

Access to Modern Energy

Assessment and Outlook for Developing and Emerging Regions



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About the Global Energy Assessment

The Global Energy Assessment involves specialists from a range of disciplines, industry groups and policy areas in defining a new global energy policy agenda, one that is capable of transforming the way society thinks about, uses and delivers energy and to facilitate equitable and sustainable energy services for all, in particular the two billion people who currently lack access to clean, modern energy.

Coordinated by the International Institute for Applied Systems Analysis (IIASA), the GEA is led by some of the world's leading energy experts, in research, academia, business, industry and policy, representing both the developed and the developing world. GEA is the first ever fully integrated energy assessment analyzing energy challenges, opportunities and strategies for developing industrialized and emerging economies. It is supported by government and non-governmental organizations, the United Nations System and the private sector.

The Assessment is subject to rigorous and independent analysis and review. The final assessment is published by Cambridge University Press and is available online at www.globalenergyassessment.org.

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Table of Contents

| | |
|---|-----------|
| Forewords..... | iv |
| Preface | vii |
| Executive Summary..... | viii |
| Introduction..... | 1 |
| 1. Global Overview of Energy Access | 1 |
| 1.1. What Constitutes Modern Energy Access? | 1 |
| 1.2. The Importance of Access..... | 4 |
| 1.3. Global Status and Trends in Energy Access | 6 |
| 1.4. Summary – Gaps in Global Energy Access | 11 |
| 2. Regional Progress and Lessons Learned..... | 12 |
| 2.1. Africa..... | 13 |
| 2.2. Asia | 16 |
| 2.3. Latin America and the Caribbean | 20 |
| 2.4. Summary – Gaps and Challenges for Universal Access | 23 |
| 3. Scenarios for Achieving Universal Energy Access by 2030 | 24 |
| 3.1. Projections of Access to Clean Cooking Options | 26 |
| 3.2. Projections for Access to Electricity | 28 |
| 3.3. Policy Scenarios till 2030: Impacts, Costs and Benefits..... | 30 |
| 3.4. Summary – Outlook for Achieving Universal Access by 2030..... | 35 |
| 4. Conclusions and Lessons for the Future | 37 |
| 4.1. Success Factors in Energy Access Expansion..... | 37 |
| 5. The Way Forward | 40 |
| 6. References | 41 |

Forewords



Kandeh Yumkella
Director-General
UNIDO

Sustainable energy powers opportunity. Yet 1.4 billion people – one in five globally – lack electricity to light their homes or conduct business. Without access to modern energy, it is not possible to achieve the Millennium Development Goals – the eight-point global agenda adopted by the United Nations in 2000 – including reducing poverty, improving women’s and children’s health, and broadening the reach of education. Energy facilitates social and economic development, offering opportunities for improved lives and economic progress.

Energy access is a matter of equity, first and foremost, but it is also an issue of urgent practical importance – this is the impetus for the UN Secretary-General’s new Sustainable Energy for All (SE4All) Initiative. Universal access to sustainable energy will become the catalyst for the Third Industrial Revolution. “Energy drives economies” – this statement has held the test of time. I would like to extend this notion further to “Sustainable Energy drives Sustainable Economies.” In current times, sustainable growth must take centre stage.

Developed countries face the combined challenge and opportunity of transforming existing energy infrastructure, and developing countries have the opportunity to adopt cleaner, more efficient technology from the start. These objectives reinforce each other in many instances, and achieving them together will power opportunity, maximize socioeconomic development, enhance domestic and international security and help to reduce climate change impacts. Recognising the importance of sustainable energy choices, IIASA and UNIDO, with support of the Global Environment Facility (GEF), have partnered to develop specific tools, reports and technical analysis to support decision makers in addressing the challenge of providing energy services for sustainable development throughout the world.

This report provides evidence and guidelines for policymakers to achieve the goal of universal access to modern energy sources. It investigates the path required for achieving universal access to clean-combusting cooking fuels and stoves, and rural electrification by 2030. It also assesses the situation at global and regional levels, and highlights the types of policies and measures that will be needed to ensure a successful household transition to modern energy in the next decades.

A handwritten signature in blue ink, appearing to read 'Kandeh Yumkella'. The signature is stylized and fluid, written on a white background.



Pavel Kabat
Director/Chief Executive Officer
IIASA

Two decades ago, decision makers from all segments of society gathered in Rio de Janeiro for the United Nations Conference on Environment and Development. The world has undergone a substantial transformation since that time – socially, economically, politically, and in many other dimensions. Along the way, the International Institute for Applied Systems Analysis (IIASA) has informed the policy process at all levels and in many regions of the world, particularly on issues that are too large or complex for any single nation or scientific discipline to solve on its own.

The changing global context has also played a role in shaping IIASA's research agenda for the next decade, with emphasis placed on three interlinked themes: Food and Water, Energy and Climate Change, and Poverty and Equity. Researchers from the Energy Program at IIASA have established a new field of research on modern energy access for development, which lies at the intersection of these three central themes. Their work in this area has focused on analyzing and modeling household energy choices and demand in developing and emerging regions, estimating the benefits of improved access, and assessing the effectiveness and impacts of alternative future policy scenarios for achieving universal modern energy access goals. This research builds on the sustained achievements of IIASA's Energy Program in assessing the multiple benefits of an energy transformation toward sustainable development. It also reflects an increasing focus on identifying short-term, growth-related objectives that can be achieved through policies and actions that simultaneously meet long-term emissions mitigation and sustainability goals by accounting for feedbacks across sectors, regions, populations and time.

The rich tradition of the Energy Program continues today with the finalization of the Global Energy Assessment (GEA), a multi-year, multi-stakeholder activity, which aims to help decision makers throughout the world address the challenges of providing energy services for sustainable development. An analysis of, and outlook for, universal modern energy access has been developed as part of this assessment and is summarized in this report. This work goes beyond the existing literature by presenting a comprehensive and integrated analysis of the challenges, opportunities and strategies, for developing and emerging economies, for achieving universal modern energy access. This study concludes that it is both technically and economically feasible to provide near universal energy access. Although significant financial investments will be required to achieve this goal, the health, environmental and other developmental benefits would be substantial and the additional climate change impacts nearly negligible.

Achieving these targets for modern energy access is of course contingent upon sufficient political and social will, as well as the willingness of decision makers to adopt a more holistic and integrated perspective to sustainable development over the coming decades. Thanks primarily to the support of the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF), this study and the interactive policy tools developed in conjunction help to inform the evolving dialogue by illuminating some of the complex relationships, synergies and trade-offs between the various dimensions of the energy access issue. Having worked at the interface of science and policy for almost three decades, I personally believe there is a key role for cross-disciplinary and systems oriented scientific research and methods to inform policy and to answer fundamental questions facing humanity. As we pass Rio+20, we have the opportunity to take stock of past lessons worldwide, as this report does, and find new solutions to eradicate energy poverty.

A handwritten signature in blue ink, reading "Fred Ky". The signature is written in a cursive style with a large, sweeping initial "F" that loops back over the rest of the name.

Preface

This report provides a high-level assessment of the progress to date, past policies and programs, and future scenarios related to modern energy access developed within the framework of the Global Energy Assessment (GEA). Providing universal access to modern energy for all is a goal increasingly discussed in international and national policy settings. Developing solutions to this challenge is one of the chief aims of policy makers, and for this reason this report attempts to synthesize a multitude of strategic insights that have resulted from the GEA analysis of this issue.

The overarching objective of the report is to provide guidance on how to facilitate the achievement of universal access to clean-combusting cooking fuels and stoves, and rural electrification by 2030. Focus is given to assessing the situation at global and regional levels, as well as to the types of policies and measures that will be needed to ensure a successful household transition to modern energy in the next decades. Of particular note are the assessment of key success factors for enhancing access at a regional level, and estimation of investments required and impacts of achieving a 2030 universal modern energy access target.

This report is complemented by two interactive, web-based analytical tools, which have been developed in support of this study: (1) the IIASA Energy Access Tool (Energy-ENACT), which permits the assessment of alternative future policy scenarios, including an estimation of investment needs and impacts at the global and regional scales; and (2) the GEA Scenario Database, which documents the full suite of GEA pathways in great detail, allowing the user to explore the consequences of different supply and demand-side technology choices for the feasibility and costs of reaching multiple energy objectives at both the global and regional levels.

Executive Summary

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- Key Challenges**
- About 20% of humanity (1.4 billion) today still lives without access to any electricity and 40% (over 3 billion) still depends on solid fuels such as unprocessed biomass, coal, or charcoal for cooking and space heating. Close to 90 percent of rural sub-Saharan Africans lack access to electricity and an equivalent percentage still rely on solid fuels. In China and India, seventy five percent of the rural population still uses solid fuels. Solid fuel use in households accounted for 2.2 million deaths in 2005, and more than 41.6 million lost Disability Adjusted Life Years, with the impacts felt mainly by women and children.
 - The Global Energy Assessment estimates that in the absence of new policies by 2030 about 2.4 billion people in sub-Saharan Africa, South Asia and Pacific Asia will still be relying on solid fuels in their homes, and over 800 million rural inhabitants would lack electricity access. In such a scenario, over 90 percent of rural sub-Saharan Africans and over 80 percent of rural South Asians would still rely on solid fuels. Over 70% of rural sub-Saharan Africans would also continue to remain without an electricity connection.
 - Access to electricity and to modern cooking energy, such as improved biomass cookstoves and LPG, contributes to economic development and to reducing income poverty and hunger, improving education, health, gender equality, and water and sanitation conditions for the poorest segments of society. Increased access to electricity and mechanical power enables an increase in agricultural productivity and the transformation of agrarian economies to industry-based economies. Access to mechanical power can play a vital role in enhancing income and food security, and fostering agricultural growth, small-scale enterprises and manufacturing processes in rural areas.

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- Lessons Learned**
- Between 1990 and 2008, almost 2 billion people gained access to electricity, compared to one billion in the previous two decades. Electricity access has been extended to most households in Northern Africa, China, and South America. A few Asian and sub-Saharan African countries, such as India, South Africa and Ghana, have made significant strides in expanding access, though still to a far greater extent in urban areas. Despite having better access, the poor in urban areas often lack affordable and reliable energy services.
 - Part of the reason that rural electrification rates have been slow to improve is that the institutional model of centralized grid expansion has been suitable for limited rural areas. Villages or communities that are closest to existing grids, have the highest population density, or where economic activity is greatest are generally connected to the grid first. Off-grid electricity access programs, based on local and renewable energy sources, where available, have had some success in remote rural regions in China, Bangladesh, Nepal, India, Brazil, and Argentina, and other countries.

- Successful electrification and fuel transition programs typically involve a strong and sustained government commitment to energy access with dedicated institutions, microcredit or other innovative financing mechanisms combined with subsidies that make energy affordable and its costs recoverable, local community involvement that widens participation and builds sustainable institutions, and flexibility to adapt to local conditions. In addition, the integration of energy access policies with other poverty alleviation policies, incentives for private and other non-governmental entities to provide financing and operate systems, and support for R&D and training have also contributed to the success of access expansion programs.
- Roughly 800 million people worldwide now use improved cookstoves, largely due to efforts in the last two decades in China and a few other countries such as Brazil. Still, the population using solid fuels for cooking and heating has increased over the last decade to 3.2 billion, even though the population share using solid fuels has reduced in many regions. There are few commercial models for large-scale dissemination of affordable cookstoves, particularly for the rural poor. Developing improved cookstove programs that can widely disseminate both affordable and culturally acceptable cookstoves remains one of the biggest challenges of universal energy access.

Looking Forward

- Improving access to modern cooking fuels has the potential to avert between 0.6 million and 1.8 million premature deaths, on average, every year until 2030, including between 0.4 million and 0.6 million deaths per year of children below the age of five in sub-Saharan Africa, South Asia, and Pacific Asia.
- From a technical and economic perspective, providing almost universal access to electricity and modern cooking fuels is achievable by 2030. This will require global investments of US\$36-41 billion annually till 2030, which is approximately 3 percent of total energy infrastructural investments. At the high end of this estimate, about half will need to be spent on electricity access and the rest on improving access to modern cooking fuels.
- This goal may have a negligible or even negative impact on greenhouse gas (GHG) emissions. This is due to the potential to replace inefficient biomass use with modern cooking fuels and kerosene for lighting with electricity. Current technologies that use traditional biomass are associated with significant emissions of greenhouse gases and aerosols due to incomplete combustion.
- Supporting policies that provide a combination of subsidies and microfinance are likely to be most successful and cost-effective in achieving universal access. In addition, government-supported investments towards energy access will need to be considerably ramped up, and targeted to rural and remote areas and poor urban communities. Increasing private sector involvement will also be crucial to reach the level of scale-up in access efforts required over the next decades.

Introduction

The expansion of global access to modern energy presents significant opportunities to influence the sustainable use of energy in developing countries. The importance of expanding energy access is underscored by the ubiquitous role of energy in achieving the Millennium Development Goals (MDG) (Modi, 2005; Karekezi et al., 2012). Since energy supply derives from land and natural resource use, the transition towards modern energy use has environmental impacts at the local, regional and global scale. The following sections describe the importance of energy access, the status of global efforts to achieve universal access, past efforts and challenges faced in achieving and monitoring progress towards this goal, and the lessons learned from these experiences. An assessment of policies needed, financing requirements and implications of achieving a universal energy access target by 2030 are presented as well. Finally, the report concludes with some overarching lessons and a discussion of specific implications for future enhancement of programs and activities.

1. Global Overview of Energy Access

Access to modern forms of energy contributes to economic development and improves the living standards of the poorest segments of society. Energy access can contribute to reducing income poverty and hunger, and improving education, health, gender equality, and water and sanitation conditions. This section describes in more detail the definition and importance of energy access, and provides a brief overview of its global status.

1.1. What Constitutes Modern Energy Access?

Modern energy access typically includes access to three forms of energy, each of which provides distinct but essential benefits for economic and social development: less polluting household energy for cooking and heating, including from improved cookstoves with traditional solid biomass fuels, from liquid and gaseous fuels such as kerosene and LPG or energy from renewable energy sources such as solar; electricity for powering appliances and lights in households and public facilities such as health clinics, schools, and government offices; and mechanical power from either electricity or other energy sources that improve the productivity of labor.

“Access” has been defined in a number of ways, which vary with respect to who is the targeted beneficiary (e.g., villages or households), the types of energy supply that are included (e.g., grid-connected or off-grid electricity), and the characteristics of service that make the service “accessible” (e.g., affordability, reliability, quality and adequacy).

These properties as well as the environmental impacts of providing energy services vary significantly based on the types of energy sources, the characteristics of the energy carriers, the end-use devices that convert energy into services and the conditions in which these devices are deployed. The simplest definition of universal access is the physical availability of modern energy carriers and improved end-use devices such as cookstoves at affordable prices for all. This is the basis for the target of energy access for all by 2030 set by the United Nations Secretary-General's Advisory Group on Energy and Climate Change (AGECC, 2010).

