WORLD BANK GROUP
Supported by ESMAP
Energy Sector Management Assistance Program
livewire
A KNOWLEDGE NOTE SERIES FOR THE ENERGY & EXTRACTIVES GLOBAL PRACTICE
2014/16

THE BOTTOM LINE

The multi-tier approach to measuring energy access proposed in the SE4ALL Global Tracking Framework of 2013 introduces a five-tier measurement methodology based on various energy attributes, such as quantity, quality, affordability, and duration of supply. The approach makes it possible to compute a weighted index of access to energy for a given geographical area. Separate notes focusing on multi-tier measurement of energy access for households, productive enterprises, and community institutions will extend the application of the new approach.

Mikul Bhatia is a senior energy specialist in the World Bank's Energy Practice (mbhatia2@worldbank.org).

Nicolina Angelou is an energy economist in the same practice (nangelou@worldbank.org).

Capturing the Multi-Dimensionality of Energy Access

Why is this issue important?

Rapid expansion of access to energy requires both accurate assessment and tracking of progress

Access to energy has gained significant interest from governments and development agencies, particularly since the call for Sustainable Energy for All (SE4ALL) by the Secretary General of the United Nations in 2012. One of the key goals of SE4ALL is to achieve "universal access to modern energy services by 2030" (SE4ALL 2012). Achieving that goal will require a concerted international effort, substantial new investment, the deployment of new technologies, and a wide range of interventions targeted on underserved populations.

The success of such interventions depends in part on the ability to assess the level of access to energy—both planning and investment, and, later, for monitoring of progress. Detailed baseline data can help support policy formulation, investment strategies, and project design, as well as better ex ante estimation of the likely impact of projects on access. For example, baseline data may reveal that a high proportion of the population in an area has 24 hours per day of electricity but suffers from frequent unscheduled outages; or that most households use liquefied propane gas (LPG) as their primary cooking fuel, but often use charcoal because of frequent shortages of LPG cylinders.

Regular and sustained data collection can also be used to evaluate how well a given project has done in improving energy access. It can help utilities to become more accountable and transparent by comparing household survey data with utility data, for example, in terms of unscheduled outages or voltage levels. In addition, comprehensive data may lead to a better assessment of the linkages between energy access and energy poverty[1] by evaluating, for example, the impact of a solar home system project on the rate of access to information and entertainment through television.

What does access to energy mean?

A full definition of energy access must be multi-dimensional

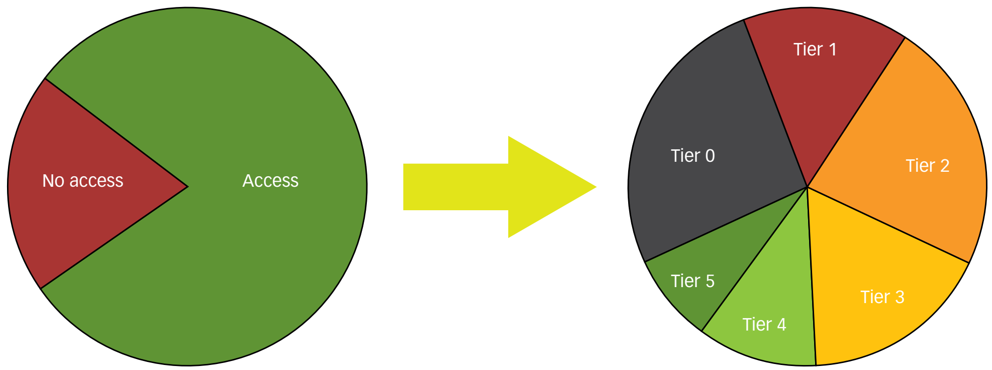
There are two initial challenges in defining and measuring energy access: the absence of a universal definition of energy access and the difficulty of measuring any definition in an accurate manner. Such difficulty lies within the multi-dimensional nature of access to energy. For example, multiple sources of energy, delivered through a range of diverse technologies, across grid-based and off-grid systems, need to be captured (IEA 2012). Also, energy is used in a wide spectrum of applications, ranging from lighting to communication and entertainment, air circulation, refrigeration, cooking, heating, and so on. The practice of "fuel stacking"—the parallel use of multiple fuels, particularly for cooking—complicates data capture because it goes beyond the simple concept of an "energy ladder" and because data on simultaneous use of multiple energy sources are scarce (Davis 1998; Heltberg 2004; Masera, Diaz, and Berrueta 2005). Finally, energy is not only needed at the household level but is also essential

