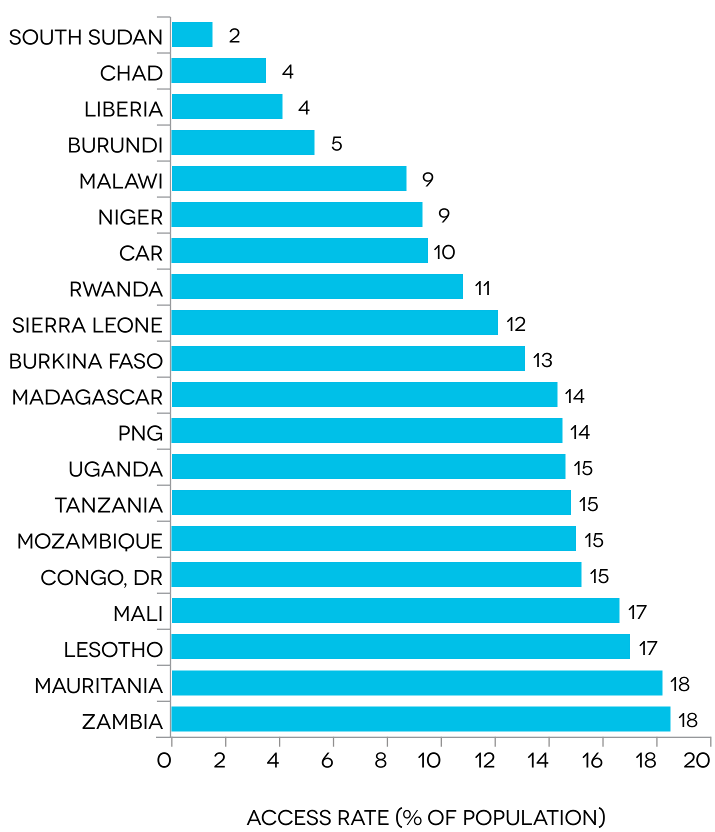


FIGURE 2.14A **TOP 20 COUNTRIES WITH LOWEST ACCESS RATES**

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: CAR=CENTRAL AFRICAN REPUBLIC; PNG=PAPUA NEW GUINEA; DR =DEMOCRATIC REPUBLIC.

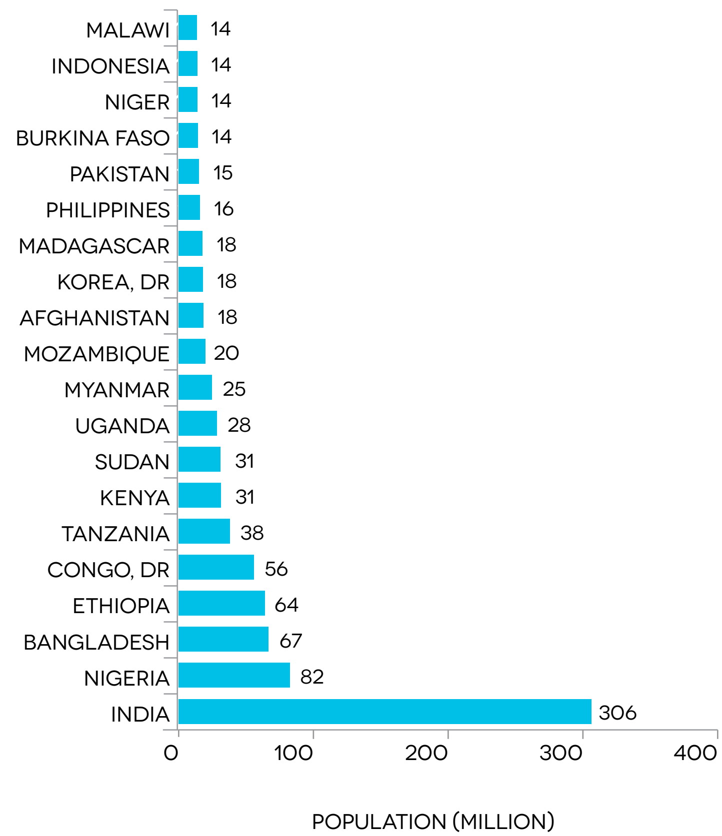


FIGURE 2.14B **TOP 20 COUNTRIES WITH LARGEST ACCESS DEFICITS**

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: DR = DEMOCRATIC REPUBLIC.

Fast-moving countries

Of the 20 countries with the largest number of people that have been electrified during the last 20 years, 12 are in Asia. Their experience could hold valuable policy lessons for other countries aiming to accelerate electrification. They introduced 1.3 billion people to electricity (of the 1.7 billion electrified globally between 1990 and 2010), 283 million more than their population increase. The most impressive expansion of electrification occurred in India, China, Indonesia, Pakistan and Bangladesh. The advances in these populous countries are of enormous significance for achievement of the global universal access target. In particular, India charted a remarkable trajectory, electrifying 474 million people over two decades, or 24 million people annually (figure 2.15), with an annual growth rate of around 1.9 percent.

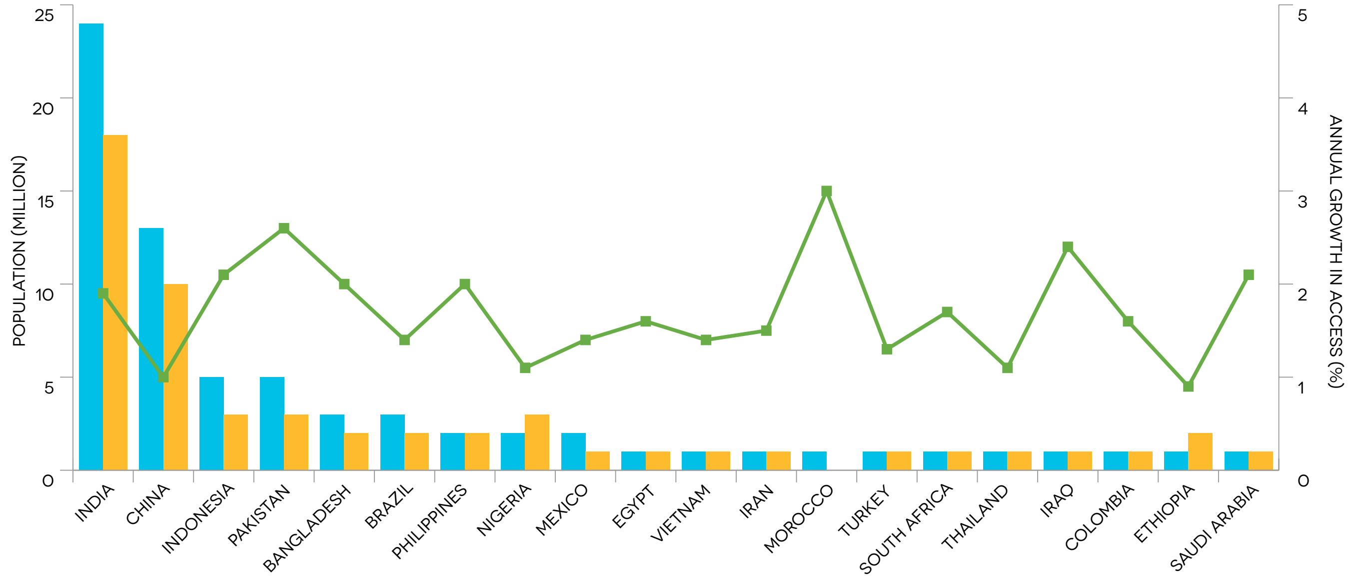


FIGURE 2.15 **TOP 20 DEVELOPING COUNTRIES WITH GREATEST ANNUAL PROGRESS IN ACCESS TO ELECTRICITY, 1990–2010**

INCREMENTAL ACCESS (MILLION) INCREMENTAL TOTAL POPULATION (MILLION) ANNUAL GROWTH IN ACCESS (%)

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.

Focusing on absolute increments in the electrified population tends to highlight the experience of populous countries. Another measure identifies a different group of 20 countries whose electrified population grew the fastest relative to the size of their overall population. The analysis shows that these countries provided new electricity service to at least 2 percent of their populations annually. Only two country—United Arab Emirates and Qatar—raised its pace of electrification beyond 3.5 percent of the population annually (figure 2.16). Interestingly, Iraq , Indonesia, Bangladesh and Pakistan belong to both groups showing substantial progress in electrification both in absolute terms and relative to the size of their respective populations.

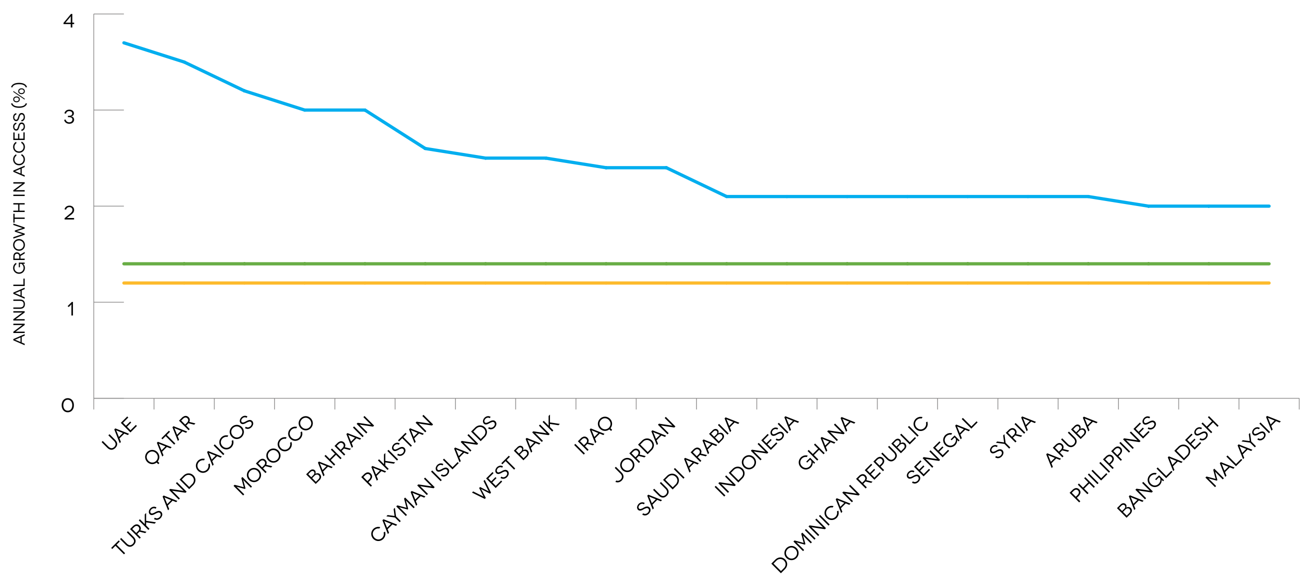


FIGURE 2.16 **TOP 20 FASTEST-GROWING COUNTRIES**

GLOBAL ANNUAL GROWTH IN ACCESS= 1.2% ANNUAL GROWTH IN ACCESS (%) DEVELOPING COUNTRIES ANNUAL GROWTH IN ACCESS= 1.4%

SOURCE: WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE 2012.
NOTE: UAE = UNITED ARAB EMIRATES.

Mapping multi-tier measurements with existing databases

The World Bank's Global Electrification Database and the IEA's World Energy Statistics and Balances can be used with the multi-tier methodology for measuring electricity access by combining the country's electrification rate with average residential electricity consumption. But it is important to recognize that the approximation of the tier (T), based on average consumption at the country level, does not provide the distribution of households across all five tiers of access for the country. Moreover, an indicator based on kilowatt hours consumed cannot accurately reflect the diversity of appliances used or appropriately account for energy efficiency. Implementation of the household-level multi-tier framework using survey data is critical to capture progress in electricity access in its entirety.

This adaptation of the multi-tier methodology to available databases employs two variables to assign a tier to a country and create an "index of access." First, each tier is transformed into annual consumption ranges by assuming indicative use (in hours) of a minimum package of electricity services (in wattage) (annex 5). Tier 0 represents a category of households that do not receive electricity by any means and is associated with an annual household consumption range of less than 3 kWh per year. From tier-tier 1 onwards, households have access to electricity at different levels of service and quality. Each tier corresponds, among other attributes, to the use of several appliances, which determine the definition of the range of kilowatt-hours per household per year equivalent to each tier. The associated annual household consumption range increases accordingly, with tier 5 corresponding to consumption in excess of 2,121 kWh per year.

Residential electricity consumption data available from the IEA,[31] together with the electrification rate, make it possible to place a country's households either in tier 0 for those who lack access or in the tier corresponding to the average residential electricity consumption of the population with access. In Zambia, for example, 81.5 percent of households are categorized as tier 0 (no access) and 18.5 percent as tier 5 based on the average annual electricity residential consumption of 5,779 Kwh per household per year. The index of access for Zambia is therefore a population-weighted average of these two tiers, which comes to 0.9.

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Indicative electricity services	-	Task lighting + Phone charging or Radio	General lighting + Air circulation + Television	Tier 2 + Light appliances	Tier 3 + Medium or continuous appliances	Tier 4 + Heavy or continuous appliances
Consumption (kWh) per household per year	<3	3–66	67–321	322–1,318	1,319–2,121	>2,121

Index of access to electricity supply = $\sum(P_T \times T)$

with P_T = Proportion of households at tier T

T = tier number {0,1,2,3,4,5}

FIGURE 2.17 **MAPPING OF TIERS OF ELECTRICITY CONSUMPTION TO INDICATIVE ELECTRICITY SERVICES**

SOURCE: AUTHORS.
NOTE: KWH = KILOWATT-HOUR.