“The global community should aim to provide access for the 2–3 billion people excluded from modern energy services, to a basic minimum threshold of modern energy services for both consumption and productive uses (100 kWh per of electricity and 100 kgoe of modern fuels or roughly 1200 kWh per person per year). Access to these modern energy services must be reliable and affordable, sustainable and, where feasible, from low-GHG-emitting energy sources.”

AGECC (2010)

This report adopts a similar goal as the basis of its analyses and projections, the details of which are discussed in the following sections.

Access Indicators

Indicators for access are important for assessing the progress of policies, projecting demand and investment requirements, and making comparisons across countries (Table 1). The measurement of access is complicated by the subjectivity in its definition. It is widely accepted that access ought to include affordable and reliable supply of energy services with minimal adverse impacts on users and the environment. However, the lack of reliable data on actual service conditions prevents the widespread use of such inclusive measures of access. Furthermore, different indicators of access are in use across countries, making comparisons particularly challenging. For instance, countries often present rural electrification rates in terms of the number of villages with access to electricity, but differ in their implicit definitions of an “electrified village” (Pachauri and Mueller, 2008). India used to consider a village electrified even if no households had access. In Cambodia, the government counted only grid-connected villages even though a large number of villages had micro grids served by independent operators.

The choice of access indicators includes a normative component. What properties should define access, and how much of the chosen properties should be considered as an adequate level of access? For example, should households have a minimum level of electricity demand met and within a certain budget? Should households

have a minimum level of reliability in terms of hours of interruption? Furthermore, since the alleviation of poverty requires the provision of energy to generate livelihoods and provide for common facilities, a broader average quantitative measure beyond that for household consumptive uses would be required to assess the adequacy of energy services for an economy. Researchers have explored the notion of thresholds for basic energy needs (Goldemberg et al., 1985; Imboden and Voegelin, 2000). However, there are no international norms for these indicators. Countries often define their own lifeline energy entitlements. These typically fall in the range of 20–50 kWh for electricity to households and 6–15 kg of LPG for cooking per month, and 10–30 kWh of useful energy per square meter of living space for heating per year.

This report does not endorse any normative assumptions about minimum energy needs. Instead, in the projections of electricity demand the models use a range of minimum electricity consumption levels of 65–420 kWh per household per year, based on assumptions that are discussed in detail in Section 3.

TABLE 1 Key international and national measures and indicators of energy poverty

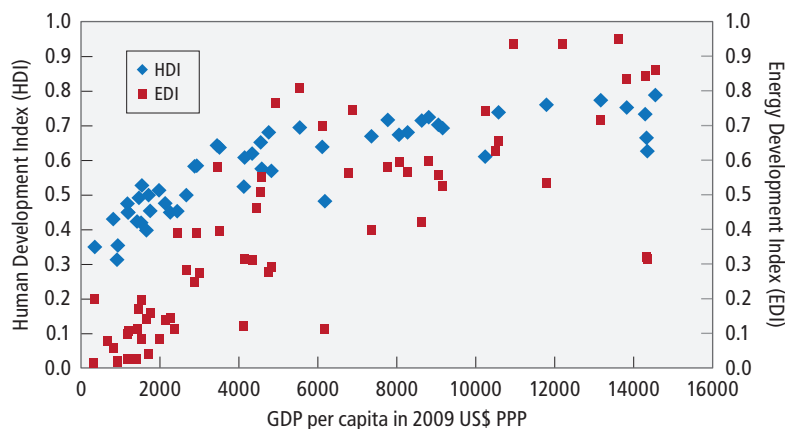
| Scope | Dimensions of energy poverty measured | Indicators/indices | Examples/sources |
|----------------|---|---|--------------------------|
| International | Physical availability or access to energy carriers | Household or population access | UNDP and WHO (2009) |
| | Energy Development Index | Index consisting of 3 equally weighted indicators: per capita commercial energy consumption, share of commercial energy in total final energy use, and the share of the population that has access to electricity | IEA (2010); IEA (2004) |
| National | Physical availability or access to energy carriers | Village or community access | Gol (2001) |
| | Energy services | Minimum level of energy services associated with different needs, e.g. lighting, cooking, etc. | Practical Action (2010) |
| | Affordability | Share of energy expenses in total household budget | Reddy et al. (2009) |
| | | Share of energy expenses and annualised cost of end-use equipment in total household budget | Ekhholm et al. (2010) |
| | Deprivation as defined as a deviation between actual energy access and/or use and estimated basic minimum needs | Minimum energy needs based on engineering estimates of a normative set of basic energy services | Goldemberg et al. (1987) |
| | | Minimum energy needs estimated as the average amount consumed by households living below the monetary poverty line | Foster et al. (2000) |
| | | Minimum energy needs estimated as the amount till which energy use is invariant with income | Barnes et al. (2010) |
| | Minimum energy needs defined in useful energy terms and access to modern energy carriers | Pachauri et al. (2004), Pachauri and Spreng (2004) | |
| Inconveniences | Associated time costs | Mirza and Szirmai (2010) | |
| | Health impacts | | |

Source: Pachauri and Spreng (2011).

1.2. The Importance of Access

The transition to modern energy use has far-reaching benefits for economic development and poverty alleviation (Cabraal, Barnes et al., 2005). The most direct benefits are the avoided ill health and time opportunity costs of women and children harvesting biomass fuels for use in traditional cookstoves. The negative health impacts that would be avoided from the use of improved cookstoves account for 2 million deaths per year, with a higher percentage of these being women and children in developing countries (WHO, 2009). The Global Energy Assessment (GEA) also estimates that about 2.2 million deaths in 2005 were on account of solid fuel use in households (Rao et al., 2011).¹ The time savings from immediate access to liquid and gaseous cooking fuels for half the world's population who are dependent on traditional cooking methods has been valued at US\$44 billion (WHO, 2006).² In addition to these opportunity costs, the lack of mechanical power for pumping water and grinding food grains results in hours of manual labor for repetitive pounding and grinding activities that pumps and mills could do much more efficiently.

FIGURE 1
EDI, HDI and per capita GDP
in Developing Countries – 2009.
Sources: World Energy Outlook
Database 2010.



Besides these direct benefits, there is much evidence to suggest that access to modern forms of energy contributes, and is perhaps even essential, to economic growth and job creation. At a country level, at low levels of per capita income, energy use correlates strongly to per capita income, as reflected in the relationship between the Energy Development Index (EDI), which encapsulates several indicators of energy access, and per capita income (Figure 1). Though this relationship is bidirectional – increased energy

¹ In the GEA (Riahi et al., 2012), health impacts due to solid fuel use are estimated using the methodology developed by WHO (see Desai et al., 2004). The GEA estimate of total health impacts is higher than the WHO's because the fraction of population dependent on solid fuels is estimated to be higher in the GEA. The GEA estimate of health impacts includes those diseases with strong epidemiological evidence for an enhanced risk due to solid fuel use, but also includes impacts from ischemic heart disease, which are not included in the WHO estimates.

² Estimated savings assume that half the population that is dependent on traditional cooking methods in 2005 shift to LPG by 2015.

access fosters income growth, and energy use tends to increase with income – there is growing evidence of the influence of energy access on GDP and income growth. The EDI and the Human Development Index (HDI) are also correlated, albeit to a lesser extent (Figure 1).³ The benefits of electricity for improving health services and education (e.g., providing refrigeration in hospitals and lighting in schools) is well known.

There is also growing consensus that enhancing access to modern, less polluting and affordable energy options has a key role to play in the alleviation of poverty. Poor people are trapped in an “energy-poverty” nexus, where the lack of access to energy services constrains productivity and the generation of livelihoods, which leave poor people with little surplus cash, and in turn the inability to purchase access to the energy services that could help alleviate their condition. Employment in formal and informal sector activities is positively correlated to access to modern energy options such as electricity, as is workers’ productivity in value-adding processes (Karekezi et al., 2012; Dinkelman, 2010).

In addition, increased access to electricity and mechanical power enables an increase in agricultural productivity and the transformation of agrarian economies to industry-based economies. Energy can play a vital role in enhancing income and food security among the rural poor who work in agriculture through technologies that can be used for irrigation, water pumping and post-harvest storage (World Bank, 2008). Irrigation, which is often possible only by mechanical pumping of groundwater, has been found in Asia to foster agricultural growth. Energy for mechanical power (water pumping or distribution) can come from electricity, local motors using fuels, or renewable-energy-derived water-lifting devices (such as treadle, wind-powered or hydraulic pumps). Small and micro-enterprises that use mechanical power enable rural households to generate nonfarm income. Rural electrification has also been shown in some studies in Asia to increase incomes of home-based industries (Khandker et al., 2009; World Bank, 2008). Expanding the scope and scale of manufacturing processes that transform raw materials to finished products requires increasing levels and types of thermal and electrical energy, such as for boilers and motors, which only electricity and commercial supply of other energy sources can sustain. Service industries as well depend on electricity to power appliances such as telecommunications equipment, space conditioning, and computers.

The importance of access to reliable energy supply is underscored by GDP losses from electricity supply interruptions in sub-Saharan Africa. Cumulative average interruptions in the year, which amount to about three months of lost service (IEA, 2010a),

³ The Energy Development Index (EDI) is a composite index of electrification, per capita commercial energy use, per capita residential electricity consumption and modern energy sources’ share of residential energy use. The Human Development Index (HDI) is a composite index of income, education and life expectancy.

cause businesses to lose 6% of their production. Others estimate the economy-wide cost of interruptions to be up to 7% of GDP (Foster and Briceño-Garmendia, 2010). Other developing countries on average also suffer similar losses, equivalent to a month of lost service, which costs businesses about 4% of their turnover. The range of further benefits to both social and economic development is best characterized by the role of energy in achieving the MDG (Table 2).

1.3. Global Status and Trends in Energy Access

The poorest countries are characterized by very limited access to modern, cleaner and affordable energy options. In addition, the majority of developing countries are characterized by inequitable access to cleaner energy options, where the rural poor suffer similar deprivations. In total, there are 1.4 billion people worldwide

TABLE 2 Energy and the Millennium Development Goals (MDG).

| Goal and target | Some direct and indirect contributions of cleaner energy options |
|--|--|
| MDG 1 <i>Extreme poverty and hunger</i> | <ul style="list-style-type: none"> ■ Access to affordable energy options from gaseous and liquid fuels and electrically driven machinery can assist enterprise development, boost income, and create jobs. ■ More efficient modern cooking fuels can reduce the large share of household income spent on cooking, lighting, and heat. ■ Post-harvest losses can be reduced through improved electric-powered preservation. ■ Energy technologies such as wind pumps and treadle pumps can be used for irrigation in order to increase food production and improve nutrition. |
| MDG 2 <i>Universal primary education</i> | <ul style="list-style-type: none"> ■ Electricity-driven lighting and space conditioning in schools can assist in retaining teachers, improving children's attendance, and enabling media use and other teaching tools. ■ Electric or solar home lighting improves children's after-school studies. |
| MDG 3 <i>Gender equality and women's empowerment</i> | <ul style="list-style-type: none"> ■ Immediate fuel access can free girls' and young women's time to attend school or earn income. ■ Modern cooking fuels and improved stoves can reduce deaths and illnesses from indoor air pollution. ■ Affordable and reliable energy options can broaden the scope for women's enterprises. |
| MDG 4 <i>Child mortality</i> | <ul style="list-style-type: none"> ■ Modern cooking fuels and improved stoves can reduce deaths and illnesses from indoor air pollution. ■ Avoided time spent gathering and preparing traditional fuels can increase time spent on child care. ■ Improved energy options can provide access to better medical facilities for pediatric care, including vaccine refrigeration and equipment sterilization. |
| MDG 5 <i>Maternal health</i> | <ul style="list-style-type: none"> ■ Electricity can enable access to better medical facilities for maternal care. ■ Improved energy options can also help retain qualified medical personnel in remote rural areas. ■ Modern energy options can reduce excessive workloads and heavy manual labor, which could adversely affect a pregnant woman's general health and well-being. |
| MDG 6 <i>HIV/AIDS, malaria, and other major diseases</i> | <ul style="list-style-type: none"> ■ Electricity in health centers can help provide medical services at night, enable refrigeration for vaccinations, and allow the use of more advanced medical equipment (e.g., sterilization). ■ Electricity can enable access to health education media through information and communications technologies. |
| MDG 7 <i>Ensure environmental sustainability</i> | <ul style="list-style-type: none"> ■ Renewable and other low-carbon household energy sources can reduce local air pollution and greenhouse gases. |

Source: Based on Karekezi et al., 2012.

(1.2 billion in rural areas) who do not have access to electricity (IEA, 2010b). Even among those who have access, several million more lack affordable and reliable supply of electricity. Over 3 billion people cook and heat their homes with solid fuels in low-efficiency stoves (UNDP and WHO, 2009; IEA, 2010b).⁴

1.3.1. Electrification

Two-thirds of the global population that lacks electricity access lives in sub-Saharan Africa and South Asia. Sub-Saharan Africa has the lowest electrification level, where only 11% of the rural population has access to electricity (UNDP and WHO, 2009). All sub-Saharan African countries with the exception of South Africa feature in the bottom half of the EDI ranking. South Asia is home to over 600 million people (or more than a third of people) without access to electricity.

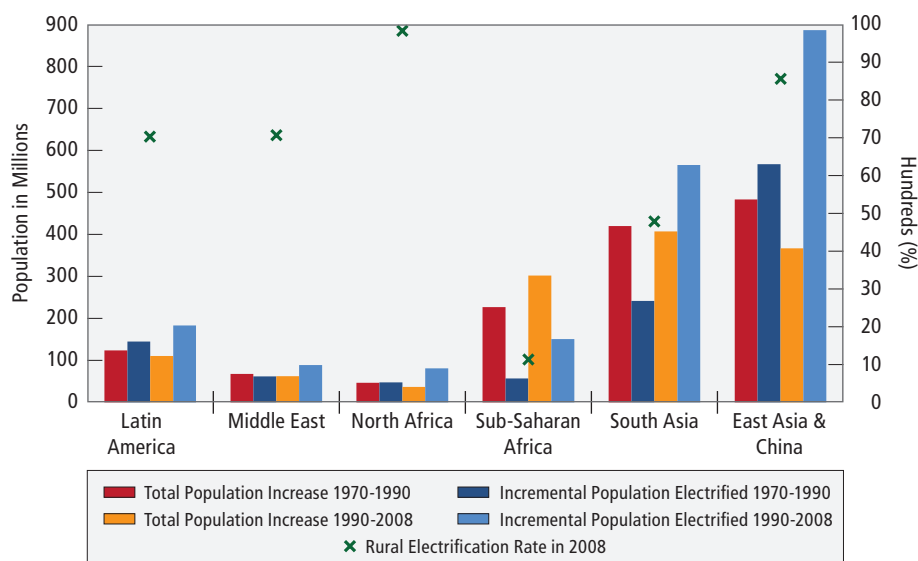


FIGURE 2
Change in population and electrified population by region between 1970 and 2008.
Source: Data from World Bank, 1996; IEA, 2002; UNDP and WHO, 2009; IEA, 2010.