---

1 Energy poverty is defined here as being deprived of certain energy services that fulfill basic human needs in a healthy, convenient, and efficient manner.

> "Access is defined as the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive enterprises, and community institutions."

Figure 1. Binary versus multi-tier measurement



Source: ESMAP 2014.

for productive enterprises in every sector (EUEI 2011), as well as for community institutions (such as schools, hospitals, and public buildings) (Cabraal, Barnes, and Agarwal 2005).

To date, access to electricity has typically been measured as having a household electrical connection, while access to modern cooking solutions has been measured as cooking with clean nonsolid fuels.[2] The first SE4ALL Global Tracking Framework report released in May 2013 used such binary metrics to determine starting points against which progress toward universal energy access can be measured, as available data did not generally allow for a more elaborate measure (Banerjee and others 2013). These binary metrics, although convenient, fail to capture the multidimensional nature of energy access.

Would the SE4ALL goal be deemed achieved if every household had electric lighting? Or should every household own a television as well? What about a refrigerator? Is energy access to be defined by round-the-clock power, or are four hours per day of electricity sufficient? Likewise, what would qualify a household as having access to modern cooking solutions? Should every household be cooking with nonsolid fuels such as LPG or electricity? What about improved cookstoves that use solid fuels and that are as clean and efficient as those using nonsolid fuels? Is any amount of time and effort involved in collecting fuel considered acceptable? How do tariffs figure in the equation? In other words, does energy have to meet an affordability standard before being counted toward universal access? How should energy access be measured in productive enterprises or community institutions?

All of these questions can be addressed by a more comprehensive definition of energy access.

What is the new approach?

Energy access is measured across five tiers and eight attributes of energy

Any new approach to defining and measuring energy access should be technology-neutral (Bazilian and others 2010). That is, it should assess all energy sources fairly—from solar lanterns to power plants, from improved cookstoves to natural gas distribution. Ideally, it should reflect the impact of all energy interventions—from generation to transmission and distribution, as well as pricing reforms and energy efficiency regulations. Energy applications should be kept at the core of the approach in order to be meaningful to users. The approach should be applicable not only to households but to productive enterprises and community institutions as well. Finally, it should also allow a diverse range of data to be compiled into an index while identifying specific deficiencies of the energy supply.

2 Nonsolid fuels include (i) liquid fuels (for example, kerosene, ethanol, or other biofuels), (ii) gaseous fuels (such as natural 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).

> "In the multi-tier approach to measuring access to energy, tiers are defined based on a combination of attributes that reflect the performance of the energy supply.... Each tier reflects the ability of the energy supply to cater to specific energy applications."

Such an approach to energy access has now been developed by the World Bank/ESMAP in consultation with a host of development agencies and programs, including EnDev, Lighting Africa, Practical Action, The Global Alliance for Clean Cookstoves, the UN Development Programme, the UN Industrial Development Organization, the World Bank, and the World Health Organization. Under the approach, access is defined as the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive enterprises, and community institutions (ESMAP 2014).