[31] The residential annual consumption per household varies in developing countries from 255 kWh in Sub-Saharan Africa to 20,000 kWh in Western Asia, with a median consumption of 1,696 kWh.

The access index can range from 0 to 5. In 2000 the global average of the simplified energy access index based on average consumption was 3.6, and by 2010 it had increased to 3.9.[32] In 2010, 103 countries (78 percent) reported a value of 3 or above; the remaining 29 countries scored between 0.6 and 2.6 (19 of them in Sub-Saharan Africa). At the regional level, all regions had an index above 3, except Sub-Saharan Africa and Southern Asia, which reported an average index of 1.4 and 2.8, respectively (figure 2.18). All regions have shown progress in their indices over time, recording both higher electrification rates and increased average consumption.[33] The strongest improvements in performance were in Southeastern Asia and Eastern Asia. Sub-Saharan Africa reported weak improvement in both electrification and average consumption.

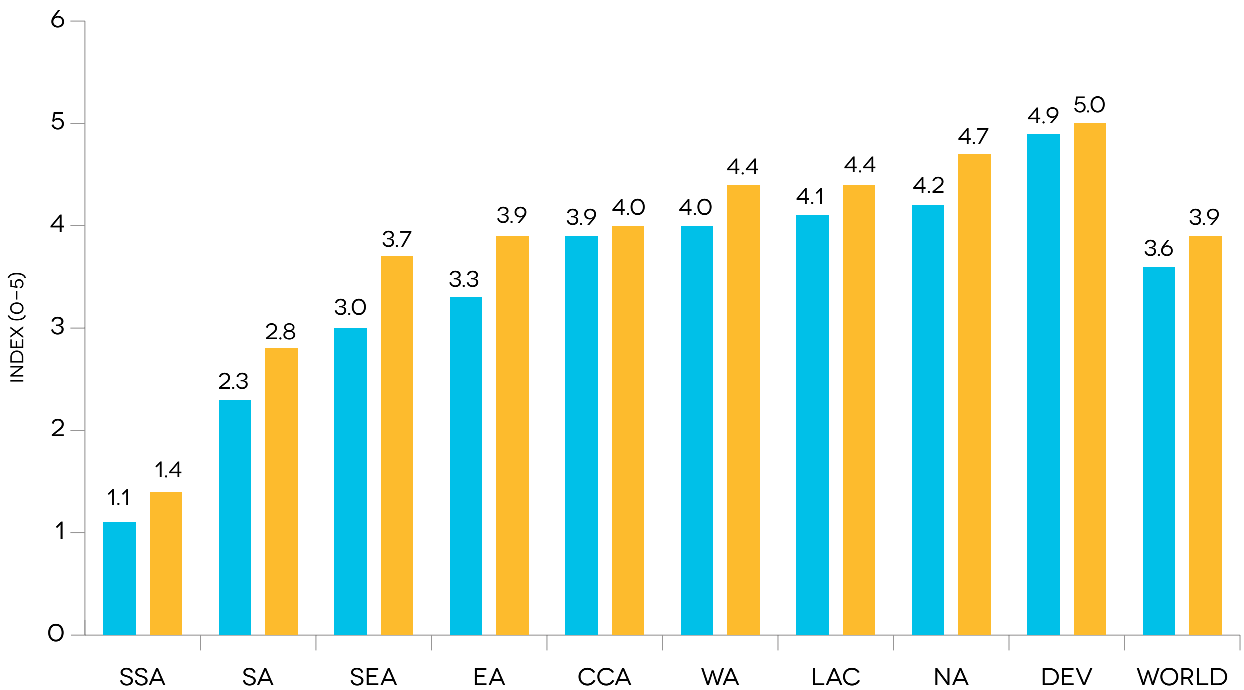


FIGURE 2.18 **APPROXIMATION TO MULTI-TIER INDEX OF ELECTRICITY ACCESS BASED ON NATIONAL DATA, 2000 AND 2010**

SOURCE: BASED ON THE WORLD BANK'S GLOBAL ELECTRIFICATION DATABASE AND IEA (2012).
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SEA = SOUTHEASTERN ASIA; SA = SOUTHERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

[32] The IEA's World Energy Statistics and Balances database reports average consumption data by country for 132 countries out of the 212 countries included in the World Bank's Global Electrification Database, leaving out 4 percent of the global population (295 million people in 2010). The lack of data is particularly acute in Sub-Saharan Africa, where 28 countries out of 49 do not report consumption data, accounting for 207 million people in 2010 (or 24 percent of Sub-Saharan Africa's population). There are relatively large countries among them—one-third of the missing countries have populations in excess of 10 million people, and one country (Uganda) has a population of more than 30 million.

[33] The only exception is the Caucasus and Central Asia region, which recorded a slight decrease in the average consumption.

SECTION 3. ACCESS TO NON-SOLID FUELS

This section presents a global and regional snapshot of access to non-solid fuels in 2010, as well as global trends since 1990. Current global data capture only primary fuel use. Given this constraint, in estimating the starting point for access to modern cooking solutions, access is defined in terms of the primary non-solid fuel used by households for cooking. The access deficit is represented by households still dependent on solid fuels.[34] The country snapshots provided in this section focus on high-impact and fast-moving nations that are introducing large numbers of new households to non-solid fuel. The analysis rests on modeled estimates from the WHO's Global Household Energy Database and explained in section 1.

Global snapshot in 2010

The starting point for global access to non-solid fuel, against which future improvement will be measured, is established as 59 percent in 2010, with the SE4ALL global objective being 100 percent access by 2030. Owing to the limitations of the binary metric in capturing usage of improved biomass cookstoves, this can be considered a slight lower bound for access to modern cooking solutions.

2.8 BILLION PEOPLE RELIED PRIMARILY
ON SOLID FUELS FOR COOKING IN 2010

If the share of the global population that used primarily non-solid fuels in 2010 was 59 percent, that means that 41 percent of the global population, or 2.8 billion people, relied mainly on solid fuels for cooking. About 78 percent of that population lived in rural areas, and 96 percent was geographically concentrated in Sub-Saharan Africa, Eastern Asia, Southern Asia, and Southeastern Asia (figure 2.19). Ensuring sustainable delivery of non-solid fuel to these households is vital to global prosperity and development (box 2.3).

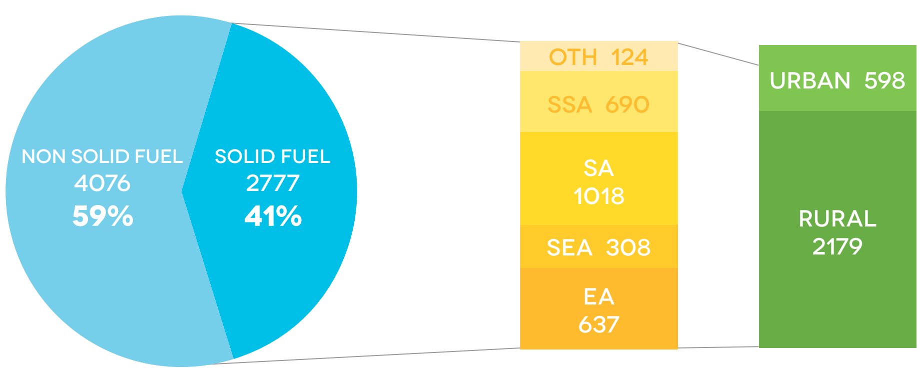


FIGURE 2.19 **DEFICIT IN ACCESS TO NON-SOLID FUEL, 2010**
(% AND ABSOLUTE NUMBER OF PEOPLE, IN MILLIONS, USING SOLID FUELS)

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: EA = EASTERN ASIA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; OTH=OTHERS.

3.5 MILLION PEOPLE DIE EACH YEAR
– MAINLY WOMEN AND CHILDREN – DUE TO HARMFUL INDOOR AIR POLLUTION CAUSED BY UNSAFE COOKING PRACTICES

[34] Non-solid fuels include (i) liquid fuels (for example, kerosene, ethanol, or other biofuels), (ii) gaseous fuels (such as natural gas, liquefied petroleum gas [LPG], and biogas), and (iii) electricity. Solid fuels include (i) traditional biomass (for example, wood, charcoal, agricultural residues, and dung), (ii) processed biomass (such as pellets, and briquettes); and (iii) other solid fuels (such as coal and lignite).

BOX 2.3 Health and safety risks of the inefficient use of household fuels

The inefficient use of energy in the home for cooking, heating, and lighting is a major health risk across the developing world. Gender roles and inequalities impose differential costs on family members, with women bearing most of the negative effects of fuel collection and transport, household air pollution, and time-consuming and unsafe cooking technologies (Clancy, Skutsch, and Batchelor 2005). The smoke resulting from the incomplete combustion of fuels (for example, wood, coal, kerosene) is a major source of household air pollution (HAP), which contains fine particles (for example, black carbon), carcinogens, and other health-damaging pollutants (for example, carbon monoxide). Exposure to HAP has been shown to increase the risk of communicable diseases (pneumonia, tuberculosis) and noncommunicable diseases (heart disease, cancer, cataracts) and is responsible for a large fraction (3–5 percent) of the total global disease burden (WHO 2006b; Lim and others 2012). WHO estimated in 2004 that close to 2 million deaths, mostly of women and children, were attributed to exposure to HAP alone, the highest among the environmental risk factors (figure A). The toll includes more than half a million deaths from childhood pneumonia, almost a million deaths from chronic obstructive pulmonary disease, and around 36,000 from lung cancer traceable to coal use (WHO 2009). Another recent global disease burden assessment, which accounts for cardiovascular disease in addition to other health outcomes, estimates that in 2010 HAP was directly responsible for around 3.5 million deaths, and another half a million deaths from the ambient air pollution produced by HAP leaking outdoors (Lim and others 2012).

Inefficient energy use in the home also poses substantial risks to safety and is the cause of a large number of burns and injuries across the developing world. More than 95 percent of the 200,000 deaths from fire-related burns occur in developing countries; many can be attributed to the use of kerosene, open fires, and simple stoves in the home (Mills 2012). Fuel collection, typically done by women and children, puts people at risk of injury (for example, from land mines, snake, or insect bites) and violence (for example, rape, harassment) (WHO 2006b; Popalzai 2012). The ingestion of kerosene, often from unsafe storage containers (for example, soft drink and water bottles), is a major cause of child poisonings worldwide and can lead to death, chemical pneumotitis, and impairments to the central nervous system (Mills 2012).

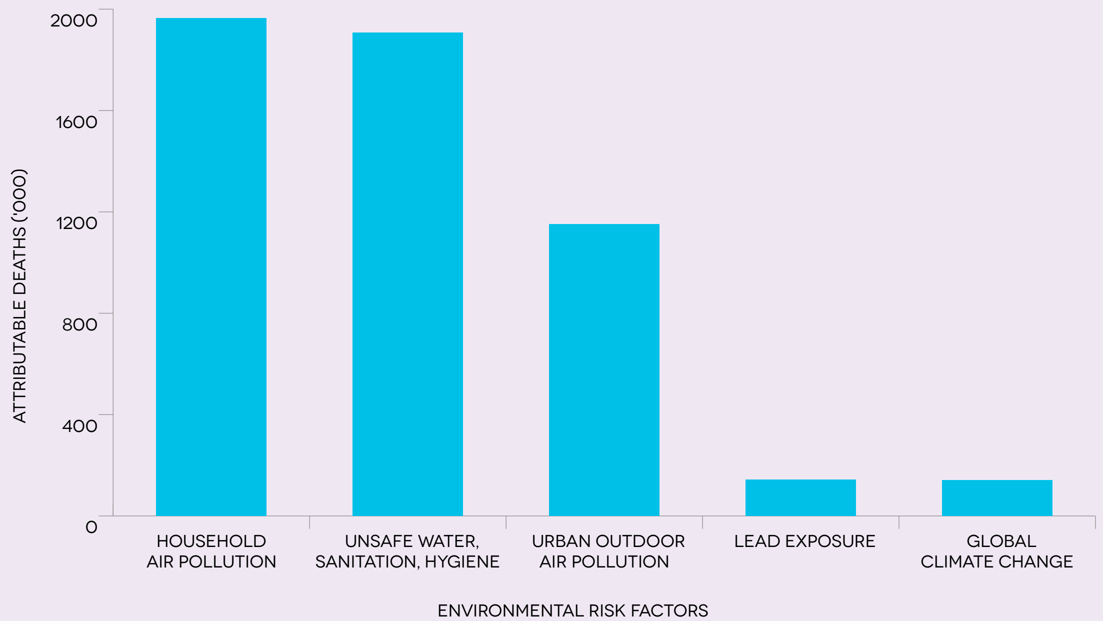


FIGURE A. **DEATHS ATTRIBUTABLE TO ENVIRONMENTAL RISK FACTORS**

SOURCE: WHO 2009.