Recent experience with electrification improvements has been uneven across regions (Figure 2). Between 1990 and 2008, almost two billion people gained access to electricity. In Latin America, North Africa, the Middle East, and East Asia, the pace of electrification outstripped the rate of growth of the population by a large margin, so that access significantly improved. In South Asia, the electrification rate has increased in this period, but not to the same extent. However, in sub-Saharan Africa, population growth has outpaced electrification. Even these numbers often belie actual levels of service, particularly in South Asia and sub-Saharan Africa. Many poor households that are connected face challenges in staying connected and increasing consumption beyond minimum levels due to poor quality, inadequate supply, and unaffordable connection costs and tariffs (PRAYAS, 2010).

⁴ Of the over 3 billion, 2.7 billion use unprocessed or processed (e.g., charcoal) biomass, and about 400 million use coal.

Future under “Business as Usual”

In the absence of new efforts to bridge the electricity access gap progress in rural electrification will likely be slowest in sub-Saharan Africa. According to the GEA (Riahi et al., 2012; Pachauri et al., 2012), rural electricity access is projected to increase from 10% in 2005 to 15–30% by 2030. In South Asia, the projected increase under the no new policies case is the largest, from 47–51% in 2005 to 77–82% in 2030, depending on the model used (discussed later in Section 3). In effect, to meet the target of universal access, almost 20 million new connections will need to be made annually in South Asia and sub-Saharan Africa together between 2010 and 2030.

Challenges and Opportunities for Future Policy

Part of the reason that electrification rates in developing countries have been slow is that the institutional model of centralized grid expansion has been suitable for limited rural areas. This is for two reasons. First, grid expansion to remote, low-density regions is relatively expensive, making access unaffordable for poor households. Second, as a general rule successful grid-extension programs require financially and technically strong utilities (Barnes, 2007). Utilities need the institutional capacity to manage high distribution losses and theft in sparse grids, offer financing mechanisms for poor households to connect to the grid, and train personnel to maintain a vast grid.

Despite the shortcomings of the centralized model, there have been many successful programs for off-grid electrification in remote rural areas in Bangladesh, Sri Lanka, Nepal, and China that have resulted from innovative programs that involve multiple players including the central government, international donor agencies, the private sector and local communities. These experiences are discussed further in Section 2.

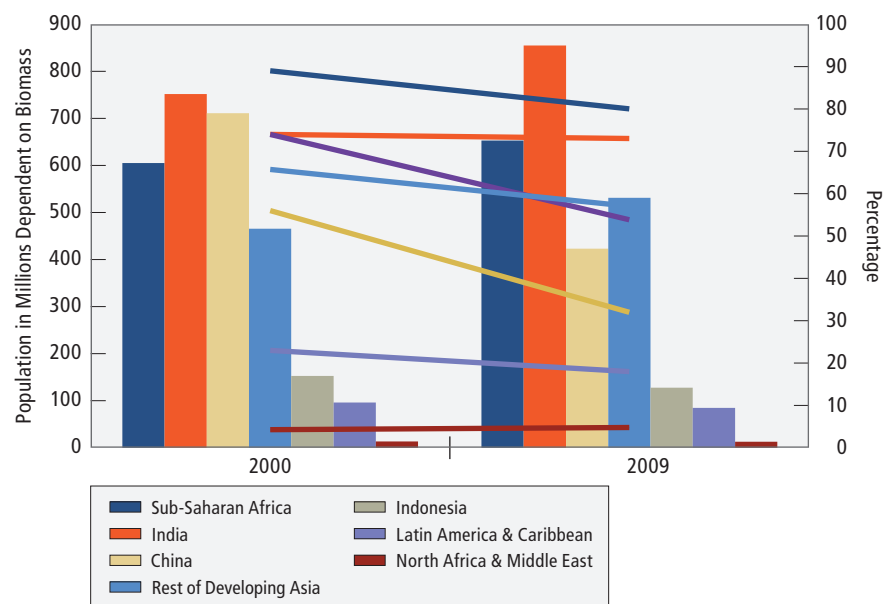


FIGURE 3

Population dependent on biomass fuels in households in developing regions.

Sources: IEA, 2002; UN, 2008; UNDP and WHO, 2009; IEA, 2010.

1.3.2. Modern Energy for Cooking and Heating

Overall, only 41% of people in developing countries have access to different types of modern fuels for cooking and space heating. Heating and cooking often go hand in hand in developing countries, particularly in cold mountainous areas where household energy is primarily used for space heating. In most countries, the lack of modern cookstoves is primarily a rural problem, but many urban and peri-urban poor also rely on solid fuels, particularly in sub-Saharan Africa. Sub-Saharan Africa, South Asia, and East Asia/China are the regions with the largest populations without access to modern household cooking and heating energy (Figure 3). In sub-Saharan Africa, only 16% of people use modern fuels as their primary cooking fuel. In India, over 800 million people – 75% of the rural households and 22% of the urban households – rely on solid fuels.

Progress with expanding access to modern fuels and technologies for cooking and heating in developing countries over the past 25 years has been poor. Unlike electricity access, the populations with no access to clean cooking fuels have continued to increase over the last decade, except in the case of China. A recent review of World Bank lending for improving energy access over the period 2000–2008 concludes that only about 1% of the total lending was dedicated to promoting a transition to more modern cooking fuels or clean cooking devices (World Bank, 2010).

Future under “Business as Usual”

The GEA (Riahi et al., 2012; Pachauri et al., 2012) projects that the total population dependent on solid fuels for cooking will rise from 2.2 billion to 2.4 billion in South Asia, Pacific Asia, and sub-Saharan Africa between 2005 and 2030, in the absence of new policies to improve access (Figure 4). In all regions the percentage of the population dependent on solid fuels, however, decreases between 2005 and 2030. The population dependent on solid fuels is projected to decline marginally in South Asia and more significantly in Pacific Asia, whereas in sub-Saharan Africa the numbers rise during this period.

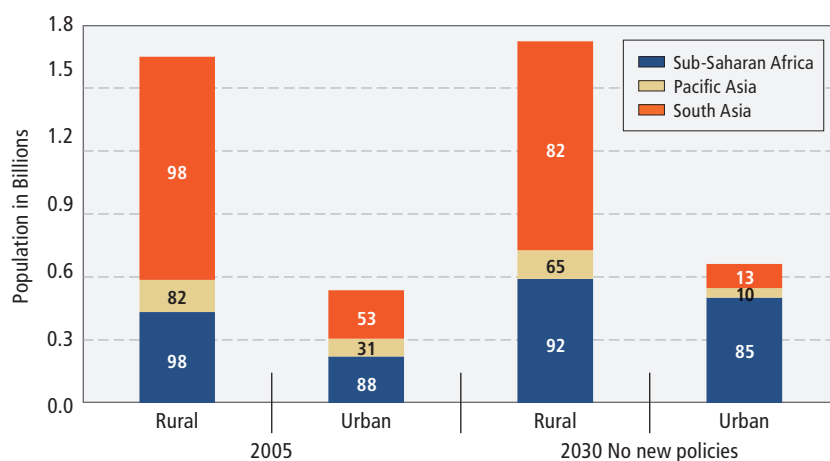


FIGURE 4 Population relying on solid fuels in three developing regions in 2005 and in 2030 in the absence of new policies. Numbers on the bars are percentages of the total population in the indicated region and year.

Challenges and Opportunities for Future Policy

Programs to disseminate improved cookstoves for solid fuels have had limited impact, despite the fact that a large number and variety of technologies have been developed and tested in pilot programs, and supported by social entrepreneurs, international development agencies and foundations. Cost effectiveness, ease of use, taste and cultural preferences play an important role in decisions concerning which cookstoves are used. Preferences therefore vary not only across cultures, but also within them based on a number of contextual conditions including geography, weather and whether households are in urban or rural settings. One of the primary challenges hampering the wide-scale dissemination of improved cookstoves has been learning and adapting technologies to these preferences. Another challenge has been establishing institutions for maintenance and replacement of stoves. Since programs so far have mostly relied on financial support, there are few commercial models for large-scale dissemination of affordable cookstoves, particularly for the rural poor.

These challenges have been surmounted in a few cases through strong government commitment to stove dissemination (e.g., China), innovative business models that target lower income, but not the poorest, households (e.g., India) and regional cooperation to increase the scale of dissemination (e.g., Kenya and neighboring countries). Future efforts can build on the lessons learned from these experiences (discussed in Section 2).

1.3.3. Mechanical Power

Energy for mechanical power is obtained from electricity and nonelectric sources and is used for daily livelihood activities including agriculture, agro processing, artisanal activities, and small and micro enterprises. In the absence of access to electricity and other commercial energy carriers, rural populations rely on manual and animal labor to perform mechanical tasks and forego the opportunity to use more advanced technologies to improve the productivity of their labor.

There is limited information available on the status and conditions of mechanical power use in developing countries. According to the UNDP, mechanical power is not included in most policy debates at the country level.⁵ Progress on the use of mechanical power can be gauged from individual sectors. For instance, mechanization in agriculture is reflected in the use of electrical or mechanical pumps for irrigation, or tractors in plowing. If tractors were a proxy, all regions outside Africa show increases in the use of mechanical power between 1981 and 2001, with South Asia having achieved the largest relative increase (**Figure 5**).

⁵ Although five out of the 50 LDCs have a national target on access to modern cooking fuels, and 22 have targets on access to electricity, none of them has a specific national target on access to motive power.

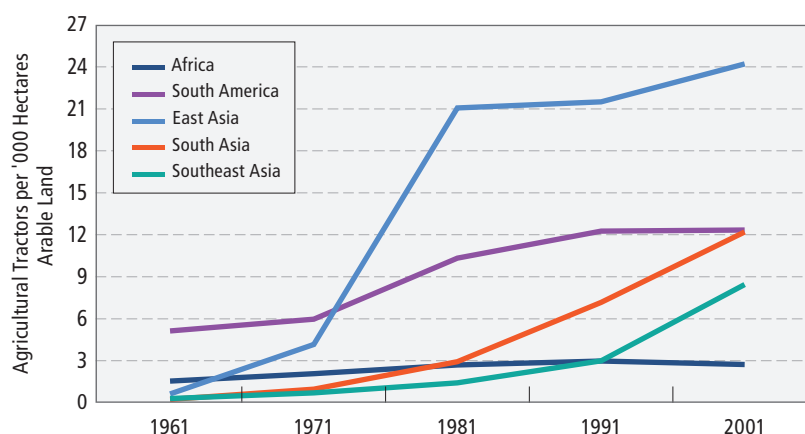


FIGURE 5
Growth in agricultural mechanization.
Source: FAOSTAT, 2010.

Challenges and Opportunities for Future Policy

There is significant opportunity to disseminate technologies to expand mechanical power for rural livelihoods in regions that have no access today. A survey of UNDP projects that expand access to modern energy at the local level indicates that the average cost per beneficiary for providing mechanical power by use of multifunctional platforms/equipment attached to stationary engines is US\$24 (Pachauri et al., 2012). The income benefits would have to be only US\$1 per person to pay back these costs in two years. The challenges, however, lie in financing the cost of the equipment and identifying cost-effective opportunities in the absence of much data on rural livelihoods that rely on mechanical power.

The knowledge gap in the use of mechanical power includes the lack of research on the role energy plays in diversifying production and expanding employment opportunities. This implies that improved monitoring and evaluation of energy access programs that provide advanced technologies for mechanical power can help fill these knowledge gaps.

1.4. Summary – Gaps in Global Energy Access

In 2030, the IEA projects that 1.2 billion are likely to lack electricity access in the absence of concerted new efforts to provide universal access, over half of whom will live in sub-Saharan Africa (IEA, 2010b). Seventy percent of sub-Saharan Africans and almost twenty percent of South Asians would fall into this group. The GEA estimates that over 0.8 billion rural inhabitants in sub-Saharan Africa, South Asia and Pacific Asia will lack access to electricity in 2030 without new electrification targets. Globally, the IEA projects that about 2.8 billion people will depend on biomass fuels in 2030 without dedicated access policies. The GEA also estimates that in the absence of new policies, about 2.4 billion people in sub-Saharan Africa, South Asia and Pacific Asia will still rely on solid fuels in their homes in 2030. These gaps in access to modern energy will perpetuate poor people's inability to use mechanical power to improve the productivity

TABLE 3A Countries with the Highest Shortfall in Modern Cooking/Heating Access in Africa and Asia

| Africa | | Asia | |
|---|--------|-------------|--------|
| <i>Top 5 countries by % population without access</i> | | | |
| Liberia | >99% | Laos | >95% |
| Mali | >99% | Myanmar | >95% |
| Burundi | >99% | Cambodia | >90% |
| Madagascar | >99% | Bangladesh | >90% |
| Somalia | >99% | Afghanistan | >85% |
| <i>Top 5 countries by population without access</i> | | | |
| Nigeria | >110 m | India | >800 m |
| Ethiopia | >80 m | Bangladesh | >150 m |
| Tanzania | >35 m | Indonesia | >120 m |
| Sudan | >35 m | Pakistan | >110 m |
| Uganda | >30 m | Myanmar | >50 m |

TABLE 3B Countries with the Highest Shortfall in Electricity Access in Africa and Asia

| Africa | | Asia | |
|---|-------|-------------|--------|
| <i>Top 5 countries by % population without access</i> | | | |
| Burundi | 97% | Myanmar | >90% |
| Liberia | 97% | Afghanistan | >85% |
| Chad | 97% | Cambodia | >85% |
| Rwanda | 95% | Bangladesh | >70% |
| CAR* | 95% | Nepal | >60% |
| <i>Top 5 countries by population without access</i> | | | |
| Nigeria | >80 m | India | >350 m |
| Ethiopia | >70 m | Indonesia | >150 m |
| Tanzania | >35 m | Bangladesh | >120 m |
| Kenya | >30 m | Pakistan | >80 m |
| Uganda | >30 m | Myanmar | >50 m |

*CAR: Central African Republic

of their livelihoods and access better health and education services that could in turn improve their income and living standards. The countries with the highest shortfalls in both percentage and population terms are shown below in [Tables 3A](#) and [3B](#).

These gaps present significant opportunities to build on the experiences of the past decades and accelerate developing countries' progress towards universal access. The progress made and the lessons learned from recent policies and programs to expand access are discussed next by region.