Based on this definition, a new measurement methodology has been devised around multiple tiers of energy usability (figure 1). The basic idea behind multi-tier approaches was initially proposed by the United Nations Secretary General's Advisory Group on Energy and Climate Change (AGECC 2010), the Energizing Development (EnDev) program (EnDev 2011), Poor People's Energy Outlook (Practical Action 2010), and the Global Alliance for Clean Cookstoves (PCIA 2012). This concept has now been further developed under an ESMAP-financed activity at the World Bank called Defining and Measuring Access to Energy for Socio-Economic Development. A summary of the emerging multi-tier framework that builds on the earlier attempts is presented here.

In the multi-tier approach to measuring access to energy, tiers are defined based on a combination of attributes that reflect the performance of the energy supply. A simplified matrix of tiers and attributes is presented in table 1. Specialized matrices for household electricity, cooking, and heating, and for productive enterprises and

Table 1. Simplified multi-tier matrix of energy access

Attributes of energy supply		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Household electricity	No electricity[a]	Very low power	Low power	Medium power	High power	
	Household cooking	Inadequate capacity of the primary cooking solution				Adequate capacity of the primary cooking solution	
Duration and availability	Household electricity	<4 hours	4–8 hours		8–16 hours	16–22 hours	>22 hours
	Household cooking	Inadequate availability of the primary cooking solution				Adequate availability of the primary cooking solution	
Reliability	Household electricity	Unreliable energy supply				Reliable energy supply	
Quality	Household electricity/cooking	Poor quality of energy supply			Good quality of energy supply		
Affordability	Household electricity	Unaffordable energy supply		Affordable energy supply			
	Household cooking	Unaffordable energy supply				Affordable energy supply	
Legality	Household electricity	Illegal energy supply			Legal energy supply		
Convenience	Household cooking	Time and effort spent sourcing energy cause inconvenience			Time and effort spent sourcing energy do not cause inconvenience		
Health and safety	Household electricity	Unhealthy and unsafe energy system				Healthy and safe energy system	
	Household cooking[b]	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5

Source: World Bank/ESMAP (forthcoming 2014).

a. The detailed multi-tier matrix for household electricity considers a continuous variable between tier 0 and tier 1 for basic lighting services so as to capture the contribution of solar lamps that do not reach the minimum output threshold required for tier 1 access but that are highly affordable and enable households to reduce or eliminate the use of kerosene for lighting.

b. Levels are defined based on the technical performance of the cookstove (for example, in terms of efficiency, pollution, and safety), kitchen ventilation, and conformity of usage (use of required accessories, regular cleaning, and so on.)

"The type of data required for a multi-tiered assessment of energy access in a given area would have to be obtained through surveys of actual energy availability and use among a scientific sample of all users in a given category."

community institutions, will be presented in follow-on briefs in the *Live Wire* series.

Depending on the attribute, indicators may be binary (yes or no) or have multiple thresholds (gradations). Once every attribute has been assessed, the overall tier for the household, the enterprise, or the community institution is calculated by applying the lowest tier of any of the attributes. For example, with reference to table 1, if a household reliably and legally obtains electricity of adequate wattage for 12 hours each day but that electricity is not affordable, access tier for that household remains in tier 2.

Each tier reflects the ability of the energy supply to cater to specific energy applications. For example, with reference to electricity for households, tier 1 encompasses basic lighting and phone charging, whereas tier 2 includes a television and electric fan. In tier 3, the use of light and discontinuous thermal or mechanical applications is made possible (such as washing machines or food processors), while tiers 4 and 5 enable heavier and continuous applications, such as air-conditioning and space heating.

Where do the data come from?

Energy surveys are an essential data-collection tool

The type of data required for a multi-tiered assessment of energy access in a given area would have to be obtained through surveys of actual energy availability and use among a scientific sample of all users in a given category (households, enterprises, community institutions). Survey questionnaires would elicit information about each energy attribute, and the results would be fed into the multi-tier matrices.

Data may also be collected from energy suppliers to indicate the tiers of access that specific projects may deliver to a targeted population. Such supply-side assessments of energy access are based mainly on the specifications of delivered assets (for example, the capacity of a solar home system or the efficiency of a cookstove). Complementary research into the local context (household income levels, fuel collection time, fuel shortages, and so on) may be carried out through focus groups or small-sample surveys to round out the information on the rest of the attributes.