Within the developing world, the rate of access to non-solid fuel varies from 19 percent in Sub-Saharan Africa to about 95 percent in Western Asia and 100 percent in Northern Africa. Except in Western Asia, the Caucasus and Central Asia, and Northern Africa, more than two-thirds of the rural population of the developing world depends on solid fuels. The situation is particularly dire in Sub-Saharan Africa (94 percent), Oceania (79 percent), Southeastern Asia (77 percent), and Southern Asia (73 percent). These four regions together account for three-quarters of the total rural use of solid fuel in the world. In urban areas, more than 70 percent of the population has access to non-solid fuel, except in Sub-Saharan Africa (42 percent) (figure 2.20).

More-urbanized and higher-income regions typically exhibit higher reliance on non-solid fuel. Western Asia, the wealthiest and most urbanized developing region, has close to universal access to non-solid fuel. At the lower end of the income and urbanization profile are Southern Asia, Sub-Saharan Africa, and Oceania, which also report the lowest access rates. But Southeastern Asia and Eastern Asia, with incomes and urbanization rates similar to those of Northern Africa, show markedly lower access rates (as indicated by the size of the bubbles in figure 2.21).

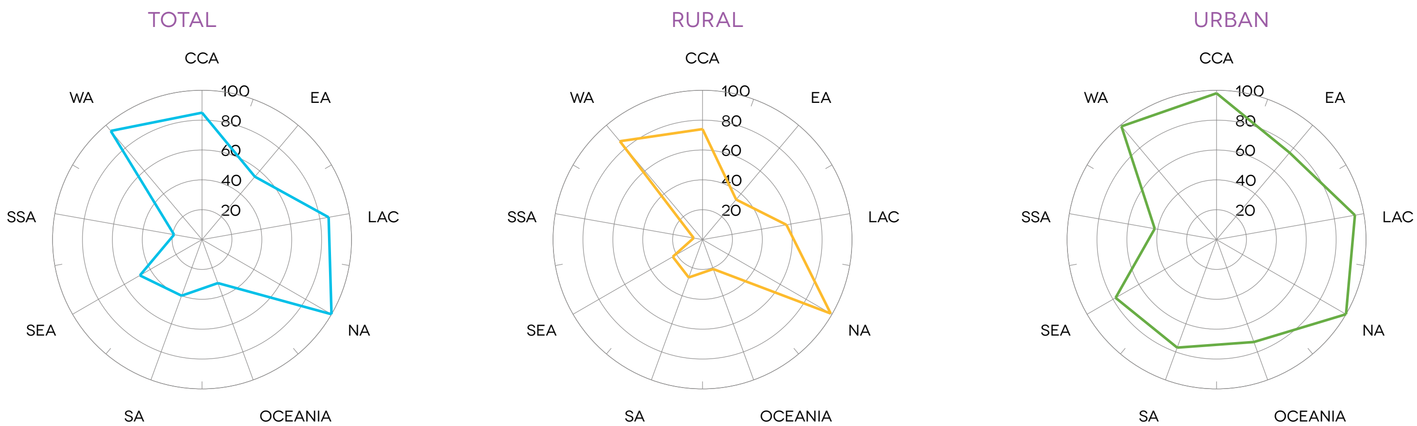


FIGURE 2.20 **RATES OF ACCESS TO NON-SOLID FUEL IN 2010, BY REGION**

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

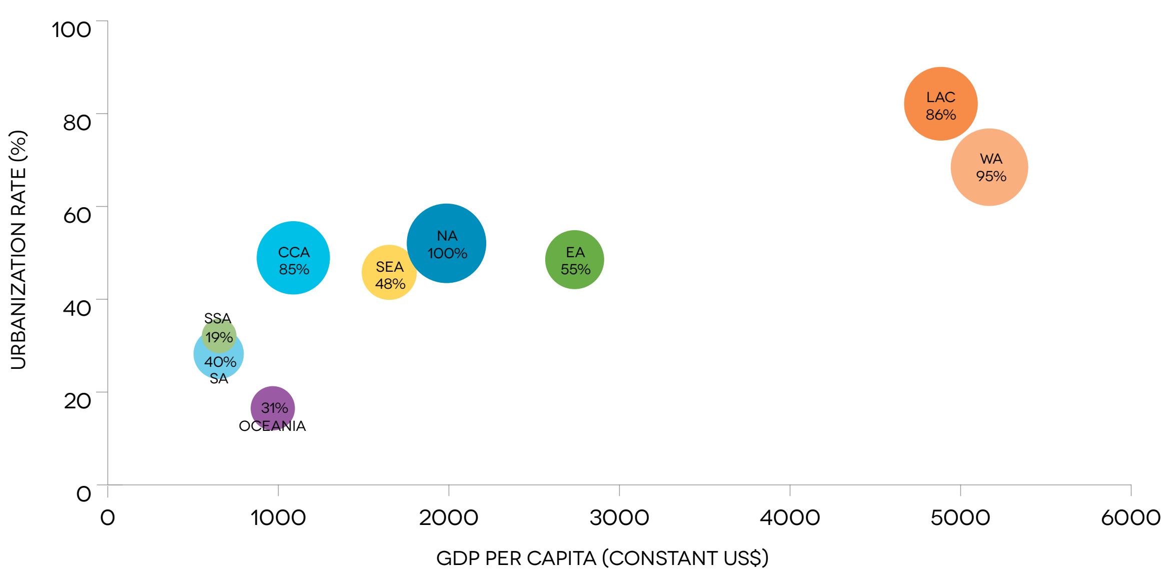


FIGURE 2.21 **RATES OF ACCESS TO NON-SOLID FUEL IN 2010, BY LEVEL OF URBANIZATION AND INCOME**

SOURCE: BONJOUR AND OTHERS 2012.
NOTE: SIZE OF BUBBLE INDICATES ACCESS RATE BY REGION. CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; GDP = GROSS DOMESTIC PRODUCT; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Global trends

The share of the global population with access to non-solid fuel rose from 47 percent (2.5 billion people) in 1990 to approximately 59 percent (4.1 billion people) in 2010 (figure 2.22). The access rate in rural areas increased over the same period from 26 percent to 35 percent; in urban areas, from 77 percent to 84 percent. The Caucasus and Central Asia and Southern Asia all witnessed dramatic progress, registering increases of 27 and 24 percentage points, respectively, over the two decades. On average, Eastern Asia, Latin America, Northern Africa, Oceania, Southeastern Asia, and Western Asia exhibited an increase in non-solid fuel use of 15 percentage points. Sub-Saharan Africa followed far behind, with an increase from 14 to 19 percent during the same period. Eastern Europe and Western Asia had accomplished near-universal access by 2010.

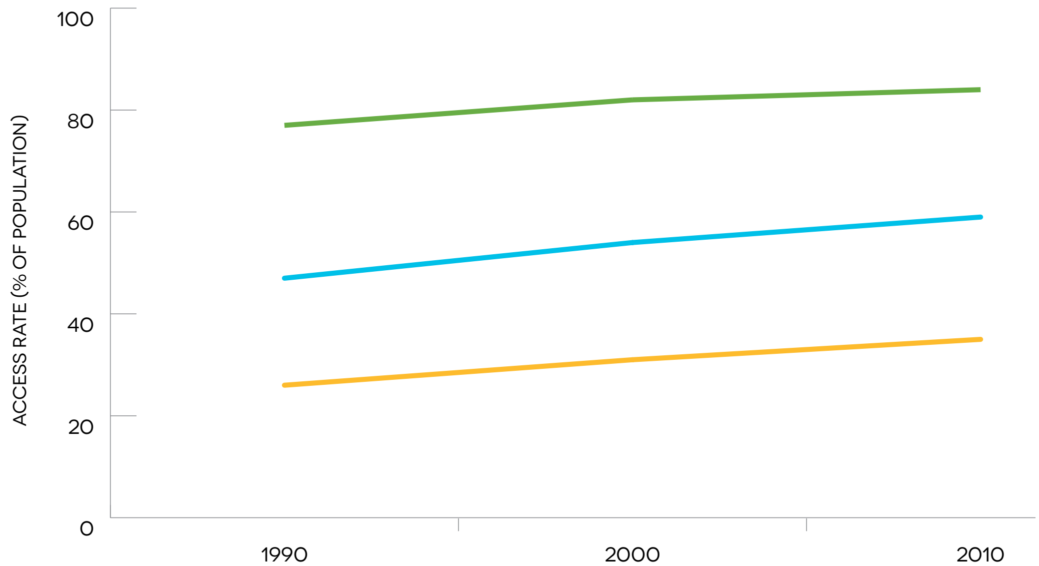


FIGURE 2.22A **GLOBAL TRENDS IN RATES OF ACCESS TO NON-SOLID FUEL, 1990–2010**

TOTAL RURAL URBAN

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.

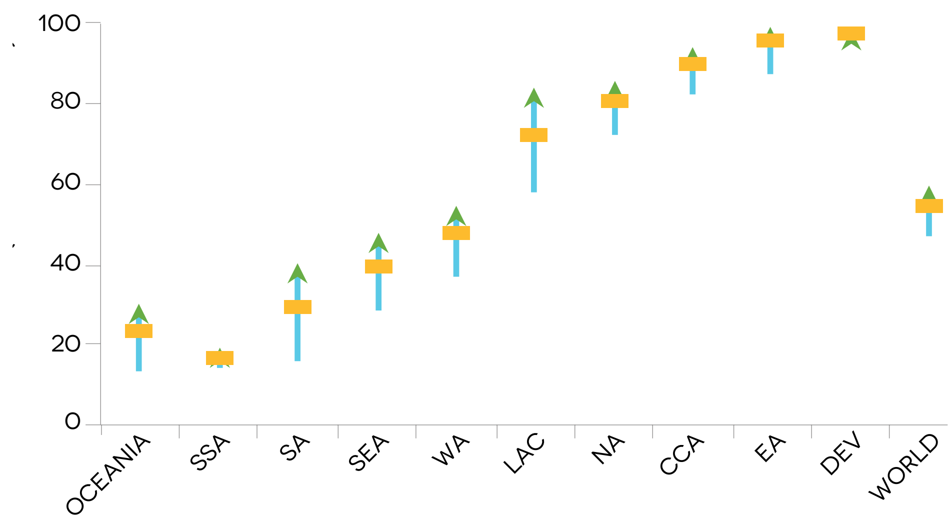


FIGURE 2.22B **REGIONAL TRENDS IN RATES OF ACCESS TO NON-SOLID FUEL, 1990–2010**

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

The global population grew by 1.6 billion in the two decades between 1990 and 2010, and non-solid fuel use almost kept pace (figure 2.23). Globally the increment in non-solid fuel access was comparable across both decades, but with some variation geographically. Growth in access kept up with population growth in Central Asia, Northern Africa, Southeastern Asia, Latin America and Oceania in both decades. In Eastern Asia, access grew much faster than the population, especially in the 2000s.

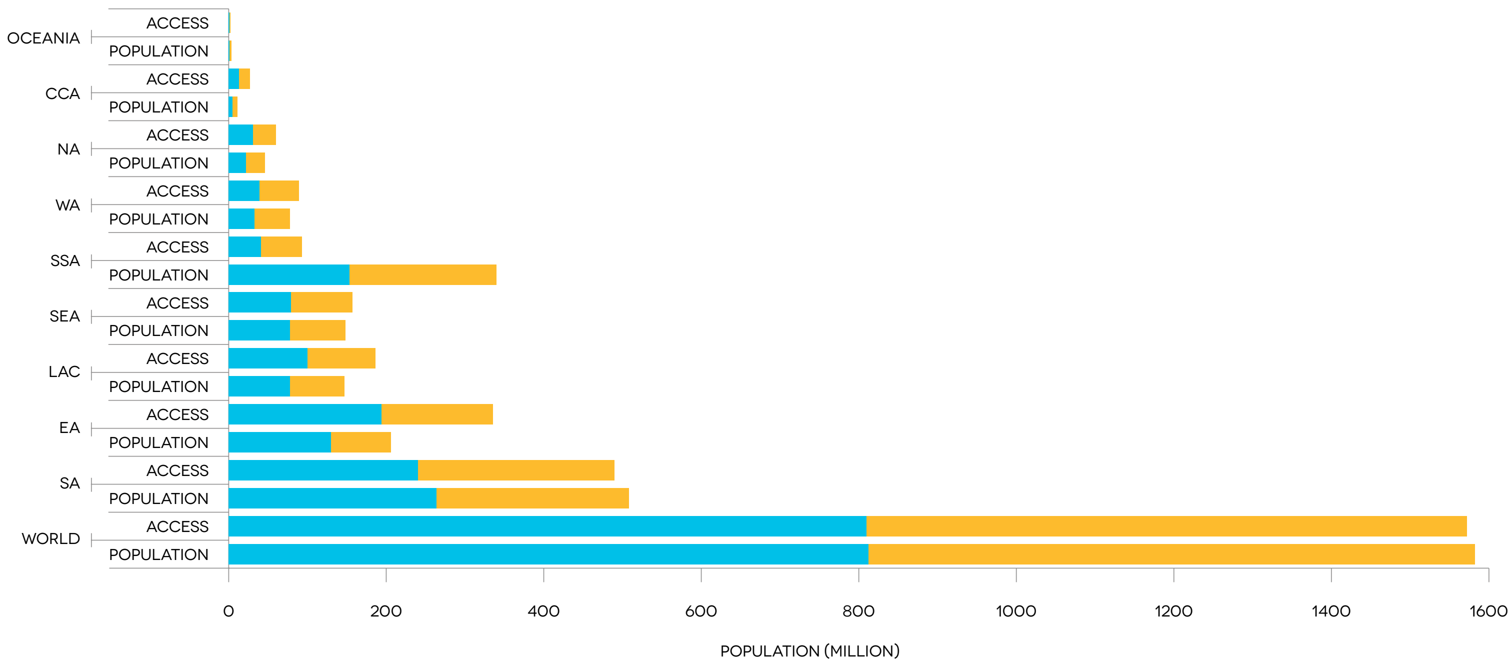


FIGURE 2.23 **GROWTH IN POPULATION AND IN ACCESS TO NON-SOLID FUEL, 1990–2010**

1990–2000 2001–2010

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE, 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

The access deficit—or the use of solid fuel—in 2010 was geographically concentrated in Sub-Saharan Africa and Southern Asia. From 1990, both regions experienced an expansion of reliance on solid fuels in both urban and rural areas. In Southern Asia, an additional 490 million people gained access to non-solid fuel as their primary cooking fuel, but even that impressive figure trailed population growth—by 18 million people in the same time period. Sub-Saharan Africa increased non-solid fuel use by only 92 million people, falling behind population growth by 248 million people (figure 2.24).