2. Regional Progress and Lessons Learned

For the least developed countries, a key challenge is how to promote the development of energy systems that can provide universal access to affordable energy services while also avoiding the unsustainable environmental impacts of traditional energy systems. Past experience has shown that the challenge in achieving this goal is to develop new, contextually appropriate models of production, financing, and distribution that can be self-sustaining. This section discusses notable policies and the main lessons learned over the last two decades on a regional basis.

Globally, the population using solid fuels for cooking and heating has increased over the last decade to 3.2 billion, even though the population share using solid fuels has reduced in most regions ([Figure 3](#)). Of this population, roughly 800 million use improved cookstoves, largely due to efforts in the last two decades in China and

a few other countries such as Brazil. The more recent experience with electrification improvements across regions continues to remain very uneven, but provides a basis for hope. Between 1990 and 2008, almost two billion people gained access to electricity, compared to one billion in the previous two decades. In Latin America, North Africa, the Middle East, and East Asia, the pace of electrification outstripped the rate of growth of the population by a large margin, so that access significantly improved. In South Asia, the progress has been less and more uneven. In sub-Saharan Africa, the electrification rate has been consistently lower than the rate of population growth.

2.1. Africa

2.1.1. Status of Access Efforts

Africa has the least access to modern energy forms of all continents, and is home to a third of all people in the world without access to electricity. Only 11% of the rural population in sub-Saharan Africa has access to electricity, and 7% access to modern cooking energy (UNDP and WHO, 2009). The use of traditional cooking fuels is still very significant (about 70%) in urban households as well (Banerjee et al., 2009).

However, there has been progress towards expanding access in many countries, particularly in Northern Africa, and a few middle-income countries in sub-Saharan Africa, as shown in [Figure 6](#). In Northern Africa over the last 30 to 40 years country governments, with the exception of Mauritania, have been able to provide almost

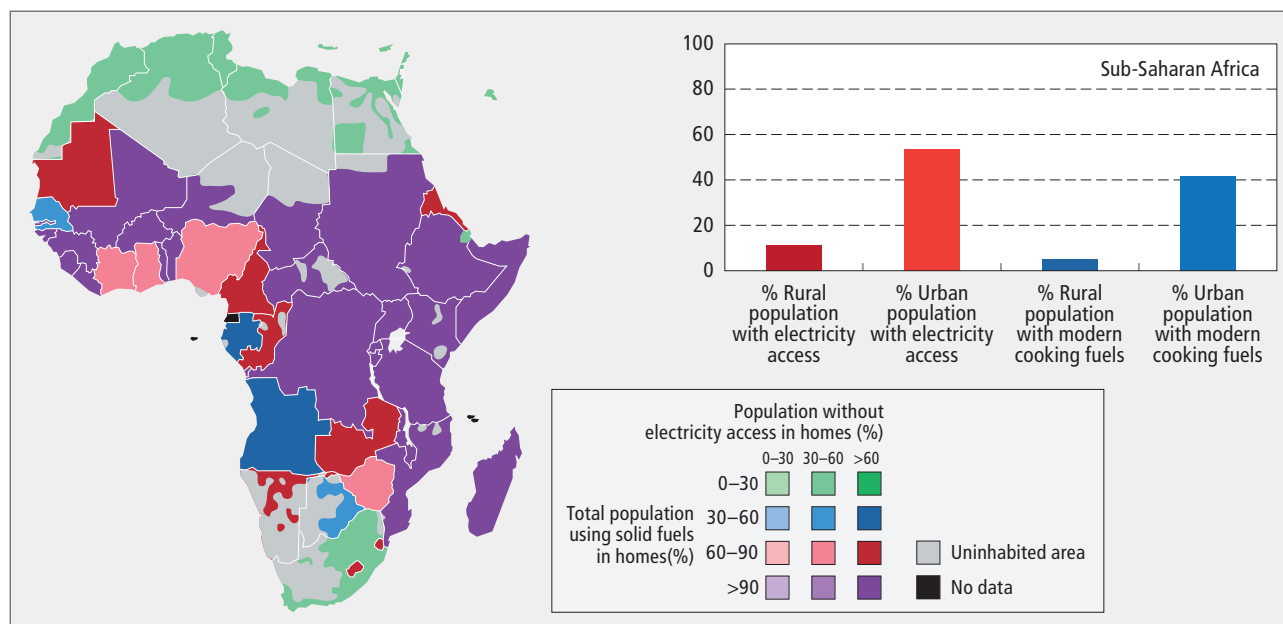


FIGURE 6 Status of Energy Access in Africa

universal access to both modern cooking fuels and electricity. In sub-Saharan Africa, however, progress has been noticeable in only a few select countries, such as Ghana, Senegal, South Africa, Zimbabwe and Botswana. Senegal was the only sub-Saharan African country to substantially increase LPG use for cooking, but mostly in urban areas. The improved charcoal-based cookstove, the Kenyan Ceramic Jiko, has been distributed to over eight million customers across Africa, from Senegal to Ethiopia and South Africa, and has become an African success story (AFREPREN/FWD, 2009). Successful electrification programs in the last few decades have been observed in South Africa, Zimbabwe, Botswana and Ghana.

Overall, it is less for a lack of adequate energy reserves that African countries have low household access to modern energy, but more due to lack of political commitment, financial resources and sustained programs designed for the conditions faced in remote areas. Most gains have taken place in urban areas, to the neglect of peri-urban and rural areas.

2.1.2. Notable Programs/Policies⁶

A list of notable programs and their success factors in Africa is presented in [Table 4](#).

2.1.3. Regional Initiatives

Following recommendations from the New Partnership for Africa's Development (NEPAD) in 2002, there has been an increased drive in sub-Saharan Africa toward regional approaches to addressing the region's developmental challenges. Regional power pools have already played a role in bridging regional imbalances in power. For example, the Democratic Republic of Congo (DRC), Lesotho, and Mozambique export electricity through the Southern African Power Pool to poorer countries in the region. In West and Central Africa, the Economic Community for West African States (ECOWAS), the West African Power Pool and the Communauté Economique et Monétaire de l'Afrique Centrale (CEMAC) have taken on ambitious roles to increase access to modern energy services. These regional organizations have set targets and outlined strategies and policies for achieving their goals. However, it is unclear how they would reverse decades of slow progress.

The Lighting Africa initiative, a joint IFC and World Bank program, is helping develop commercial off-grid lighting markets in Sub-Saharan Africa as part of

⁶ This is not an exhaustive listing of success factors or access programs. Examples have been selected to highlight some of the critical success factors in countries that have had success in expanding energy access. Factors other than those shown have also contributed to these successes. This also applies to the tables in Sections 2.2 and 2.3.

the World Bank Group's wider efforts to improve access to energy. Lighting Africa is mobilizing the private sector to build sustainable markets to provide safe, affordable, and modern off-grid lighting to 2.5 million people in Africa by 2012 and to 250 million people by 2030.

2.1.4. Lessons Learned

■ *Government commitment was essential for providing affordable access*

In all the examples of electrification and expansion in modern cooking fuels, the governments spearheaded and sustained programs with workable financing schemes that made access affordable to the poorest. The success of providing almost universal access over the last 30 years in most of Northern Africa has been partly a result of the high priority accorded to universal access by the country governments. Other examples include Botswana and South Africa's electrification policies. Many governments in Central and West Africa cite access as a priority in their energy policies, but few translate these goals into concrete programs and actions.

TABLE 4 Notable Programs and their Success Factors in Africa

| Success Factor | Country | Achievement | Description |
|--|--------------|---|--|
| Government Commitment to Affordability | Senegal | LPG scale-up of 10% p.a. growth from 1974 to 2005 | Government exempted import duties, subsidized capital costs and used a small cylinder to lower upfront costs. |
| | South Africa | Electricity grid access expanded from 36% in 1995 to 75% in 2007 | National Electrification Program awarded free electricity to households up to 50 kWh per month, "ring-fenced" funds for electrification. |
| | Botswana | Electricity grid access | Government was responsive to customer needs by spreading out payments until customers were able to afford smaller investments. |
| Community Mobilization | Ghana | Electricity grid access grew from 23% in 1985 to 54% in 2005 ¹ | Self-Help Electrification Project (SHEP) gave communities within 20 km of the grid incentive to connect by offering access if they purchased local distribution equipment and set up a minimum number of customers. The program connected 2,350 communities in the first 10 years. |
| Financing mechanisms | Tunisia | Solar Water Heaters (SWH) use expanded. | Financially supported by the utility with a government subsidy, external financial support and a loan program that was repaid through rates over five years. |
| | Morocco | Solar Water Heaters (SWH) use expanded. | Supported by the GEF, used a lease approach to make the technology affordable. |
| | Zimbabwe | Electricity grid access grew from 20% in 1980 to 42% in 2001 | In response to low demand and cost recovery, the Rural Electrification Agency targeted small and commercial enterprises, whose participation increased demand and uptake of grid access. |

¹A government review in 2010 indicates that the electrification rate may have risen to 70 percent.

The governments in Northern Africa also committed both fossil fuel and financial resources to the goal. In sub-Saharan Africa, even nations with significant fossil fuel endowments like Chad and Nigeria, have been unable to provide universal access to modern energy to their populations, in part because of limited government commitment to the issue.

- ***Governance reform hasn't worked as a vehicle for access expansion***
More than 80% of sub-Saharan African countries had enacted power reform laws by 2006 in order to bring in private participation in the generation sector, encourage efficiency to generate funds for widening energy services, and rationalize prices. However, these reforms led to a policy vacuum with regards to the needs of poor people (GNESD, 2006). Countries that ensured that funds were dedicated to access targets, such as South Africa, were able to successfully expand access and undertake governance reform.
- ***Making access affordable requires flexible programs that are responsive to local conditions*** Getting information on the status of electrification projects, and the needs and conditions of remote rural communities is challenging. Programs that set up effective monitoring and are open to change in policies can learn from ongoing program efforts and better adapt to households' conditions. The progress in electrification in Botswana and Zimbabwe, for example, altered significantly from such feedback and change in policies.
- ***Cooperation between neighbors enhances available resources*** There are high regional disparities in resources across Africa, which can be partly surmounted through regional cooperation. Morocco and Senegal both import gas from their neighbors, which is increasingly being used in households along with LPG. These two countries are also cooperating on rural electrification programs based on the successful experiences in Morocco.

2.2. Asia

Sixty percent of the global population lives in the Asia and Pacific region, of which one-fifth – about 800 million people – still lack reliable access to electricity. Significant variations are evident in the level and growth of access to electricity and modern cooking fuels, across countries and between urban and rural areas within countries (Figure 7). Access to modern cooking fuels remains the biggest challenge, with most of the rural population in Asia having no access. Significant strides in electrification have been made in China, Nepal and Sri Lanka over the last few decades. On average across the Asia-Pacific growth in electricity access exceeded the global average electrification growth rate, but it was far below GDP growth in the same period.

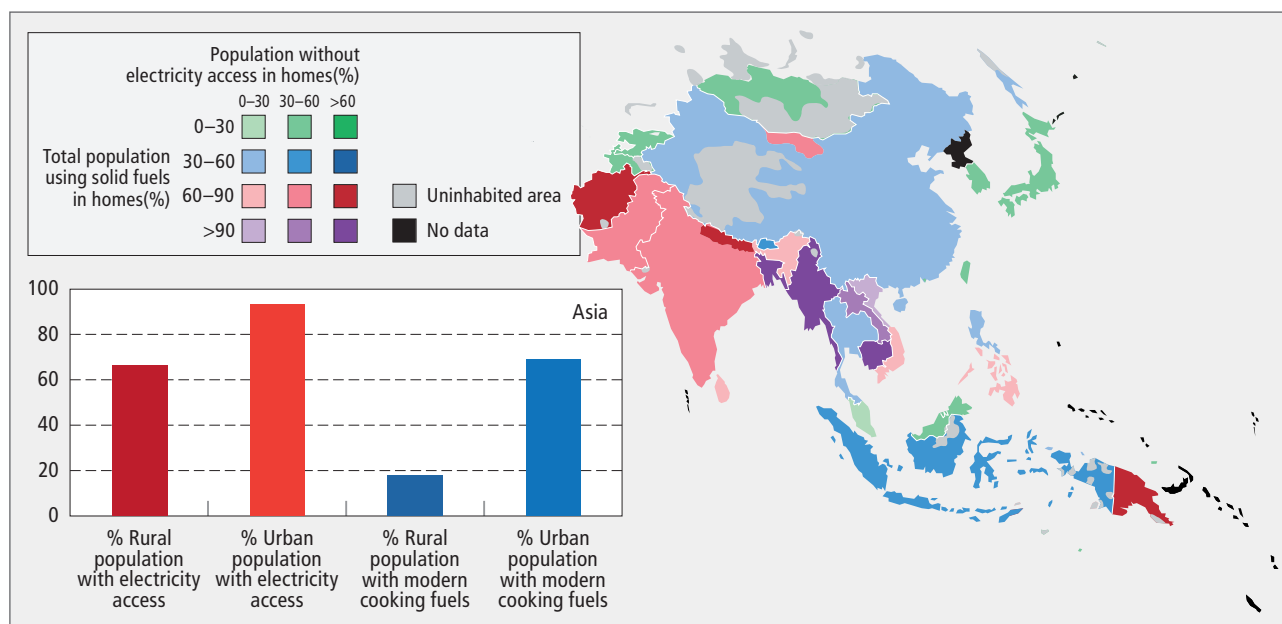


FIGURE 7
Status of Energy Access
in Asia

China and India, the two most populous countries, have had aggressive rural electrification programs with very different results. Together they are also home to half the world's population that depends on biomass. Their progress in extending access to poor people are summarized briefly below, followed by a discussion of the broader lessons learned from past efforts in Asia.

2.2.1. China

The Chinese government has demonstrated a commitment to providing all its citizens with a basic minimum standard of living, which includes meeting their basic energy needs. Most urban residents have access to modern forms of energy. China has almost universal electricity access, but over half the population still depends on biomass and coal for cooking and heating. About 75% of the rural population still relies on biomass for cooking and heating. While biomass is not used in urban areas, coal is used widely particularly in Northern China. However, as discussed below, the government disseminated 180 million improved cookstoves to households across the country using biomass. The status of these installations and their acceptability is, however, not well known. However, recent estimates in the UNDP & WHO (2009) report suggest that many of these may still be in use.

The government's strategy for providing electricity access in rural areas has been two-pronged: most rural areas have been provided access as have been urban areas (such as from grid expansion for electricity), while in mountainous and very remote regions the government has used local resources, such as hydro, solar or wind, with advanced technologies to provide relatively cheap energy.

Under this multi-pronged strategy, China has developed a biogas program, a rural hydropower-based program and a rural grid development program. Overall, the Chinese government has been very successful with achieving almost universal access to electricity and restricting the use of biomass in urban centers. However, efforts to expand access to clean cooking fuels and devices are still required as over 750 million people still rely on solid fuels.