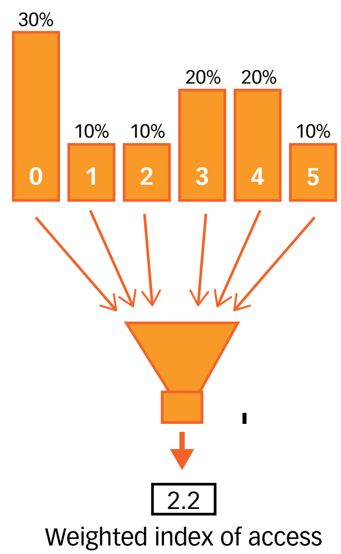
Such supply-side evaluations help estimate the impact that projects or programs may claim to have or may have had in a selected area. They can be performed more quickly and cheaply than surveys of actual energy availability and use. However, they must be validated by periodic demand-side surveys, which more accurately reflect the actual level of access in a given area.

What results does the multi-tier framework yield?

"Energy access diagnostics" deliver disaggregated data analysis and an access index

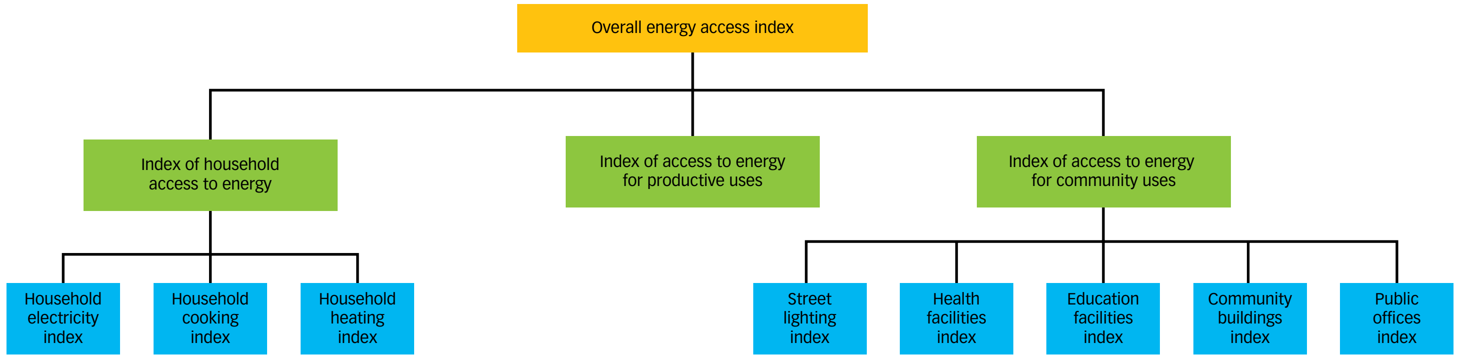
Under the new multi-tier framework, data from energy surveys are compiled and analyzed to produce an energy access diagnostic for a given area. The diagnostic includes an in-depth disaggregated data analysis and an aggregate analysis comprising a series of indices of energy access.

Figure 2. Weighting of tiers to arrive at an index of access to energy



Source: ESMAP 2014.

Figure 3. Indices of energy access for households, enterprises, and community institutions



Source: ESMAP 2014.

"A simple energy access index can be calculated by weighting the tiers and arriving at a weighted average. The index evaluates both the extent of access and its intensity."

Data from questions related to the performance of the energy supply are used to assess deficiencies in various energy attributes. For example, among the various indicators for household electricity that can be calculated are: (i) the proportion of households connected to the grid, (ii) the proportion of legal connections, (iii) the proportion of people receiving electricity in the evening, (iv) the average number of hours of supply, (v) the proportion of households reporting problems of low voltage, (vi) the proportion of households using solar lanterns, (vii) the proportion of households using home systems (solar or other), (viii) the proportion of households using rechargeable batteries, (ix) the average number and length of unscheduled interruptions experienced by households, and (x) the proportion of households that are unable to afford greater use of electricity.