1.6 BILLION
PEOPLE GAINED ACCESS
TO NON-SOLID FUELS BETWEEN BETWEEN 1990 AND 2010

[17] Further details are provided in IEA 2012b.

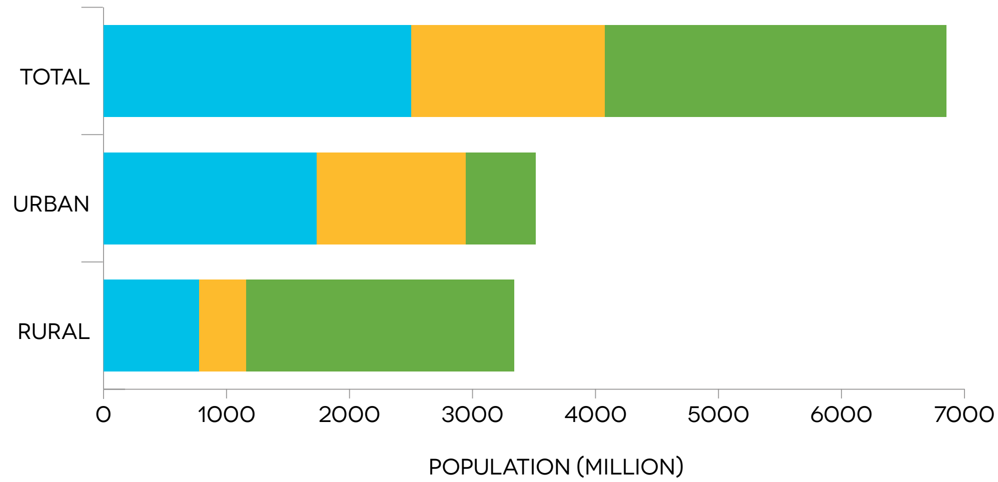


FIGURE 2.24A **GLOBAL PROGRESS IN ACCESS TO NON-SOLID FUEL, BY URBANIZATION STATUS, 1990–2010**

POPULATION WITH ACCESS IN 1990 INCREMENTAL ACCESS IN 1990–2010 POPULATION WITHOUT ACCESS IN 2010

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.

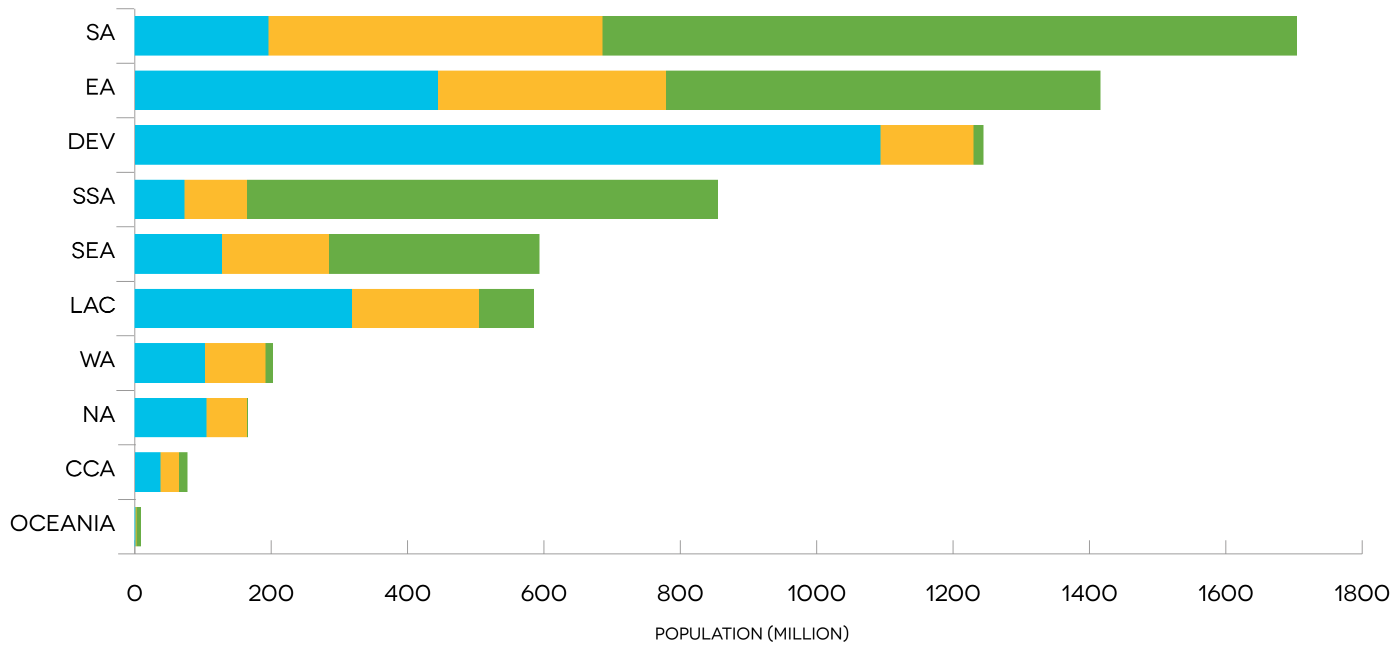


FIGURE 2.24B **GLOBAL PROGRESS IN ACCESS TO NON-SOLID FUEL, BY REGION, 1990–2010**

POPULATION WITH ACCESS IN 1990 INCREMENTAL ACCESS IN 1990–2010 POPULATION WITHOUT ACCESS IN 2010

NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Between 1990 and 2010 the rapid rate of urbanization added 1.2 billion people to urban populations; populations living in rural areas increased by only 0.4 billion over the same period. The growth rate of access to non-solid fuel in urban areas, at 1.7 percent, far outpaced the rural growth rate of 0.6 percent (figure 2.25). Nevertheless, the rapid pace of urban population growth over this period made it difficult for non-solid fuel access in urban areas to keep up, with the expansion of access falling short of population growth by 51 million people over the two decades. In rural areas, by contrast, access grew faster than the population by 67 million people. The remarkable urban growth story has occurred for the most part in the Asian regions (Eastern Asia, Western Asia, Southern Asia, and Southeastern Asia), which together managed to provide 760 million people—or 38 million people annually—with access to non-solid fuel. The rural increment was highest in Western Asia, Southern Asia, and the Caucasus and Central Asia, where 334 million people—or 17 million annually—began to use primarily non-solid fuel for cooking.

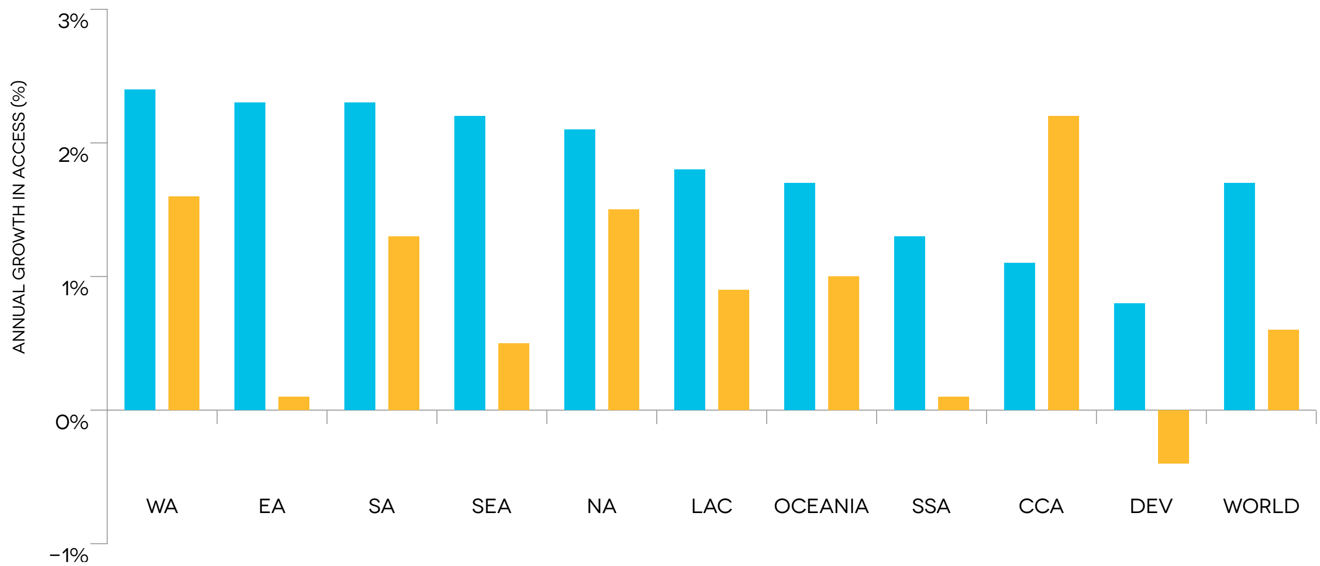


FIGURE 2.25 **ANNUAL INCREMENTS IN GROWTH OF ACCESS TO NON-SOLID FUELS IN URBAN AND RURAL AREAS, 1990–2010**

RURAL URBAN

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

Country snapshots in 2010

The rate of access to non-solid fuel spans a wide range: from 2 percent in many Sub-Saharan African countries to near-universal access (greater than 95 percent access) in 73 countries of the world (37 of which are developing countries). Even within a given region, access rates are heterogeneous.

The world can be arbitrarily divided into three country blocks based on the degree of access to non-solid fuel: those at the lower end (<30 percent), those in the middle (30–95 percent), and those at the higher end (>95 percent). At the low end are 47 countries, 33 of which are in Sub-Saharan Africa. Among them, 21 show less than 10 percent access to non-solid fuel. Mauritius and Seychelles are the outliers in Sub-Saharan Africa, with access rates above 95 percent; South Africa can also be considered an outlier, as its rate of access to non-solid fuel is 85 percent. Northern Africa and Western Asia are the only regions with an almost homogenous universal access rate (figure 2.26).

The heterogeneity stems primarily from rural areas, where 68 countries still have less than 30 percent non-solid fuel access. The median rural access rate is at 5 percent in Sub-Saharan Africa, compared to a global median of 63 percent. Non-solid fuel access is relatively uniform in urban areas; 92 countries report near-universal urban access. In urban areas, the median is 100 percent in all regions except Sub-Saharan Africa, where it stands at 28 percent.

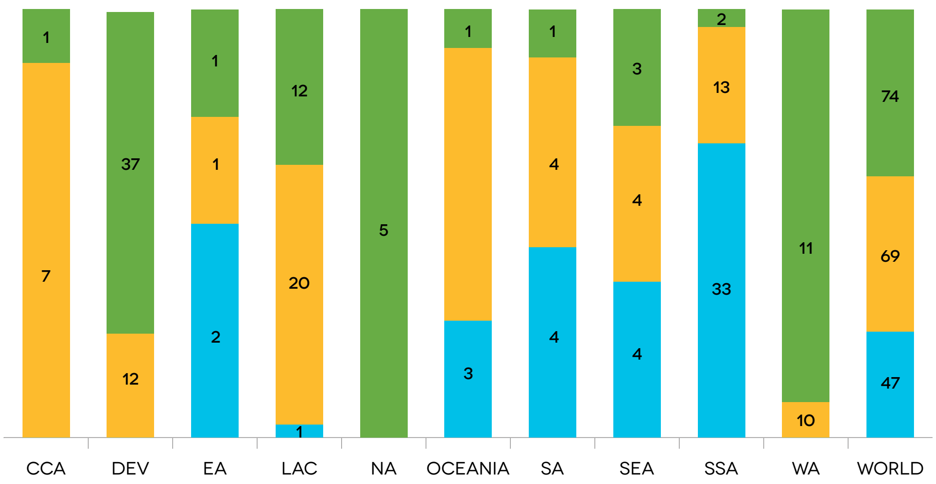


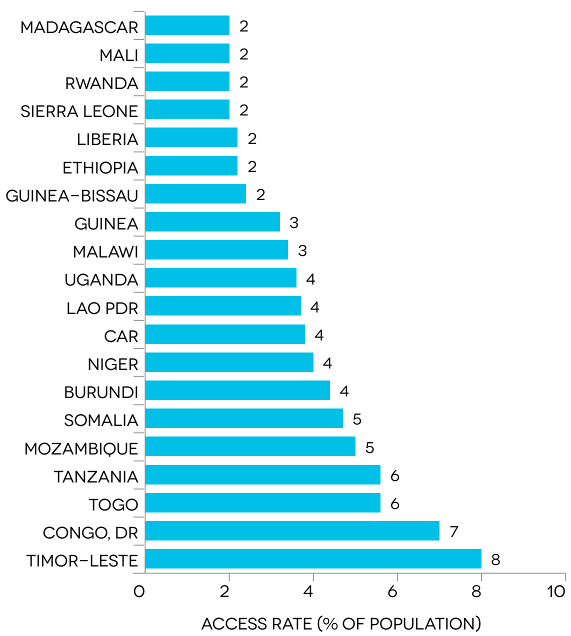
FIGURE 2.26 **DISTRIBUTION OF RATES OF ACCESS TO NON-SOLID FUEL, BY NUMBER OF COUNTRIES PER REGION**

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE, 2012.
NOTE: CCA = CAUCASUS AND CENTRAL ASIA; DEV = DEVELOPED COUNTRIES; EA = EASTERN ASIA; LAC = LATIN AMERICA AND CARIBBEAN; NA = NORTHERN AFRICA; SA = SOUTHERN ASIA; SEA = SOUTHEASTERN ASIA; SSA = SUB-SAHARAN AFRICA; WA = WESTERN ASIA.