2.2.2. India

Over 800 million people – 75% of the rural households and 22% of the urban households – still rely on solid fuels for cooking and heating. Despite aggressive policies to subsidize and expand LPG access in the last two decades, only 12% of rural households, who are in the highest income quintile, use LPG. In urban areas, use of biomass, and to an extent kerosene where biomass is not accessible, is also still common due to the lack of affordable and reliable LPG. India has had a number of improved cookstove initiatives led by government, foundations and corporations. Since the mid-eighties, over 5 million stoves have been disseminated from different programs, but which individually have been unable to achieve scale due to challenges in making stoves affordable and acceptable to households. Looking forward, the Ministry of New and Renewable Energy of the Government of India has launched a new initiative on biomass cookstoves. The goal of the program is to sell 150 million stoves in 10 years. Under this initiative, a series of pilot-scale projects are envisaged using several existing commercially-available and better cookstoves and different grades of processed biomass fuels.

India has made concerted efforts to provide universal electricity access through law (Electricity Act 2003), national policies and nation-wide infrastructure schemes in the last three decades. The main and most recent vehicle was the **Rajiv Gandhi Grameen Vidhutikaran Yojana (RGGVY)**, a centrally funded grid expansion project that aimed to provide universal electricity access by 2010, which would offer free connections to households below the poverty line (BPL). Through this program the government offers capital subsidies of up to 90% based on performance over five years. By 2011, 91% of villages and over 60% of rural households had access. However, the scope of the program has been short-sighted. Electrified villages lack reliable electric supply and the supporting institutions to maintain the network infrastructure over time, while the scheme itself did not establish sufficient monitoring capacity to track progress (PRAYAS, 2011).

The national government also has a number of initiatives to provide energy security to remote villages that would be out of reach of the national grid. The Village Energy Security Program (VESP) of 2004, for example, is a community-based initiative to use

local resources to provide cooking energy and electricity as well as to fuel livelihood generation. The Ministry for New and Renewable Energy (MNRE) as well as a number of state governments have also sponsored a number of schemes to provide energy to households in remote areas. These schemes include solar home lighting systems, subsidies for solar water heaters, and dissemination of compact fluorescent bulbs. The MNRE's Remote Village Electrification (RVE) program is innovative in that it requires vendor that supply equipment to offer five-year performance warranties and annual maintenance contracts.

2.2.3. Notable Programs/Policies (All Asia)

A list of notable programs and their success factors in Asia are presented in [Table 5](#).

TABLE 5 Notable Programs and their success factors in Asia

| Success Factor | Country | Achievement | Description |
|------------------------|------------|---|--|
| Local Institutions | China | 180 million stoves disseminated mostly by private, rural companies | Program benefited from the establishment of local energy offices that provided training, service, installation support and program monitoring. |
| | Bangladesh | Electrification helped generate employment, ¹ reduce system losses by 50% and improve billing collection. ² | Two-tiered institutional arrangements were employed. Grid supply was managed by the Rural Electricity Board (REB) and rural electricity cooperatives known as Palli Biddut Samities (PBSs). Similarly, the Infrastructure Development Company Ltd (IDCOL) provided Solar Home Systems (SHS) through its 30 Partner Organizations (PO). |
| | Thailand | Increased rural electricity from 7% in the 1970s to 99% by 2007 | A dedicated entity, the Office of Rural Electrification, was created with specific responsibilities to implement the rural electrification program, involved end users in planning. |
| Community Mobilization | Nepal | Electricity access increased from 27% in 2001 to 64.5% in 2008 | With the Renewable Energy Development Program (REDP), a hierarchy of committees was established comprising men and women from villages to run micro-hydro projects. The REDP installed 185 micro-hydro plants, which provided electricity to over 120,000 people. |
| | Indonesia | Off-grid electrification promoted with, stand-alone Solar Home Systems (SHS) | Communities were mobilized through focus-group discussions that involved both men and women. |
| Financing mechanisms | Sri Lanka | Electricity access increased from 11% in 1986 to over 76% in 2005, including 2% of the population with off-grid systems | A successful credit program was prepared and implemented by the private sector and village communities. |
| | Thailand | Rural electricity access increased from 7% in the 1970s to 99% by 2007 | Success factors included financing of the development of the distribution network, subsidies to residential customers, and self-sustainable revenue generation. ³ |

¹Barkat, 2005; ²Rijal et al., 2007; ³Shrestha et al., 2004.

2.2.4. Lessons Learned (All Asia)

- **Government leadership and subsidies essential for providing sustainable access**
 The successful electrification programs in China, Thailand, and Sri Lanka, and to an extent in India and Bangladesh, all had the benefit of government-led initiatives that established dedicated institutions. For extremely poor populations, access was made affordable only with significant subsidies or external support. In China and India, the government subsidized the production or the initial investment, while Sri Lanka had donor support. The importance of government's leadership is also that the projects integrate social equity goals and encourage broader access to services amongst these poor communities.
- **Universal access requires diversified strategies** Many developing countries have diverse terrains with dense urban areas and some remote rural regions. China, Sri Lanka, Bangladesh and Nepal have all developed different programs for remote and mountainous regions with different configurations (off-grid), technologies (local resource-based) and institutional structures that cater to the poorest households.
- **Self-sustainable revenue generation enhances program success**
 In Thailand and Bangladesh, the ability to recovery at least operating costs of the programs from new customers or from cross subsidies from existing customers contributed to the long-term viability of the established institutions. In Thailand, the ability to cross-subsidize from non-residential customers enabled the project to sustain over 30 years. In Bangladesh, PBS's success lay in part on subsidized power from the Bangladesh Power Development Board, and inter-sectoral cross subsidy provision for customers (Rijal et al., 2007; GNESD, 2007).
- **Local community involvement essential for sustainable off-grid rural electricity**
 All the off-grid programs in Sri Lanka, India, Bangladesh and Nepal had high involvement of local community. This creates a sense of ownership, which helps sustain programs for longer periods, which in turn increases the likelihood that these programs create livelihood and other socioeconomic benefits to these remote regions.

2.3. Latin America and the Caribbean

Close to 90% of Latin American households have access to electricity, and about 80% have access to modern fuels for cooking and heating (Figure 8). However, the disparity in access between the poorest quintile and the rest is nowhere starker. Excluding Mexico, about 30 million people still lack electricity access, 70% of whom are poor. Brazil and Peru are each home to a third of these unelectrified households, while

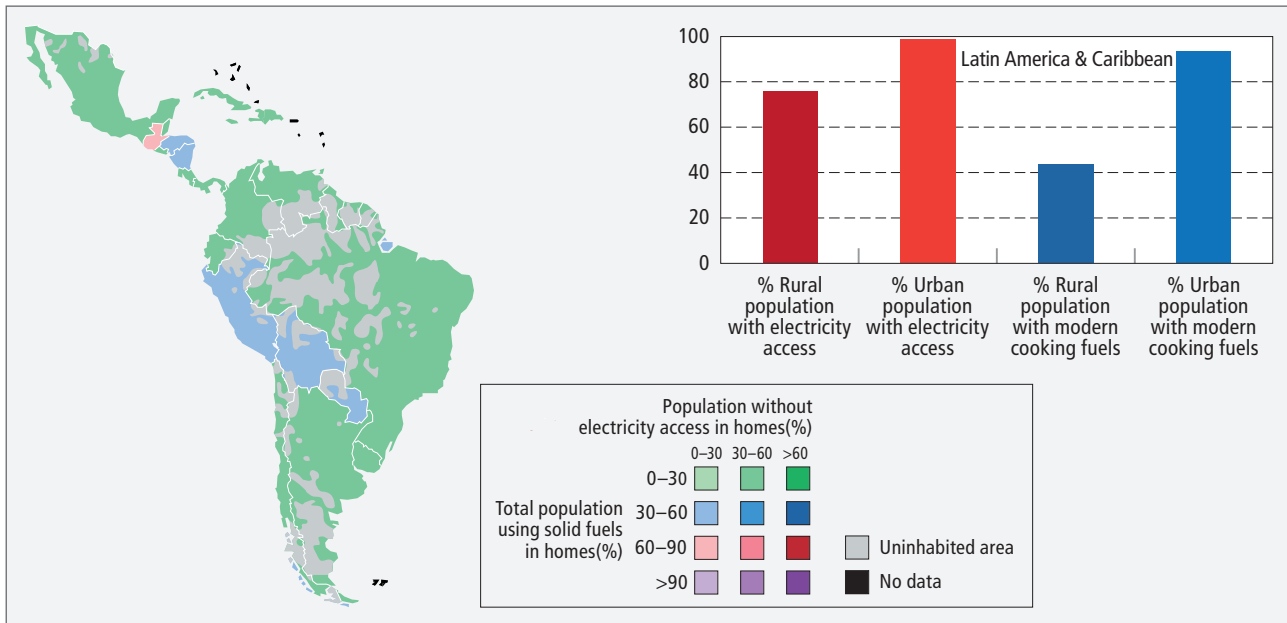


FIGURE 8
Status of Energy Access
in Latin America and
the Caribbean

the remaining live in Bolivia, Guatemala, Honduras and Nicaragua. These households represent 60–90% of poor people in these countries. As in other developing countries, these households are almost entirely located in rural areas.

Among poor people who largely depend on solid fuels, the consumption of firewood has increased since the nineties, owing in part to marketized LPG prices and also to income – and therefore per capita energy – growth in certain parts of Brazil, Chile and Uruguay that lack access to alternative fuels. Nicaragua and Guatemala have the highest per capita consumption of firewood, which is predominantly consumed by the rural poor.

2.3.1. Notable Programs/Policies

A list of notable programs and their success factors in Latin America and the Caribbean is presented in [Table 6](#).

2.3.2. Lessons Learned

- **Energy access reflects government priority towards equitable development**

The correlation between poverty and lack of energy access is glaring in Latin America, both across and within countries. Many Latin American countries that continue to have low levels of electricity access among the rural poor have focused electricity policy on introducing market reforms, such as competition and privatization, rather than on electrification. The role of the state has diminished

significantly due to these reforms, which leaves little incentive for serving electricity to the poorest regions. That poor households spend up to 10% of their expenditure on energy also reflects the limited attention given to affordability of energy, as well as to poverty alleviation in general. The few exceptions, in the cases highlighted above, show that with a strong government commitment to poverty alleviation targeted energy access policies can achieve significant success. This commitment is reflected in the longevity of programs, public funding and strong regulatory frameworks.

- **Different challenges arise in urban areas** Seventy percent of poor people in South America live in urban areas, which is far higher than the share of poor who live in urban areas in Asia and Africa. Thus, the problem of providing affordable energy services to the urban poor is particularly acute. In poor urban settlements, such as in Brazil, providing physical access to modern infrastructure is not as much of a concern as providing affordable and reliable energy services with this infrastructure. The urban poor lack the income and good credit needed to buy efficient equipment, and rely on irregular channels of access, due in part to illegal occupation of lands and clandestine connections to the grid.

TABLE 6 Notable Programs and their success factors in Latin America and the Caribbean

| Success Factor | Country | Achievement | Description |
|---|-----------|--|---|
| Government commitment to affordability | Brazil | LPG access extended to 98% of households between 1973 and 2001 | Access was provided at a uniform rate across the country, which included a subsidy, on average, of 18% of the retail price. Although prices were liberalized in 2001, the poorest families continued to receive a subsidy (gas vouchers). |
| | Colombia | Gas provided to 4 million households over 15 years | Subsidized rates enabled the poor to obtain access. 85% of households fell in the lower half of the income strata, and half in the lowest two income strata. |
| Aligning energy access and development policy | Brazil | Provided lighting to 50,000 schools, water pumping to drought-prone areas, and electricity access to 1.8 million homes | A law in 2002 acknowledged the right of citizens to have electricity supply as a public service. ¹ Off-grid electrification programs were implemented as part of poverty alleviation policies. |
| Effective regulation | Argentina | Off-grid renewable energy through private concessionaires | Independent provincial regulating agencies regulated concessions, monitored customer satisfaction and service quality. The government provided 50–60% subsidies to concessionaires, conditional on meeting targets and participating in market studies. Costs were kept low by devolving responsibility to local subcontractors and microenterprises, for fee collection, installations and operations. |
| External financing | Peru | Increased rural electricity access from 8% in 1993 to 30% in 2007 | External donors played an important role in supplementing scarce funds. |
| | Bolivia | Increased rural electricity access from 6.8% in 1976 to 28.3% in 2001 | External donors played an important role in supplementing scarce funds. |

¹ Winkler et al. 2011.

- **Local involvement critical to success of off-grid programs** As with other regions, several experiences with rural electrification (e.g. Argentina and Brazil) demonstrate that providing strong training and knowledge, involving locals in operations, and mobilizing local funds through microenterprises helps programs with new technologies endure.

2.4. Summary – Gaps and Challenges for Universal Access

Close to universal access to modern energy for cooking and heating has been achieved in most Northern African countries, in a few island-nations in Southern Africa, and in urban regions in Latin America. In addition, there have been a few countries that have had a rapid expansion of LPG infrastructure, such as Ghana and Senegal in Western Africa, or India, but also primarily in urban areas. All the successful programs have had a strong and sustained government commitment to expand the modern fuel infrastructure. The affordability of energy supply has been a key determinant of whether poor people have availed of this access.

Besides these cases, over three-quarters of the rural population in Asia and sub-Saharan Africa continue to use solid fuels for cooking and heating despite the policy initiatives undertaken in the last two decades. Developing improved cookstove programs that can widely disseminate both affordable and culturally acceptable cookstoves to these households remains one of the biggest challenges of universal energy access.

Electricity access has been extended to most households in Northern Africa, China, and South America. A few Asian and sub-Saharan African countries, such as India, South Africa and Ghana, have made significant strides in expanding access, though still to a greater extent in urban areas. Improving access to electricity requires accelerating the pace of electrification in the least developed countries and regions, particularly in sub-Saharan Africa and South Asia. A key challenge is overcoming the institutional incentives to only support electrification where it is cheapest. Even though decisions about setting targets for grid expansion are generally made by national governments or regional bodies, the literature shows that public or private utilities generally bear the financial responsibility for these programs (Zomers, 2001; Kemmler, 2007; World Bank, 2008). Utilities often select projects that require the least infrastructure investment relative to demand. Villages or communities that are closest to existing grids, have the highest population density, or where economic activity is greatest, are generally connected to the grid first. Social criteria, including preferential selection of the poorest households or more remote rural regions, also influence the decision for grid expansion in some nations, but to a lesser extent.