Demographic and economic data pertaining to households may be used to complement the diagnostic analysis. For example, the affordability of electricity for various income quintiles can be examined in light of the prevailing tariff structure and how modification of that structure could make electricity more affordable for households at lower-income quintiles. Moreover, environmental conditions, such as housing characteristics, can provide insight into household choices, health issues, or affordability. Such diagnostics can provide useful inputs for policy formulation, project design, utility performance accountability, regulatory processes, and evaluations of project impact.

To compile the information captured by the multi-tier matrix into a single number representing the level of energy access across a selected geographical area—an approach akin to the Human Development Index (UNDP 2014)—a simple energy access index can be calculated by weighting the tiers and arriving at a weighted average (figure 2). The index evaluates both the extent of access (how many households have access) and the intensity of that access (the level of access that households have). It can be easily aggregated across geographic areas and tracked over time.[3]

Using the same concept of an overall energy access index, indices can be calculated for households, productive enterprises, and community institutions to provide an overall picture of the energy access situation in a given geographical area, making it possible to spot gaps and opportunities for improvement in specific cases (figure 3).

[3] This aggregation method is used by the Multi-Dimensional Energy Poverty Index of Nussbaumer, Bazilian, and Modi (2012).

“Under this logical framework, not only the output (for example the delivery of solar home systems, or MWh of electricity) but also the outcome (the usability of energy supply for energy applications) needs to be assured by the energy provider.”

As noted, the multi-tier approach requires data from energy surveys that are costly, time-consuming (taking months to complete), and need to be repeated every few years. Governments may be tempted to bypass this effort in the interest of saving resources that could be directly used to increase energy access. However, the data make possible a more accurate measurement of energy access and an improved understanding of the underlying shortfalls, both of which are crucial for the success and sustainability of energy projects.

How does this approach affect our thinking?

All energy interventions have an impact on energy access by improving attributes of energy supply

Defining and measuring energy access by considering attributes of energy supply yields a better understanding of how various interventions improve access. Energy access projects are typically thought of as those that either provide additional grid connections or deliver off-grid systems, such as solar lanterns or solar home systems. However, other types of projects also contribute to improving energy supply and may have a positive effect on access (table 2). For example, a

Table 2. Electricity interventions and their potential effect on access

	Project type	Grid connections	Legality	Peak capacity (W)	Duration (hours)	Evening supply	Quality (voltage)	Reliability (outages)	Affordability
Typical energy access projects	Grid electrification	↑	↑	↑	↑				↑
	Mini-grid electrification	↑		↑	↑	↑	↑	↑	↑
	Off-grid and solar lanterns			↑	↑	↑		↑	↑
Other energy projects	Generation and X-border T/M	↑			↑	↑	↑	↑	↑
	Transmission and distribution	↑	↑				↑	↑	↑
	Rural feeder segregation		↑		↑	↑	↑	↑	↑
	Energy efficiency			↑	↑	↑			↑
	Regulations and market reform	↑	↑	↑	↑	↑	↑	↑	↑

↑ Positive impact of intervention on energy attributes

Source: ESMAP 2014.

> "The multi-tier measurement of energy access allows governments to set their own targets by choosing any tier above tier 0."

generation project may allow for longer hours of supply and improve voltage; an efficiency intervention may increase the duration of supply or improve affordability. Such contributions, which cannot be accounted for under the traditional definition of energy access, are reflected in the multi-tier approach.