High-impact countries

Among the 20 countries with the lowest rates of access to non-solid fuel (figure 2.27a), 18 are in Sub-Saharan Africa. Solid-fuel users make up 369 million. Another 20 "high impact" countries account for 85 percent (2.4 billion people) of the absolute global deficit in access to non-solid fuel (figure 2.27b). Eleven of the 20 are in Asia and nine in Sub-Saharan Africa. India and China together account for 1.3 billion solid-fuel users.

A. LOWEST ACCESS RATES, 2010: 369 MILLION SOLID-FUEL USERS



B. LARGEST ACCESS DEFICITS, 2010: 2.4 BILLION SOLID-FUEL USERS

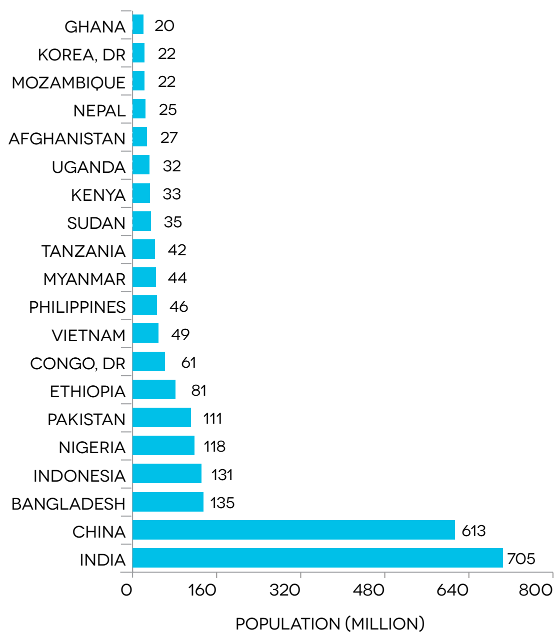


FIGURE 2.27 **TOP 20 COUNTRIES: THE LOWEST ACCESS RATES AND LARGEST DEFICITS IN ACCESS TO NON-SOLID FUEL**

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: CAR = CENTRAL AFRICAN REPUBLIC; DR = DEMOCRATIC REPUBLIC OF.

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.
NOTE: DR = DEMOCRATIC REPUBLIC OF.

Fast-moving countries

Of the 20 countries that have shown the largest numbers of people transitioning to primary use of non-solid fuels, most are in Asia (figure 2.28). The 20 countries moved an additional 1.2 billion people to non-solid fuel in 1990–2010, but that figure was 200 million behind their overall population increase. The greatest growth was in India, China, and Brazil, where a total of 783 million people secured access to non-solid fuel as their primary cooking fuel during this period. India charted a remarkable trajectory, providing access to non-solid fuel to 402 million over two decades, or 20 million people annually.

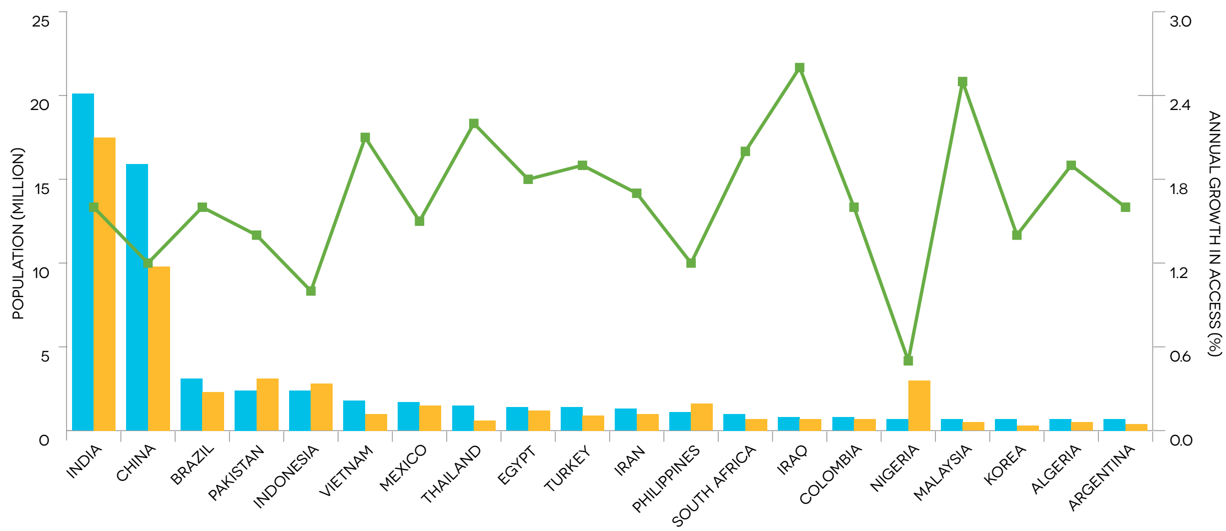


FIGURE 2.28 **TOP 20 COUNTRIES WITH HIGHEST ANNUAL INCREMENTAL GROWTH IN ACCESS TO NON-SOLID FUEL, 1990–2010**

INCREMENTAL ACCESS (MILLION) INCREMENTAL TOTAL POPULATION (MILLION) ANNUAL GROWTH IN ACCESS (%)

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012.

Focusing on absolute increments in non-solid fuel access tends to highlight the experiences of large countries. Twenty fast-moving small countries—many of them island nations—also showed substantial growth in access as a percentage of their population over the two decades from 1990 to 2010 (figure 2.29). Fourteen countries transitioned at least 2.5 percent of their population annually to primary use of non-solid fuel. But only the United Arab Emirates (UAE) and Qatar increased access to non-solid fuel at an annual rate greater than 3.5 percent of the population. Their performance is the upper bound of what any country has been able to achieve in the past two decades.

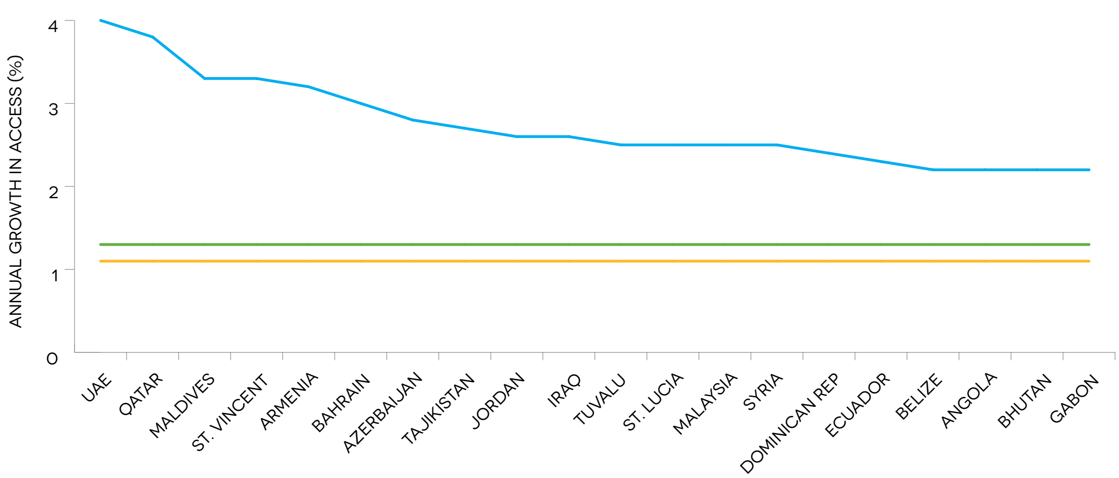


FIGURE 2.29 **TOP 20 FASTEST-GROWING COUNTRIES IN NON-SOLID FUEL USE, 1990–2010**

SOURCE: WHO'S GLOBAL HOUSEHOLD ENERGY DATABASE 2012. **NOTE:** UAE = UNITED ARAB EMIRATES.

SECTION 4. SCALE OF THE CHALLENGE

Building on the foregoing analysis, this section looks to the future, mapping out today's energy access trajectory and quantifying the scale of the challenges that must be overcome to achieve the SE4ALL goal of universal access to modern energy services by 2030. Drawing on the World Energy Outlook (IEA 2012), it presents global and regional projections for modern energy access under a so-called New Policies Scenario (NPS) that estimates the likely impact of existing and announced policy commitments. The projections provide a basis from which to analyze what needs to be done to achieve universal access by 2030. Variables include how many more people will need to obtain access to modern energy services by region, the levels of investment and types of technologies required, the barriers to achieving the goal, and the benefits and broader implications of achieving it (such as the impact on energy demand and energy-related carbon dioxide [CO2] emissions).

Methodology for projecting energy access developments to 2030

This section draws heavily on data, projections, and analysis from the IEA's *World Energy Outlook*[35] (box 2.4). The energy access projections under the NPS reflect the impact that existing and announced policy commitments (assuming cautious implementation) are expected to have by 2030.

For this analysis, the following definitions and methodology have been adopted.[36] Access to electricity is indicated by a household's first connection to electricity and by consumption of a specified minimum level of electricity, with the amount varying depending on whether the household is in a rural or an urban area. The initial threshold level of electricity consumption for rural households is defined as 250 kilowatt-hours (kWh) per year; for urban households, 500 kWh. The higher consumption in urban areas reflects urban consumption patterns. Both levels are calculated based on an assumption of five people per household. In rural areas, the minimum level of consumption could, for example, provide for the use of a floor fan, a mobile telephone, and two compact fluorescent light bulbs for about five hours per day. In urban areas, consumption might also include an efficient refrigerator, a second mobile telephone per household, and another appliance (such as a small television or computer).

Different levels of electricity consumption are adopted in other published analyses. Sanchez (2010), for example, bases access on consumption of 120 kWh per person (600 kWh per household, assuming five people per household). As a point of reference, the observed average electricity consumption in India in 2009 was 96 kWh per person in rural areas and 288 kWh in urban areas, for all people connected to electricity, with those connected more recently consuming lower amounts (Government of India 2011).

In the spirit of the multi-tier candidate proposal presented in section 1, the projections for electricity access that follow go beyond a simple binary definition and make some allowance for different tiers of access, as reflected in differentiated levels of electricity consumption. Once an initial connection to electricity is made, the level of consumption is assumed to rise gradually over time, moving toward a regional average level of consumption after several years. The initial period of growing consumption is a deliberate attempt to reflect the fact that eradication of energy poverty is a long-term endeavor. In the analysis, the average level of electricity consumption per capita across all households newly connected over the period is assumed to rise to about 750 kWh by 2030.

Access to modern cooking solutions focuses on the provision of an appropriate stove and refers primarily to biogas systems, LPG stoves, and advanced biomass cookstoves that have considerably lower emissions and higher efficiencies than traditional three-stone fires for cooking. We assume that LPG stoves and advanced biomass cookstoves require replacement every five years, while a biogas digester is assumed to last 20 years.

[35] This section of the report uses the IEA's World Energy Outlook databases on electricity access and on the traditional use of biomass for cooking. On many counts, the IEA's electricity access database, which reports 1.3 billion people without access, is consistent with the World Bank's Global Electrification Database, which reports 1.2 billion people lacking access. The major share of the discrepancy between the two global estimates can be ascribed to differences in a relatively small number of countries, including Pakistan, Indonesia, South Africa, Thailand, and Gabon, where the IEA uses government data (which typically report more people without access) while the World Bank uses estimates derived from various types of surveys.

[36] For more about the IEA's energy access data and modeling methodologies, see http://www.worldenergyoutlook.org/resources/energydevelopment.