Off-grid electricity access programs, based on local and renewable energy sources where available, have been successfully adopted in remote rural regions in China, Bangladesh, Nepal, India, Brazil, and Argentina, among others. The successful programs almost universally involve a strong government commitment to energy access as a vehicle for poverty alleviation, microcredit or other financing mechanisms combined with subsidies that make energy affordable and its costs recoverable, and local community involvement. A key challenge is to replicate some of these successes more broadly in rural regions, particularly in sub-Saharan Africa.

3. Scenarios for Achieving Universal Energy Access by 2030

Sections 1 and 2 have highlighted recent historical trends and the current status of access to electricity and modern cooking fuels and stoves globally, as well as assessed some of the key factors responsible for the success or failure of particular programs and policies. Although there have been significant reductions in the number of people without electricity globally over the last couple of decades, access to electricity still remains beyond the reach of the majority of sub-Saharan Africans and rural South Asians. Unlike the case of electricity access, populations without access to clean cooking fuels or stoves have continued to increase over the last decade, except in the case of China. Reversing this trend will require significant advances to be made in the rapid diffusion of low-cost, high performing and standardized stoves, and creative financing mechanisms to enable low-income households to afford modern cooking options. Lessons from past programs and policies suggest that sustained government commitment and policy and institutional frameworks are vital for enabling improvements in energy access.

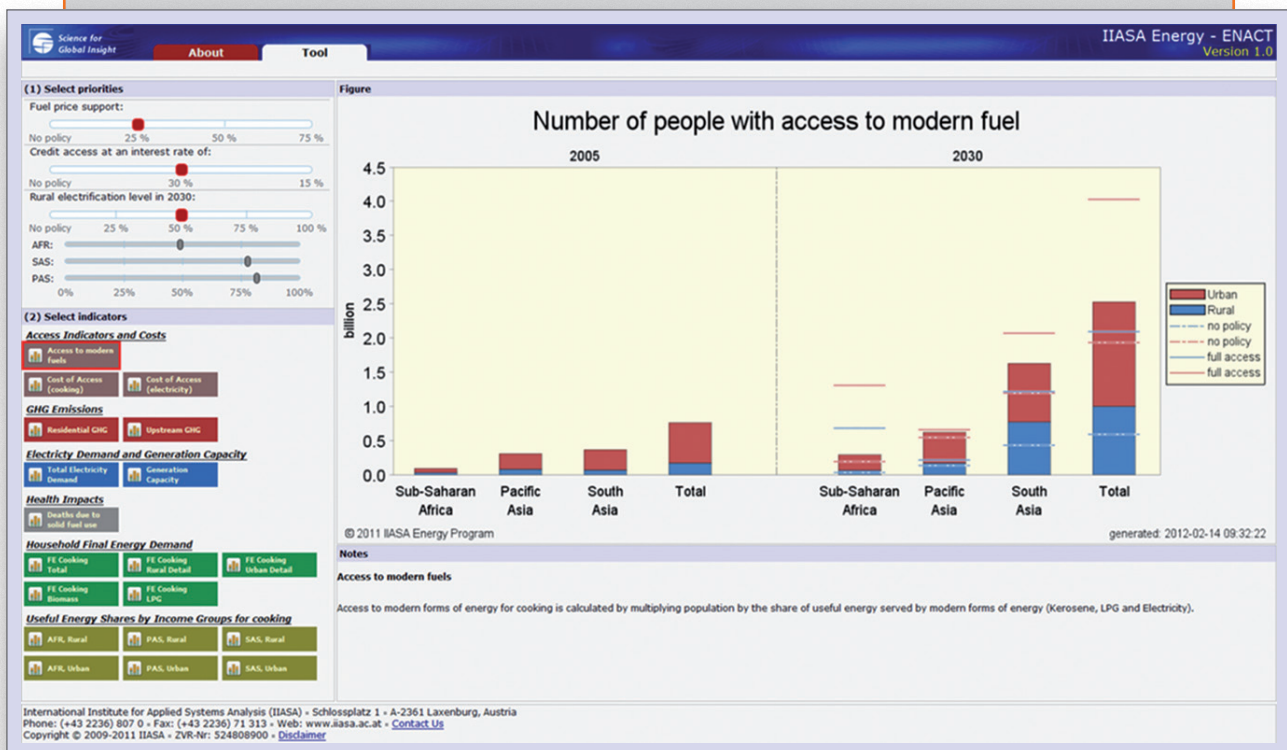
In what follows, we explore possible future scenarios for achieving a universal access target by 2030. We assess policies that might enable this target to be met, estimate the costs and impacts of such policies for improving access, and assess their implications for future energy demand, GHG emissions and for the health of impacted populations. The section starts with the GEA-Mix pathway and provides a detailed breakdown of specific access policies and their contribution to reaching the target (see Riahi et al., 2012, for a complete description of GEA pathways). The section then presents the impacts of providing universal access on energy demand, GHG emissions, and health. The detailed access modeling presented here focuses on three key regions where lack of access is currently the most acute – sub-Saharan Africa, South Asia, and Pacific Asia – and for which disaggregated data on energy choices and use in the household sector are available. The detailed results from these regions are used to inform the estimation of costs and impacts of alternative policies to improve access to clean cooking options and electricity.

The IIASA Energy-ENACT (Energy Access Tool)

An interactive Web-based scenario analysis tool gauging the effectiveness and impacts of various energy access policies and measures in the major developing regions of the world

URL: www.iiasa.ac.at/web-apps/ene/ENACT

The ENACT policy tool is based on the Global Energy Assessment energy access scenarios and methodology and allows policy makers and other users to select alternative rural electrification targets and other access policies (such as fuel subsidies and microfinance) to encourage a more rapid transition to clean, modern forms of energy in the households of the developing world. The interactive PC-based software presents in real-time quantitative estimates of the impacts of the chosen policies and targets in each region and how various combinations of measures compare to each other in terms of health impacts, energy demand, GHG emissions, and funding requirements.



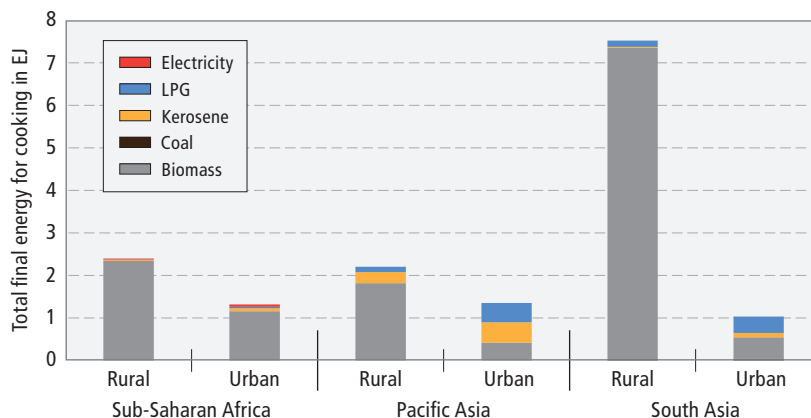
The policy tool focuses its analysis on three major world regions – sub-Saharan Africa, South and Pacific Asia, which face the most acute lack of access today. It allows for assessing policies and measures to enhance access to electricity and modern fuels and stoves for cooking in the residential sector.

3.1. Projections of Access to Clean Cooking Options

3.1.1. Modeling Approach

The starting point for this analysis is data on existing energy choices and the demand to meet cooking energy needs in each of the three regions. The estimates of energy choices and demand are based on bottom-up estimates using detailed household survey data for key nations in each of the regions (see Ekholm et al., 2010, and Riahi et al., 2012, for details regarding data sources and methods). There is enormous diversity in the types and amounts of fuels used for cooking in households in developing countries. Most rural and low-income urban households in developing nations still depend predominantly on biomass to meet their cooking energy needs. As can be seen from **Figure 9**, in rural sub-Saharan Africa and South Asia the share of biomass (including charcoal) in total final cooking energy used was as high as 97–98% in 2005. Among households in rural Pacific Asia, this share was about 60%. In urban centers of South and Pacific Asia, a larger share of kerosene and LPG is used for cooking. However, even in urban sub-Saharan Africa, about 87% of total final energy used for cooking is biomass (including charcoal).

FIGURE 9
Composition of final energy use for cooking in rural and urban households in three developing regions in 2005.



The GEA access scenarios for residential cooking energy employ the MESSAGE-Access modeling framework (see Ekholm et al., 2010, and Riahi et al., 2012, for details of the model). The model has several novel features that capture some of the special circumstances prevailing in developing countries. Demand is disaggregated both by rural and urban region and by income or expenditure quantile groups. Data from detailed household surveys for key nations in each region are used to calibrate the model. The model also accounts for changes in income level and distribution, urbanization, and population growth and for the consequent impact of these factors on the transition in cooking energy choices.

Various scenarios simulating different combinations of policy packages are modeled within the MESSAGE-Access framework to determine their impact on access to cooking fuels in these regions. This study considers a final transition to LPG as the favored choice for cooking for those who have access to and can afford it. This is not an endorsement of LPG as the best of the available choices.⁷ Rather, LPG serves as a proxy for all modern cooking fuels, which enables the analysis to focus on the costs and impacts of alternative policies to achieve a single goal.

The main policies considered to encourage a more rapid transition away from solid fuels for cooking include: price support mechanisms, such as smart subsidies, to reduce the cost of less polluting fuels; grants; and microlending, to make access to credit easier and lower households' cost of borrowing. The GEA scenarios model policy packages that combine different levels of subsidies with microfinance options. The objective of these policies is to make it cheaper and easier for households to purchase both the fuel and the end-use equipment (cookstoves). Purchasing these cookstoves often involves a capital outlay beyond the reach of poor and rural households, which often have irregular cash inflows. **Table 7** provides an overview of the different access scenarios constructed.

TABLE 7 GEA policy scenarios for achieving universal access to modern cooking fuels

| Policy Scenarios | | | |
|------------------|--------------------------|--------------------------------|------------------------------------|
| Name | "Subsidy Only" Scenarios | "Microfinance Only" Scenarios | "Subsidy + Microfinance" Scenarios |
| Description | Subsidy range 20–50% | Interest charged 15% or 30% | Both Subsidy and Microfinance |

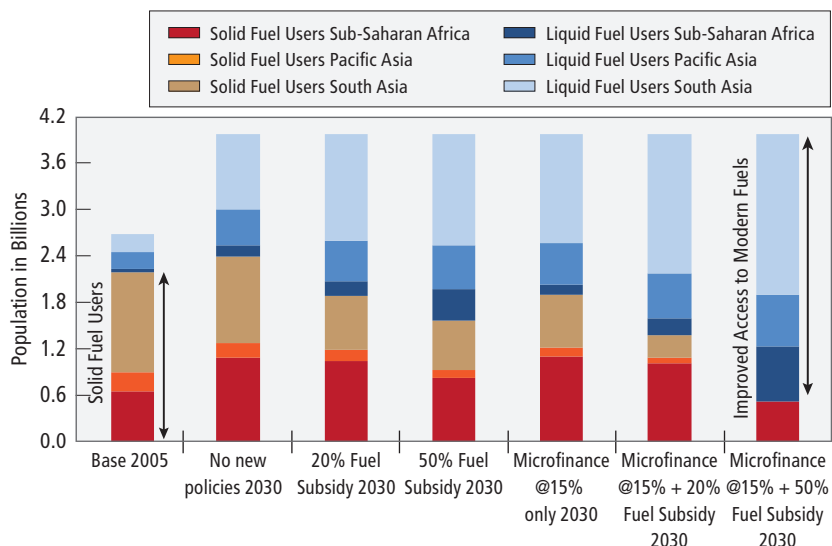
3.1.2. Results

With no new policies, the total numbers of people dependent on solid fuels in the regions considered will rise between now and 2030. The impact of the alternative policy packages on the numbers of people dependent on solid fuels varies across the different regions from slight to dramatic. **Figure 10** depicts the impact of the policies on the number of people dependent on solid fuels for each region, for the urban and rural sectors separately. The "Subsidy + Microfinance" scenario with a 15% interest rate is more effective in all regions in accelerating a shift away from solid fuels than either a subsidy-only policy or providing microfinance alone. The combination of policies is more effective because it leads to a transition to modern cooking fuels and stoves for the largest number of people and is thus, most cost-effective,

⁷ Other alternative cooking fuels, such as biogas, natural gas, and other emerging sources such as ethanol gel and dimethyl ether, in combination with different stove technologies, might be better suited to certain regions or nations. In some regions, there might even be a transition to electricity for cooking.

FIGURE 10

Impact of alternative policy scenarios on access to clean cooking fuels in three developing regions. Subsidies are relative to consumer price levels and are additional to existing subsidies.



i.e. the cost per person gaining access is lower than in the case when the policies are pursued individually. However, even such a combination of policies will leave about 500 million people, virtually all of them in sub-Saharan Africa, reliant on solid fuels in 2030. For these populations, the use of advanced biomass stoves that have an efficiency level and emissions standards that provide a performance similar to cooking with LPG, will be necessary.

3.2. Projections for Access to Electricity

Progress with electrification in different regions, as presented in the previous sections of the report, has been very uneven. In particular, rural electrification levels in sub-Saharan Africa and South and Pacific Asia are still very low. The shortfall with respect to a universal access target by 2030 is largest in sub-Saharan Africa. Less than 11% of households in rural sub-Saharan Africa, had access to electricity in 2005 (UNDP and WHO, 2009). In South Asia as well, only half of the rural population had access to electricity in 2005. Reaching a universal electrification target by 2030 in these regions will require a significant expansion of the existing grid infrastructure or additional investments in decentralized electrification solutions.

3.2.1. Modeling Approach

To analyze the requirements to provide universal electricity access to the entire rural populations in our three model regions, we use two separate model frameworks. Within the MESSAGE-Access and IMAGE models, rural electrification and grid infrastructure expansion are modeled in slightly different ways (see Riahi et al., 2012, for details of the models and methods). As a starting point, both models take

existing levels of electrification by nation, or by subpopulation within a nation, in the base year. Future rates of electrification in both models are driven by future income growth. However, within the IMAGE framework, a model that regresses national electrification levels on GDP per capita (in US dollars at purchasing power parity) is used to project future electrification levels by region, based on future income growth. Within the MESSAGE-Access model, future electrification in the case of no new policies or targets is determined by income growth and distribution across rural and urban income quintile groups and electrification levels across these heterogeneous population groups in the base year.

TABLE 8 GEA scenarios for minimum household electricity demand for achieving universal electricity access

| Policy Scenarios | | |
|------------------|---------------------|----------------------|
| Name | “Low Threshold” | “High Threshold” |
| Description | 65 kWh/household/yr | 420 kWh/household/yr |

For the purposes of quantification, two alternative levels of demand are assumed for household consumption as the minimum amount needed to meet basic electric service needs and that can be considered adequate access (Table 8):

- Low demand or minimal access: each household has one conventional light bulb (40W), and one out of three households has a television set (60W) that is used for three hours a day. This is equivalent to approximately 65 kWh/household/year.
- Medium demand or sustainable universal access: consumption is assumed to be 250W for four hours per day for lighting and other applications, as in the Tanzanian reference study of Modi et al. (2005), amounting to 420 kWh/household/year.