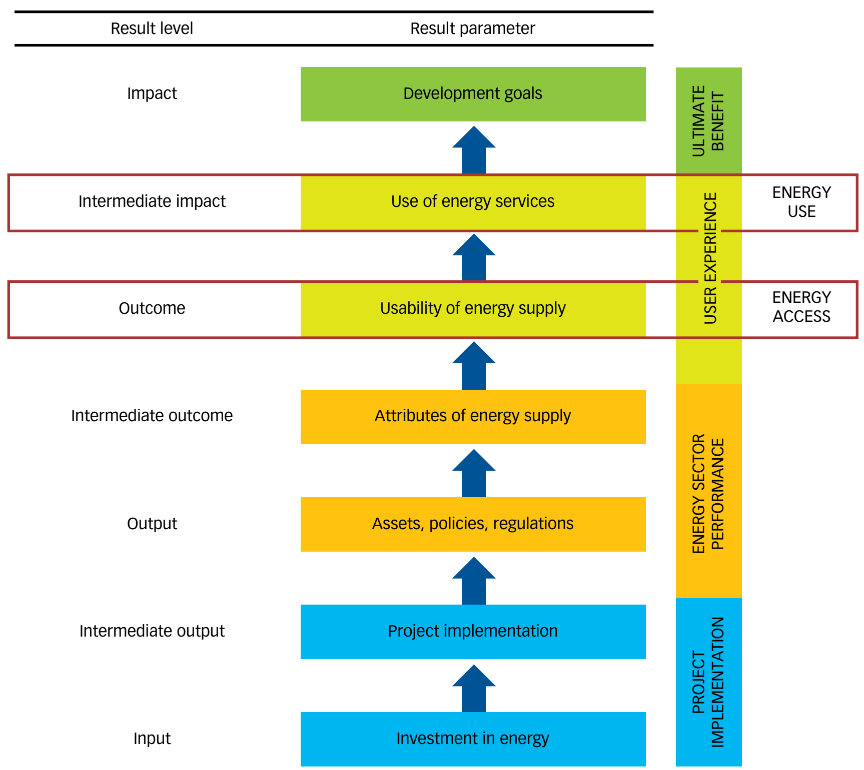
By improving energy access, energy interventions contribute to the achievement of development goals through a series of result levels described by the energy result chain shown in figure 4. Energy investments (inputs) lead to the delivery of assets or to policy reforms (outputs), which in turn improve one or more attributes of energy supply (intermediate outcomes), such as greater availability, improved quality, or increased affordability of energy. Collectively, these attributes increase the usability of the energy supply, thus improving energy access (outcome) and, eventually, the actual use of energy services (intermediate impact). This in turn facilitates the achievement of developmental goals (impact).

As the individual attributes of the energy supply improve, a growing number of energy services becomes feasible, thus widening access to energy. Under this logical framework, not only the output (for example the delivery of solar home systems or MWh of electricity) but also the outcome (the usability of energy supply for energy applications) needs to be assured by the energy provider.

The adoption of the multi-tier approach for measuring energy access as a standard tool for planning, monitoring, and evaluating energy access interventions will allow a better understanding of how energy interventions can be translated into development goals.

The multi-tier measurement of energy access allows governments to set their own targets by choosing any tier above tier 0. Such targets will depend on the situation in a country, its development status, the needs of its population, and the budget available. For example, countries in which a high proportion of the population lacks electricity in any meaningful form might set a target of moving people from tier 0 to tier 1 to ensure basic lighting services, whereas countries in which most people already have some form of access to electricity could focus on moving people into tier 4 or 5. Similarly, countries with a low penetration of LPG or natural gas for cooking may decide to launch a program to introduce advanced biomass cookstoves that would move households into the middle tiers (2 or 3), while other countries may focus on higher tiers by increasing natural gas connections. Where funding is limited, governments will need to make trade-offs, for example between moving more people to tier 1 or 2 or raising some percentage of the population to higher tiers.

Figure 4. Energy result chain



Source: ESMAP 2014.

MAKE FURTHER CONNECTIONS

Live Wire 2014/7. "Understanding Differences Between Cookstoves," by Koffi Ekouevi, Kate Kennedy Freeman, and Ruchi Soni.