To arrive at estimates of the investments needed to achieve the SE4ALL goal of universal access to electricity, an assessment was conducted of the required combination of on-grid, mini-grid, and isolated off-grid solutions in each region. This assessment accounts for regional costs and consumer density to determine a regional cost per megawatt-hour (MWh). When delivered through an established grid, the cost per MWh is cheaper than other solutions, but extending the grid to sparsely populated, remote, or mountainous areas can be very expensive, and long-distance transmission systems can have high technical losses. Grid extension is the most suitable option for urban areas and for about 30 percent of rural areas, but not for more remote rural areas. The remaining rural areas are connected either with mini-grids (65 percent of this share) or small, stand-alone off-grid solutions (the remaining 35 percent) that have no transmission and distribution costs.

Investment needs for modern cooking solutions are based on the expectation that a combination of different technical solutions will be provided. These include advanced biomass cookstoves, LPG stoves, and biogas systems. Advanced biomass cookstoves and biogas systems are relatively more common solutions in rural areas, while LPG stoves play a more significant role in urban areas. Related infrastructure, distribution, and fuel costs are not included in the estimate of investment costs.

Projections are shown at the regional level because the available data do not permit a more disaggregated analysis over the time frame. The regional aggregations used in this section differ slightly from those in the first three sections of this report, reflecting the usages of the IEA's World Energy Model.[37] As examples of the differences in country classification, the IEA's World Energy Outlook groups Iran in the Middle East region, rather than in Southern Asia. The IEA excludes Bhutan and the Maldives from Southern Asia; both are part of Eastern Asia and Oceania in the figures shown in this section. Furthermore, Timor-Leste is part of Eastern Asia and Oceania, not Southeastern Asia, in the data presented here. Finally, the Republic of Korea is not included in Eastern Asia or any other region here, whereas it is included in the UN region of Eastern Asia.

BOX 2.4 IEA's energy access model

The energy access projections presented in this section of the report come from the IEA's World Energy Model, which integrates trends in demography, economy, technology, and policy. This kind of integrated analysis offers valuable insights into the globe's energy trajectory and what will have to be done to attain the SE4ALL goal of universal access to modern energy services by 2030. The projections for access to electricity and to modern cooking solutions are based on separate econometric panel models that regress the electrification rates and rates of reliance on biomass for different countries over many variables to test their level of significance. In the case of electrification, the variables that were determined to be statistically significant and thus included in the equations are per capita income, demographic growth, urbanization level, fuel prices, level of subsidies for electricity consumption, technological advances, electricity consumption, and electrification programs. In the case of cooking solutions, variables that were determined statistically significant and consequently included in the equations are per capita income, demographic growth, urbanization level, level of prices of alternative modern fuels, level of subsidies to alternative modern fuel consumption, technological advances, and government programs to promote modern cooking.

The models are run under the following economy and population assumptions: world gross domestic product (in purchasing power parity terms) grows by an average of 3.6 percent per year over the period 2010–2030, with the rate of growth slowing gradually over time as the emerging economies mature. The assumed rate varies by region. The rates of population growth assumed for each region are based on UN projections (UNDP 2011). World population is projected to grow from an estimated 6.8 billion in 2010 to 8.3 billion in 2030. In line with the long-term historical trend, population growth slows over the projection period. Almost all of the increase in global population is expected to occur in countries outside the Organisation for Economic Co-operation and Development (OECD), mainly in Asia and Africa.

SOURCE: AUTHORS.

Access to electricity in 2030 under the New Policies Scenario

Under the assumptions of the NPS the number of people lacking access to electricity around the world will decline to just over 990 million in 2030, around 12 percent of the global population at that time (figure 2.30). About 1.7 billion people will gain access to electricity by 2030, but that achievement will be counteracted, to a large extent, by global population growth. Those gaining access to electricity will reach a range of consumption levels, and therefore a range of tiers in the electricity access framework, by 2030—ranging from the defined minimum consumption levels in urban and rural areas to consumption levels above the regional average at that time. Access to electricity will improve in relative terms for all regions except Sub-Saharan Africa, where the current trend will worsen over time.

12%
OF THE WORLD'S POPULATION
WILL STILL LACK ACCESS TO ELECTRICITY IN 2030 UNDER BUSINESS AS USUAL

The NPS projects the largest populations without access in 2030 to be found in developing Asia (mainly Southern Asia) and Sub-Saharan Africa. Sub-Saharan Africa is projected to overtake developing Asia in a few years as the region with the largest population without access to electricity.

FIGURE 2.30 **NUMBER OF PEOPLE WITHOUT ACCESS TO ELECTRICITY IN RURAL AND URBAN AREAS, BY REGION, 2010–2030**

SUB-SAHARAN AFRICA · SOUTH ASIA · SOUTH-EASTERN ASIA · REST OF THE WORLD

SOURCE: BASED ON DATA/ANALYSIS FROM IEA (2012).

In developing Asia the number of people without electricity access under the NPS scenario is projected to be halved by 2030, reaching around 335 million. That will extend an already positive trend, with China (which today reports more than 99 percent access) expected to reach universal access by the middle of the current decade. The remainder of Eastern Asia and Southeastern Asia will have much smaller numbers without access in 2030; Southern Asia is also expected to see significant improvement. Even so, a population larger than that of the United States today is still expected to be without access to electricity in developing Asia in 2030, with India expected to have the largest single no-access population, at around 150 million. Nine out of 10 people without access to electricity in developing Asia in 2030 are expected to live in rural areas.

In Sub-Saharan Africa, the number of people without access to electricity is projected to increase under the NPS by around 11 percent, to 655 million in 2030. Projections suggest that the worsening trend will extend to around 2025 and that the prospect of improvement from that date is fragile, remaining vulnerable to upset by a change in economic fortunes, higher energy prices, or a failure to implement policy. Over the projection period, those lacking electricity access in Sub-Saharan Africa will be increasingly concentrated in rural areas, which will account for more than 85 percent of the regional deficit in 2030. Owing to projected improvements elsewhere, Sub-Saharan Africa will account for an increasing share of the global population without electricity access, going from less than half to around two-thirds by 2030.

The regions projected to reach universal access to electricity before 2030 are Latin America and the Caribbean, the Middle East, and Northern Africa. That success is not guaranteed but relies on the continuation of trends in economic growth, investment, and policies to improve electricity access.

Access to electricity in 2030: Achieving universal access

To achieve universal access to electricity by 2030, some 50 million more people will have to gain access to electricity each year than under the NPS. About 40 percent of the additional electricity supply needed for universal access in 2030 would come from grid solutions (of which almost two-thirds would be fossil-fuel based) and the remainder from mini-grid and stand-alone off-grid solutions (of which around 80 percent would be based on renewables).

It is estimated that universal access to electricity by 2030 will require investment of around $890 billion over the period (2010 dollars), of which around $288 billion is projected to be forthcoming under the NPS, meaning that an additional $602 billion would be required to provide universal access to electricity by 2030—an average of $30 billion per year (2011–2030). The annual level of investment would increase over time, reflecting the escalating number of connections being made. More than 60 percent of the additional investment required would come in Sub-Saharan Africa, because the region would need the equivalent of an extra $19 billion per year to achieve universal electricity access by 2030 (figure 2.31). Achieving universal access in Sub-Saharan Africa would depend more heavily than elsewhere on mini-grid and isolated off-grid solutions, particularly in countries such as Ethiopia, Nigeria, and Tanzania, where a relatively high proportion of those lacking electricity live in rural areas. Developing Asia accounts for 36 percent of the additional investment required to achieve universal electricity access, with Southern Asia accounting for the largest share.

WORLD ACCESS TO CLEAN COOKING FACILITIES: **$3.8 BILLION** & WORLD ACCESS TO ELECTRICITY: **$30.1 BILLION**

FIGURE 2.31 **ADDITIONAL AVERAGE ANNUAL INVESTMENT NEEDED TO ACHIEVE UNIVERSAL ACCESS TO MODERN ENERGY SERVICES BY 2030, BY REGION AND TECHNICAL SOLUTION**

SOURCE: BASED ON DATA/ANALYSIS FROM IEA (2012).

As a high-quality and highly flexible form of energy, electricity can enable a whole range of social and economic benefits, empowering the leap from poverty to a better future. Electric light extends the day, providing extra hours for studying and work. Access to radio and television can help keep communities up to date on events both local and global. Street lighting has been reported to increase social mobility, especially of women. Electricity in schools can improve education by enabling access to lighting, heating, water, and sanitation. In health facilities, it can also bring benefits by powering medical and communications equipment. Refrigeration allows health facilities to keep needed medicines on hand and for households to keep food fresh. Access to electricity also provides the means to generate income and improve productivity, which in turn creates wealth and new markets. In agriculture, electricity can support various forms of modernization, enabling people to pump water for household use and irrigation and to use mobile phones to access new markets for their crops. Expanding access to modern energy services can yield significant social and economic returns, especially when integrated with efforts to promote the efficient use of limited energy resources and the harnessing of locally available renewable energy sources.

Access to modern cooking solutions in 2030 under the New Policies Scenario

Under the NPS, the number of people lacking access to modern cooking solutions is projected to remain, because of population growth, almost unchanged at around 2.6 billion in 2030—more than 30 percent of the projected global population in that year (figure 2.32).

30%
OF THE WORLD'S POPULATION
WILL STILL DEPEND ON SOLID FUELS IN 2030 UNDER BUSINESS AS USUAL

FIGURE 2.32 **NUMBER OF PEOPLE WITHOUT ACCESS TO MODERN COOKING SOLUTIONS IN RURAL AND URBAN AREAS BY REGION, 2010–2030**

SUB-SAHARAN AFRICA · SOUTH ASIA · EAST ASIA AND OCEANIA · SOUTH-EASTERN ASIA · REST OF THE WORLD

SOURCE: BASED ON DATA/ANALYSIS FROM IEA (2012).

In developing Asia, China is projected to show the single biggest improvement, with almost 150 million fewer people lacking access to modern cooking solutions by 2030. That improvement will come from economic growth, urbanization, and deliberate policy interventions, such as actions to expand natural gas networks. India will see a small improvement but is still expected to account for the largest single population going without modern cooking solutions—nearly 30 percent of the world's total in 2030. The rest of developing Asia is also projected to see only a marginal improvement by 2030, with half of its population still lacking access to modern cooking solutions at that time.

In Sub-Saharan Africa, NPS projections reveal a worsening situation over time, with the number of people without modern cooking solutions increasing by more than a quarter, reaching around 880 million in 2030. While more than 310 million people will achieve access to modern cooking solutions by 2030, their number will not keep pace with the population growth expected over the period. As in all regions, the lack of access will continue to be concentrated in rural areas.

Latin America and the Middle East have much smaller populations lacking modern cooking solutions. There, NPS projections show a slight improvement over time, focused on urban areas. In rural areas, the size of the population without access to modern cooking solutions will remain essentially unchanged, as population growth offsets positive efforts. In Latin America, 11 percent of the population is projected still to be without access to modern cooking solutions in 2030, while the figure is less than 3 percent in the Middle East.

Access to modern cooking solutions in 2030: Achieving universal access

To achieve universal access, modern cooking solutions will need to be provided to an additional 135 million people per year, on average, over and above those gaining access under the NPS. This could occur through a combination of various technical solutions, including advanced biomass cookstoves, LPG stoves, and biogas systems.[38] In rural areas, advanced biomass cookstoves and biogas systems are relatively more common solutions, whereas in urban areas LPG stoves play a more significant role. While the target population is much larger than for access to electricity and the operational challenge no less significant, it is striking how much less investment is needed is to provide universal access to modern cooking solutions than to electricity.

It is estimated that universal access to modern cooking solutions by 2030 would require investment of about $89 billion over the period (in 2010 dollars), of which about $13 billion is projected to be forthcoming under the NPS, meaning that an additional $76 billion ($3.8 billion per year, 2011−2030) would be required to provide universal access to modern cooking solutions by 2030. Figure 2.31 breaks down the additional investment required by region, as well as technical solutions to achieve universal access to modern cooking solutions by 2030. For comparison, the Global Energy Assessment of the International Institute for Applied Systems Analysis, IIASA, also estimates the investment required to achieve universal energy access in 2030, but based on different assumptions (box 2.5).

The benefits of universal access to clean cookstoves are clear. A huge proportion of the world's population still uses polluting, inefficient cookstoves that emit toxic smoke. Indoor air pollution is the fifth-largest health risk in the developing world. Millions of people are estimated to die prematurely each year from exposure to cookstove smoke many of which are children (WHO, 2009). Moving away from biomass for cooking and heating would also free women and children from spending hours each week collecting wood, allowing this time to be used more productively. It would also reduce or remove the personal security risks that women face when searching for fuel. Finally, use of clean fuels and cookstoves, many of which do not consume wood fuel, could help reduce the risks of local deforestation and other forms of damage to natural resources (see boxes 2.2 and 2.3).