Rural electrification levels differ in the base year across the two models in part because of differences in regional definitions in the IMAGE and MESSAGE models and in part due to differences in the sources of data used. For sub-Saharan Africa and South Asia, differences in regional composition across the two models are minor, and thus rural electrification levels are fairly similar. However, the regional definition for the Pacific Asia region differs significantly across the two models and consequently so does the base-year electrification level.⁸ Progress with rural electrification in the two scenarios differs across the two models because of differences in base-year electrification levels and in methodology.

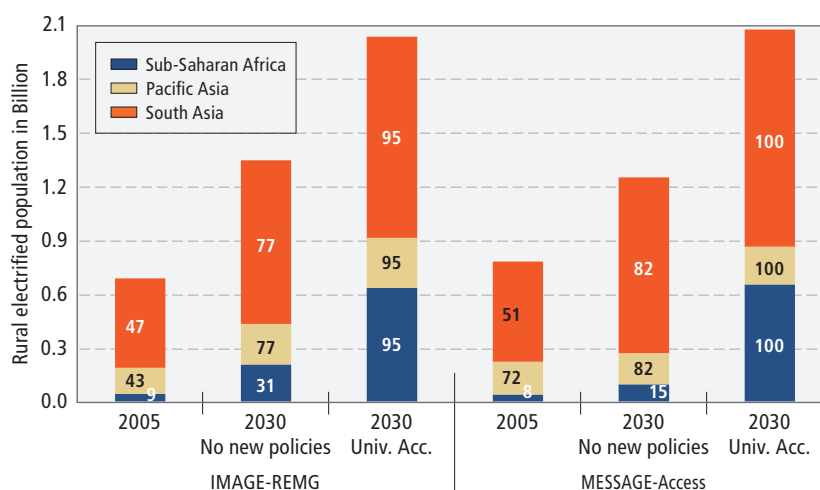
⁸ For a description of regional composition across the two models see the Appendix of the GEA.

3.2.2. Results

Without access targets and specific policies to expand electricity access, the GEA projects that between 795 million and 822 million people living in rural areas of sub-Saharan Africa, South and Pacific Asia will remain unelectrified by 2030 (see [Figure 11](#)). A target of complete rural electrification by 2030 will require additional electric generation capacity to be put in place and significant expansion of the existing transmission and distribution infrastructure. While more decentralized off-grid and micro-grid solutions might be more appropriate for some of the more remote low population density rural areas in these regions, both the MESSAGE-Access and IMAGE-REMG models estimate the additional capacity and investments required to electrify the rural populations of the three regions through grid extension alone. The cost of grid expansion in both models rises sharply with distance from existing grid infrastructure and population remoteness and density.

FIGURE 11

Rural population with electricity in three developing regions in 2005 and in 2030 under business-as-usual and universal access scenarios. Numbers on the bars are percentages of the total rural population in the indicated region and year. Rural electrification level in the MESSAGE model refers to the 420 kWh/household scenario.



It is estimated that between 9–22GW of additional electric capacity will be required to electrify the rural populations in the three regions assessed by 2030. The lower and upper ends of this range correspond to the capacity addition required for the “Low Threshold” and “High Threshold” scenarios respectively.

3.3. Policy Scenarios till 2030: Impacts, Costs and Benefits

In the following we present the finance requirements of the policy scenarios, their impacts on energy demand, GHG emissions and health of populations, and a qualitative discussion of other benefits for the three modeled regions of sub-Saharan Africa, South Asia, and Pacific Asia.

3.3.1. Financing Requirements

The costs of policies aimed at encouraging a more rapid transition to the use of clean cooking fuels and stoves depend on the combination of the policy instruments deployed and the extent of subsidy. As mentioned in Section 3.1, the “Subsidies + Microfinance” scenario with a 15% rate of interest is the most effective in all regions in accelerating a shift away from solid fuels by 2030. As this is the only scenario that achieves near universal access to modern cooking, costs are provided for this scenario alone. The estimated cost for such a combination of policies to accelerate the transition to modern cooking is about US\$15.8–US\$17.0 billion/year. This estimate is significantly higher than indicated by previous studies (IEA, 2010b; AGECC, 2010), which account for the initial capital costs of improved stoves and deposit or connection fees, but do not account for higher costs of improved fuels or the ability of households to pay for these fuels. The range in the cost represents the difference between recovering the capital cost of cookstoves from households through cheap loans provided by microfinance institutions and recovering them through grants from governments.

The additional investments required for universal electricity access amongst the rural populations in the three regions is estimated at about US\$300 billion cumulatively between 2010 and 2030 (see Figure 12). This investment includes the cost for

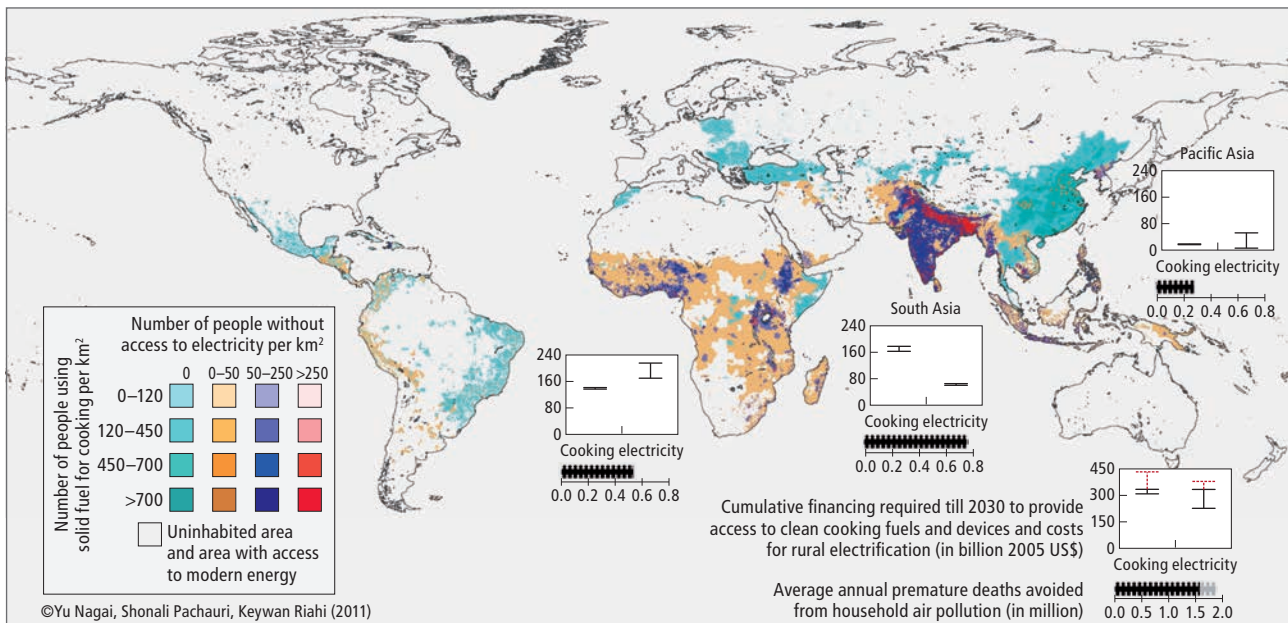


FIGURE 12

Density of population lacking access to modern energy in 2005 and costs (in billion 2005 US\$) and health (in million) benefits of achieving a universal modern cooking and electrification goal by 2030. Colored areas show densities of people per km² without access to electricity and those that use solid fuels for cooking, e.g., dark blue and brown areas are where people do not have access to electricity and cook predominately by solid fuels. Cumulative investment requirements between 2010 and 2030 are shown for three GEA world regions and for the globe as a whole. Also shown is the estimated population that would die prematurely from household air pollution if universal access is not achieved by 2030.

additional electricity generation, transmission and distribution corresponding to the “High Threshold” scenario. This is towards the midrange of previous estimates (Bazilian et al., 2010). Over two-thirds of this investment will need to occur in sub-Saharan Africa where the current rural electrification rate is the lowest.

The three regions considered account for over 85% of the total global population without access to electricity and over 70% of the global population still dependent on solid fuels. Extrapolating the cost estimates for these policy scenarios from three key regions to the entire globe suggests that between US\$36 billion and US\$41 billion will need to be spent annually until 2030 to ensure that universal access to clean cooking fuels and stoves and access to electricity in rural areas is achieved. At the high end of the estimate, about half of this amount will need to be spent on improving access to electricity and the rest on improving access to clean cooking fuel. While significant, the estimate of financing required to achieve access goals by 2030 comprises approximately 3% of the current global annual energy sector investments of US\$1.3 trillion per year.

3.3.2. Impacts of Access Policies on Energy Demand and Greenhouse Gas Emissions

The impacts of alternative policies for improving access to electricity and clean fuels for cooking are relatively modest in comparison with changes in demand in other sectors. As seen in **Figure 13**, compared with the base year 2005, energy demand in 2030 is projected to almost double in the case where no new access policies are implemented, from 17.7 EJ to 33.2 EJ. Most of this rise is accounted for by additional LPG demand for cooking and kerosene and electricity for lighting and appliances. In an access scenario with “Microfinance Only” with a 15% interest rate and “Low Threshold” electricity demand, total energy demand in 2030 is lower than in the no new policies case, but LPG and electricity demand are higher. In this scenario, if all households that are dependent on solid fuels are provided with improved biomass stoves that double the efficiency of combustion, then biomass demand in this scenario is cut in half, from 10 EJ to about 5 EJ. Finally, in the “Subsidy + Microfinance” scenario with “High Threshold” electricity demand, total energy demand drops to 16.8 EJ. This is explained by a rapid shift away from biomass to more efficient LPG for cooking and a substitution away from kerosene to electricity for lighting. Total LPG demand in this scenario is projected to rise from 1.1 EJ in the base year to 9.4 EJ in 2030; biomass demand declines from 13.4 EJ to 1.7 EJ over the same period. This increase in LPG demand over the entire projection period for the three developing regions amounts to less than half of the energy use in 2005 in the Western European transportation sector alone. Electricity demand rises in this scenario from 1.7 EJ in 2005 to 5.7 EJ by 2030, displacing about 6.6 EJ of kerosene.

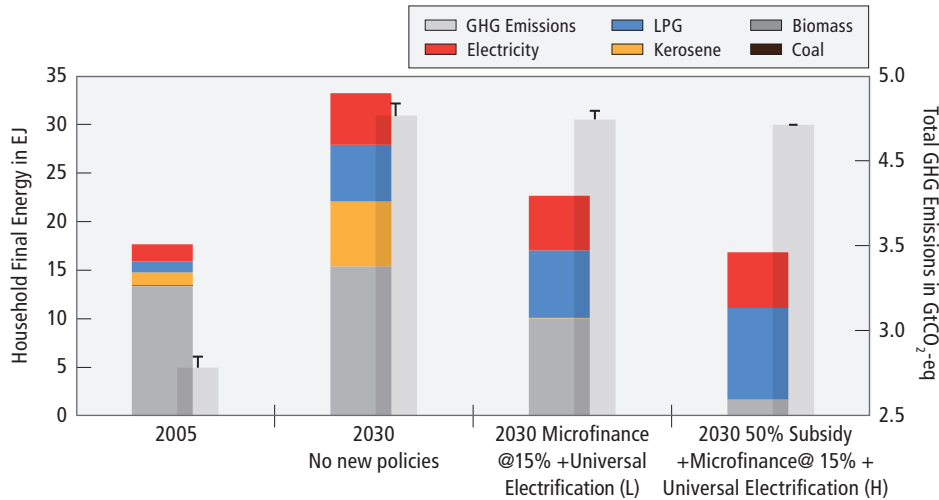


FIGURE 13

Household final energy demand and total GHG emissions in three developing regions (sub-Saharan Africa, Pacific Asia, and South Asia) in 2005 and in 2030 under alternative access policy scenarios. GHG emissions include those on both the supply and the demand side. Error bars represent additional emissions on the assumption that 20% of biomass consumption in households is not sustainably harvested.

The changes in final energy demand due to various access policies also have implications for greenhouse gas (GHG) emissions. The climate impacts of achieving universal access to modern energy carriers and technologies are negligible or might even be negative, even in the case where access is provided entirely from fossil energy sources. This is because transitioning to such fuels will displace large quantities of traditional biomass use. Current technologies that use traditional biomass are associated with significant emissions of non-CO₂ Kyoto gases (e.g. CH₄, N₂O) and aerosols (e.g. BC) due to incomplete combustion (Grieshop et al., 2011). The IEA estimates that achieving universal modern energy access by 2030 would raise CO₂ emissions as compared to their current practices scenario by only 0.7% (IEA 2011). The GEA includes emissions of non-CO₂ Kyoto gases, CH₄ and N₂O in addition in its estimates and uses standard IPCC emissions factors to estimate impacts. **Figure 13** shows the impacts of various access policies on total GHG emissions relative to the base year of 2005. The grey columns (scale on the right axis) depict total emissions, assuming that all biomass consumption is sustainably harvested, and the error bars indicate emissions in the case where 20% of biomass consumption is assumed to be harvested unsustainably. Without any access policy, total GHG emissions increase by 65%, to 4.7 gigatonnes of carbon dioxide-equivalent (GtCO₂-eq) in 2030 compared with 2.9 GtCO₂-eq in 2005. As a consequence of implementing access policies, GHG emissions decline marginally, having a negligible impact overall. **Figure 14** shows the breakdown of the GHG emissions by region for the baseline 2030 scenario (with no new policies). South Asia has the largest absolute contribution, followed by Africa and then Pacific Asia. Assuming a future carbon price of 30€/t CO₂-eq access policies in 2030 could result in financial savings too, albeit negligible.

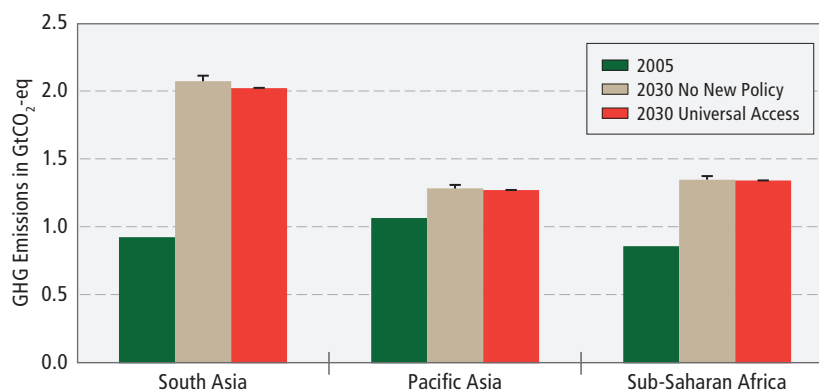


FIGURE 14
GHG Emissions by
Region for 2005 and
2030 Baseline and
Universal Access Scenarios.