Live Wire 2014/8. "Widening Access to Nonsolid Fuel for Cooking," by Sudeshna Ghosh Banerjee, Elisa Portale, Heather Adair-Rohani, and Sophie Bonjour.

Live Wire 2014/9. "Expanding Access to Electricity," by Sudeshna Ghosh Banerjee and Elisa Portale.

References

AGECC (Advisory Group on Energy and Climate Change). 2010. *Energy for a Sustainable Future.* The Secretary General's Advisory Group on Energy and Climate Change, Summary Report and Recommendations. New York: United Nations.

Banerjee, Sudeshna, Mikul Bhatia, Gabriela Elizondo Azuela, Ivan Jaques, Ashok Sarkar, Elisa Portale, Irina Bushueva, Nicolina Angelou, and Javier Gustavo Inon. 2013. *Global Tracking Framework* (vol. 3). Working Paper 77889, World Bank, Washington, DC. May. http://documents.worldbank.org/curated/ en/2013/05/17765643/global-tracking-framework-vol-3-3- main-report.

Bazilian M., P. Nussbaumer, A. Cabraal, R. Centurelli, R. Detchon, D. Gielen, H. Rogner, M. Howells, H. McMahon, V. Modi, N. Nakicenovic, B. O'Gallachoir, M. Radka, K. Rijal, M. Takada, and F. Ziegler. 2010. "Measuring Energy Access: Supporting a Global Target." Earth Institute, Columbia University, New York.

Cabraal, R. A., D. Barnes, S. G. Agarwal. 2005. "Productive Uses of Energy for Rural Development." *Annual Review of Environment and Resources* 30: 117–44.

Davis, M. 1998. "Rural Household Energy Consumption: The Effects of Access to Electricity—Evidence from South Africa." *Energy Policy* 26 (3): 207–17.

EnDev (Energizing Development). 2011. *EnDev's Understanding of Access to Modern Energy Services.* Unpublished presentation. GIZ and NL Agency.

ESMAP (Energy Sector Management Assistance Program). 2014. A New Multi-tier Approach to Measuring Energy Access. http://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Multi-tier%20BBL_Feb19_Final_no%20annex.pdf.

EUEI (European Union Energy Initiative). 2011. *Productive Use of Energy—PRODUSE: A Manual for Electrification Practitioner.* Eschborn, Germany: GIZ.

Heltberg, R. 2004. "Fuel Switching: Evidence from Eight Developing Countries." *Energy Economics* 26 (5): 869–87.

IEA (International Energy Agency). 2012. *World Energy Outlook*. 2012. Paris.

Masera, O. R., R. Diaz, and V. Berrueta. 2005. "From Cookstove to Cooking Systems: The Integrated Program on Sustainable Household Energy Use in Mexico." *Energy for Sustainable Development* 9 (1): 25–36.

Nussbaumer P., M. Bazilian, and V. Modi. 2012. "Measuring Energy Poverty: Focusing on What Matters." *Renewable and Sustainable Energy Reviews* 16 (2012) 231–43.

PCIA (Partnership for Clean Indoor Air). 2012. ISO IWA Cookstoves. http://www.pciaonline.org/files/ISO-IWA-Cookstoves.pdf.

SE4ALL (Sustainable Energy for All). 2012. "About us." http://www.se4all.org/about-us/.

UNDP (United Nations Development Programme). 2014. Human Development Index. http://hdr.undp.org/en/statistics/hdi.

World Bank and ESMAP (Energy Sector Management Assistance Program). Forthcoming 2014. "Defining and Measuring Access to Energy for Socio-Economic Development." Washington, DC.

The peer reviewers for this note were Morgan Bazilian (lead energy specialist, mbazilian@worldbank.org) and Dana Rysankova (senior energy specialist, drysankova@worldbank.org), both of the World Bank's Energy Practice.