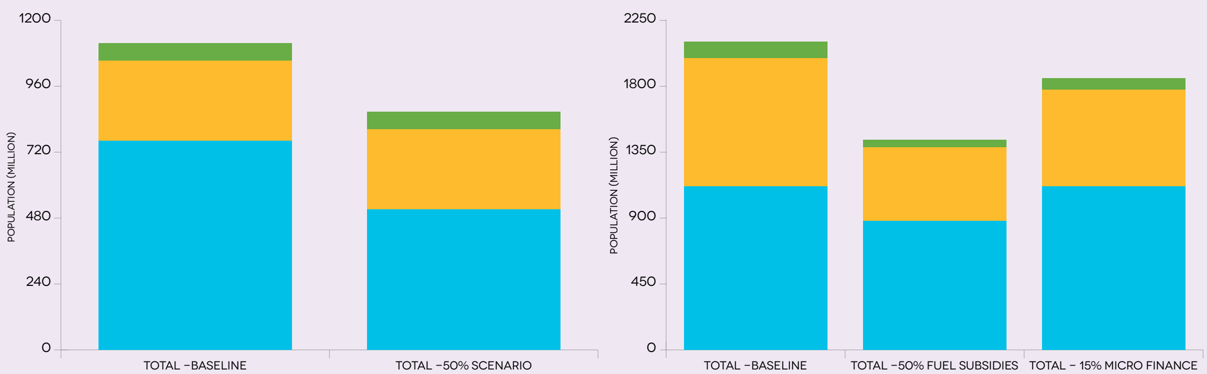
[38] Section 3 of this chapter presented global and country snapshots of household access to non-solid fuels. But the projections presented here are based on access to improved cooking appliances, which are captured in various tiers of the multi-tier framework in figure 2.3.

BOX 2.5 GEA investment cost projections to reach universal access

The Global Energy Assessment (GEA) of the International Institute for Applied Systems Analysis, which models 41 energy "pathways" (or scenarios designed to meet certain prespecified objectives) has estimated the investment costs associated with reaching near-universal access to electricity and modern cooking solutions by 2030. Six of these pathways are consistent with meeting all three global SE4ALL goals, in addition to achieving emissions reductions consistent with the 2°C climate target, limiting health-damaging air pollution, and improving energy security.

The analysis estimates the global cost of reaching universal access with a specific focus on Sub-Saharan Africa, Southern Asia, and Pacific Asia, which are home to the bulk of the populations without access today. For modern cooking solutions, the model puts forth critical policy measures—assuming a final transition to LPG (as a proxy for modern cooking solutions) for those who have access to it and can afford it as well as microfinance options to enable households to finance new cookstoves. In the scenarios that meet SE4ALL objectives, the model assumes 50 percent fuel subsidies for LPG (70 percent for Sub-Saharan Africa) and microfinancing to purchase cookstoves at a 15 percent interest rate. This model internalizes the demographic and income changes associated with growth in these regions. For electrification, the GEA pathways assume achievement of near-universal power supply through grid-based options. Mini-grid and off-grid options are not included in the model. The SE4ALL scenario assumes a 100 percent electrification rate in all regions and consumption of 420 kWh/household/year arising from the use of 115 watts for 10 hours a day (for television, lighting, refrigeration, and other small appliances).

The GEA model estimates an annual investment requirement of $71.3 billion for modern cooking facilities and $15.2 billion for rural electrification to reach universal access by 2030. These figures are the same across all the six energy pathways. This total of more than $85 billion annual spending is several times higher than the $9.6 billion currently spent annually to expand access.



SOURCE: RIAHI AND OTHERS 2012.
NOTE: SSA = SUB–SAHARAN AFRICA; SAR = SOUTH ASIA; EAP = EAST ASIA AND PACIFIC.

$49 BILLION WILL NEED TO BE INVESTED

EVERY YEAR TO REACH UNIVERSAL ACCESS TO ENERGY BY 2030

Broader implications of universal access, and key barriers

If universal access to modern energy services were achieved, global primary energy demand would be around 167 million tons of oil equivalent (Mtoe) higher in 2030 than under the NPS, an increase of around 1 percent (figure 2.33). Less than half of the additional energy demand would be for fossil fuels, with the remainder coming from renewables. For cooking, an additional 0.85 million barrels per day (mb/d) of LPG would be required in 2030.

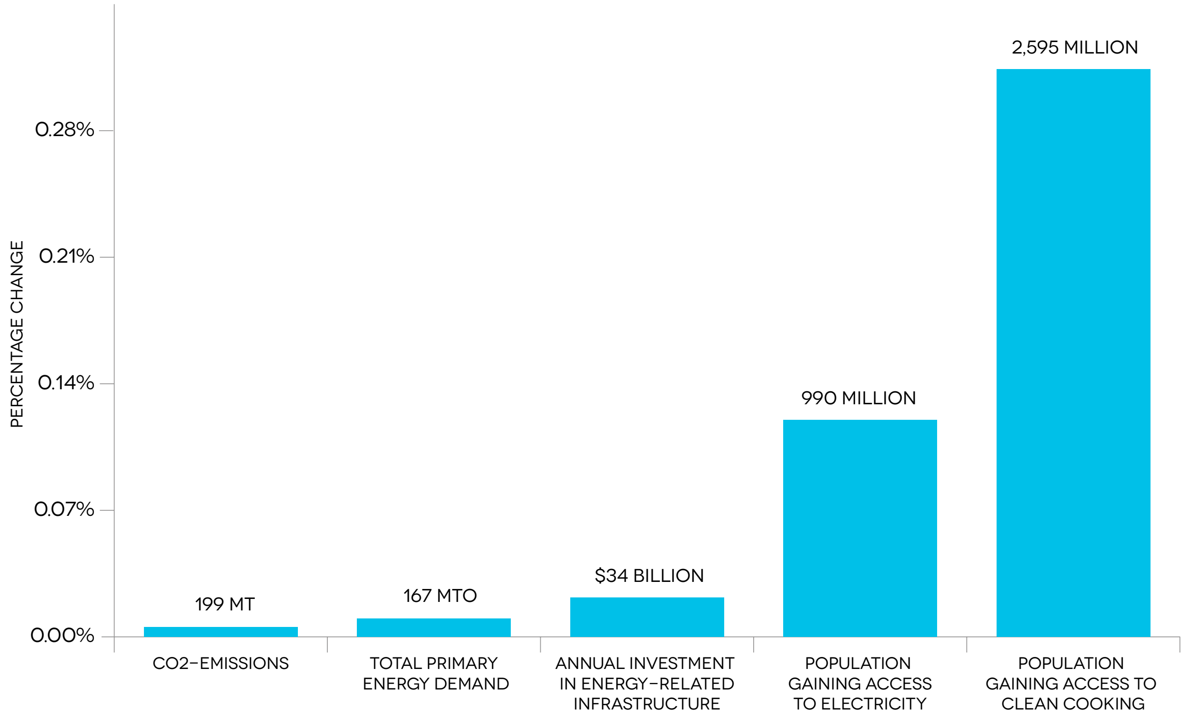


FIGURE 2.33 **ADDITIONAL GLOBAL IMPACT OF UNIVERSAL ACCESS TO MODERN ENERGY SERVICES OVER THE NEW POLICIES SCENARIO, 2030**

SOURCE: IEA 2012.
NOTE: PERCENTAGES ARE A SHARE OF GLOBAL ENERGY–RELATED CARBON DIOXIDE (CO_2) EMISSIONS (2030), GLOBAL PRIMARY ENERGY DEMAND (2030), GLOBAL ENERGY RELATED INFRASTRUCTURE INVESTMENT (ANNUAL AVERAGE, BASED ON THE NEW POLICIES SCENARIO, IN 2010 DOLLARS), AND GLOBAL POPULATION (2030). MT = MILLION TONS; MTOE = MILLION TONS OF OIL EQUIVALENT.

The significant role of renewables in delivering universal access to electricity means that the impact of increased access on global CO_2 emissions is projected to be relatively small, increasing the total by around 0.6 percent (199 Mt) by 2030. Even with such as increase, emissions per capita in those countries achieving universal access would still be less than one-fifth of the OECD average in 2030. The small size of this increase in emissions is attributable to the low level of energy per capita consumed by the people newly provided with modern energy access and to the significant proportion of renewable solutions adopted, particularly in rural and peri-urban households. The diversity of factors involved in these projections means that the estimate of the total impact on greenhouse gas emissions of achieving universal access to modern cooking facilities must be treated with caution. It is, however, widely accepted that advanced stoves and greater conversion efficiency would reduce emissions and thus reduce this projection.

Several barriers must be overcome if universal access to energy is to be achieved. As highlighted by SE4ALL (2012), a set of common elements will have to be put in place to overcome those barriers:

- High-level commitments on the part of each country's political leadership to achieving universal energy access.
- A realistic energy-access strategy and clear implementation plans linked to overall national development and budget processes.
- Strong communication campaigns to inform stakeholders of planned changes and related benefits.
- Sufficient funding to support the delivery of energy services from appropriate sources and at affordable rates. An increase in financing from all sources and in various forms is required, from large projects down to the micro level.
- A robust financial sector, willing to lend to the energy sector and to provide end-user financing.
- A legal and regulatory framework that encourages investment.
- The active promotion of project and business opportunities and a consistent flow of deals or transactions to attract a critical mass of private sector players (such as banks).
- Processes to match actors around specific projects and proposals, particularly in public-private partnerships.
- Energy access for community institutions (for example, rural multifunctional platforms, typically driven by diesel that powers pumps, grain mills, generators etc.).
- The means to support successful small-scale projects and solutions to reach a larger scale.
- Robust and effective public utilities.
- Strong internal capacity, potentially supported by external technical assistance.
- A deliberate effort to improve the availability of accurate and timely information.
- Reconciliation of regional and national interests in energy projects.

While some of these solutions are context-specific and need to be supported by efforts to build the capacity of local institutions, most address generic problems found in all or most countries seeking to deliver access to modern energy. They involve financial, planning, and regulatory measures needed to strengthen the operating environment of private developers and service providers. The barriers are not insurmountable, but they will require the collective strengths of national governments, the private sector, and civil society. The SE4ALL initiative provides a platform for addressing these barriers in a comprehensive manner, offering countries a menu of options based on global good practices.

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ANNEX 1: Approaches to defining and measuring access to energy

METHODOLOGY	NAME	DESCRIPTION	OBJECTIVE
Single indicator	Energy Poverty Line (Barnes, Khandker, and Samad 2011)	Demand-based approach to define an energy poverty line at the threshold point at which households consume a bare minimum level of energy needed to sustain life.	Define a threshold point at which households consume a bare minimum level of energy.
Dashboard of indicators	Energy Indicators for Sustainable Development (IAEA 2005)	Set of 30 indicators of sustainable development aiming to measure the current and future effects of energy use on human health, human society, air, soil, and water to determine whether current energy use is sustainable and if not how to change it.	Measure the social, economic, and environmental impact of energy.
	Energy access situation in developing countries (UNDP/WHO 2009)	Measures percentage of population in developing countries with access (or lack of) to three key areas of energy supply; electricity, modern household fuels, and mechanical power (data limited to 3 countries); plus measures access to improved cookstoves and analyses overall fuel use.	Estimate the penetration rate of modern energy.
	Ecosystem Health Indicator (PPEO 2012)	Set of 17 indicators across three elements of an energy access ecosystem—financing, policy, and capacity.	Evaluate the health of energy-access ecosystems.
Composite index	Energy Development Index (IEA 2004—amended 2010 and 2012)	Tracks progress in a country's transition to the use of modern fuels.	Estimate the penetration rate of modern energy and levels of energy consumption across households and community indicators, compiling a country-level index.
	Multidimensional Energy Poverty Index (Nussbaumer and others 2011)	Measure of deprivation of access to a range of modern energy services affecting individuals.	Measure lack of access to energy services by ownership of appliances.
	Total Energy Access (PPEO 2010)	Categorizes five essential energy access services with quantitative minimum standards.	Set minimum access standards for five energy services.

METHODOLOGY	NAME	DESCRIPTION	OBJECTIVE
Multi-tier	Energy Supply Index (PPEO 2010)	Categorizes three key areas of energy supply with qualitative levels of supply.	Create a multidimensional measure of the quality of energy supply.
	Incremental levels of access to energy services (AGECC 2010)	Multilevel access to energy services: (i) basic human needs, (ii) productive uses, and (iii) modern society needs.	Estimate level of access to energy services through energy usage (kWh/per capita).
	Minimum levels and priorities of access to energy services (EnDev 2011)	Defines minimum levels for three key energy services—(i) lighting (ii) cooking, and (iii) communication and information, based on quantitative and qualitative indicators.	Measure minimum access to basic energy needs in terms of quantity, quality, and affordability.
	Multi-tier standards for cookstoves (GACC/PCIA 2012)	Multi-tier standards for household cookstoves (levels not finalized).	Establish standards for cookstoves in terms of efficiency, safety, and emissions.

SOURCE: AUTHORS' COMPILATION.

ANNEX 2: Compilation of World Bank's Global Electrification Database and World Health Organization's Household Energy Database

An intensive data compilation effort underpins the establishment of the starting point and the analysis of historical evolution presented in this report. Those efforts took form in the World Bank's Global Electrification Database and World Health Organization's (WHO's) Household Energy Database. As a first step in the creation of the two databases, data on electrification and use of primary fuels for cooking were collected from nationally representative household surveys, including the United States Agency for International Development's (USAID's) demographic and health surveys (DHS) and living standards measurement surveys (LSMS), the Nations Children's Fund's (UNICEF's) multiple indicator cluster surveys (MICS), the WHO's World Health Survey, and other nationally developed and implemented surveys, and from various government agencies (for example, ministries of energy, utilities).

This data-gathering effort resulted in 126 data points for electrification and 142 countries for household energy around the starting point in 2010 (latest year available) (figure A2.1). For electrification the major sources are the DHS and LSMS. For cooking solutions, data are primarily from the DHS, national census or national household surveys, and MICS.