3.3.3. Health Benefits of Access Policies

Estimates of the current health impacts of household pollution are based on the effects of solid fuel dependence today, whereas future estimates are based on the detailed access scenarios described above and account for forecasted demographic change and trends in background disease and mortality levels as estimated by the WHO. The methodology is described in detail in Rao et al. (2012). In 2005, total deaths attributed to solid fuel combustion in traditional stoves were about 2.2 million, and more than 41.6 million Disability Adjusted Life Years or DALYs were lost, with the impacts felt mainly by women and children. Although substantial uncertainty is associated with these estimates, policies that improve access to modern cooking fuels have the potential to avert between 0.6 million and 1.8 million premature deaths, on average, every year until 2030, in the three regions of sub-Saharan Africa, South Asia, and Pacific Asia. These include between 0.4 million and 0.6 million deaths per year of children below the age of five. Deaths attributable to acute lower respiratory infection (ALRI) among children under five are expected to decline between 2005 and 2030 even in the absence of any access policies, but deaths due to chronic obstructive pulmonary disease (COPD) and ischemic heart disease (IHD) in adults are expected to increase during the same period. These trends are in line with those reported by Bailis et al. (2005), who find that the observed decline in childhood ALRI mortality over time is a result of additional factors, whereas the upward trend in adult incidence of COPD is mainly due to population aging. Alternatively, in the absence of any new policies to enhance access to modern cooking fuels or devices, it is estimated that in 2030 there could still be over 24 million DALYs lost due to household air pollution. See [Table 9](#) for details on disease-specific impacts by region in 2005.

TABLE 9 Health Impacts of Household Air Pollution (HAP) in 2005

| Disease, sex and age | HAP related Mortality (Million) | | | | |
|-------------------------------------|---------------------------------|---------------------|---------------------|---------------------|---------------------|
| | SAS | PAS | AFR | CPA | LAM |
| ALRI, Children < 5 | 0.22 (0.18–0.25*) | 0.05 (0.04–0.06) | 0.50 (0.42–0.56) | 0.03 (0.02–0.03) | 0.01 (0.00–0.01) |
| COPD, Women > 30 | 0.19 (0.16–0.23) | 0.1 (0.08–0.12) | 0.03 (0.02–0.03) | 0.26 (0.18–0.34) | 0.02 (0.01–0.03) |
| Lung Cancer, Women > 30 | 0 | 0 | 0 | 0.02 | 0 |
| COPD, Men > 30 | 0.16 (0.00–0.25) | 0.06 (0.00–0.11) | 0.03 (0.00–0.05) | 0.12 (0.00–0.25) | 0.01 (0.00–0.02) |
| Lung Cancer, Men > 30 | 0 | 0 | 0 | 0.03 | 0 |
| Ischaemic heart disease, Women > 30 | 0.11 | 0.03 | 0.02 | 0.02 | 0.01 |
| Ischaemic heart disease, Men > 30 | 0.08 | 0.02 | 0.02 | 0.01 | 0.01 |

NOTE Based on mean relative risks. Numbers in parenthesis are the ranges of impacts from the low and high confidence intervals of risk rates.

3.3.4. Other Potential Benefits of Access Policies

A quantification of other potential benefits of achieving universal modern energy access is not carried out in the scenarios assessed here. However, the evidence of significant benefits of access to modern energy forms for improved literacy, productivity, and overall economic development are well documented in literature and have already been discussed in Section 1. In addition, some recent studies suggest that there can be significant benefits to government finances from saved subsidies (kerosene displaced) (Singh and Jaiswal, 2008; Khandker et al., 2009). One important general feature of the perceived benefits from energy interventions is that benefits appear to be highly context-specific. Methodologies for quantifying benefits are still being developed and the detailed data needed for such analysis is often not available. However, as methodologies are developed and more detailed data becomes available, the evidence for significant additional benefits of access policies and programs is likely to rise.

3.4. Summary – Outlook for Achieving Universal Access by 2030

An analysis of future scenarios for energy access carried out within the GEA described in the previous sections suggests that it is feasible to electrify the existing 20% of the global population without access to electricity and provide clean cooking to the 40% of the world's population that currently rely on solid fuels, as well as additions to the population between now and 2030. The investment requirements estimated for achieving the energy access objective by 2030 are between US\$36–US\$41 billion annually till 2030. About half of this amount will need to be spent on improving

access to electricity and the rest on improving access to clean cooking fuels and stoves. The largest share of this spending (more than a third of the total cost to achieve clean cooking fuel access and two-thirds of the electrification bill) will need to occur in sub-Saharan Africa. While this amount may be significant, particularly from the point of view of the poorest nations and regions, the benefits are likely to be substantial. Spending on policies and measures to achieve access goals by 2030 will improve welfare in several ways, provide an impetus to economic growth, and could even benefit the environment.

The GEA estimates that access policies could avert between 0.6 million and 1.8 million premature deaths, on average, every year until 2030. Additional benefits that are likely to be substantial include time savings for women and children and the potential for improved literacy and livelihood opportunities. The climate impacts of achieving universal access to modern energy carriers and technologies are estimated to be negligible or might even be negative, even in the case where access is provided entirely from fossil energy sources such as LPG. This is because transitioning to such fuels will displace large quantities of inefficient biomass use. Current technologies that use traditional biomass are associated with significant emissions of non-CO₂ Kyoto gases (e.g. methane) due to incomplete combustion. Recent evidence indicates that the carbonaceous aerosols (e.g. Black Carbon) also produced due to the incomplete combustion of traditional biomass may also be giving rise to a much higher level of radiative forcing than previously estimated. Emissions associated with current biomass use maybe even higher if it is assumed that some percentage of current biomass use is unsustainably harvested.

Other benefits of access policies have not been monetized in this study. However, previous research suggests that these far outweigh the costs of providing access to modern energy forms and technologies. The WHO (2006) has estimated the total economic benefits associated with improved access, including reduced health-related expenditure as a result of less illness, the value of assumed productivity gains resulting from less illness and fewer deaths, time savings due to the shorter time spent on fuel collection and cooking, and environmental impacts at the local and global levels. Their estimates suggest that the total economic benefits amount to roughly US\$91 billion per year for halving the total population without access to LPG between 2005 and 2015, which is over twice as much as the estimates of costs of access policies estimated by the GEA.

Financing energy access is likely to remain a significant challenge in the coming decades. While the approximately US\$40 billion needed annually to achieve a universal energy access target by 2030 is comparatively small compared to other energy sector investments, it remains significantly larger than estimates of current investments for access expansion. Bazilian et al. (2011) estimate about US\$9.67 billion was available

for the energy sector in the form of official development finance to non-OECD countries in 2008. This is less than a fourth of what is required for access. In addition, most of these investments flowed to large-scale electricity and energy infrastructure expansion projects, bypassing the needs of the poorest. A lack of data on actual investments and benefit flows from access policies and programs remains a significant impediment to more informed analysis and planning.

4. Conclusions and Lessons for the Future

Among the many challenges to achieving universal access, mobilizing US\$40 billion in financing and putting in place the institutions to appropriately invest these finances rank high. Several common themes and lessons emerge from the experiences of energy access policies worldwide. These lessons apply broadly for designing successful and sustainable approaches to energy access programs, but also inform the design of programs to cater to local conditions. These are presented in the first section based largely on the synthesis of international experiences contained in the GEA, but supplemented with other relevant literature.

4.1. Success Factors in Energy Access Expansion

4.1.1. Strong Supporting Government Role

The role of central governments has been shown in numerous examples to be critical for the success of access expansion programs, despite the fact that several different types of entities have contributed to their success as well. There are many important roles that a central government plays, of which some of the important ones are highlighted below:

- Ensure longevity of access programs by creating dedicated institutions to manage programs that often need to extend for decades to achieve substantial penetration of modern energy services.
- Provide subsidies to make access affordable to the poorest households. Many mechanisms have been used, such as introducing some form of lifeline subsidy rates (e.g., South Africa), providing capital cost subsidies (numerous examples), direct cash transfers (e.g., Brazil LPG program), regulate concessions to condition subsidies on electrification targets for poor people (e.g., Argentina), creating incentives for commercial lending, to name a few.
- Assist in coordinating participating entities and help create local institutional and organization capacity for operating and maintaining new systems.

- Provide performance-driven, capital subsidies to investors.
- Provide systems for defining and enforcing appropriate technical standards, standardized operational metrics, and support for R&D and training.

4.1.2. Integration of Energy Access and Other Development Policies

Tied to the critical role of central governments is the importance of tying income generation policies to energy access policies, so as to create the enabling conditions for energy access to support livelihood development, and raise living standards.

The promotion of productive uses of energy with the objective to stimulate economic development should go hand in hand with other activities and instruments to support the establishment and/or development of enterprises. This requires cooperation with many actors and provision of other conditions for entrepreneurship and business (e.g., the availability of easy credit). Energy access on its own will not lead to the establishment of new enterprises and the alleviation of poverty. It is linked with factors of rural development, market demand and access, infrastructure, and entrepreneurship.

4.1.3. Responsive, Accountable Institutions with Local Involvement

The institutions that set up energy systems need to take advantage of countries' strengths and specific conditions (World Bank 2010). Furthermore, they need to have continuous monitoring to allow for strategic corrections to programmatic activities. This has been wanting in past programs. For example, field surveys undertaken in Thailand show that despite flaws in the implementation of heavily subsidized solar and PV systems in rural areas, the inefficient policy continued over a 15-year period at a cost of over US\$11 million (1984–2001), past the point that 60% of the systems were no longer operational (Green, 2004). In Lao PDR, a survey undertaken in 2006 found that 80% of solar home systems in a project were not working properly (World Bank, 2008).

Path dependencies and institutional inertia can make mid-course corrections difficult to implement (Annecke 2008). That is why institutions need to be set up with the intent and flexibility to monitor and revise programs.

The previous examples show that adaptiveness to local conditions is critical to sustain projects long enough and attract sufficient customers to make new infrastructure viable. This is particularly important for rural and off-grid electrification programs, and for improved cookstoves, where affordability, cultural preferences and skills can be learned and incorporated into program design. Programs that involve local

community in operations, provide training and knowledge on new technologies, involve small and commercial enterprises, can instill a sense of ownership, lower costs, attract more households to join, and potentially increase the sustainability of established energy systems.

4.1.4. Innovative, Solution-specific Financing Mechanisms

There are a number of ways to overcome the problems of cost, affordability, and access to financial resources that do not rely entirely upon subsidies.

- Reduce capital cost requirements by reducing the size of systems (e.g., lower wattage PV systems or smaller LPG canisters).
- Use rental, lease or fee-for-service models. This saves the household from having to raise enough capital to purchase the technology, and dealers can improve their buying power and access different credit facilities. These can be run by a local entrepreneur, the local government, a cooperative, or an NGO, who can raise funds through government-provided subsidies, or other mechanisms.

Another innovation in finance that has proven successful in a number of programs highlighted in Section 2 and in a number of non-energy areas is microcredit lending (Martinot et al., 2002; Armendáriz and Morduch, 2005). For example, Grameen Shakti has been successfully providing credit for the purchase of solar home systems in Bangladesh (Biswas et al., 2004; Uddin et al., 2006). The challenge with microcredit is that the sums may be too small for some energy purposes. At the household level, energy purchases may not lead directly to increased income, which is often a requirement for microlending. A number of development agencies are helping to facilitate microcredit schemes or small scale financing options by assisting the private sector and providing the interface between poor communities, energy providers, and private capital (UNDP, 2009). The financial commitment of communities and entrepreneurs, together with a commercial approach, offers more guarantees for sustainability and poverty alleviation.

For income-generating activities (for instance, grain milling or manufacturing), soft and/or commercial loans, coupled in some instances with small subsidies, are instrumental in creating thriving businesses. The success story of microhydro in Nepal is mainly based on an implicit strategy aimed at prioritizing microhydro for productive end-uses through mechanical power and income-generating activities. Experiences highlighted in Khennas and Barnett (2000), based on case studies from five countries in Latin America, Africa, and Asia, illustrate the relatively low financial

barriers to enter the microhydro business aimed at end-uses supplied by mechanical power. Despite interest rates of up to 17%, hundreds of schemes were developed on a sustainable basis in Nepal by small entrepreneurs.

For technology-intensive financing, it is also important to match financial models to the technical features of energy systems so that households are not faced with unexpected costs from equipment failures or expired warranties (Schäfer et al., 2011).

4.1.5. Institutional Support and Capacity Building

As discussed in Section 4.1, an almost universal challenge in access expansion programs and policies across the developing world is the need for institutional capacity to support the deployment of new technologies in remote rural regions and to provide innovative financing mechanisms to make these technologies affordable at a commercial scale.

Since many of the neediest developing countries do not have national plans in place or have not set goals for universal access, international donor support could incentivize policymakers to develop such plans and goals. Such support could also enable or support the creation of new institutions at the local and regional level that could support technology deployment. Institutions for measuring and monitoring the progress in achieving access goals as well as the environmental sustainability of various access initiatives may also have to be put in place.

5. The Way Forward

The recent international momentum towards setting a universal modern energy access target provides a unique opportunity to renew efforts to achieve this goal. Providing universal access to electricity and modern cooking fuels and technologies would improve the lives of billions of people, whose energy use patterns have remained virtually unchanged over the last century, depriving them of a means of improving their livelihood and living conditions.

The report makes abundantly clear that, from both a technical and economic perspective, it is feasible to provide near universal energy access by 2030. While significant additional investments will be required to achieve this goal, the health and other wider developmental benefits that result will be substantial and can be achieved with negligible climate change impacts. Mobilizing the additional investments will not be easy, especially for the least developed nations

that face the most acute shortage in modern energy services. This will require global partnerships and concentrated efforts, especially in sub-Saharan Africa and parts of Asia. Private sector involvement will also be crucial to reach the level of scale-up required.

Experience to date has resulted in a number of lessons that we need to incorporate in designing future policies and programs. Access programs that actively involve communities, train them to understand, operate and maintain energy systems, adapt to their local conditions, encourage technology providers' long-term involvement, and are integrated into broader livelihood development policies are more likely to succeed and sustain over time. In addition, programs that make access affordable through government support and financing mechanisms have a higher likelihood of success.

These lessons point to the need for a paradigm shift in the approach to energy planning to meet the energy needs of the poor. An explicit focus is required that includes a comprehensive assessment of the poor's heterogeneous needs and constraints, and opportunities to support their livelihoods. Supporting policies that provide a combination of subsidies for modern fuels and microfinance for the purchase of modern stoves are likely to be most successful and cost-effective in achieving universal access.

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