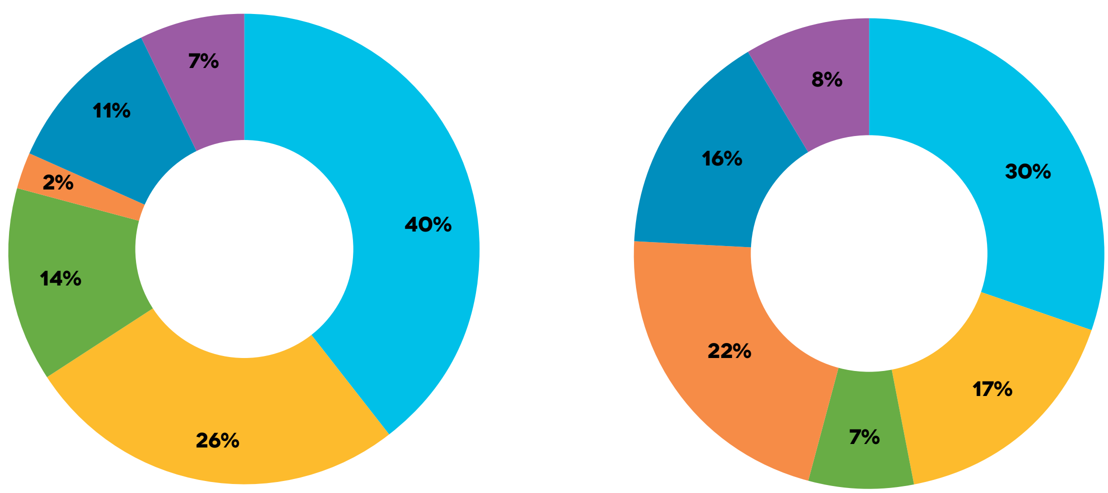

FIGURE A2.1 **DISTRIBUTION OF SURVEY SOURCES FOR ORIGINAL DATA—LATEST YEAR AVAILABLE**

DHS LSMS/IE CENSUS MICS
OTHER SURVEYS NON SURVEY

DHS LSMS/IE CENSUS MICS
OTHER SURVEYS WHS

SOURCE: AUTHORS

NOTE: HH = HOUSEHOLD; DHS = DEMOGRAPHIC AND HEALTH SURVEY; IES = INTEGRATED EXPENDITURE SURVEY; LSMS = LIVING STANDARD MEASUREMENT SURVEY; MICS = MULTIPLE INDICATOR CLUSTER SURVEY; WHS = WORLD HEALTH SURVEY

To develop the historical evolution and starting point of electrification rates, a simple modeling approach was adopted to fill in the missing datapoints – around 1990, around 2000, and around 2010. Therefore, a country can have a continuum of zero to three datapoints. For 42 countries there are no observed rates in all the time series and 170 countries have between one and three datapoints. For the latter group of countries, a model with region, country, and time variables was used to estimate the missing observations. The model keeps the original observation if data is available for any of the time periods. For the former group of countries, the weighted regional average was used as an estimate for electrification in each of the data periods (see annex 2). This modeling approach allowed the estimation of electrification rates for 212 countries over these three time periods.

First over, the sample of countries for which there was at least one observation the following model was estimated:

$$y = \alpha * R + \beta * C + \delta * time + u$$

Where R denotes region dummies, t denotes time dummies; y denotes percentage with access, C denotes a vector of dummy variables reflecting the country. The α; β and δ are unknown parameters and u is an error term.

For the sake of constructing the series, the model then uses the latest access rates available from the above household surveys. For those countries with at least one observation but missing values the study then uses the estimates of β ; α and δ to make predictions of the missing values.

For predicting access for countries with no observed values for any time period the study estimates the model over the following model over the sample which is available.

$$y = \alpha_1 * R + \delta_1 * time + u_1$$

where R denotes region dummies, t denotes time dummies; and y denotes percentage with access. The α_1 and δ_1 are unknown parameters and u_1 is an error term. For those countries with no observations the study then uses the estimates of α_1 and δ_1 to make predictions.

In the case of WHO Global Household Energy Database, a mixed model was used to derive solid fuel use estimates for 193 countries. Generating time-series curves for countries based on available actual data points has several advantages. It can derive point estimates for those countries for which there are no data by using regional trends. It also incorporates all the available data to derive point estimates and is not unduly influenced by large fluctuations in survey estimates from one year to the next. For example, in the case of household cooking solutions in Namibia, household survey data for use of solid fuels are available for 1991, 2000, 2001, 2003, and 2006, but not for 2010. Using the mixed model, an estimate of 55 percent was obtained for Namibia in 2010. For Nepal an even greater number of surveys are available (n = 8), some of which report substantially different estimates. Looking at the Nepal graph (figure A2.3), it is evident that the mixed model derives estimates that lie at or near the median of various survey estimates and derives a reasonable estimate of 82 percent for 2010.

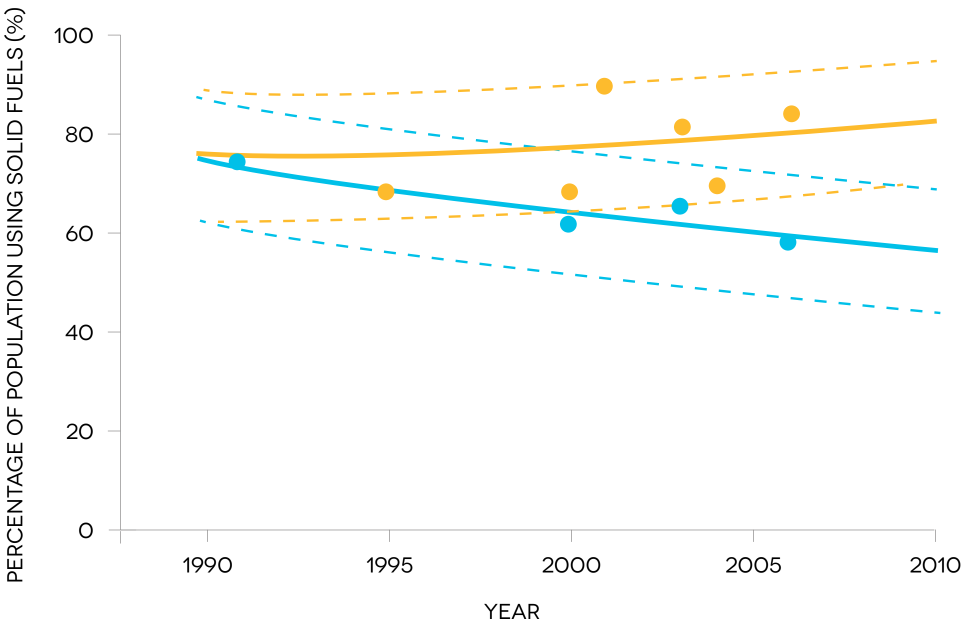

FIGURE A2.3 **EXAMPLE OF MODEL ESTIMATES IN SELECTED COUNTRIES**

NAMIBIA SURVEY DATA MODEL ESTIMATE 95% CONFIDENCE INTERVAL

NEPAL SURVEY DATA MODEL ESTIMATE 95% CONFIDENCE INTERVAL

SOURCE: WHO.

Finally, the World Bank Global Electrification Database encompasses 212 countries and WHO Household Energy Database includes 193 countries, both representing near universal coverage of global population (table A2.1).

	COUNTRY COVERAGE	% OF POPULATION
Electricity		
Household survey data available	126 *	96 *
Data from model estimates	212	100
Household cooking fuel		
Household survey data available	142 *	97 *
Data from model estimates	193	99.6

* REFERS ONLY TO LOW- AND MIDDLE-INCOME COUNTRIES.

ANNEX 3: Matrix for measuring household access to electricity supply and electricity services

Supply tiers

ATTRIBUTES

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Quantity (peak available capacity)	—	>1W	>50W	>200W	>2,000 W	>2,000 W
Duration of supply (hours)	—	>4	>4	>8	>16	>22
Evening supply	—	>2	>2	>2	4	4
Affordability (of a standard consumption package)	—	—	Affordable	Affordable	Affordable	Affordable
Legality	—	—	—	Legal	Legal	Legal
Quality (voltage)	—	—	—	Adequate	Adequate	Adequate

	TIER 0		TIER 1		TIER 2		TIER 3		TIER 4		TIER 5	
				Watts		Watts		Watts		Watts		Watts
Likely feasible applications (May not be actually used) (Wattage is indicative)			Radio Task lighting Phone charging	1 1 1	Radio Task lighting Phone charging General lighting Air circulation Television Computing Printing Etc.	 18 15 20 70 45	Radio Task lighting Phone charging General lighting Air circulation Television Computing Printing Air cooling Food processing Rice cooking Washing machine Etc.	 240 200 400 500	Radio Task lighting Phone charging General lighting Air circulation Television Computing Printing Air Cooling Food processing Rice cooking Washing machine Water pump Refrigeration Ironing Microwave Water heating Etc.	 500 300 1,100 1,100 1,500	Radio Task lighting Phone charging General lighting Air circulation Television Computing Printing Air Cooling Food processing Rice cooking Washing machine Water pump Refrigeration Ironing Microwave Water heating Air conditioning Space heating Electric cooking Etc.	 1,100 1,500 1,100
Possible electricity supply technologies	Dry cell Solar lantern Rechargeable batteries Home system Mini-grid/grid		— Solar lantern Rechargeable batteries Home system Mini-grid/grid		— — Rechargeable batteries Home system Mini-grid/grid		— — — Home system Mini-grid/grid		— — — Home system Mini-grid/grid		— — — Home system Mini-grid/grid	

NOTE: — = NOT APPLICABLE

Service tiers

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Actual use of indicative electricity services	—	Task lighting AND phone charging OR electric radio	General lighting AND television AND air circulation	Tier 2 package AND light and discontinuous application (thermal or mechanical)	Tier 3 package AND medium and/or continuous application (thermal or mechanical)	Tier 4 package AND heavy and/or continuous application (thermal or mechanical)

SOURCE: AUTHORS' COMPILATION.
NOTE: — = NOT APPLICABLE

ANNEX 4: Technical performance standards for cookstoves

In February 2012, the Global Alliance for Clean Cookstoves (the Alliance) in collaboration with the World Health Organization (WHO) and International Standards Organization (ISO) achieved an International Workshop Agreement (IWA) on multi-tier standards for measuring technical performance of cookstoves. The IWA acknowledges the emerging scientific consensus that not all reductions in emissions are of equal value to human health and to climate change. The IWA multi-tier guidelines provide the basis for measurement of cookstove performance on the four technical attributes—efficiency, indoor pollution, overall pollution, and safety.

TECHNICAL ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4
Efficiency	HPTEa (%) LPSCb (MJ/min/L)	>15 >0.05	<15 <0.05	>25 <0.039	>35 <0.028	>45 <0.017
Indoor pollution	CO (g/min) PM (g/min)	>0.97 >40	<097 <40	<0.62 <17	<0.49 <8	<0.42 <2
Overall pollution	HPCOc (g/MLd) LPCOd (g/min/L) HPPMe (mg/MJd) LPPMf (mg/min/L)	>16 >0.2 >979 >8	<16 <0.2 <979 <8	<11 <0.13 <386 <4	<9 <0.1 <168 <2	<8 <0.09 <41 <1
Safety	Iowa protocol	<45	<45	>75	>88	>95

SOURCE: AUTHORS' COMPILATION.
NOTE: — = NOT APPLICABLE

The above guidelines could potentially form the basis for determining the overall technical performance of the primary and secondary cookstoves as the first step in the multi-tier measurement of household access to cooking solutions. In addition to technical performance of primary and secondary cookstoves (including the use of non-solid fuels), measurement of household access to cooking solutions takes into account the conformity, convenience, and adequacy attributes for the household as a whole, as indicated in figure 2.4 of this document.

It should be noted that the IWA standards have been developed separately for each technical parameter and are not designed to be aggregated to obtain an overall rating for the cookstove. The different technical parameters have been kept separate in the IWA to allow programs, donors, investors, and consumers the ability to distinguish and prioritize between different parameters.

ANNEX 5: Mapping of consumption ranges to proposed multi-tier measurement of access

APPLIANCES	WATT$_{EQ}$ PER UNIT	HOURS/ DAY	TOTAL (KWH/ YEAR)	BASIC ACCESS	ADDITIONAL ACCESS			
				TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Radio	1	2	0.7	**0.7**	0.7	0.7	0.7	0.7
Task lighting	1	4	1.5	**1.5**	1.5	1.5	1.5	1.5
Phone charger	1	2	0.7	**0.7**	0.7	0.7	0.7	0.7
General lighting	18	4	26.3		26.3	26.3	26.3	26.3
Air circulator (fan)	15	4	21.9		21.9	21.9	21.9	21.9
Television	20	2	14.6		14.6	14.6	14.6	14.6
Food processors	200	1	73.0			73.0	73.0	73.0
Washing machine	500	1	182.5			182.5	182.5	182.5
Refrigerator	300	8	876.0				876.0	876.0
Iron	1,100	0.3	120.5				120.5	120.5
Air conditioner	1,100	2	803.0					803.0
				3	66	321	1,318	2,121

SOURCE: AUTHORS' COMPILATION.
NOTE: WATT$_{EQ}$ = WATT EQUIVALENT; KWH = KILOWATT-HOUR.